P1.5 INTER-SEASONAL AND INTER-DECADAL VARIABILITY OF FRESHWATER AND HEAT CONTENT IN THE ARCTIC OCEAN

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1. INTRODUCTION

Our main goal is to better understand the most recent (last half of the twentieth century) variations in freshwater and heat content of the Arctic Ocean. We looked at seasonal variations (winter vs. summer) and variations on a decadal scale. The study provides historical reference and a first order estimate of climate trends in the Arctic Basin.

2. DATA

The analysis is on the 50 x 50 km gridded fields of Arctic Ocean salinity, temperature and density provided by the EWG (Environmental Working Group) Atlas hydrographic datasets for the period 1950-1989. The temperature and salinity fields utilized the U.S. Navy's Generalized Digital Environmental Model (GDEM) interpolation methodology. The density grids were generated using UNESCO standard routines (Millero, 1978). The 40-year period was subdivided into four decades: 1950-1959, 1960-1969, 1970-1979 and 1980-1989. The data extend from the ocean surface to depths of 4,000 m, with a spatial coverage ranging from 65 ^{o} N to 90 ^{o} N, and are divided seasonally into winter (DJFMAM) and summer (JJASON).

3. RESULTS

3.1 *Freshwater thickness climatology*

Climatologies were constructed over the period 1950-1989. The freshwater thickness (FT) for the winter and summer period are shown in Figure 1 and Figure 2. Freshwater thickness: $H_h = \int_{z_i=-h}^{0} \left(\left(S_{ref} - S_z \right) / S_{ref} \right) dz$, for all z_i such as $S_z < S_{ref}$, where $S_{ref} = 34.75\ ‰$ is the Atlantic layer salinity. Effective water mass is the halocline water, or the surface of the Arctic Water from the sea surface to 200 - 300 m depth.

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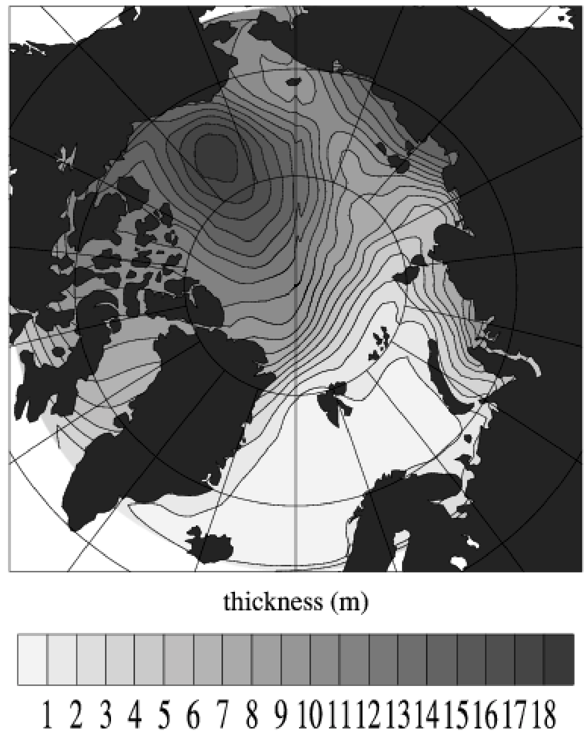

Figure 1. Freshwater thickness climatology, winter 1950-1989.

3.2 *Freshwater thickness summer anomalies*

Several processes (e.g., in-situ melting of sea ice, river inflow, freshwater inflow through Bering Strait or Fram Strait, and precipitation) can cause changes in freshwater thickness. In the 1950s (Figure 3) a strong negative anomaly is located at the center of the anticyclonic Beaufort Gyre, while an additional negative anomaly appears in the center of cyclonic ice motion near the Laptev Sea region. Additionally, there is a strong positive anomaly north of Greenland, where ice exiting the Beaufort Gyre converges into Fram Strait.

