Contribution of Warm and Salty Anticyclones to the Convection in the Labrador Sea

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1.Motivation

The Labrador Sea is a site of deep convection in the North Atlantic. The formation rate of Labrador Sea Water (LSW) undergoes interannual cycles. This variability is due to changes in both air-sea fluxes as well as interior–boundary current exchange. One important contributor to the lateral fluxes are **warm, salty anticyclones shed by the Irminger Current (IC)**. It has been estimated that these eddies can balance up to 50-92% of annual heat loss to the atmosphere (Lilly 2003; Katsman 2004). How these anticyclones evolve and decay is still unknown.

2. Objectives

- Document the population and properties of Irminger Current eddies;
- Study the evolution of an eddy, particularly under strong winter forcing;
- Investigate seasonal and interannual variability of the eddies.

3. Circulation and data set:

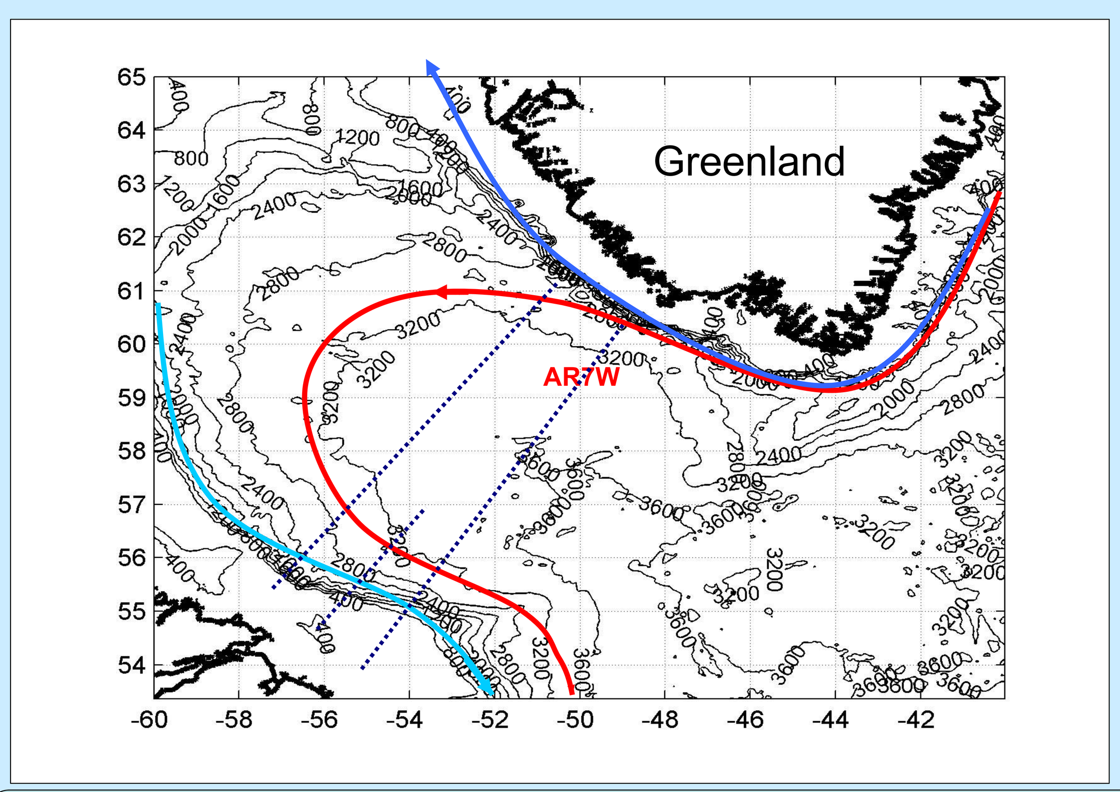


Figure 1. Map of the sections occupied in the Labrador Sea during 15 years of measurements. Arrows show major currents of the region: Irminger Current (red), West Greenland Current (WGC, dark blue) and Labrador Current (light blue).

