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Seasonal and Interannual Variability of the West Greenland Current System in 1992-2008

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Introduction

As the primary site for the formation of Labrador Sea Water (LSW), an intermediate dense water, the Labrador Sea is an important component of the Meridional Overturning Circulation (MOC). Variations in LSW formation (Yashayaev, 2007) have been associated with variability of MOC and, in turn, with climate variability over the North Atlantic (Curry and McCartney, 2001). Part of the LSW formation variability can be attributed to changes in the atmospheric fluxes (Dickson et al., 2002). Part of it, however, results from changes in the lateral exchange between the basin's interior – where convection occurs – and the boundary current around it (Spall, 2004; Straneo, 2006b). Thus, the boundary current's variability has a direct influence on the properties and amounts of LSW formed. Here, we investigate both the seasonal and interannual variations of the boundary current and the associated lateral fluxes.

1. Objectives

1. What are the seasonal and interannual changes in the boundary current as it enters the Labrador Sea?

2. What is the relation between the variability in the boundary current and that of the lateral exchange with the interior?

2. Data

1. Hydrographic data 1990-2007 across the West Greenland Current system (AR7W line, Fig. 1) including both spring (14) and fall (5) sections.
2. Altimeter (**AVISO**) 1992-2008 gridded data product
3. Float data: PALACE (**1996-2000**) floats; ARGO (**2002-2009**) floats.

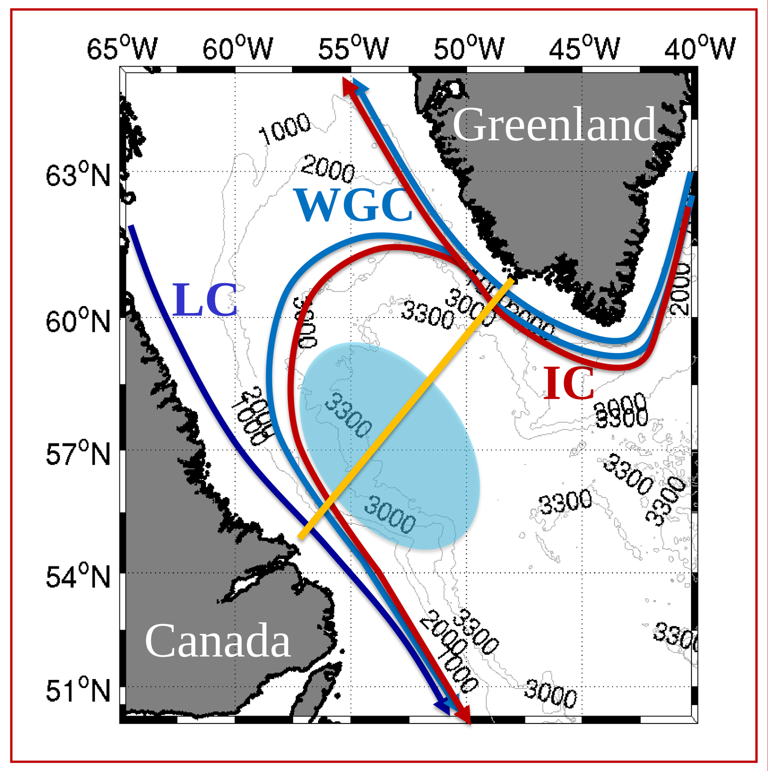
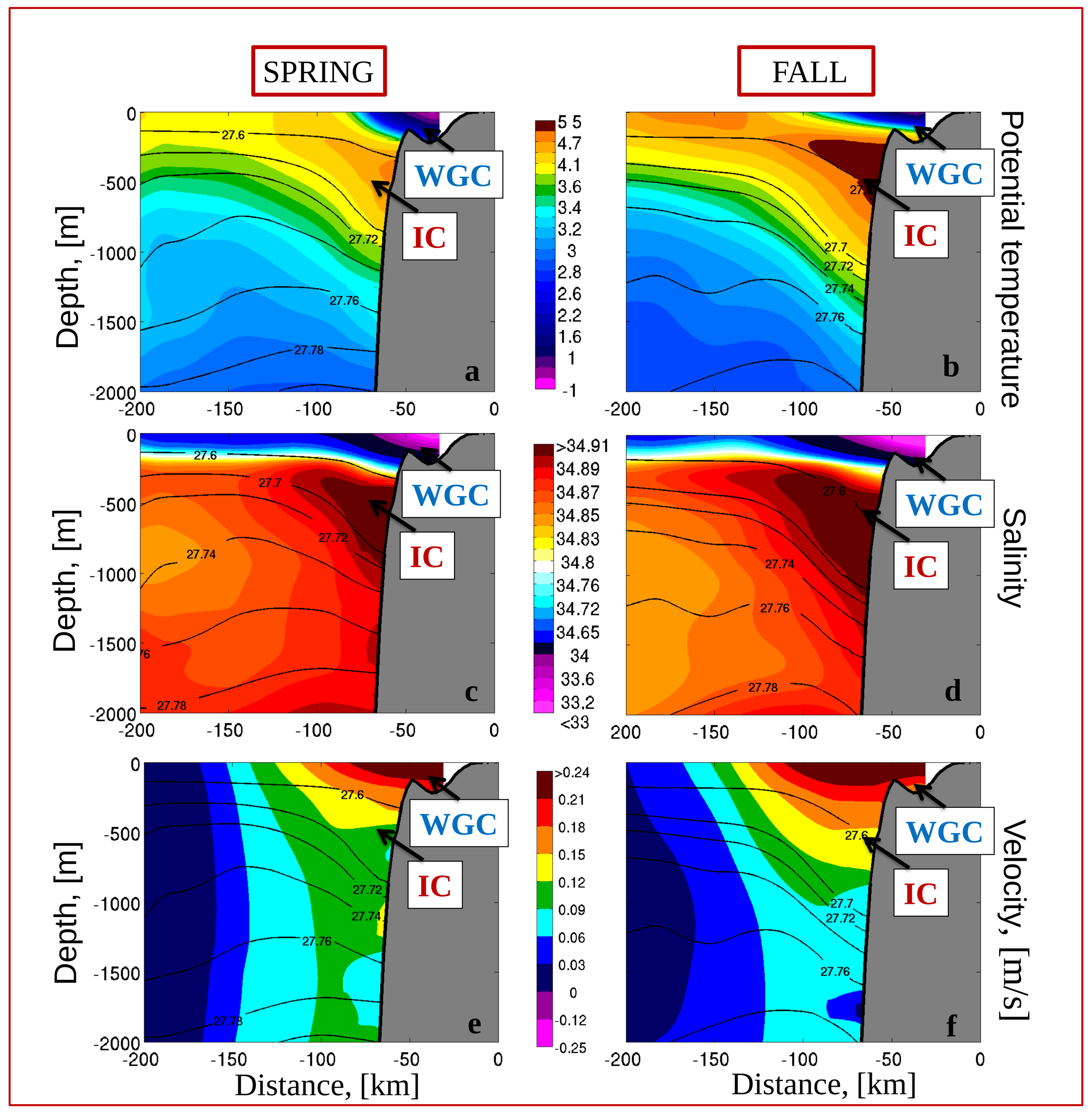


