Two years of observations of warm core anti-cyclones in the Labrador Sea

M. Femke de Jong (fdejong@whoi.edu), Amy S. Bower, Heather H. Furey

Abstract

A heavily instrumented mooring was deployed near the formation area of Irminger rings in the Labrador Sea to study the properties of newly formed Rings. Twelve events resembling Rings were seen at the mooring, two of which were likely from the same Ring. The core properties show a seasonal cycle in mid-depth temperature (1.9˚C) and salinity (0.07). A fresh cap is typically seen in spring and strongly reduces towards fall. The variability in properties combined with a large range in radii (11 to 35 km) leads to a large spread in heat and freshwater contributions from these eddies (12 to 108 MJ m^{-2} and -0.5 to -4.7 cm respectively)

1. Introduction

The Labrador Sea is an important region for the Atlantic Meridional Overturning circulation. During strong winters, deep convection forms Labrador Sea Water, which is the lightest constituent of North Atlantic Deep Water. After winter the convective area, located in the southwest of the Labrador Sea, is quickly restratified by buoyant water from the boundary current. The main source is thought to be buoyant eddies shed by the West Greenland Current/Irminger Current system west of Greenland (Figure 1). Because of the warm Irminger Current water in their core, these anti-cyclones are called Irminger Rings. They are observed to carry a freshwater cap (originating in the fresh West Greenland Current waters) as well as a warm core, which is thought to contribute to the relatively fresh signature of Labrador Sea Water. However, previous estimates of the eddy fluxes were based either on isolated observations of eddies or at a location far from the formation area (the Bravo site, Figure 1). This study uses a time series from the IRINGS mooring closer to the Eddy Kinetic Energy maximum associated with the formation area.

F1

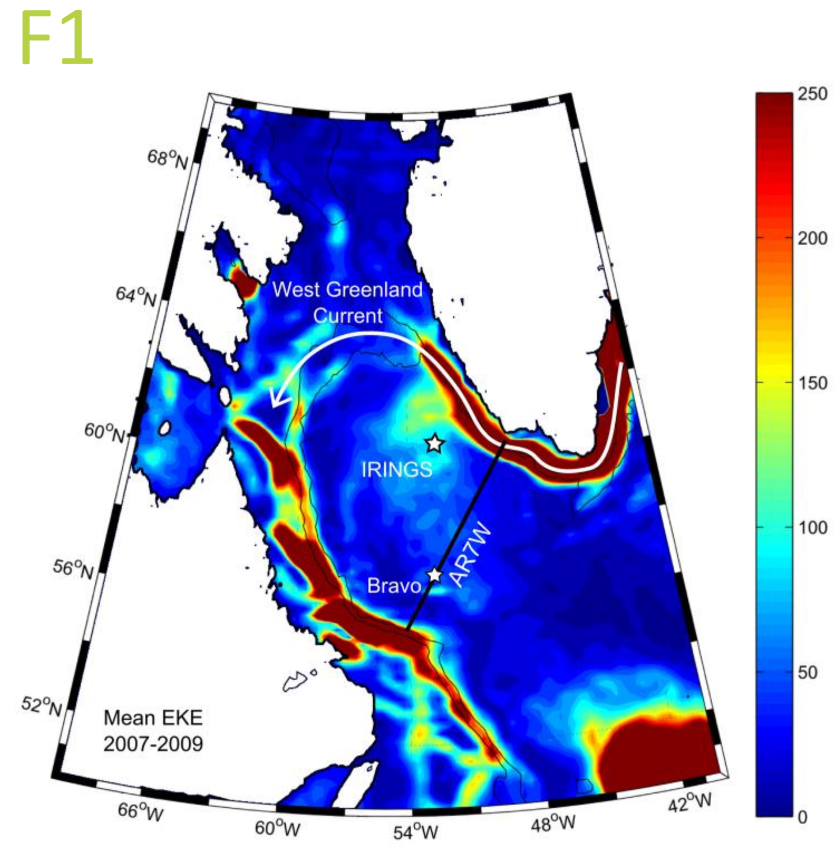

Figure 1. Map of mean Eddy Kinetic Energy (EKE) in the Labrador Sea during the IRINGS mooring deployment. The EKE maximum associated with the Irminger Rings is located west of Greenland. The IRINGS mooring was located south of the maximum, in the path of Irminger Rings heading into the interior Labrador Sea.

