Ocean

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Surface circulation regime

The circulation of the sea ice cover and ocean surface layer are closely coupled and are primarily wind-driven (Proshutinsky and Johnson, 1997). Data from satellites and drifting buoys indicate that the entire period of 2000-2006 has been characterized by an anticyclonic (clockwise) circulation regime due to a higher sea level atmospheric pressure over the region north of Alaska, relative to the 1948-2005 mean, and the prevalence of anticyclonic winds (Figure O1). Under these conditions, the clockwise circulation pattern in the Beaufort Sea region (the Beaufort Gyre) tends to be relatively strong. Conversely, in the cyclonic regime the clockwise circulation pattern in the Beaufort Sea region weakens, and the flow across the basin, from the Siberian and Russian coasts to Fram Strait (the Transpolar Drift), shifts poleward. The cyclonic pattern dominated during 1989-1996; the anticyclonic pattern has prevailed since 1997. The dominance of the anticyclonic regime during last decade of 1997-2006 is consistent with the Arctic Oscillation (AO) index (Figure A1) which fluctuated about zero indicating a relatively low level of influence from the Atlantic on these Arctic processes (Rigor et al., 2002).

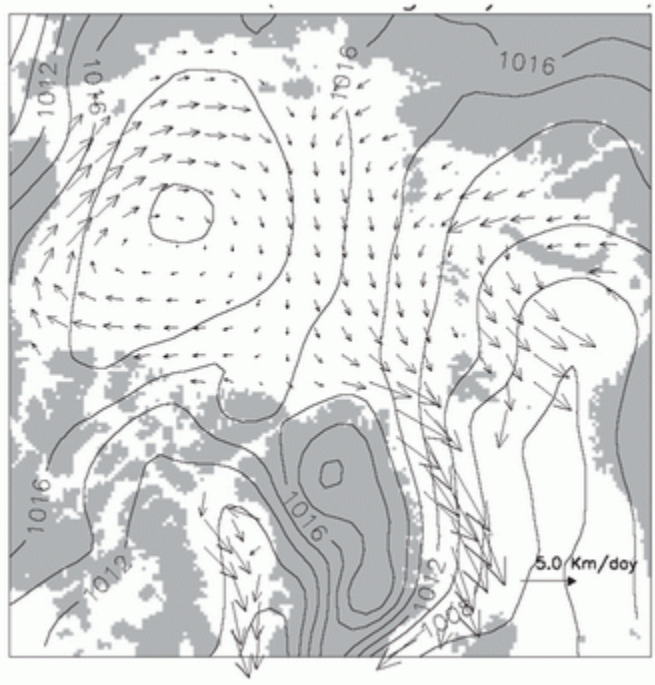

Figure O1. Sea ice drift pattern (arrows) in October-May 2000-2006 and sea surface atmospheric pressure distribution. Sea level atmospheric pressure is shown by lines (hPa) (courtesy of Ron Kwok).

Heat and freshwater content

From 2000 to 2006, intensive investigations have been conducted in the vicinity of the North Pole (North Pole Environmental Observatory, NPEO, http://psc.apl.washington.edu/northpole/) and in the Canada Basin (Beaufort Gyre Observing System, BGOS, http://www.whoi.edu/beaufortgyre/index.html). Observations show that in the previous decade (1990s) the water temperature and salinity fields of the Arctic Ocean changed dramatically relative to the climatology of the Environmental Working Group (EWG) Atlas of the Arctic Ocean (Arctic Climatology Project, 1997, 1998) where water temperature and salinity from observations were averaged and gridded for the decades of 1950, 1960, 1970 and 1980. Hydrographic data acquired at the North Pole in the 1990s show a strong increase in upper ocean salinity and a large increase in Atlantic Water temperature relative to EWG climatology.

