RR2004 VPR Team Cruise Report
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Dennis McGillicuddy
Phil Alatalo
Andrew Hirzel
Hilde Oliver

Shoreside team: Olga Kosnyrev, Valery Kosnyrev, Josh Eaton, Fred Thwaites

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1. Introduction

The SAMW 2021 cruise was redirected from the South Indian Ocean to the Pacific Sector of the Southern Ocean. The pre-cruise planning process included extensive deliberations on the precise location for the operational area, and we settled on the 150W meridian where prior measurements along the P16 line indicate ample volume of SAMW in this region (Figure 1). Patterson and Whitworth (1989) provide an excellent review of the descriptive physical oceanography of the region; locations of the primary fronts are described in Orsi et al. (1995). Extensive biogeochemical measurements were carried out along 170W as part of the JGOFS AESOPS Program (Anderson and Smith 2001; Smith and Anderson 2003; Smith et al. 2000)

Summertime climatologies of chlorophyll and particulate inorganic carbon (PIC) show similar patterns, with relatively modest expressions of the Great Calcite Belt (GCB; Balch et al. 2016) in the 43-55S latitude band (Figure 2). Farther south, filaments of enhanced chlorophyll and PIC correspond to fronts in Mean Dynamic Topography (MDT). Topographic steering by the Pacific-Antarctic Ridge (Figure 3) causes a confluence of the Subantarctic, Polar, and Southern Antarctic Circumpolar Current fronts (SAF, PF, SACCF; Orsi et al. 1995; Patterson and Whitworth 1989). Seasonal climatologies of PIC show distinctive variations in the 45-67S latitude band (Figure 4).

The overall cruise plan consisted of (1) a meridional transect from 30-60S along 150W, supplemented by VPR tows from 47-60S (**Section 2**), (2) Mesoscale surveys of fronts and eddies of interest (**Section 3**), and revisitation of a portion of the 150W transect, during which a coccolithophore bloom was observed (**Section 4**). Distribution of an unexpected planktonic "spindle" is described in **Section 5**. **Appendix 1** provides information on evaluation and calibration of CTD conductivity and oxygen sensors.

Plankton were sampled using three distinct methods: high-speed video sampling using the towed VPRII platform, self-recording video using the DAVPR on the CTD rosette for discreet casts, and a small 150um plankton net mounted on the rosette that was used opportunistically. Overall impressions for this cruise were similar to the South Indian Ocean mission last year, with regards to the lack of zooplankton in the sub-tropical regions. Initially we were getting very low image counts in both optical instruments and plankton hauls were very meager. As we approached the 60S on the meridional transect, the number of images captured increased dramatically, particularly as we passed through the various frontal regions further south.

Diagnostic plankton species are quite useful to validate water masses. Given the remote area, lack of sampling, and confluence of distinct water masses, we were especially cognizant of distinct particles that either dominated or were present in various regions. For this cruise, we were surprised to see great numbers of very small pteropods, polychaete worms, and unusual diatom formations several times. While limacinid pteropods are not unusual, they occurred sometimes in great numbers often together with worms and an unidentified organism, which we have tentatively identified as *Thalassiothrix antarctica* colony (**Section 5**). While forams and phaeodarians were fairly common, acantharian radiolarians formed dense patches in the lower salinity water of the meander in the northern section of the meridional transect. The colonial alga *Phaeocystis antarctica* occurred briefly several times, presumably indicating water from the

SubAntarctic Front. Large diatom mats were present in high abundance at the Polar Front and swamped the VPRII camera with images. These mats were often found at depth with the DAVPR, indicating that they were sinking out of the system. Regarding larger taxa such as krill, gelatinous predators, and fish larvae, these organisms were present, but never in huge abundances. Much more often, we were surprised by the lack of organisms; our last VPRII tow netted a record low of images for a 13-hour tow, while we towed through the coccolithophore bloom from 43-50S (**Section 4**).

Use of the Convolutional Neural Network (CNN) approach to image classification provided for some real-time mapping of selected taxa, using CNN classifiers trained on images from prior cruises. Initial vetting of the CNN results, along with preliminary analysis of new taxa to be added to the classifier, is presented in **Appendix 2**. **Appendix 3** contains an atlas of the hydrographic, bio-optical, and taxonomic plots for all VPR tows combined.

Note: higher resolution figures are available in the accompanying powerpoint file.

2. Meridional transect

Seventy-four CTD casts spanning from 30-60 S were conducted from 8 to 26 January 2021 along the 150 W meridian. The transect was divided into two sections: a northern "classic meridional transect" extending from 30-47 S and a southern "enhanced meridional transect" extending from 47-60 S. "Classic" meridional transect casts (Casts S1 to S35) were spaced 0.5 degrees apart, while "enhanced" transect casts (Casts S35 to S74) were spaced 1/3 degrees apart, and were complemented by four VPR II tows for high-resolution hydrographic and bio-optical surveys of the surface ocean.

Over the span of the meridional transect, the surface ocean became substantially cooler, fresher, and denser (Figure 5, Figure 6, Figure 7). Four major oceanographic fronts were crossed: 1) the STF at ~36 – 39 S (salinity at 100 m drops from 35.0 to 34.6), 2) the SAF at ~53.0 – 53.5 S (where temperature at 400 m dips below 5ºC and salinity at 300 m becomes fresher than 34.2), 3) the PF at ~ 55.5 S (where the temperature minimum rises above 200 m), and 4) the SACCF at ~57.5 (where the temperature minimum above 150 m goes below 0ºC and the salinity maximum below 800 m rises above 34.73) (Orsi et al. 1995). SAMW (defined where 26.5 kg $m^{-3} < \sigma_\theta <$ 27.1 kg m^{-3}) was present at all stations north of the SACCF; casts south of 37.5 S were extended from 900 m to 1000 m to better encapsulate the 27.1 kg m^{-3} isopycnal. SAMW was present at the surface between the SAF and SACCF.

Chlorophyll concentrations estimated from florescence varied widely over the span of the meridional transect (Figure 8). The Subtropical Zone (STZ, north of the STF) was characterized by deep (> 100 m), low magnitude (< 1 µg/L) chlorophyll maxima. South of 42 S, higher chlorophyll concentrations were present in the upper 100 m, with maximum chlorophyll concentrations generally increasing southward. The highest chlorophyll concentrations measured along the meridional transect (> 8 µg/L) were observed just north of the PF. High (> 3 µg/L) concentrations were also measured in the vicinity of the SACCF, before dropping off at the southern terminus of the transect.

While the oxygen saturation of the upper water column was consistently high through the meridional transect, oxygen saturation below 150 m varied substantially (Figure 9). In the subtropical zone, the several-hundred-meter thick SAMW layer was characterized by slightly elevated oxygen saturation relative to the overlying and underlying waters. South of the STF and north of the PF, oxygen was highly saturated (> 90%) from the surface down to deeper than 300 m, with the $\sigma_\theta = 27.1$ kg m^{-3} isopycnal (the densest SAMW) bounding the deepest high-oxygen waters. This deeper, highly oxygenated water disappears with the outcropping of the $\sigma_\theta = 27.1$ kg m^{-3} isopycnal at ~ 57.5 S. The denser waters that then extend to ~150 m south of the $\sigma_\theta = 27.1$ kg m^{-3} isopycnal outcropping have a much lower oxygen saturation of ~50-60%, with an oxygen saturation minimum between the $\sigma_\theta = 27.6$ kg m^{-3} and the $\sigma_\theta = 27.7$ kg m^{-3} isopycnal. With the sub-zero temperatures characterizing the southern transect terminus, these casts were the site of both the highest and lowest oxygen concentrations observed during the entire meridional transect.

Along the "enhanced" transect south of 47 S, VPR Tows 2, 3, 4, and 5 ran from 47 S to 60 S along the 150 W meridian to provide higher resolution of the surface ocean in that interval (Figure 10, Figure 11, Figure 12, Figure 13). Pairing the VPR tows across the dynamic frontal regions with the CTD cast data demonstrates how submesoscale variability in temperature, salinity, density, and fluorescence measured in the top 100-120 m relates to deeper mesoscale ocean variability. As in the CTD data, the largest chlorophyll concentrations measured by the VPR were captured between the SAF and the PF, with the highest chlorophyll concentrations closely following density surfaces (Figure 13).

Nutrient (nitrate, phosphate, nitrite, ammonium, silicate) data across the meridional transect were collected, compiled, and made available by the Scripps ODF team (Figure 14). Nitrate and phosphate were depleted north of 42 S, with nitrate drawn down to the approximate detection limit. At 42 S (Station 25), surface nitrate concentrations rise to ~ 1 µM, and the chlorophyll maximum was 35 m below the sea surface, shallower than the deeper (90 m or deeper) chlorophyll maxima for stations further north (Figure 8). Moving southward, all measured nutrients typically increased. An exception was surface silicate, which was somewhat patchier than other macronutrients. While surface silicate was depleted to < 1 µM over much of the STZ, it was also drawn down north of the SAF and north of the PF. We calculated Silicate* (Si*, silicate – nitrate) over the entirety of the meridional transect to assess the relative drawdown of silicate relative to nitrate. As demonstrated in Sarmiento et al. (2004), the SAMW layer was distinguished from overlying and underlying waters by its comparatively low Si* values (~14 µM). The lowest Si* values observed over the meridional transect (< -20 µM) were observed near the PF, the location where the highest chlorophyll concentrations were observed (Figure 8). South of the PF, Si and Si* values rapidly rise.

Carbonate system data for the meridional transect were collected and provided by the BIOS team aboard (Figure 15). Throughout the transect, the SAMW layer had higher DIC than less dense waters and lower DIC than denser waters. Total alkalinity (TALK) was low in the surface waters north of the STF and high for waters denser than $\sigma_\theta = 27.1$ kg m^{-3}, with low TALK found in the subsurface SAMW in the Subantarctic Zone corresponding to high oxygen saturation. Upper water column pCO_2 was lowest where the largest chlorophyll concentrations were observed: in the region north of the SAF extending to the SACCF, with the lowest pCO2 observed north of the PF. Below the surface in the SAMW layer north of 42 S, low pCO_2 was associated with enhanced oxygen saturation (like TALK). This deeper depletion of pCO_2 and TALK was not observed in waters denser than $\sigma_\theta = 27.1$ kg m^{-3}.

Nutrient and other water mass properties vary systematically in temperature-salinity space (Figure 16, Figure 17). Several water masses were captured over the transect: SAMW (26.5 kg $m^{-3} < \sigma_\theta$ 27.1 kg m^{-3}), warm and salty Subtropical Surface Water (STSW) north of ~39 S, slightly fresher and less warm Subantarctic Surface Water (SASW) between the SAF and the STF, cold and fresh Antarctic Intermediate Water (AAIW) and Antarctic Surface Water (AASW), and slightly wamer-and-saltier-than-AAIW upper circumpolar deep water (UCDW). North of 42 S, temperature is the primary control on density, and the highest oxygen saturations are associated with the warmest waters. Here, chlorophyll concentrations are low, and nitrate, silicate, and Si* are all near zero. South of 42S, the SAMW layer moves closer to the surface, chlorophyll concentrations increase, and surface nitrate concentrations increase while surface silicate concentrations remain low, and surface Si* becomes negative. Both AAIW and UCDW had high nitrate and silicate concentrations, and positive Si*.

Despite overall consistently cloudy conditions, the enhanced portion of the meridional transect crossed several distinct PIC (Figure 18) and chlorophyll (Figure 19) features detected by satellite ocean color. The northern portion of VPR 2 (47 to 50 S) traversed a low-chlorophyll, high PIC eddy (Figure 20, Figure 21); satellite measurements of absolute dynamic topography (ADT) show cyclonic "Eddy 1" at ~47.5 S (Figure 22). VPR bio-optical measurements confirmed Eddy 1 as a region of low chlorophyll and high backscatter (b_b) down to ~60 m (Figure 20). Farther south, satellite ADT also revealed a meander of the ACC at ~50.25 S, and anticyclonic "Eddy 2" at ~51.6 S depressing the main pycnocline (Figure 23, Figure 24). VPR 4 (53 to 56 S) also crossed two bands of high PIC and high chlorophyll measured by satellites at ~53.5 S and ~55.5 S, which were both captured by the VPR fluorescence and b_b measurements (Figure 25). The dropping sea surface height shown by satellite ADT and rapid currents measured by the ship ADCP suggest that VPR 4 was towed through the ACC (Figure 26).

The VPR was towed across three major oceanographic fronts as determined by the CTD meridional transect profiles: 1) the SAF at ~53.0 – 53.5 S, 2) the PF at ~ 55.5 S, and 3) the SACCF at ~57.5 S (Figure 20). Between the SAF and the SACCF, isopycnals are sloped; north and south of the frontal region isopycnals are relatively flat. Upon encountering the SAF, the entire water column freshened, and both chlorophyll and b_b increased. Chlorophyll and b_b were also enhanced on both sides of the PF, and on the southern side of the SACCF. The highest b_b of the VPR enhanced transect was recorded at the PF, and the highest chlorophyll was measured just north of the PF.

Results from the individual VPR tows comprising the enhanced meridional transect (VPR 2-5) will now be presented in detail.

VPR 2 crossed through Eddy 1 and clipped the northeast flank of a meander in the SAF (Figure 21, Figure 22). Selected taxonomic distributions (Figure 23) reveal a patch of acantharians associated with a warm surface layer in the meander spanning 49.5 – 49.8S. Diatoms were distributed throughout the tow, with peak abundances in between Eddy 1 and the meander.

Calanoid copepods were present within Eddy 1, and observed only occasionally in waters south of 48.4S.

VPR 3 extended the sampling of a meander in the SAF initiated in VPR 2, passed through Eddy 2, and then crossed the SAF itself (Figure 24, Figure 25). Another patch of acantharians was observed at the edge of the SAF; diatoms, marine snow, and copepods were abundant in a band centered on 51 S between the meander and Eddy 2 (Figure 26).

VPR 4 continued sampling of the SAF initiated in VPR 3, extending into the northern flank of the PF (Figure 27, Figure 28). The high fluorescence regions in the southern SAF and northern PF were manifested in the "Phaeo bloom" taxon by the classifier (Figure 29). Upon examination of the sorted ROIs, it was clear the classifier put the following plankton types into this taxon: colonial algae, diatom mats, *P. antarctica*, and ghost colonies (Figure 30). Pteropods, polychaetes, and copepods were also abundant in these high fluorescence regions (not shown).

VPR 5 continued through the PF, crossed the SACCF and into the Ross Gyre (Figure 31, Figure 32). The southern flank of the PF contained a high abundance of diatoms, as well as same the collection of plankton types allocated to "Phaeo bloom" by the classifier in VPR (Figure 33). *Chaetoceros*, "spindles" (*Thalassiothrix antarctica*?), and segmented diatom chains were also present in the polar front, as well as pteropods and worms. The southern edge of the polar front (57.5S-58.5S) contained a dense diatom bloom composed of *Chaetoceros*, "spindles", and segmented diatom chains. Pteropods and worms were absent in this area. Waters of the Ross Gyre (58.5S south) contained mostly large zooplankton (e.g., krill, amphipods, and salps) and fecal strings.

To summarize the dominant trends in microplankton biogeography in VPR 2-5, based on the above taxonomic distributions plus additional qualitative analysis:

- Subantarctic Front
  - Acantharians (northern flank)
  - Large colonial phytoplankton (*Phaeocystis*?)
  - Polychaetes
  - Pteropods
- Interstitial region
  - *P. Antarctica*
- Polar Front – northern branch
  - Warm, fresh, high F, b_b
  - Aggregates of small rod-shaped diatoms
- Polar Front – southern branch
  - Cold, salty, low F, b_b
- Polar Front zooplankton
  - Pteropods
  - Copepods
- Ross Gyre
  - Large zooplankton (e.g., krill, amphipods, and salps)
  - Fecal Strings

Satellite imagery received after the completion of the enhanced meridional transect revealed high PIC and chlorophyll associated with the SACCF, consistent with the VPR results (Figure 34, Figure 35).

Note that the starting points of VPR 4 and VPR 5 were moved farther north in order to provide two time points bracketing CTD observations. Overlap regions for VPR 3-4 and 4-5 are shown in Appendices 4 and 5, respectively.

3. Feature surveys

3.1 Survey of Eddy A

After completion of the 30-60 S meridional transect, the VPR was towed northeastward from to survey Eddy A, a persistent mesoscale cyclonic feature with relatively high satellite-detected PIC (Figure 36) and chlorophyll concentrations (Figure 37). The VPR was towed across the PF during transit to the center of Eddy A (VPR 6, 7), then towed in a bow-tie pattern to complete the eddy survey (VPR 7-9). Note that the strobe failed during the latter part of VPR 6 and ROIs were not available for that portion of VPR 6 or VPR 7.

The transit towards Eddy A allowed for additional high-resolution surveying of the high-fluorescence, high-backscatter PF (Figure 38, Figure 39). East of 150 W, the PF (at ~55.5 S on 150 W) splits into northern and southern branches, which were both measured by the VPR (Figure 39). The more southern of the two branches was colder and saltier with lower fluorescence and backscatter. Taxonomic observations (Figure 40) show a similar distribution to that of the southern branch of the PF on the meridional survey. Predominant taxa are Chaetoceros, “spindles”, segmented diatoms, copepods, pteropods, and worms. From 147W to 146W, there was a cold and salty anomaly with lifted isopycnals separating the two branches of the polar front. This anomaly was characterized by lower chlorophyll, backscatter, and overall plankton abundance than either of the two branches. The more northern of the two is warmer and fresher (33.85) with higher fluorescence and backscatter, with conditions more similar to those of the crossing of the PF on the 150 W meridional transect. The taxonomic distribution reflected that seen in the northern branch of the PF in the meridional survey, with overall lower abundance than the peak concentrations seen in VPR4.

Hydrographic properties measured by the VPR and XBTs, satellite ADT, and ADCP data were used to pinpoint the center of Eddy A (Figure 41, Figure 42,Figure 44). Like the northern branch of the PF and the 150 W meridional transect, the core of Eddy A was characterized by low salinity (33.85) (Figure 41). Unlike the high-chlorophyll and high b_b PF, however, fluorescence and b_b in the core of Eddy A were moderate. Zooplankton were abundant in the eddy though; the VPR captured images of copepods, pteropods, marine snow, and chaetognaths. The northern edge of the eddy was comprised of the SAF and had both high chlorophyll and high b_b. Image data recommenced just prior to making the turn southeast at the northwest corner of the eddy (Figure 43); this high-biomass area was characterized by colonial alga, *P. antarctica*, pteropods, and worms, similar to that which was seen within waters of the SAF during the meridional survey.

Following the VPR survey, ten CTD profiles comprising two transects crossing Eddy A were conducted (Figure 45, Figure 46, Figure 47). Like the VPR data, the CTD profiles indicate a colder eddy core than the outer eddy regime. In the top ~200 m, the eddy core is fresher; at depth it is saltier than the surrounding water. Nutrient data collected by the Scripps ODF team reveal the upward doming of nutriclines. This high-nutrient water doming at eddy center is also associated with low oxygen saturation, a signature of UCDW.

High-resolution satellite imagery of Eddy A suggests that the presence of a spiral streamer of high PIC / chlorophyll around the eddy (Figure 48, Figure 49). Cross-eddy variability in temperature and salinity captured by VPR hydrographic measurements also indicates a cold spiral streamer (Figure 41). This potentially indicates lateral entrainment and advection of colder, fresher, high chlorophyll, and high b_b waters from high-biomass frontal regions to form the ring of high chlorophyll and high backscatter in the periphery of the eddy.

The origin of Eddy A was estimated by comparing the eddy core water to the 150 W meridional transect in temperature-salinity space (Figure 50). The eddy core appears to have originated from the northern flank of the PF based on its water mass characteristics. Comparing CTD cross sections of Eddy A and the meridional transect also suggest consistency between water observed at the core of Eddy A and the PF region (Figure 51). The deeper waters of the core of Eddy A appear to be a mixture of AAIW and UCDW; the upper water column is likely to be composed of warmed AASW.

3.2 Survey of Polar Front at 141W

Satellite ocean color images from mid-December revealed high PIC (Figure 52) and high chlorophyll (Figure 53) across the PF at 141 W. The frontal configuration at 141 W differed from than at 150 W, however, due to topographic steering by the Pacific Antarctic Ridge. The SACCF and PF converge in the vicinity of the Udintsev Fracture Zone, as illustrated by ADT overlaid on bathymetry (Figure 54). These differences between the PF at 141 W relative to the 150 W meridian motivated an extensive VPR cross-sectional survey (VPR 10). February satellite imagery suggests that PIC and chlorophyll may have declined in the PF since December (Figure 55, Figure 56), though high PIC and chlorophyll appeared to continue in the Southern ACC front.

Consistent with satellite measurements, high fluorescence and backscatter were detected in the SACCF during VPR 10 (Figure 57). Backscatter and chlorophyll were enhanced to a lesser degree at the PF, which had converged with the SACCF (Figure 58), with the strongest signals detected ~50 m below the surface. In the PF (56.8 – 57.2 S), diatom mats predominated from ~ 60-80m below the surface. In the SACCF (57.6-58.0 S; Orsi et al. 1995), diatom mats were abundant in the surface layer. The tow was characterized by sharp horizontal gradients in bio-optical measurements, with “vertical walls” in chlorophyll and b_b detected at 56.8 S, 57.55 S, and 57.95 S.

Colonial alga and diatom mats were common throughout the tow. *P. antarctica*, pteropods, and worms were present within the PF. South of 57.5 S, those three taxa were replaced with

Chaetoceros, “spindles”, and segmented diatom chains typical of the southern branch of the PF and the SACCF.

3.3 Survey of Eddy C

Satellite images from 20 January 2021 indicate a hotspot of PIC and chlorophyll in the interior of cyclonic “Eddy C” (Figure 59, Figure 60), motivating a VPR eddy survey from its southwest to northeast corners on 2 February (Figure 61). An XBT survey was used to help pinpoint eddy center (Figure 62). Whereas original expectations were for Eddy C to be a younger version of Eddy A, their hydrographic and bio-optical properties were quite different. In contrast to Eddy A, the interior of Eddy C contained a warm and salty interior, low fluorescence, low microplankton abundance, but high b_b (Figure 63). Also unlike Eddy A, nutrient measurements made during CTD profiles through the eddy document high ammonium at eddy center (Figure 64, Figure 65, Figure 66). Patches of higher chlorophyll consisting of diatom mats were detected on the eddy flank (Figure 67); *P. antarctica*, pteropods, and worms were also present.

In the center of the eddy, the higher backscatter reaches the surface, creating a “Bull’s eye” backscattering pattern consistent with the satellite imagery. As PIC concentrations are estimated by the relation PIC ~ b_b / (a + b_b) (Gordon et al. 1988), low values of *a* can allow the PIC to shine forth, which we suspect may have been the case for Eddy C.

Zooplankton (e.g., copepods, pteropods) were present in eddy center, but the overall abundance of ROIs was extremely low. Eddy center had roughly 300 ROIs/hour for 5 straight hours, as compared to a typical hour of 1-2k ROIs and blooms which have upwards of 6-20k ROIs.

3.4 Revisitation of Eddy A

After completion of the Eddy C survey, Eddy A was revisited while transiting to the meander of the SAF for VPR 12. The VPR 12 track was designed to bisect Eddy A, then travel into the eddy south of the SAF meander (“Eddy D”) before entering the SAF itself (Figure 68, Figure 69). As the configuration of the meander had shifted in the period since its first occupation on 19 January, a short northeastward segment following our passage through Eddy D ensured we had indeed traveled across the SAF. High fluorescence and backscatter signals were still present in low-salinity Eddy A during its revisitation (Figure 70), and zooplankton remained abundant.

3.5 Survey of Eddy D / Subantarctic Front

While satellite images suggested the presence of high PIC and chlorophyll waters wrapping around the southern flank of Eddy D, this was not detected by VPR sensors; fluorescence and b_b remained low throughout the Eddy D cross section (Figure 70).

Fluorescence increased somewhat when entering the SAF, however backscatter remained near background levels. At no point in VPR12 did colonial algae or diatom mats appear in similar abundance to prior visitations of the SAF (Figure 71). *P. antarctica* was still present.

4. A coccolithophore bloom along 150W

During the transit north to re-occupy a portion of the meridional transect along 150W, a bloom of coccolithophores was detected from 50.5S to 43.3S, with b_b' values of up to 3E-3 (Figure 72). These values were almost an order of magnitude larger than what we have observed up to this point. VPR 13 surveyed the northern edge of this bloom (Figure 73), spanning the background conditions to the north (warm SST, > 16C; low fluorescence, low backscatter) into the bloom interior with b_b' values of ~2E-3. The total backscatter mimics the pattern of b_b', with an increasing trend from north to south, interrupted by a dip in the vicinity of 44.1S. Note that the surface expressions of peaks in b_b' centered at 43.8S and 44.6S both have subsurface extensions to the north. Salinity anomalies centered at 43.5S and 44.5S appear to be associated with a frontal meander (Figure 74). Based on satellite imagery, the dip in b_b' at 44S (Figure 72) coincides with an eddy with low PIC in the interior (Figure 75, left panel).

A satellite image subsequent to the survey reveals PIC-rich water to the east of where high b_b' was observed along 150W (Figure 75, right panel).

Comparison of the CTD data from the two occupations of this portion of the meridional transect reveals surface warming (Figure 76), as to be expected this time of year. However, near-surface waters also freshened by ~0.2 psu, indicating the presence of a different water mass (Figure 77). The associated nutrient data (Figure 78) reveal some deepening of the nitracline and an increase in ammonium.

Ten Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) BGC Argo floats were deployed over the 30-60 S, 150 W meridional transect (float IDs 19018, 0887, 1115, 1204, 19072, 1205, 17328, 19085, 19327, 19067 (Figure 79); for details see SOCCOM section of the SAMW21 cruise report). Every ten days, each float reports a profile of hydrographic and bio-optical measurements; these data can inform how the waters originating at the 150 W meridional transect evolved over the cruise period, in a quasi-Lagrangian framework. An eleventh, older SOCCOM float (12701) was also near 60 S, 150 W during the January-February 2021 cruise period, providing data for the southern terminus of the meridional transect, where RR2004 SOCCOM floats were not deployed until later in January. The optical nitrate sensor on float 0887 deployed at 35 S was not operational, and the backscatter measurements from float 17328 between ~600 and 850 m are problematic.

The SOCCOM float data corroborate the increased temperature and decreased surface salinity found between 50.5 S to 43.3 S during the reoccupation of the 150 W transect (Figure 80 Figure 81). 10 m salinities for float 19072 deployed at 46 S declined from 34.48 to 34.26 between 15 January and 14 February. Float 19072 also saw increasing chlorophyll (Figure 82) and backscatter (Figure 84), which was also found during the second occupation of the meridional transect. The trajectory of float 19072 suggests net northwestward transport, and ADCP data from VPR 13 also show generally northward transport from 0-700 m south of 43.5 S (Figure 85), where enhanced backscatter was observed (Figure 73).

Analysis of the DAVPR data provides an initial assessment of changes in the plankton community between the first and second occupations of this portion of the 150W transect. We found that the first transect in early January showed a mix of zooplankton species and a modest number of ROIs (average = 66) or images captured per cast to 1000m. The second survey in early February showed slightly higher numbers of RIOs (average = 86). While a diverse assemblage of zooplankton was present in both surveys, forams, copepods, and gelatinous organisms were more common in January. By February, fecal strings and marine snow dominated most of the stations. More noticeable, however, were diatom chains which were present in all casts in January, had all but vanished in February. Oddly, chlorophyll was greater in February, light transmission less, and slightly higher phosphate, silicate, nitrite, and ammonium ion. Temperatures had increased at the surface along with a fresher lens of seawater.

Low microplankton abundance was also evident in VPR13, which contained only 653 total ROIs over a 10 hour towing period (excluding the first and last hours of the tow). Zooplankton (e.g., copepods, krill) were more abundant in higher chlorophyll waters to the south (Figure 86).

5. Distribution of planktonic "spindles" perhaps *Thalassiothrix antarctica*

An unusual plankton specimen appeared in the video images of both the DAVPR and the VPRII about halfway through the cruise, which had a distinctive, lined, elongated ovoid shape, about 1 mm long (Figure 87, Figure 88). Although it had the shape of a dinoflagellate, it was like nothing seen in routine identification manuals. Occurrences of what we called 'spindles' were common enough to be larval invertebrates or large phytoplankton; eventually collection in the 150um plankton net secured a more positive identification as a colonial diatom.

Spindles appear abruptly at Sta. 69, at 58S, where they were very abundant, present with many other types of zooplankton, except copepods. Coincidentally, the tow before it, Sta. 68 (58.3S), had virtually all marine snow particles. The next two stations (up to 57.3S) Stations 70 and 71 had abundant spindles and other diatoms such as rods and *Chaetoceros sp*. as well as a diverse zooplankton fauna. Then just as abruptly, they vanished from the next station, #72 at 57.0S. Small pteropods were very abundant at both stations 71 and 72, but the associated spindles were gone in the more northern station. This one-degree of latitude (57 to 58) is south of the PF and at the convergence of SAMW water and the cold fresh SACCF.

The next occurrence of spindles in the DAVPR videos are at Stations 85, 86, and 87 as part of the survey across the PF at 141W, just south of Eddy B. Moving north, spindles showed up at 58S (Station 85) together with a diverse zooplankton assemblage including abundant acantharians and diatom mats. Stations 86 and 87 were also rich with many zooplankton and phytoplankton along with spindles. Spindles abruptly disappeared at Station 88, 57.1S, but small pteropods, worms, and diatom mats were particularly abundant in this diverse assemblage. This water appeared to be the transition from PF to SACCF waters: salinity was about 34.1 ppt, 3C, with chlorophyll values ranging from 2.5 to 4 and backscatter of 3 to $5 * 10^{-4}$.

Corroboration with the plankton samples was problematic in that the net was not always deployed on every DAVPR cast and consisted of a small mouth opening. Still, spindles were found in abundance at Station 85 for the PF section. Only 2 specimens were found at Station 71 and a single specimen at Station 72, where none were seen on video. While our current identification is the diatom colony *Thalassiothrix antarctica*, we hope to confirm this in the laboratory and to better define the association with the water mass at this location.

6. Summary of VPR tows

VPR #	Date	Description	Operational notes
1	28-Dec	Test tow	
2	Jan 15-16	Section 47-50	Tail skid broke
3	Jan 17-18	Section 50-53	
4	Jan 20-21	Section 53-56	
5	Jan 23-24	Section 56-60S	
6	26-Jan	Eastward, northeastward section	Strobe failed, replaced bulb and board
7	27-Jan	Northeastward section Eddy A center determination	Strobe failed; then CTD / bio-optical data failed
8	27-Jan	Continuation of VPR7, restarted deck	
9	Jan 27-28	Completion of eddy A survey	New board failed (burnt diodes); put new bulb back into old board; tail skid broke during haul back
10	31-Jan	Polar front transect	
11	2-Feb	Eddy C transect	
12	Feb 3-4	Eddy A revisitation; meander survey	
13	Feb 7-8	Revisitation of meridional transect	

7. Acknowledgements

We gratefully acknowledge support of this research by the National Science Foundation. The Video Plankton Recorder II was kindly made available as shared use equipment by the Dalio Family Foundation; the Digital Autonomous Video Plankton Recorder was kindly made available as shared use equipment from WHOI's Biology Department. The VPR team very much appreciates the superb efforts of ResTechs Matt Durham and Charlie Brooks, as well as assistance from our RR2004 shipmates in launch and recovery operations.

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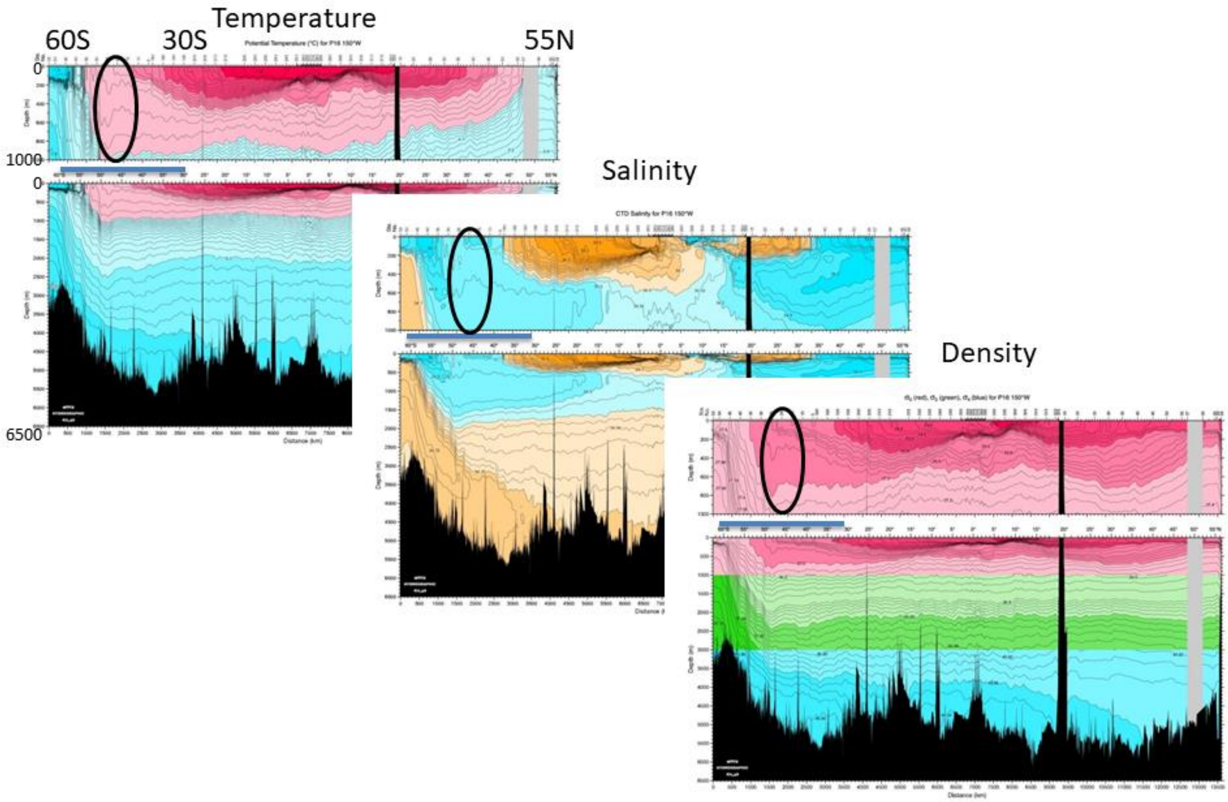


Figure 1. Temperature, salinity, and density sections from P16. Oval shape indicates SAMW. Source: WOCE Atlas Volume 2: Pacific Ocean, http://whp-atlas.ucsd.edu/pacific/p16/sections/sct_menu.htm

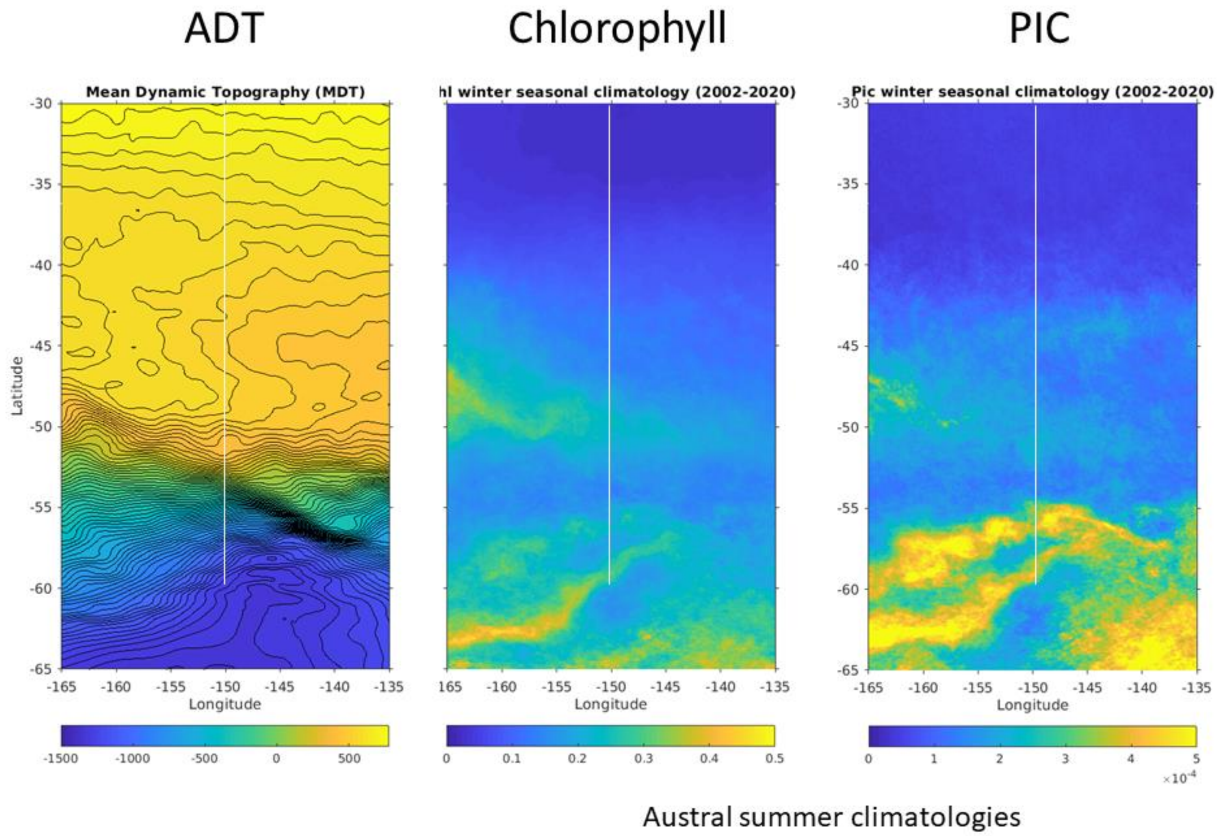


Figure 2. Climatologies of absolute dynamic topography (ADT), chlorophyll, and PIC.

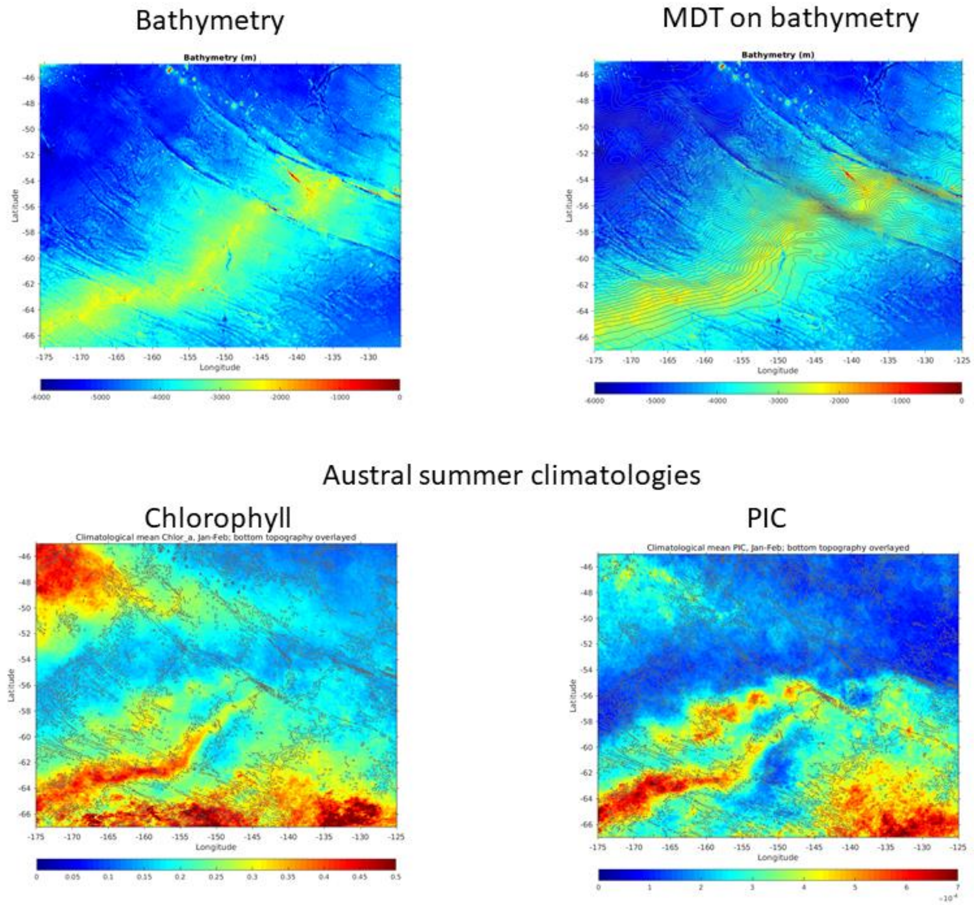


Figure 3. Upper left: bathymetry; upper right: contours of mean dynamic topography (MDT) overlaid on bathymetry; lower left: austral summer chlorophyll climatology with bathymetric contours overlaid; lower right: austral summer PIC climatology with bathymetric contours overlaid.