In the 1960s (Figure 4), opposite anomalies are evident. Two strong positive anomalies correspond to centers of cyclonic and anticyclonic ice motion, and a negative anomaly appears north of Greenland. The reduced-anomaly separation between the positive anomaly in the Canadian region of the Arctic Basin and the positive anomaly near the Laptev Sea corresponds to the approximate location of the Trans-Polar Drift stream (TPD). In the 1970s (Figure 5)

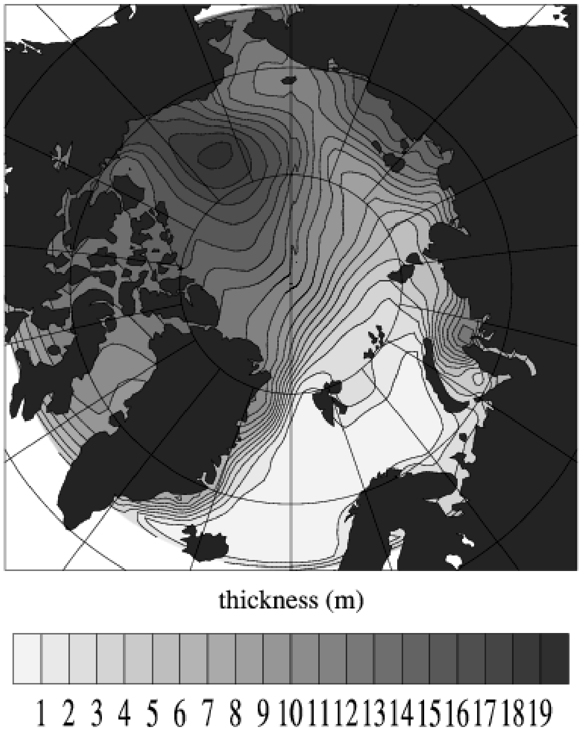

Figure 2. Freshwater thickness climatology, summer 1950-1989.

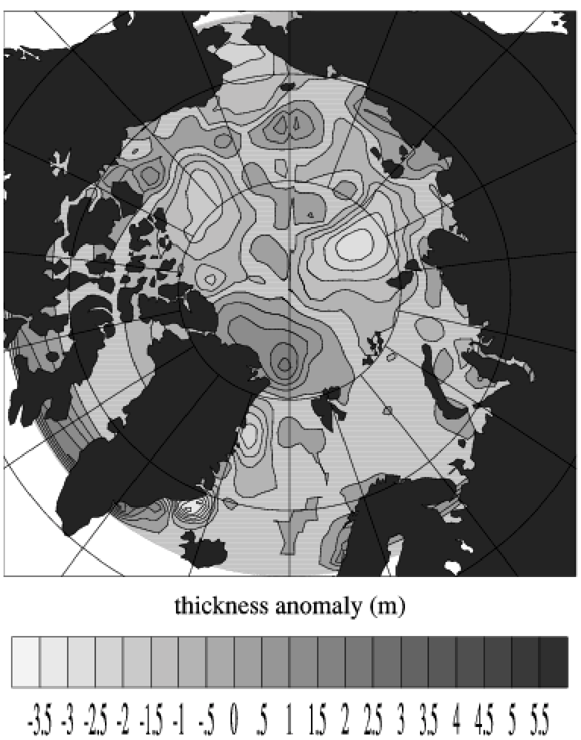

Figure 3. Freshwater thickness anomaly, summer 1950-1959.

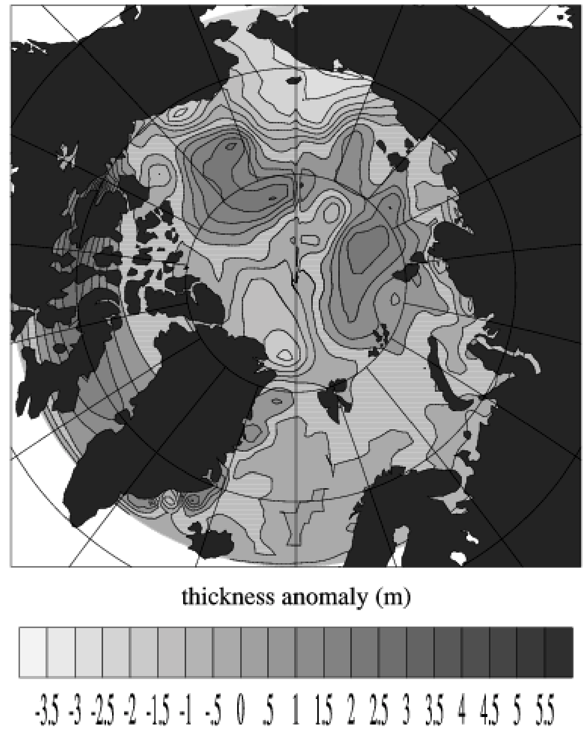

Figure 4. Freshwater thickness anomaly, summer 1960-1969.

