Sea ice decline and changing primary productivity in the Bering Sea during Marine Isotope Stage (MIS) 11

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Introduction and Study Area

The extent of Arctic summer sea ice has been at or near a record low six times within the past decade and the extent of multi-year ice is declining at an even faster rate (Comiso, 2012.) As sea ice continues to retreat in the Arctic Ocean, the natural variability of its extent has been advanced as a priority research question. This project aims to document the past spatial and temporal variability of sea ice, and the associated ecological changes that take place as sea ice advances or retreats. during a past interval of climate warming in the Bering Sea; the transition from Marine Isotope Stage 12 to 11 at ~424 ka. This will allow evaluation of the rates of change of sea ice and productivity and provide a baseline against which current and future change can be measured.

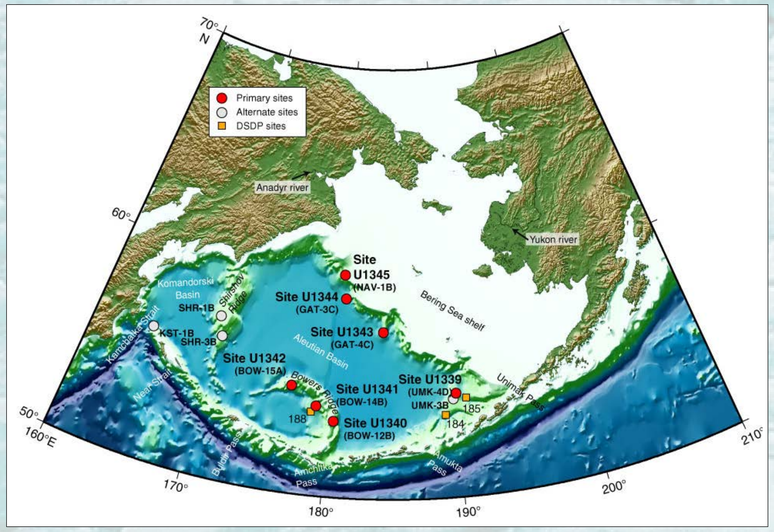

Figure 1. Map showing the location of the seven sites cored during IODP Expedition 323 in the Bering Sea, including the three sites (U1339, U1340 and U1343) used in this study. Figure courtesy of Takahashi et al., 2011.

- Study area of the Bering Sea located at the gateway between the Pacific and the Arctic Oceans, at the dynamic margin of Arctic sea ice
- One of the most biologically productive regions in the worlds oceans.
- An ideal recorder of past sea ice
- History of sea ice extends back to the Pliocene
- High variability in sea ice since 2.5 Ma (Takahashi et al., 2011)
- Three core sites from IODP Expedition 323 selected for this study

Methodology

1. Shipboard data (core images; magnetic susceptibility; NGR)
2. Centennial-scale grain size analysis, using a Mastersizer 3000 laser diffraction particle size analyzer
3. Diatom assemblage counts
4. Bulk sedimentary nitrogen and carbon isotopes, total organic carbon, nitrogen
5. Potentially, diatom-bound nitrogen

Results and Data Analysis

Both glacial and sea ice are effective at transporting terrigenous and near-shore particles far from land; however, sea ice preferentially entrains silt and clay sized particles. Preliminary evaluation of the sedimentology for site U1339 shows a dramatic decrease in clay at ~422 ka, which correlates with a drop in NGR (considered as a proxy for clay content) and a notable change in core lithology. These changes are consistent with the onset of MIS 11, suggesting that the transition from MIS 12 to MIS 11 (also known as Termination V) may have been marked by rapid sea ice retreat. The sediment colour change (less green, more yellow) at the termination may be related to a change in diatom content. Fine-scale analysis of Termination V laminated sediments will provide further information on the rates at which sea ice retreated., and more specifically, whether it responded to climatic forcing gradually, or in a more abrupt, stepwise manner.

The percentage of sand-sized particles fluctuates considerably throughout the core. The pronounced peak in sand at ~364 ka is most likely related to the presence of a tephra layer; this layer is visible in core images and corresponds to an increased magnetic susceptibility of 272.9 (Takahashi et al., 2011). However, in general, tephra does not neatly correlate with increases in sand. Interestingly, magnetic susceptibility is also not well correlated with tephra layers, but shows surprising similarities to the U1339 $\delta^{18}O$ curve. An alternative explanation for the variability in sand-sized grains is that spikes in sand throughout MIS 11 may be related to an increase in the number of foraminifera preserved in sediments, as the calcite compensation depth increases.

