R/V Oceanus 369 Cruise Summary: Irminger Sea Circulation and Convection

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Voyage 369 (leg II) of R/V Oceanus was carried out from 2–27 August, 2001 in the Irminger Sea. This was the first cruise of the collaborative projects "Is LSW formed in the Irminger Basin?" (WHOI) and "LSW formation and variability in transport and mixing of ISOW and DSOW in the Irminger Basin" (LDEO). The main objectives of the cruise were (1) to conduct a detailed hydrographic/tracer/velocity survey of the Irminger Sea, with emphasis on the western basin; and (2) to deploy two profiling CTD moorings (MPs), one in the western boundary current and one in the region where deep convection likely occurs. The cruise was successful on all accounts, and produced some exciting and unexpected results.

Brief Synopsis

The ship departed Reykjavik, and within 24 hours we were occupying our first station. Early in the cruise we experienced some instrument problems—most notably a failure of one of the pylons—but these were overcome, and the quality of the data obtained throughout the cruise was excellent. R/V Oceanus is well-suited for such work, and the crew was most helpful. Of particular value was the CTD 'track-system', which allowed us to move the package into the wet lab (and hence out of the weather and seas) for sampling. This is essentially the same system found on larger vessels, and we were lucky and thankful to have it on a mid-class vessel.

The CTD stations occupied during the cruise are shown in Figure 1 (a total of 162 stations, denoted by inverted triangles). In all but a few instances CFCs and dissolved oxygen were collected, and, with the exception of the shelf stations, lowered ADCP measurements were made as well. Throughout the cruise the vessel-mounted ADCP was running, as was the underway thermosalinograph (for which surface salinity samples were collected for calibration purposes). Operationally our biggest challenge was working near the ice in the vicinity of Greenland (i.e. the shoreward ends of all the sections). This included both the pack-ice and icebergs. This area of the North Atlantic is also notorious for storms. While we had our share of rough weather, overall we faired quite well.

The general plan was to occupy a series of cross-basin sections, with higher resolution in the west. Two of the sections extended eastward to the crest of the Reykjanes Ridge to measure the cyclonic flow around the perimeter of the basin (Note: We are collaborating with investigators in the UK GLOBEC program who have a cruise this fall to the Irminger Sea. We discussed beforehand that our cruise would focus more on the west, and they would put increased effort in the vicinity of the Ridge. Our surveys, when joined, will provide extensive coverage of the entire basin.) On the western ends of the sections the resolution was increased on the upper slope and across the shelfbreak. In all there were five crossings of the western boundary current system. South of Cape Farewell we did a “zig-zag” section in order to detect water being pulled offshore of the Deep Western Boundary Current by the nearby recirculating gyre.

During the occupation of our third section, the two MPs were deployed (blue squares in Figure 1). The onshore mooring was put near the 2500 m isobath in the outer part of the boundary current (this could not be placed any farther onshore due to the risk from icebergs). The interior mooring was deployed in the region where the deepest overturning is suspected to occur.

A Few Results

Interior

Since 1996, when the NAO dropped precipitously, there has been reduced convective activity in the Labrador Sea. This means that the deep and dense LSW formed during the early 1990s has not been renewed for six years. Despite this, the Irminger Sea still contains a significant amount of this older vintage of LSW, which is evident in the composite T/S/O2 plot of the interior stations (the extremum near 2.9–3.0°C, Figure 2). Subsequent to the mid-1990s, a lighter version of LSW has been formed, which appears as a second extremum in Figure 2 (near 3.5–3.7°C). One of our aims is to understand why the LSW distribution appears “bi-modal” like this, rather than being spread over a continuum of density surfaces.

Of course the main goal of the experiment is to determine if any of the LSW observed in the Irminger Sea is formed locally there. Therefore we deployed two MPs along the WOCE A1E line (see Figure 1). The CFC distribution along this line reveals that our choice for the offshore mooring site was ideal, as it is centered in the most highly ventilated waters in the basin (Figure 3). The hypothesis is that these waters are formed by local overturning during winter; the MP will tell us unequivocally whether this is true or not.

