The role of turbulence and double-diffusion in the exchange of central waters at the Cape Verde Frontal Zone

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Study area

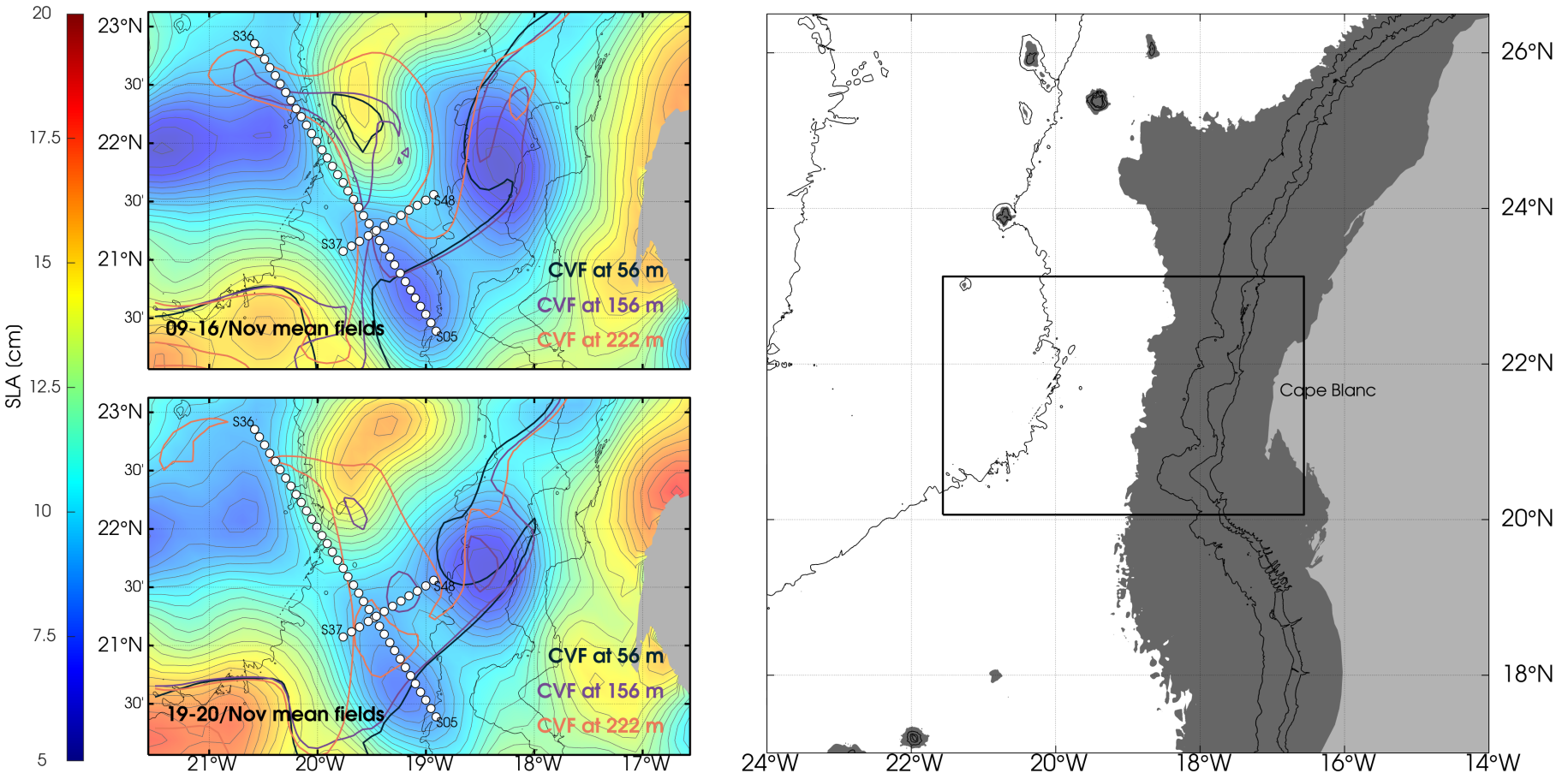


Figure 1. Study area. The map on the right shows the location of Cape Blanc with the isobaths of 5000, 4000, 3000, 2000, 1000, and 500 m. In dark gray is the seafloor equal or less than 3000 m depth. Here the empty square enclose the area showed on the left figures. These two figures show the Sea Level Anomaly averaged during the sampling period of T1 (upper) and T2 (lower). Also, the averaged position of the CVF at different depths according to Burgoa et al. (2021) is shown in both pannels. White dots indicate the oceanographic stations.