Figure 1. Map of the Labrador Sea. Boundary current system (upper part) is shown by arrows: LC – Labrador Current (dark blue); WGC – West Greenland Current (light blue); IC – Irminger Current (red). WOCE AR7W line is shown in orange and the interior of the Labrador Sea is shaded in blue.

3. Variability of the boundary current system

A. SEASONAL

1) WGC is thicker, fresher, faster in the spring
2) IC is warmer, saltier, thicker, and faster in the fall
3) Seasonal changes in the velocity are dominated by the geostrophic baroclinic* component.



* *Barotropic velocity component* = absolute velocity at 1000m where the horizontal density gradients are small;
* *Baroclinic velocity component* = geostrophic velocity referenced to 1000m

Figure 2. Potential temperature and salinity for the spring (a, c) and fall (b, d) with potential density contours overlaid. Absolute velocity for the spring (e) and fall (f) seasons. Gray indicates the bathymetry and the contours with black labels are the lines of potential density. The width of the boundary current system is about 150 km.

B. INTERANNUAL

1) Trend 1992-2004
- The decrease in the surface flow derived from altimeter by Hakkinen and Rhines (2004) is associated with a decrease in the barotropic component of the flow, as opposed to a decrease in the lateral density gradient;
- Irminger Current is becoming warmer, saltier and thicker during this period with no trend in the baroclinic component;

2) Anomalous years 1997 and 2003 characterized by an abrupt increase in the temperature, salinity and velocity of the IC mainly reflecting the baroclinic component changes.

