OS41B
0598

Observation and Simulation of Deep Water Renewal in Foxe Basin, Canada

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Introduction

New time series observations exhibit a marked seasonal cycle in a deep trough of Foxe Channel whereas high salinity waters were thougth to be trapped at the bottom of the channel [1]. We use a sea ice-ocean-atmosphere regional climate model [2] in order to describe the circulation of deep waters in the whole Hudson Bay system. Although dense water production in Foxe Basin is often thought as a sole cascade [3, 4] we show here that this cascade is in fact altered by a denser gravity current. Since most of dense water cascades are found at high latitude [4], this phenomenon may be important in Arctic/Subarctic waters.

Seasonal cycle in Foxe Channel

Foxe Basin's (FB) general circulation is cyclonic (Fig.1). Well mixed Arctic waters enter the north of FB through Hecla and Fury Strait (HFS), and flow southward toward Southampton Island (SI) along FB's western coast. These Arctic waters remain above denser waters already in FB and thus can enter Hudson Bay (HB) through Roes Welcome Sound (RWS) by crossing over a sill at 60 m depth. Model results show that bottom currents with a mean velocity of 7 cm/s appear by end of winter in Foxe Channel (FC, see area defined by the green ellipse on Fig.1). They are associated with the horizontal circulation of new dense waters produced through brine rejection.

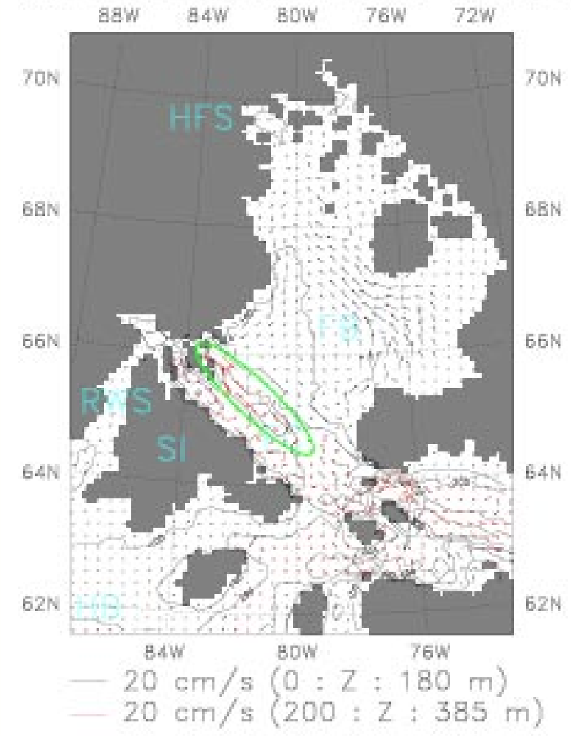

Fig.1. Upper (black arrows) and bottom (red arrows) layer currents in Foxe Basin. The modeled velocity field is time-averaged from March to May.