From 2000 to 2005, the oceanographic conditions in the North Pole region relaxed to near the pre-1990 climatology (Figure O2). As characterized by average temperature and salinity anomalies relative to EWG climatology within 200 km of the North Pole, the change in the 1990s and the subsequent retreat to climatology are roughly consistent with a first order response to the AO with a 5-year time constant and 3-year time delay (Morison et al., 2006a). Recent results indicate conditions in 2006 at the Pole reverted to near 2004 conditions, but measurements of bottom pressure trends from 2002 to 2006 by the Gravity Recovery and Climate Experiment (GRACE) suggest a return of oceanographic conditions over the whole Arctic Ocean to pre-1990s conditions (Morison et al., 2006b). Preliminary 2007 data shows a slowing of this rate of return.

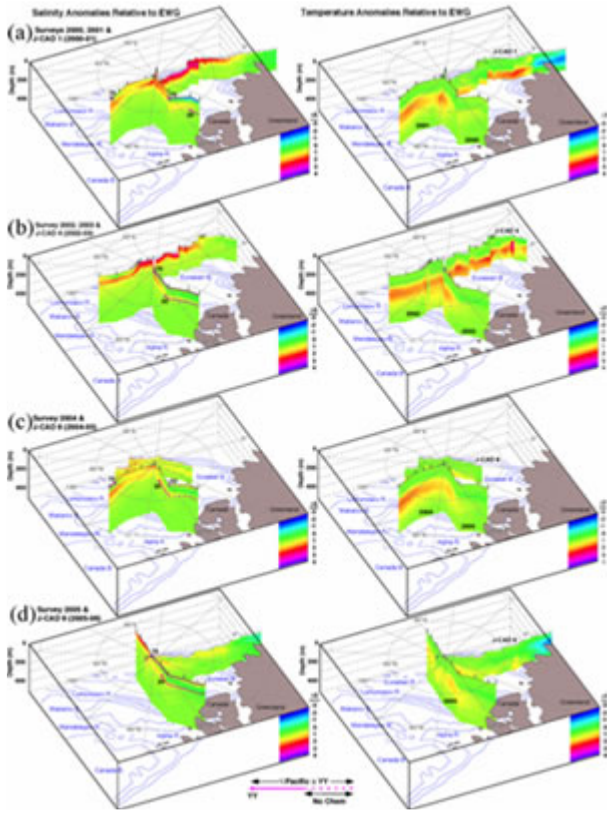

Figure O2. Salinity (l) and temperature (r) anomalies relative to EWG climatology along the NPEO surveys & JAMSTEC Compact Arctic Drifter (J-CAD) tracks for the years indicated on the temperature sections. Gray vertical lines mark survey station sites. Deep magenta lines (l) mark location of greater than 20% Pacific-derived water at 100-150 m. Surface lines mark greater than 70% Pacific-derived in the surface layer. From Morison et al., 2006a.

The Canada Basin hydrography in the 1990s has also changed relative to climatology but, in opposition to the salinity increase at the North Pole, the salinity of the upper layer in the Western Arctic was reduced. There are some indications that in the 2000s, relative to the 1990s, the salinity in this region has increased but it is still significantly less than in EWG climatology. Since 2000, the temperature of the Pacific and Atlantic waters in the Canada Basin is higher than in the 1990s and 0.8-1.0°C higher than in EWG climatology.

The Beaufort Gyre is the major reservoir of fresh water in the Arctic Ocean. In 2000-2006, the total freshwater content in the Beaufort Gyre has not changed dramatically relative to climatology but there is a significant change in the freshwater distribution (Figure O3, panels 3 and 4). The center of the freshwater maximum has shifted toward Canada and significantly intensified relative to climatology. Significant changes were observed

in the heat content of the Beaufort Gyre (Figure O3, panels 1 and 2). It has increased relative to the climatology, primarily because of an approximately 2-fold increase of the Atlantic layer water temperature (Shimada et al., 2004). The Pacific water heat content in the Beaufort Gyre regions has also increased and it is possible that the pronounced sea ice reduction in this region, observed in 2006 (see Figure I1, right panel), resulted from heat released from this layer (Shimada et al., 2006). It is speculated that the major part of these changes in the freshwater and heat content occurred in the 1990s, but there are not enough data to confirm this.