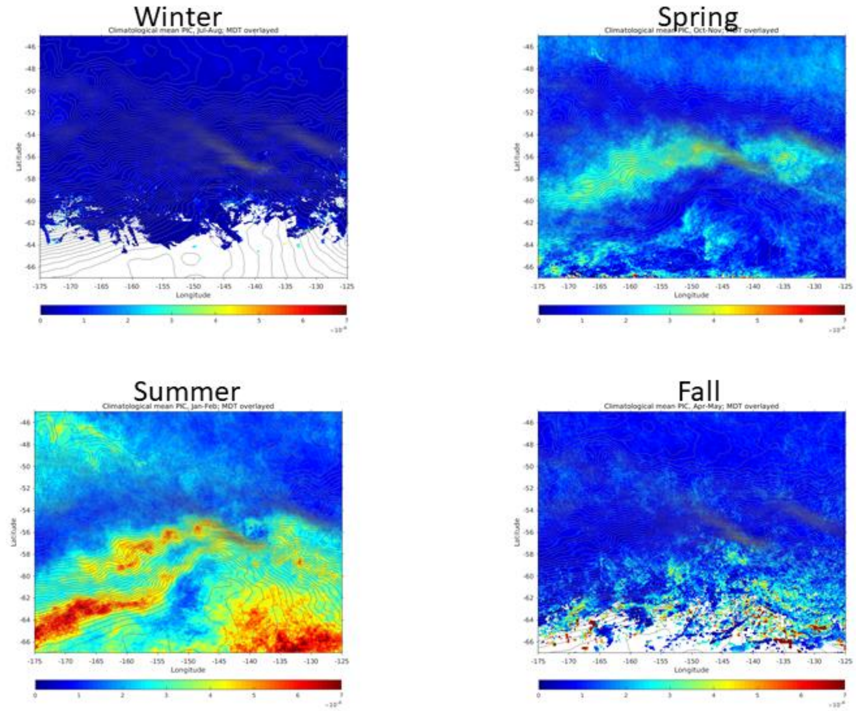


Figure 4. Seasonal PIC climatology, 45-67S.

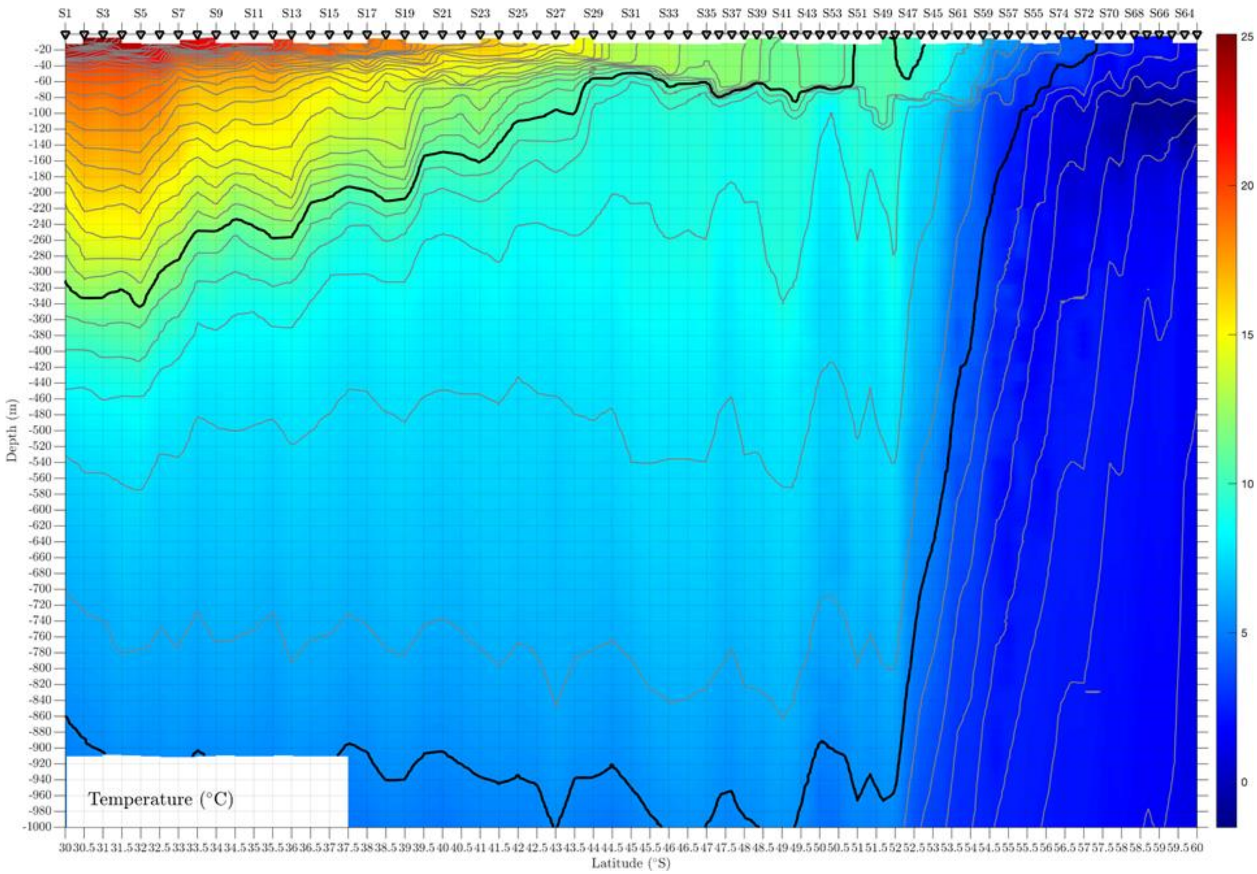


Figure 5. Temperature from 30-60S along 150W.

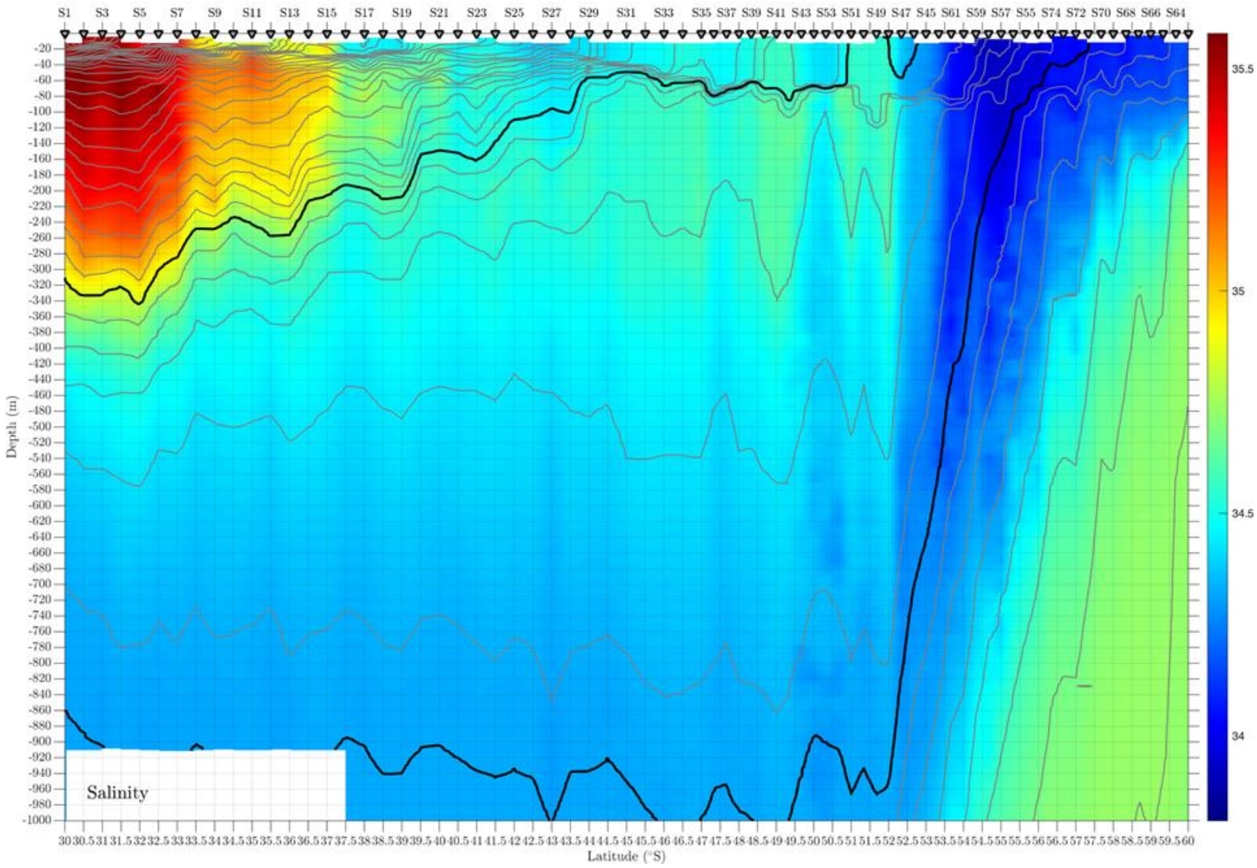


Figure 6. Salinity from 30-60S along 150W.

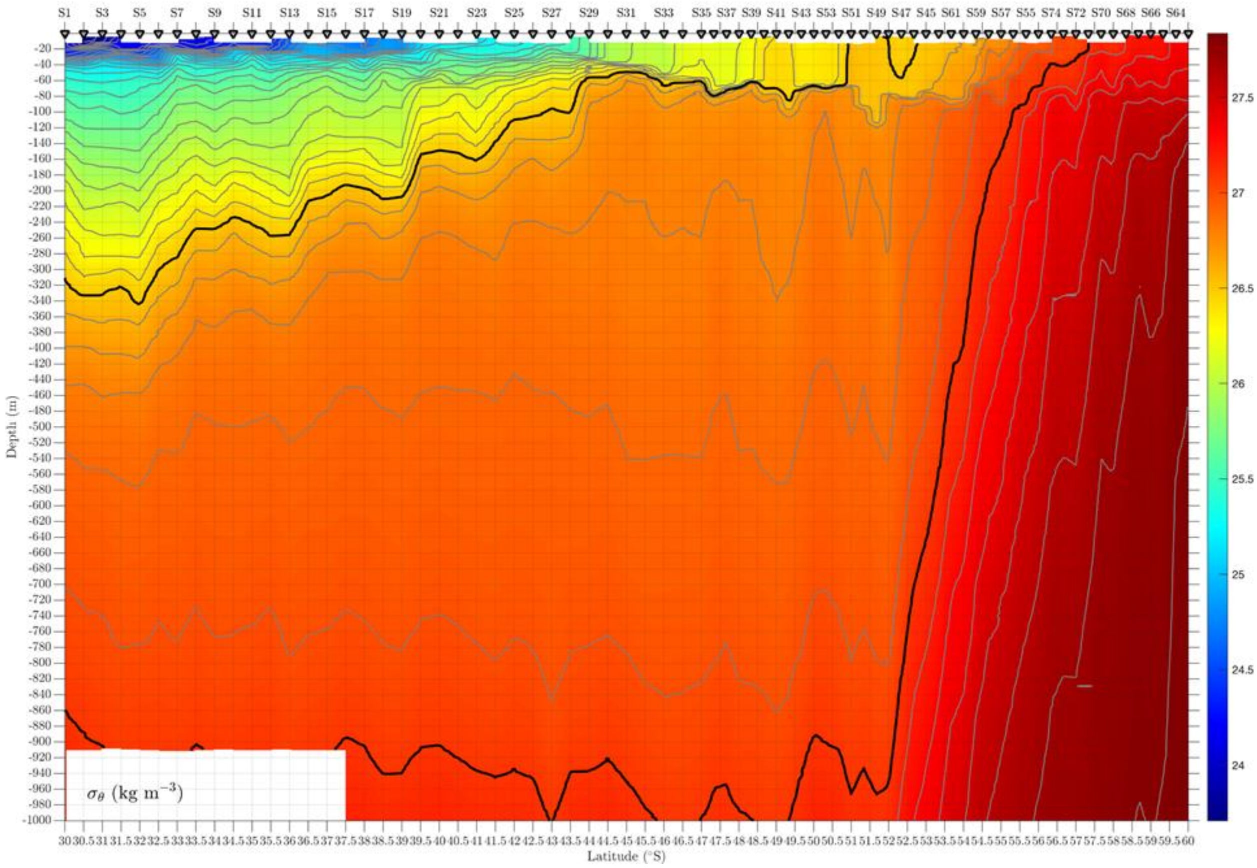


Figure 7. Density from 30-60S along 150W.

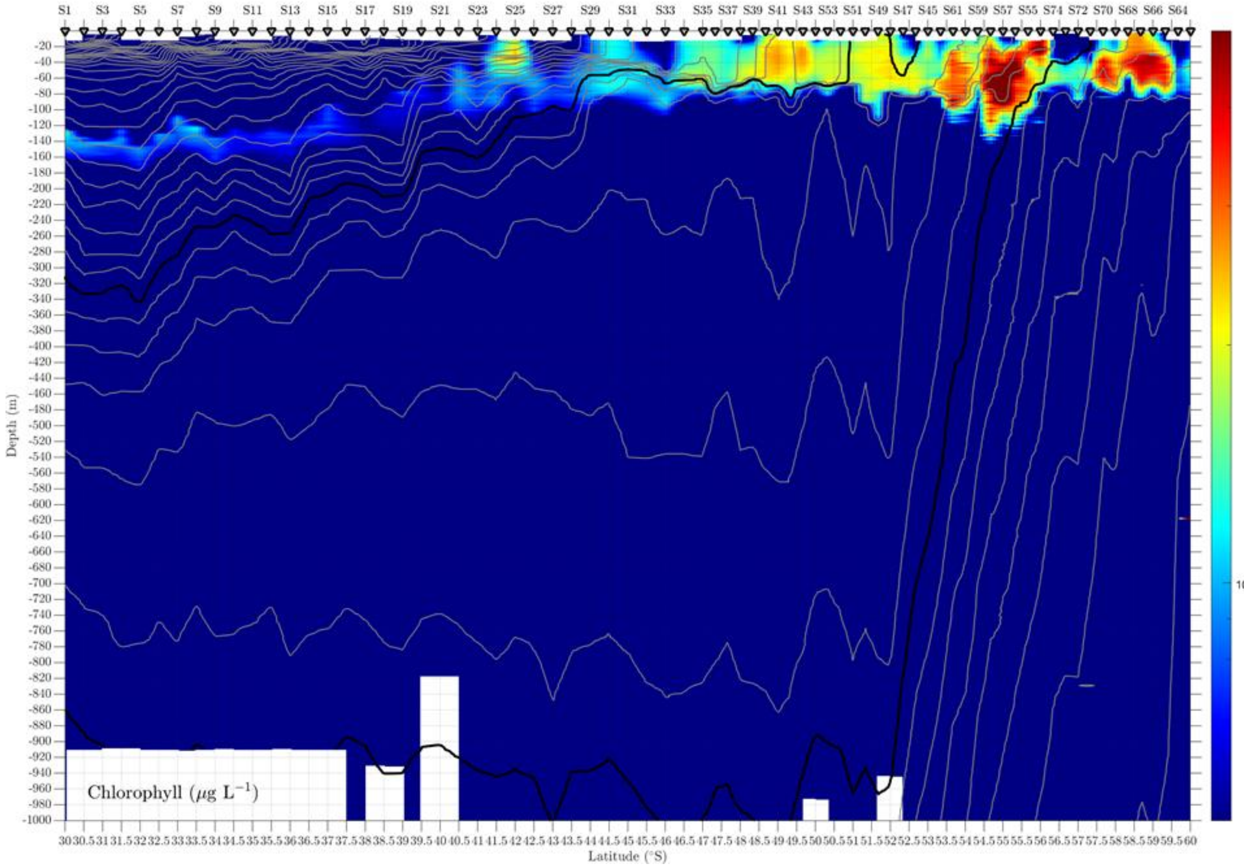


Figure 8. Fluorescence from 30-60S along 150W.

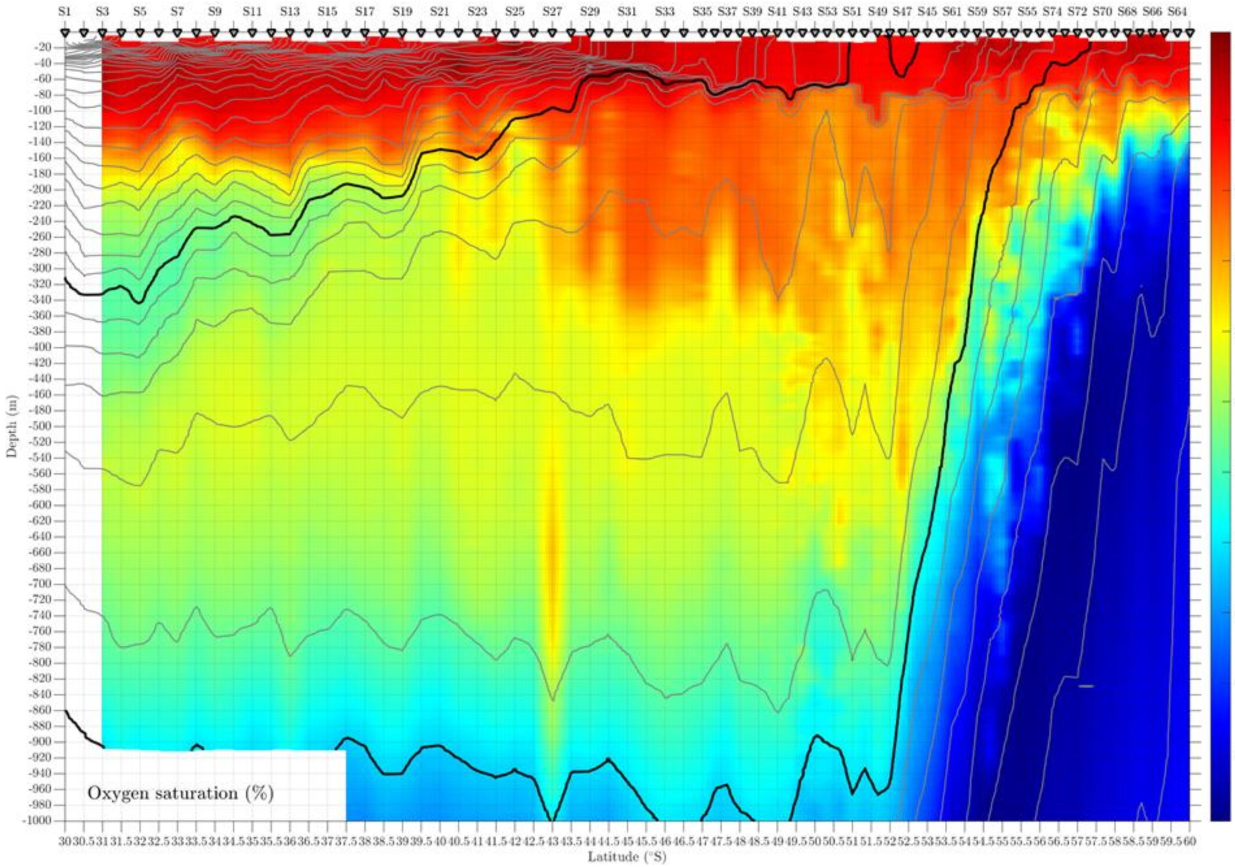


Figure 9. Oxygen saturation from 30-60S along 150W.

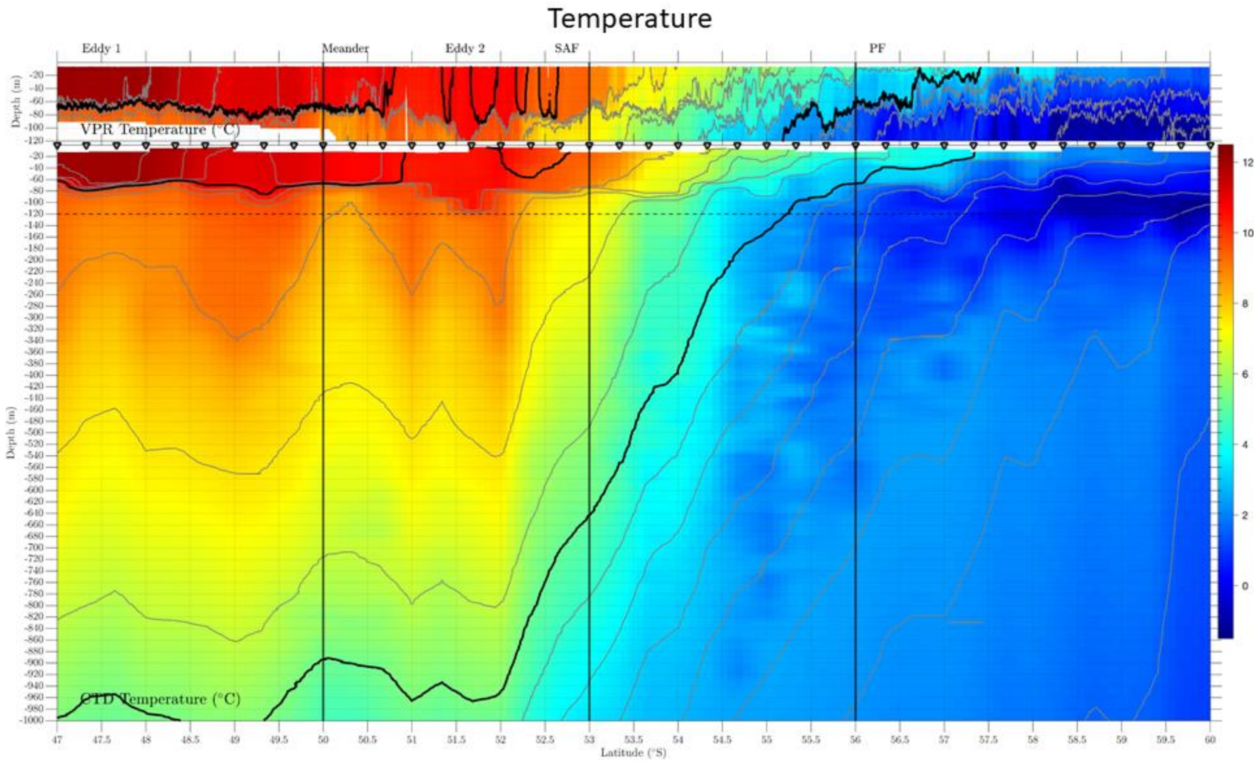


Figure 10. Temperature along 150W from VPR (top) and CTD (bottom) between 47 and 60S.

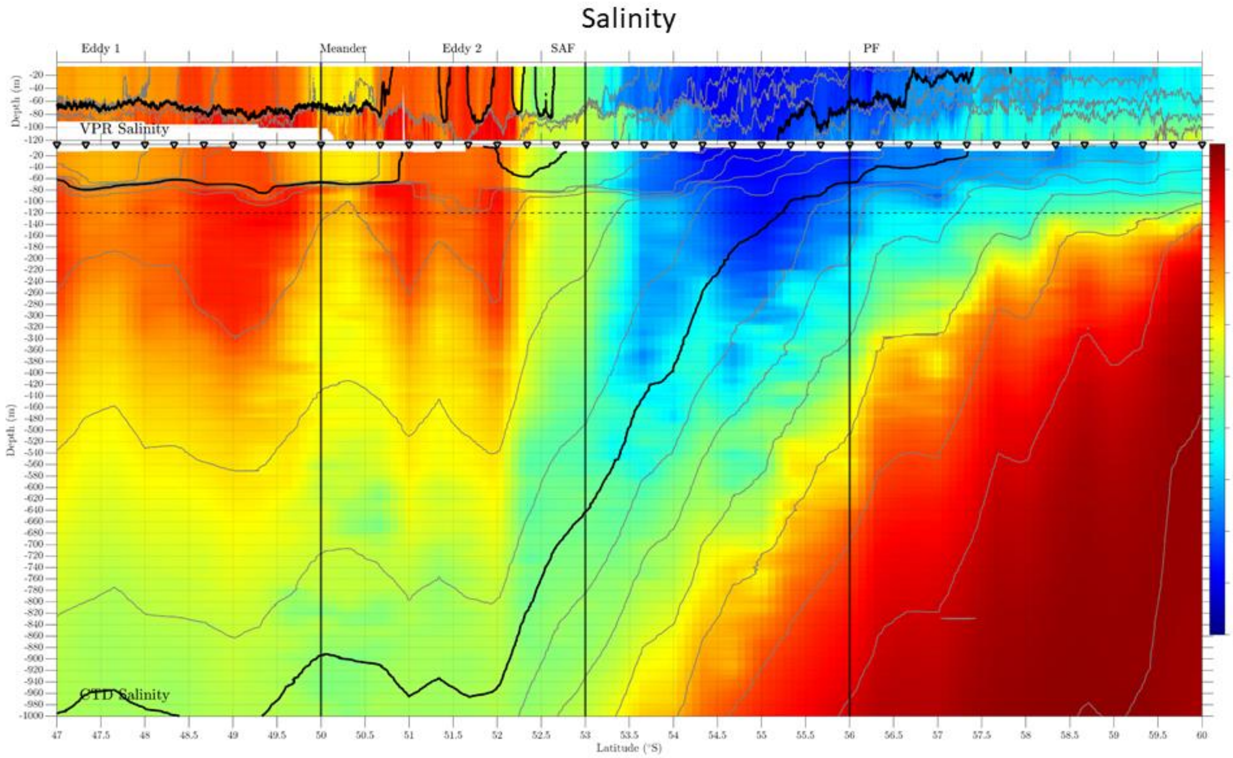


Figure 11. Salinity along 150W from VPR (top) and CTD (bottom) between 47 and 60S.

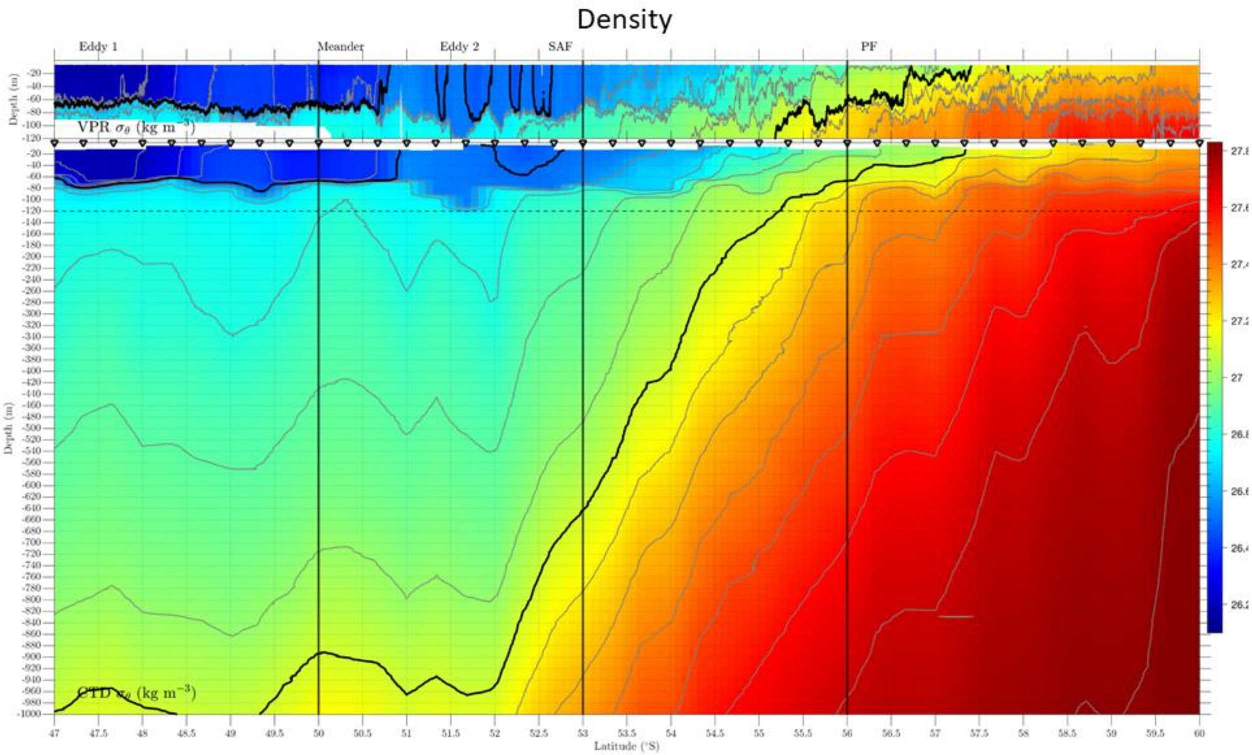


Figure 12. Density along 150W from VPR (top) and CTD (bottom) between 47 and 60S.

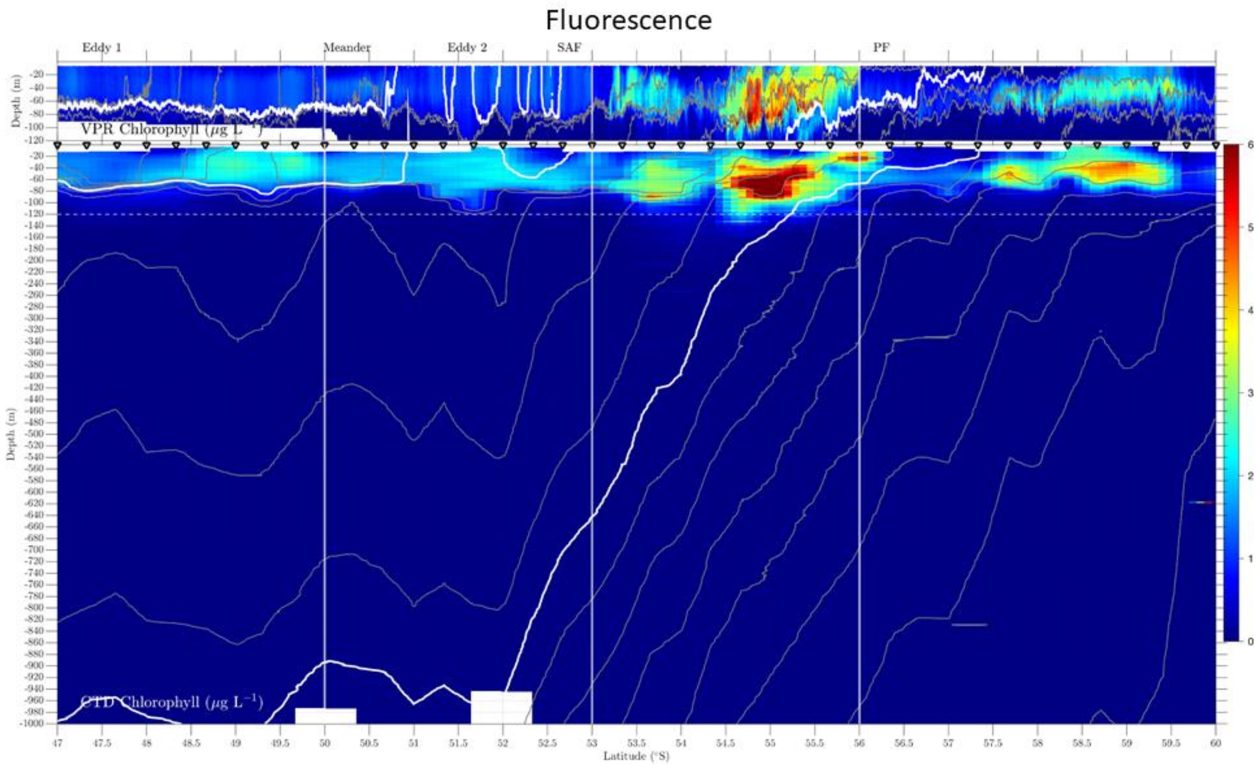


Figure 13. Fluorescence along 150W from VPR (top) and CTD (bottom) between 47 and 60S.

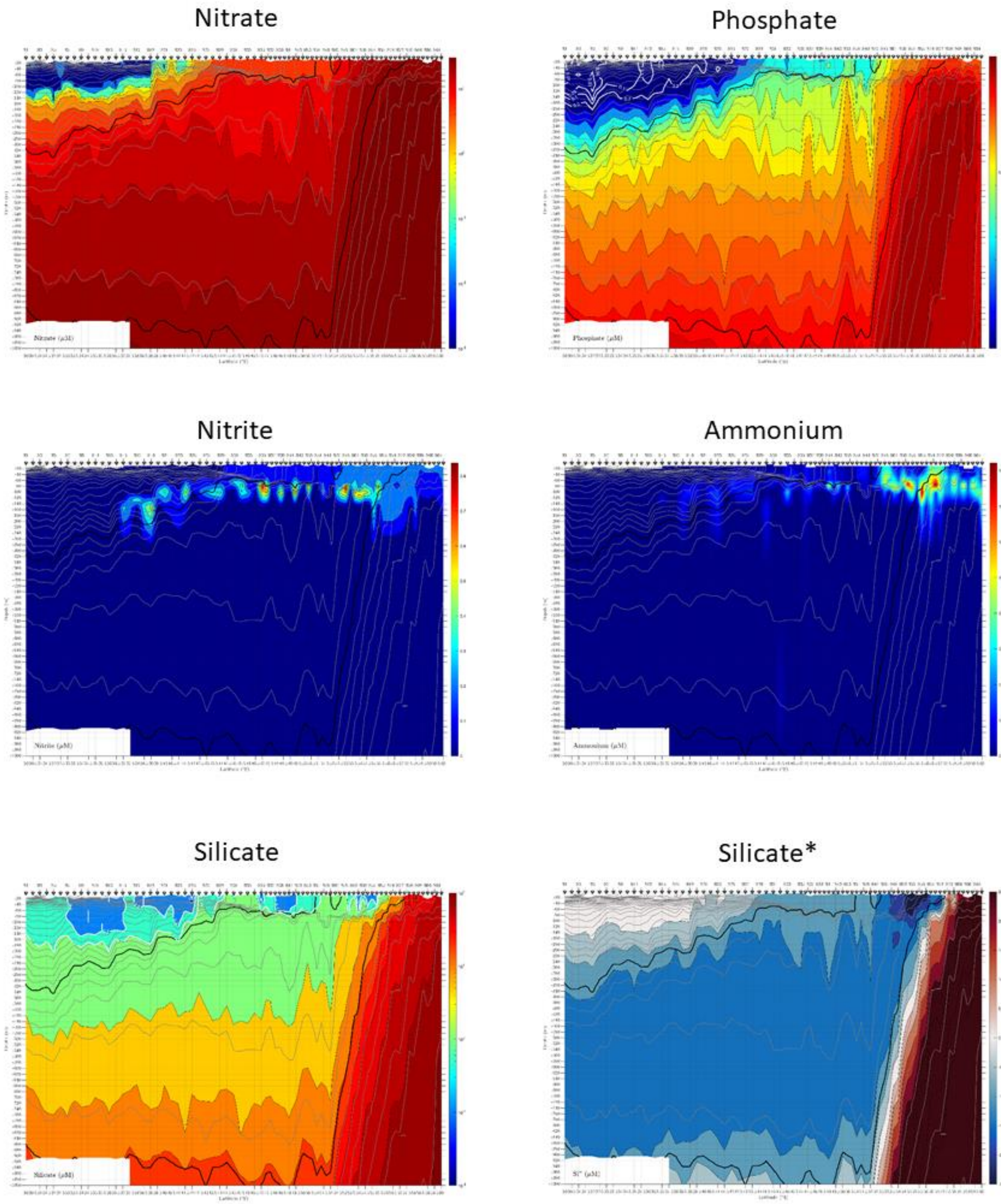


Figure 14. Nitrate, phosphate, nitrite, ammonium, silicate, and silicate from 30-60S along 150W.*

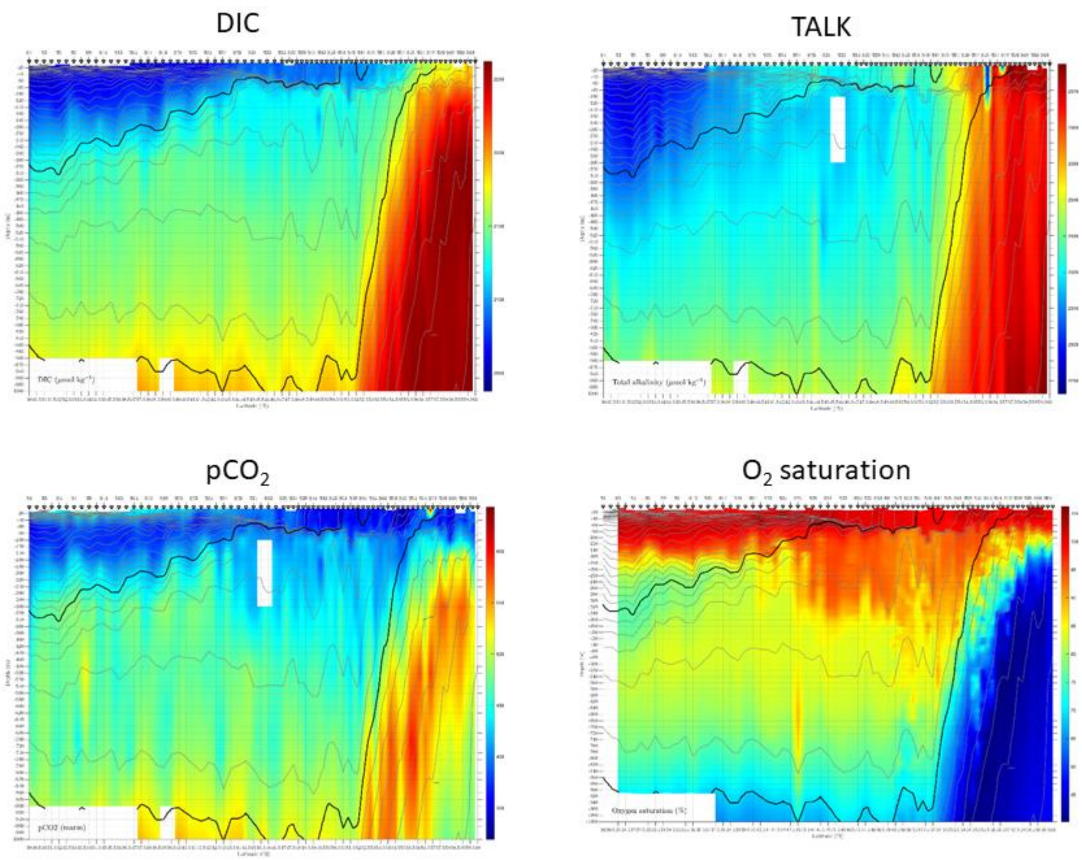


Figure 15. DIC, Total Alkalinity, pCO$_2$, and O$_2$ saturation from 30-60S along 150W.

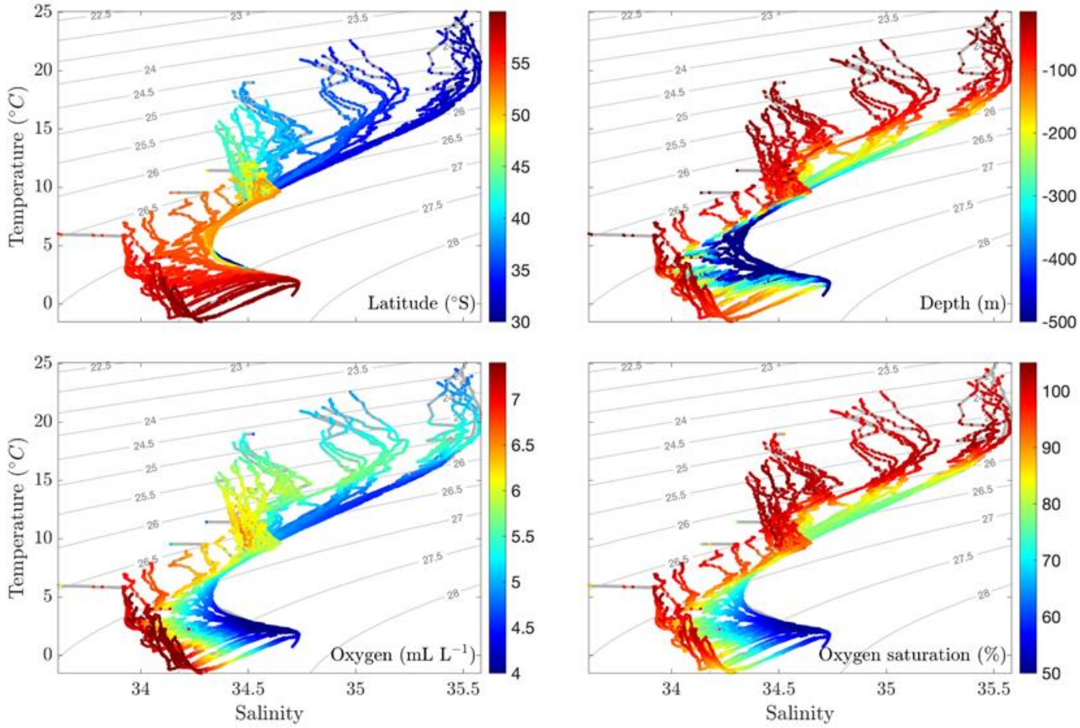


Figure 16. Temperature - salinity characteristics from 30-60S along 150W.

