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Environmental conditions in the Labrador Sea in Spring 2001

Conditions ambiantes dans la mer du Labrador au printemps 2001

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Abstract

The upper layers of the Labrador Sea were observed to be warmer, saltier, and less dense in the summer of 2001 compared with conditions in 2000. These changes seem to be due largely to advection: there is no evidence for convective overturning during the winter of 2000-2001 to depths greater than 500 m.

Résumé

À l'été 2001, les couches d'eau supérieures de la mer du Labrador étaient plus chaudes, plus salées et moins denses qu'en 2000. Ces différences semblent être largement attribuables à l'advection; il ne semble pas y avoir eu de renversement convectif au-delà de 500 m de profondeur au cours de l'hiver 2000-2001.

Introduction

The most recent transect of WOCE Line AR7W by Ocean Sciences Division (Fisheries and Oceans Canada at the Bedford Institute of Oceanography) was made during May 30 - June 15, 2001 on board CCGS Hudson. Chief scientist for Expedition Hudson 2001022 was R. Allyn Clarke of Ocean Sciences Division. There were no major problems and all expedition goals were achieved.

Fig. 1 shows a map of the Labrador Sea with station positions for the 2001 Hudson expedition, including 31 full-depth AR7W stations with water samples for a suite of chemical measurements. The Bravo mooring site in the central Labrador Sea near the historical location of Ocean Weather Ship Bravo is marked. TOPEX/POSEIDON ground tracks are also shown.

Vertical sections

Contoured sections of potential temperature, salinity, and potential density anomaly for the 2001 AR7W section are shown in Figs. 2a, b, and c.

The most noticeable features of the upper layers are the warm, saline waters of the West Greenland Current at the eastern boundary of the Labrador Sea and the cold, fresh waters of the Labrador Current on the western boundary. A seasonal thermocline with a maximum surface temperature of about 6.1 ^{o}C had developed at the time of the survey. Its effects are limited to the upper 100 m. Below the seasonal layer, the upper 2000 m of the water column show considerable horizontal and vertical structure in all fields. Centered near distance 450 km there is a prominent pool of cool, fresh water. This feature has a horizontal extent of 100 – 200 km and extends to 400 – 500m depths. Potential density contours are somewhat depressed in and below the feature relative to the adjacent waters. The origin of this feature is unclear.

Fig. 2a shows a widespread temperature minimum in the vertical (values near 3.1 ^{o}C) that deepens from 700-900 m to 900-1100 m depths from west to east. This is a remnant of the convection that took place during the winter of 1999-2000 and was observed in Spring 2000. The persistence of this layer through the winter of 2000-2001 shows that convection did not reach these depths during this past winter.

The vertical structure in potential temperature and salinity may be seen more clearly in Fig. 3 which shows the average potential temperature - salinity curve derived from the four Year 2001 stations in the distance range 320-520 km. Depth annotations are added at 500 m intervals. A similar average for the Year 2000 AR7W occupation is included for comparison. The shape of the 2001 curve is similar to the 2000 curve in the 500-2000 m depth range. The similarity suggests that any convection that may have occurred during the winter of 2000-2001 was limited to depths less than 500 m.

Deeper Labrador Sea Water (LSW) formed by deep convection in a series of severe winters between 1988 and 1993 is still present in 2001. This is shown in Fig. 3 by the cold, fresh salient in the potential temperature - salinity curve at depths near 2000 m. Since 1994, the core of this water has steadily become warmer and saltier. This trend continued in 2001: the 2001 values are 0.02 to 0.03 ^{o}C warmer and 0.002 to 0.003 saltier on density surfaces than the 2000 values in this depth range.

Contoured sections of the changes in potential temperature, salinity, and potential density relative to the previous year's occupation (Expedition HUDSON 2000009, May 20 - June 8, 2000) are shown in Figs. 4a, b, and c.

The cool and fresh pool near 450 km distance noted above is prominent in the difference plots for potential temperature and salinity, but less so for potential density. The general trend to warmer, more saline, and less-dense properties shown in Fig. 3 for the western side of the Labrador Sea is widespread in the upper 1000 m. The likely source is an increased warm water input from the West Greenland Current: the effects are more pronounced closest to the presumed source on the eastern side of the Labrador Sea. We should note that the gridded differences depend on interpolating the 2000 results across a gap in coverage in the distance range 615 to 730 km.

