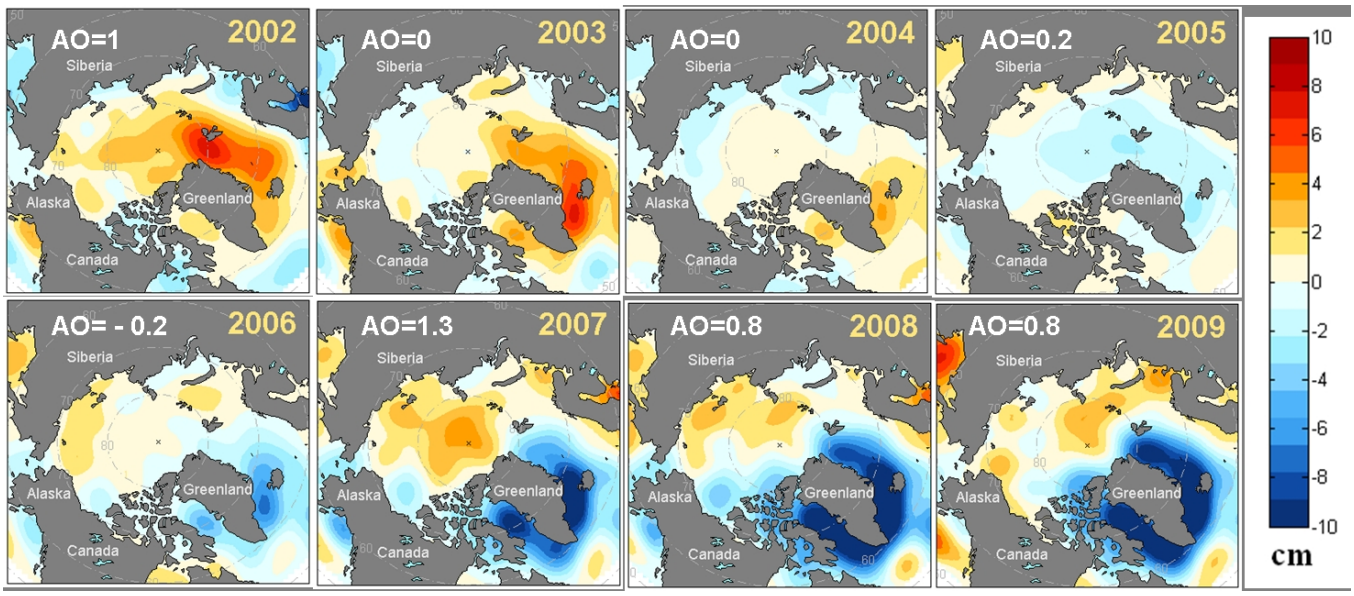
Changes in Arctic Ocean Circulation Patterns Revealed by GRACE

Variations in the Arctic Ocean circulation are associated with clockwise and counterclockwise shifts in the front between salty Atlantic-derived and less salty Pacific-derived upper ocean waters. This Atlantic-Pacific (AP) Front passes roughly between Greenland and the Novosibirskiye Islands (along the Lomonosov Ridge) in the clockwise mode and between Greenland and Wrangell Island (Alpha-Mendeleyev ridges) in the counterclockwise mode. Shifts to the counterclockwise mode are due to the advance of saltier, and hence denser, Atlantic-derived water across the Russian side of the Arctic Ocean. The orientation of the front is climatically important because it aligns the Transpolar Drift of sea ice across the Arctic Ocean and into the North Atlantic. In the counterclockwise mode, ice is pulled more rapidly from the Beaufort Gyre region off Canada and Alaska, tending to reduce the average age, thickness, and extent of Arctic sea ice. The counterclockwise orientation of the AP Front has been related to the wintertime strength of the Northern Hemisphere Polar Vortex, the counterclockwise circulation of the atmosphere associated with low atmospheric pressure over the Arctic and quantified the Arctic Oscillation (AO) index. Conversely, high pressure over the Beaufort Sea and a low AO index in summer have been associated with reduced ice extent at the end of summer because ice is pulled away from the coasts into a convergent gyre under a high-pressure system.

The Gravity Recovery and Climate Experiment (GRACE) tracks the shifts in the Arctic Ocean's Atlantic-Pacific Front. Our chief problem in tracking the AP Frontal position has been that the region where the salinity changes are greatest, the Makarov Basin between the Lomonosov and Alpha-Mendeleyev ridges, has been difficult to reach and has few *in situ* oceanographic measurements. However, comparison of direct hydrographic measurements of ocean salinity (density) with GRACE and single-point *in situ* ocean bottom pressure variations in the central Arctic Ocean [*Morison et al.,* 2007] indicate that GRACE ocean bottom pressure variations at interannual time-scales are mainly accounted for by changes in ocean density. Plots (below) of the annual average bottom pressure measured by GRACE from 2002 to 2009 show that bottom pressure, and by inference salinity and density, decreased across the Russian side of the Arctic ocean from 2002 to 2005, representing a shift to the clockwise mode during a period of declining wintertime AO index. From 2006 to 2009, the bottom pressure on the Russian side of the Arctic Ocean has risen again in a counterclockwise shift associated with increased AO index. This was punctuated in 2007 by a very high bottom pressure arguably related to the summertime buildup of a freshwater dome due to an unusually high atmospheric pressure in the Beaufort Sea that pulled ice from the coasts and contributed to the record minimum of sea ice extent of 2007.



Contours of annual average Arctic Ocean bottom pressure, 2002-2009, from GRACE in cm water equivalent, and winter (NDJFMA) AO index relative to the AO index average 1950-1988.

Reference: Morison, J., et al., 2007, *Geophys. Res. Lett.*, 34, L07602, doi:10.1029/2006GL029016.