Impacts of climate change on fresh water content and sea surface height in the Beaufort Sea

Fisheries and Oceans Canada / Pêches et Océans Canada

Will Perrie and Zhenxia Long

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth NS, Canada

Canada

IAbstract:

We explore how fresh water content and sea surface height in the Beaufort Sea may be modified by warming-induced conditions due to climate change. We performed simulations for 1970 - 2069 with a coupled ice-ocean model (CIOM) implemented for the Arctic Ocean. Surface fields to drive CIOM are provided by the Canadian Regional Climate Model (CRCM), driven by the 3rdgeneration Canadian global climate model (CGCM3) following the A1B climate change scenario. Simulated sea ice concentration in the entire Arctic and the fresh water content in the Beaufort Sea are shown consistent to reanalysis data. For future climate, CIOM simulations suggest 11% decrease/ decade in ice volume, with the Arctic becoming largely ice free in summers by about 2070. Moreover, increased sea ice melt and Ekman transport, give increased fresh water content (FWC) and sea surface height (SSH) in the Beaufort.

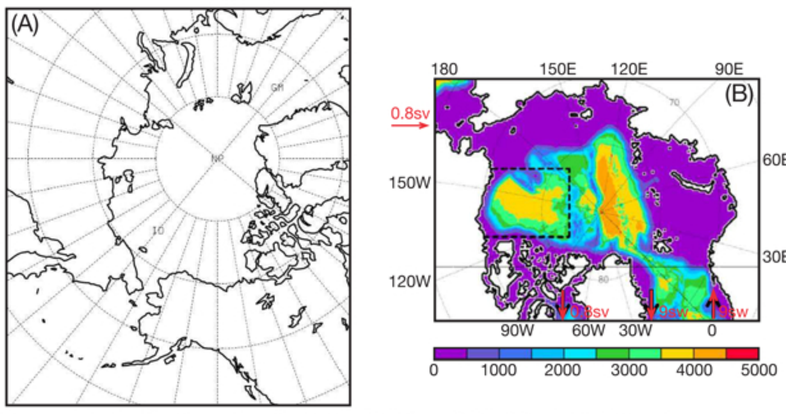

Figure 1. Model domains for (a) CRCM and (b) CIOM. In (b), units are in m, and the thin solid line is the equator of the rotated spherical coordinate system. The box indicated by the thick dashed line is the area where the variables are averaged to show their trends for the Beaufort Sea area.

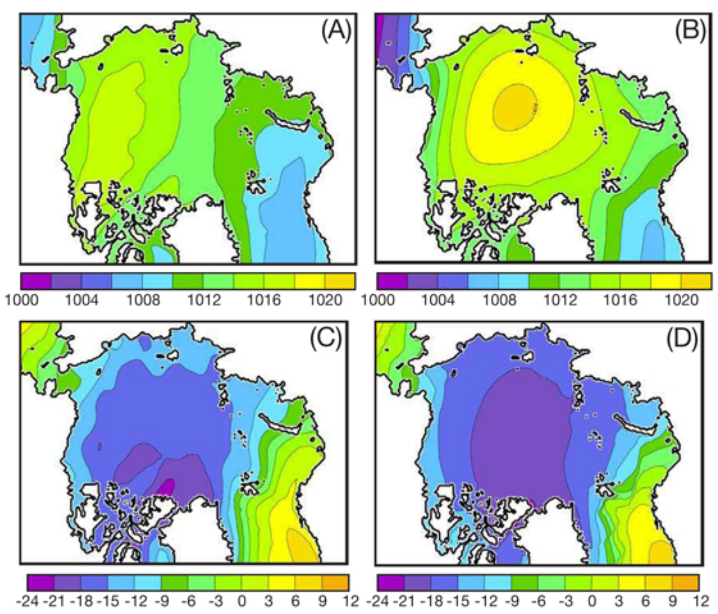

Figure 2. Annual fields for (a) sea level pressure from NCEP, (b) sea level pressure from CRCM, (c) 2m air temperature from NCEP(c) and (d) 2m air temperature from CRCM simulation, averaged during 1979-2008. Units are hPa in (a) and (b), and oC in (c) and (d).