The 2000 survey observed an energetic eddy centered at 530 km. At depths greater than 500 m, density surfaces in the eddy were displaced downwards. The effects penetrated all the way to the bottom. This transient feature in the 2000 fields increased the potential temperature and decreased the potential density on pressure surfaces. It is responsible for the apparent cooling and increase in density of the deeper waters near the 530-km distance mark in the contoured difference fields.

The Northeast Atlantic Deep Water (NEADW, underlying the deep LSW) appears to have freshened by 0.002 to 0.003 and become correspondingly colder on density surfaces. The deepest waters, originating in the Denmark Strait Overflow Water (DSOW), do not appear to have changed appreciable since the previous year.

Sea level changes from TOPEX/POSEIDON altimetry and hydrography

Time series of sea level at the site of the central mooring were extracted from the Maps of Sea Level Anomaly TOPEX/POSEIDON (T/P) altimeter data products (MSLA) produced by the French Archivage, Validation et Interprétation des données des Satellites Océanographiques (AVISO) (http://www-aviso.cls.fr/). Data were available for the period October 22, 1992 through September 5, 2001. The mean for the entire measurement period was removed, and a seasonal signal was estimated by a least-squares fit to annual and semiannual harmonics. After the seasonal signal was removed, a low-pass filtered times series was produced using a squared second-order Butterworth filter with a 1.5-year cut off period.

Fig. 5 shows the time series of the original 10-day MSLA samples and the low-pass filtered series with and without the seasonal signal. Also shown are the time changes in geopotential height relative to 2000 dbar calculated from AR7W measurements since 1900 relative to the mean of Spring values during the T/P measurement period. Each value is an average of approximately 4 stations in the 320 - 520 km distance range. Sample standard deviations for each cruise are also shown. The seasonal signal has a range of just less than 9 cm. There is reasonable agreement between the changes in geopotential height relative to 2000 dbar and the changes measured by the altimeter when seasonal effects are included. The low-frequency sea level time series shows an increase of 1-2 cm between the 2000 and 2001 AR7W occupations.

Fig. 6 shows a map of the change in low-passed T/P sea level in the Labrador Sea between Spring 2000 (central date June 2, 2000) and Spring 2001 (central date June 7, 2001). There is a widespread increase in sea level over much of the region, with typical values of 1-3 cm. The changes at the Bravo mooring site appear to be representative of this broader region. There is a contrasting decrease in sea level shoreward of the 3000-m depth contour on the western side of the Labrador Sea.

Acknowledgments

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Cruse Report, Hudson 2001022, Labrador Sea, WOCE Line AR7W.
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http://www.mar.dfo-mpo.gc.ca/science/ocean/woce/reports/CHUD2001022a.pdf