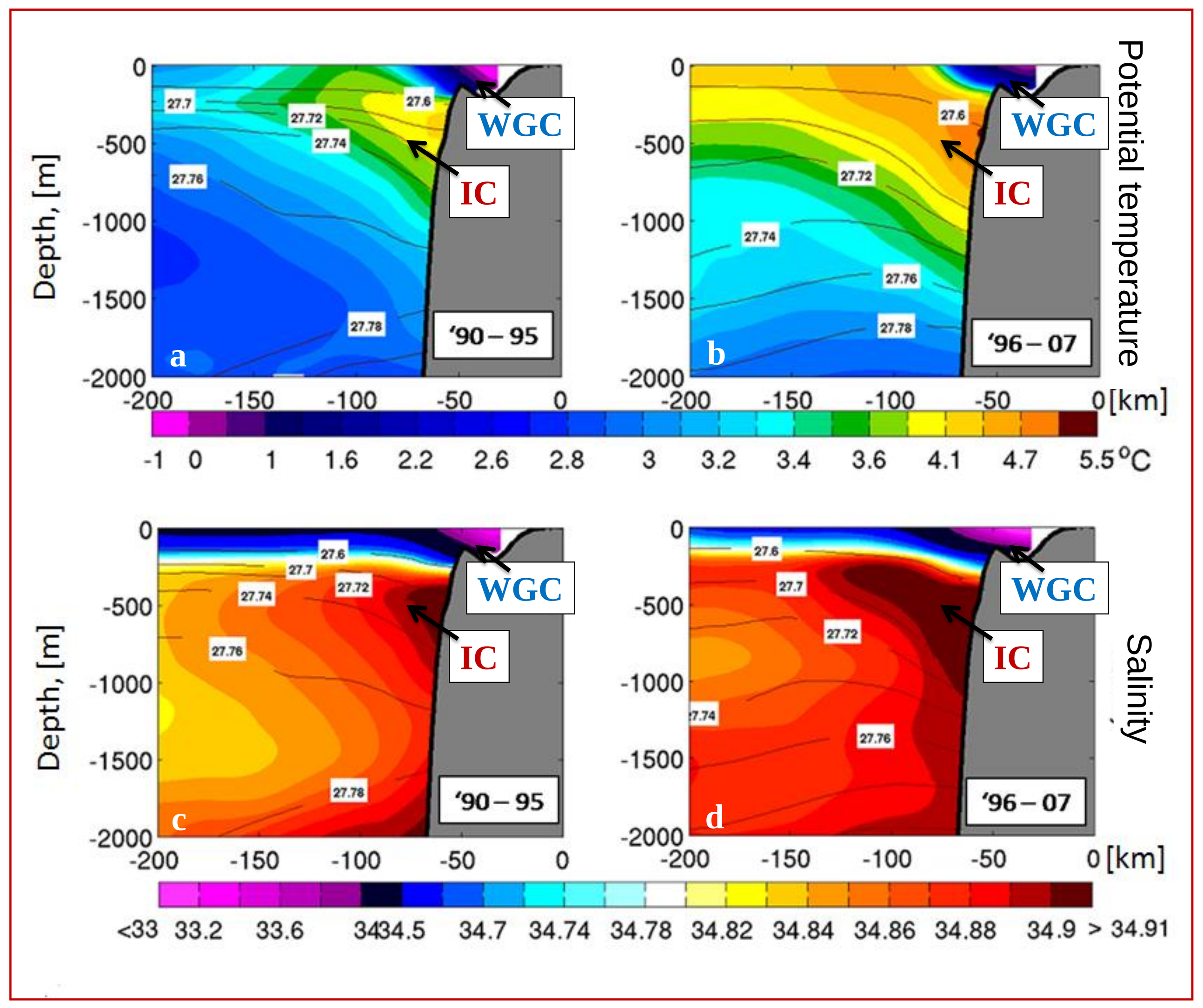


Figure 3. Potential temperature and salinity for 1990-1995 (a, c) and 1996-2007 (b, d) with potential density contours overlaid.

4. Lateral fluxes

What controls the heat content in the Labrador Sea?
The surface fluxes or the lateral fluxes?

$$\Delta HC = Q\Delta t - LF\Delta t$$

- ΔHC: annual (May-April) change in interior heat content (hydrography/floats)
- $Q\Delta t$: annual surface heat flux (OA Fluxes, Yu and Weller, 2007)
- $LF\Delta t$: *Method 1 (M1):* Residual from the first two terms; *Method 2 (M2):* From theory (Spall, 2004 and Straneo, 2006b) lateral fluxes using the interior/boundary current density gradient, $\Delta\rho$, and derived boundary current velocity (V): $\overline{v'T'} = cV\frac{1}{\alpha}\frac{\Delta\rho}{\rho_0}$, $\rho_0 = 1027$ kg m^{-3}, $c = 0.025$