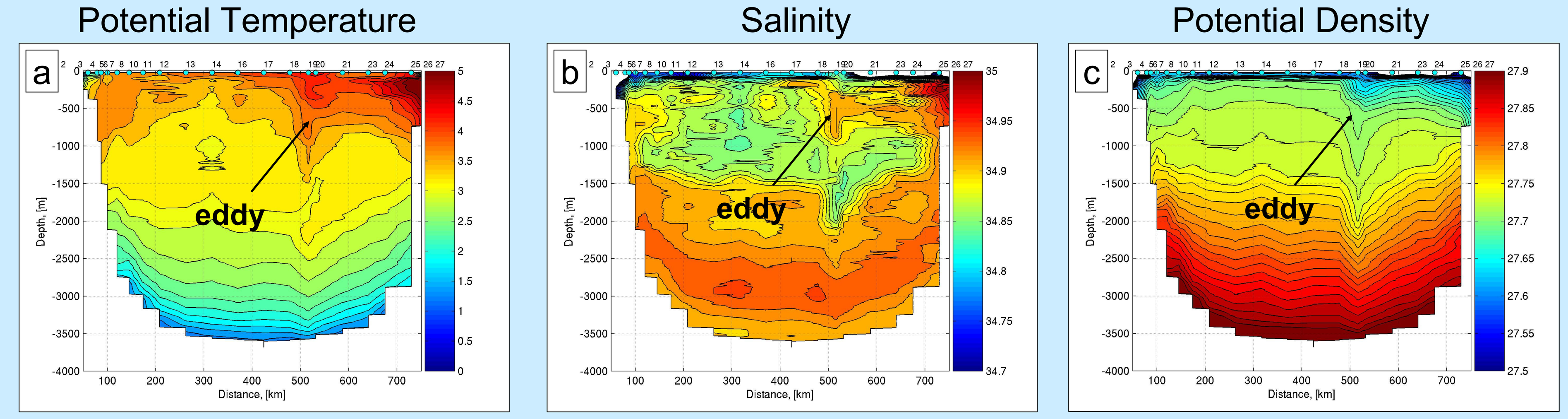
Hydrographic data collected during the years 1990-2004 (see table below) along the WOCE line AR7W and two other lines are shown in Fig.1.

Winter: 1997;
Spring: 1996, 1997, 2000, 2004;
Summer: 1990, 1993, 1994, 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003;
Fall: 1996, 2002.

Statistics:

42 eddy-like anomalies;
- 30 anticyclones, 7 cyclones, 5 ambiguous anomalies;
- Temperature anomaly of the majority of anticyclones = 0.5°C;
- Density anomaly = 0.03 kgm^{-3};
- Isopycnal displacement = 300m.