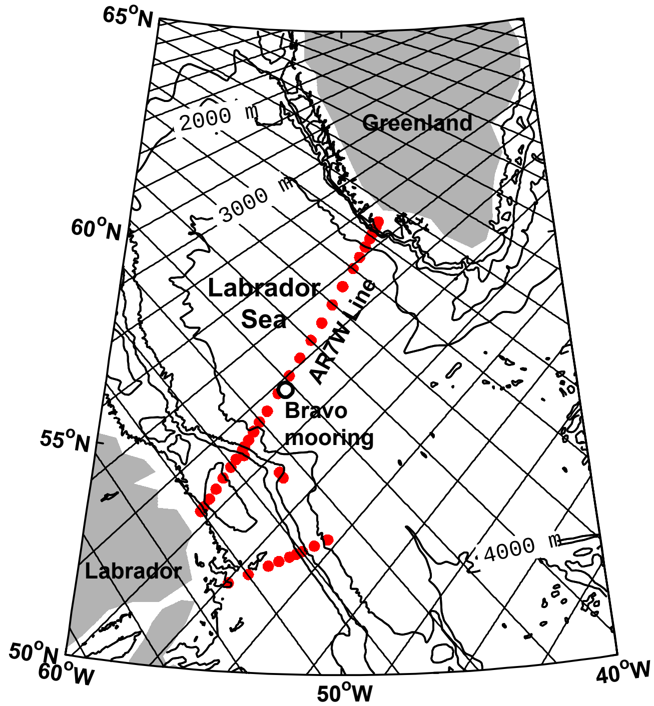

Fig. 1 Map of the Labrador Sea showing CTD station positions for Hudson Expedition 2001022 (solid circles). The Bravo mooring site is marked with an open circle. TOPEX/POSEIDON ground tracks and selected bathymetric contours are also shown.

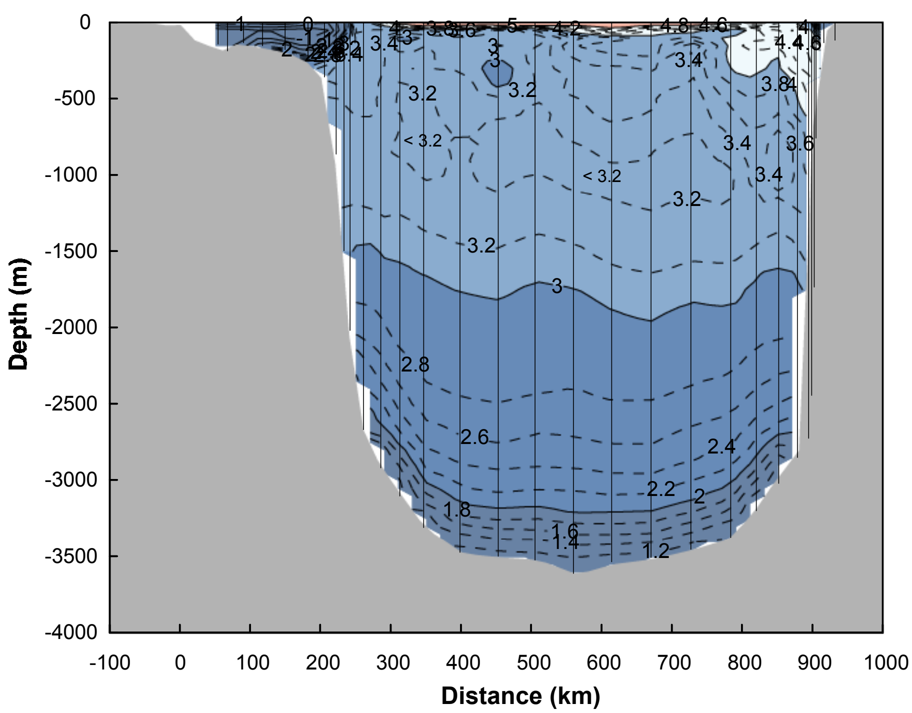

Fig. 2a AR7W potential temperature (oC) section for Hudson 2001022, May 30 - June 15, 2001.