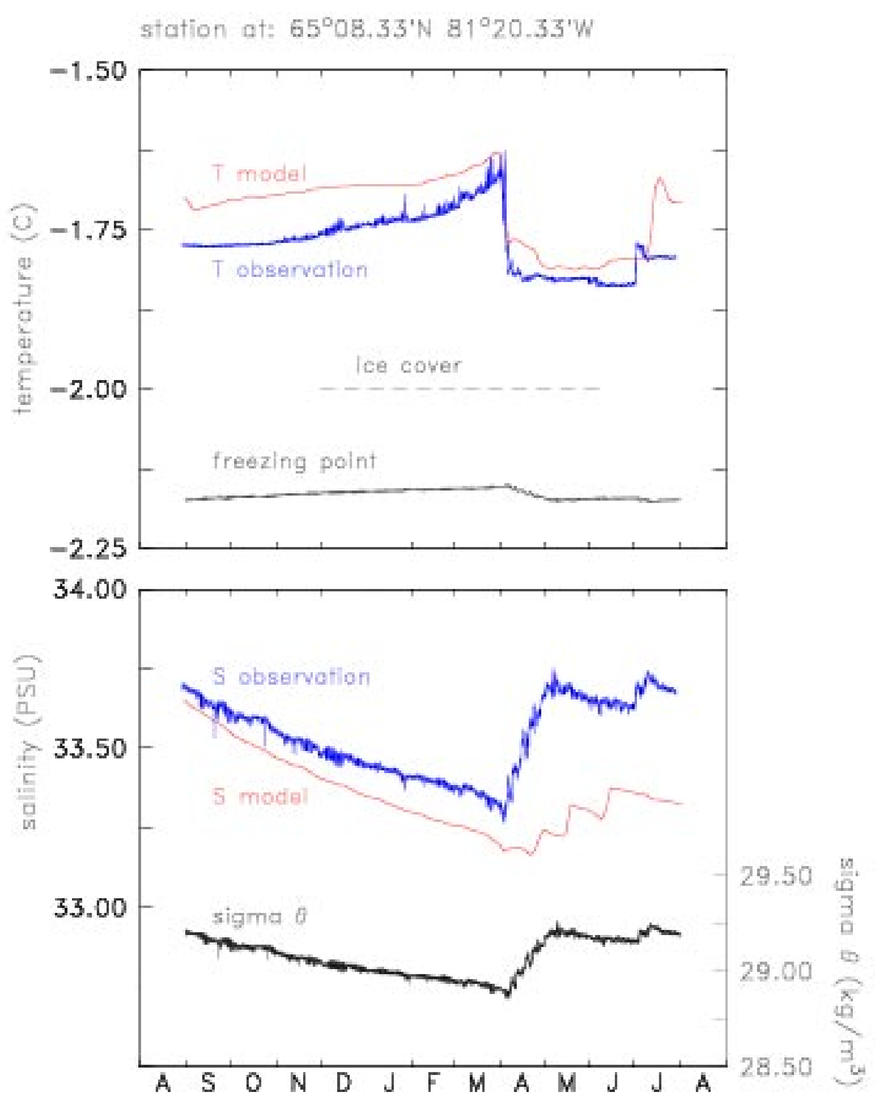

Fig.2. Deep waters seasonal cycle in Foxe Channel, observations from 08/2003 to 08/2004 *vs.* simulated data from 08/1996 to 08/1997.

This seasonal cycle has been observed for the first time with a mooring deployed at 440 m depth in FC (Fig.2); it is divided into three intervals: 1) in April, the abrupt arrival of near freezing and saline water; 2) the throughflow of dense waters over a two month period; and 3) a progressive warming and freshening during fall and winter. The mean estimated southeastward transport of dense waters during the production period is 0.1 Sv (with peaks reaching 0.4 Sv) which corresponds to a volume of 1.6×10^{12} m^3 (4 times the volume of FC's deep trough). Results from the fully coupled model (CRCM, Montréal) confirm that there is a strong seasonal cycle at the bottom of FC (Fig.3).