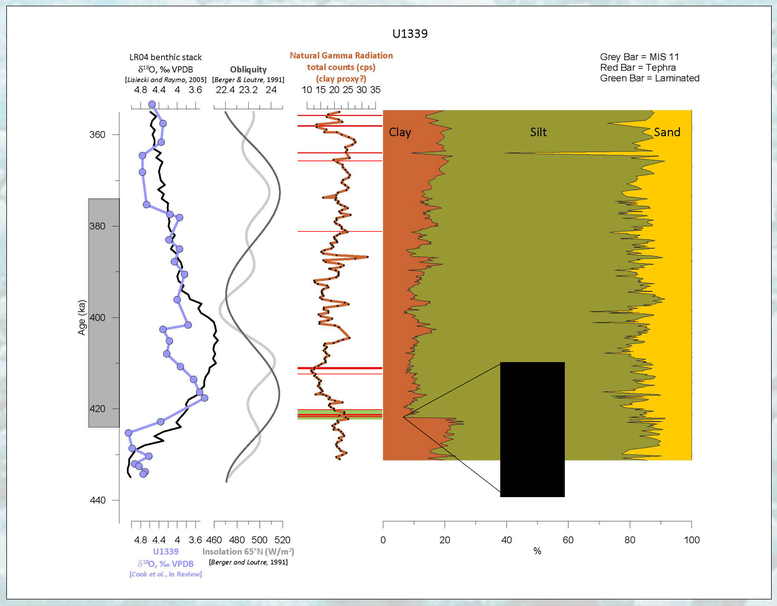

Figure 2. Plot showing grain size data for core site U1339 as percentage clay, silt and sand sized particles, plotted against the global benthic $\delta^{18}O$ curve (Lisiecki and Raymo, 2005), obliquity and insolation (Berger and Loutre, 1991). Also shown is the $\delta^{18}O$ curve for site U1339 (Cook et al., in review) and NGR. The core image shows a noticeable change in lithology that correlates with a dramatic decrease in clay at approximately 422 ka.

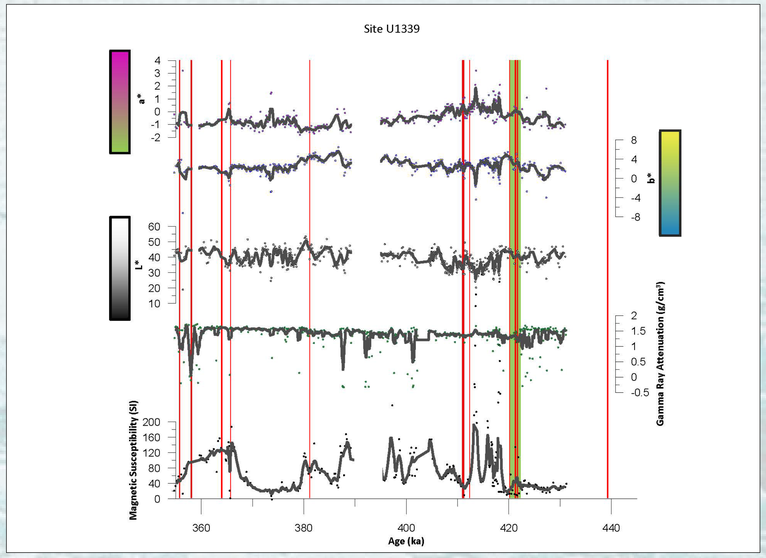

Figure 3. Shipboard data (colour reflectance; gamma ray attenuation; magnetic susceptibility) plotted as running averages for site U1339. Red bars show tephra layers and green bars show laminations. Data from Takahashi et al., 2011.

Summary

- Several proxies for sea ice extent and productivity, including grain size analysis, shipboard data, diatom assemblages and bulk nitrogen and carbon ratios, will be applied to a suite of cores in the Bering Sea.
- This will allow for a robust, high resolution analysis of the spatial and temporal variability of sea ice and primary productivity during MIS 11.
- Palaeoclimate reconstructions will allow evaluation of the rates of change of sea ice and primary productivity, and provide a baseline against which current and future change can be measured.

References

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Acknowledgements

Samples were provided by the IODP Kochi Core Repository. This work is supported by ISU Marine Sediments Lab, the Department of Geology & Atmospheric Sciences at Iowa State University and the Department of Environmental Science at Iowa State University.