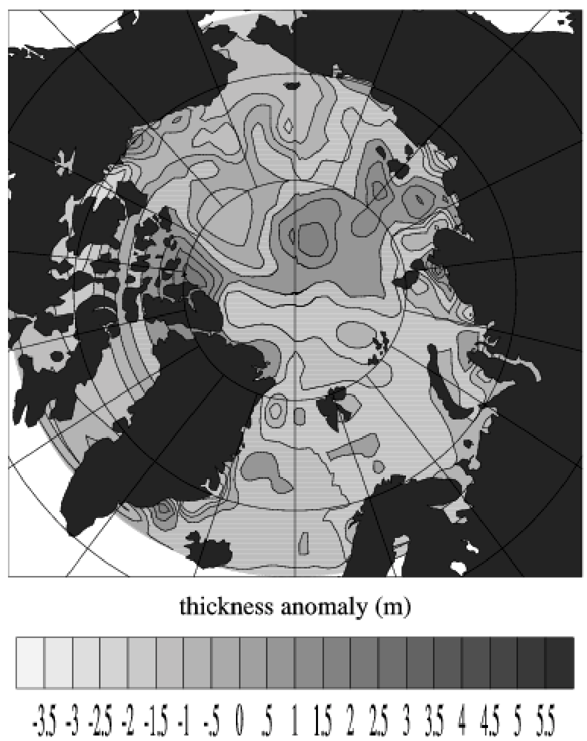

Figure 5. Freshwater thickness anomaly, summer 1970-1979.

a negative anomaly near the center of the Beaufort Gyre persists, while the anomaly near the Laptev Sea remains positive, but the center of this anomaly now shifts closer to the North Pole. During the 1980s (Figure 6), a negative anomaly spreads across the Central Arctic Basin from the center of the Beaufort

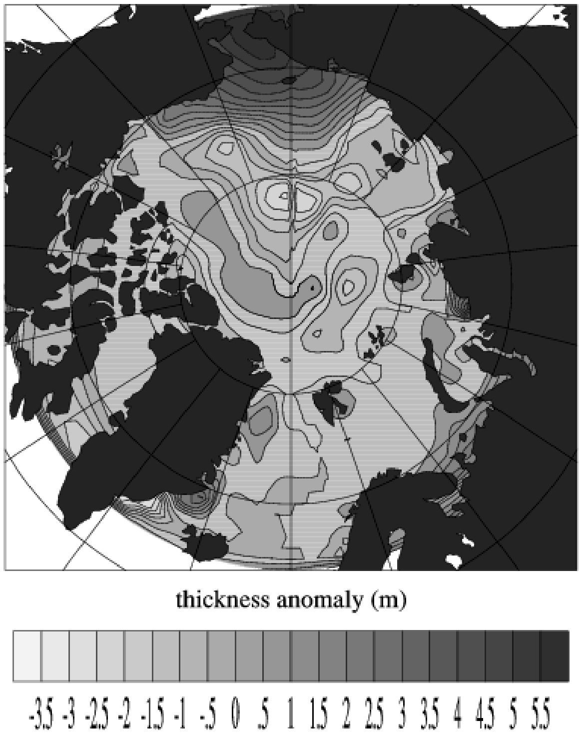

Figure 6. Freshwater thickness anomaly, summer 1980-1989.

Gyre to the Laptev Sea region, while a strong positive anomaly appears in Bering Strait and the Chukchi Sea where anomalies were negative for the preceding three decades. This positive anomaly may reflect an anomalously strong inflow of fresh water into the Arctic.