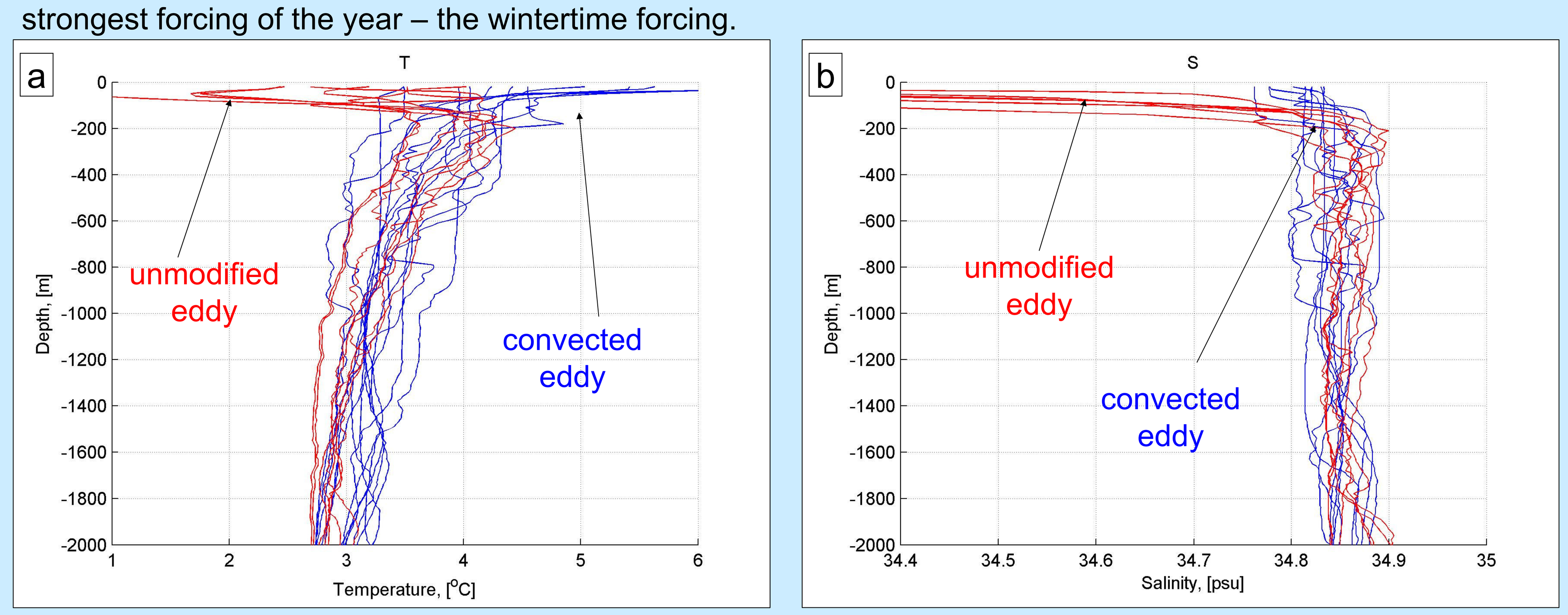
Example of an anticyclone from the Irminger Current:

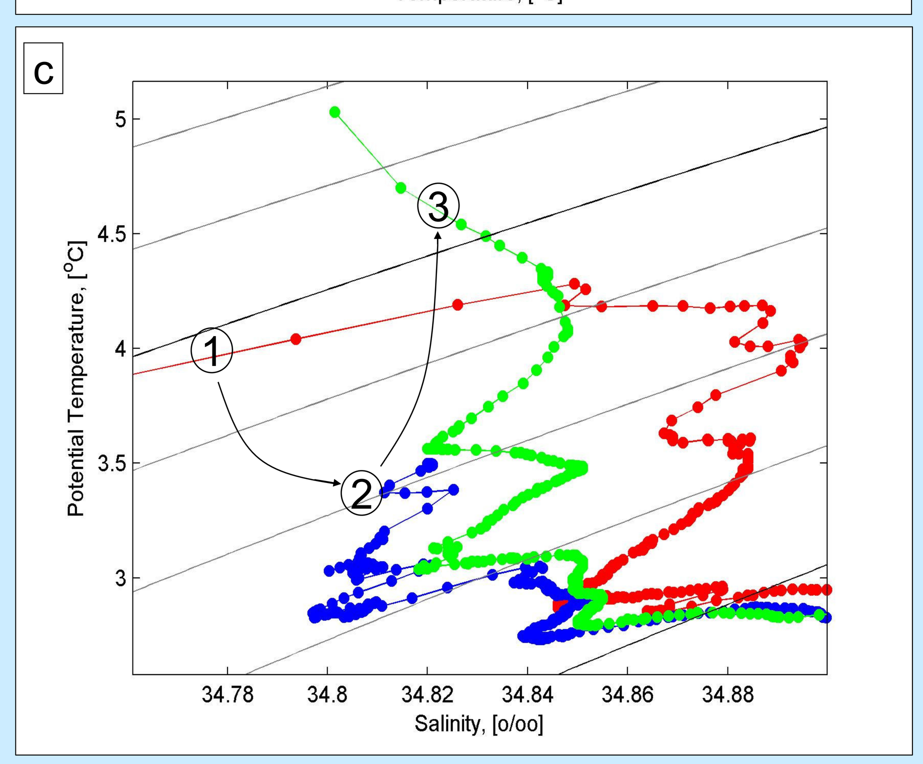


Figures 2 a–c show section AR7W in 2004. Stations 19 and 20 captured a strong anticyclonic eddy with a warm, salty and light core. It contains modified Irminger Current Water at the surface and Labrador Sea Water at depth.