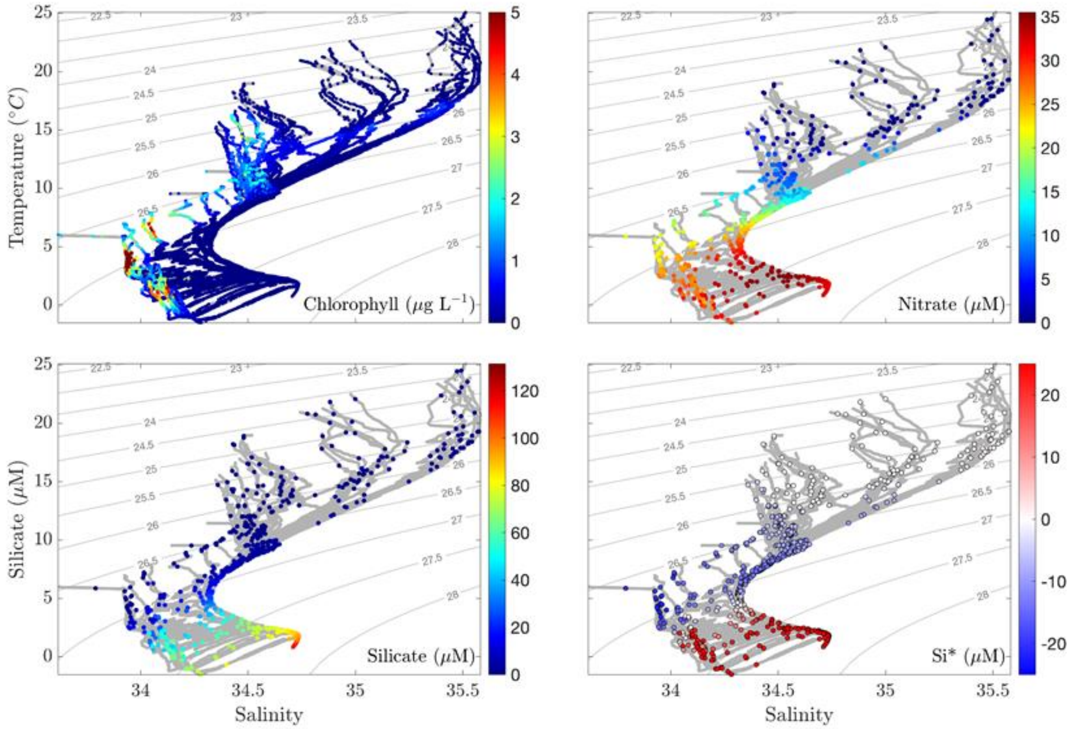


Figure 17. Temperature - salinity characteristics from 30-60S along 150W.

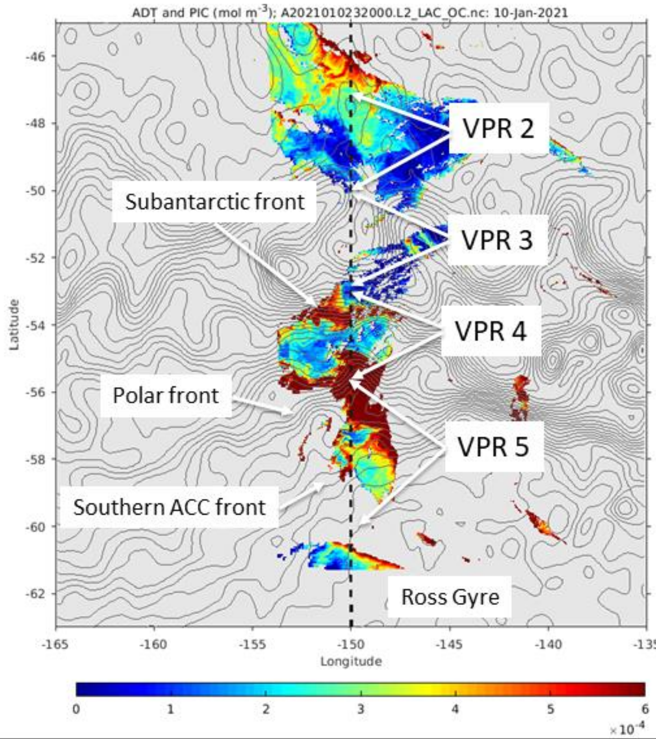


Figure 18. VPR 2-5 locations with contours of ADT and PIC indicated in color.

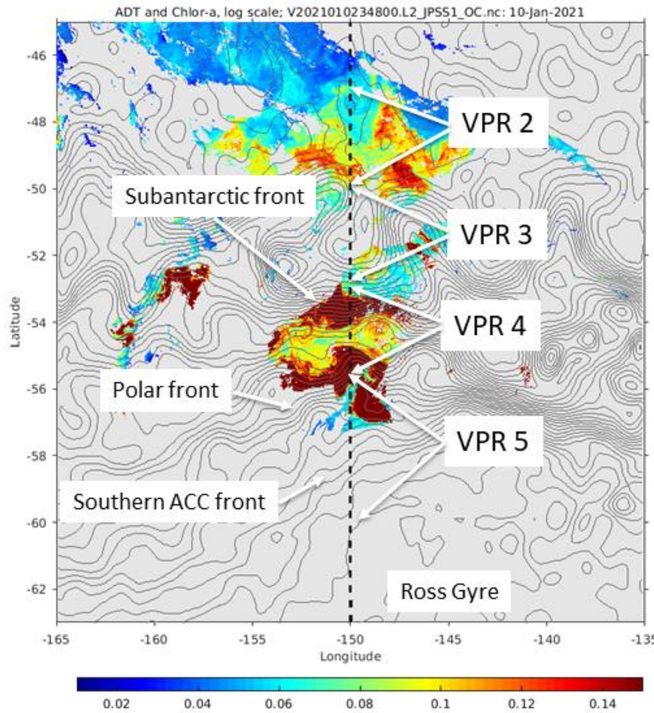


Figure 19. VPR 2-5 locations with contours of ADT and chlorophyll indicated in color.

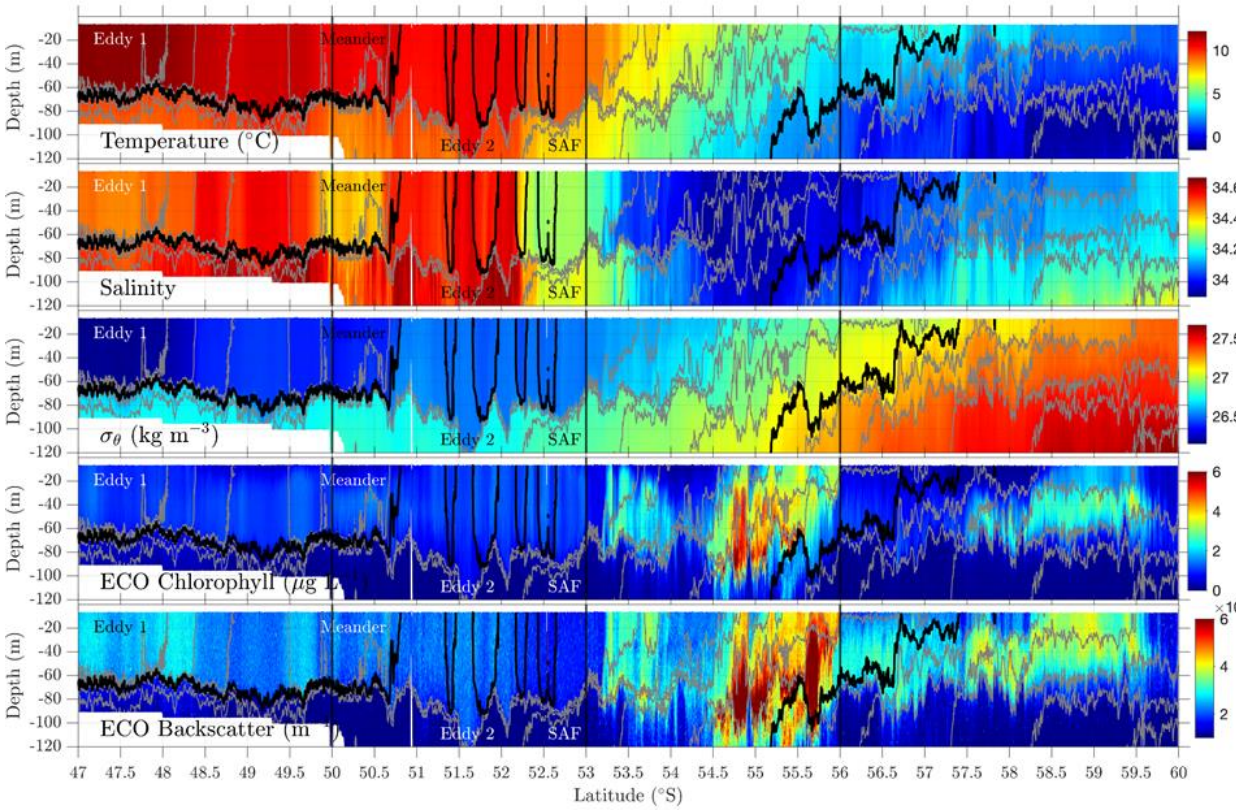


Figure 20. VPR 2-5 Temperature, salinity, density, fluorescence, and backscatter along 150W from 47-60S.

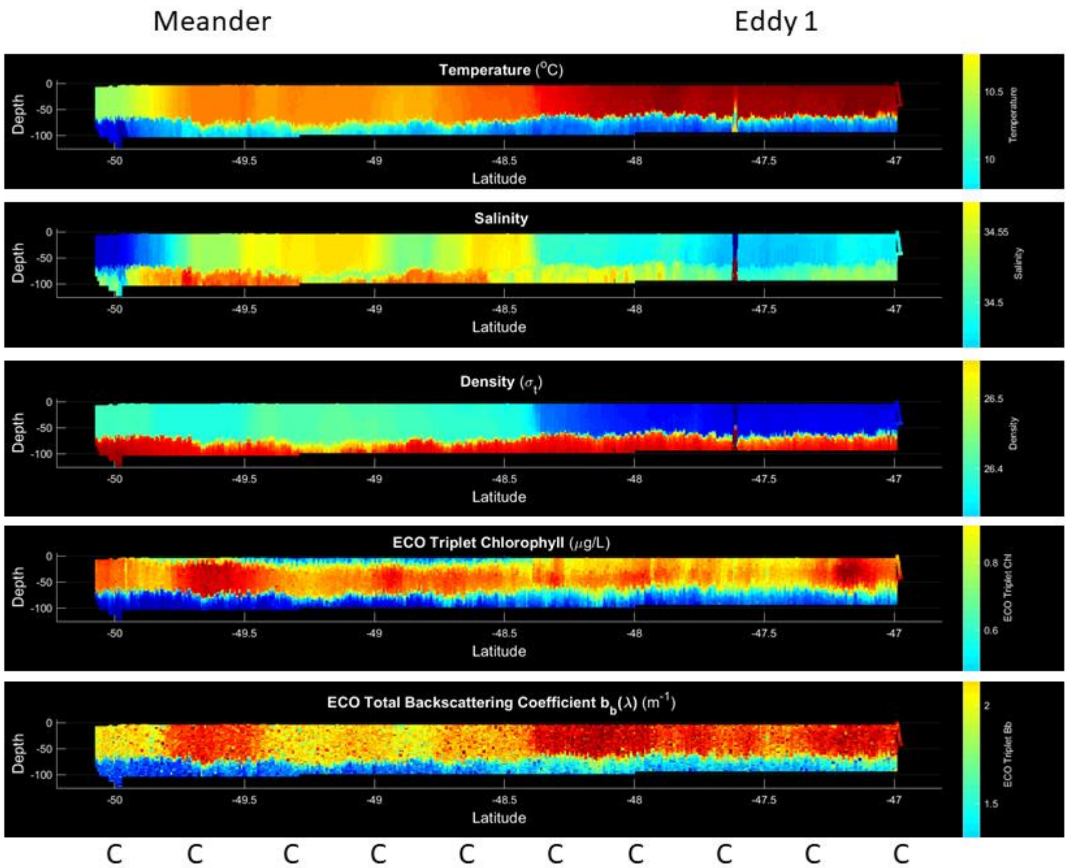


Figure 21. VPR 2 temperature, salinity, density, fluorescence, and backscatter.

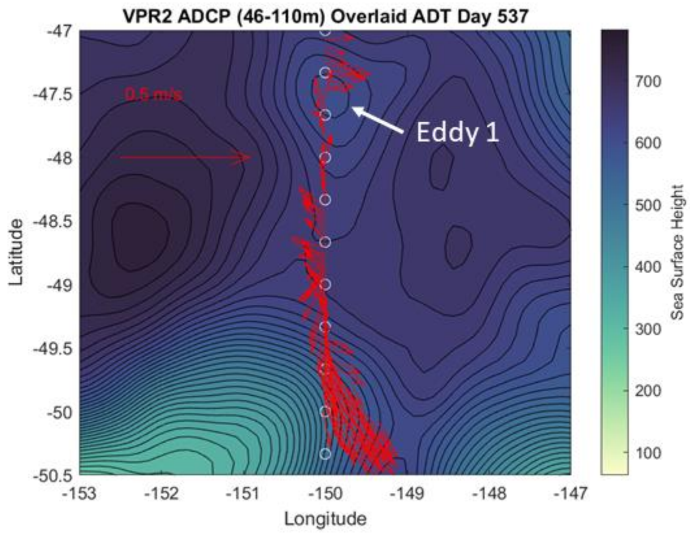


Figure 22. ADCP currents along VPR 2 track.

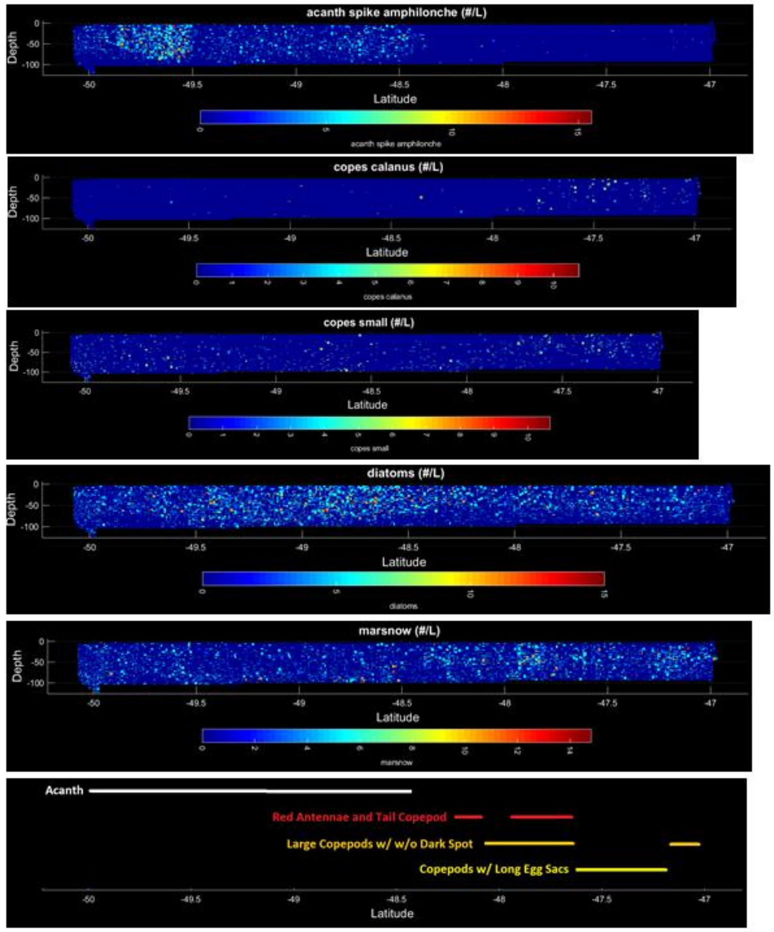


Figure 23. VPR 2 taxa plots (see text).

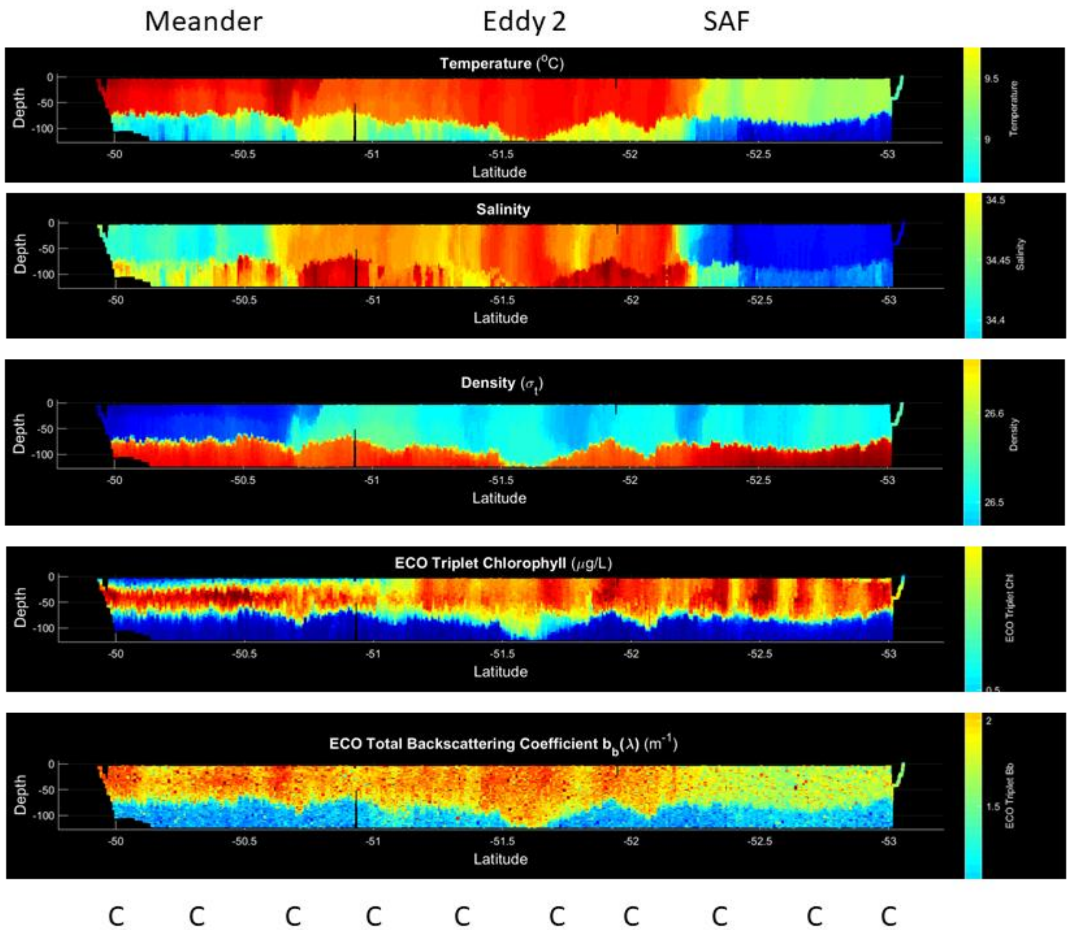


Figure 24. VPR 3 temperature, salinity, density, fluorescence, and backscatter.

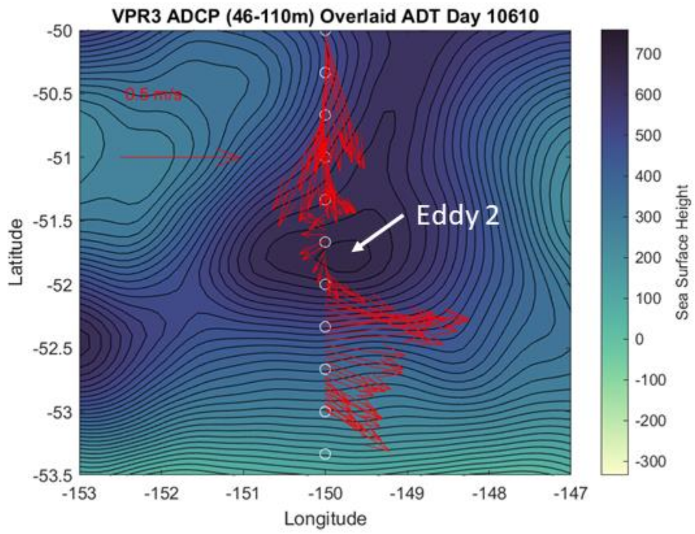


Figure 25. ADCP currents along VPR 3 track.

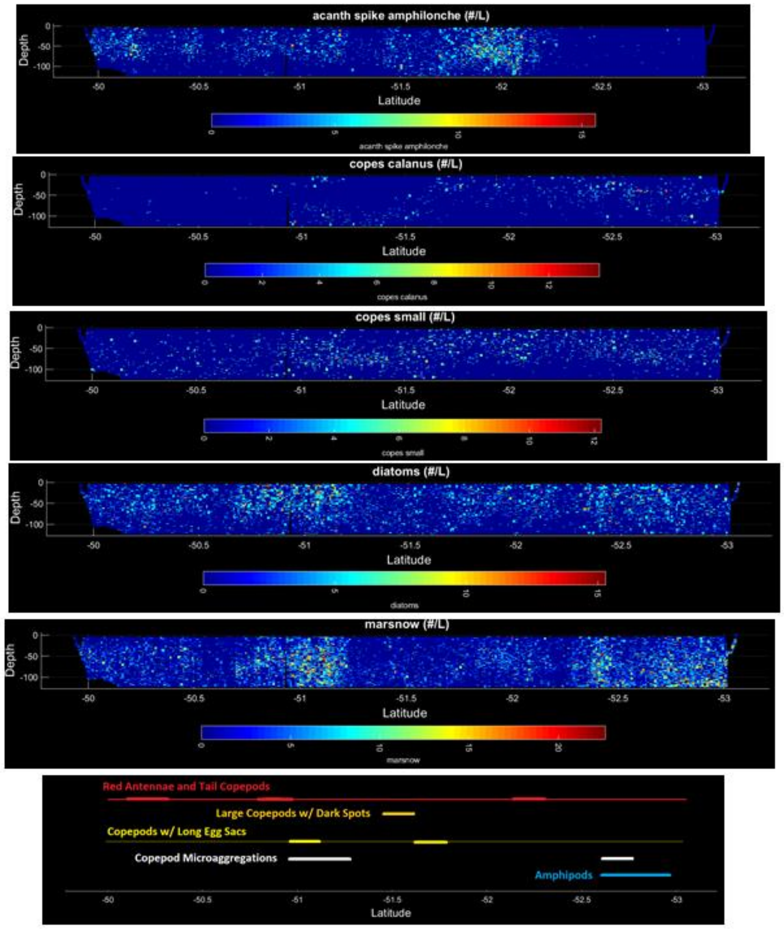


Figure 26. VPR3 taxa plots (see text).

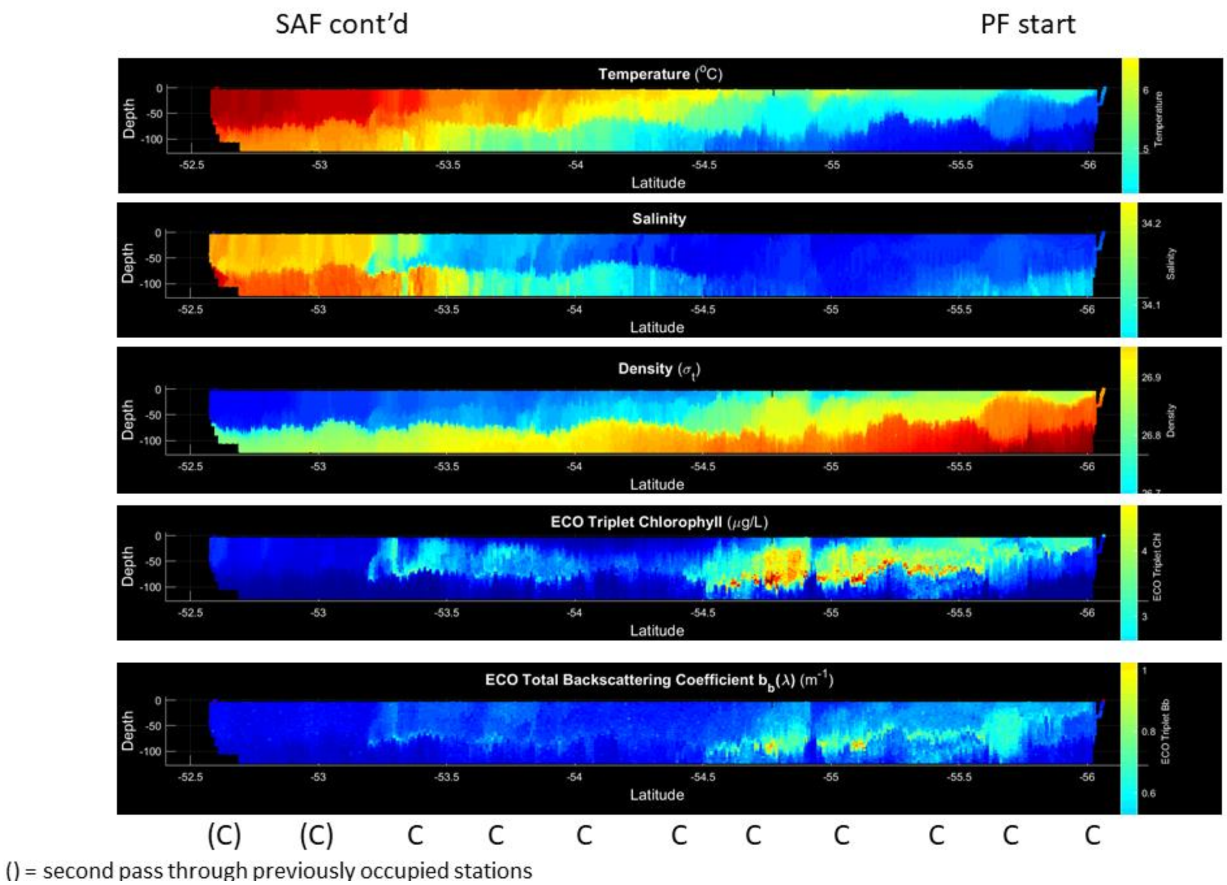


Figure 27. VPR 4 temperature, salinity, density, fluorescence, and backscatter.

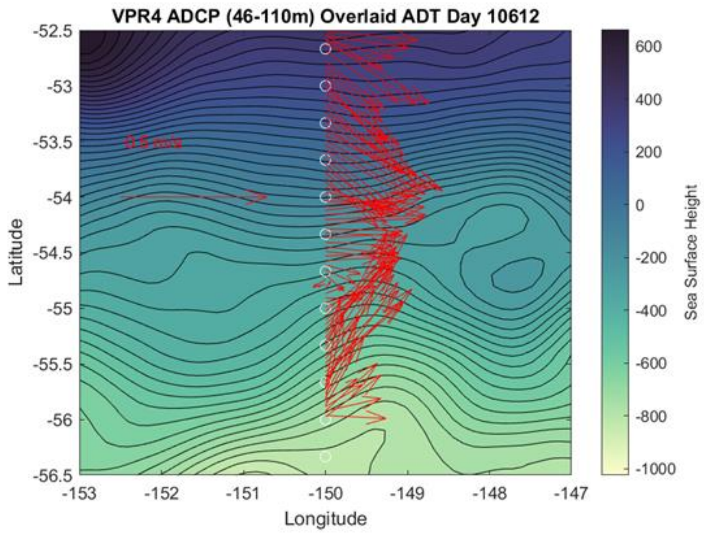


Figure 28. ADCP currents along VPR 4 track.

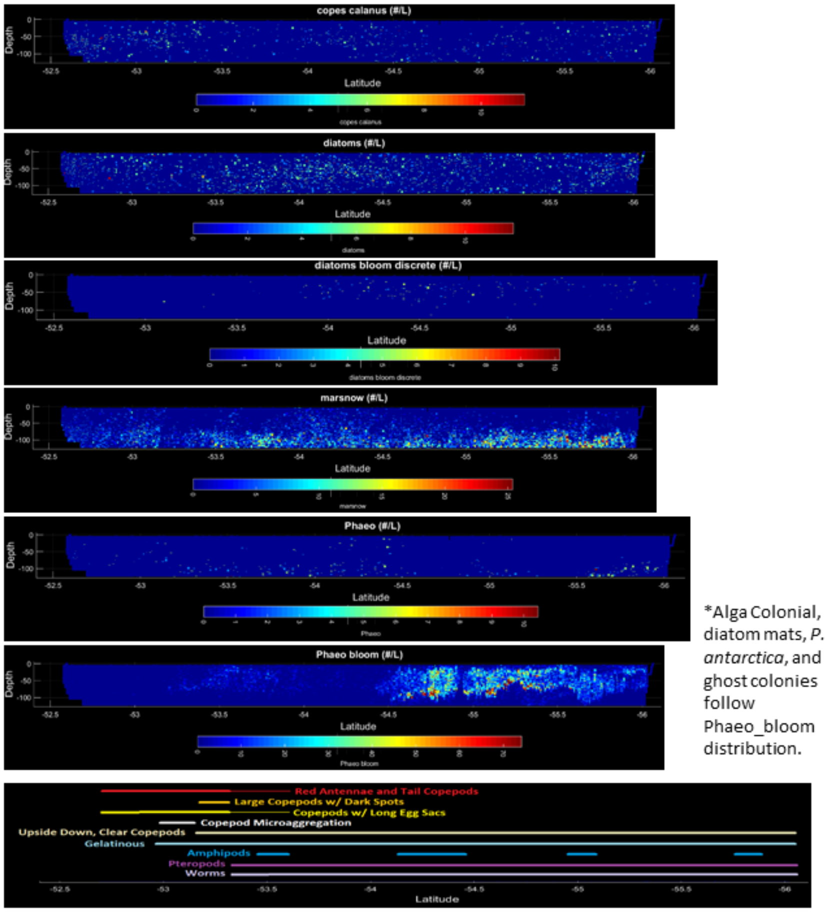


Figure 29. VPR4 taxa plots (see text).

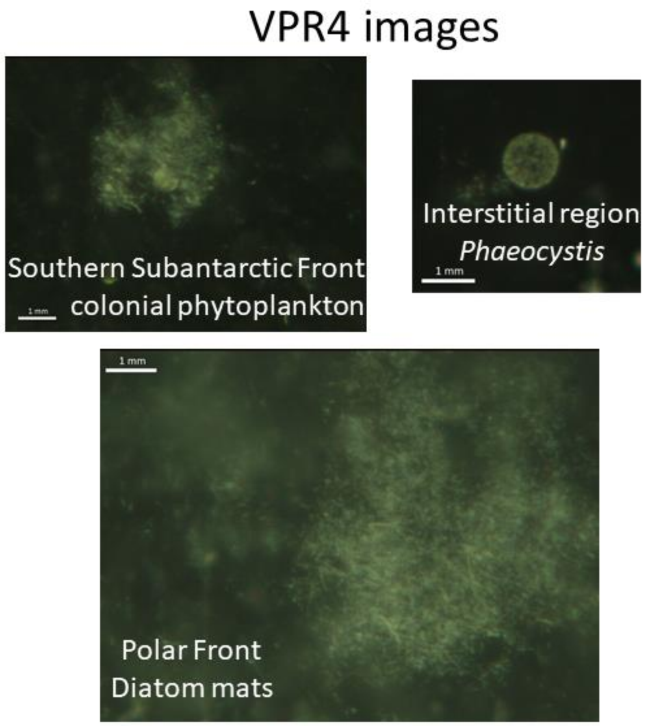
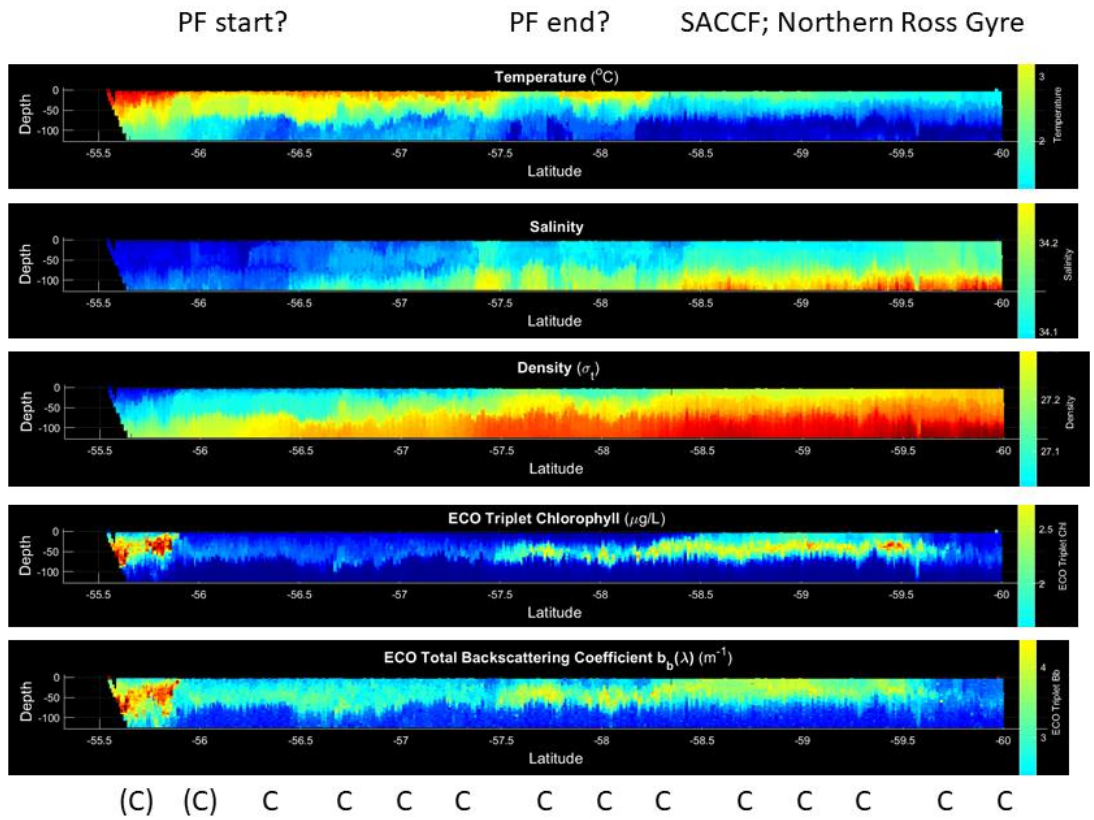


Figure 30. Sample images from VPR 4.



() = second pass through previously occupied stations

Figure 31. VPR 5 temperature, salinity, density, fluorescence, and backscatter.

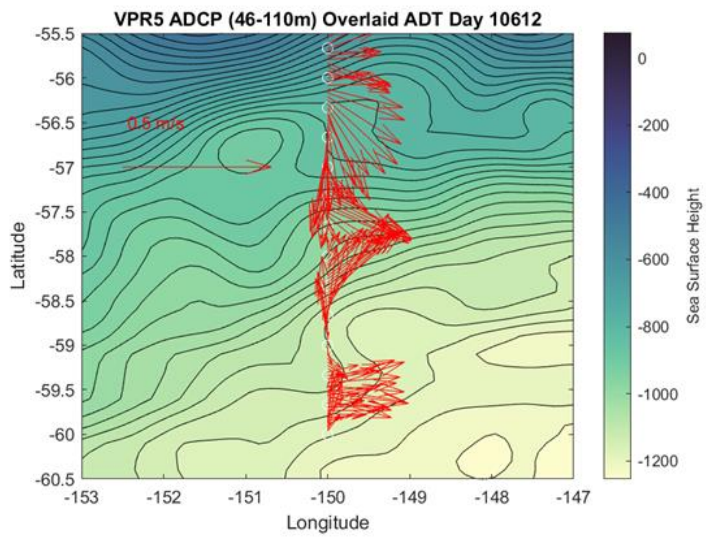


Figure 32. ADCP currents along VPR 5 track.

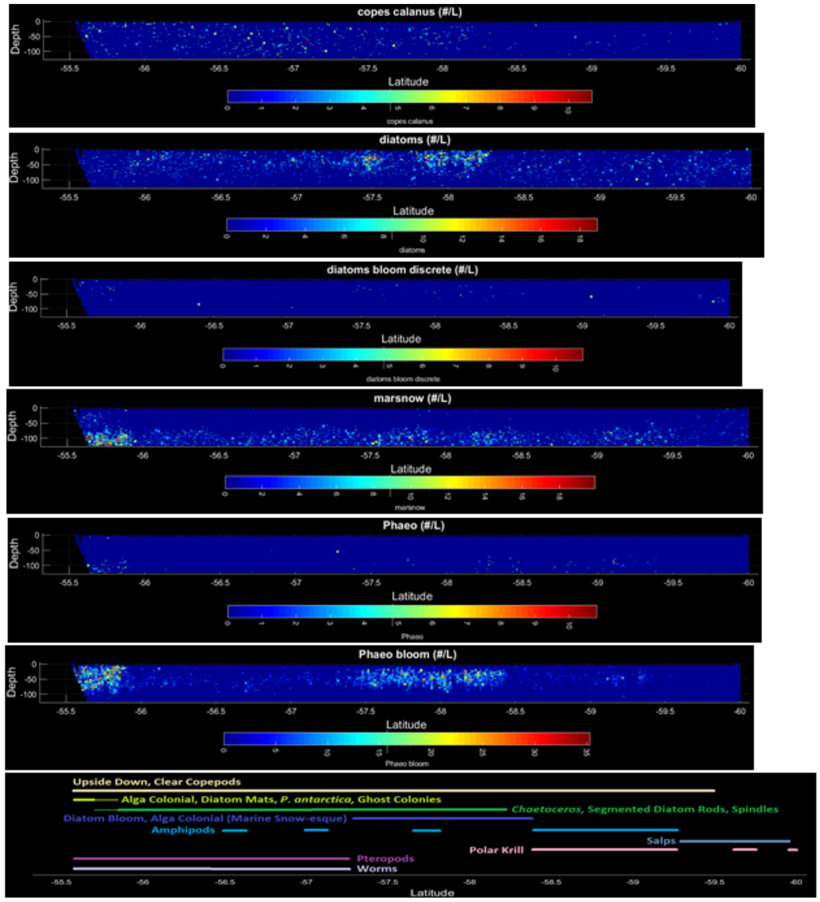
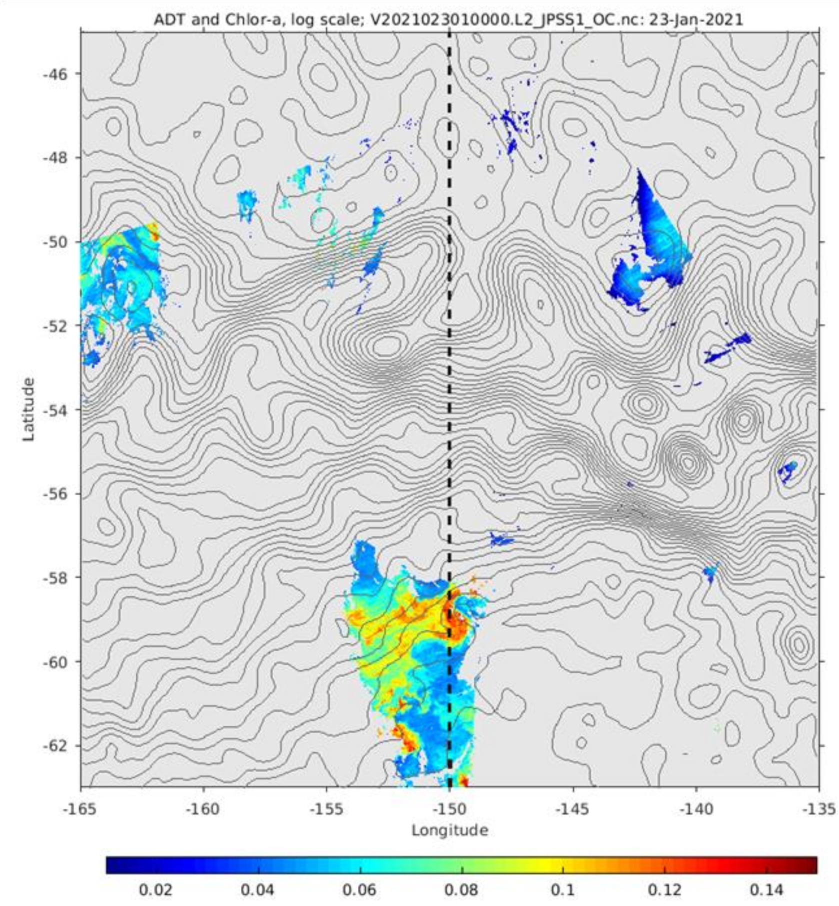


Figure 33. VPR5 taxa plots (see text).



Note high chl / PIC filament 58.5-59.5S consistent with VPR survey

Figure 34. PIC image revealing structure at the Southern ACC Front.

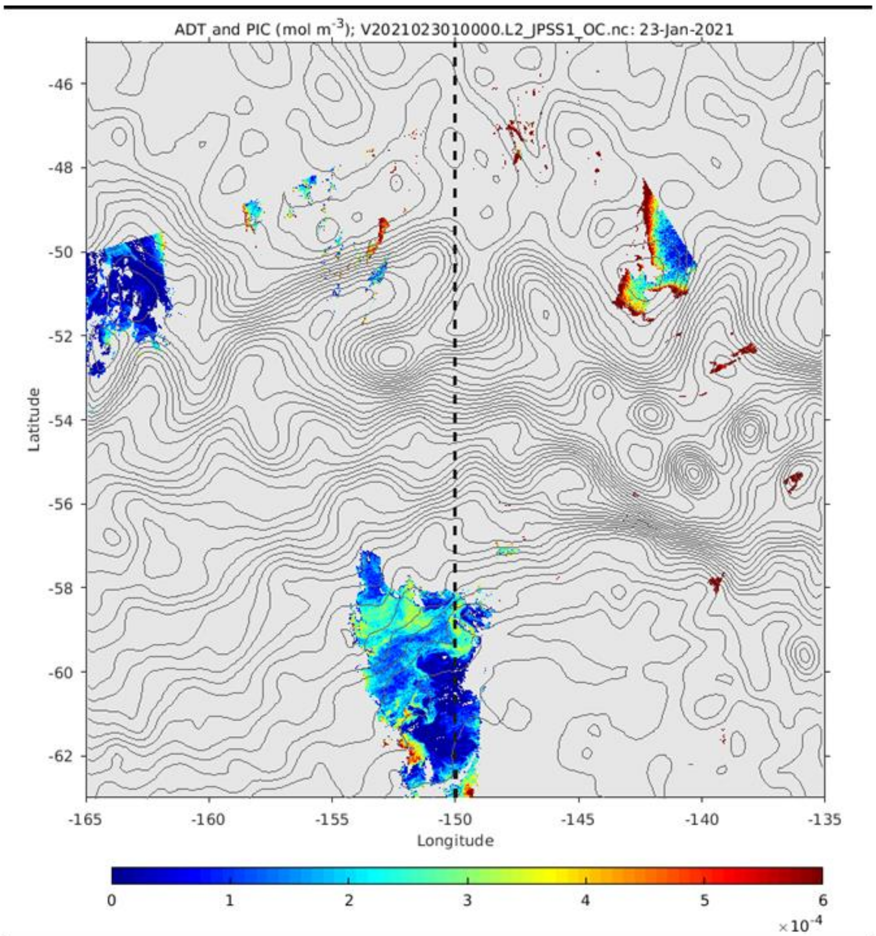


Figure 35. Chlorophyll image revealing structure at the Southern ACC Front.