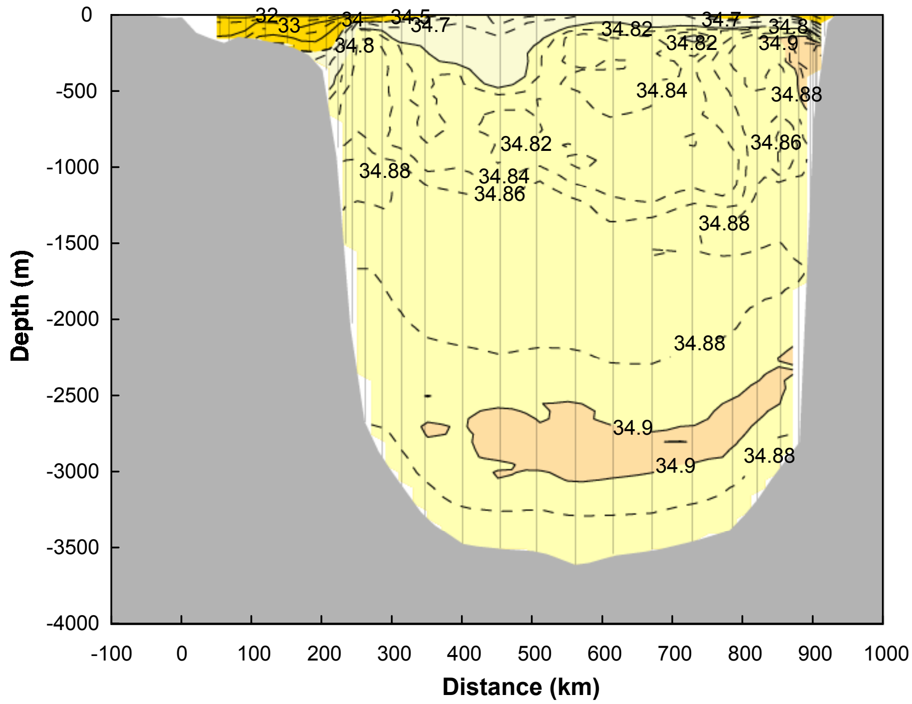

Fig. 2b Salinity section as in Fig. 2a.

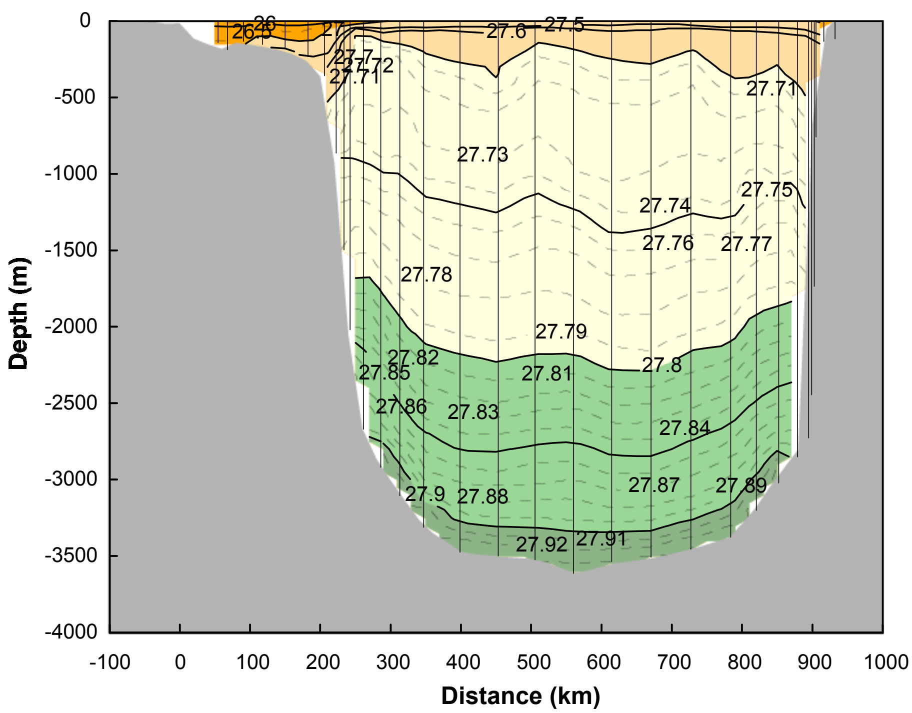

Fig. 2c Potential density anomaly (kg m^{-3}) section as in Fig. 2a.