2. The IRINGS mooring

The IRINGS mooring was located at 60.6°N and 52.4°W (Figure 1), at a water depth of 3200 m. The location, just outside of the Eddy Kinetic Energy maximum, was chosen to be in the path of Irminger Rings on route to the interior Labrador Sea. It was deployed from 25 September 2007 to 28 September 2009. The mooring was equipped with nine SBE37 microcats and eight RCM11 current meters, resulting in a two-year time series of temperature, salinity between 120 and 2000 m depth and lateral velocities between 120 and 3000 m depth. The vertical profiles were derived through shape preserving spline fitting.

F2

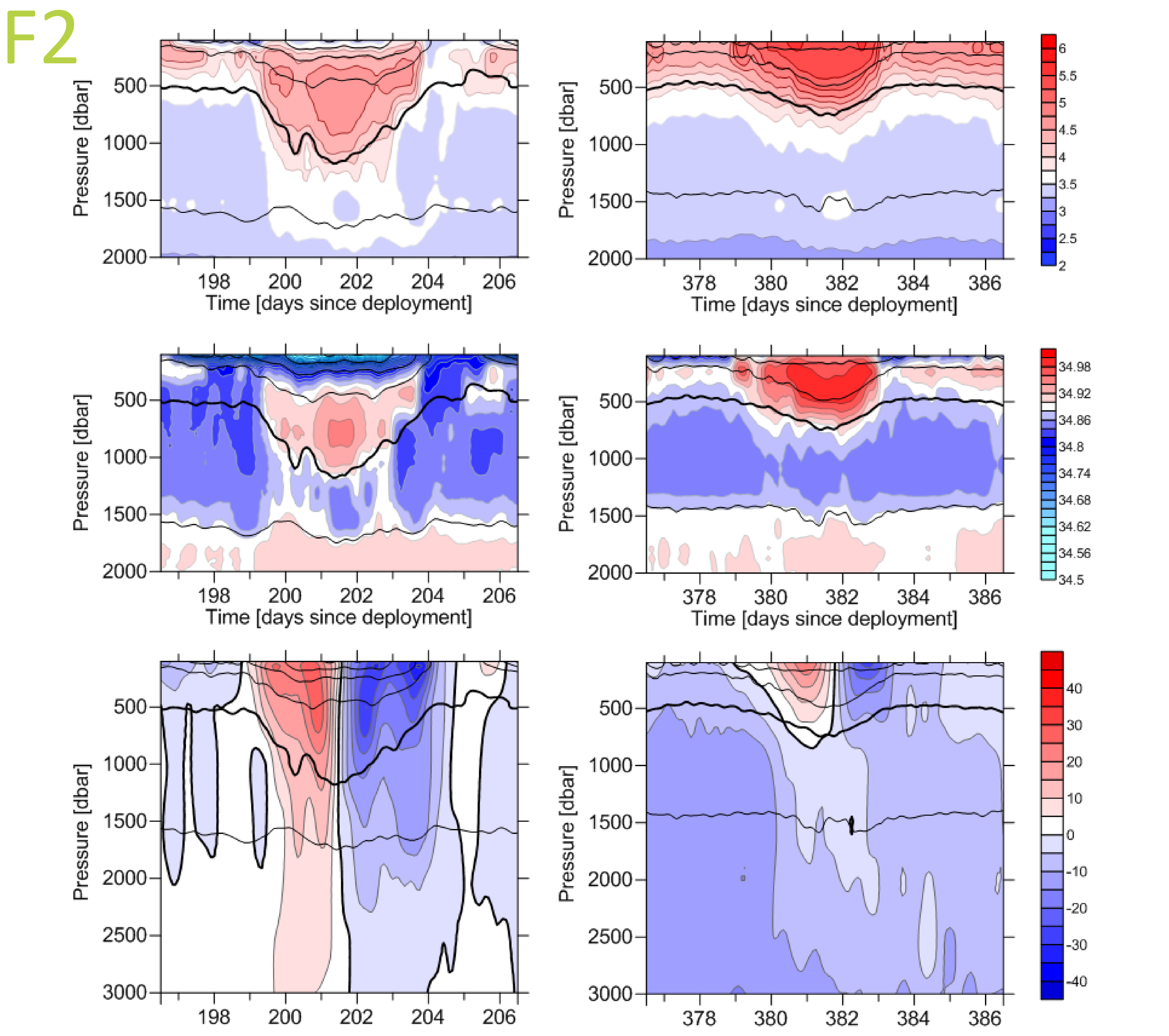

Figure 2. Examples of observed Irminger Rings. Shown are potential temperature (top), salinity (middle) and cross velocities (bottom). Isopycnals are drawn (every 0.05 kg m^{-3}) in black, with the 27.7 kg m^{-3} isopycnal drawn with a thick black line. The eddy on the left was observed in spring, with a strong fresh cap and a deep temperature maximum. The eddy on the right was observed in fall, with warmer and shallower temperature maximum and no trace of a fresh cap within the eddy. The eddy velocities are surface intensified, with a barotropic signature in some eddies.

3. Observed Irminger Rings

Twelve Irminger Rings were observed during the two year deployment. Eleven of these have distinct properties, which suggest one eddy may have passed the mooring twice (with 10 days between the two passes). The Irminger Rings show a large range of sizes and properties. The radii were estimated to be between 11 and 35 km. The core properties show a seasonal cycle, with strong fresh caps and deeper temperature/salinity maxima in spring and weak freshwater caps and stronger, shallower temperature/salinity maxima in fall (Figures 2 and 3). The change in properties of these newly formed eddies are likely due to the seasonal cycle seen in the boundary current itself (Figure 4).