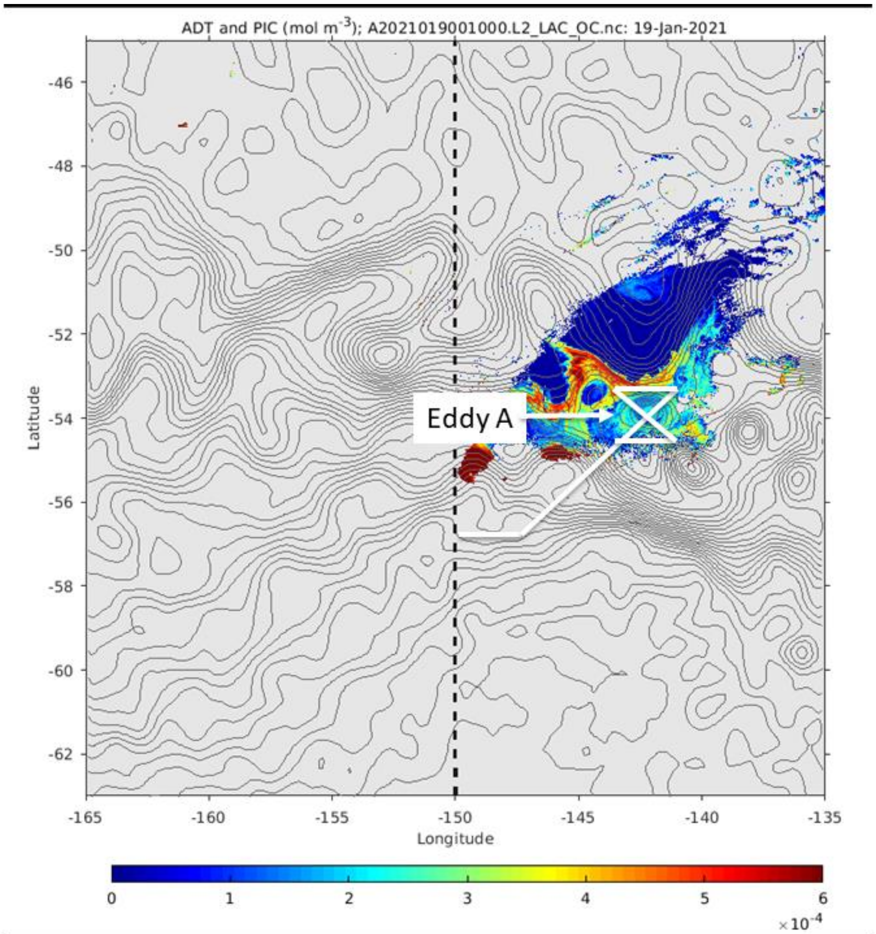


Figure 36. VPR 6, 7, [8], 9 tracks with contours of ADT and PIC indicated in color.

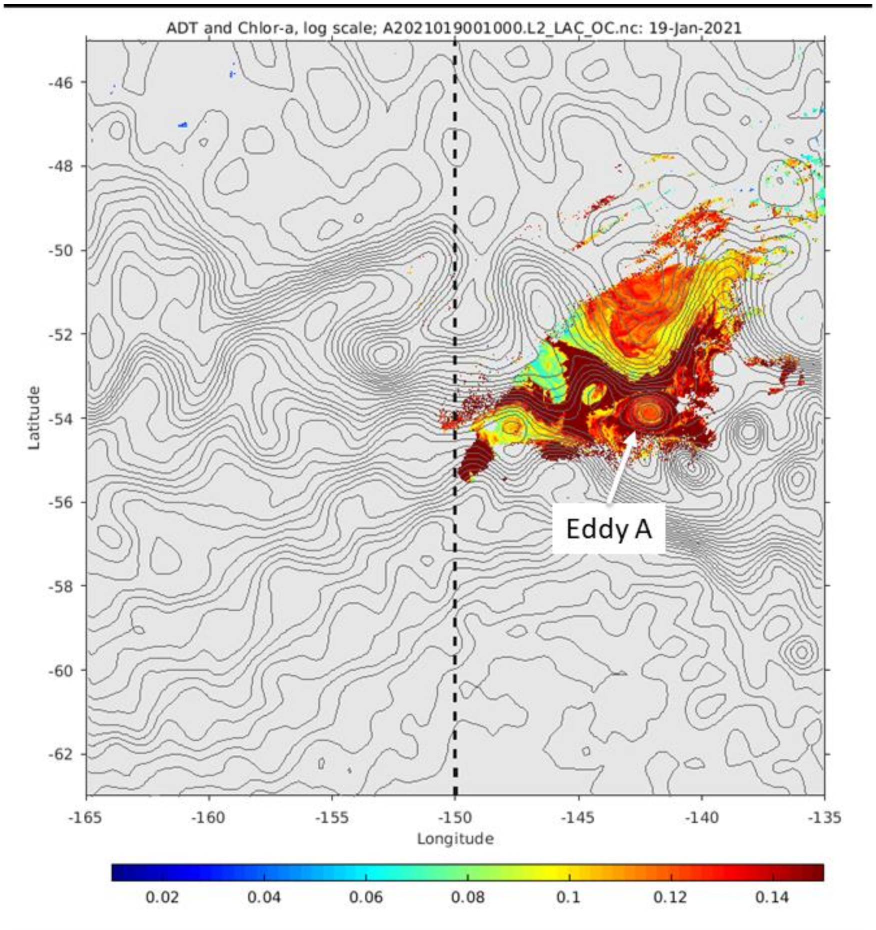


Figure 37. VPR 6, 7, [8], 9 tracks with contours of ADT and chlorophyll indicated in color.

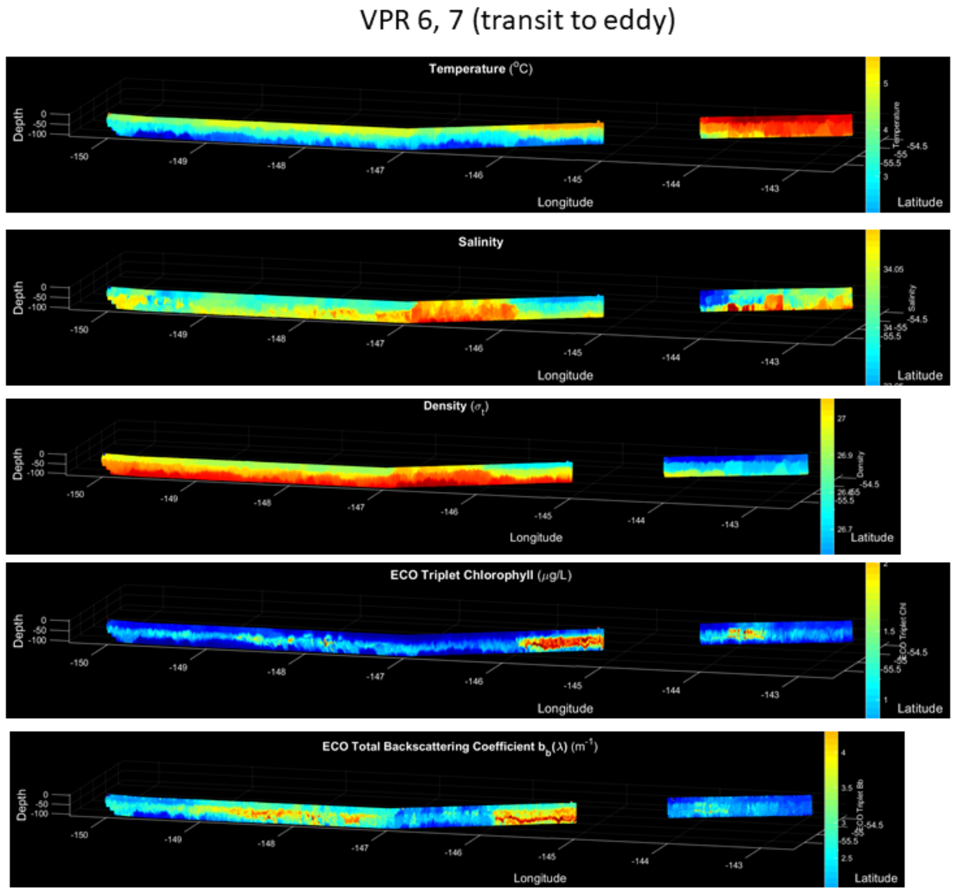


Figure 38. VPR 6, 7 (partial) temperature, salinity, density, fluorescence, and backscatter.

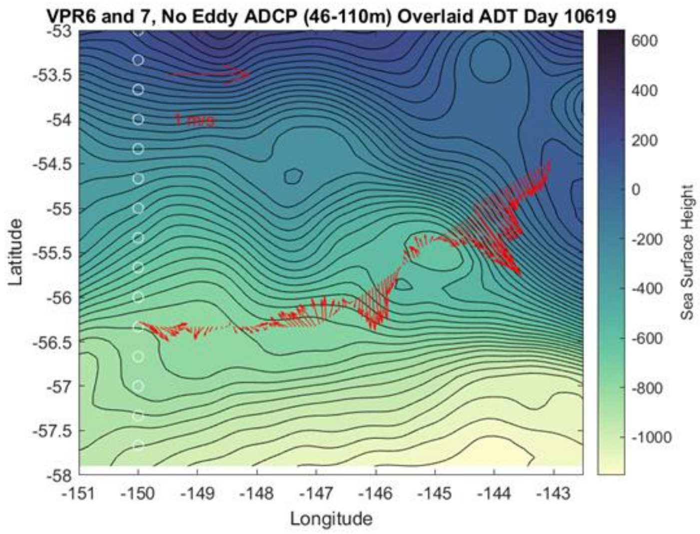


Figure 39. ADCP currents along VPR 6,7 (partial) tracks.

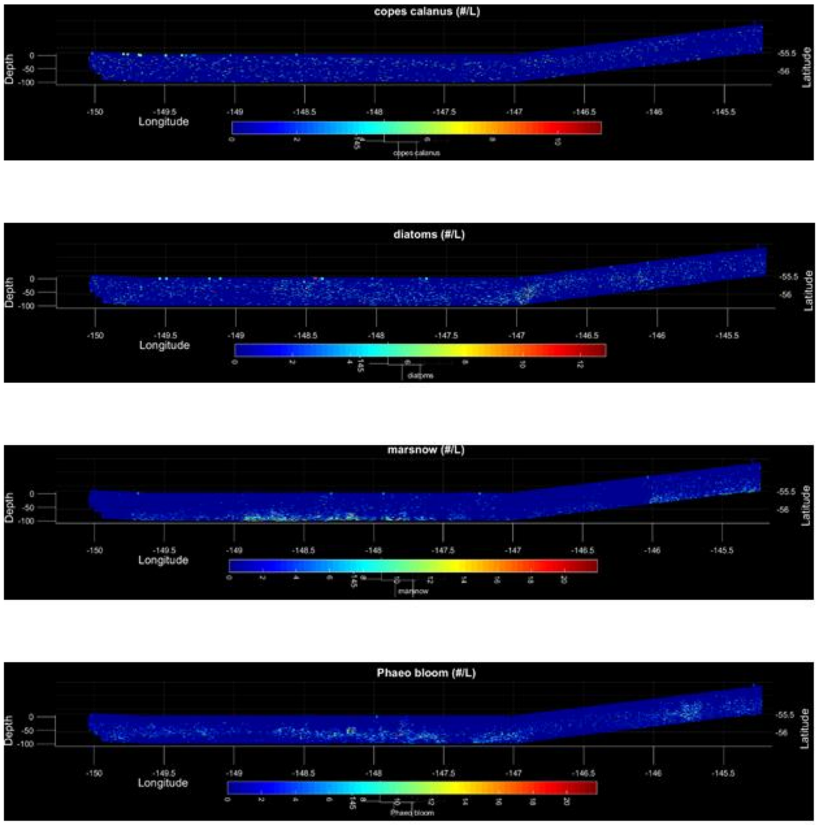


Figure 40. Taxon plots for VPR 6. Note that the strobe failed and so ROIs were not available for VPR 7; only the hydrographic and bio-optical data for VPR 7 are shown in Figure 38.

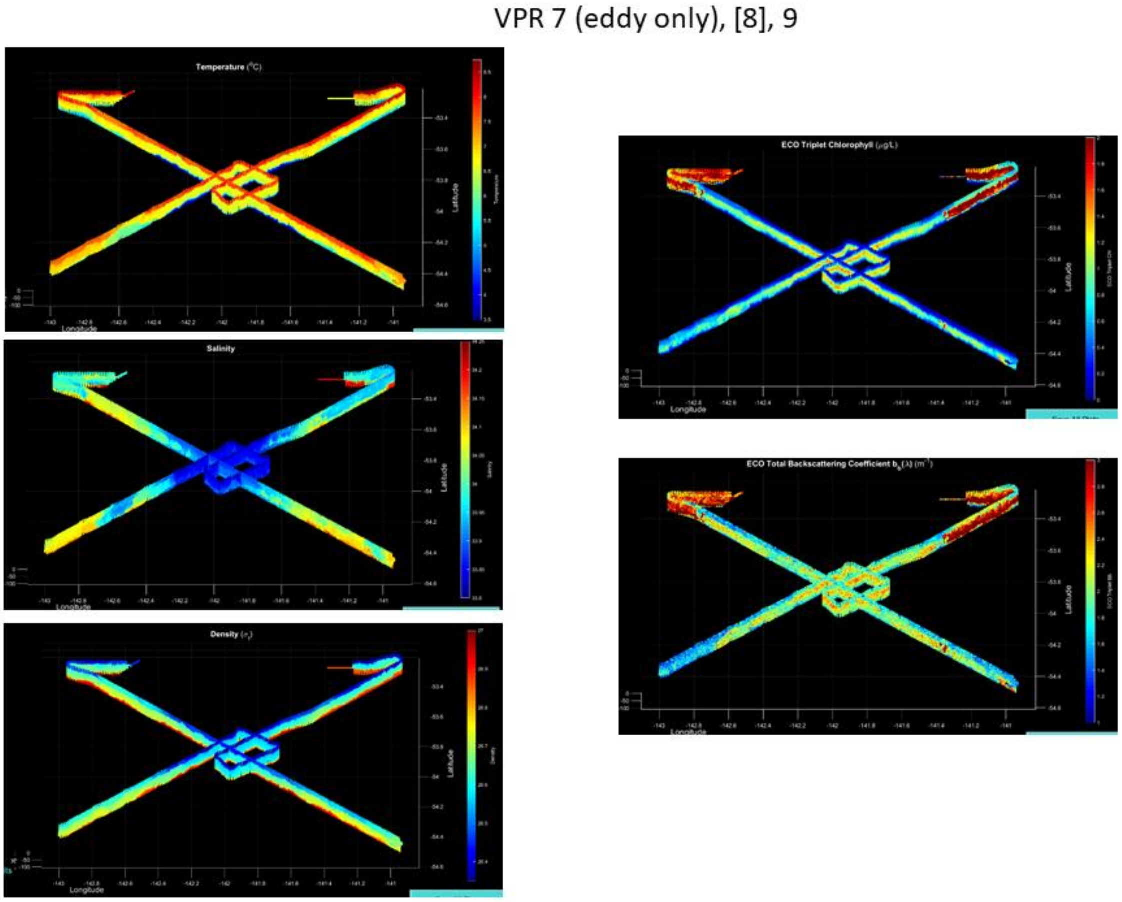


Figure 41. VPR 7 (partial), [8], and 9 temperature, salinity, density, fluorescence, and backscatter.

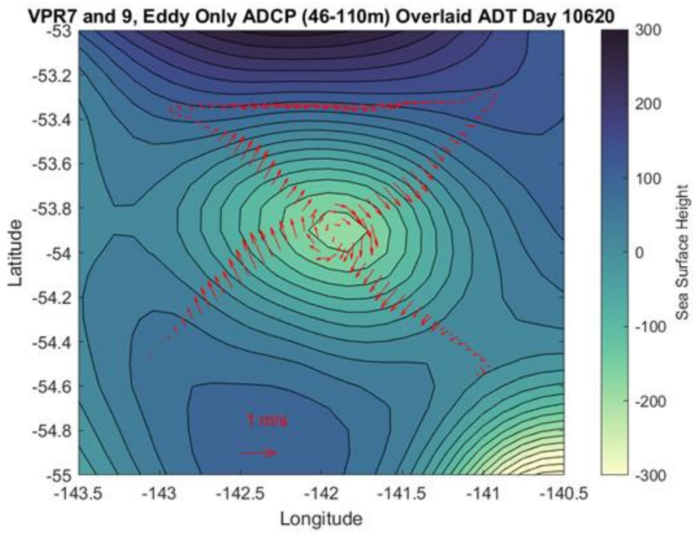
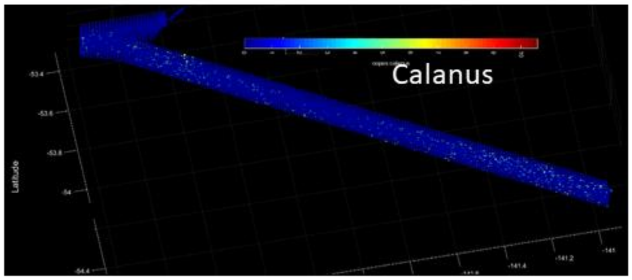


Figure 42. ADCP currents along VPR 7 (partial), [8], and 9 tracks.



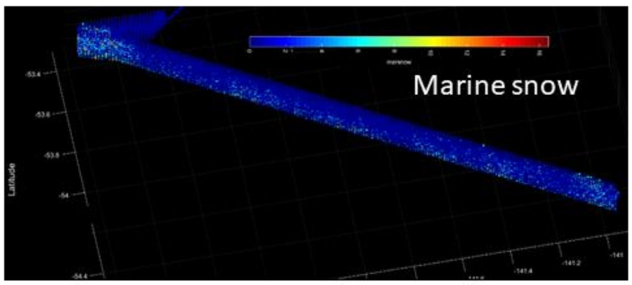


Figure 43. Taxon plots for VPR 9, turning southeast at the northwest corner of Eddy A.

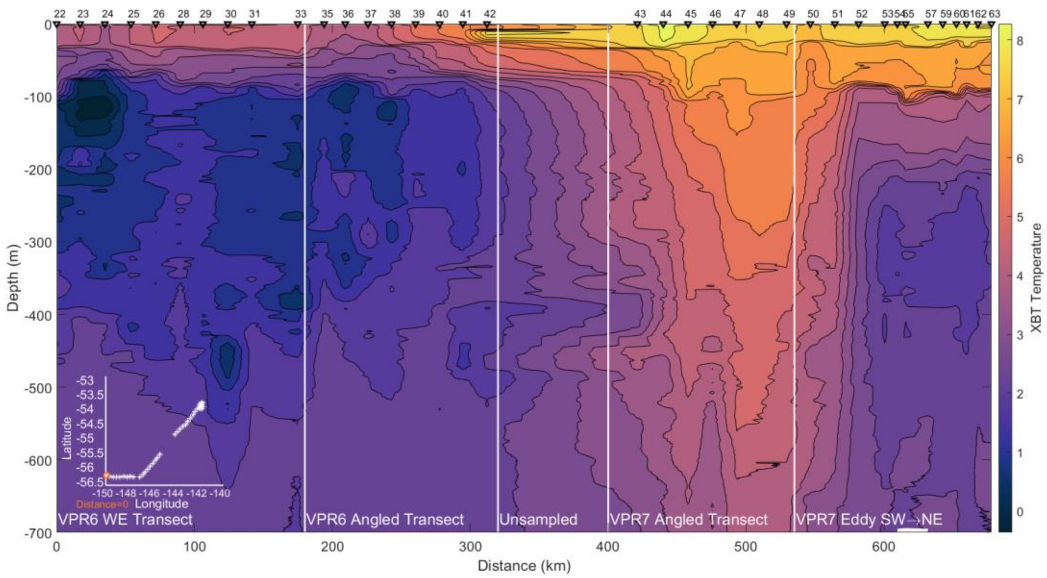


Figure 44. XBT survey used to help locate the center of Eddy A.

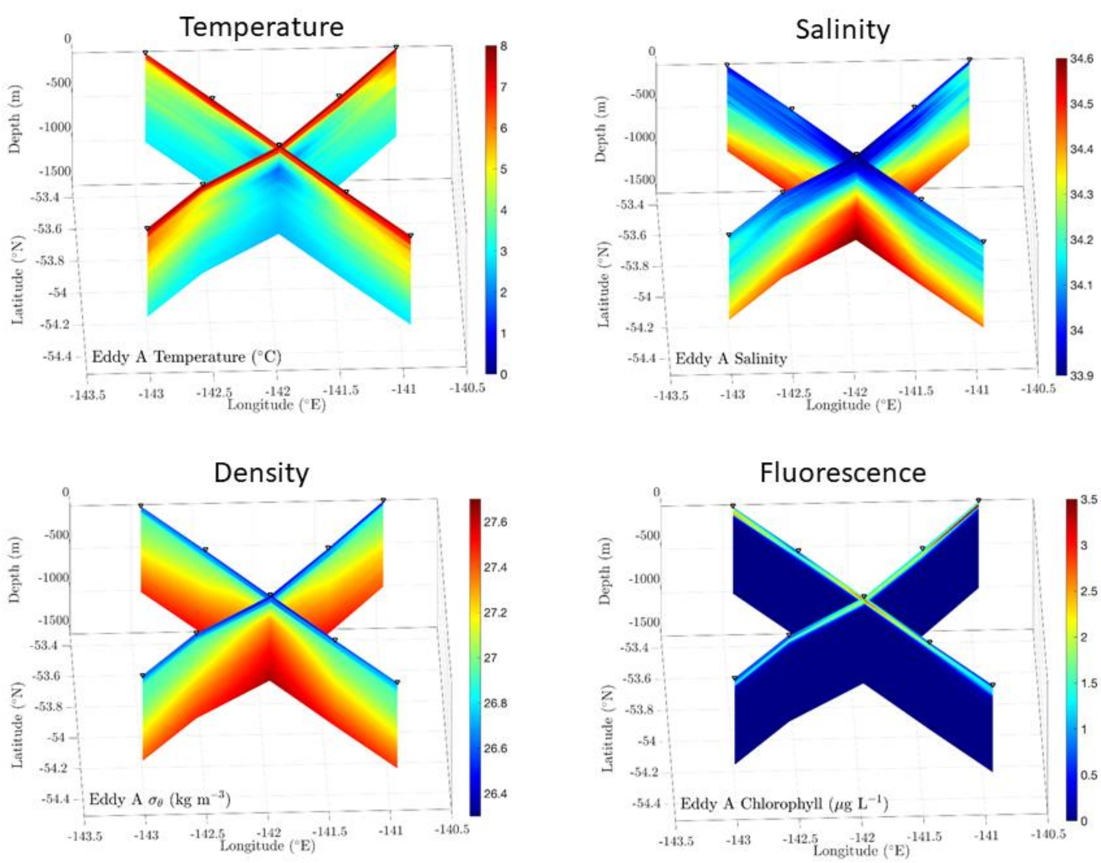


Figure 45. CTD cross sections of Eddy A: temperature, salinity, density, and fluorescence.

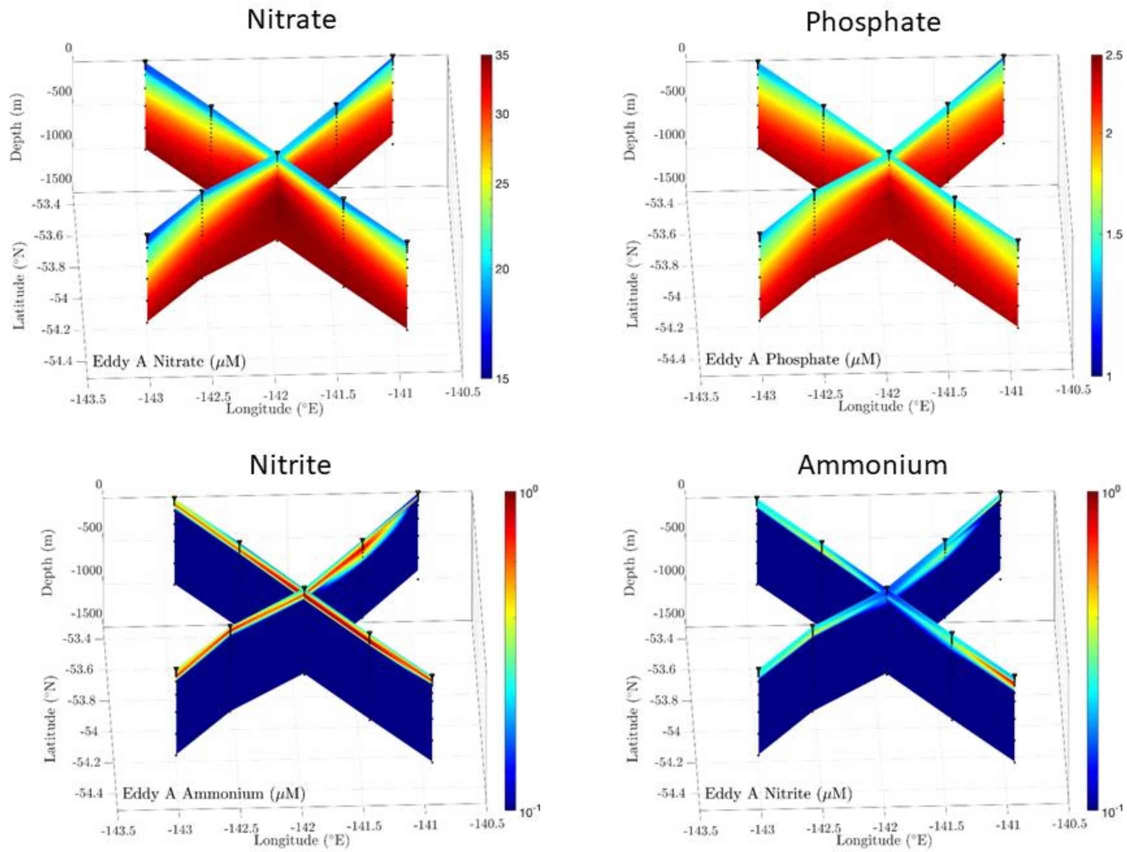


Figure 46. CTD cross sections of Eddy A: nitrate, phosphate, nitrite, and ammonium.

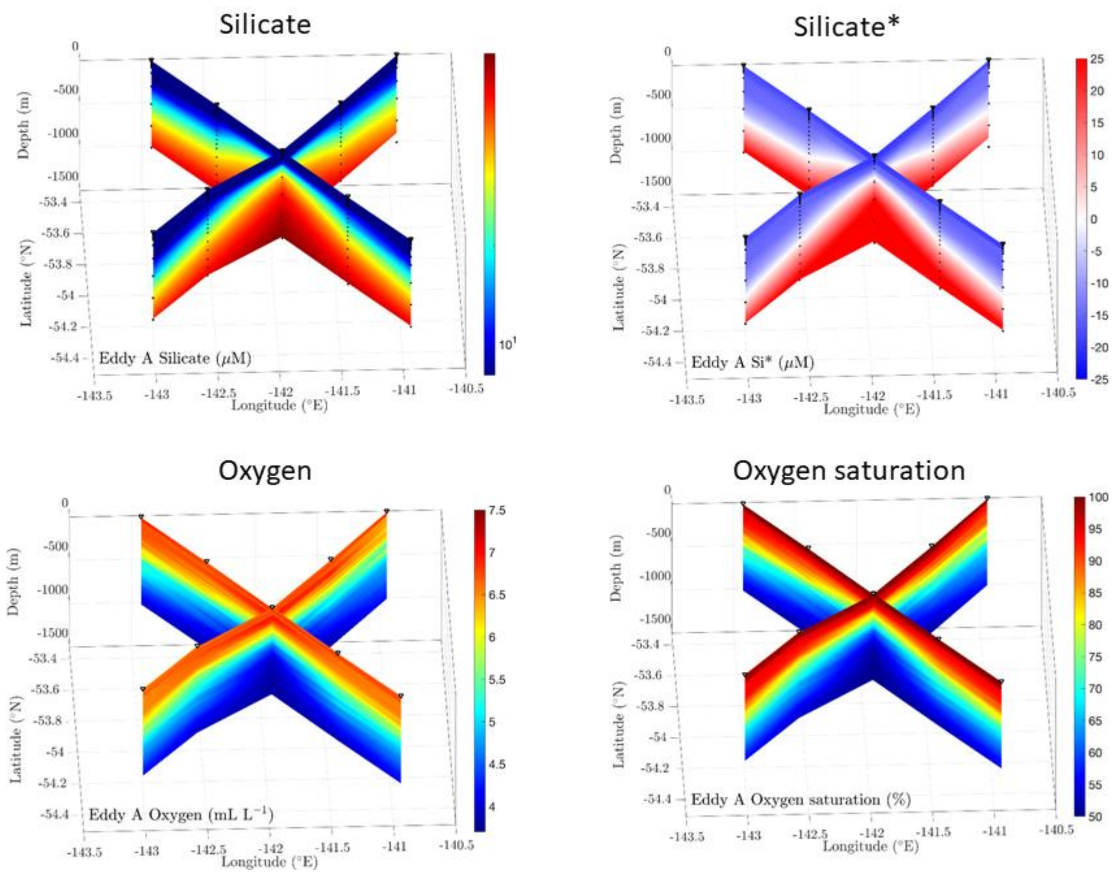


Figure 47. CTD cross sections of Eddy A: silicate, silicate, oxygen, and oxygen saturation.*

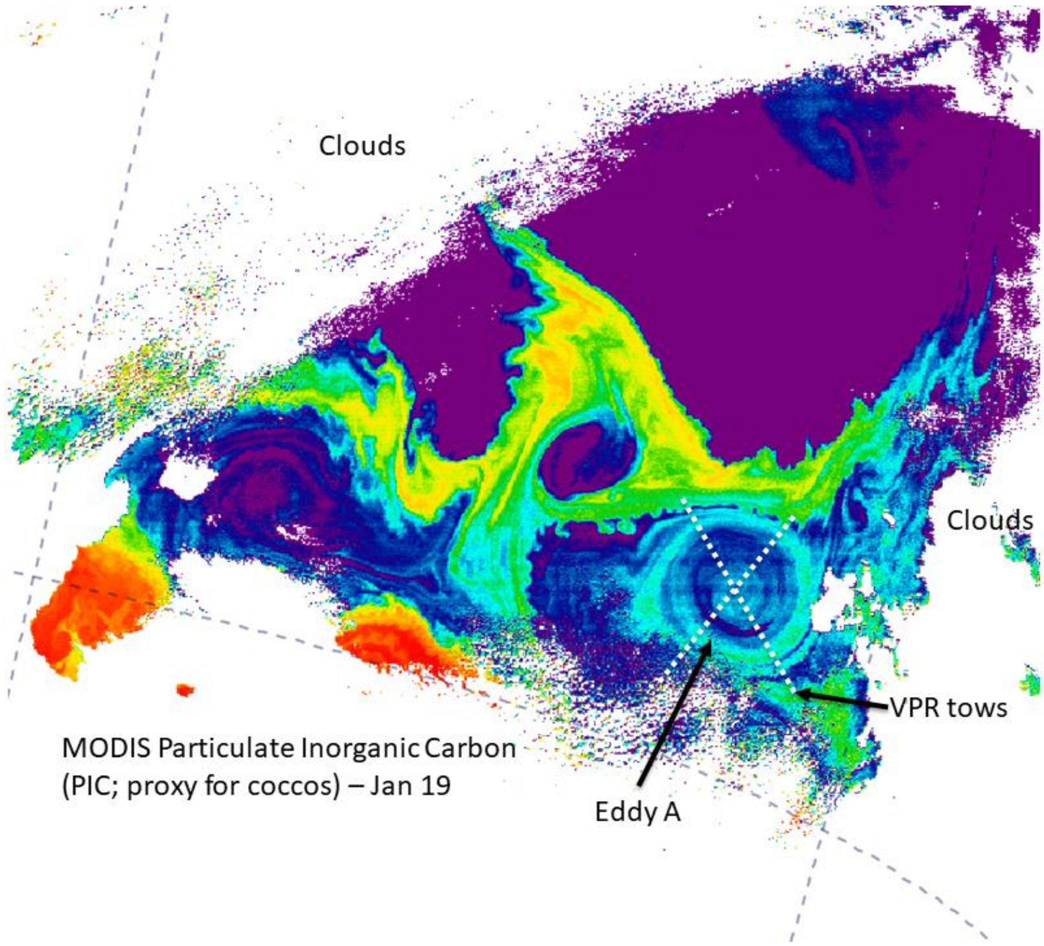


Figure 48. High resolution PIC image of Eddy A.

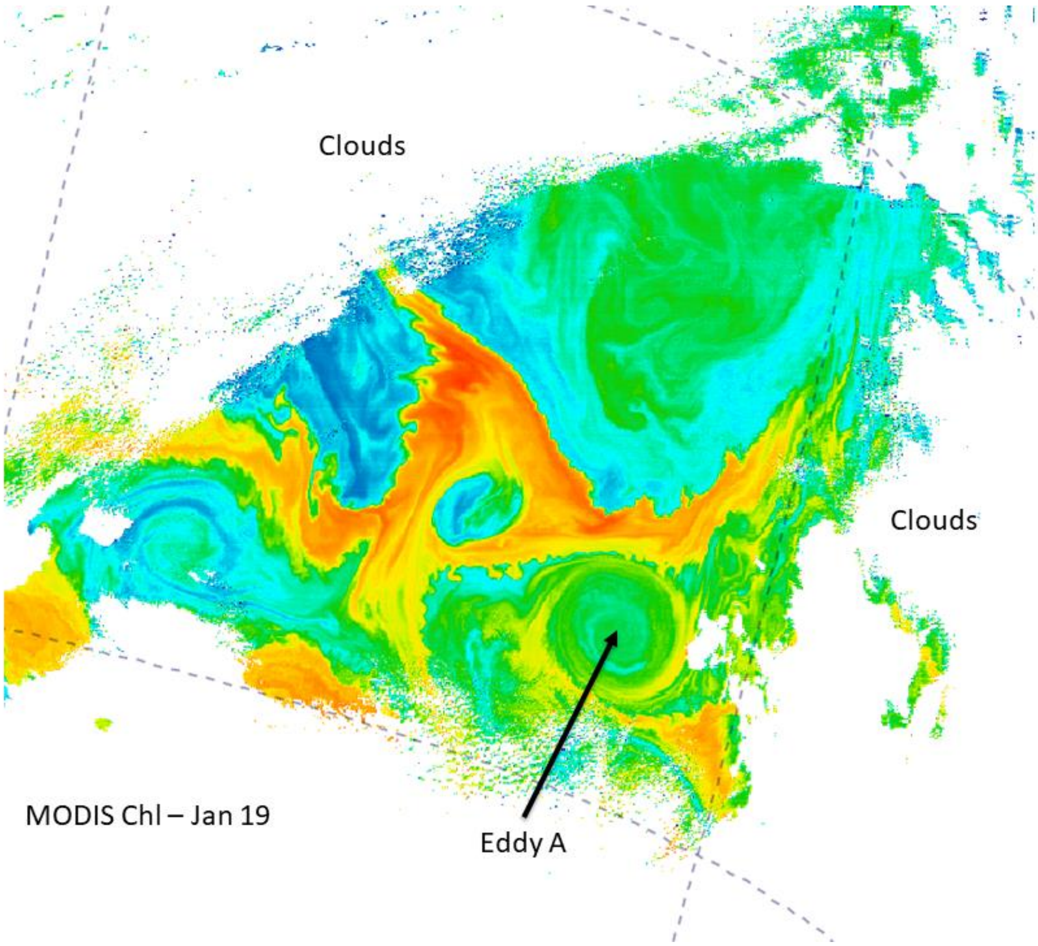


Figure 49. High resolution chlorophyll image of Eddy A.

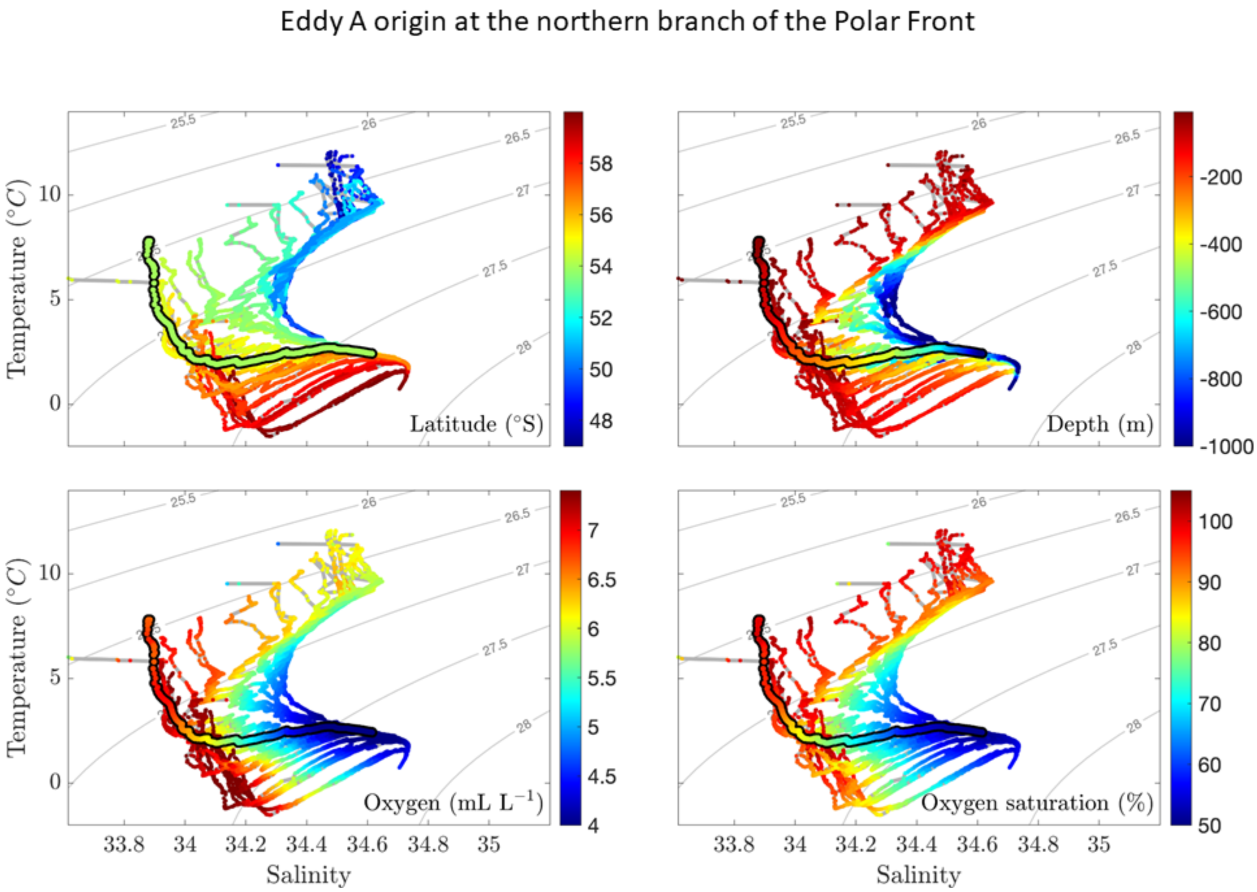


Figure 50. Temperature - salinity characteristics from Eddy A center (green) superimposed on those from the meridional transect.