First look

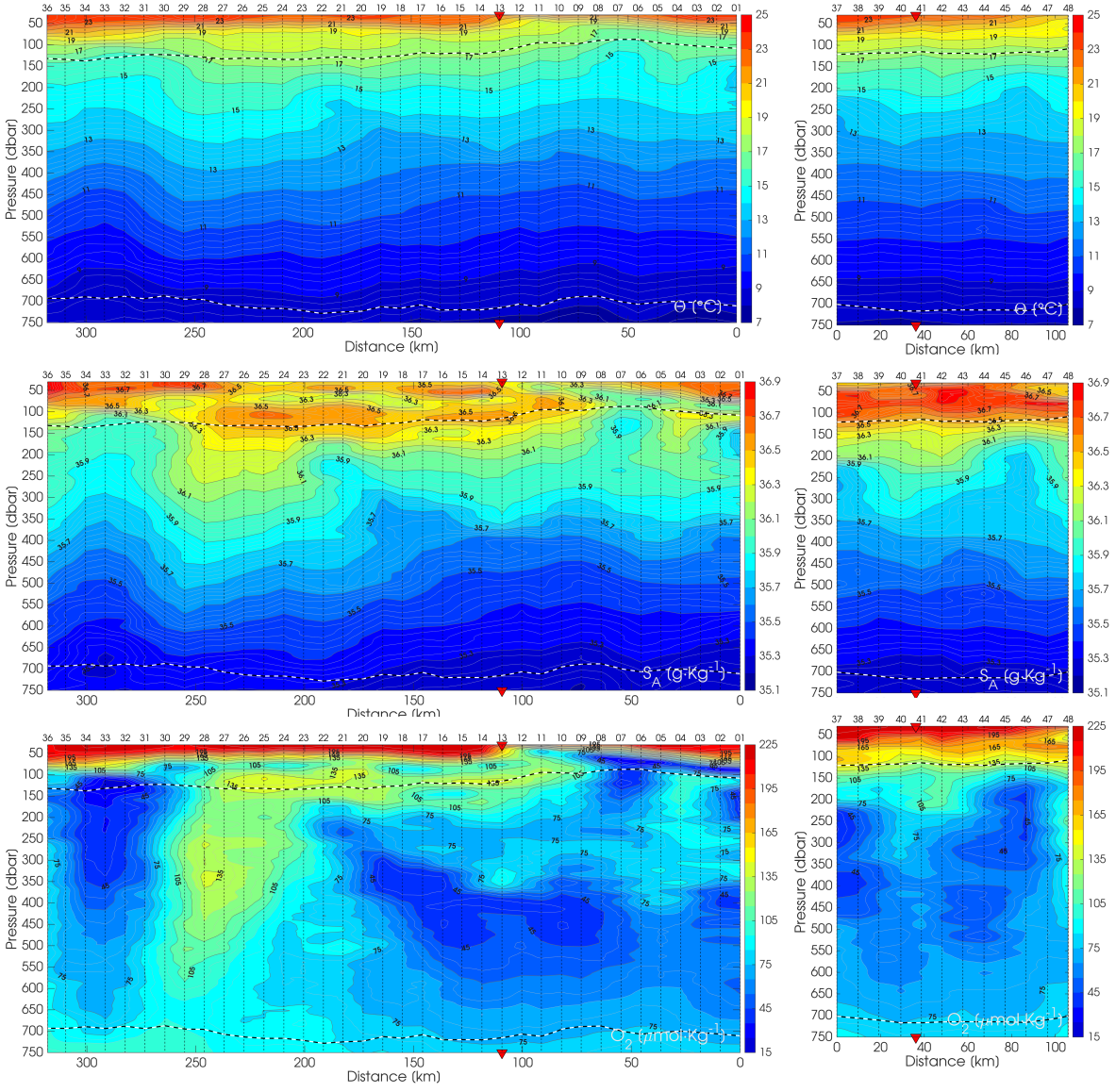


Figure 2. Vertical sections of absolute salinity (upper) and dissolved oxygen (lower) for T1 and T2 (left and right respectively). The dashed lines are the isoneutrals which enclose the central waters in the study area (Burgoa et al., 2021). The inverted red triangle marks the intersection between these two transects.

$$\gamma_{upper} = 26.46\, kg \cdot m^{-3}$$

$$\gamma_{lower} = 27.40\, kg \cdot m^{-3}$$

Presence of several intrusion-shaped structures, more prominent above 300 dbar.