F3

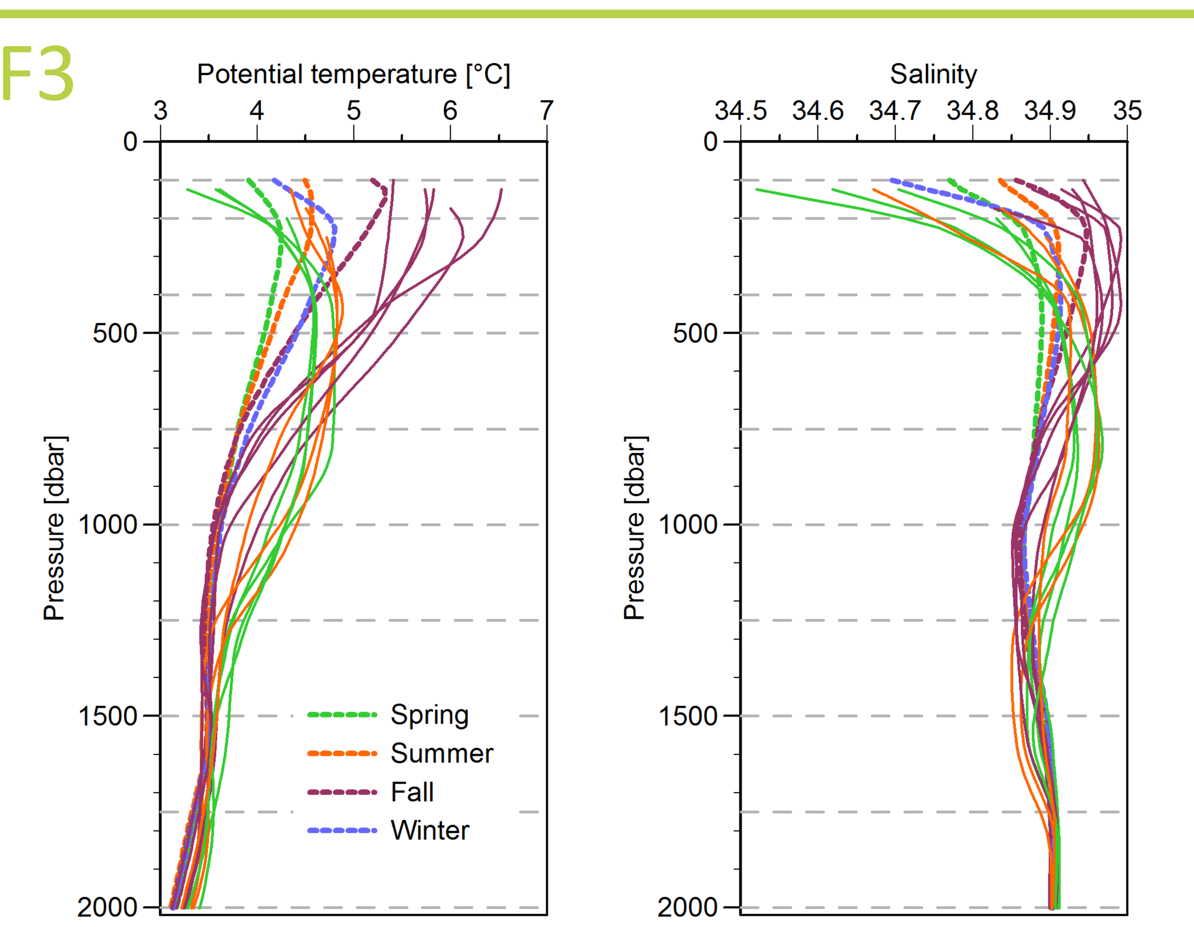

Figure 3. Seasonal change in properties observed at the IRINGS mooring. Shown are the seasonal mean background profiles (dashed lines) and of the eddy cores for Winter; JFM (no eddies), Spring; AMJ (4 eddies), Summer; JAS (3 eddies), Fall; OND (5 eddies). The grey dashes lines are the instruments depths of the microcats.

