The northeastern Chukchi Sea: A complex high-latitude ecosystem

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Summary:

The enormously productive Chukchi Sea shelf arises as a consequence of water transport from the Pacific Ocean to the Arctic Ocean through Bering Strait and thus forms a transition zone between the boreal-arctic Bering Sea and the high-arctic Arctic Ocean. These contrasts are particularly evident on the northeastern Chukchi Sea shelf in summer and fall and are related to the bathymetry of the shelf, in conjunction with seasonal changes in ice-cover and winds and Bering Strait transport. These factors shape this ecosystem's spatio-temporal structure and processes. In aggregate, these physical factors, reflected in the vertical and horizontal distribution of summer-fall temperature, salinity and dissolved carbon properties, can lead to substantial ecological differences and complexity over short (~20 km) spatial scales. In particular, the distribution of summer waters from the Bering Sea and cold, salty bottom waters (established by sea-ice formation during the previous winter) exerts an important influence on the pelagic components of this ecosystem. Consequently, large inter-annual variations in winds, summer sea-ice extent, and Bering Strait transport can lead to correspondingly large inter-annual differences in the distribution and abundance of zooplankton, planktivorous seabirds, pelagic-feeding marine mammals, and low-pH bottom waters.

Introduction:

The enormous biological productivity of the Chukchi Sea shelf is a consequence of water transport from the Pacific Ocean to the Arctic Ocean through Bering Strait. This seasonally varying transport (Woodgate et al., 2012) delivers heat, salt, nutrients and plankton to this shelf. In addition, fluxes from the Arctic Ocean basin and the seasonal formation and ablation of shelf sea ice affects water mass transformation processes, which affect the stratification and frontal formation (Weingartner et al., 2013). In general, the Chukchi shelf is shallow (~50 m deep), but contains a number of troughs and shoals. The distribution of the Bering inflow, exchange with the basin, and the products of ice formation/ablation are affected by these bathymetric variations, which leads to considerable spatial variability in water masses and the distribution of biological communities (Day et al., 2013). As a consequence the shelf ecosystem can be considered a transition zone between the boreal-arctic Bering Sea and the high-arctic Arctic Ocean (Day et al., 2013). There are, in addition, substantial inter-annual differences in ice cover, Bering Strait transport, and winds, which are reflected in ecosystem components. These natural ecosystem variations must be understood in order to assess possible changes associated with a warming Arctic and/or potential industrial activities associated with offshore hydrocarbon production and development.

Methods and Materials:

We use a combination of data derived from oceanographic moorings, satellite-tracked drifters, satellite imagery, shore-based high frequency radars, and shipboard sampling of the water column, benthos, and seabird surveys, all collected from 2008 – 2013. Subsets of these data are used in our description of the time-varying circulation and ecosystem parameters of the northeastern Chukchi Sea shelf.

Results and Discussion

The northeastern Chukchi shelf is, in most years divided by regions consisting of warm, moderately saline Bering Sea water. The Bering waters are separated from regions containing the products of ice formation and ablation. The former results in cold (near-freezing), saline winter-formed bottom waters, while the latter consists of cool, dilute surface waters. Both of these water masses are, to some extent, bathymetrically-constrained by Hanna Shoal. Of particular importance is the apparent constraint exercised by the Shoal on the spatial distribution of the winter-formed bottom water. The highest densities of benthic biomass are found here and it is within this region that the highest concentrations of benthic-feeding marine mammals, particularly walrus, are found (Hannay et al., 2013). Given the different densities, the juxtaposition of these three water masses substantially affects stratification and frontal formation on the shelf. These density differences lead to meso-scale flow variations that include both frontal instabilities and differential responses of the circulation to the winds. Moreover, the spatio-temporal structure of the physical environment leads to similar spatio-temporal variability in the distribution of pelagic components of the ecosystem. Consequently, the northeastern Chukchi Sea shelf exhibits a pelagic-benthic dichotomy in food-web composition and in ecological function that varies both seasonally and interannually. These differences are in the distribution and abundance of zooplankton (Questel et al., 2013), fish (Norcross et al., 2013) planktivorous seabirds (Gall et al., 2013), pelagic-feeding marine mammals (Hannay et al., 2013), and low-pH bottom waters (Mathis and Questel, 2013).

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