The intrusion-shaped structures tend to be aligned with the isoneutral (isopycnal) surfaces, however between station 1 and 12 one of them deflects upward along the transect (a possible buoyancy gain).

At deeper levels, the three variables shows fluctuations of longer scales (mesoscale) probably linked to the mesoscale scenario that took place during the survey (e.g. St. 29-36 and cyclonic mesoscale eddy, Figure 1)

Water masses

Here we present the results of the Optimum Multi Parameter analyses (OMP) for the water mass calculation (Figure 3.1). As expected from the Potential Temperature – Practical Salinity diagram (Figure 3.2), the OMP shows that almost the entire water column is dominated by SACW, with NACW restricted to levels above 150 dbar. The tilted intrusion mentioned earlier also exhibit a high content of SACW.

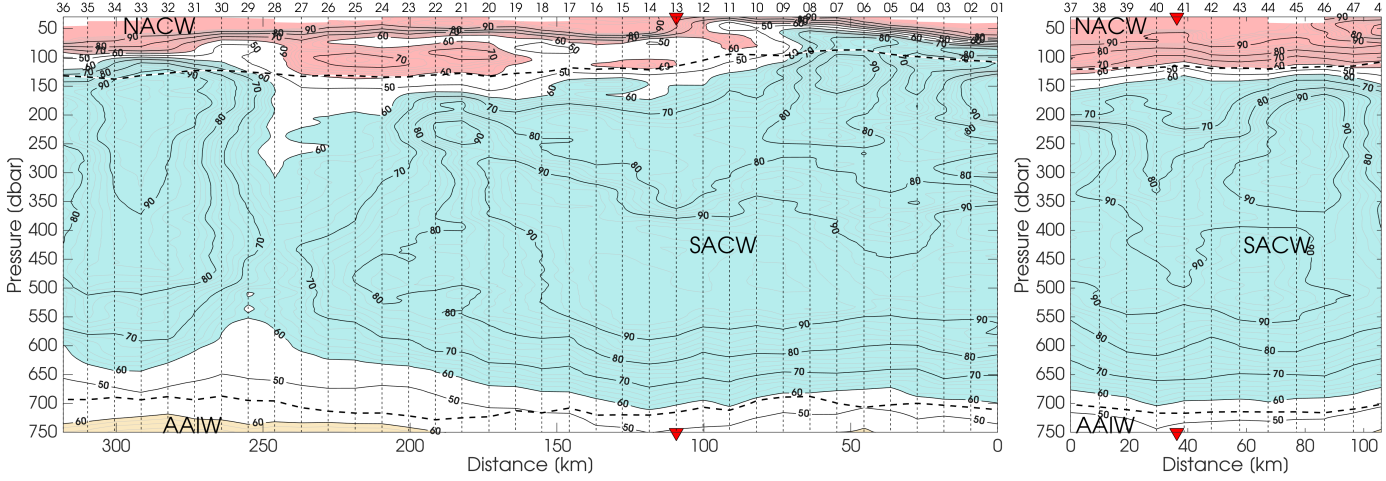


Figure 3.1, Vertical section the participation of the central waters, SACW and NACW, and the Antarctic Intermediate Water (AAIW) along T1. In color is the region were they had a participation equal or greater than 60%. Dashed lines and inverted red triangle depicted the same as in Figure 2.