4. Do eddies survive strong winter forcing?

Part 1: Property modification. To understand the contribution of eddies to the restratification processes one needs to know more about the evolution of these anticyclones. Their evolution (and decay) is dominated by the strongest forcing of the year – the wintertime forcing.





Figures 3a–b: comparison of the eddies which have experienced convection (convected, blue) and the eddies which have not been modified by the surface fluxes (unmodified, red).
- convected eddies have a deep mixed layer underlying a thin warm layer at the surface and no fresh cap;
- unmodified eddies have a fresh cap at the surface and no mixed layer;

Figure 3c diagrams the evolution of an eddy in TS space. **1** – unmodified eddy with properties of the boundary current (WGC at the surface, IC - below); **2** – convecting eddy; **3** – post-convection eddy with restratified surface layer

Part 2: Trapping of older LSW. More evidence that eddies survive convection can be seen from the properties of their intermediate layers.

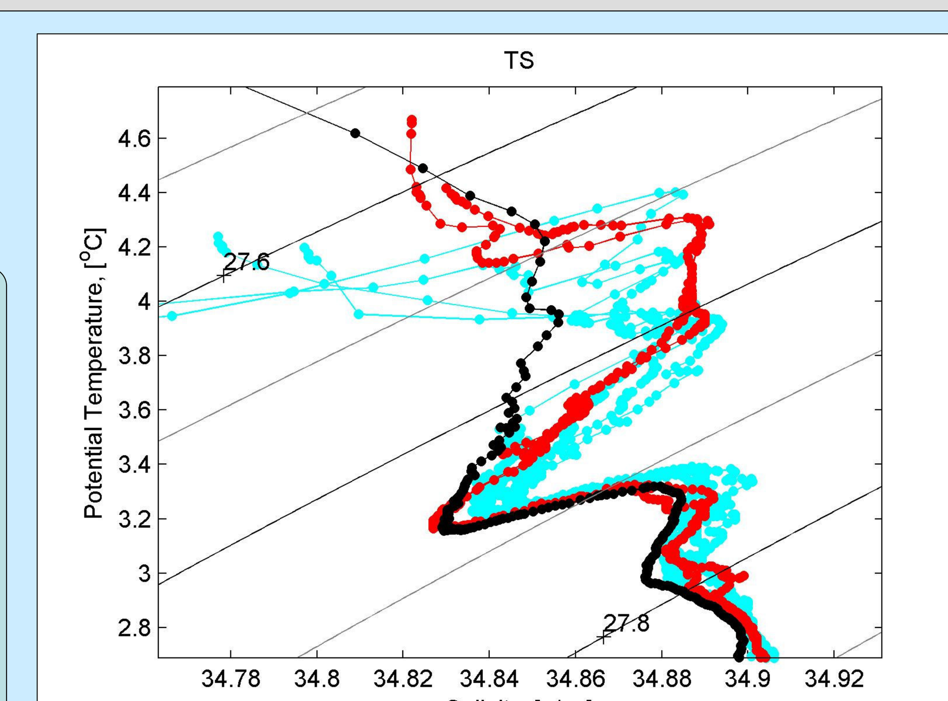


Figure 4 presents profiles taken within an eddy shown in Fig.2 (red), mean Labrador Sea profile from the previous year (black) and adjacent profiles surrounding the eddy (light blue). At depth the eddy contains an old LSW (from the last year) which implies that anticyclone was formed in 2003.

5. Are eddies energized by convection?

Three of eight convected eddies appear to have been energized by the convection. These anticyclones are the strongest eddies in the whole data set (strength is measured in terms of isopycnal displacement and depth of penetration, for deep eddies 700m and 2000m respectively).