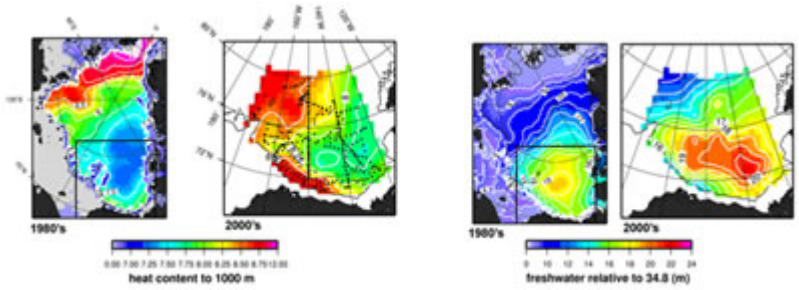

Figure O3. Summer heat (1.E^10 J/m^2, left) and freshwater (m, right) content. Panels 1 and 3 show heat and freshwater content in the Arctic Ocean based on 1980s climatology (Arctic Climatology Project, 1997, 1998). Panels 2 and 4 show heat and freshwater content in the Beaufort Gyre in 2000-2006 based on hydrographic surveys (black dots depict locations of hydrographic stations). For reference, this region is outlined in black in panels 1 and 3. The heat content is calculated relatively to water temperature freezing point in the upper 1000m ocean layer. The freshwater content is calculated relative to reference salinity of 34.8.

Sea Level

Figure O4 shows sea level time series from 9 coastal stations in the Siberian Seas (Arctic and Antarctic Research Institute data archives). These stations are still operational in the Arctic and have records for the period of 1954-2006. There is a positive sea level trend along arctic coastlines. Proshutinsky et al. (2004) estimated that for 1954-1989 the rate of sea level rise along arctic coastlines (40 stations), corrected for the glacial isostatic adjustment (GIA), was 0.185 cm/year. For the 9 stations shown in Figure O4 the rate for 1954-1989, after correction for their GIA, was 0.194 cm/year. Addition of 1990-2006 data increases the estimated rate of sea level change, beginning in 1954, to 0.250 cm/year.

The sea level time series correlates relatively well with the AO index and with the inverse of the sea level atmospheric pressure (SLP) at the North Pole. Consistent with these influences, sea level dropped significantly after 1990 and reached a minimum in 1996-1997 when the circulation regime changed from cyclonic to anticyclonic. In contrast, from 1997 to 2006 the mean sea level has generally increased in spite of the more or less stable behavior of AO and SLP. Since sea level change exhibits large interannual variability and is the net result of many individual effects of environmental forcing, it is difficult to evaluate the significance of the change in relative terms. The observed sea level rise during last 6-7 years could be related to decadal variability in combination with a general tendency of sea level to rise due to global warming (Greenland and Antarctic ice sheet melt) and, correspondingly, to the Arctic change expressed in an expansion of the water column due to increased water temperature (reduction of sea ice and solar warming in summer) and a decrease of water salinity (sea ice melt, increase of river runoff).