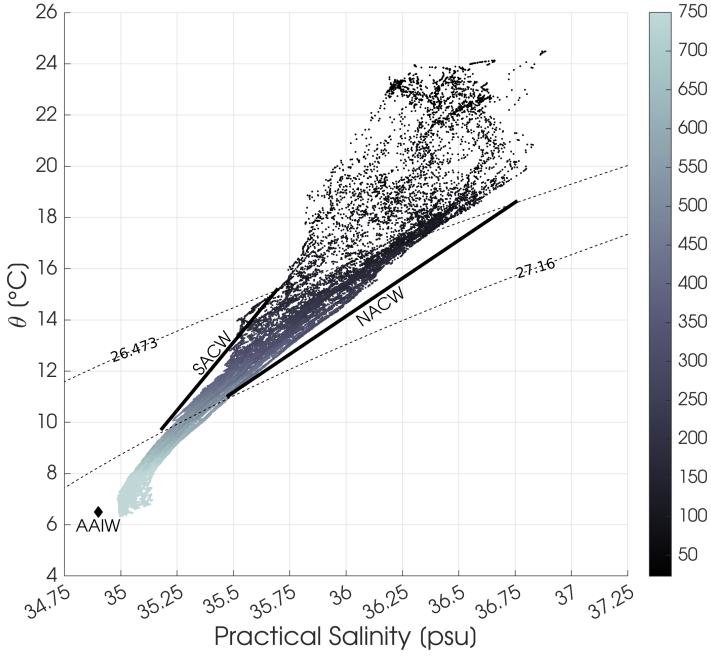
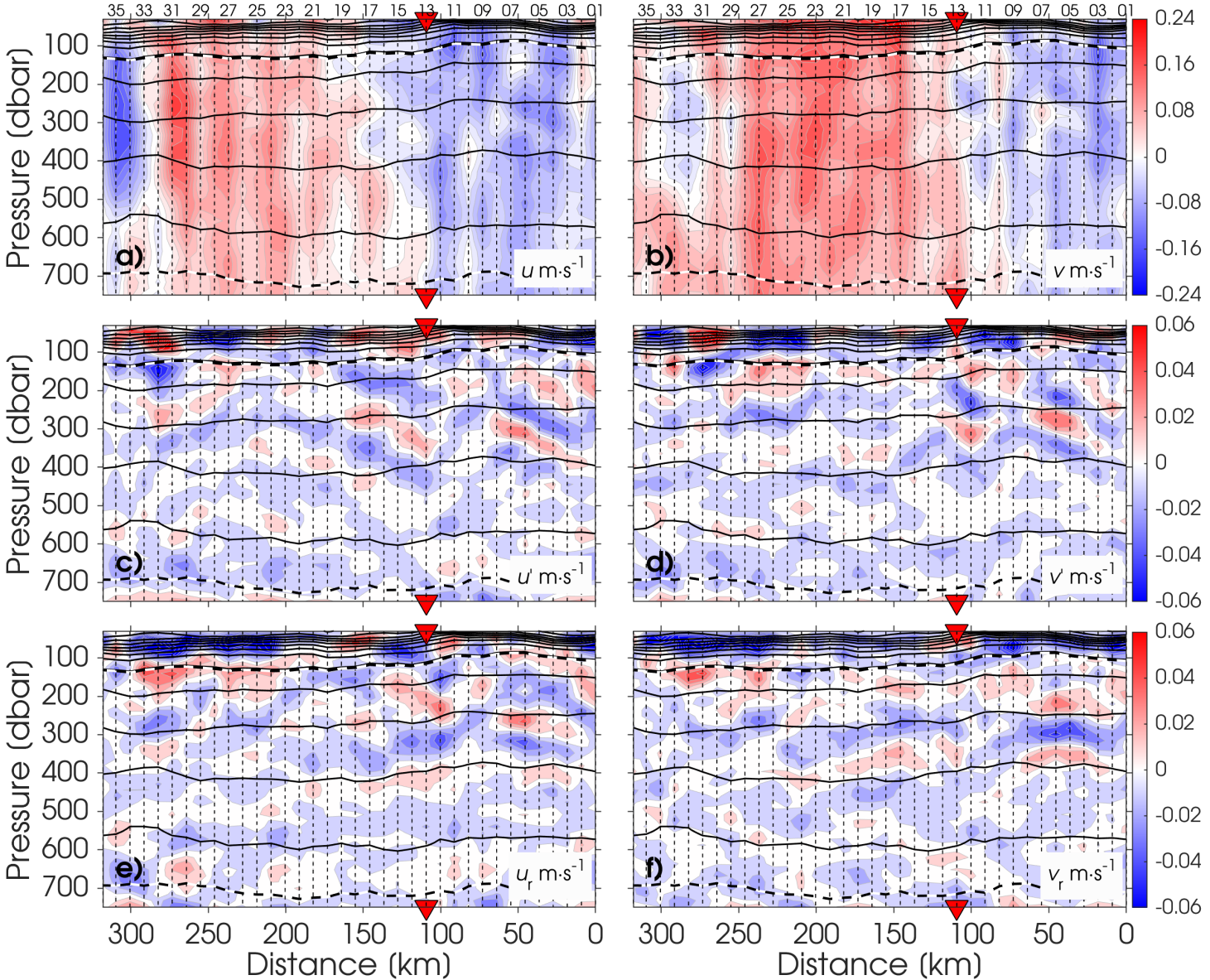