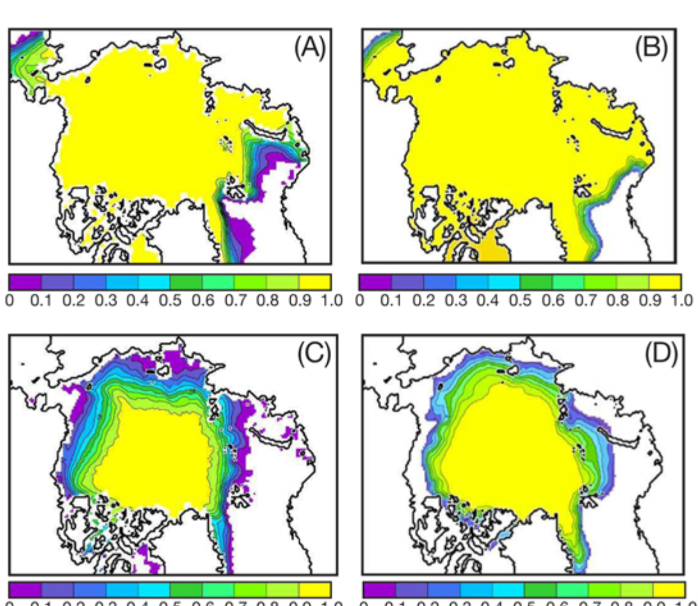

Figure 3. Ice concentration in March for (a) Hadley data and (b) CIOM simulation, and September for (c) Hadley data, and (d) CIOM simulation, averaged during 1979-2008.

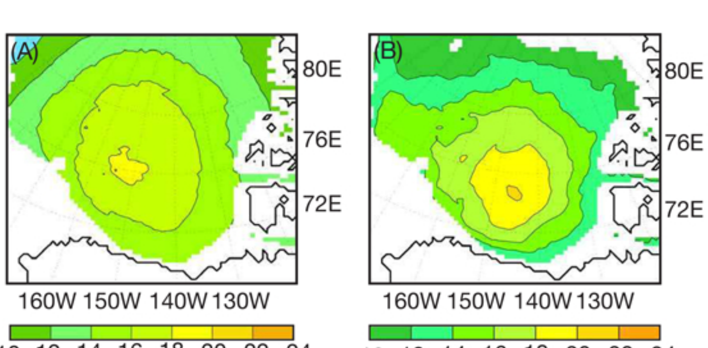

Figure 4. Annual fresh water content (a) estimated from PHC data and (b) CIOM simulation, averaged during 1979-2008, for the area (rotated) indicated by the thick dashed line in Figure 1b. Units are m.

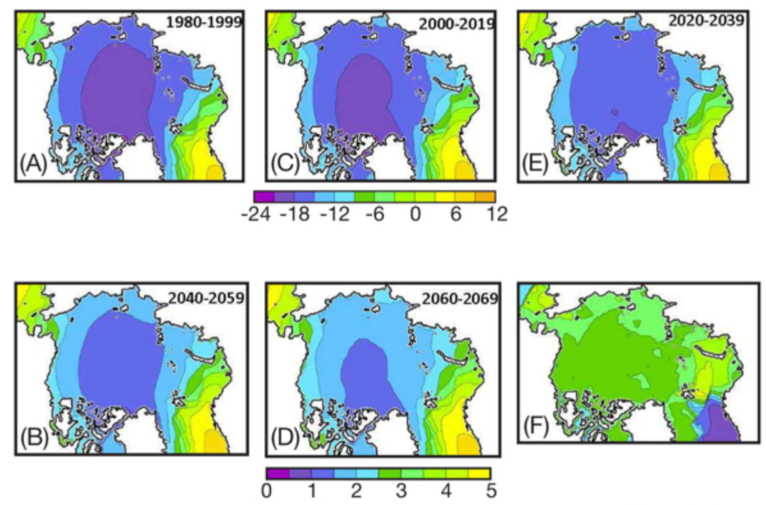

Figure 5. Annual surface air temperature simulated by CRCM (a) - (e). Change in annual surface air temperature, averaged from 2040-2069, relative to the average from 1980 to 2009 is shown in (f). Unit: oC . Colorbar for (a)-(e) is on left, for (f) is on right.

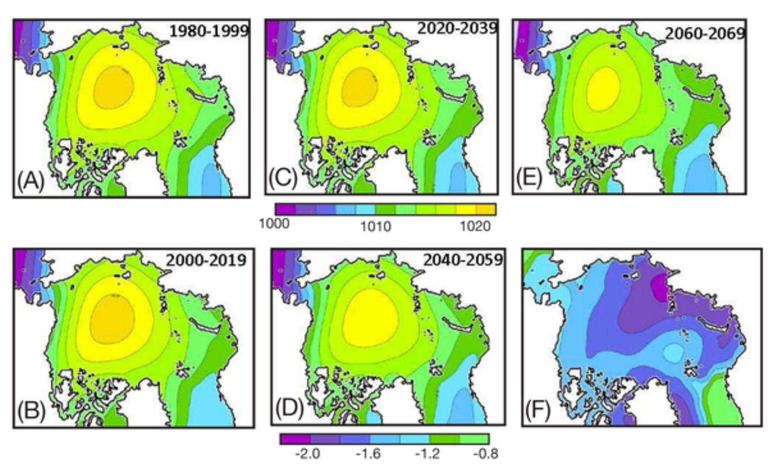

Figure 6. Annual sea level pressure simulated by CRCM (a) – (e). Change in annual sea level pressure, averaged from 2040-2069, relative to the average from 1980 to 2009 is shown in (f). Colorbar for (a)-(e) is on left, for (f) is on right. Units: hPa.