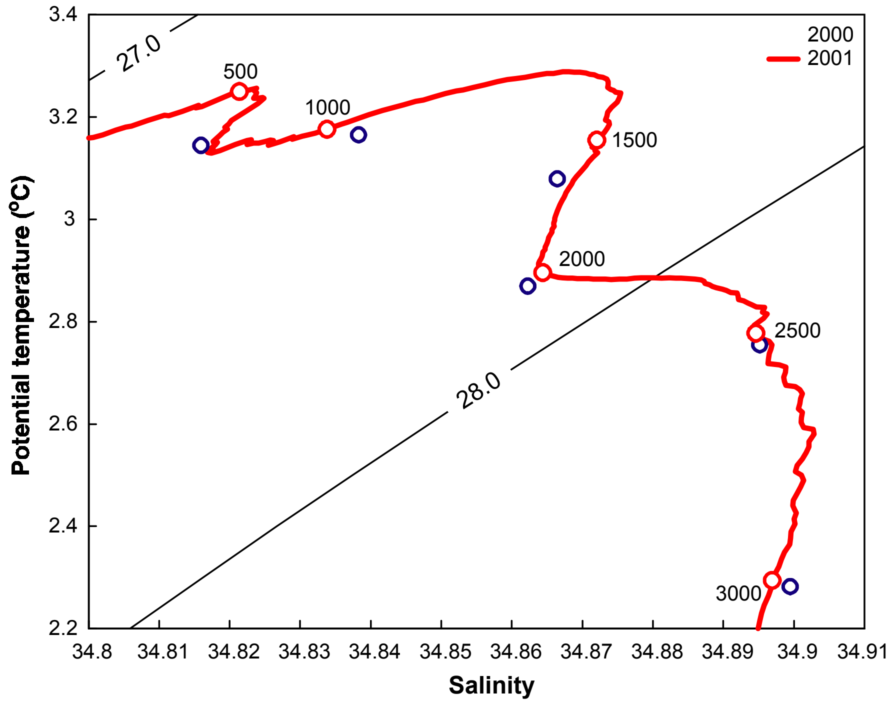

Fig. 3 Potential temperature - salinity curve for the western Labrador Sea from Hudson 2001022 (solid curve). The curve is average over four stations in the distance range 320 to 520 km. Depths are indicated at 500 m intervals. A similar curve for the Spring 2000 occupation of AR7W is also shown (dashed curve). Selected potential density anomaly curves at 0.2 kg m^{-3} intervals are shown.

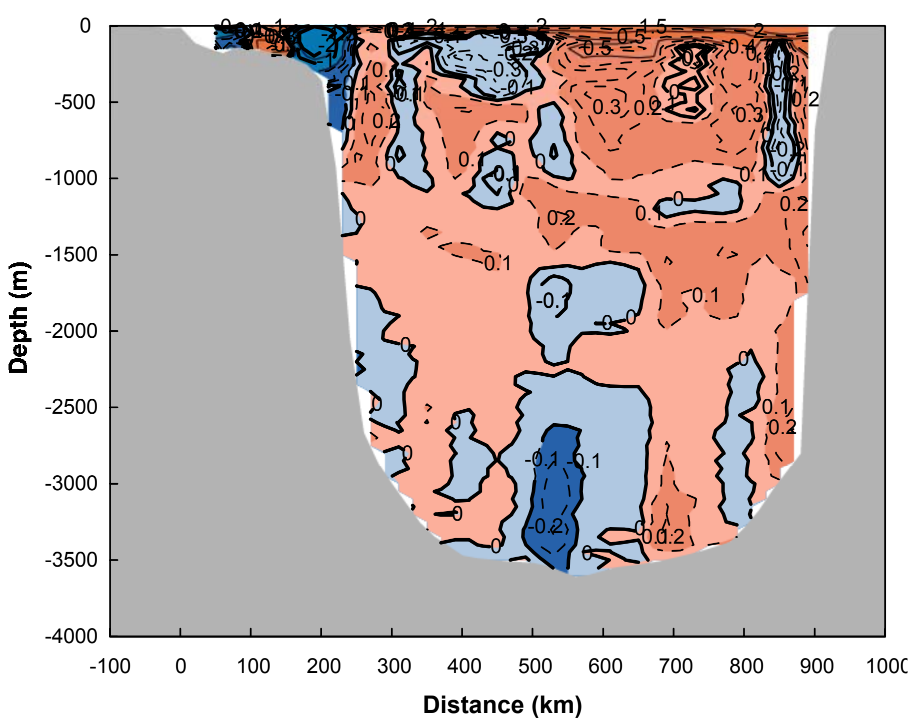

Fig. 4a Contoured change in potential temperature (°C) from Spring 2000 to Spring 2001.