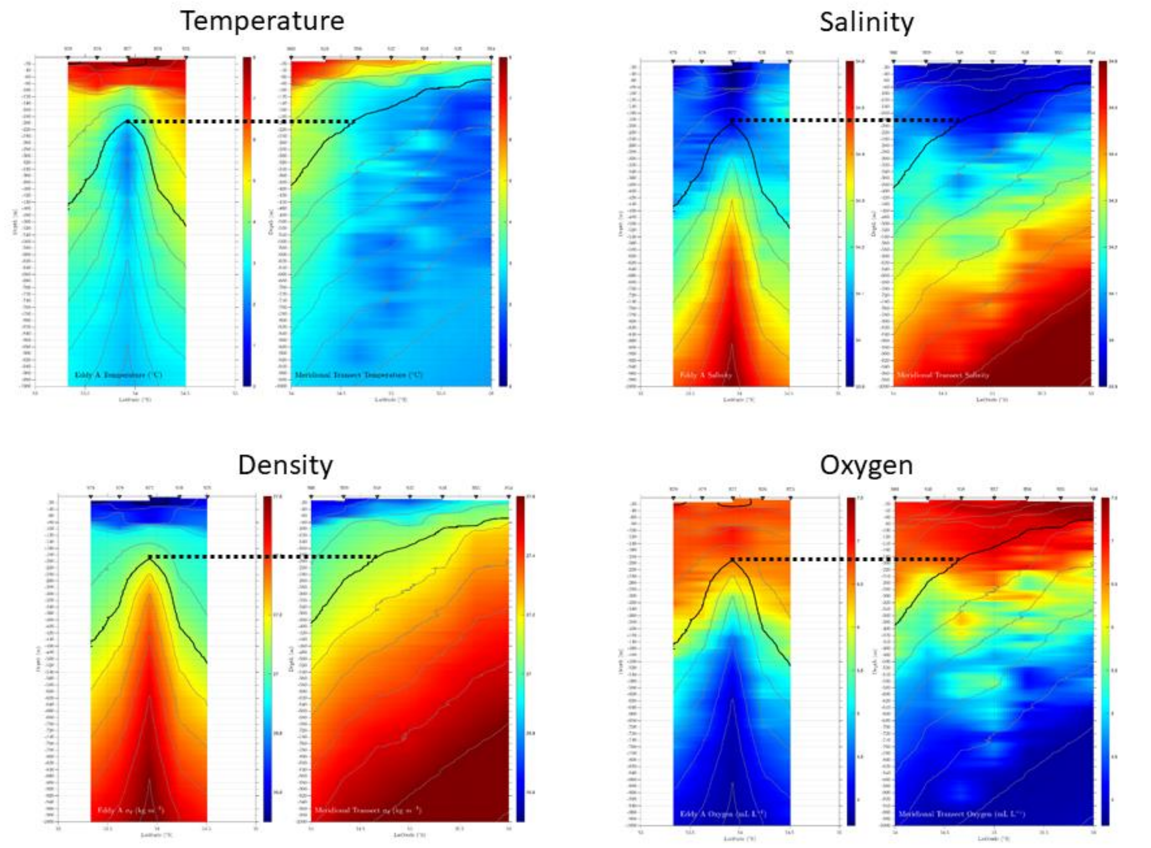


Figure 51. Cross-sections of temperature, salinity, density, and oxygen in Eddy A (left) versus the meridional transect (right). Horizontal line connects the peak in the 27.1 isopycnal (lighter bound of SAMW) within Eddy A to its level in the meridional transect.

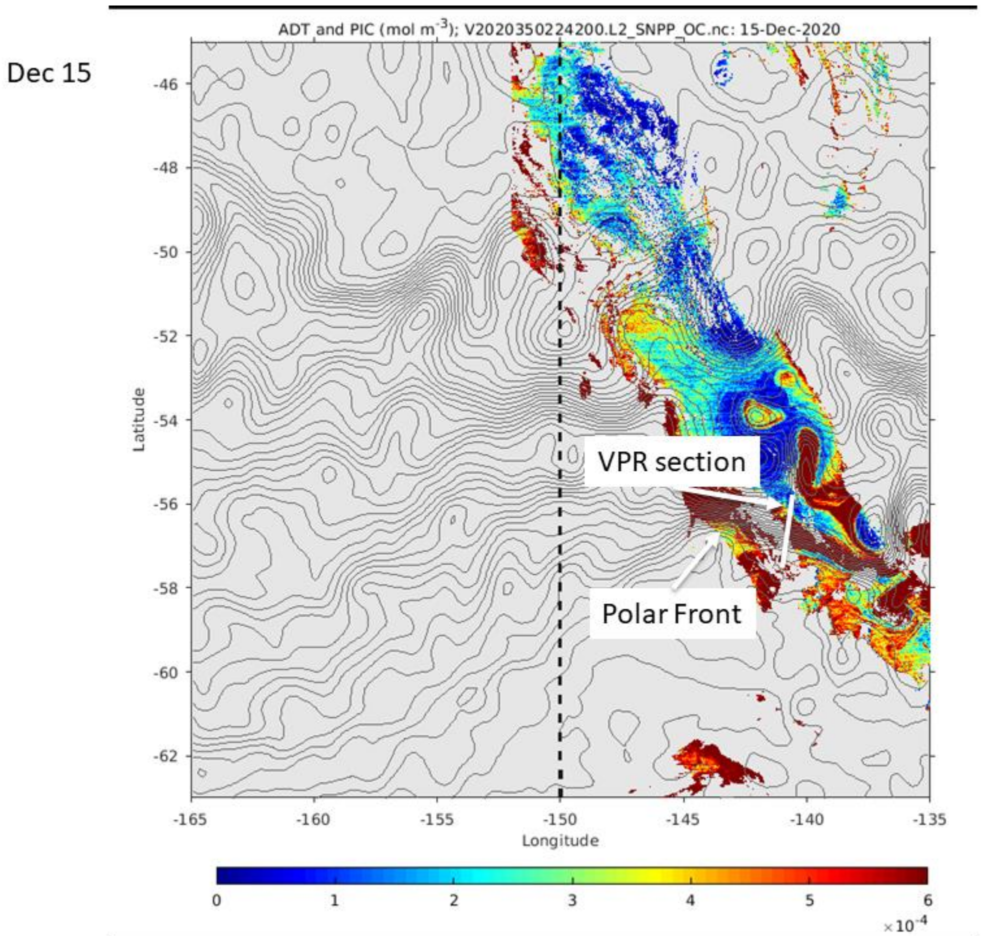


Figure 52. VPR 10 section across the Polar Front at 141W with contours of ADT and PIC indicated in color (image from 15 December 2020).

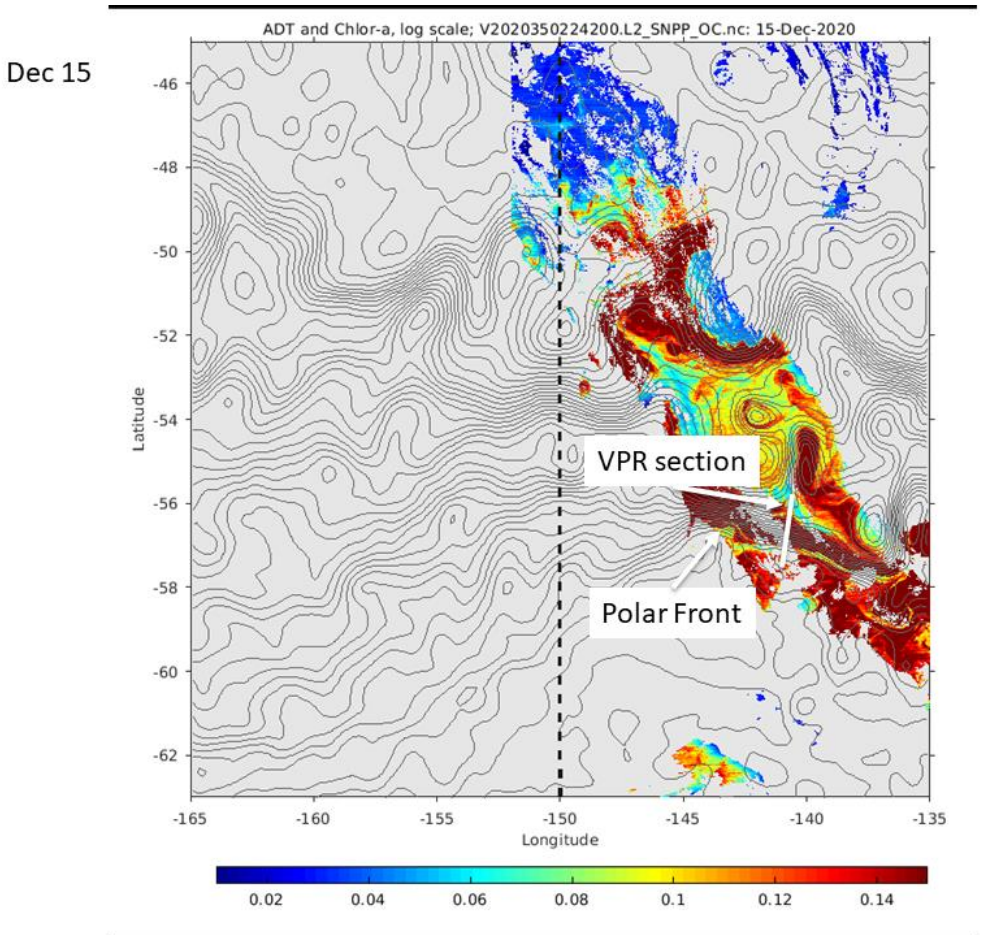


Figure 53. VPR 10 section across the Polar Front at 141W with contours of ADT and chlorophyll indicated in color (image from 15 December 2020).

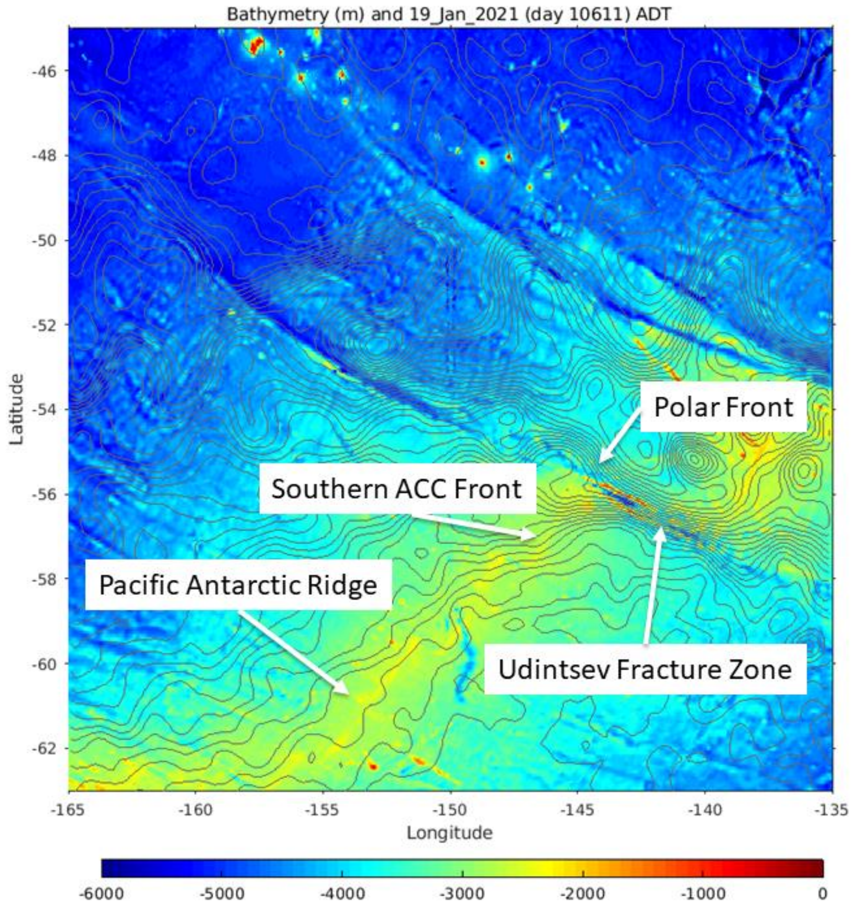


Figure 54. Contours of ADT overlaid on bathymetry.

Feb 2

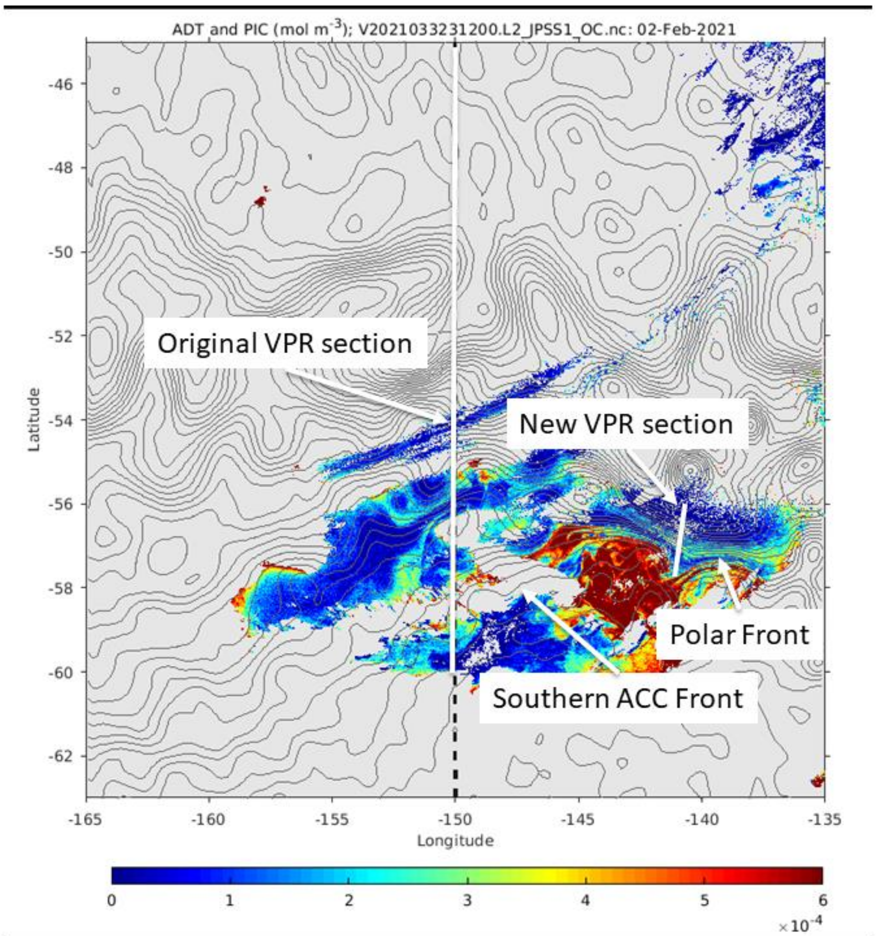


Figure 55. VPR 10 section across the Polar Front at 141W with contours of ADT and PIC indicated in color (image from 2 February 2021).

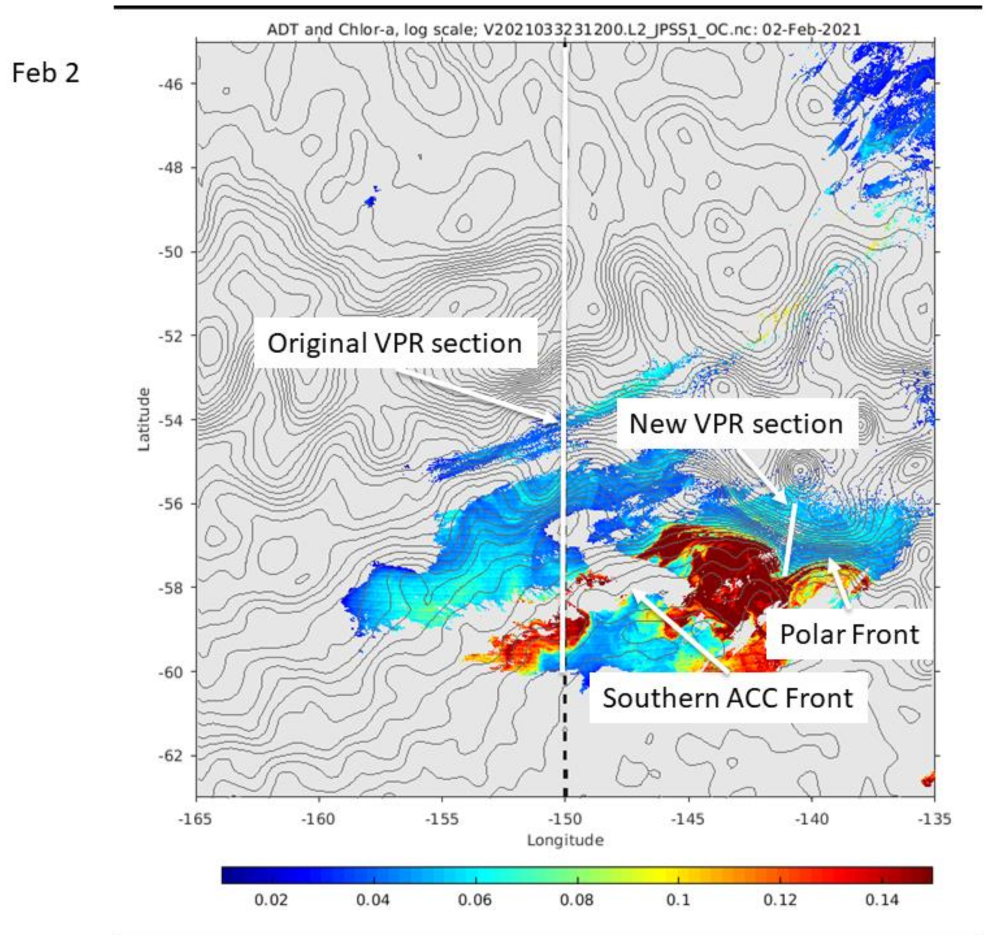


Figure 56. VPR 10 section across the Polar Front at 141W with contours of ADT and chlorophyll indicated in color (image from 2 February 2021).

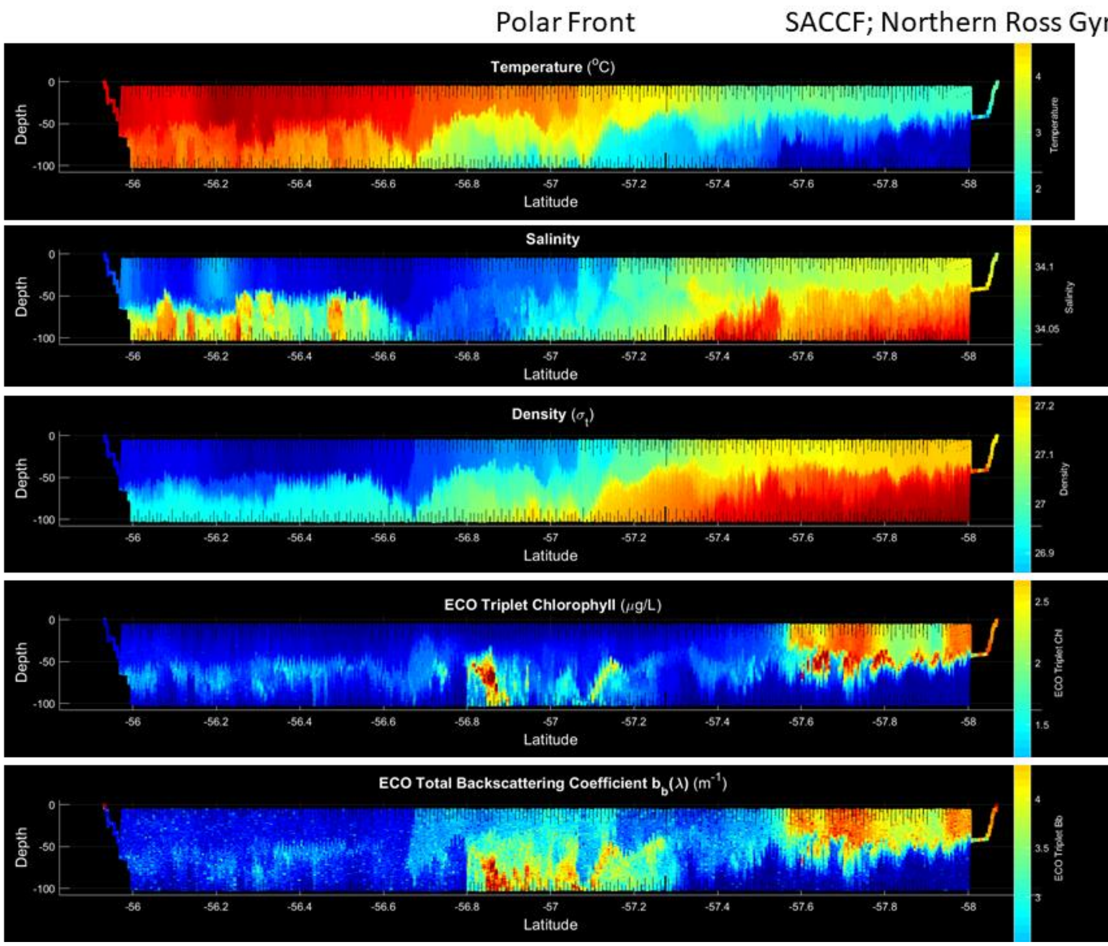


Figure 57. VPR 10 temperature, salinity, density, fluorescence, and backscatter.

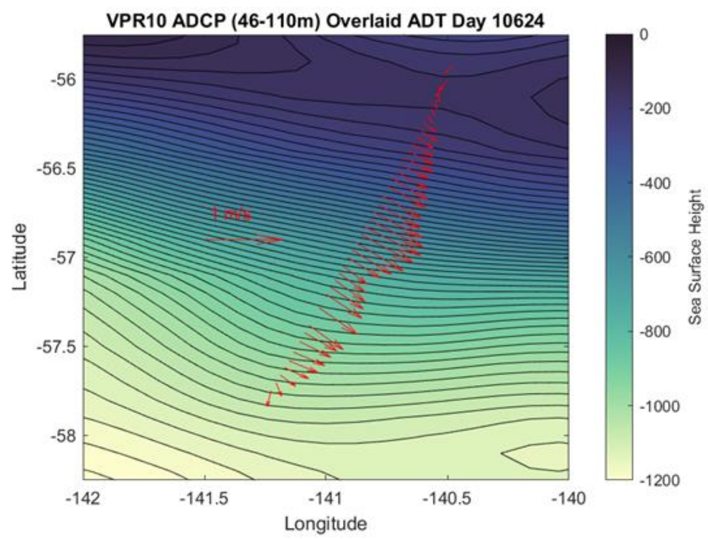


Figure 58. ADCP currents along VPR 10 track.

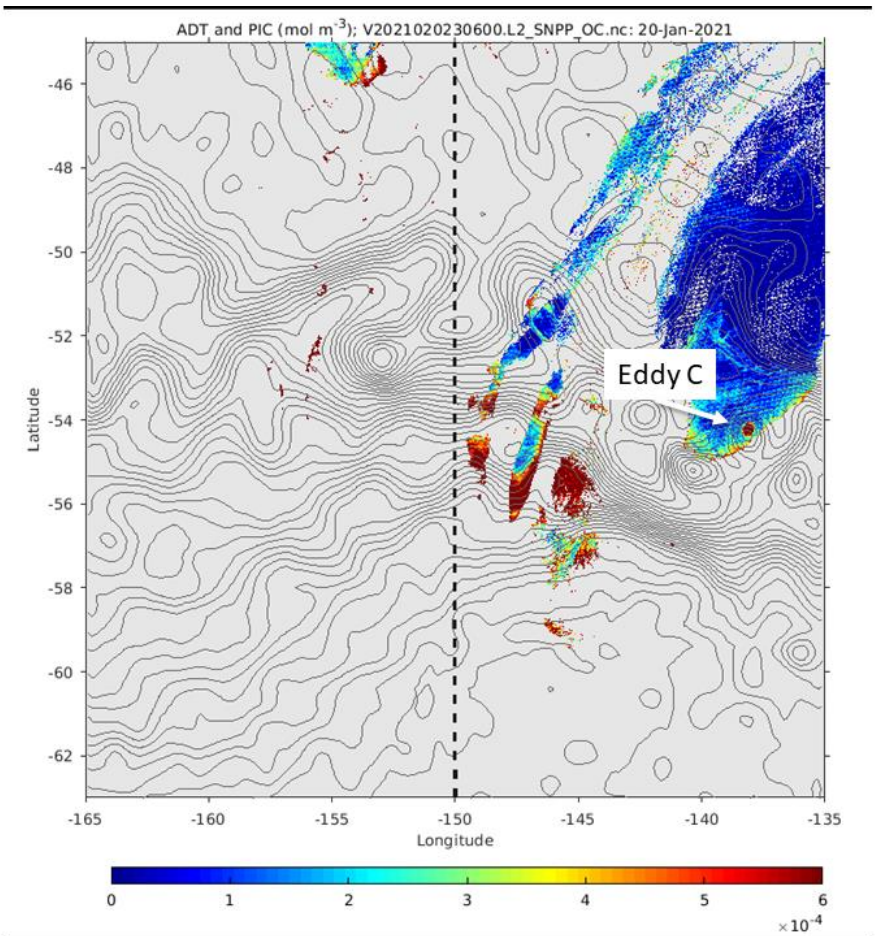


Figure 59. PIC image from 20 January highlighting Eddy C.

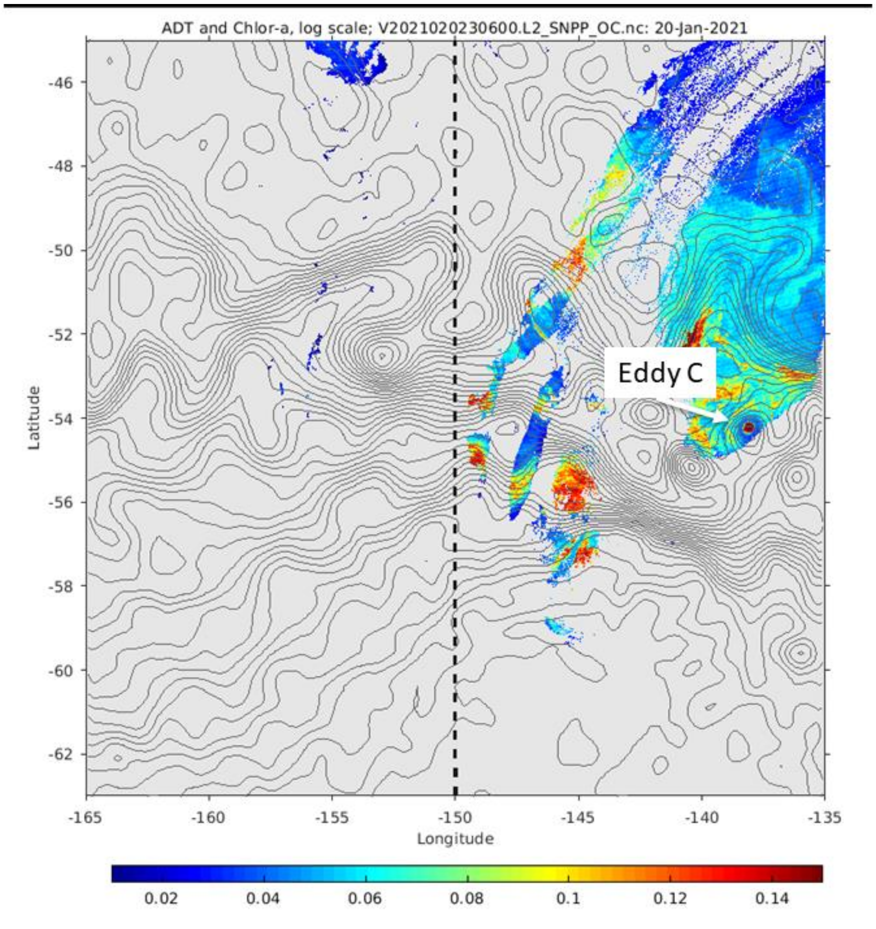


Figure 60. Chlorophyll image from 20 January highlighting Eddy C.

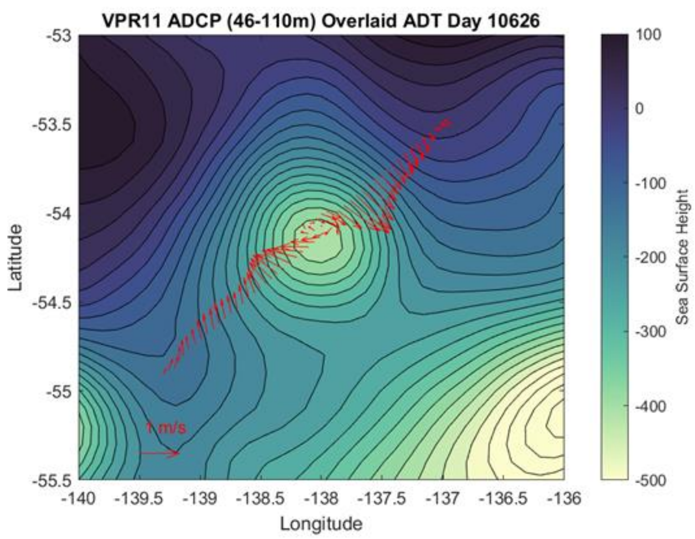


Figure 61. ADCP currents along VPR 11 track across Eddy C.

50

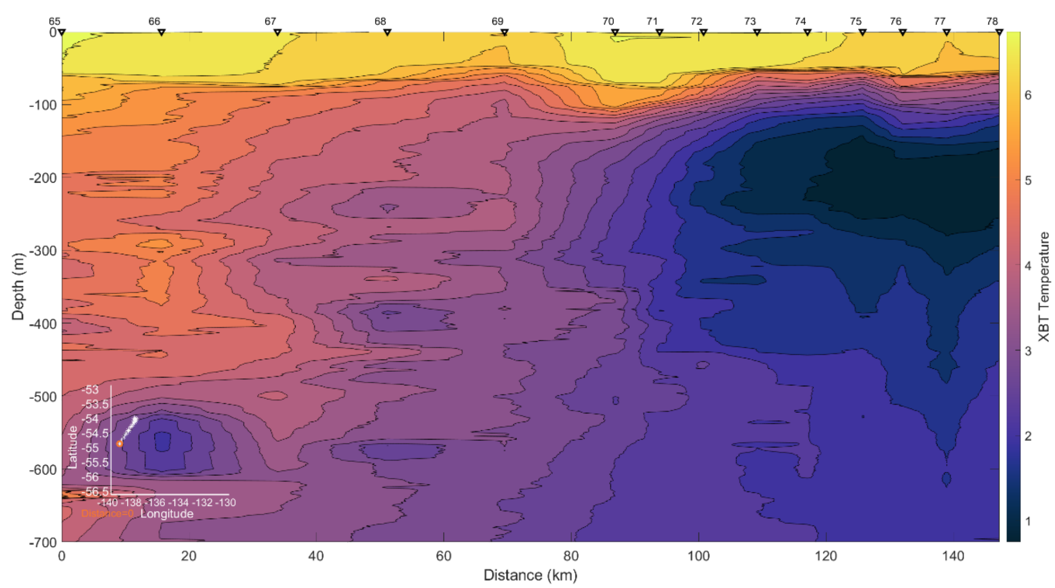


Figure 62. XBT survey used to help locate the center of Eddy C.

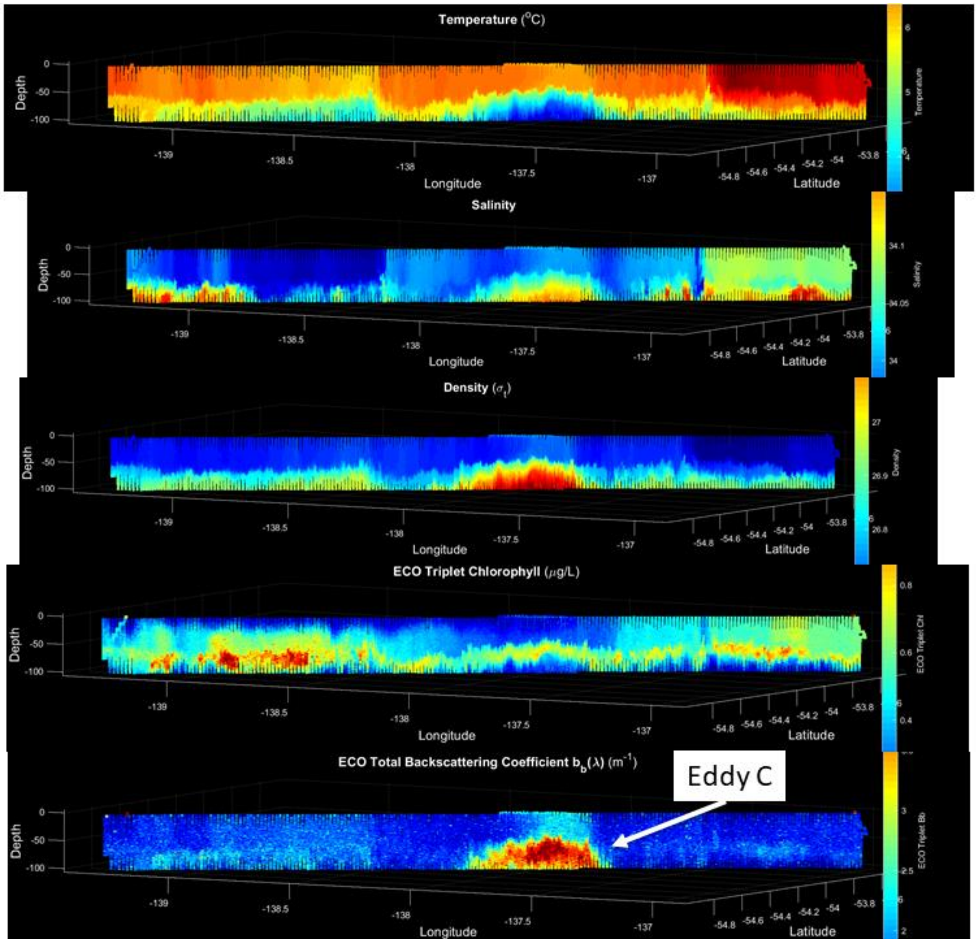


Figure 63. VPR 11 temperature, salinity, density, fluorescence, and backscatter.

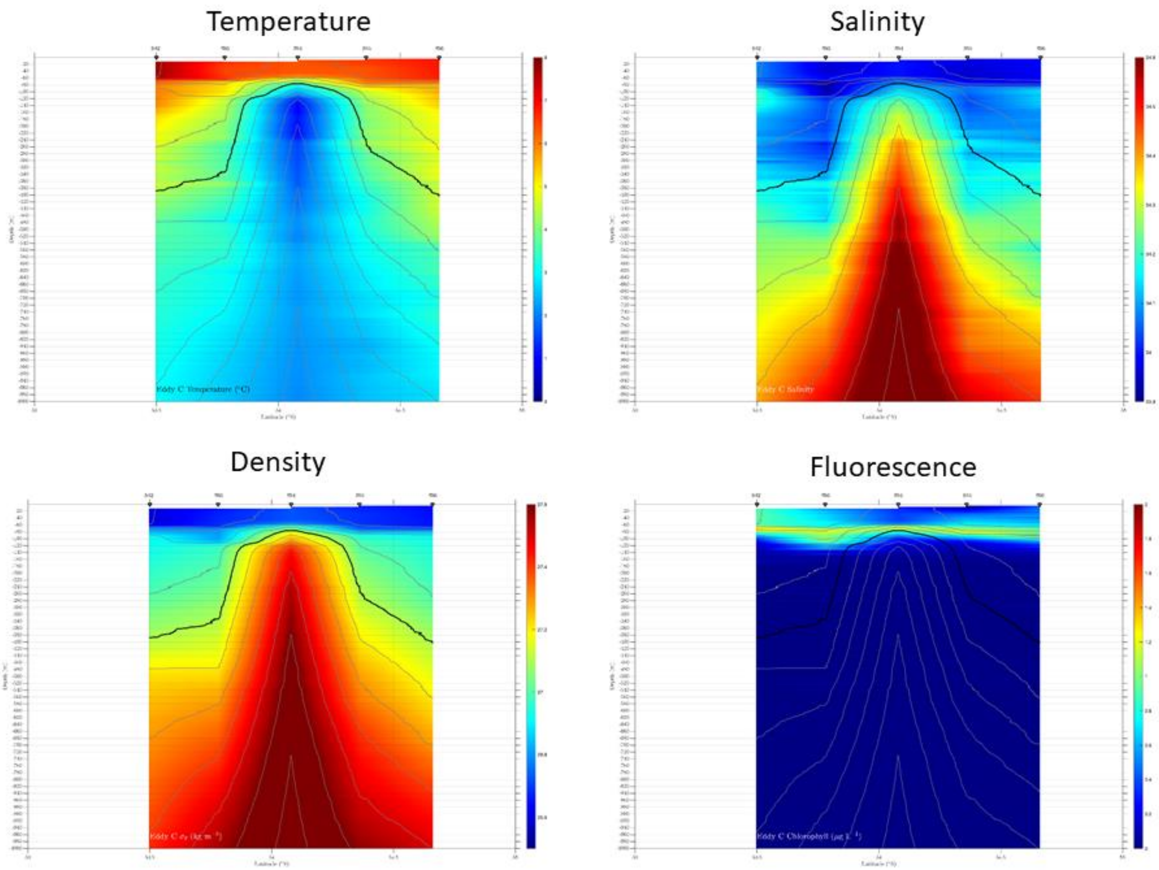


Figure 64. Cross sections of temperature, salinity, density, and fluorescence across Eddy C.

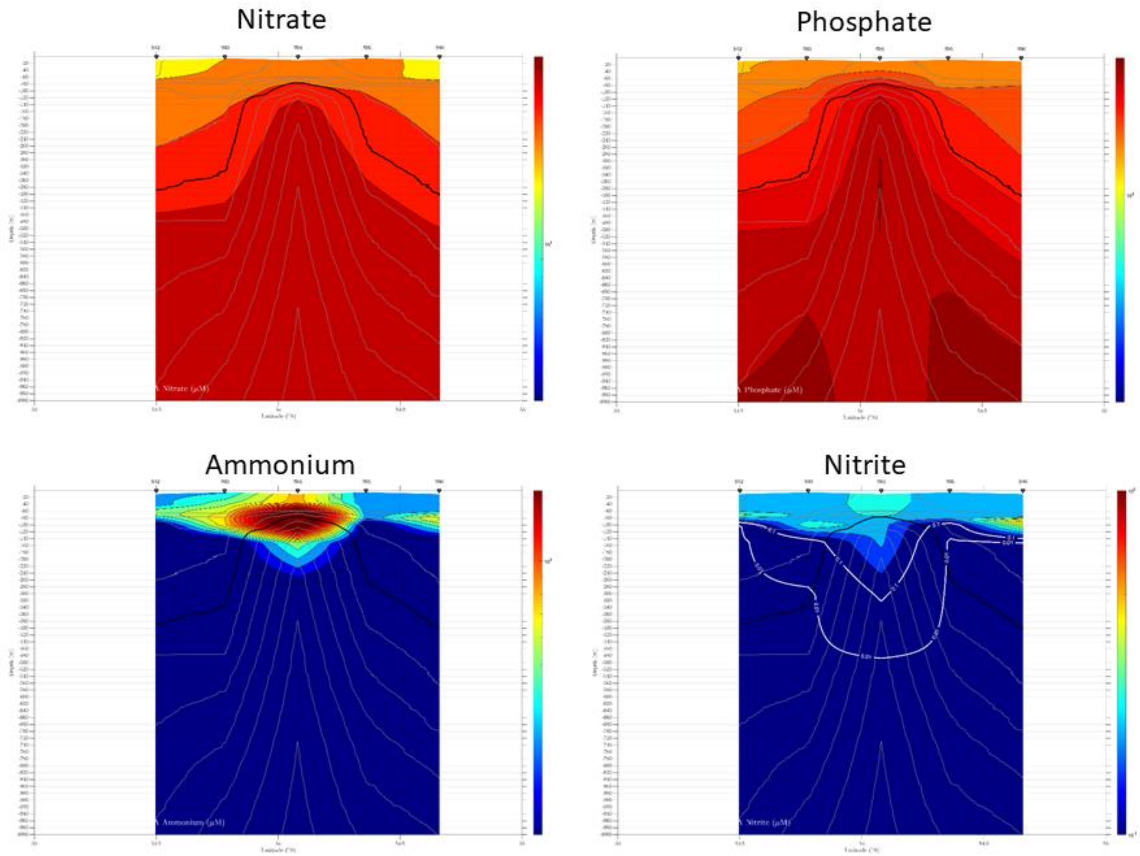


Figure 65. Cross sections of nitrate, phosphate, ammonium, and nitrite across Eddy C.

