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ABSTRACT: We processed and analyzed six years (2013 – 2018) of surface current data collected by high-frequency radar (HFR) systems on the coastlines of the western Beaufort and northeastern Chukchi Seas and derived surface flow patterns based on 362 days during the open water season. Maps of vorticity and divergence are presented as averages and as a function of wind speed and direction. Flow convergence occurs where the Alaska Coastal Current meets the Beaufort Sea coastal flow in the middle of Barrow Canyon, at the head of Barrow Canyon, and near the mouth of Barrow Canyon. Flow divergence occurs over the northwestern Beaufort shelf within and west of a small canyon at 153 °W. A recurrent gyre forms at the site of this divergent flow. The gyre straddles the shelf and slope region, normally rotating in an anti-cyclonic (clockwise) fashion during strong northeasterly winds, but relaxes when wind forcing is absent or weak. The gyre appears to be a consequence of the Alaska Coastal Current flow through Barrow Canyon, the prevailing wind, and the coastal constraint on the western Beaufort shelf.

Oceanographic moorings that measured subsurface currents were analyzed in conjunction with the HFR data to assess velocity shears in the upper 10 m of the water column. While the HFR-based currents are similar to the water column average flow, there is appreciable shear in speed and/or direction as a function of the relative orientation between the surface wind and the underlying currents.

The complexity of the flow field in this region precludes simple wind speed/direction-based estimates of surface drift and has application to oil spill trajectory predictions.

BACKGROUND: An open-water season surface current velocity dataset that covers the western Beaufort (2013 – 2018) and northeastern Chukchi Seas (2009 – 2018) was collected as part of BOEM OCS studies 2012-079 and 2017-065, along with funding from several partner agencies. Data coverage extends from the coastal zone to beyond the Beaufort/Chukchi shelf break, including Barrow Canyon’s intersection with the continental slope. We evaluate the relation between surface currents measured by the HFR systems and subsurface currents measured by year-round oceanographic moorings, as well as the relation between the wind and the surface flow field structure and evolution and satellite-tracked drifters. This study provides a newly updated scientific understanding of the surface circulation in the northeastern Chukchi Sea near Hanna Shoal and Barrow Canyon, in the western Beaufort Sea from Point Barrow to Smith Bay, and for surface-to-subsurface relationships in flow throughout the study region. Improving our knowledge of the regional circulation is directly related to identifying the potential effects of offshore drilling.

OBJECTIVES: We examined the relationship between regional winds and the circulation patterns that develop over the western Beaufort Sea and Barrow Canyon. To successfully classify surface circulation in the western Beaufort Seas as well as surface to subsurface shear relationships throughout the region.

1. Process and quality control surface current data from 2014 – 2018 and archive these with ISO-compliant metadata.
2. Examine the relationship between the regional winds and the circulation patterns that develop over the western Beaufort Sea and Barrow Canyon.
3. Compare surface currents with moored ADCPs that were previously deployed in the western Beaufort and northeastern Chukchi Seas to derive the relationship of surface waters to those at depth.
4. Summarize findings in a project report and one peer-reviewed publication.

METHODS: We utilized surface currents collected by 5 MHz CODAR Ocean Sensors HFR systems, subsurface currents collected by moored ADCPs, 30 m drogued drifter data from NOAA PMEL, and winds collected at Utqiagvik airport (National Weather Service station PABR) during periods of open water from 2013 – 2018.

RESULTS: Mean surface currents show westward flow on the inner Beaufort Sea shelf (offshore of Elson Lagoon) and cross-isobath flow from the shelf onto the upper continental slope just east of the mouth of Barrow Canyon (near 154°W).

A recurrent gyre exists in the western Beaufort Sea, straddling the shelf and slope region, normally rotating in an anti-cyclonic (clockwise) fashion during strong northeasterly winds, but relaxes when wind forcing is absent or weak.

Although the HFR data reflect surface conditions only, comparison with available current velocity profiles shows that the surface conditions are generally representative of sub-surface conditions, although there often exists shear (speed and/or direction) in the upper 10 m of the water column that is controlled by the wind speed and direction relative to the underlying oceanic flow speed and direction.

CONCLUSIONS: Our study represents a newly updated understanding of flow pathways across the region. Our aggregated results depict a complex flow field in the vicinity of Barrow Canyon whose variations can be largely understood in terms of time-varying local wind field stresses along with interactions of the ocean currents with the seafloor bathymetry. We identified a recurrent anticyclonic gyre that straddles the northwestern Beaufort continental shelf and slope. While the gyre more typically circulates in a clockwise fashion, winds from the south and southwest can reverse the sense of rotation. The eastern leg of the gyre tends to advect water from the slope region toward the inner portion of the Beaufort shelf, while the western leg of the gyre directs waters off-shelf. The flow field maps suggest

some key locations where flow convergences, divergences, and changing rotations hint at the dynamics that regulate the flow field.

Throughout the northeastern Chukchi and western Beaufort Seas, surface currents were found to be similar to the water column average flow, but there is appreciable shear in speed and/or direction as a function of the relative orientation between the surface wind and the underlying currents.

The regional flow field is very energetic, driven by a Pacific-Arctic pressure head and other pressure gradients. Complexities of the coastline shape and the seafloor bathymetry combined with the energetic flow field determine the typical oceanic current speed and direction in this area. As a consequence, the wind-driven ocean currents here are not simply a function of surface wind speed and direction in the study region. This complex flow regime precludes our ability to apply simple wind-based metrics for predicting the fate of ocean-borne contaminants in this region.

STUDY PRODUCTS:

- BOEM Study report: Potter, R.A. and S.L. Danielson, 2022. An Analysis of Surface Currents in the Western Beaufort and Northeastern Chukchi Seas. Final Report OCS study BOEM 2022-014. University of Alaska Coastal Marine Institute and USDOJ, BOEM Alaska OCS Region.
- Oral presentations:
 - Potter, R., and S. Danielson. 2022. An Analysis of Surface Currents in the Western Beaufort and Northeastern Chukchi Seas. CMI Annual Research Review (virtual)
 - Potter, R., and S. Danielson. 2021. An Analysis of Surface Currents in the Western Beaufort and Northeastern Chukchi Seas. CMI Annual Research Review (virtual)
 - Potter, R., and S. Danielson. 2020. An Analysis of Surface Currents in the Western Beaufort and Northeastern Chukchi Seas. CMI Annual Research Review, Anchorage, AK
- Poster presentations:
 - Potter, R., S. Danielson, Y-C. Fang, E. Dobbins, and H. Statscewich. (2022) Surface Circulation and Vertical Shear in the Northeastern Chukchi and Western Beaufort Seas. Alaska Marine Science Symposium, virtual.
 - Potter, R., S. Danielson, Y-C. Fang, E. Dobbins, and H. Statscewich. (2022) Surface Circulation and Vertical Shear in the Northeastern Chukchi and Western Beaufort Seas. Ocean Sciences Meeting, virtual.

MAP OF STUDY AREA

Report No.: OCS Study BOEM 2022-014