3.3 *Heat content climatology*

Climatologies were constructed over the period 1950-1989. Figures 7 and 8 present heat content (HC) for the winter and summer period. Heat Content:

$$Q_h = \int_{z_i=-h}^{0} \rho_z c_{p\,w} \left(T_z - T_{ref}\right) dz, \quad \text{for all } z_i \text{ such as}$$

$$T_z > T_{ref}, \quad \text{where} \quad T_{ref} = T_{Atlantic\ Water} = 0^\circ C.$$

Effective water mass is Atlantic Water from 200 -300 m to 800 - 1,000 m depth.

3.4 *Heat content summer anomalies*

Positive HC anomalies appear to migrate counterclockwise across the Arctic over the 40-year period. In the 1950s (Figure 9), the anomalies are close to the Russian and Norwegian coasts. Through the 1960s and 1970s, the anomalies appear in the central Arctic and the Chukchi Sea, closer to the Canadian sector of the Arctic Basin, and away from the Russian/ Norwegian coasts. Finally, in the 1980s (Figure 10), the warm anomalies appear along the Canadian Archipelago. The pattern suggests counterclockwise heat advection on long, multi-decadal time scales. A positive heat content anomaly is also co-located with a positive freshwater anomaly

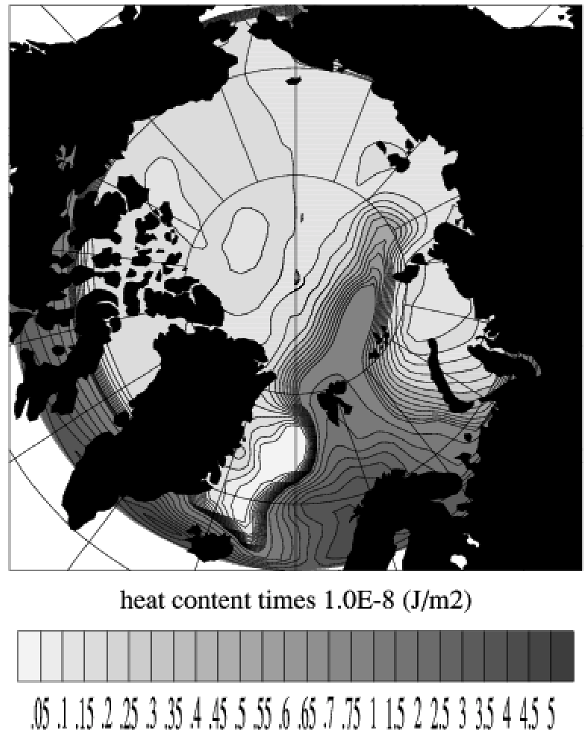

Figure 7. Heat content climatology, winter 1950-1989.

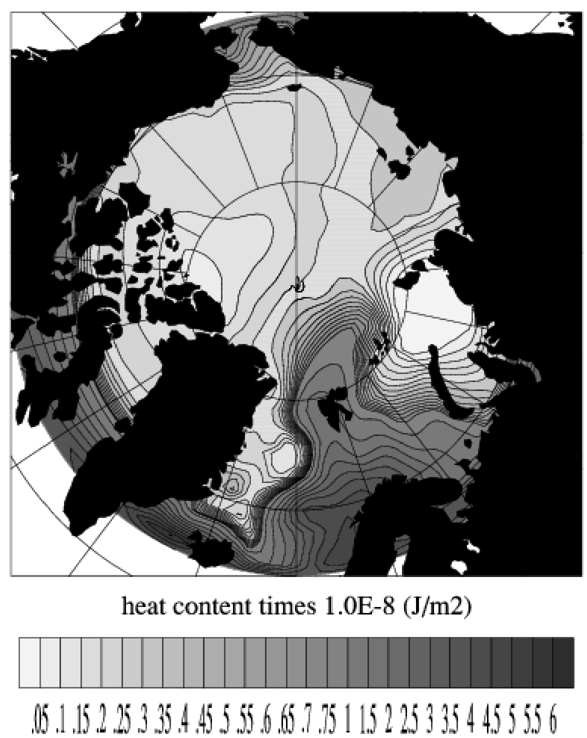

Figure 8. Heat content climatology, summer 1950-1989.