Figure 3.2. Potential temperature – Practical salinity diagram. Thermohaline information from T1 and T2 is included. Water masses used from the OMP analysis are pointed out (central waters as a linear fit and antarctic intermediate water as a point). The contours of potential densitity which according to Tomckzac (1981) encloce central waters are also shown, Depth is color-coded.

Cross and Along transect currents



We extracted from the horizontal velocity profiles their the vertical trend. obtaining in this manner horizontal velocity anomaly profiles which resemble most of their shorter scale variability (Figura 4c,d). For example, between station 1 and 10 at ~250-400 dbar signs of a near inertial wave (NIW) packet are evident. Once, black-rotated the wave packet rested parallel to the isoneutral (isopycnal) surfaces (Figure 4e, f)

Figure 4. Vertical sections of horizontal cross and along-front currents (u and v). Mesoscale horizontal currents (a and b). Horizontal current anomalies (c and d). Back-rotated horizontal current anomalies (e and f). Dashed lines and inverted red triangle depicted the same as in Figure 2.

Diapycnal Spiciness Curvature

Following Shcherbina et al. (2009) we estimate the Diapycnal Spice Curvature, which is considered as a variable appropriate for intrusions identification (Figure 5.1). From DSC we can see that beetween 50-450 dbar intrusions are persistent in stations 1-24, with some of them following closely the isoneutral (isopyncal) surfaces with along front extensions >50 km.