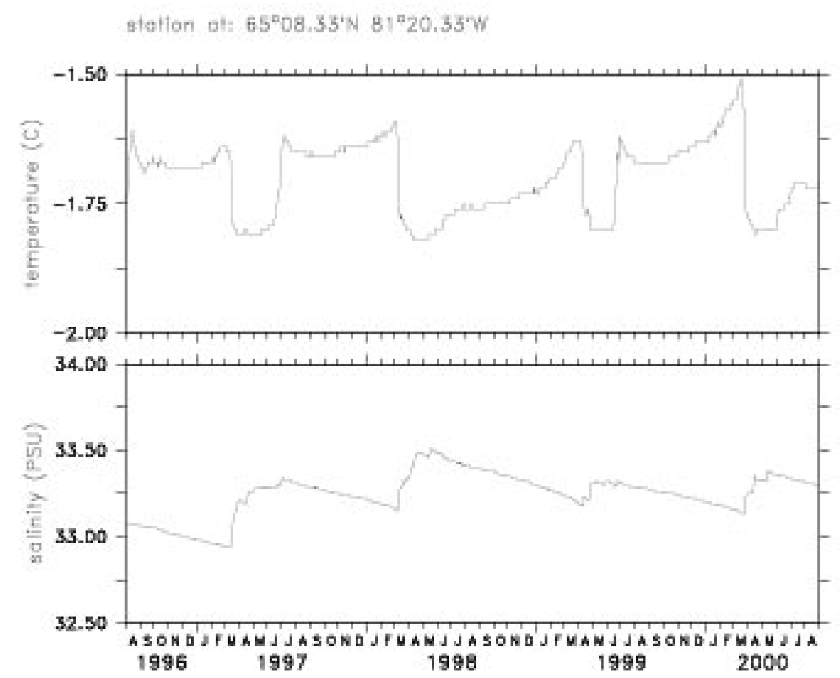

Fig.3. Pluriannual modeled seasonal cycle in Foxe Channel at 403 m depth.

Origin and circulation of dense waters in Foxe Basin and Hudson Bay

Since the new dense waters have well defined characteristics (see Fig.2), a simple backtracking procedure has been used to examine their trajectory. The production site has been found near shore at 66.3°N, 83.1°W. This is confirmed by the dense waters distribution (Fig.5a).

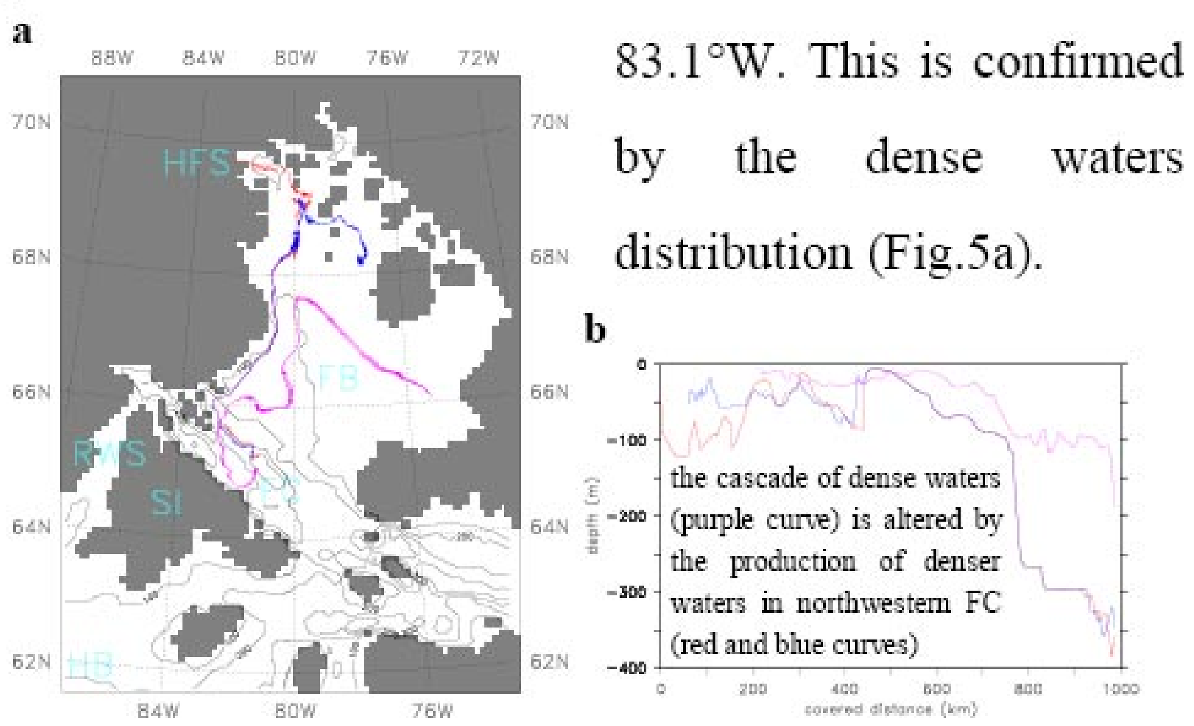

Fig.4. Lagrangian tracers in Foxe Basin followed backward from April 10, 1998 to their origin. **a** path followed by Foxe Channel deep waters (red and blue curves) and intermediate waters (purple curve). **b** depth of the Lagrangian tracers as a function of the distance along their trajectories.