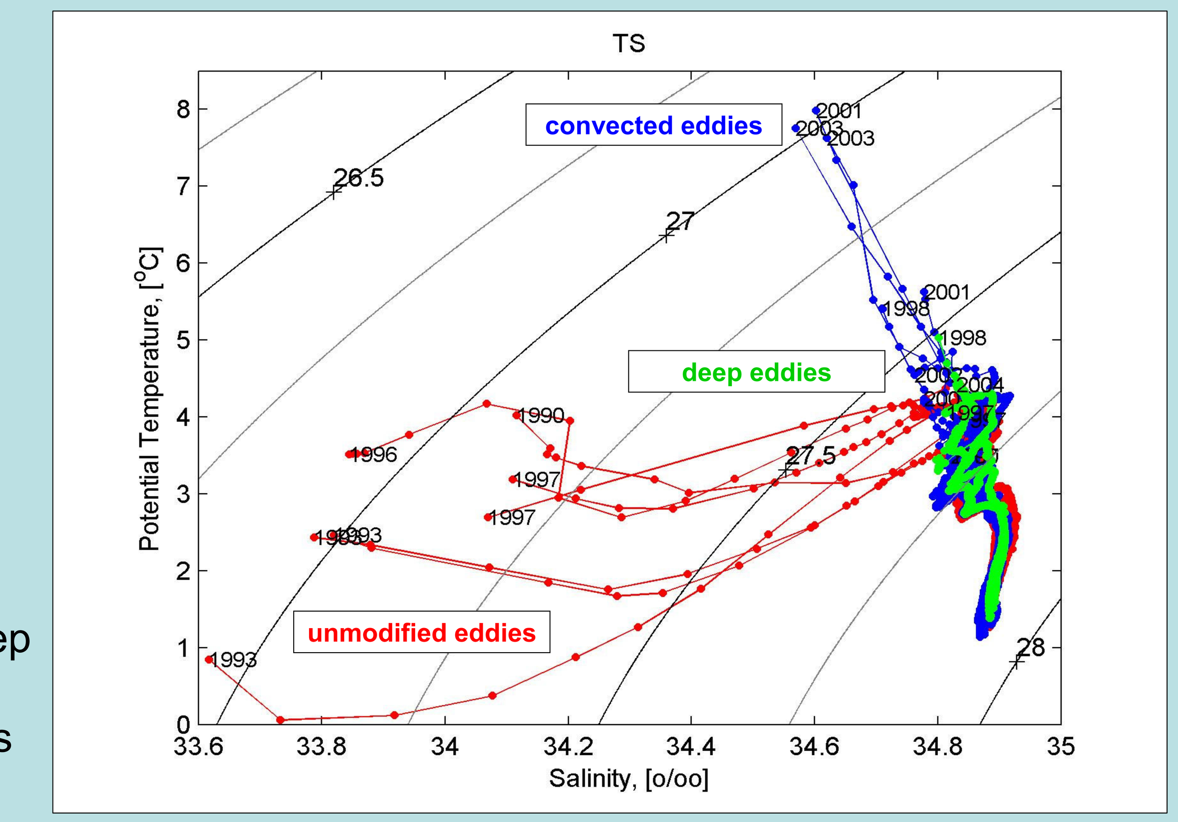


Figure 5. Comparison of TS properties of all unmodified, convected and deep convected eddies. Number represents the year of observation.

- deep eddies have experienced convection since:
  - * their surface/intermediate layer properties have been modified
  - * deep layer has trapped LSW from previous year => wintertime modification;
- deep eddies were energized by convection.

6. Conclusions

- Analysis of the data shows that **eddies can survive convection**. Factors pointing to that are:
  - * Absence of fresh cap at the surface;
  - * Presence of a homogeneous mixed layer below thin stratified surface layer;
- Some convected eddies are much stronger and deeper than any of the eddies in the data set. This could indicate that the eddies were energized by convection.

7. References

- J.Lilly, P.Rhines, F.Schott, K.Lavender, J.Lazier, U.Send, E.D'Asaro, 2003: Observations of the Labrador Sea Eddy Field, Progr. in Ocen.,59 (2003) 75-176;
- C.Katsman, M.Spall, R.Pickart, 2004: Boundary Current Eddies and Their Role in the Restratification of the Labrador Sea, J. Phys. Oceanogr., 34, 1967-1983

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