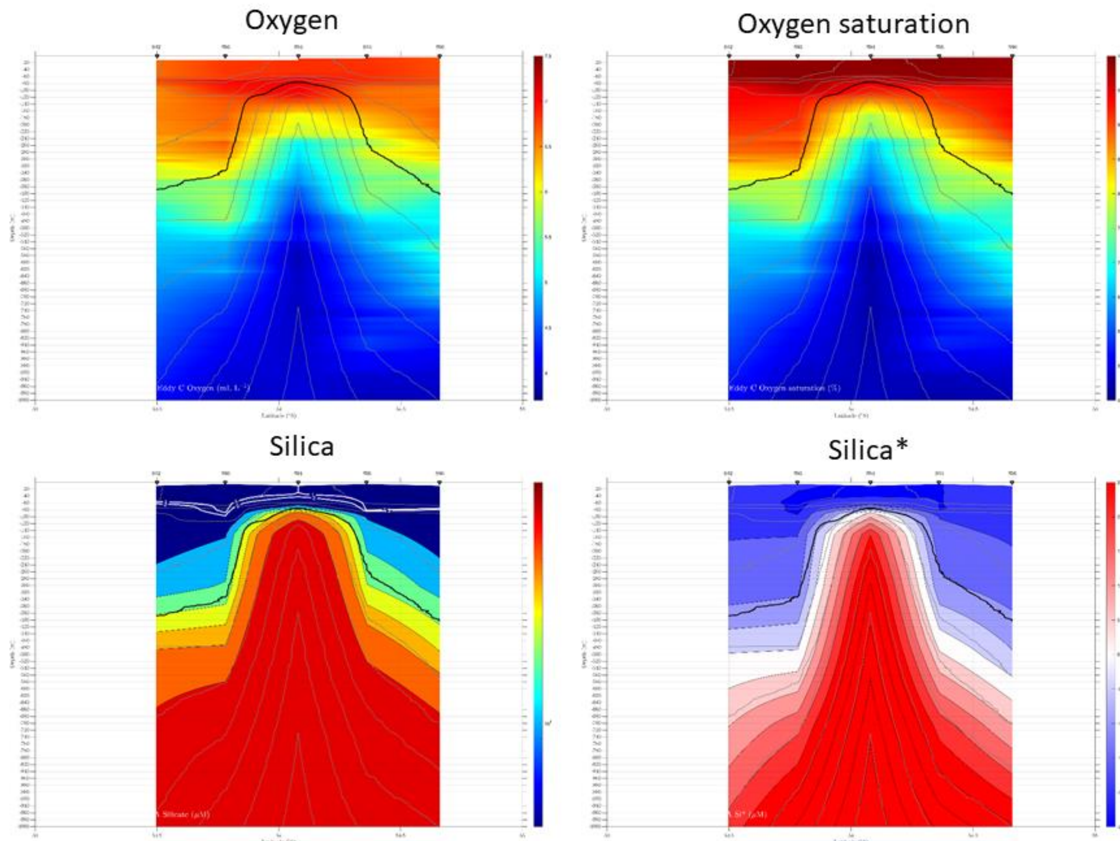


Figure 66. Cross sections of oxygen, oxygen saturation, silicate, and silicate across Eddy C.*

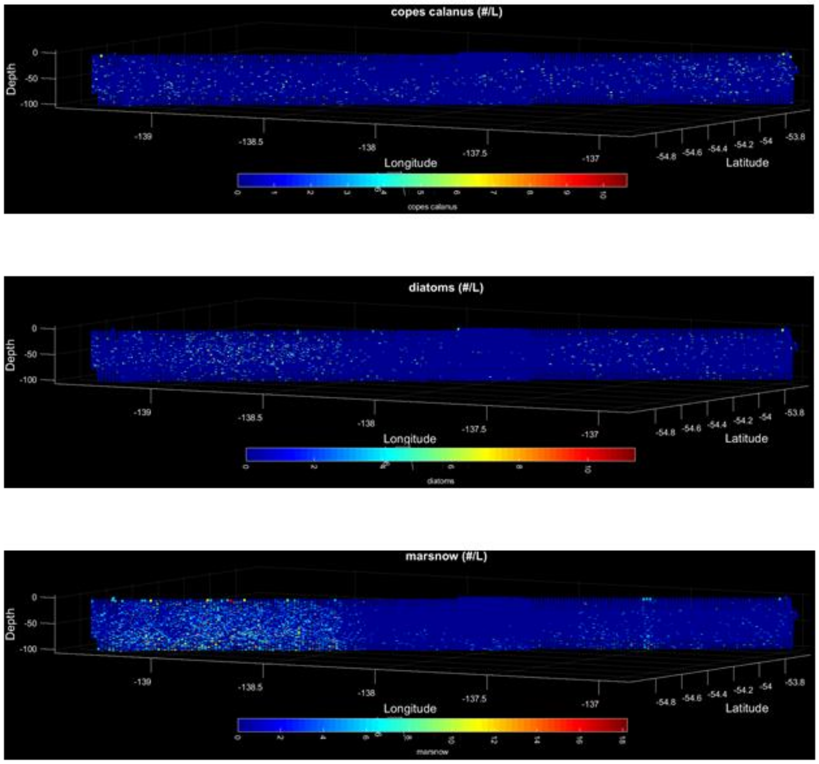


Figure 67. Taxon plots for VPR 11 transecting Eddy C.

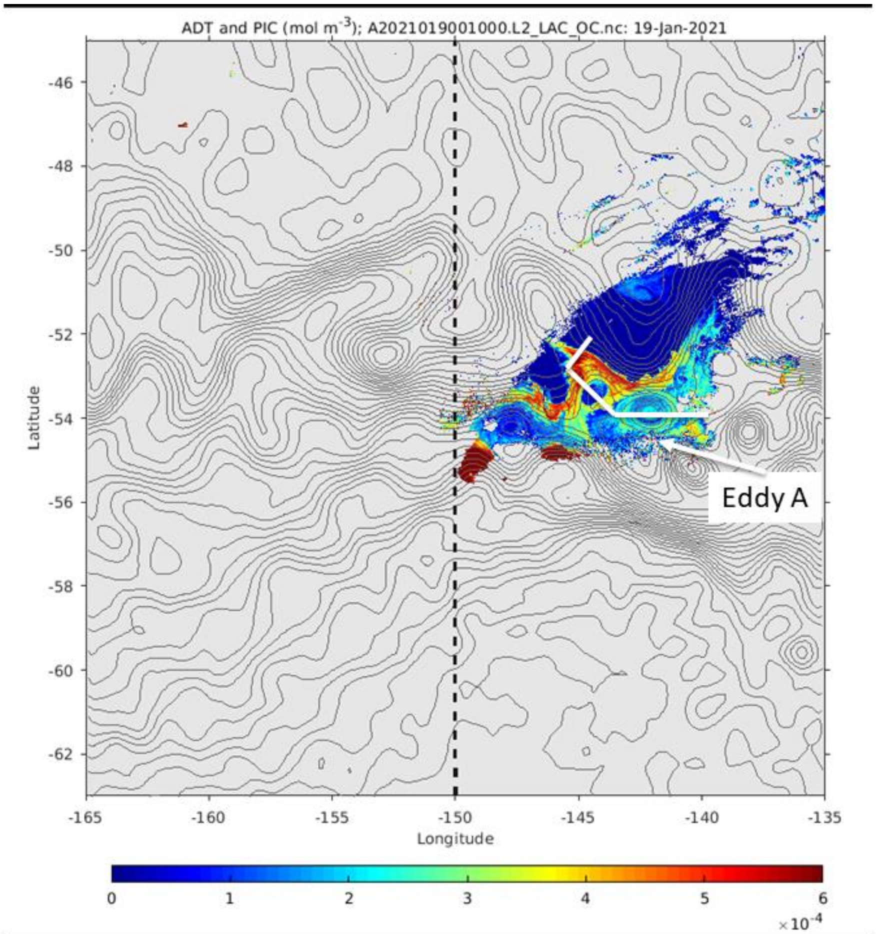


Figure 68. VPR 12 track through Eddy A, Eddy D, and the Subantarctic Front.

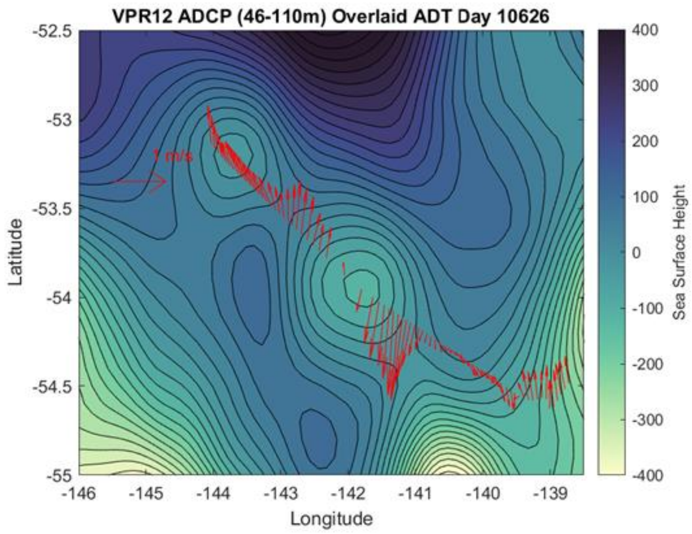


Figure 69. ADCP currents along VPR 12 track.

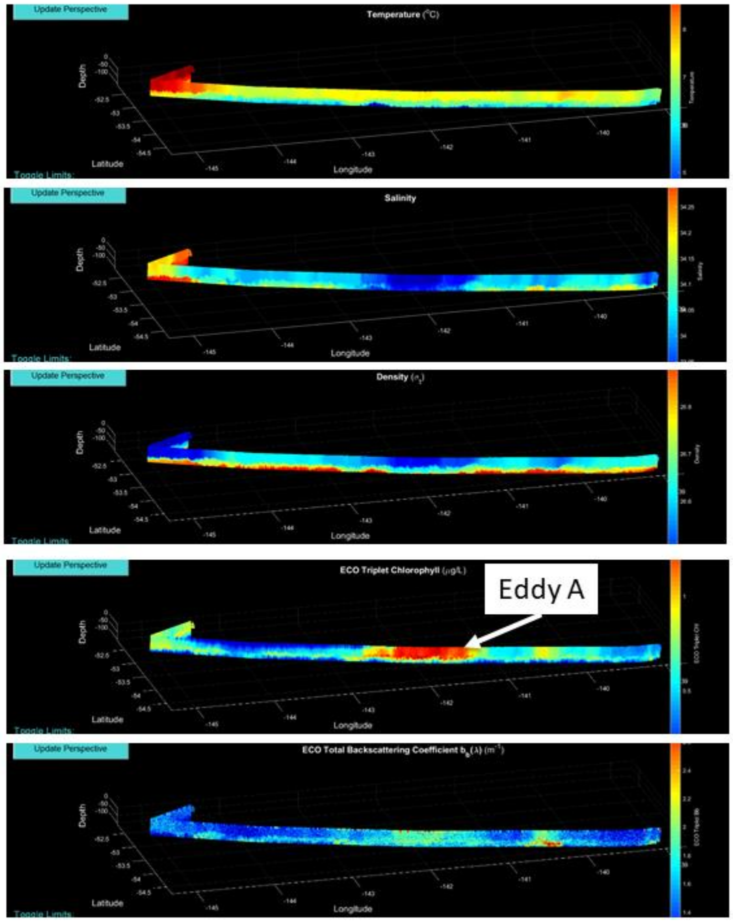


Figure 70. VPR 12 temperature, salinity, density, fluorescence, and backscatter.

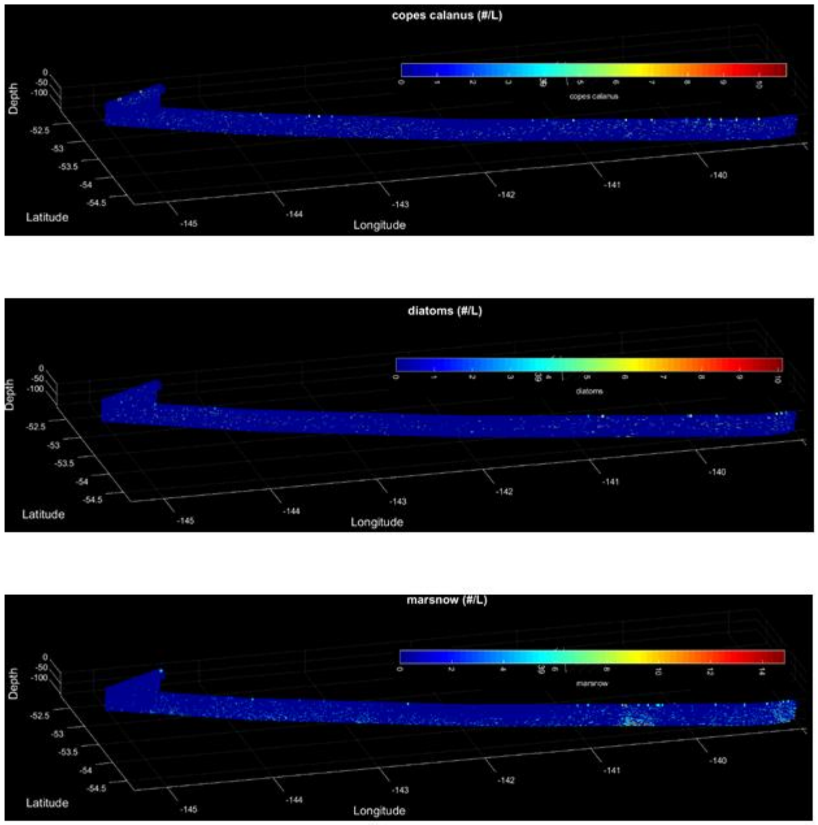


Figure 71. VPR 12 taxon plots.

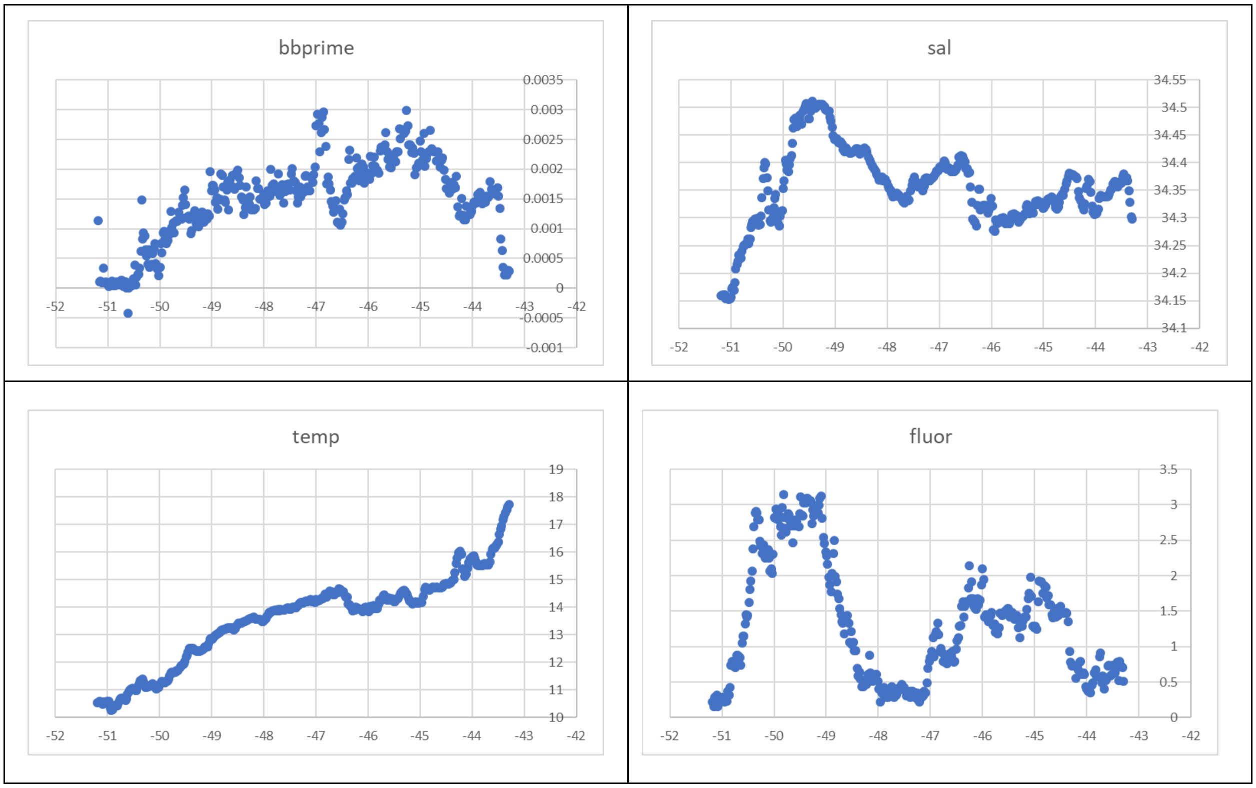


Figure 72. Balch lab underway data from northward transit: bb prime, temperature, salinity, and fluorescence.

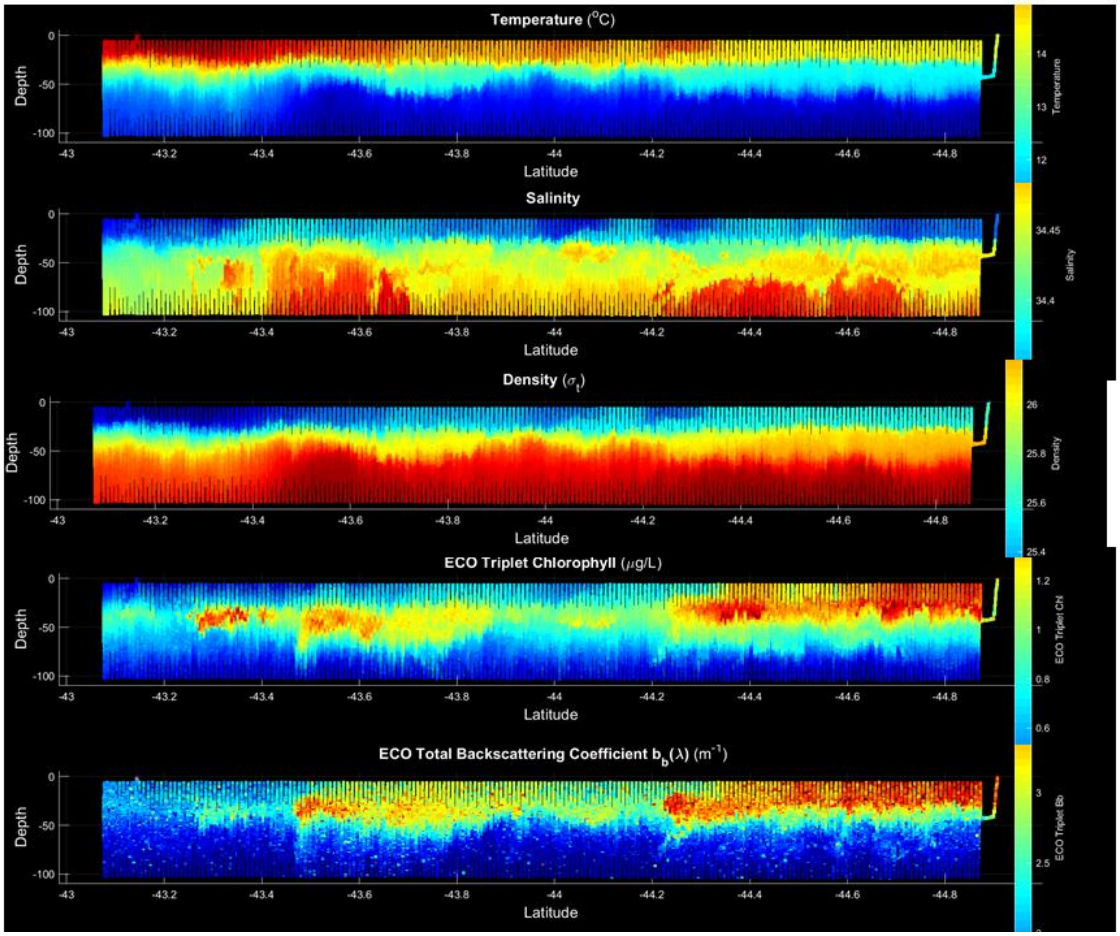


Figure 73. VPR 13 temperature, salinity, density, fluorescence, and backscatter.

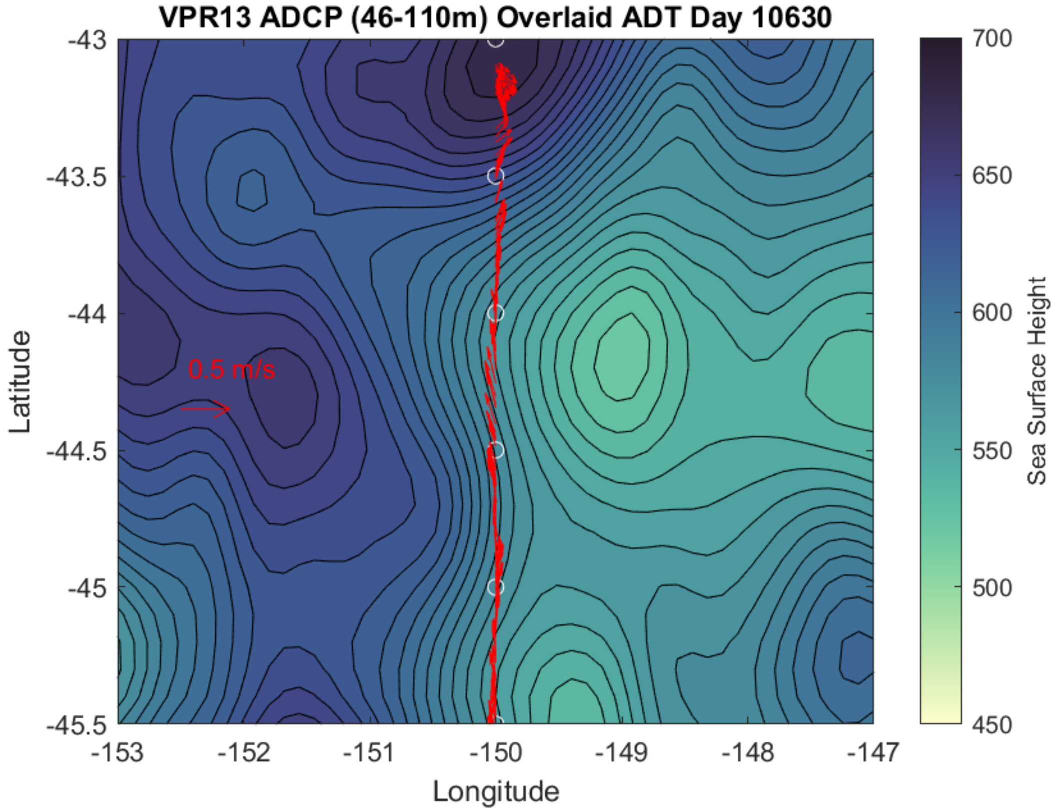


Figure 74. ADCP currents along VPR 13 track.

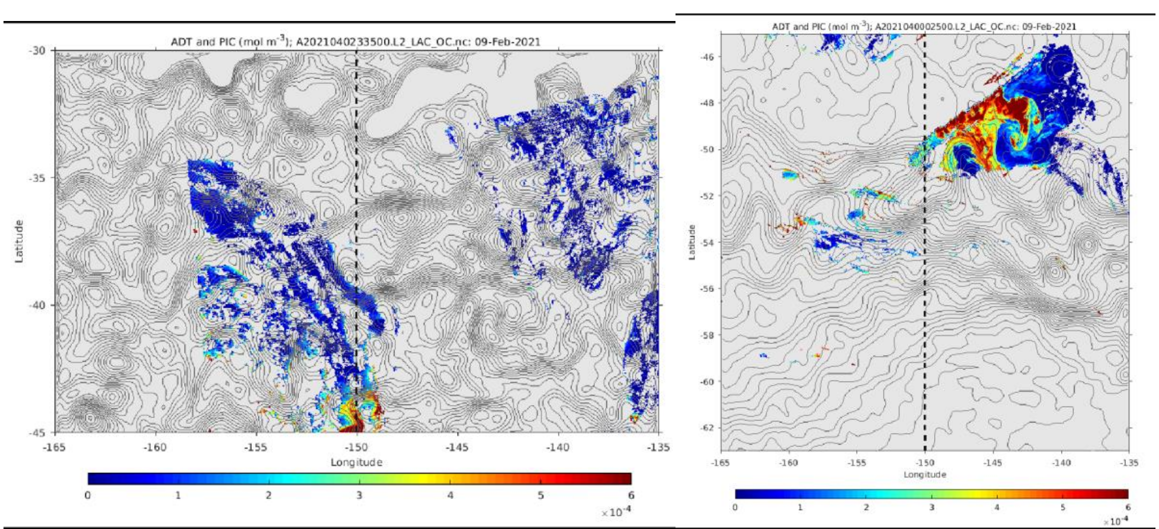


Figure 75. Satellite-derived PIC (color) with ADT contours overlaid. Images from 9 February indicate the dip in b_b' at 44S was associated with a meander; PIC-rich water to the east of the sampling area at approximately the same latitude high b_b' was encountered along 150W.

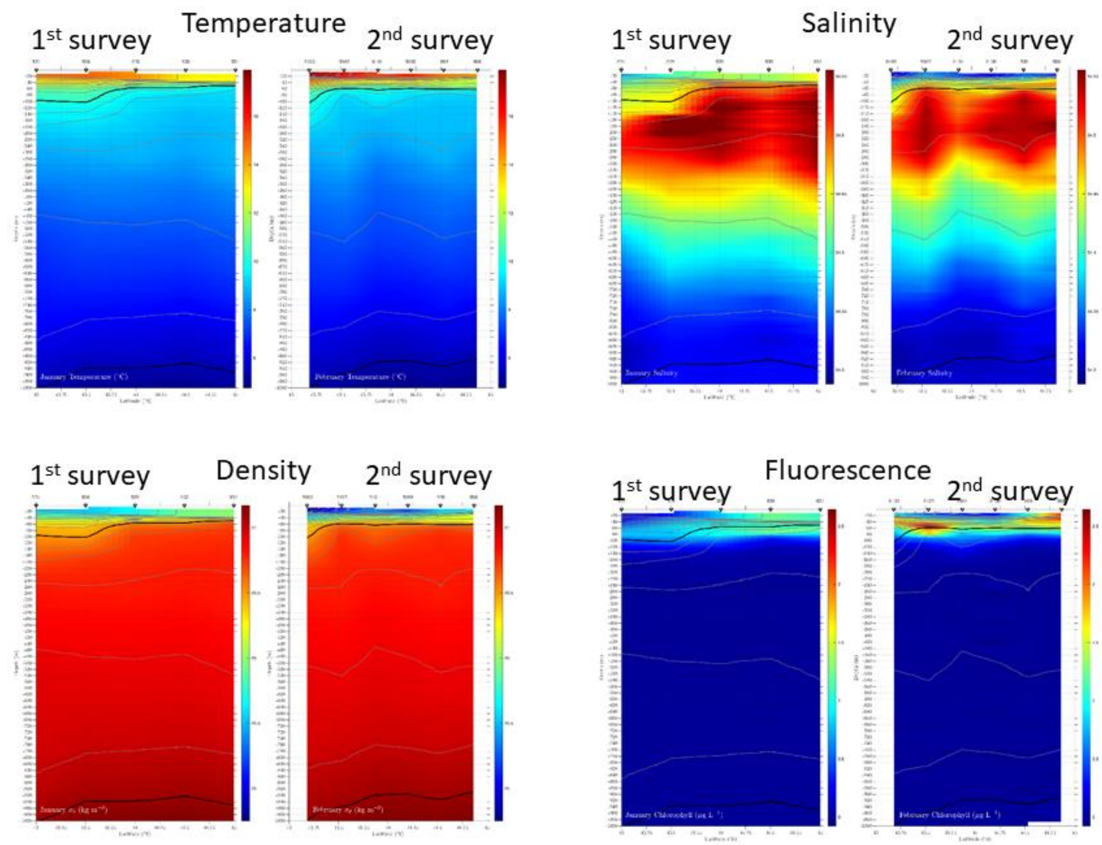


Figure 76. Comparison of CTD sections from the first and second surveys of the 150W transect between 43 and 45S.

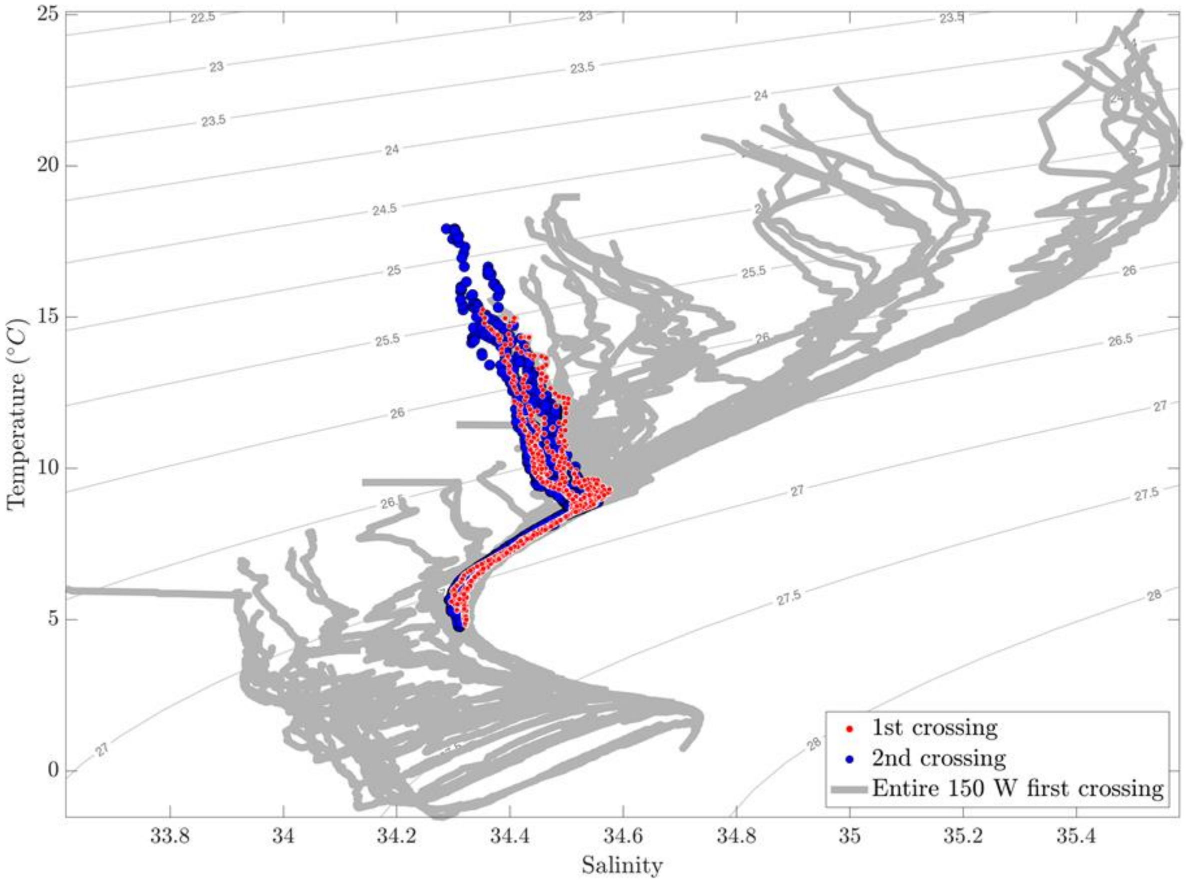


Figure 77. Temperature-salinity properties of the 43-45 S portion of the meridional transect, comparing the first and second occupations to the envelope of variability for all measurements.

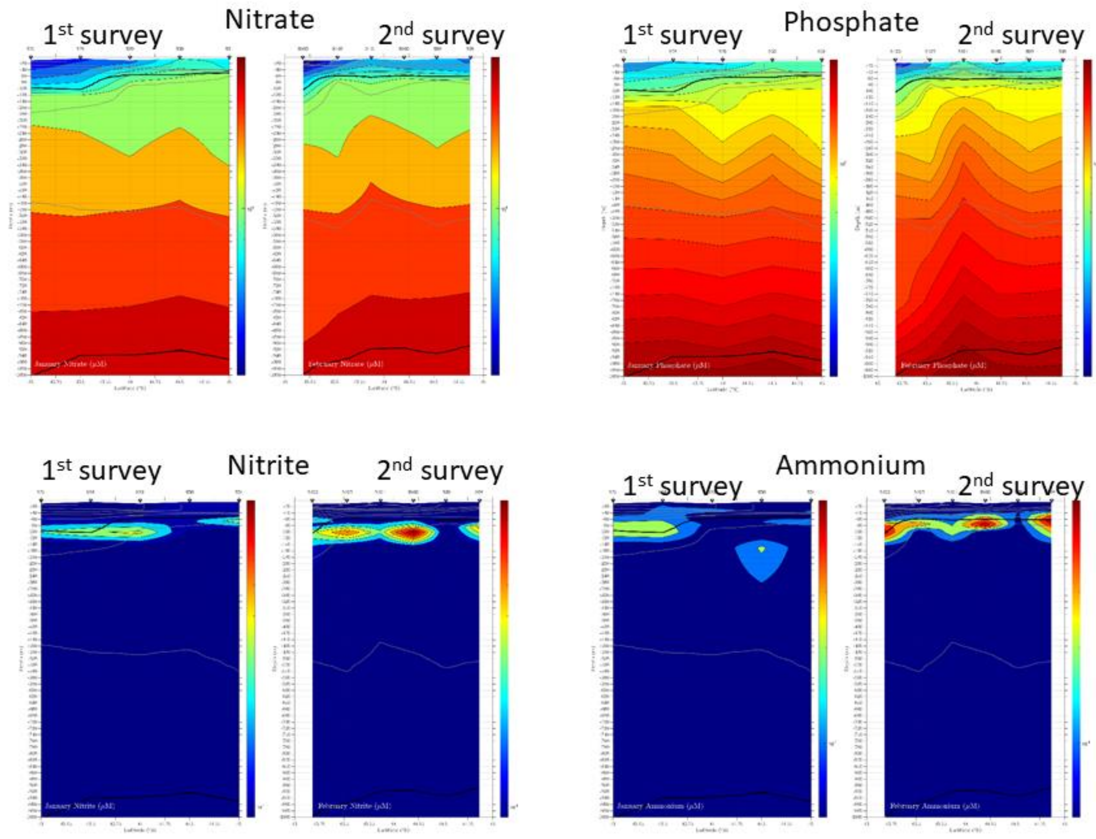


Figure 78. Comparison of nutrient sections from the first and second surveys of the 150W transect between 43 and 45S.

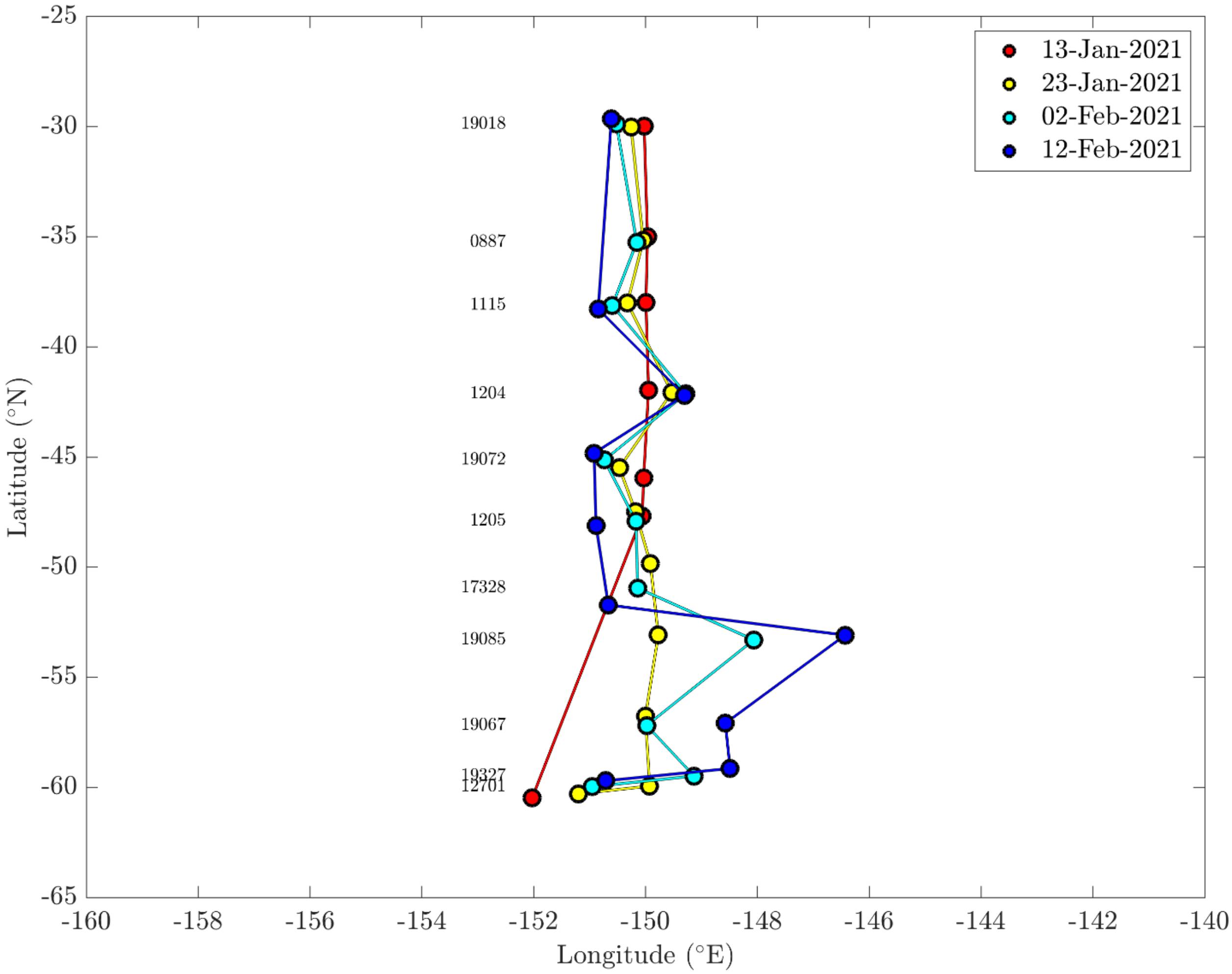


Figure 79. Locations of the 10 SOCCOM floats deployed during RR2004, and float 12701 for the four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021.

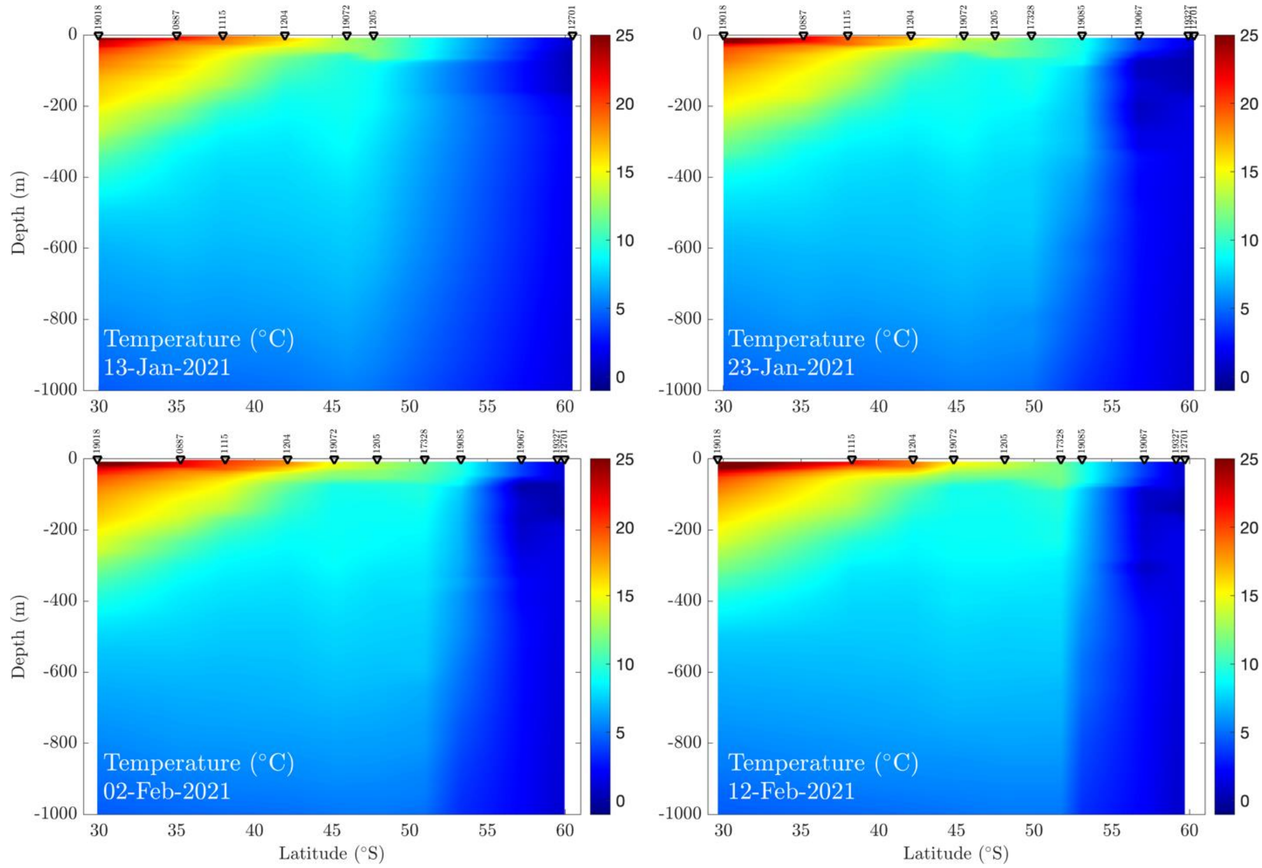


Figure 80. Cross-sections of temperature measured by SOCCOM floats for four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021. Float locations are plotted in Figure 79.

