Stabilizer for World Climate?  
(DeBoer & Nof, 2004)
- if Bering Strait is open, excess freshwater in the Atlantic (from, for example, ice sheet collapse) can “vent” through the Bering Strait, allowing a speedy return to deep convection in the Atlantic.

Land Bridge for migration of mammals and people?

Note: in modern times, people have swum, driven and walked across!
Global role of Arctic Freshwater

A Freshwater source for the Atlantic Ocean

Freshwaters exit the Arctic through the Fram Strait and through the Canadian Archipelago (Jones et al, 2003)

Freshwater inhibits deep convection, slowing the Atlantic Ocean overturning circulation (see Wadley & Bigg, 2002, for a discussion)

Models suggest the Bering Strait throughflow also influences the deep western boundary currents & the Gulf stream separation (Huang & Schmidt, 1993)
Deep waters of the Atlantic

Potential Temperature at 25W

from http://sam.ucsd.edu/sio210/gifimages/A16_THETA.gif
Deep waters of the Atlantic

from http://www.jochemnet.de/fiu/DeepCir4.jpg
Where do waters sink??

2) Arctic??

Generally thought NOT much deep convection in the Arctic Ocean.

Caveats:
- IS convection on shelves
- Rudels arguments for plumes through AW to account for differences in Deep Waters in two main basins

Jones et al., 2001, Polar Research

Fig. 2. Schematic circulation of surface water (grey arrows) and the Atlantic Layer plus Upper Polar Deep Water to depths of about 1700 m (black arrows). The straight arrows represent the mouths of major rivers.
Arctic Deep Waters

Canadian Basin Deep Water = Warmer, Saltier
Eurasian Basin Deep Water = Colder, Fresher

- relic??
- leaky ridge
- plumes? (Rudels et al)
- geothermal heating

Woodgate et al, 2001 and see also Bjork et al, 2007

Timmermanns et al, 2003
Bathymetry and deep-water exchange across the central Lomonosov Ridge at 88–89°N

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Abstract

Seafloor mapping of the central Lomonosov Ridge using a multibeam echo-sounder during the Beringia/Healy-Oden Trans-Arctic Expedition (HOTRAX) 2005 shows that a channel across the ridge has a substantial shallower sill depth than the ~2500 m indicated in present bathymetric maps. The multibeam survey along the ridge crest shows a maximum sill depth of about 1870 m. A previously hypothesized exchange of deep water from the Amundsen Basin to the Makarov Basin in this area is not confirmed. On the contrary, evidence of a deep-water flow from the Makarov to the Amundsen Basin was observed, indicating the existence of a new pathway for Canadian Basin Deep Water toward the Atlantic Ocean. Sediment data show extensive current activity along the ridge crest and along the rim of a local Intra Basin within the ridge structure.

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Fig. 3. Comparison between the bathymetry of the central Lomonosov Ridge as portrayed by the 2500 × 2500 m resolution DBM (a) compiled within the IBCAO project (Jakobsson et al., 2006) and (b) the new 500 × 500 m resolution DBM compiled here. The bold black contour line shows the 2500 m isobath. Fig. 2 shows the distribution of the bathymetric sources used to assemble the new 500 × 500 m DBM. Note the large discrepancies between deepest sill depths of the Intra Basin on the Makarov Basin side. Panel (b) includes also the proposed mean circulation of deep waters around the 2000 m level in the Intra Basin area based on hydrographical observations and sediment structures. Red arrows show the flow trajectory of Makarov Basin water and orange arrows the flow trajectory of Amundsen Basin water.
Where do waters sink??

3) North Atlantic

GIN (Greenland-Iceland-Norwegian) and Labrador out of phase?

Irminger, local wind forcing

What feeds NADW (North Atlantic Deep Water)?
Denmark Strait Overflow

Dickson et al, refs

Denmark Strait
~ 650m deep

Iceland Scotland Ridge
~ 400-650m deep

i.e. Deep water from the Arctic and the GIN Seas doesn’t get out!!!