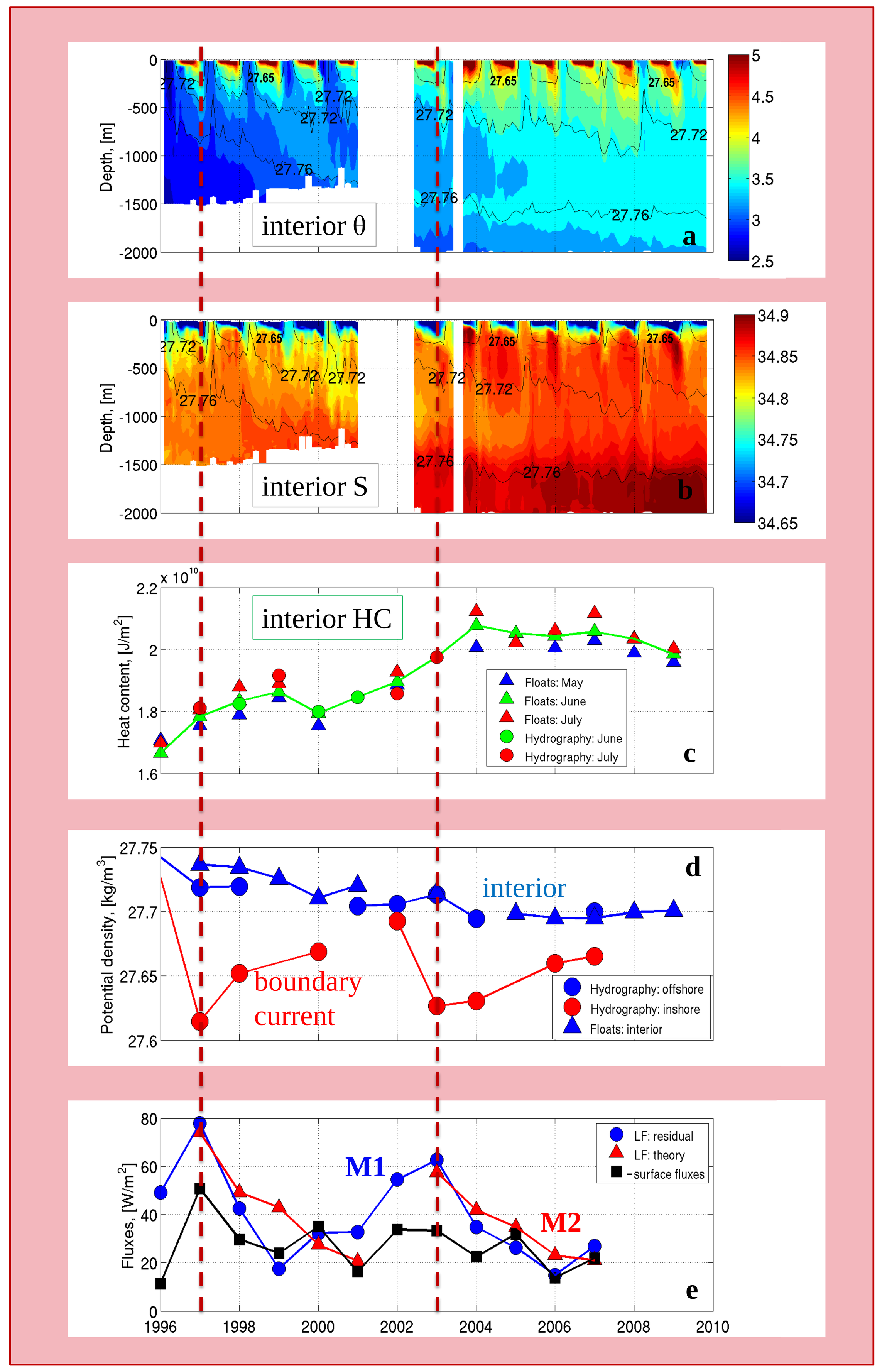


Figure 4. a) Potential temperature; b) salinity; c) interior heat content; d) potential density; e) surface and lateral fluxes estimated using methods 1 and 2 (M1 and M2).

The lateral fluxes estimated from both M1 and M2 agree well and roughly balance the surface fluxes except for 1997 and 2003. During these years, warm, salty anomalies advected into the basin by the boundary current resulted in an unusually large heat flux into the Labrador Sea's interior.

Conclusions

1. Both components of the boundary current system have a pronounced seasonal cycle in velocity and θ/S properties: spring – cold, fresh and fall – warm and salty current;
2. From 1996 to 2008 the boundary current has slowed down and become warmer and saltier;
3. The years 1997 and 2003 stand out and are associated with a faster and larger volume of warm, salty waters flowing into the Labrador Sea;
4. Lateral fluxes overall balance the surface fluxes, except in the years 1997 and 2003 when the lateral fluxes are the largest. It explains the observed sudden increase in the interior temperatures, salinities and the number of eddies.

Acknowledgements and references

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