Western Boundary

The second goal of the experiment is to investigate the presence of newly ventilated waters within the western boundary current system. Toward this end we did five high-resolution sections across the slope and shelfbreak. Since the CTD package had an altimeter, we were able to take each of these casts to $\sim$1 m off the bottom, revealing fascinating aspects of the bottom boundary layer (which often contained pure Denmark Strait Overflow Water). One of the biggest surprises was the discovery of an additional mechanism by which the upper-slope waters are ventilated in this region, i.e. distinct from the advection of overflow water from upstream. In the northern-most section we observed dense shelf water “spilling” over the shelfbreak to $\sim$500 m (Figure 4a). This appears to be a complex process, possibly involving baroclinic instability of the shelfbreak front (note the lens of warm, salty water on the shelf (Figure 4b), whose formation might be related to a spilling event). Finally, note the swift, narrow jet associated with the strongly tilted isopycnals banked against the upper slope (centered near 400 m, Figure 4c). This is further evidence that such local ventilation is a complex dynamical process, one which we aim to learn more about using these hydrographic and vessel-mounted ADCP data.

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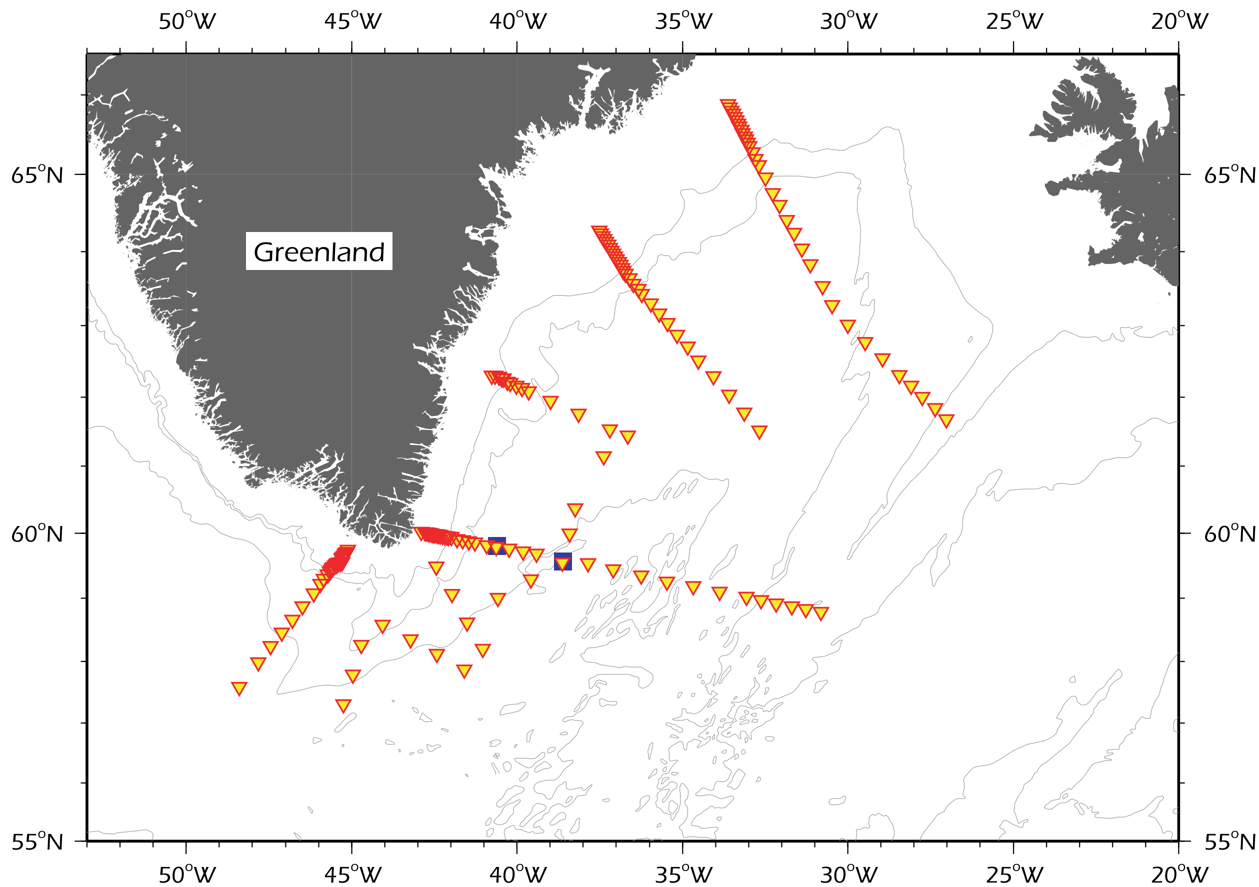

Figure 1: CTD stations occupied by R/V *Oceanus* 369 (inverted triangles) in August, 2001. The two moored profilers are denoted by the blue squares. The isobaths shown are 1000 m, 2000 m, and 3000 m.