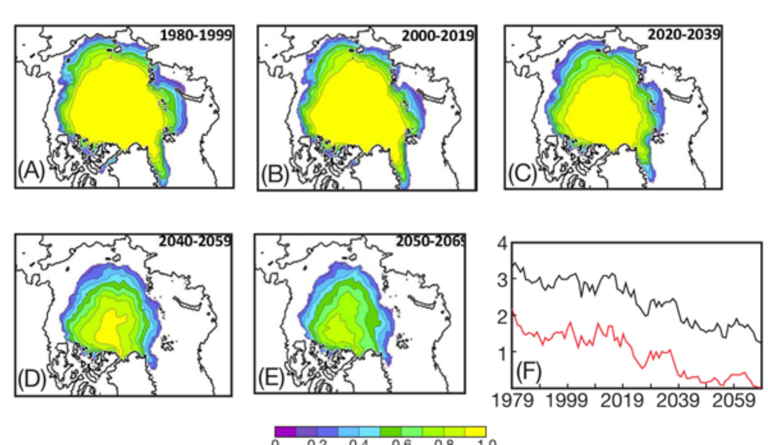

Figure 7. Decadal comparisons of summer ice concentration (a) – (e). Time series of total ice volumes in March (black) and September (red) are shown in (f), in units of 104kg3.

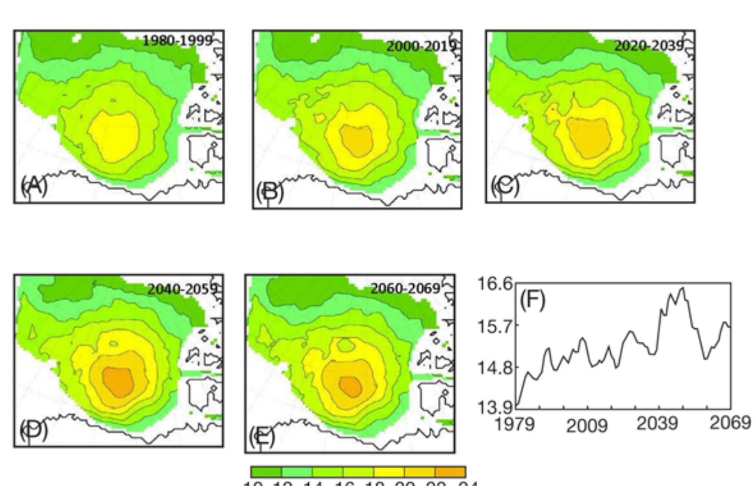

Figure 8. Comparisons of fresh water content in the Beaufort Sea in (a) – (e). Time series of fresh water content is shown in (f), averaged over the area (rotated) indicated by the thick dashed line in Figure 1b. Units in m.

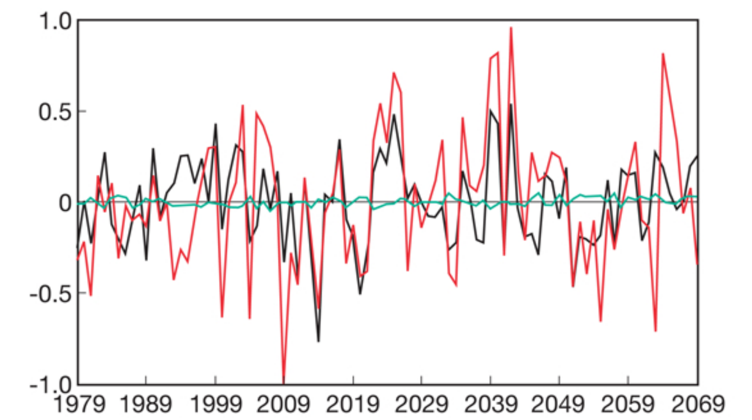

Figure 9: The budget for the Deaufort Gyre fresh water content, showing fresh water flux anomalies (into the box indicated by dashed lines in Figure 1) due to: (a) ice formation and melting (red), (b) Ekman pumping (black) and (c) surface moisture flux (P-E, green. Units are m/year. Anomalies are computed with the averages over the period 1979-2069 removed.