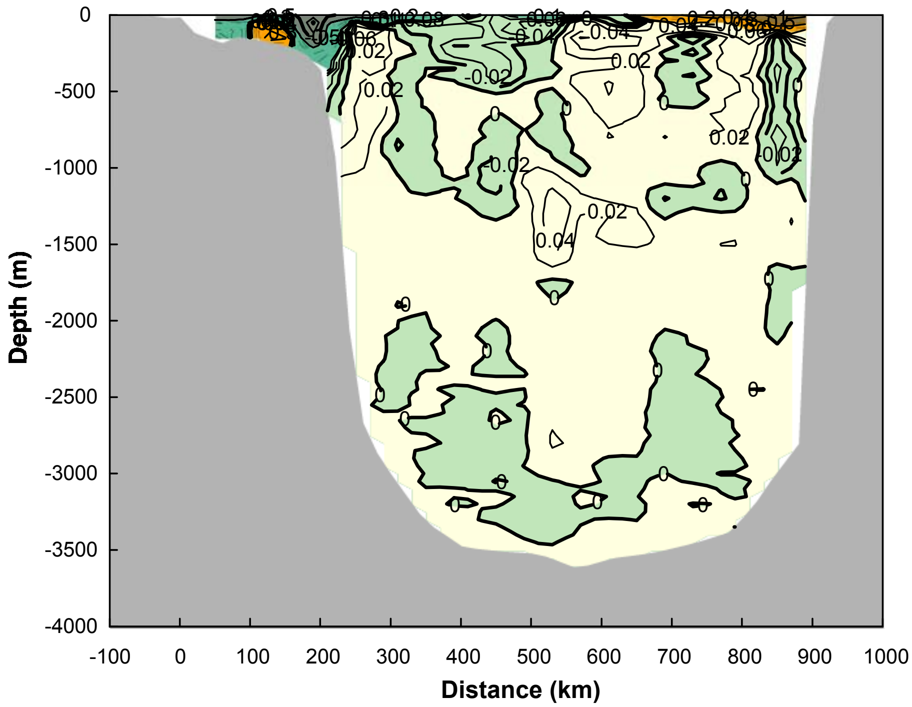

Fig. 4b Contoured change in salinity as in Fig. 4a.

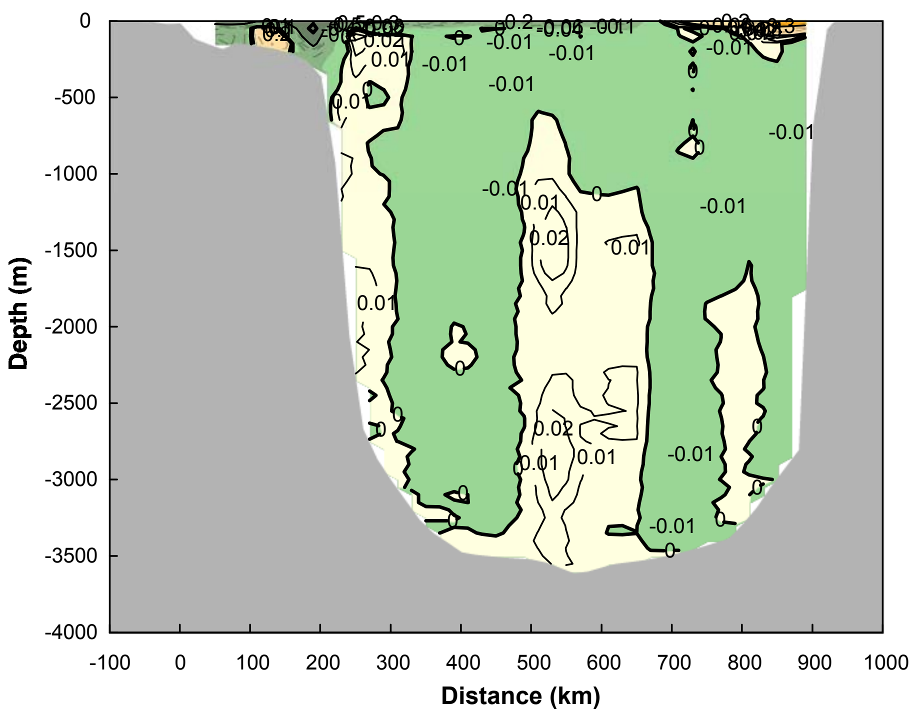

Fig. 4c Contoured change in potential density (kg m^{-3}) as in Fig. 4a.