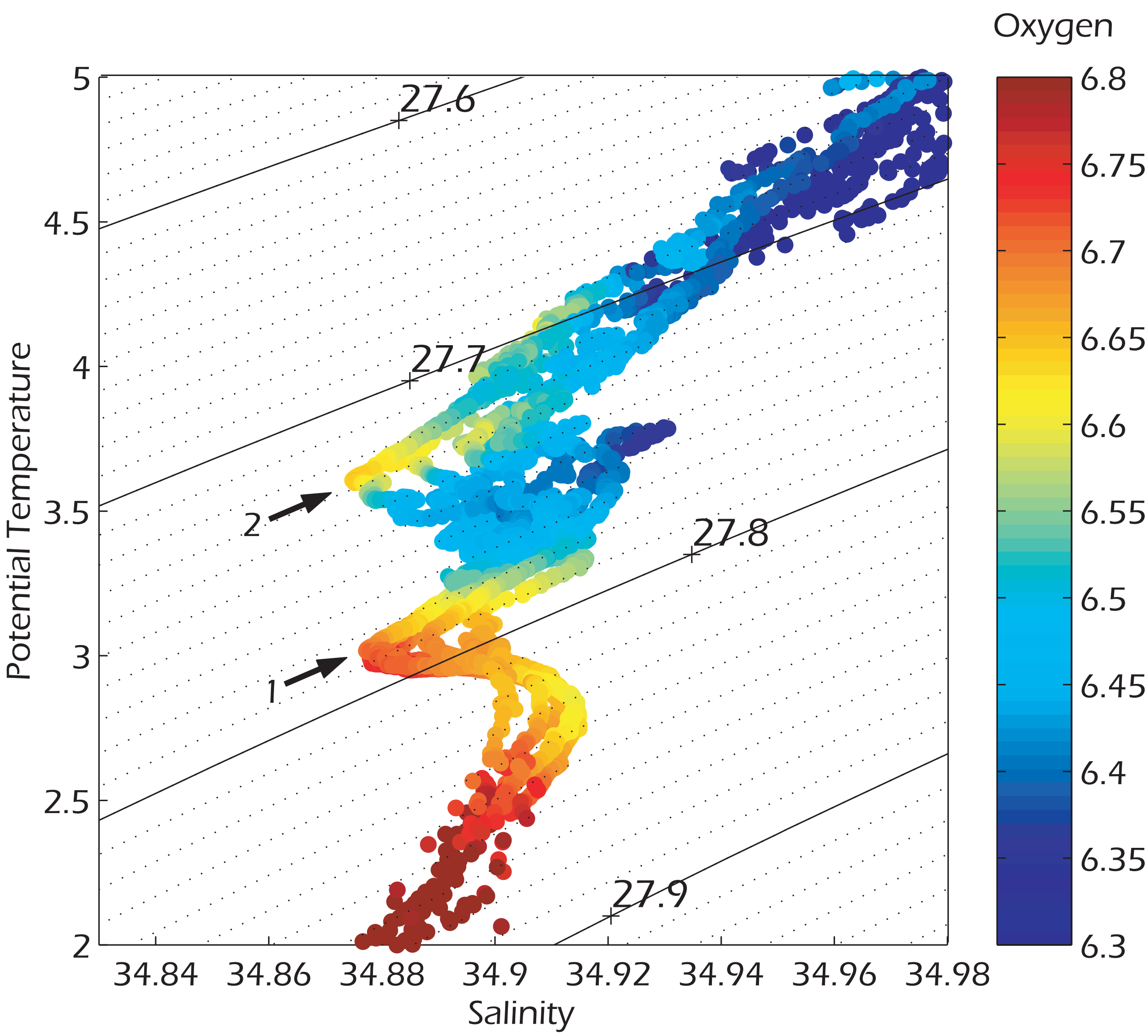

Figure 2: Theta/S Plot for the interior stations of the Irminger Sea (defined as those offshore of 2500-m isobath). The curves are color-coded in oxygen (ml/l). The older and newer vintages of LSW, characterized by an oxygen maximum, are indicated with arrows 1 and 2, respectively.