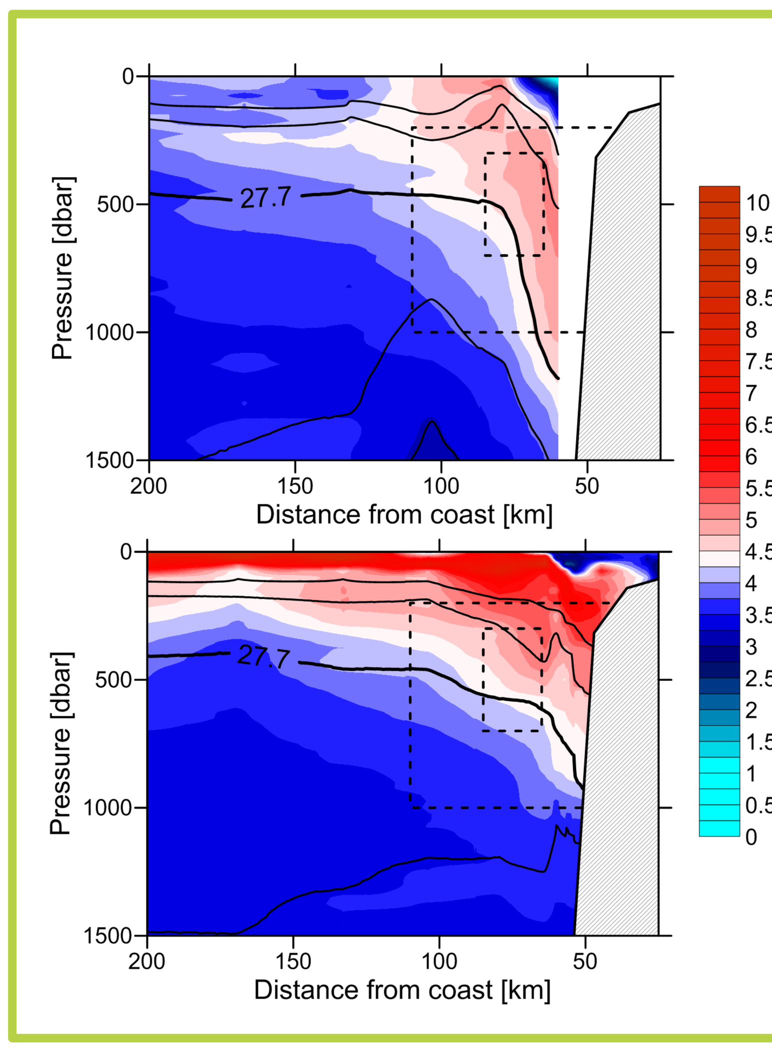

Figure 4. Seasonal changes in potential temperature observed along the western side of the AR7W (Figure 1) across the West Greenland Current / Irminger Current system. The top panels shows observations from May 2008 (BIO, Canada). The bottom panel shows observations from August 2008 (NOC, UK). The change in temperature stratification matches the seasonal cycle in the eddy core properties.

F4

4. Heat and freshwater

The heat and freshwater contributions (dH and dF) are defined as the amount of heat and freshwater the eddy carries between 200 and 1000 m depth per m^2 of convective area. Per year the convective area is thought to lose about 1 GJ/m^2. This must be compensated through restratification. The heat and freshwater contribution per eddy depends on its core properties and its volume. We calculated dH and dF with both on a constant radius and with the radius as estimated from the mooring data. The former shows the effect of the seasonal cycle in core properties. The latter shows the effect of size, with is stronger because of the square relationship. Previous estimates of dH and dF, based on a single eddy, were 43 MJ m^{-2} and -1 cm.

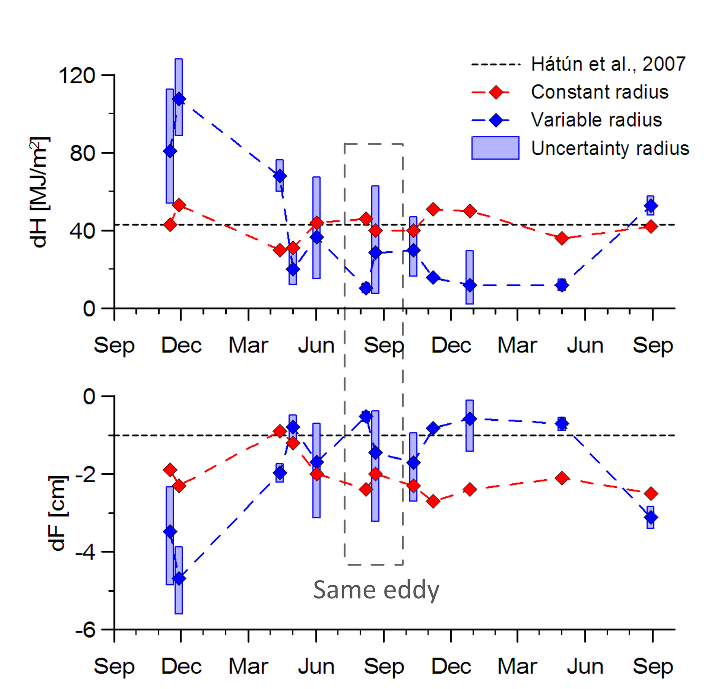

Figure 5. Heat (top) and freshwater (bottom) contributions for each eddy. Contributions were calculated using a constant radius of 21 km (red) and using the radius estimates from the mooring data (blue). Blue bars indicate the uncertainty in the radius estimates. Previous estimates are indicated by the black dashed line.

F5

5. Conclusions

A two-year mooring deployment off West Greenland revealed the core properties of 11 Irminger Rings, one of which passed the mooring twice. The eddies show a seasonal cycle in their temperature and salinity profiles. Deep temperature/salinity maxima topped by strong fresh caps are seen in spring. In fall the temperature/salinity maximum shallows and strengthens and the fresh caps weakens or possibly disappears completely. These seasonal changes likely originate from the seasonal cycle in their source, the West Greenland Current/Irminger Current system. The eddies show a large range of sizes, with radii between 11 and 35 km. The combination of the seasonal cycle and size variability results in a large spread in heat and freshwater content carried by the eddies.

This work was supported by the U.S. National Science Foundation and the Postdoctoral Scholar Program at the Woods Hole Oceanographic Institution, with funding provided by the Devonshire Foundation.

Woods Hole Oceanographic Institution