This presentation describes changes in Arctic Ocean circulation as revealed by the combined use of satellite gravity observations of ocean bottom pressure, satellite altimetry, and traditional hydrographic measurements. Variations in the Arctic Ocean circulation can be characterized in terms of cyclonic and anticyclonic modes [1]. These are associated with clockwise (anticyclonic mode) and counterclockwise (cyclonic mode) shifts in the front between salty Atlantic-derived and less salty Pacific-derived upper ocean waters [2]. This Atlantic-Pacific (AP) Front passes roughly between Greenland and the Novosibirskiye Islands (along the Lomonosov Ridge) in the anticyclonic mode and between Greenland and Wrangell Island (Alpha-Mendeleyev ridges) in the cyclonic mode. Shifts to the cyclonic mode are due to the advance of saltier, and hence denser, Atlantic-derived water across the Russian side of the Arctic Ocean. The cyclonic 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 [3] and quantified the Arctic Oscillation (AO) index [4]. 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 cyclonic mode with a high wintertime AO index, ice is pulled more rapidly from the Beaufort Gyre and East Siberian Sea region, tending to reduce the average age, thickness, and extent of Arctic sea ice [5] [6] [7]. 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 Alaska coast under a high-pressure system.

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 Gravity Recovery and Climate Experiment (GRACE) and single-point *in situ* ocean bottom pressure variations in the central Arctic Ocean [8] indicate that GRACE ocean bottom pressure variations at interannual time-scales are mainly accounted for by changes in ocean density. The annual average bottom pressure measured by GRACE 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. This result is supported by hydrographic measurements in the central Arctic Ocean

[9][10]. From 2006 to 2009, the bottom pressure on the Russian side of the Arctic Ocean rose again in a counterclockwise shift associated with increased AO index. This was punctuated in 2007 by a very high bottom pressure in the central Arctic Ocean. This was arguably related to the summertime buildup of a freshwater dome due to an unusually high atmospheric pressure in the Beaufort Sea. The high pressure pattern produces clockwise circulation in the atmosphere , and because near surface transport of ice and surface waters tends to be to the right of the surface wind, it has been argued that the high pressure pattern in the summer of 2007 pulled ice and surface water from the coasts and contributed to the record minimum of sea ice extent of 2007 [11][12].

GRACE ocean bottom pressure data, hydrographic data, satellite altimetry and ice drift observations from the International Arctic Buoy Program suggest that after the circulation pattern of the Arctic Ocean returned to an anticyclonic pattern last seen in the 1980s, circulation in 2008 had again become more cyclonic. This in spite of a strong anticyclonic circulation in the southeast Beaufort Sea that was important to reduced ice extent in 2007 and 2008.

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