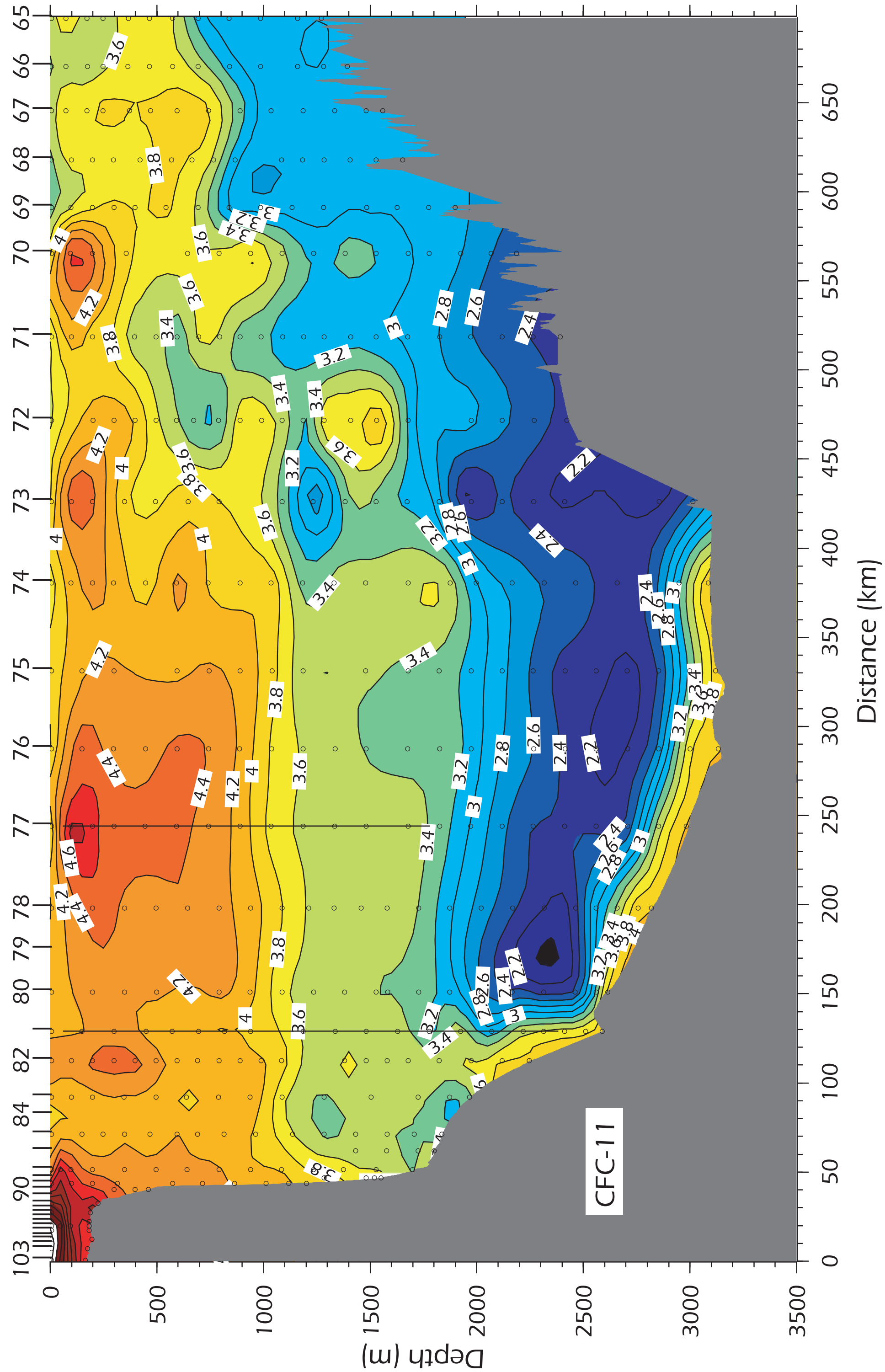

Figure 3: Vertical section of CFC-11 along the re-occupation of the WOCE A1E line (near 59–60°N, see Figure 1). The location and vertical extent of the two moored CTD profilers are indicated by the two thin black lines.