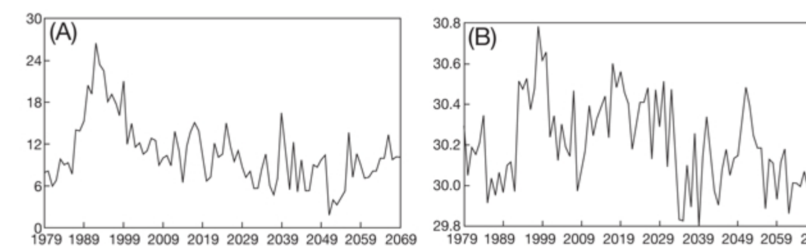

Figure 10. (1) Annual water transport (m) into the box indicated by dashed lines in Figure 1, and (b) averaged water salinity over the lateral boundaries along the box.

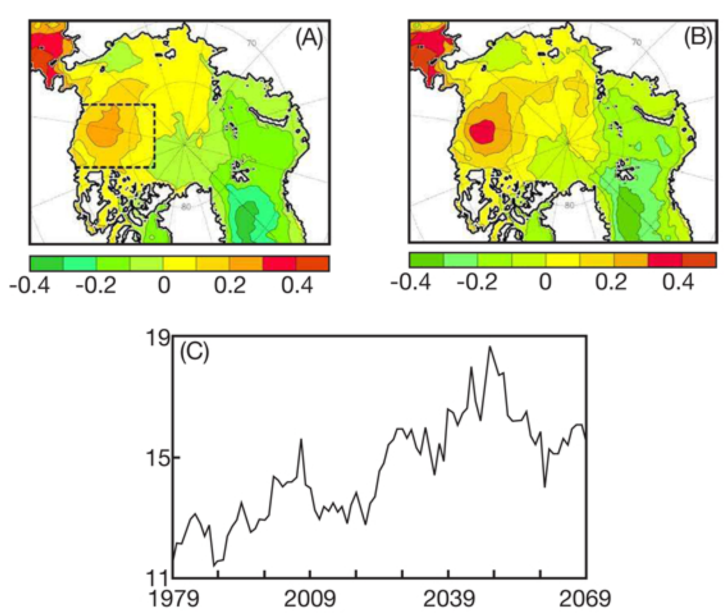

Figure 11. Annual sea surface height (unit: cm), averaged over (a) 1979-2008, and (b) 2040-2069. Time series of sea surface height (unit: cm) is shown in (c), averaged over the area indicated by the thick dashed line in (a).

Conclusions:

1. Comparisons with NCEP reanalyses suggest that CRCM can capture the main features of sea level pressure and surface air temperature, but tend to overestimate the Beaufort Sea High (BSH), and underestimate the Icelandic low pressure system over Barents and Norwegian Seas.
2. Compared to the Hadley data, CIOM can reliably reproduce the ice concentration climatology, consistent with observed maximum FWC in the Beaufort Sea suggested by the PHC data.
3. CRCM simulations suggest increases of 2.5oC-3oC in surface air temperature, decreases by 1.5-2hPa in sea level pressure in the central Arctic during 1979 -2069, and 11% decrease per decade in ice volume, suggesting the Arctic would be largely ice free during summers, by about 2070.
4. During 1979-2009, due to (a) Ekman transport and (b) increased sea ice melting, the CIOM show increasing FWC and SSH in the Beaufort Sea, respectively, by 2 m and 6 cm, in the Beaufort; surface moisture flux contributions are relatively small.
5. During 2009-2039, increased ice melt is the dominant factor in FWC increase in the Beaufort, and Ekman transport is secondary; during 1979-2000 increased EP is mainly from enhanced water volume advection, while after 2000 increased EP is mainly from more surface freshening.
6. Changes in the FWC and SSH in the Beaufort Sea are related to surface field changes; intensified BSH 1970-2000 increases Ekman transport due to more water volume transport, increasing FWC. Increased ice melt is secondary. After 2000, weakened BSH tends to weaken Ekman transport, reducing the FWC. But Arctic warming accelerates ice melt, making it more dominant, contributing to increased FWC locally and by more Ekman FWC transport by surface freshening.
7. A caveat is that the river runoff is prescribed as climatology; but recent studies suggest that the increased river runoff can significantly impact the FWC in the Beaufort (Morison et al. 2012; Jahn et al. 2013).Thus, increases in SSH and FWC in the Beaufort may be underestimated.

Acknowledgements: Support for this research comes from the Federal IPY Office, and Government of Canada's ACCASP (Aquatic Climate Change Adaptation Service Program) Initiative.

Citation: Long, Z., and Perrie, W. Impacts of climate change on fresh water content and sea surface height in the Beaufort Sea: 2013. Ocean Modelling, http://dx.doi.org/10.1016/j.ocemod.2013.05.006