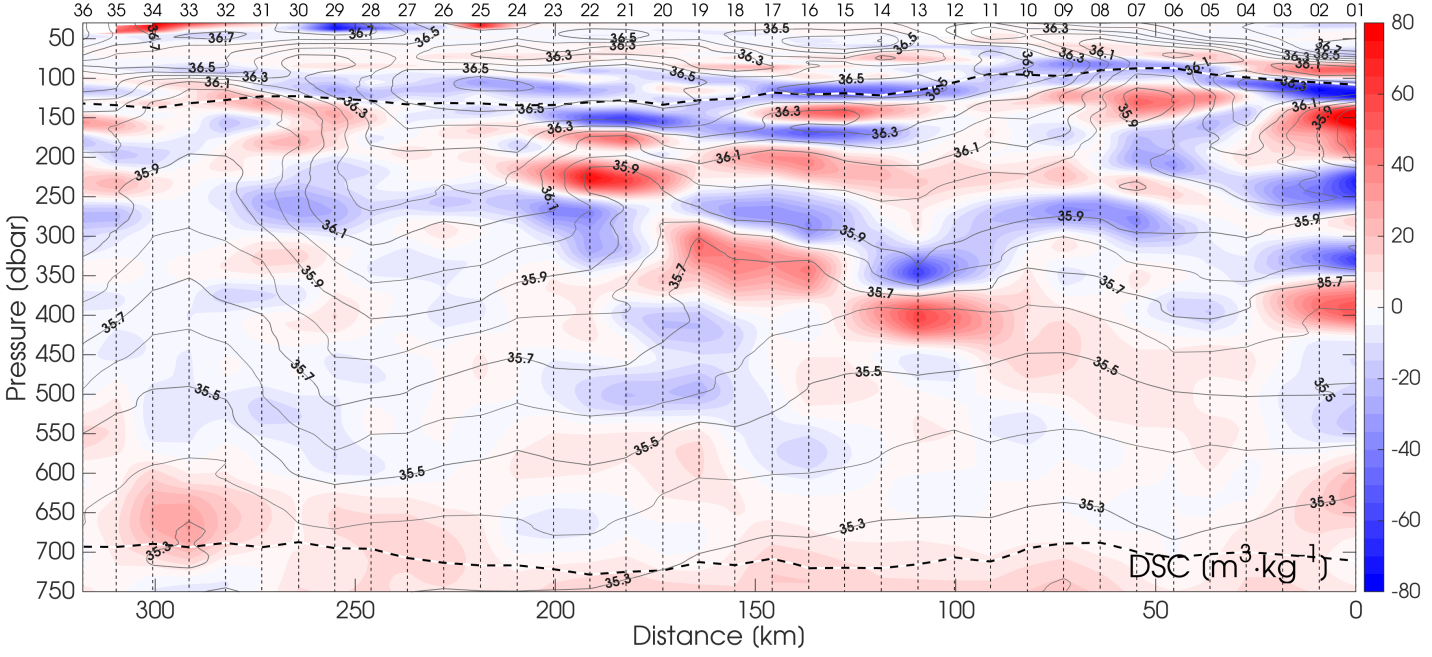


Figure 5.1. Vertical section of the Diapycnal Spiciness Curvature with contours of absolute salinity. Dashed lines depicted the same as in Figure 2.

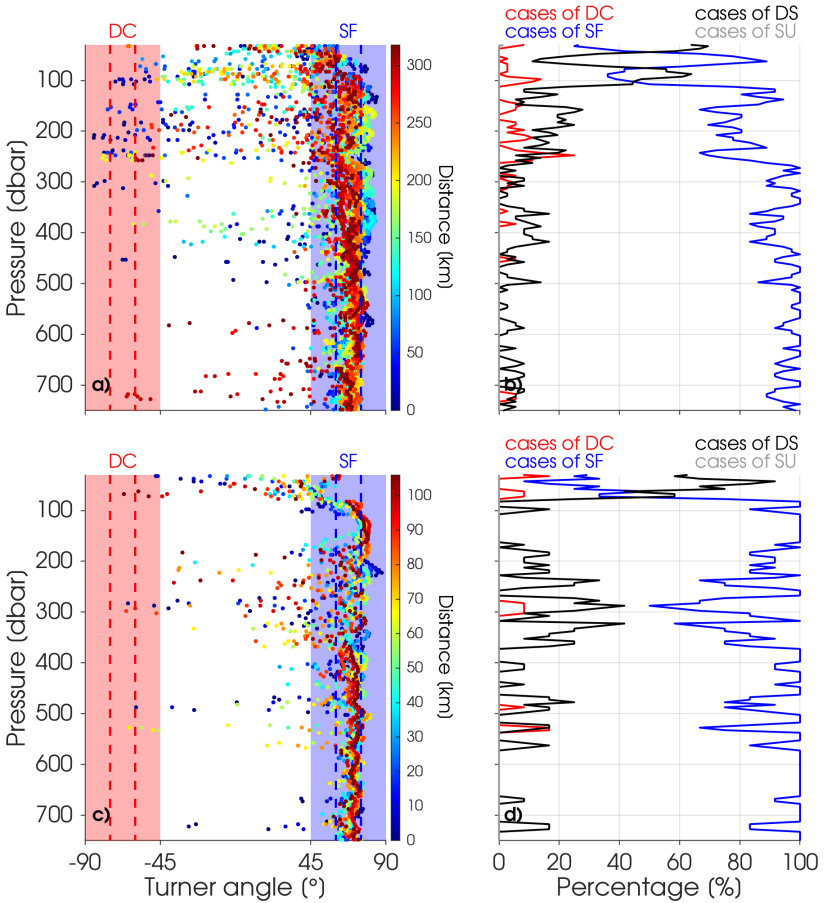


Figure 5.2. Vertical profiles of the Turner Angle (a, c) and percentage of cases of each double diffusive regime (b, d) for T1 and T2 (top and bottom, respectively). Double diffusion regime of diffusive convection (DC), salt fingers (SF), doubly stably (DS) and statically unstable (SU) are also indicated. Color in a, c indicate the along transect distance.