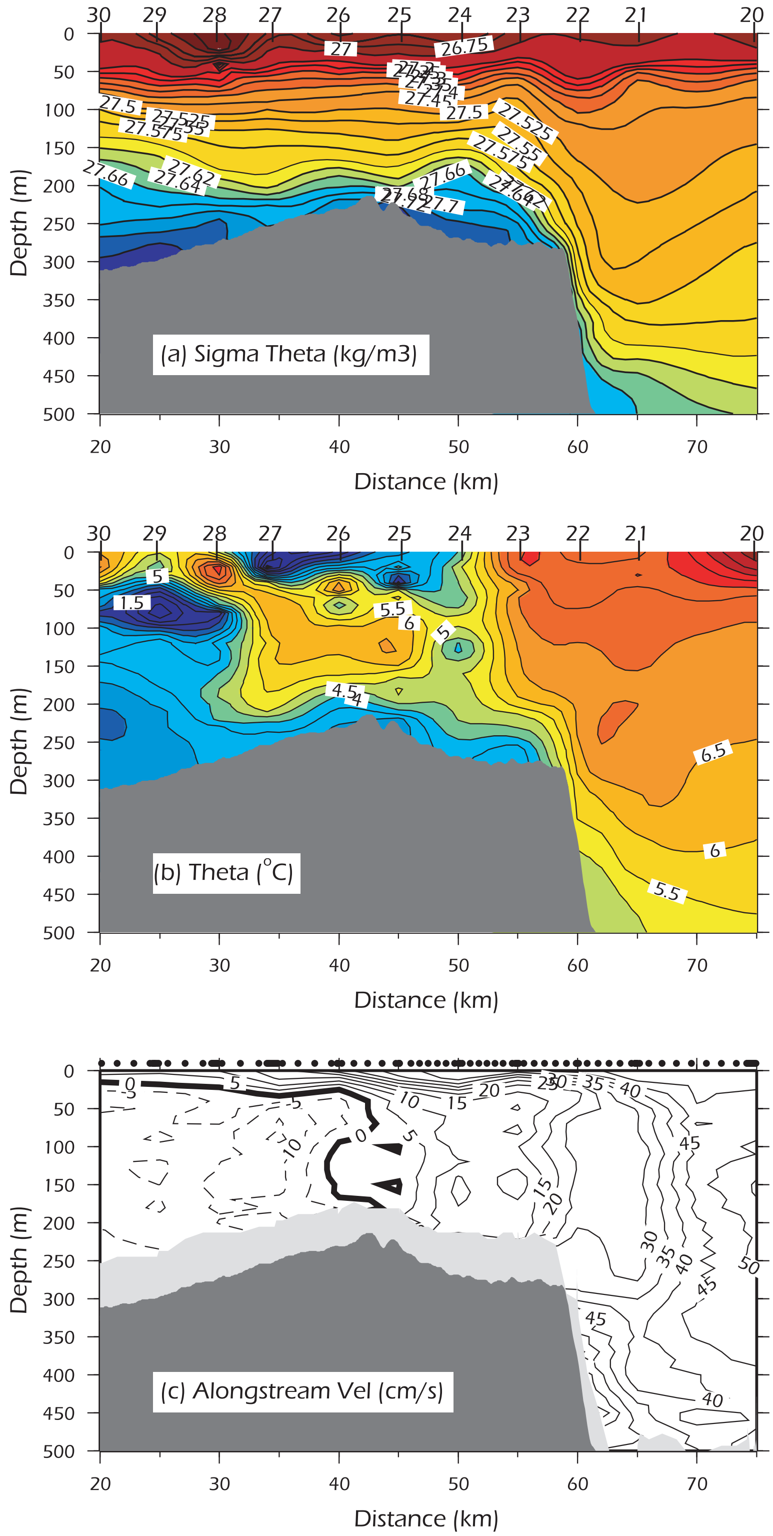

Figure 4: Vertical sections across the shelfbreak and upper-slope for the northern-most CTD line. (a) Potential density referenced to the sea surface. The CTD stations are numbered; (b) Potential temperature; (c) Vessel-mounted ADCP alongstream velocity (positive is equatorward). The bin locations are marked (solid circles).