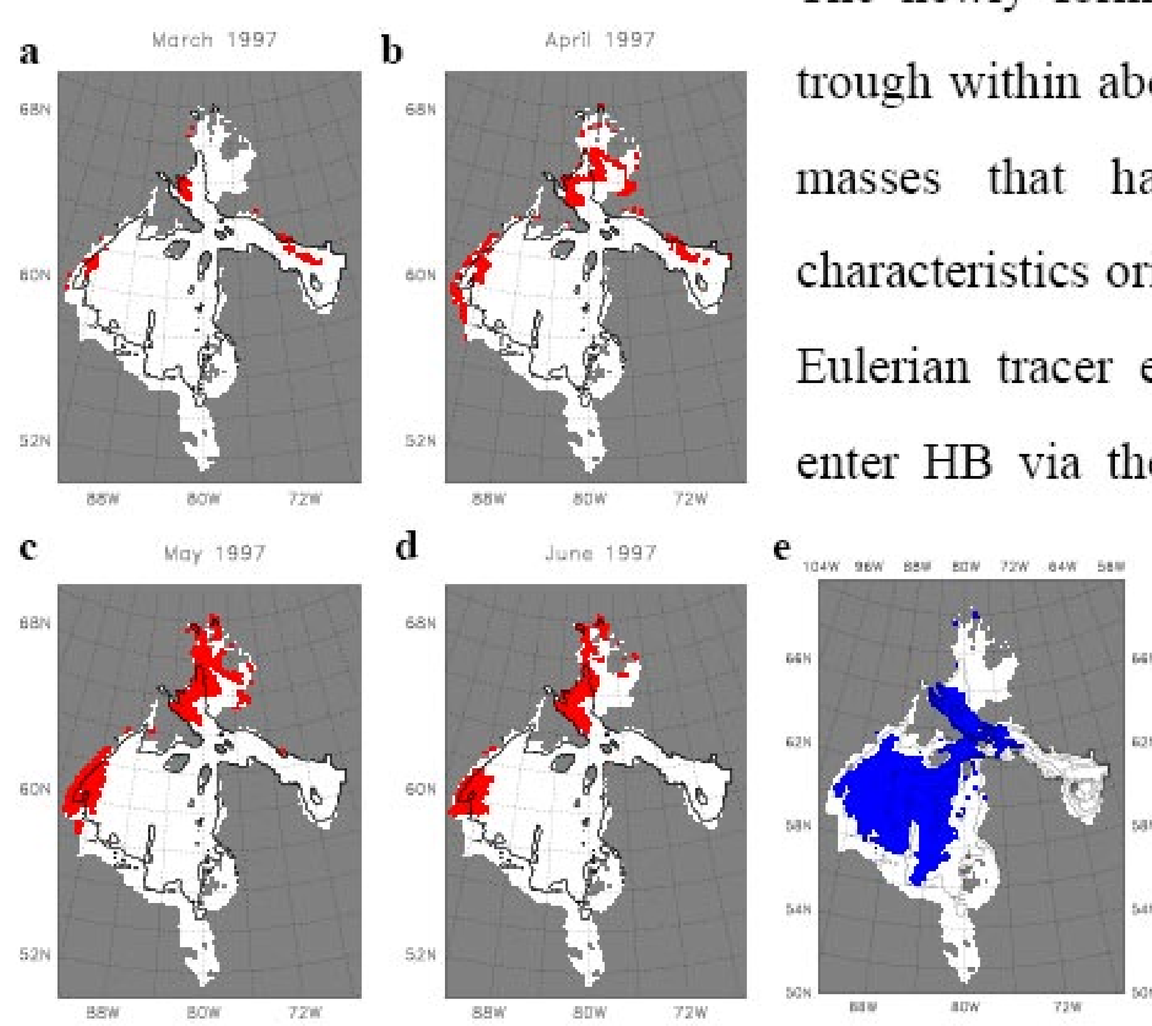

Fig.5. Dense waters repartition modeled in Foxe Basin and Hudson Bay. **a** to **d** March to June area expansion of newly formed dense waters (-1.80 < T (°C) < -1.76; 33.10 < S (PSU) < 33.34). **e** maximum area covered by permanent dense waters (T < -1.25°C; S > 32.75 PSU).

The newly formed dense waters are advected to FC's deep trough within about 20 days. Also, Fig.4a indicates that water masses that have not yet acquired FC dense waters characteristics originally come from FB's northernmost region. Eulerian tracer experiments show that dense waters masses enter HB via the east of SI (Fig.6) with an annual volume almost equal to the amount of dense waters produced in FC. The estimated amount of dense waters formed in northwestern HB polynya is 1.9×10^{12} m^3. Note in Fig.5 that dense waters appear simultaneously in FB and HB. The volume of deep waters (Fig.5e) in HB is equal to 1.8×10^{13} m^3, thus the estimated replacement time to renew them is 5.2 years.

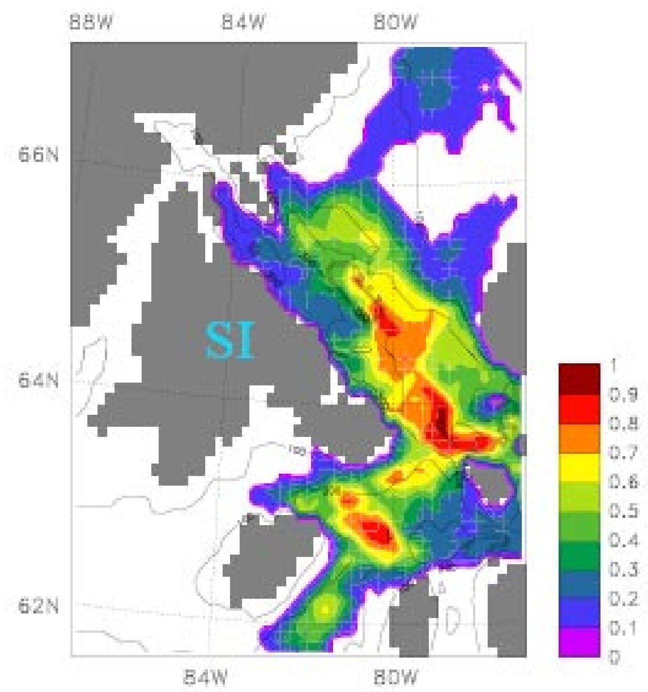

Fig.6. Eulerian tracers showing modeled circulation of dense waters in Foxe Channel and Northeastern Hudson Bay. Picture shows the situation 244 days after tracers originally (04/01/97) filling the bottom of the deep trough in Foxe Channel started to diffuse.

[1] **Jones EP**, Anderson LG (1994) Northern Hudson Bay and Foxe Basin: water masses, circulation and productivity. Atmos. Ocean 32: 361-374
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[3] **Campbell NJ** (1964) The origin of cold high-salinity water in Foxe Basin. J. Fish. Res. Bd. Canada 21(1): 45-55
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Conclusions

1) There is a strong seasonal cycle at depth in Foxe Channel starting with an abrupt arrival of dense waters at the onset of April;

2) New dense waters produced in northwestern Foxe Channel circulate southeastward as a gravity current;

3) Almost all dense waters produced in Foxe Basin flow into Hudson Bay over the following year;

4) The amount of dense waters formed in northwestern Hudson Bay polynya is comparable to the one produced in Foxe Basin.