Considering that the whole area is favorable for the development of salt fingers (Figure 5.2) we would expect that intrusions driven by them were abundant. So, the fact that their were localized makes us think that the driver mechanism should be other. Correlations with horizontal currents anomalies were in general not significant except for St. 10-13 where correlations values were on average of ~0,5 (Table 1, supplementary material).

Table 1. Values of the correlation between Diapycnal Spiciness Curvature and horizontal current anomalies only for the stations were it was significant.

Station	Correlation
10	0,64
11	0,38
12	0,53
13	0,41

Evaluating turbulence

Using our CTD and horizontal currents data we estimated the Gradient Richardson number (Ri), aiming to the identification of areas susceptible to turbulence (Ri<0,25). At central levels (<450 dbar) the only place were relatively low values of Ri appeared were where we supposedly found NIW signs (Stations 1-10 at ~250-400 dbar, Figure 6.2l).

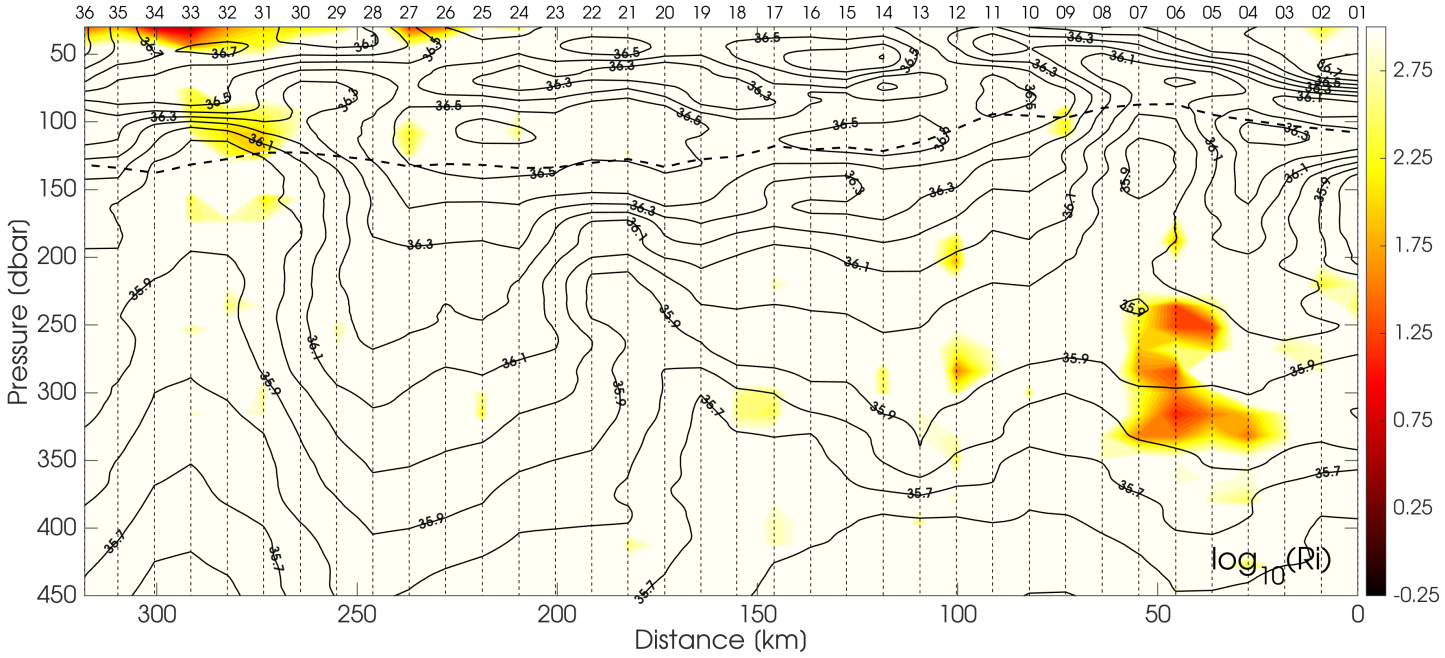


Figure 6.1. Vertical section of the Gradient Richardson Number (Ri) with contours of absolute salinity. The dashed line depicted the same as in Figure 2.