What exits through Denmark Strait?
- near surface
- at depth

from http://iodp.tamu.edu/publications/PR/303PR/images/Fig01.jpg
Source for Denmark Strait Overflow Water?

Still debated:

**Swift 1980, Swift & Aagaard, 1981**
- uAIW from Iceland Sea

**Strass et al, 1993**
- rAW & uAIW carried in East Greenland Current

**Mauritzen 1996a and b**
- rAW plus FSBW from Arctic

**Jonsson & Valdimarsson, 2004**
- Iceland Sea

Role for Arctic and GIN seas in Deep Overflows ...
... and in surface layers
Where do waters sink??

1) Antarctica

Some mechanisms invoke High Salinity Shelf Water and processes under Ice Shelves

Antarctic = major source
Formation of platelet ice and green ice bergs

http://www.awi-bremerhaven.de/Meereis/gruener-eisberg-e.html
Climate Change??

Fig. 2. Hypothesized dependence of the convective renewal rate (CRR) on freshwater supply (FWS) from the Arctic Ocean under (a) present conditions, (b) increased freshwater supply, and (c) decreased supply. The size of the arrows through the right-hand side is representative of the strength of the thermohaline circulation forced from the far northern seas. The barred arrows represent the extreme locations of convection. The solid arrows in the insets indicate the trend in convective renewal with changing freshwater supply, and the dashed arrows indicate possible transitions to different circulation modes.

Bitz et al., 2006
- effects of increasing CO2
- separate out ice-albedo effect

= more overturning at shallow depths in Arctic

Aagaard and Carmack, 1994
Ice Albedo Feedback

$S =$ Shortwave radiation from sun (reflects off clouds and surface)

$albedo =$ how much radiation reflects from surface

$albedo$ of ice $\sim 0.8$

$albedo$ of water $\sim 0.04$

(if sun overhead)

$L =$ Longwave radiation (from surface and clouds)

$F =$ Heat flux from Ocean

$M =$ Melt (snow and ice)

$P =$ Precipitation

$T =$ Atmospheric Heat Transfer

$q =$ Atmospheric moisture transfer

LESS Ice Melt

+ve Feedback

LESS SW absorbed by water

Other possible important factors
- clouds??
- ocean circulation??

Water colder
Global models in the Arctic

From M. Holland, pers.comm.
updated from Holland & Bitz, 2003
On the reliability of simulated Arctic sea ice in global climate models

I. Eisenman,¹ N. Untersteiner,² and J. S. Wettlaufer³

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[1] While most of the global climate models (GCMs) currently being evaluated for the IPCC Fourth Assessment Report simulate present-day Arctic sea ice in reasonably good agreement with observations, the intermodel differences in simulated Arctic cloud cover are large and produce significant differences in downwelling longwave radiation. Using the standard thermodynamic models of sea ice, we find that the GCM-generated spread in longwave radiation produces equilibrium ice thicknesses that range from 1 to more than 10 meters. However, equilibrium ice thickness is an extremely sensitive function of the ice albedo, allowing errors in simulated cloud cover to be compensated by tuning of the ice albedo. This analysis suggests that the results of current GCMs cannot be relied upon at face value for credible predictions of future Arctic sea ice. Citation: Eisenman, I., N. Untersteiner, and J. S. Wettlaufer (2007), On the reliability of simulated Arctic sea ice in global climate models, Geophys. Res. Lett., 34, L10501, ice sensitivity calculations with specific Arctic.

[4] Here we consider intermodel differences in Arctic cloud cover, which are large in the GCMs and produce significant differences in downwelling longwave radiation. At the time of this analysis, output fields were available from 16 of the GCMs currently being evaluated for the IPCC AR4 (Figure 1 legend). The range of simulated fields in the GCMs for cloud cover and downwelling longwave radiation at the 500 m vertical level in the atmosphere. As an example, broad intermodel spread in cloudiness, mean seasonal cycle in total vertically integrated cloud fraction is plotted for each GCM in Figure 1a. A range in cloudiness is associated with a 40 W m⁻² range in downwelling longwave radiation at the surface (Figure 1b).

[5] We use two standard thermodynamic