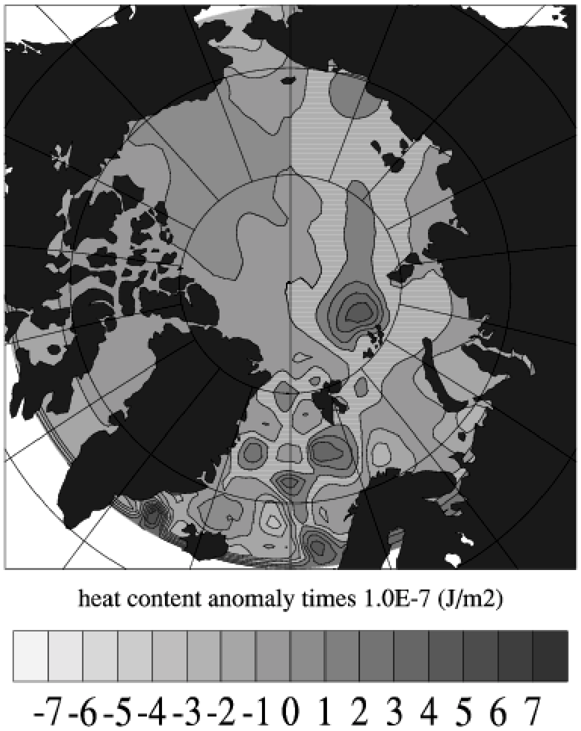

Figure 9. Heat content anomaly, summer 1950-1959.

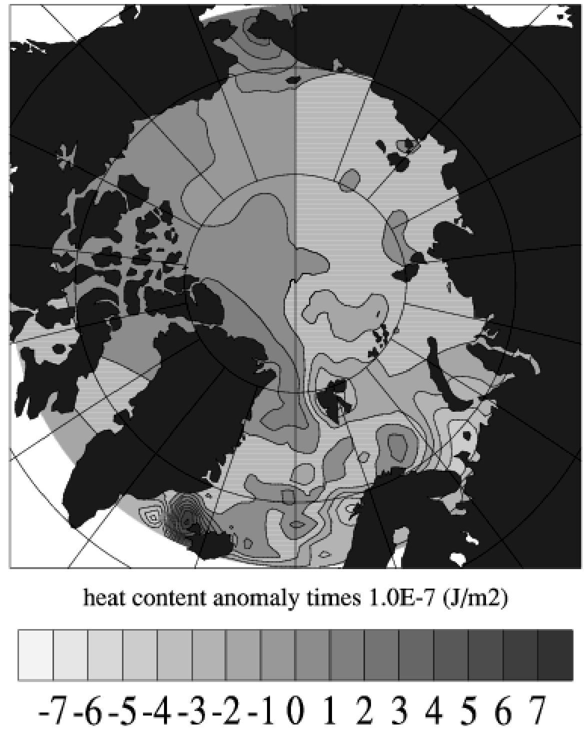

Figure 10. Heat content anomaly, summer 1980-1989.

in Bering Strait/ Chukchi Sea for the 1980s (Figure 6), suggesting an anomalously warm and fresh inflow into the Arctic.

4. SUMMARY

1. Freshwater anomalies had two highs and two lows in the 1950s and 1960s, which shifted to a single high and low anomaly during the 1970s and continued through the 1980s. Negative freshwater anomalies in the 1950s and positive anomalies in 1960s are associated with regions of the Arctic away from the Trans-Polar flow and at the center of Arctic circulations (anticyclonic Beaufort Gyre and cyclonic near the Laptev Sea).

2. Positive heat content anomalies have progressively migrated counterclockwise from the Russian/Norwegian coasts in the 1950s to the Canadian Archipelago in the 1980s.

3. A strong positive freshwater and heat content anomaly appears in Bering Strait and the Chukchi Sea for the 1980s, suggesting an anomalous warm, fresh inflow into the Arctic Basin from the North Pacific.

5. ACKNOWLEDGMENTS

This work was funded by Frontier Research System for Global Change. Authors thank Dr. J. Swift for useful discussions, and Mr. C. Swingley for help with computer support.

6. REFFERENCES

Environmental Working Group Joint U.S. Russian Atlas of the Arctic Ocean, Oceanography Atlas for the Winter Period, Version 1.0, 15 March 1997.

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