On the other hand, the Turbulent Kinetic Eddy Dissipation Rate (TKEDR) at central levels (Figure 6.2) showed several relative increases (of 1-2 orders of magnitude) scattered along the transect. It seems that they coincide with the region of relatively low values of Ri, although their magnitudes aren't the highest. The most prominent increases in TKEDR grouped together in the areas where the isohalines showed sharp deflections (e.g. St. 19-22 at 150-260 dbar).

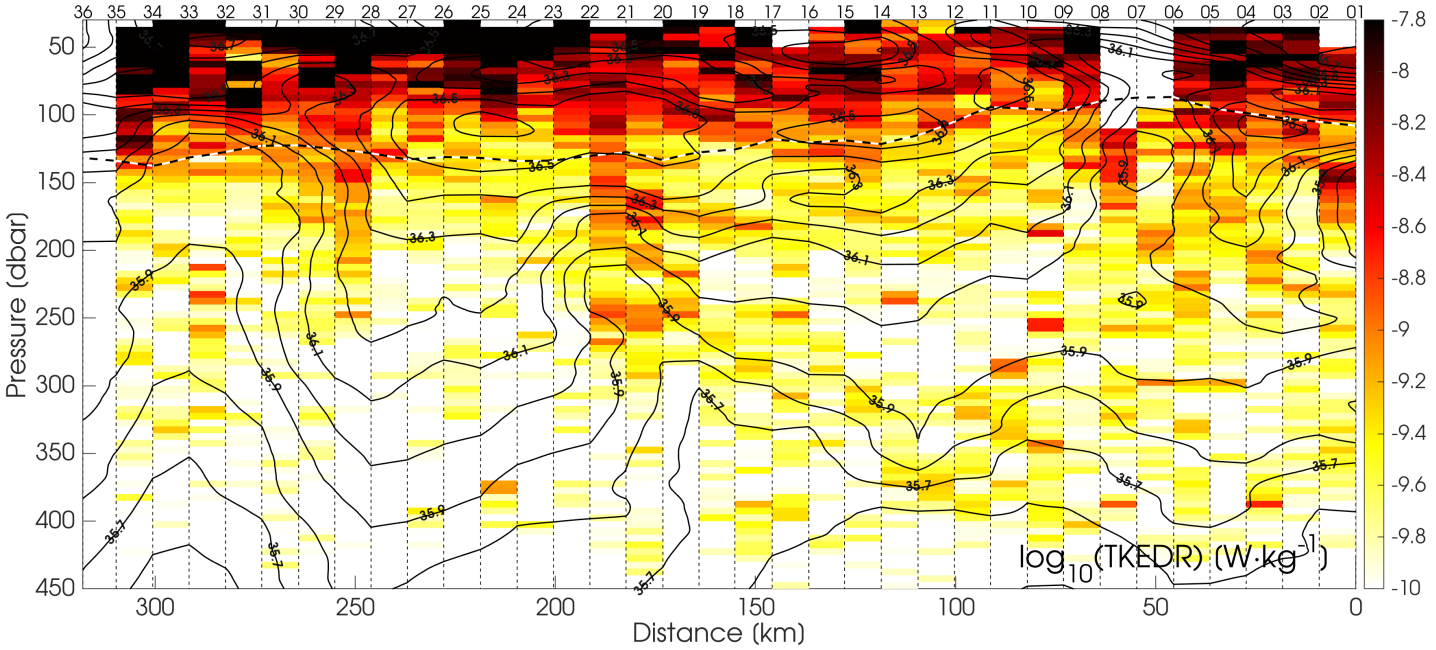


Figure 6.2. Vertical section of the turbulent kinetic eddy disipation rate (TKEDR) a with contours of absolute salinity. The dashed line depicted the same as in Figure 2.

A possible driver

Figure 7. Wind conditions during survey. The top panel shows the wind magnitude during October-November 2017. In the middle panel the time series of zonal (u) and meridional (v) wind velocity components are zoomed during the survey days, also as a shaded dark gray is the wind magnitude. The bottom panel shows the monthly climatology of wind for 2007-2020 together with 2017 monthly wind. In the three panels the time when T1 and T2 were carried out are showed as a shaded pale gray.

Winds during November 2017 were 50% higher than the climatological mean. During the first days of campaign energetic diurnal oscillations dominated their high frequency variability.