Ramifications of a longitudinally shifting Aleutian Low

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Summary:

North Pacific storm locations vary synoptically, seasonally, and inter-annually, subjecting the ecosystems of the Gulf of Alaska, the Bering Sea, and beyond to the effects of non-stationary forcing. Examination of National Center for Environmental Prediction atmospheric Reanalysis fields over 1948-2014 shows that the amount of time the Bering Sea is subjected to energetic low pressure systems can vary by +/- 30 days per October-to-April winter season. These longitudinal relocations of the Aleutian Low help mediate the annual mean northward delivery of Pacific waters through Bering Strait. As a consequence, advection of heat, nutrients, and plankton into the Arctic can vary by 25% on inter-annual to decadal time scales. Coincident changes are found in the Bering Sea winter ice extent, setup of energetic continental shelf waves, Ekman suction rates in the Aleutian Basin and Gulf of Alaska, and sea surface height anomalies. This talk reviews and presents evidence for oceanic adjustments to longitudinal migrations of the Aleutian Low and describes some of the observed biological consequences, including changes in primary and secondary production, fish diets, and invertebrate abundances.

Introduction:

The Bering and Chukchi seas are linked by the narrow (85 km) and shallow (50 m) Bering Strait, through which the North Pacific communicates with the Arctic. The net northward transport of Pacific waters through Bering Strait extensively affects Arctic sea ice, the global hydrologic cycle, and the global thermohaline circulation. These waters also carry carbon, nutrients, and plankton that sustain the enormously productive northern Bering-Chukchi ecosystem. Hence, an understanding of the dynamics, properties, and fate of the transport through Bering Strait is essential to studies of these ecosystems.

Despite the annual mean winds being northerly (blowing from the north) in the Bering Strait, the long-term (mutli-decadal) mean transport through the Bering Strait is ~0.8 Sv northward (Woodgate *et al.*, 2005). Transport variations are substantial, however, and occur on timescales from hourly to interannual, and longer. From 2006-2011, the mean winter position of the Aleutian Low shifted eastward into the Gulf of Alaska relative to a more westward position over the Bering Sea from 2000-2005 (Danielson *et al.*, 2014). Over the same interval, the annual mean northward Bering Strait transport increased from 2001 to 2011 (Woodgate *et al.*, 2012).

This talk focuses on the consequences of a slowly varying Pacific-Arctic transport. Although many linkages are poorly understood, we describe observed ecosystem changes that accompanied the Aleutian Low transition following 2005 and we speculate about other possible changes that have not yet been observed.

Materials and Methods:

To support our interpretation of past and potential future changes in the study region, we evaluate the effects of wind stress over the North Pacific and western Arctic using atmospheric reanalyses, current meter observations, satellite-based sea surface height (SSH) measurements, hydrographic data, numerical model integrations, and results from a variety of complementary biological field studies.

Results and Discussion:

The instantaneous flow field over the shallow Bering-Chukchi shelves is primarily mediated by wind stress that directly forces the underlying ocean and triggers continental shelf waves, which rapidly propagate away from the generation region. The annually averaged transport through Bering Strait also appears to be strongly influenced by the effects of wind stress, but through different mechanisms than those that control the instantaneous flow field. Changes in wind stress curl over the deep North Pacific waters alter the dynamic height and SSH here, while changes in coastal divergence driven by Ekman transport mediate the SSH along the coastlines (*Danielson et al., 2014*). Together, these SSH levels control the magnitude of the Pacific-Arctic pressure head, driving variations in the annual mean flow of Bering Strait (Figure 1).

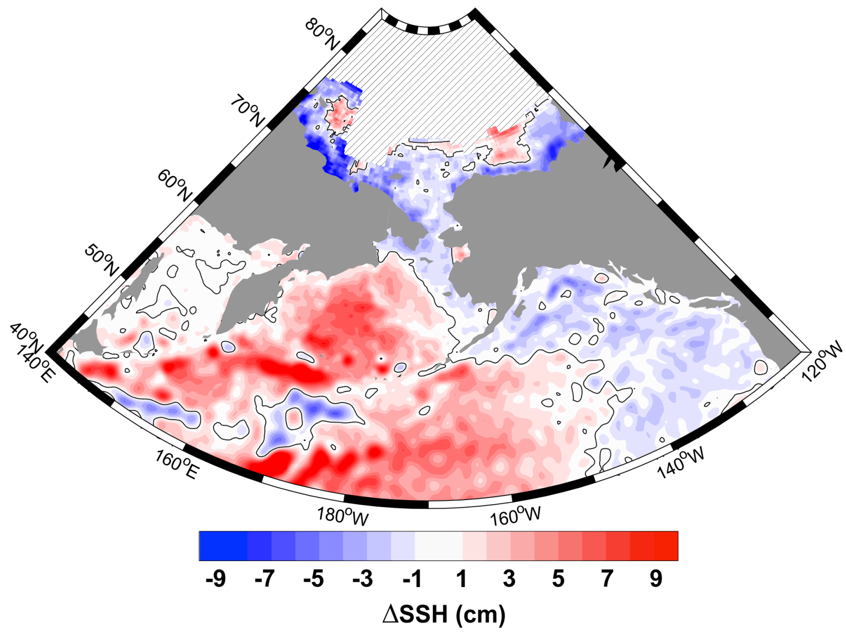

Figure 1. Difference in the satellite-measured sea surface height (SSH) anomaly field between 2000-2005 and 2006-2011. The increase in SSH signal over the Bering Sea and the decreased SSH signal over the Chukchi Sea shelf depict the altered Pacific-Arctic Pressure gradient. Reproduced from Danielson *et al.* (2014).

Anomalies in the Bering Strait transport likely play a role in altering the cross-shelf and the subarctic-arctic advection of oceanic zooplankton and nutrients. For example, due to changes in the macronutrient fluxes, we might expect changes in the Chukchi Sea net primary productivity when comparing years that fall near either end of the range of observed transports, (e.g., 2001 and 2011). Alterations to primary productivity would presumably have a cascading effect on the benthos and marine mammal populations that ultimately depend on the nutrients and organic matter supplied by the Bering Strait throughflow. In the Gulf of Alaska, cold winters that are associated with an eastward-displaced Aleutian Low correspond with changes in shrimp abundance. In the Bering Sea, observations reveal a dramatic ecosystem reorganization following the 2005 transition, including changing timing match-mismatches between primary and secondary production, and changes in the diets of chum salmon (Coyle *et al*., 2011).

References:

Coyle, K. O., L. B. Eisner, F. J. Mueter, A. I. Pinchuk, M. A. Janout, K. D. Ciecel, E. V. Farley, and A. C. Andrews, 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. Fisheries Oceanography, 20: 139–156. doi: 10.1111/j.1365-2419.2011.00574.x

Danielson, S. L., T. J. Weingartner, K. S. Hedstrom, K. Aagaard, R. Woodgate, E. Curchitser, and P. Stabeno, 2014. Coupled wind-forced controls of the Bering–Chukchi shelf circulation and the Bering Strait through- flow: Ekman transport, continental shelf waves, and variations of the Pacific–Arctic sea surface height gradient.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner, 2005. Monthly temperature salinity, and transport variability of the Bering Strait throughflow, *Geophys. Res. Lett*., 32, L04601, doi:10.1029/2004GL021880.

Woodgate, R. A., T. J. Weingartner, and R. Lindsay, 2012. Observed increases in Bering Strait oceanic fluxes from the Pacific to the Arctic from 2001 to 2011 and their impacts on the Arctic Ocean water column, *Geophys. Res. Lett*., 39, L24603, doi:10.1029/2012GL054092.