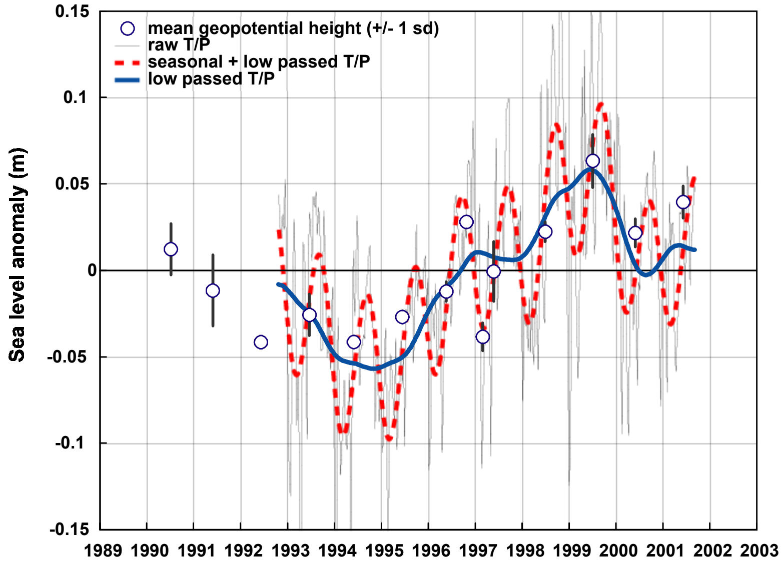

Fig. 5 **TOPEX/POSEIDON sea level anomaly at the central Labrador Sea mooring site. Shown are 10-day MSLA values relative to their overall mean (thin line), seasonal cycle plus low-passed sea level (dashed line), and low-passed sea level (thick line). Also shown are changes in mean geopotential height relative to 2000 dbar from AR7W occupations and sample standard deviations as discussed in the text.**

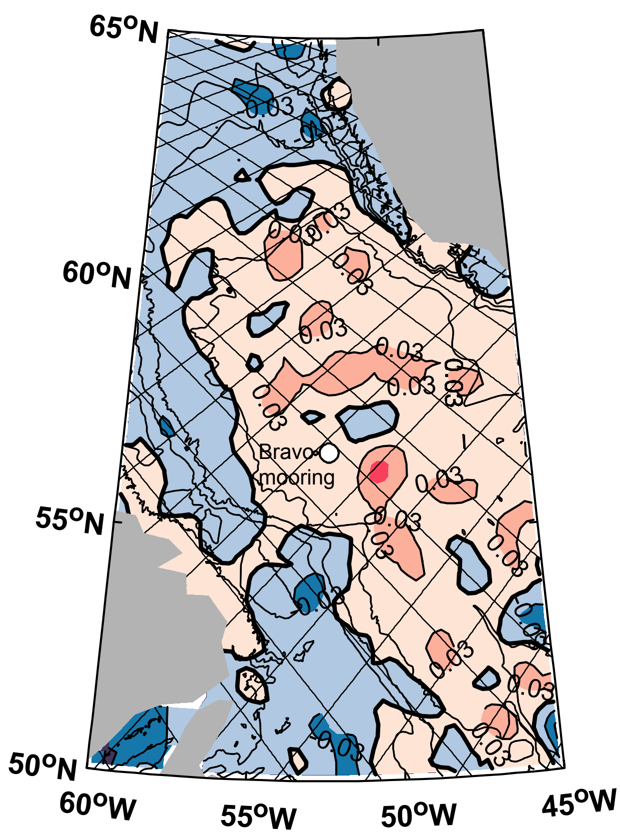

Fig. 6 **Spatial map of the change in low-passed T/P sea level in the Labrador Sea from Spring 2000 (central date June 2, 2000) to Spring 2001 (central date June 7, 2001). Contour interval is 0.03 m.**