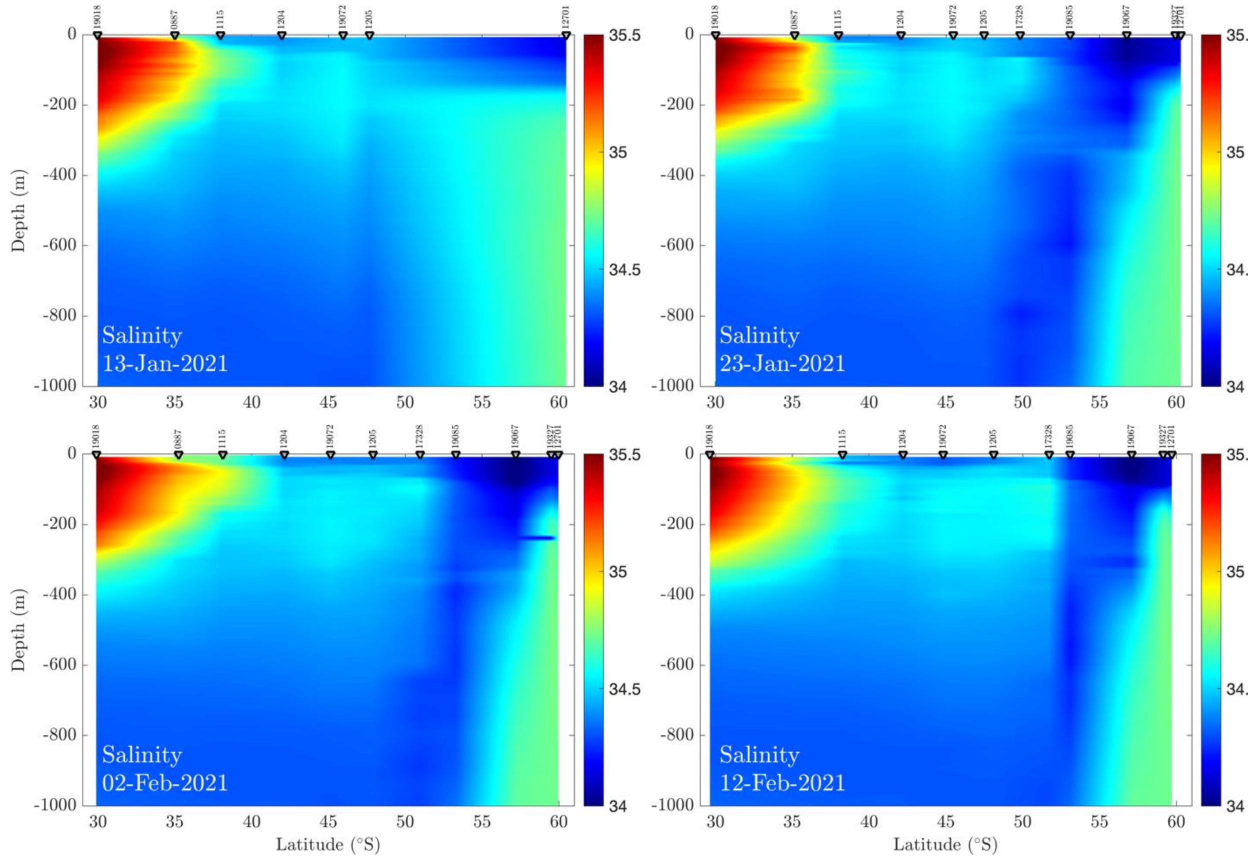


Figure 81. Cross-sections of salinity measured by SOCCOM floats for four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021. Float locations are plotted in Figure 79.

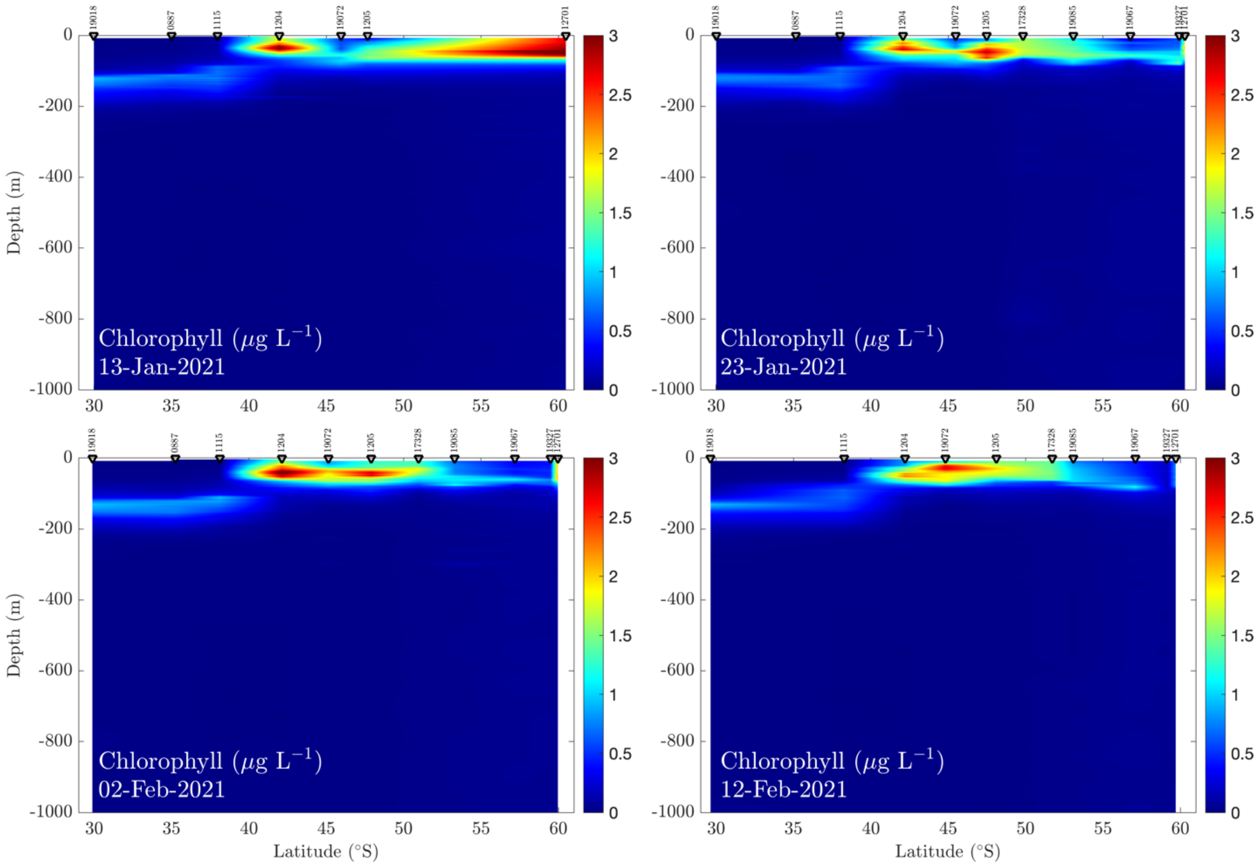


Figure 82. Cross-sections of chlorophyll concentrations estimated from SOCCOM float fluorometers for four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021. Float locations are plotted in Figure 79.

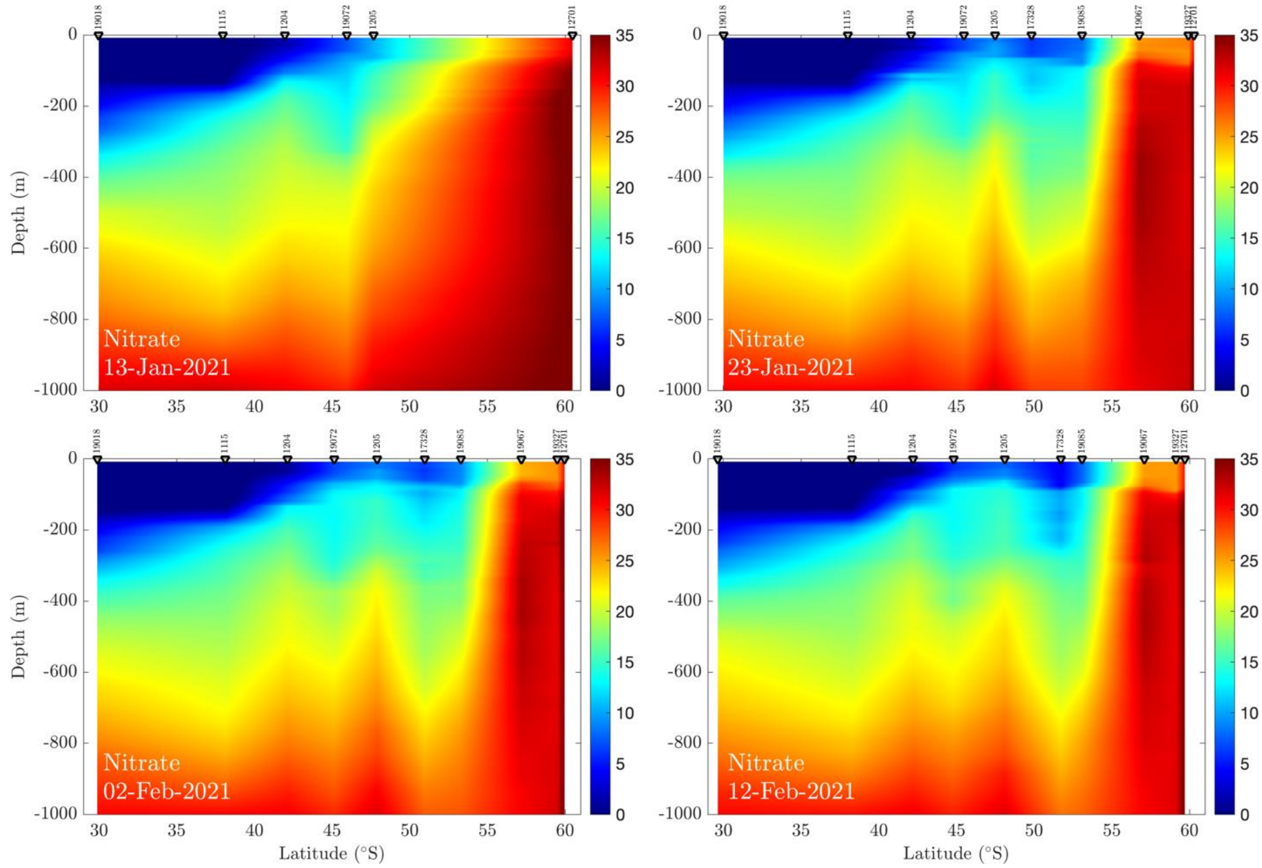


Figure 83. Cross-sections of nitrate estimated from SOCCOM float optical nitrate sensors for four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021. Float locations are plotted in Figure 79.

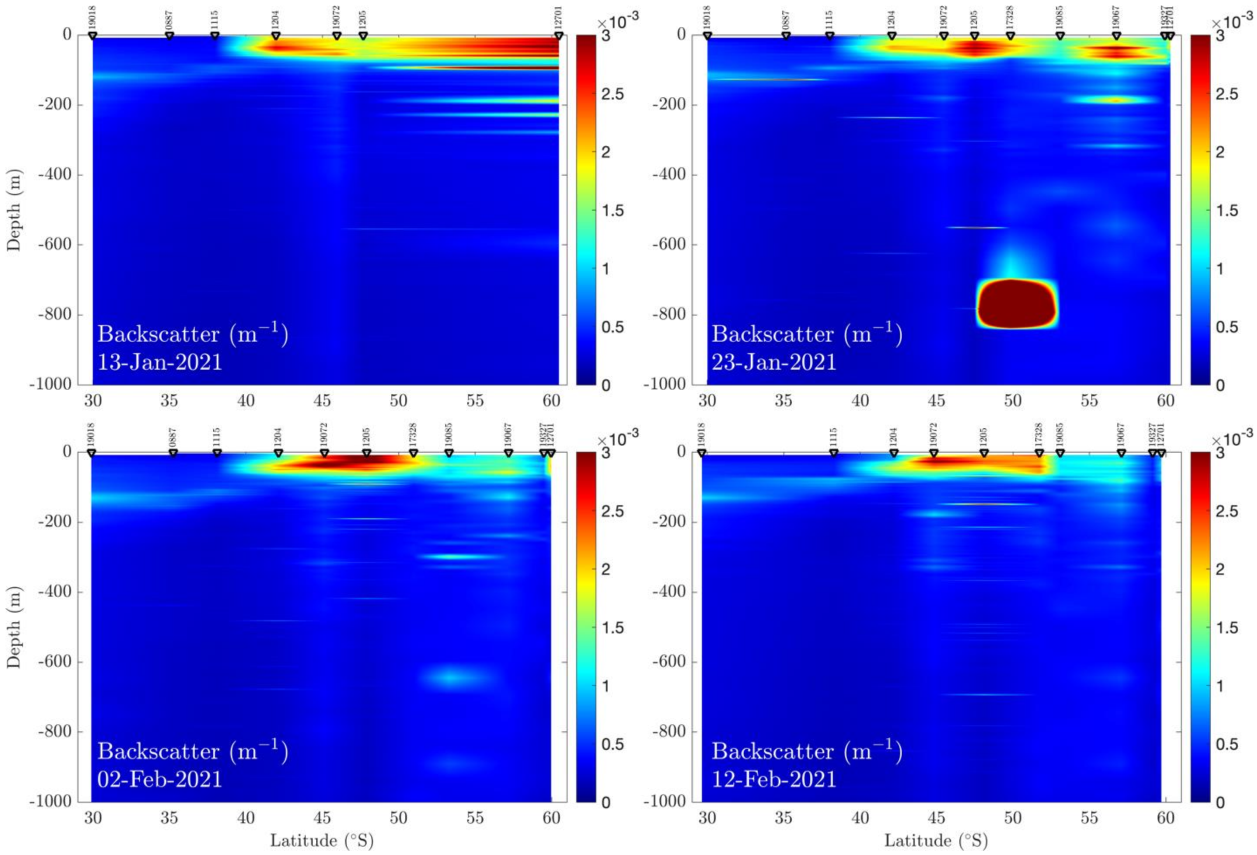


Figure 84. Cross-sections of backscatter (bbp700) measured by SOCCOM floats for four 10-day periods centered at 13 January, 23 January, 2 February, and 12 February 2021. Float locations are plotted in Figure 79.

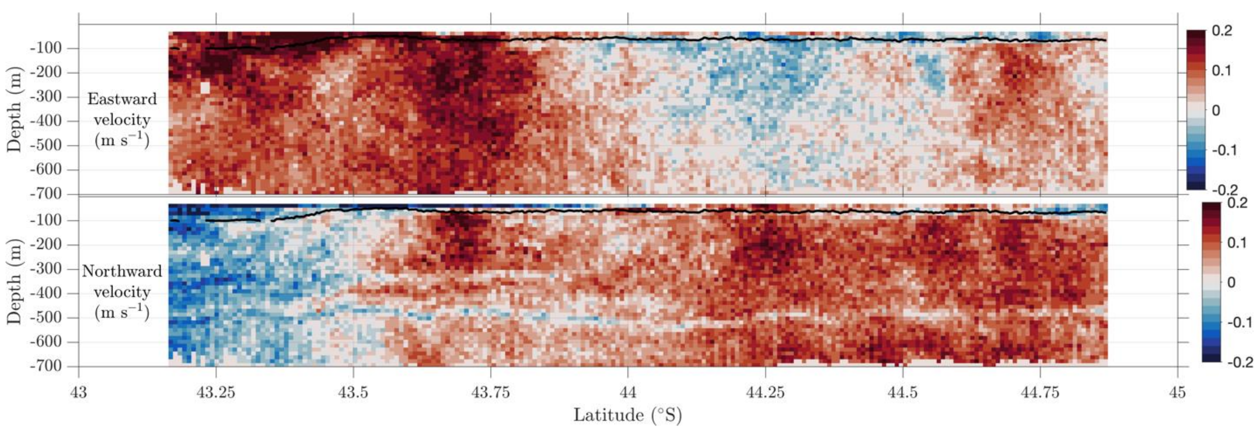


Figure 85. Cross-section of 75 KHz narrowband ADCP data recorded during VPR 13.

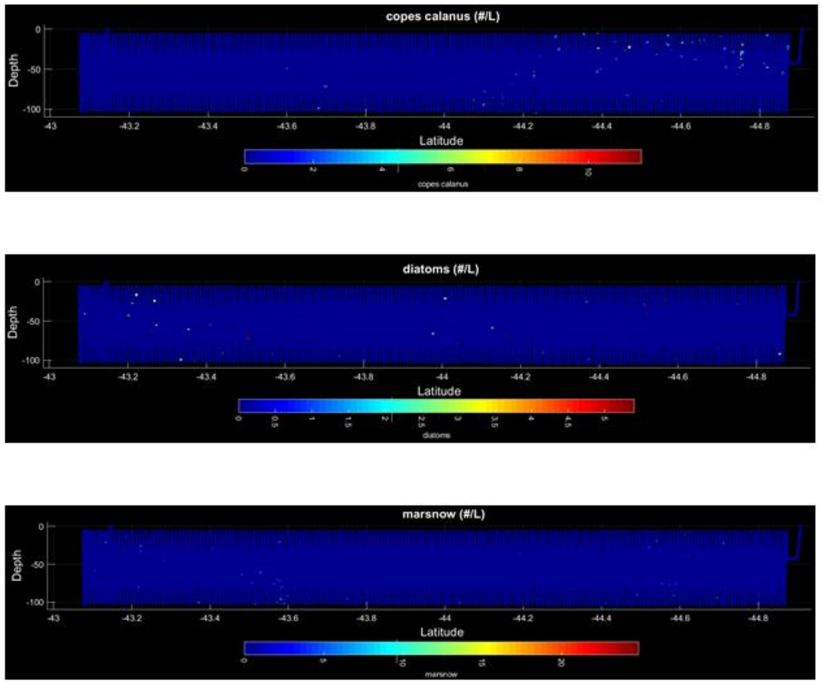


Figure 86. Taxon plot for VPR 13.

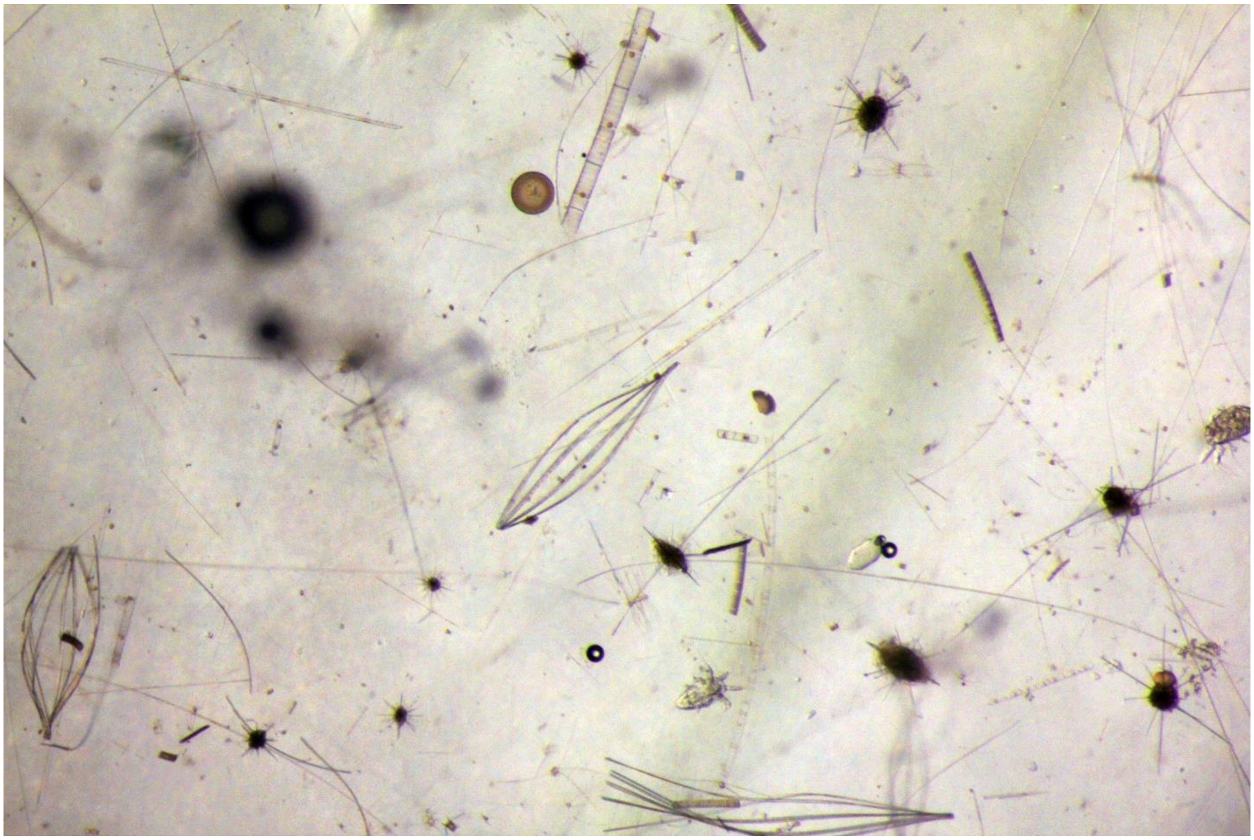


Figure 87. Microscope picture of Thalassiosira antarctica colonies, single cells, diatom chains, a centric diatom, acantharian & radiolarian protozoans, copepod nauplii from plankton net sample.

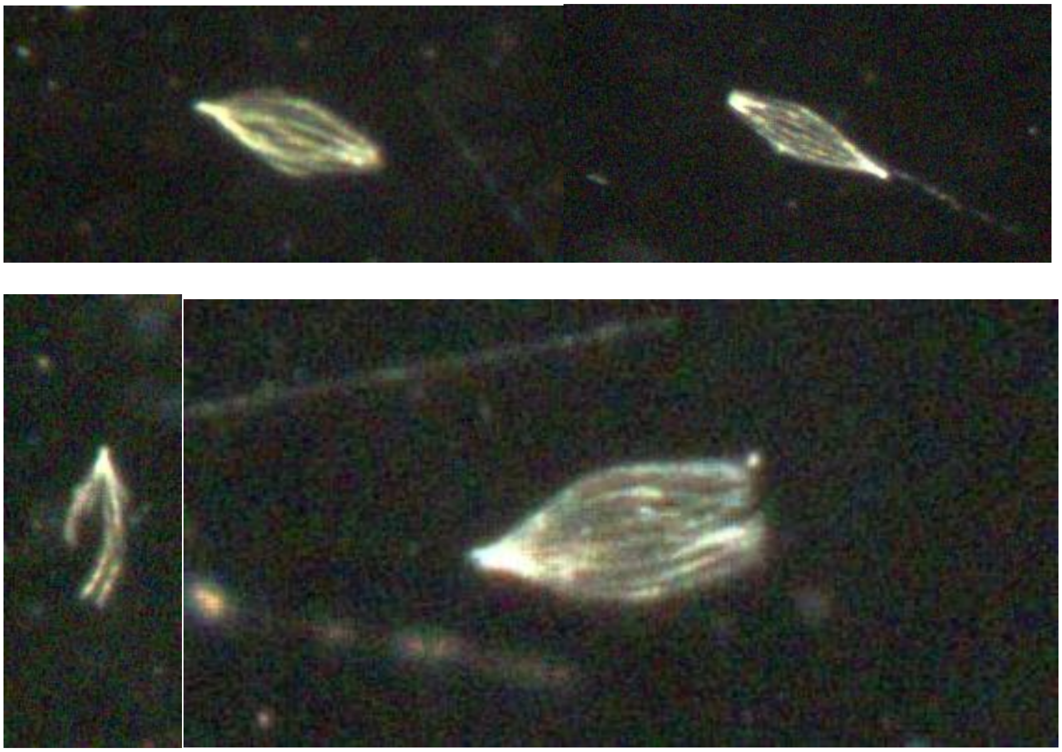


Figure 88. Diatom colonies, presumed to be Thalassiothrix antarctica in various configurations, from DAVPR video images.

Appendix 1. Evaluation and calibration of CTD conductivity and oxygen sensors

Salinity

For the first 62 stations of RR2004, there was a consistent salinity offset of 0.016 ± 0.033 between conductivity sensors. There was a 0.013 ± 0.006 difference in salinity estimated from the salinometer and conductivity sensor 1, and a -0.004 ± 0.034 difference for conductivity sensor 2. The large standard deviations in the offset for conductivity sensor 2 were due to casts 32 and 33, where the pump for CTD 2 became disconnected. Removing these stations reduces the salinometer/conductivity sensor 2 offset to -0.0005 ± 0.006. Given the high agreement of conductivity sensor 2 with the salinometer, conductivity sensor 1 was replaced for stations 63 through the end of the cruise. After switching out the sensor, the difference between salinities between conductivity sensor 1 and 2 was reduced to 0.004 ± 0.002 (Figure S1), with a difference between the salinometer and CTD 1 0.0001 ± 0.0233 and a difference between the salinometer and CTD 2 of -0.0039 ± 0.0233. The difference between CTD 1 and the salinometer and CTD 2 and the salinometer was statistically significant (Student's t-test, $t = -49.9$, 95% confidence interval: -0.0041 – -0.0038, $p < 0.001$, 452 degrees of freedom), and so the salinometer measurements are significantly better represented by salinities measured by CTD 1 than CTD 2 for stations 63 onwards.

To summarize: users of salinities from RR2004 conductivity sensors should consider 1) applying a correction factor of ~ 0.01 to conductivity sensor 1 salinities, at least for stations 32 and 33 where conductivity sensor 2 was not operational, 2) using salinities from conductivity sensor 2 for stations 1-62, except stations 32 and 33, 3) using salinities from conductivity sensor 1 for stations 63 onward.

Oxygen

Systematically low measurements recorded by CTD oxygen sensor during casts 1 and 2 led to its replacement for the remainder of the cruise. For stations 3 and onward, there was good agreement between the O_2 sensor and the oxygen measurements made in the Hydrolab (Figure S2), with

$$O2 = 1.0079[CTD\ O2] + 0.0643$$

which has $R^2 > 0.99$. For stations 1-2, the calibration is

$$O2 = 1.5205[CTD\ O2] + 0.9027$$

which has $R^2 = 0.91$.

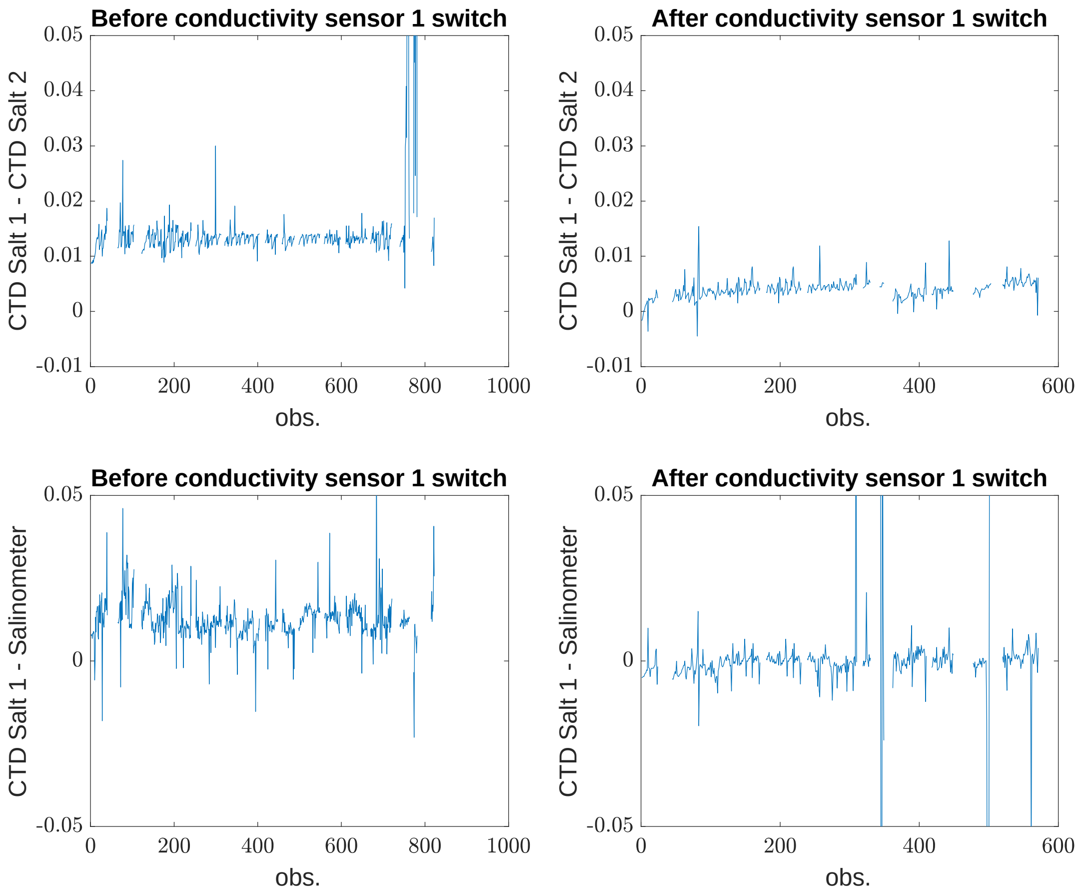


Figure S1. Differences between salinities for conductivity sensor 1 and conductivity sensor 2, and between conductivity sensor 1 and the salinometer.

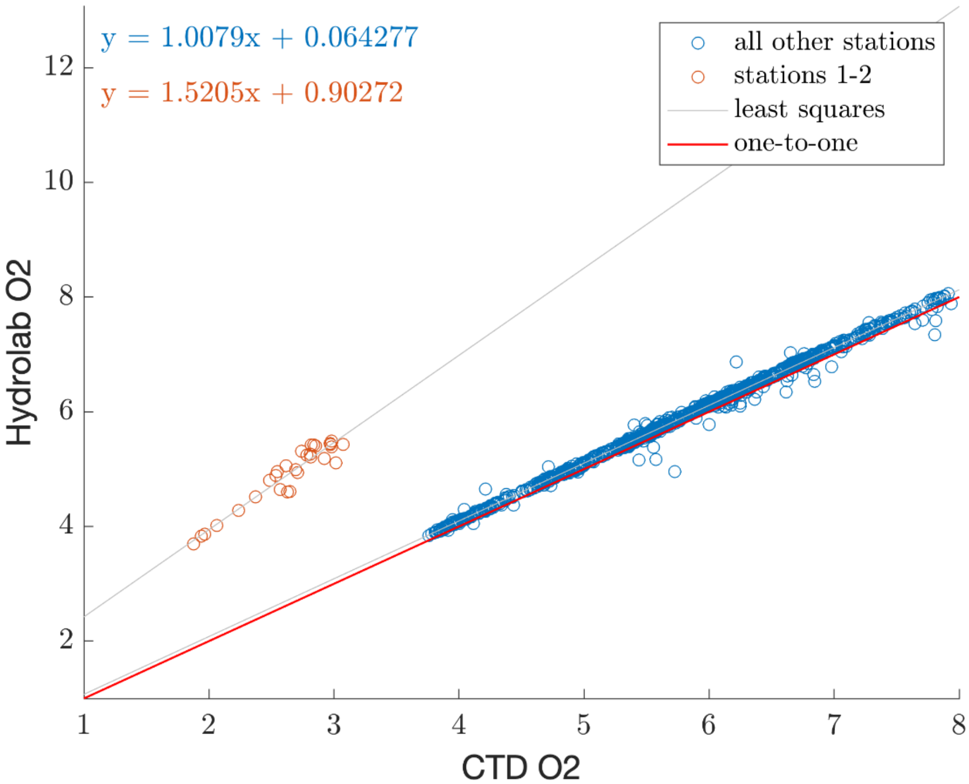


Figure S2. Agreement between the Hydrolab O2 measurements and the CTD oxygen sensor.

Appendix 2. Initial vetting of CNN classification of VPR imagery

The following table includes a summary of the most abundant taxa observed in RR2004. Two classifiers were used: CNN6 and CNN4(10b). All taxa with over 500 ROIs and/or were interesting for another reason (bloom, etc.). Overall CNN6 is more accurate for these purposes, although in a few cases CNN4(10b) performed better. Taxa for which the resulting distributions are reliable based on preliminary analysis are indicated in bold.

Tow 2 (47 S -> 50 S, Day 014-015):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
Y	**CNN6**	**Acanth_spike**	**5979**	**Highly Accurate**
	CNN6	Alga_colonial	3228	All OOF or Bubbles
	CNN6	Chaetog	1501	Mostly Acanth, some bubbles
Y	**CNN6**	**Copes_calanus**	**521**	**Early tow is all krill, later hours are large copepods**
Y	**CNN6**	**Copes_small**	**2108**	**Highly Accurate**
Y	**CNN6**	**Diatoms**	**14900**	**Highly Accurate**
	CNN6	Fecal_strings	2565	Accurate, but distribution is pretty much a more sparsely populated version of marine snow
Y	**CNN6**	**Marsnow**	**10775**	**Accurate, with a some out of focus Acanth included**
	CNN6	Trichodesmium	600	Mostly copepods and marine snow

Tow 3 (50 S -> 53 S, Day 016-017):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
Y	**CNN6**	**Acanth_spike**	**6828**	**Highly Accurate**
	CNN6	Alga_colonial	5416	All OOF or Bubbles
	CNN6	Chaetog	716	Mix of Acanth, gelatinous, krill, and chaetognaths
Y	**CNN6**	**Copes_calanus**	**1739**	**Predominately normal copepods, with a bias towards *Calanus*-like. Some krill.**
	CNN6	Copes_pseudo-calanus_w_eggs	973	Even split between actual copepods with egg sacs, marine snow, and too OOF to distinguish between the two
Y	**CNN6**	**Copes_small**	**4122**	**Highly Accurate**
Y	**CNN6**	**Diatoms**	**11720**	**Highly Accurate**
	CNN6	Diatoms_ coscinodiscus	542	Marine snow and blurry copepods
	CNN6	Fecal_strings	3887	Accurate, but distribution is pretty much a more sparsely populated version of marine snow

Y	**CNN6**	**Marsnow**	**26171**	**Highly Accurate**
	CNN6	Trichodesmium	1446	Mostly acanth and blurry copepods

Tow 4 (53 S -> 56 S, Day 019-020):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	3004	Mix of copepods, chaetognaths, worms, and ghost colonies
Y	**CNN6**	**Copes_calanus**	**2042**	**Mostly copepods, some pteropods and worms.**
Y	CNN6	Copes_small	409	Accurate, with the occasional other taxa
Y	**CNN6**	**Diatoms**	**5144**	**Highly Accurate**
Y	CNN4(10b)	Diatoms	1949	Diatoms and fecal strings
Y	CNN4(10b)	Diatoms_bloom	521	Accurate, diatom dense conditions with about half showing colonial alga
Y	**CNN6**	**Diatoms_bloom _discrete**	**370**	**Highly Accurate**
Y	CNN6	Diatoms_bloom _snow	1122	Accurate, though the snow observed was predominately Phaeo/diatom mats
	CNN6	Fecal_strings	1249	Even split between fecal strings and worms
Y	CNN6	Marsnow	146557	Mostly colonial alga within blooms
Y	**CNN4(10b)**	**Marsnow**	**26260**	**Accurate**
Y	**CNN4(10b)**	**Phaeo**	**624**	***P. antarctica* and colonial algae**
Y	**CNN4(10b)**	**Phaeo_bloom**	**70997**	**Colonial algae with some *P. antarctica* and ghost colonies**

Tow 5 (56 S -> 60 S, Day 022-023):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	6011	Complete mess of other taxa
Y	**CNN6**	**Copes_calanus**	**1786**	**Highly Accurate, all copepods**
	CNN6	Copes_pseudo-calanus_w_eggs	876	Some copepods with eggs, mostly marine snow
Y	CNN6	Copes_small	422	Accurate, but with low abundance
Y	**CNN6**	**Diatoms**	**10463**	**Highly Accurate**
Y	CNN4(10b)	Diatoms	2017	Mostly diatoms with some fecal strings
Y	**CNN6**	**Diatoms_bloom _discrete**	**222**	**Highly Accurate**

	CNN6	Fecal_strings	1919	Even split between fecal strings and worms, worms absent for second, southern bloom
Y	CNN6	Marsnow	51074	Mostly colonial algae within blooms
Y	**CNN4(10b)**	**Marsnow**	**10907**	**Accurate**
Y	**CNN4(10b)**	**Phaeo**	**342**	**Colonial algae throughout entire tow**
Y	**CNN4(10b)**	**Phaeo_bloom**	**27204**	**Phaeo_bloom (colonial algae for 56 S bloom, fecal strings and marine snow in bloom conditions for second, southern bloom (though Phaeo and marsnow (CNN6) taxa say there are some there)**

Tow 7 (Finish NE transit to Eddy A, SW->NE through Eddy A, Day 026-027)):
Strobe died d026, h18. Minimal ROIs were collected after this point.

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	11233	Worms, copepods, chaetognaths, some gelatinous organisms
Y	**CNN6**	**Copes_calanus**	**779**	**Accurate with occasional worms**
	CNN6	Copes_small	24	Accurate, but with low abundance
	CNN6	Decapods_misc	861	Various OOF
Y	**CNN6**	**Diatoms**	**948**	**Accurate, with an occasional copepod (after bloom)**
Y	CNN4(10b)	Diatoms	1092	Accurate with some fecal strings
Y	CNN6	Marsnow	6006	Not accurate, mostly other taxa
Y	**CNN4(10b)**	**Marsnow**	**2010**	**Accurate, with some colonial algae**
	CNN4(10b)	Phaeo	77	*P. antarctica* and colonial algae (located within frontal bloom). Omitted due to low abundance
	CNN4(10b)	Phaeo_bloom	21	Bubbles

Tow 9 (NW->SE through Eddy A, Day 027-028):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	525	Worms, copepods, and chaetognaths
Y	**CNN6**	**Copes_calanus**	**1062**	**Accurate with occasional worms**
	CNN6	Copes_small	63	Accurate, but with low abundance
Y	CNN6	Diatoms	574	Inaccurate, mostly zooplankton

Y	CNN4(10b)	Diatoms	697	Inccurate, mostly zooplankton with some diatoms and fecal strings
Y	CNN6	Marsnow	5568	Accurate with some zooplankton
Y	**CNN4(10b)**	**Marsnow**	**4632**	**Accurate**
	CNN4(10b)	Phaeo	127	Almost entirely marine snow but there were a few *P. antarctica* within the eddy
	CNN4(10b)	Phaeo_bloom	46	Bubbles

Tow 10 (Cross through Polar Front South of Eddy B, Day 030-031):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	2073	Colonial algae, chaetognaths, copepods
Y	**CNN6**	**Copes_calanus**	**1009**	**Accurate with occasional other taxa**
	CNN6	Copes_small	68	Accurate, but with low abundance
Y	**CNN6**	**Diatoms**	**2181**	**Accurate, with some fecal strings**
Y	CNN4(10b)	Diatoms	2040	Accurate, with some fecal strings
Y	**CNN6**	**Marsnow**	**12263**	**Accurate with some diatom mats**
Y	CNN4(10b)	Marsnow	9119	Accurate with some diatom mats
Y	CNN4(10b)	Phaeo	321	*P*. antarctica, colonial algae, marine snow, and pteropods
	CNN4(10b)	Phaeo_bloom	67	Bubbles

Tow 11 (Eddy C, Day 032-033):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	1323	Chaetognaths and copepods with some other taxa
Y	**CNN6**	**Copes_calanus**	**1291**	**Accurate with occasional other taxa**
	CNN6	Copes_small	79	Accurate, but with low abundance
Y	**CNN6**	**Diatoms**	**1392**	**Accurate, with some fecal strings**
Y	CNN4(10b)	Diatoms	1268	Accurate, with some other taxa
Y	**CNN6**	**Marsnow**	**6143**	**Accurate with some diatom mats and pteropods**
Y	CNN4(10b)	Marsnow	4760	Accurate with some diatom mats and pteropods
Y	CNN4(10b)	Phaeo	142	*P*. antarctica, colonial algae, marine snow, and pteropods
	CNN4(10b)	Phaeo_bloom	30	Bubbles

Tow 12 (West of Eddy C through Eddy A, Eddy 0, and Subantarctic front, Day 034-035):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	1274	Chaetognaths, gelatinous, copepods
Y	**CNN6**	**Copes_calanus**	**3261**	**Accurate with some worms**
	CNN6	Copes_small	210	Accurate, but with low abundance
Y	**CNN6**	**Diatoms**	**1744**	**Accurate, with some fecal strings**
Y	CNN4(10b)	Diatoms	1805	Accurate, with some other taxa
Y	**CNN6**	**Marsnow**	**6502**	**Highly Accurate**
Y	CNN4(10b)	Marsnow	5385	Accurate with some other taxa
Y	CNN4(10b)	Phaeo	266	Mostly marine snow
	CNN4(10b)	Phaeo_bloom	22	Bubbles

Tow 13 (NW->SE through Eddy A, Day 037-038):

Plotted	Classifier:	Taxon:	# ROIs in Taxon:	Other Notes:
	CNN6	Chaetog	176	Bubbles
Y	**CNN6**	**Copes_calanus**	**116**	**Accurate, though there are few ROIs**
	CNN6	Copes_small	10	Accurate, but with low abundance
Y	**CNN6**	**Diatoms**	**82**	**Accurate with some other taxa**
Y	**CNN6**	**Marsnow**	**156**	**Accurate with some other taxa**

Initial analysis of ROI data yielded some suggestions for additional taxa to add to future classifiers, summarized in the following table.

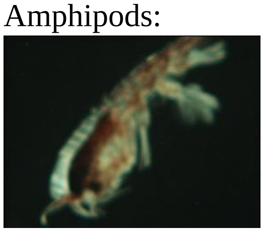
Preliminary taxon name:	Reason to add:	Sources in CNN:
Acanth w/ ID	Currently not a taxon, reduce false positives in other taxa	All tows: acanth_spike_amphilonche Tow 2, 3: chaetog Tow 2: marsnow Tow 3: trichodesmium
Amphipods	Currently not a taxon	Tow 9: Large ROIs
Colonial Algae	Currently not a taxon (though AR29 Phaeo works reasonably well)	Tow 4: Phaeo (CNN6, CNN4(10b))
Colonial Algae Bloom	Currently not a taxon (though AR29 Phaeo_bloom works reasonably well)	Tow 4: Marsnow (CNN6), Phaeo_bloom (CNN4(10b))
Diatoms _Chaetoceros	Split into several different subtaxa?	Tow6: Trichodesmium
Diatom Mats	Combine with diatoms_bloom _discrete? Or create new taxa?	VPR5: Southern bloom seems to be ideal
Eucalanus	Split copepods into better defined taxa	
Forams	Expand current trrois	CNN6 works well for most tows.