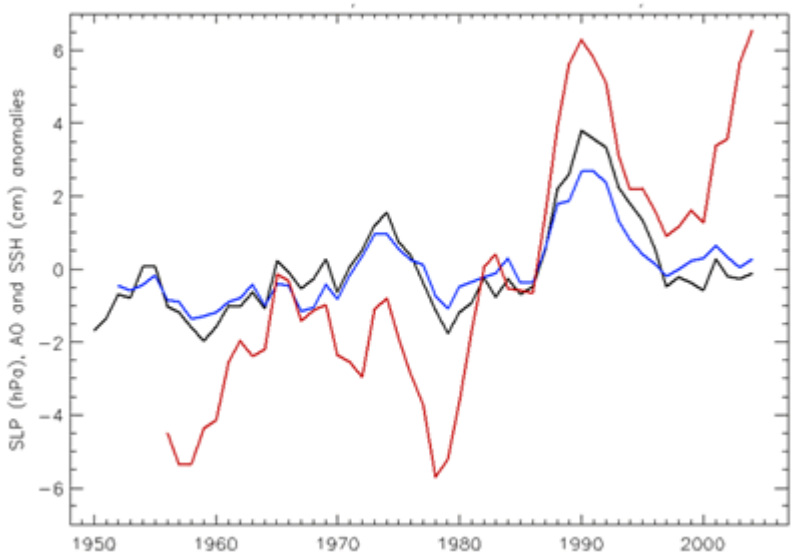

Figure O4. Annual mean anomalies of sea level at 9 tide gauge stations located along the Kara, Laptev, East-Siberian and Chukchi Sea coastlines (red). The blue line is the 5-year running mean anomalies of the annual mean Arctic Oscillation (AO) index multiplied by 3. The black line is the sea surface atmospheric pressure (SLP) anomaly at the North Pole (from from National Center for Atmospheric Research/NCEP reanalysis data) multiplied by -1.

References

Arctic Climatology Project (1997) Environmental Working Group joint U.S.-Russian atlas of the Arctic Ocean - winter period. Edited by L. Timokhov and F. Tanis. Ann Arbor, MI: Environmental Research Institute of Michigan in association with the National Snow and Ice Data Center. CD-ROM.

Arctic Climatology Project (1998) Environmental Working Group joint U.S.-Russian atlas of the Arctic Ocean - summer period. Edited by L. Timokhov and F. Tanis. Ann Arbor, MI: Environmental Research Institute of Michigan in association with the National Snow and Ice Data Center. CD-ROM.

Morison, J., M. Steele, T. Kikuchi, K. Falkner, and W. Smethie (2006a) Relaxation of central Arctic Ocean hydrography to pre-1990s climatology. *Geophys. Res. Lett., 33*, L17604, doi:10.1029/2006GL026826.

Morison, J., J. Wahr, R. Kwok, and C. Peralta-Ferriz, (2006b) Change in the Arctic Ocean as Observed with GRACE and In Situ Bottom Pressure Measurements. *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract G12A-03 of presentation at the 2006 Fall AGU Meeting.

Proshutinsky, A., I.M. Ashik, E.N. Dvorkin, S. Häkkinen, R.A. Krishfield, and W.R. Peltier (2004) Secular sea level change in the Russian sector of the Arctic Ocean. *J. Geophys. Res., 109*, C03042, doi:10.1029/2003JC002007.

Proshutinsky, A.Y., and M.A. Johnson (1997) Two circulation regimes of the wind-driven Arctic Ocean. *J. Geophys. Res., 102*(C6), 12493-12514, 10.1029/97JC00738.

Rigor, I.G., J.M. Wallace, and R.L. Colony (2002) Response of Sea Ice to the Arctic Oscillation. *J. Climate, 15*, 2648-2663.

Shimada K., T. Kamoshida, M. Itoh, S. Nishino, E. Carmack, F.A. McLaughlin, S. Zimmermann, and A. Proshutinsky (2006) Pacific Ocean inflow: Influence on catastrophic reduction of sea ice cover in the Arctic Ocean. *Geophys. Res. Lett., 33*, L08605, doi:10.1029/2005GL025624.

Shimada, K., F. McLaughlin, E. Carmack, A. Proshutinsky, S. Nishino, and M. Itoh (2004) Penetration of the 1990s warm temperature anomaly of Atlantic Water in the Canada Basin. *Geophys. Res. Lett., 31*, L20301, doi:10.1029/2004GL020860.

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