Gelatinous	Improve trrois, perhaps get enough to split into more specific taxa (medusas, salps, etc.)	All tows: gelatinous Can also find ROIs for large taxa by sorting by size
Krill	Currently not a taxon	All tows: copepod taxa (calanus best bet) Tow 3: chaetog
OOF_bubbles	VPRII bubbles are distinct	All Tows: At deployment and retrieval Decapods_misc is also usually bubbles.
Paracalanus	Split copepods into better defined taxa	
Phaeocystis antarctica	Currently not a taxon	Tow 4: marsnow (CNN6) in bloom conditions, Phaeo (CNN4(10b))
P. antarctica ghost colonies	Currently not a taxon	Tow 4: chaetog
Phaeod_knob_ Pcystida	Expand current trrois	CNN6 works well for most tows.
Phil's Unknown (Spindles?)	Currently not a taxon, cooccurs at bloom	Tow 4: No specific taxa
Pteropods	Missing most pteropods, would be good to grab more trrois	Tow 4: copes_calanus, copes_small
Worms	Currently not a taxon, cooccurs at bloom	Tow 4: copes_calanus, trichodesmium

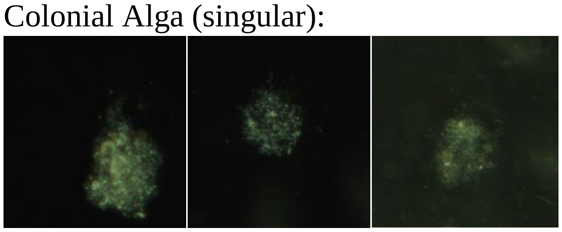
Sample ROIs from RR2004 new taxa

Acanth w/ ID:

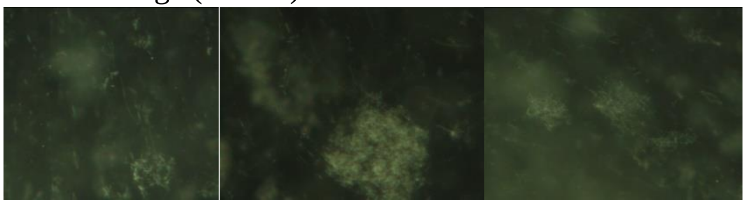
Amphipods:



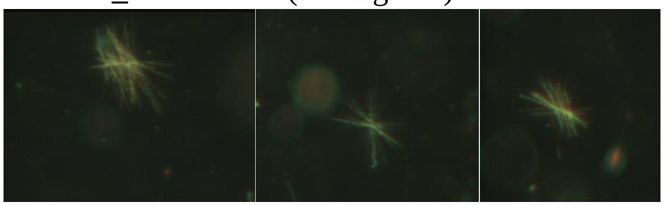
Colonial Alga (singular):



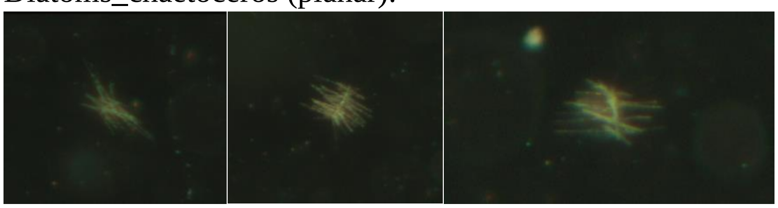
Colonial Alga (Bloom):



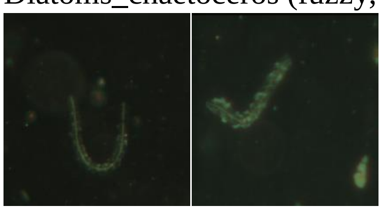
Diatoms_chaetoceros (Orthogonal):



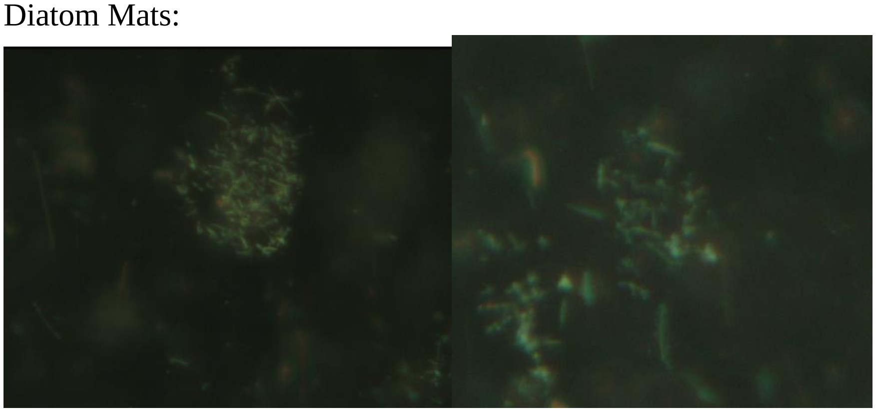
Diatoms_chaetoceros (planar):



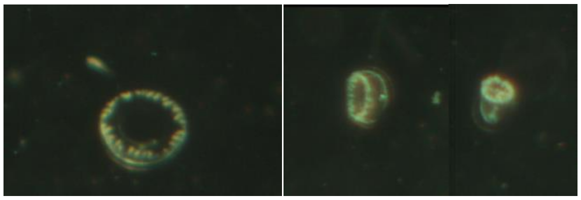
Diatoms_chaetoceros (fuzzy, short spines):



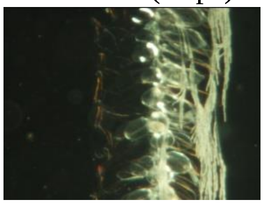
Diatom Mats:



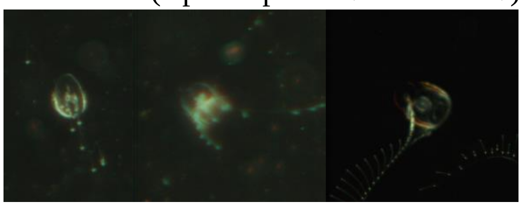
Gelatinous (medusa, in rr2004 ROIs as cool_jelly):



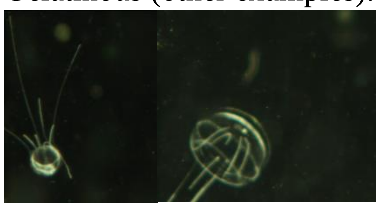
Gelatinous (salps):



Gelatinous (siphonophores? Medusa 2?):

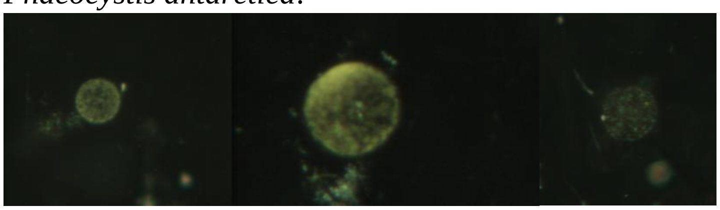


Gelatinous (other examples):



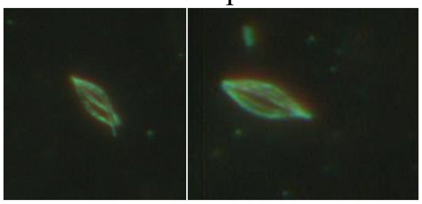
Krill (and krill-like):

Phaeocystis antarctica:

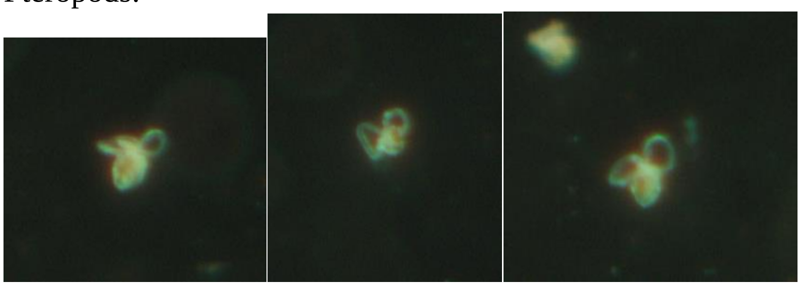


P. antarctica ghost colonies:

Phil's unknown spindles:



Pteropods:



Worms (polychaetes):

Additional analysis was conducted to determine presence / absence of new and/or poorly classified taxa. These results are presented in the table below, as well as in the lower panels of the taxon plots presented in the main body of this report.

VPR 2:

Preliminary taxon name:	Hours:	Notes
Acanths	16-01	See taxon plots for distribution
Forams	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).

Krill	Throughout tow	Rare, red and White Colorations
Large Copepods w/ and w/o dark spots	4, 5, 6, 10	Rare, likely eucalanus or paracalanus.
Long egg sac copes	7, 8, 9	Small, hours listed is for most common. Later hours have presence but low abundance.
Phaeod_knob_Pcystida	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).
Red antennae and tail copepods	3, 5, 6	Calanus or calanoid, distinctive red antennae and band on tail. Low abundance in later hours.

VPR 3:

Preliminary taxon name:	Hours:	Notes
Acanths	Throughout tow	See taxon plots for distribution
Amphipods	14, 15	Rare
Blue backed Copes	13	Likely red antennae and tail copes with weird optics
Copes Microaggregations	4, 5, 14	Only present for isolated frames
Forams	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).
Krill	Throughout tow	Rare, red ends 6, silver starts 9, white throughout.
Large Copepods w/ and w/o dark spots	7	Rare, likely eucalanus or paracalanus.
Long egg sac copes	4, 8	Small, hours listed is for most common. Other hours have presence but low abundance.
Phaeod_knob_Pcystida	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).
Red antennae and tail copepods	23, 3, 11	Calanus or calanoid, distinctive red antennae and band on tail. Low abundance in other hours.
Smaller dark spot copes		Unknown if important, few found

VPR 4:

Preliminary taxon name:	Hours:	Notes
Amphipods	20, 0, 1, 5, 10	Rare
Chaetognaths	Throughout Tow	Rare, more common in dense bloom hours.
Copes Microaggregations	17	Only a single frame?
Forams	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).

Gelatinous	17 onwards	More common during blooms, with 3 marking another increase in abundance and 6 an increase in diversity
Krill	Throughout Tow	More common in bloom hours
Large Copepods w/ and w/o dark spots	H18	Rare, likely eucalanus or paracalanus.
Long egg sac copes	15 – 18, Rare 19 and 20	Copes_small with distinct egg sacs
Phaeod_knob_Pcystida	Throughout tow	Rare, our CNN correctly classifies them. Identical in appearance TN368 (to 1st order).
Pteropods	19 onwards	Most abundant in bloom hours
Red antennae and tail copepods; Orange Butt is same?	15 – 18, Rare 19 and 20; 17	Calanus or calanoid, distinctive red antennae and band on tail.
Upside down, clear copes	18 onwards	Most abundant in bloom hours
Worms	19 onwards	Most abundant in bloom hours

Bloom Progress:
A_Col=Alga Colonial; Dia_Mat=Diatom Mats; Ghost=Ghost colonies; P_Ant=*Phaeocystis antarctica*.

Preliminary taxon name:	H18	H19	H20	H21	H22	H23	H00	H01	H02
# ROIs:	2954	3920	8514	7483	8308	7924	6684	6812	10774
A_Col	Low	High	Low	Low	Low	Low	Low	Low	Bloom
Dia_Mat	Low?	Low?	Low?	Low	Low	Low	Low	Low	Bloom
Ghost	Low	Low	Low	Low	High	High	Low	Low	Bloom
P_Ant	Low	High	Low	Low, Ill	Low	Low	Low	Low	Bloom
Spindles									

Preliminary taxon name:	H03	H04	H05	H06	H07	H08	H09	H10	H11
# ROIs:	16763	14961	15467	16021	16396	13475	17050	12819	8170
A_Col	Bloom	Bloom	Bloom	Bloom	Bloom	High	High	High	Low
Dia_Mat	Bloom	Bloom	Bloom	Bloom	Bloom	High	High	High	Low
Ghost	Bloom	Bloom	Bloom	Bloom	Bloom	High	Low?	Low?	Absent?
P_Ant	Bloom	Bloom	Bloom	Bloom	Bloom	High	Low?	Low?	Absent?
Spindles			Only 1?			Only 1?	Low	Low*	High*

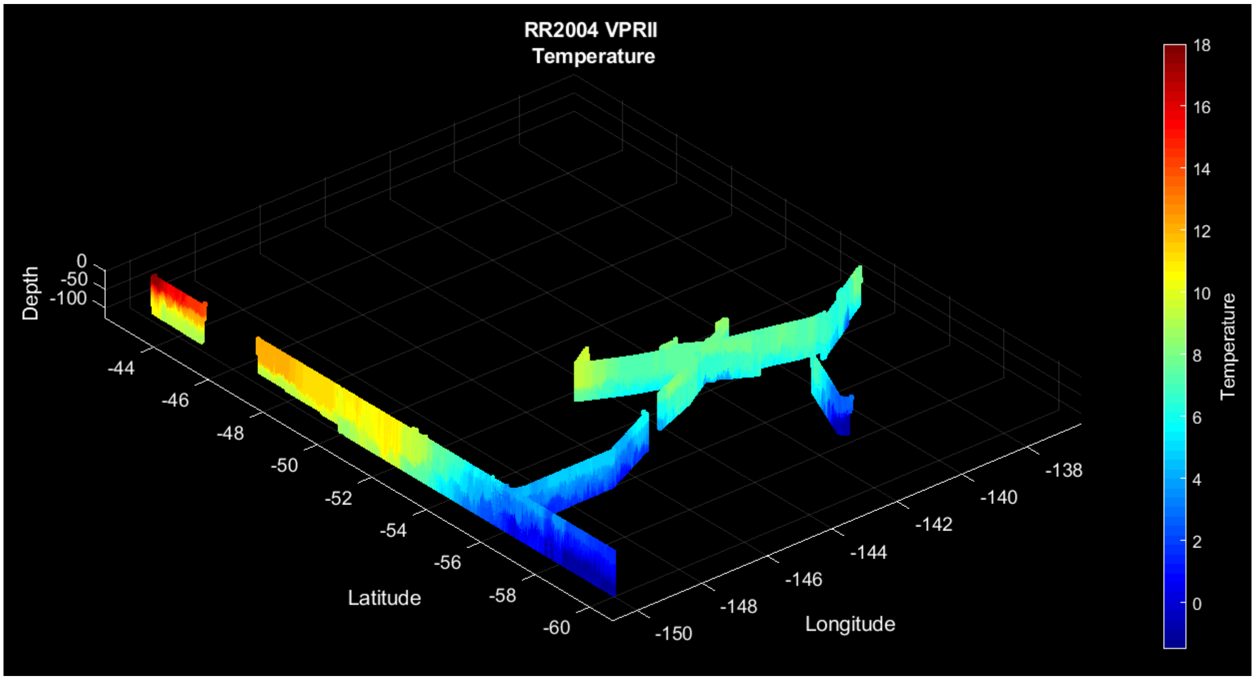
*With increase in spindles, so too does Chaetoceros, regular marine snow, and segmented diatoms

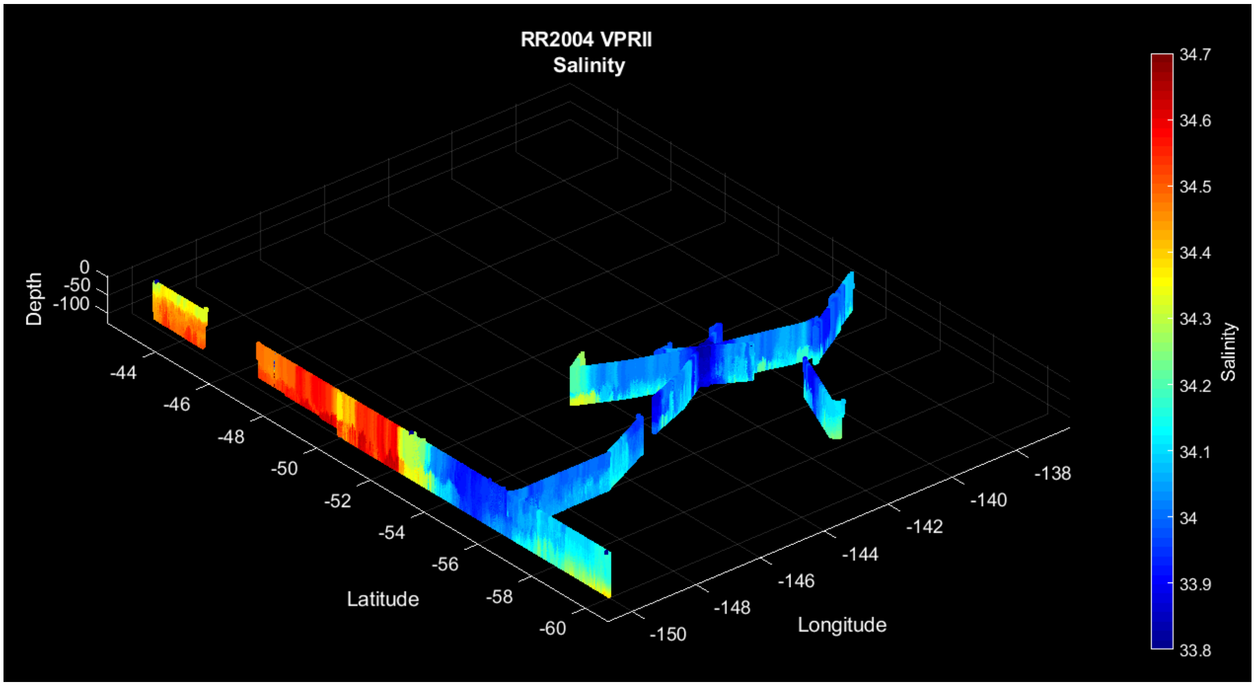
VPR 5:

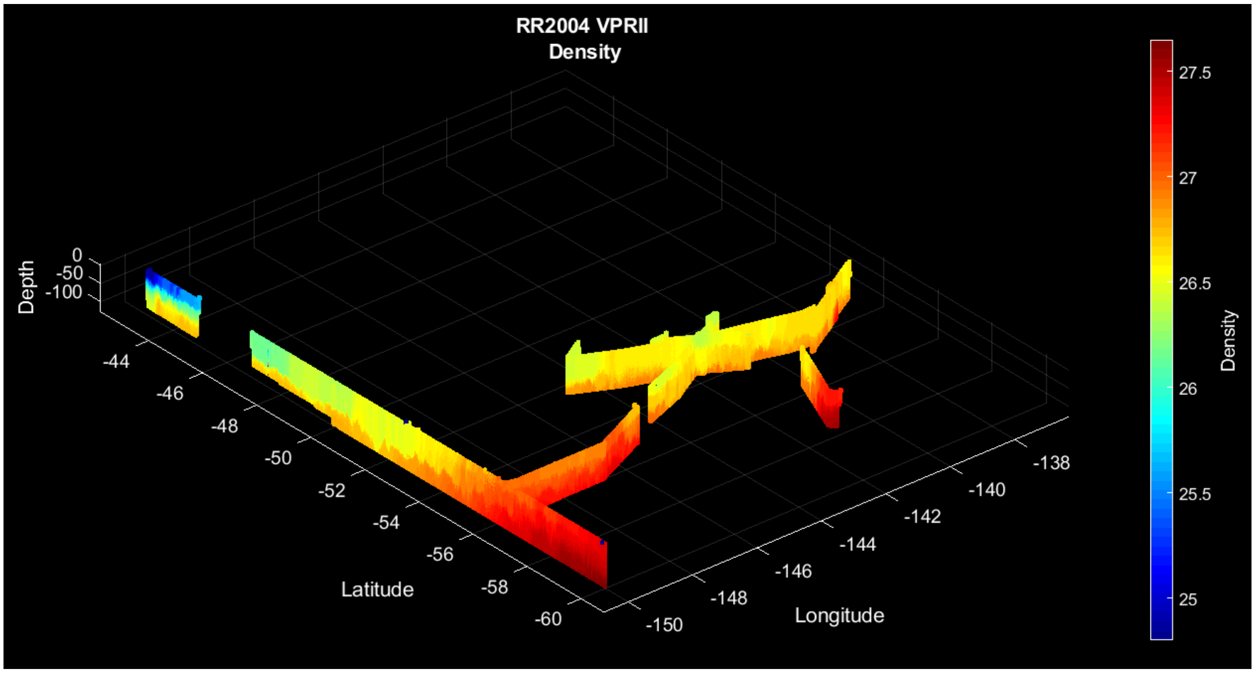
Preliminary taxon name:	Hours:	Notes
Amphipods	14, 17, 21	Rare
Chaetognaths	Throughout Tow	Rare, more common in dense bloom hours.
Polar Krill	H02-H07, H10, H12	Larger than normal krill below 58 S
Upside down, clear copes	Before H09	Included in H02-H07copepod increase

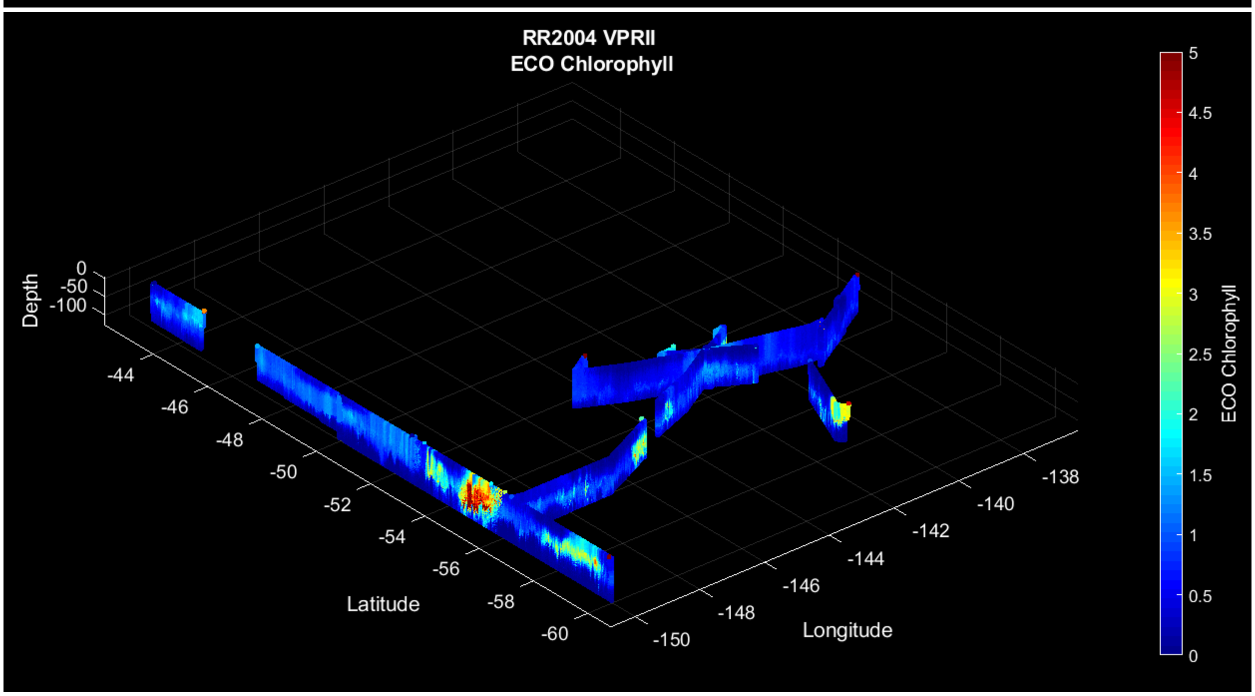
Hour (s):	Notes and Taxa:
H08:	Same as most of last tow: A_Col, P_Ant, Ghost, Pteropods, Worms
H09 & H10:	Chaetoceros, spindles, and segmented diatoms appear, other taxa fade
H11-H18:	No bloom, no A_Col or P_Ant. Present taxa are segmented diatom rods, spindles, worms, and pteropods
H19-H00	Bloom of diatoms (not mats, think diatoms_bloom_discrete) builds then falls. Spindles, segmented diatoms, chaetoceros common.
H01	Less of everything. A_Col appears, though it looks distinctly like marine snow and has no accompanying diatom mats
H02-H07	Lots of large zooplankton (Amphipods, polar krill, copes) and large fecal strings. Little to no phytoplankton (no spindles, Chaetoceros)
H08-H11	Salps particularly common.

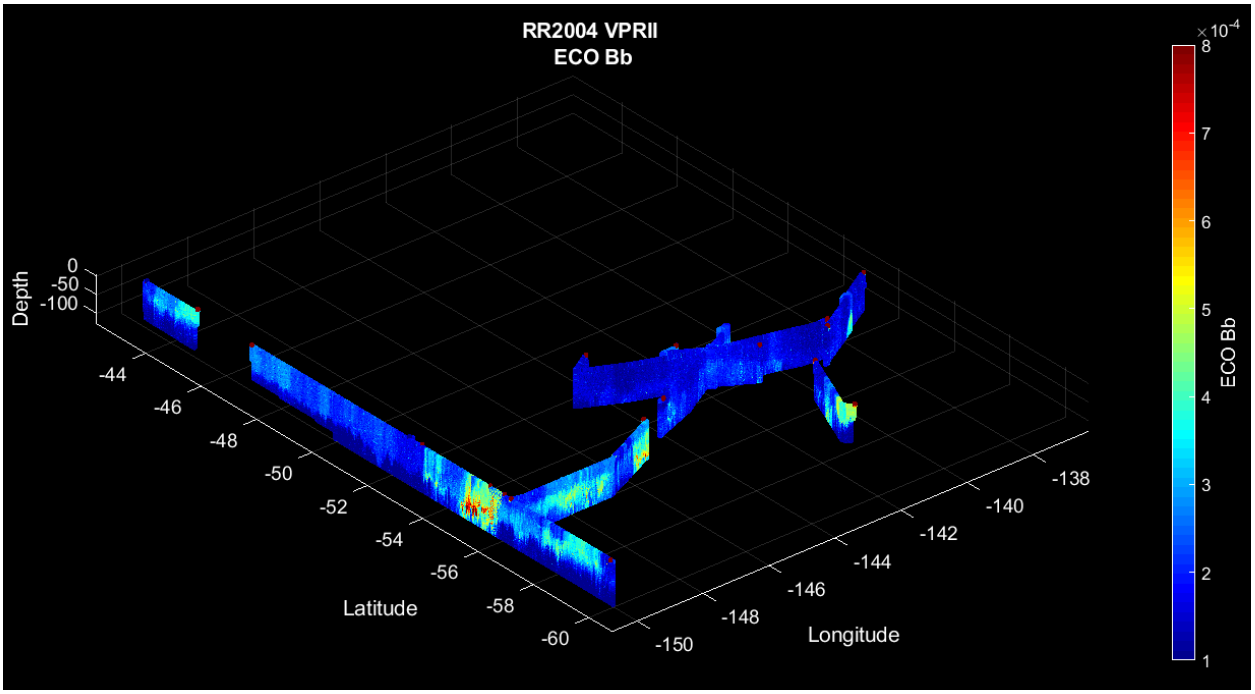
Appendix 3. Atlas of the hydrographic, bio-optical, and taxonomic plots for all VPR tows combined

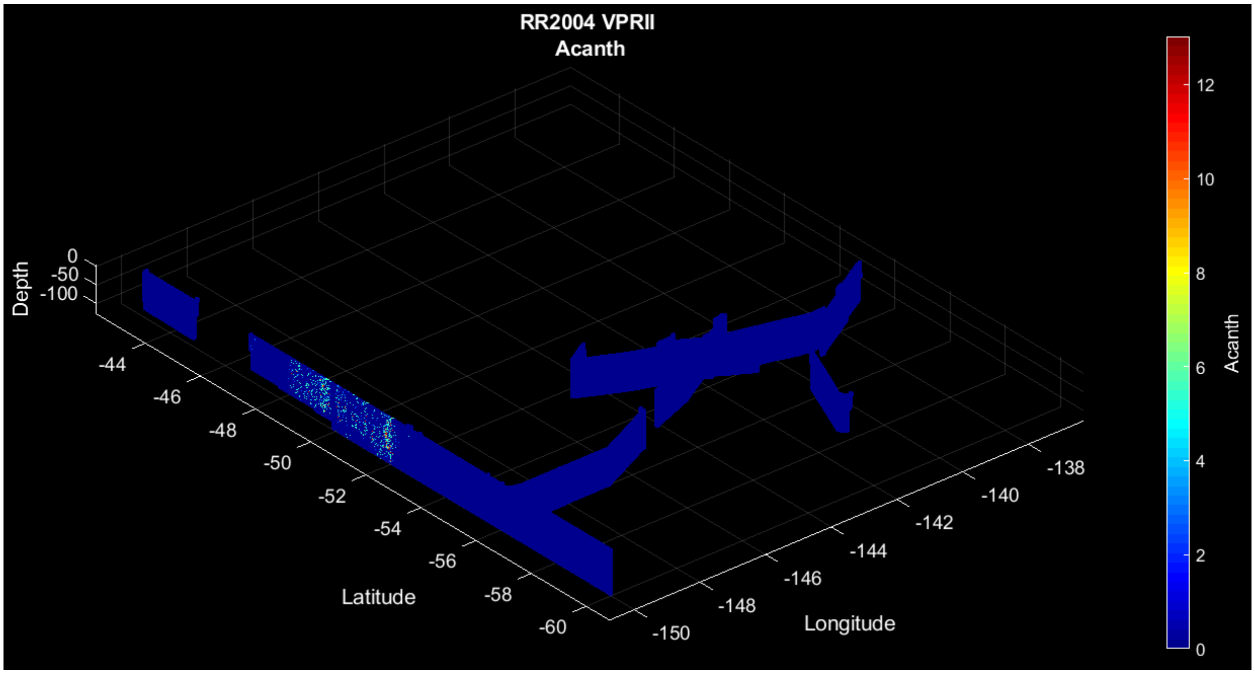


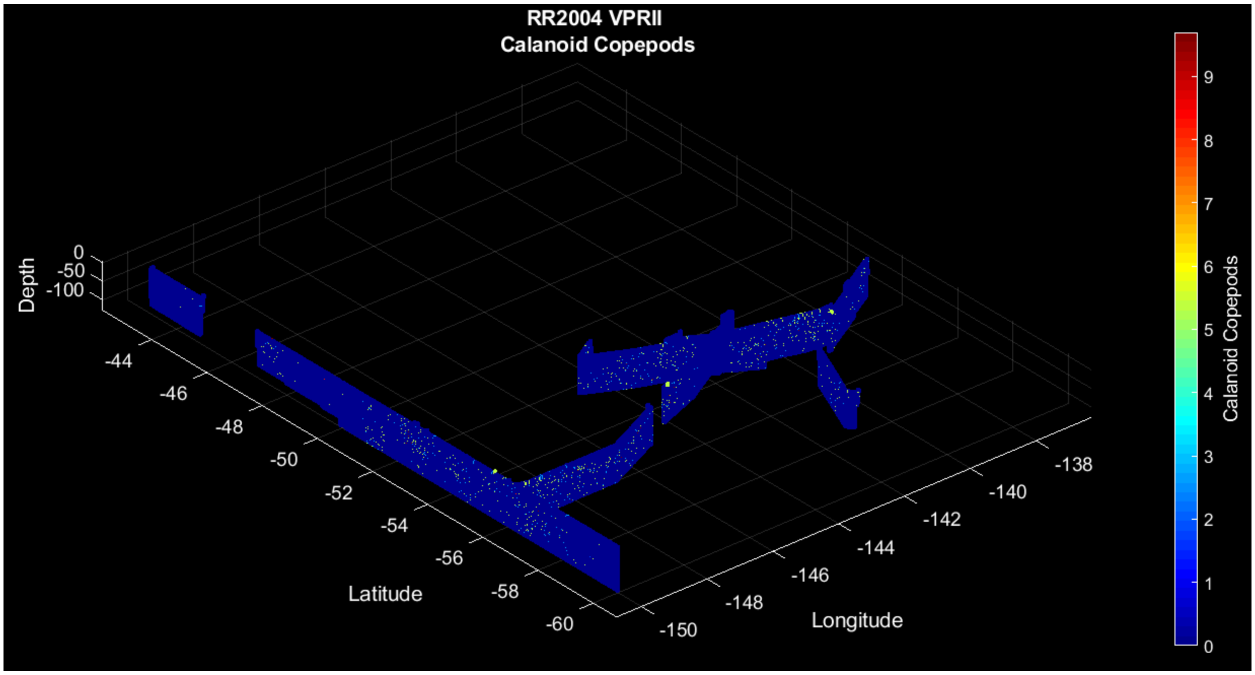



RR2004 VPRII
Density
Depth
0
-50
-100
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude
27.5
27
26.5
26
25.5
25
Density

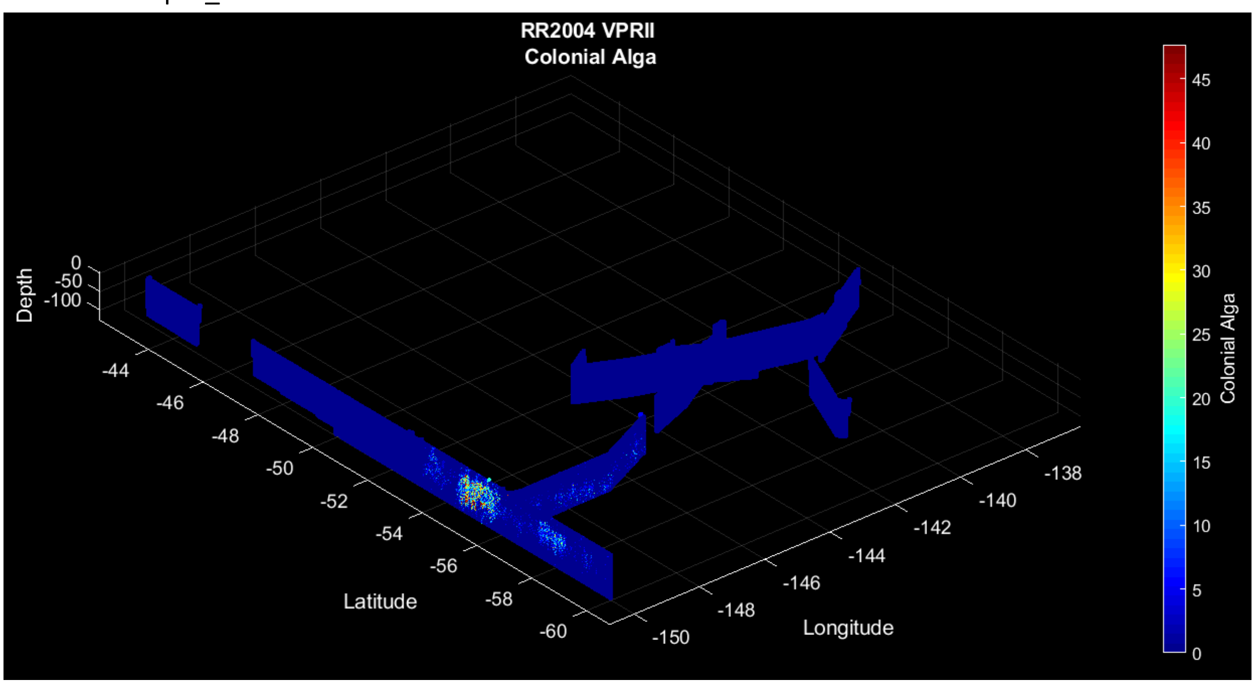

RR2004 VPRII
ECO Chlorophyll
Depth
0
-50
-100
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
ECO Chlorophyll


RR2004 VPRII
ECO Bb
×10-4
8
7
6
5
4
3
2
1
ECO Bb
0
-50
-100
Depth
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude

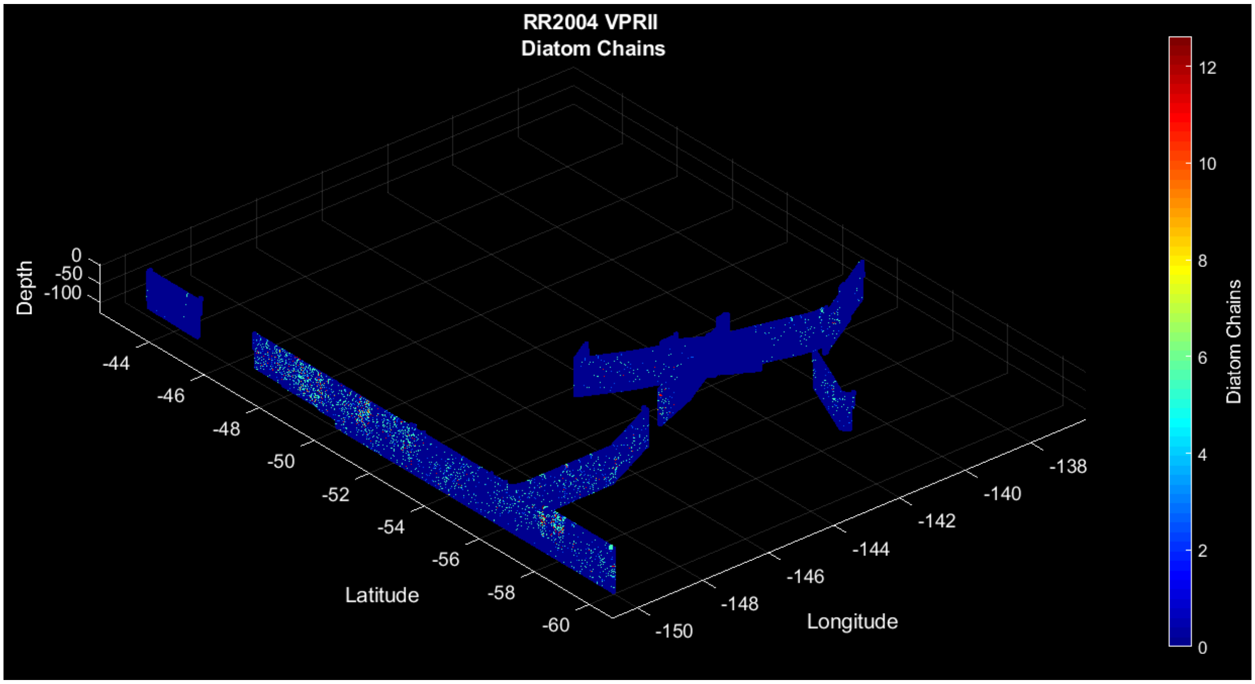

RR2004 VPRII
Acanth
12
10
8
6
4
2
0
Acanth
0
-50
-100
Depth
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude

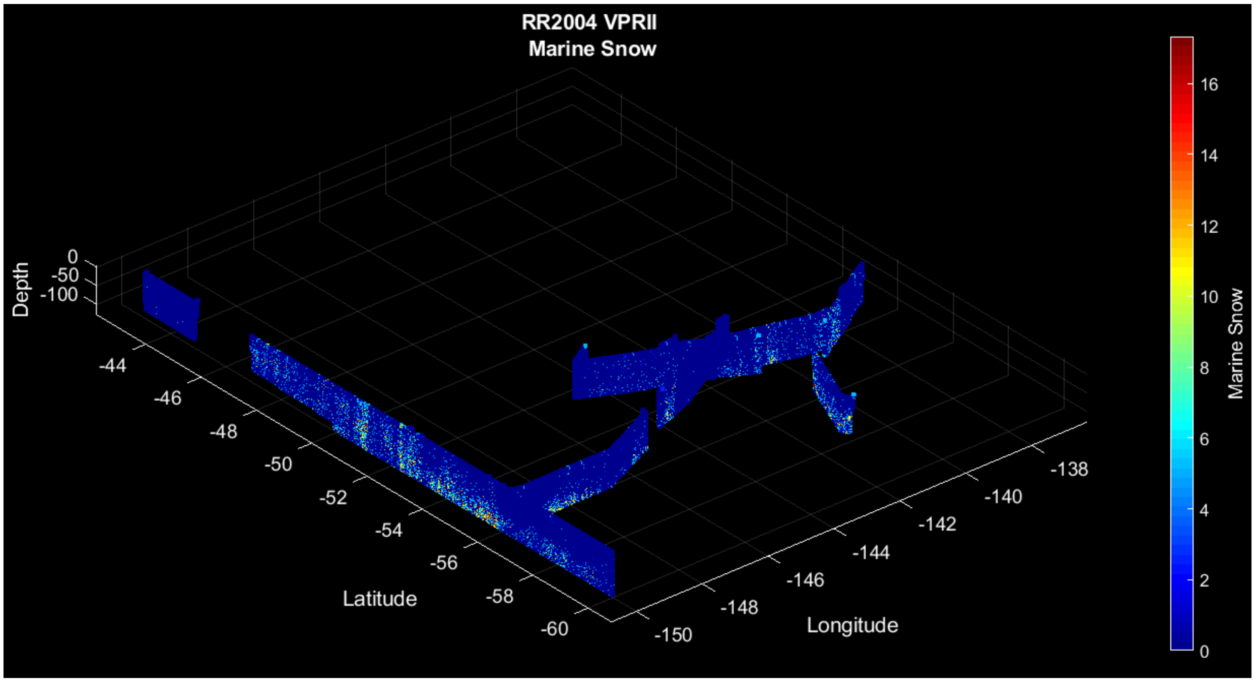


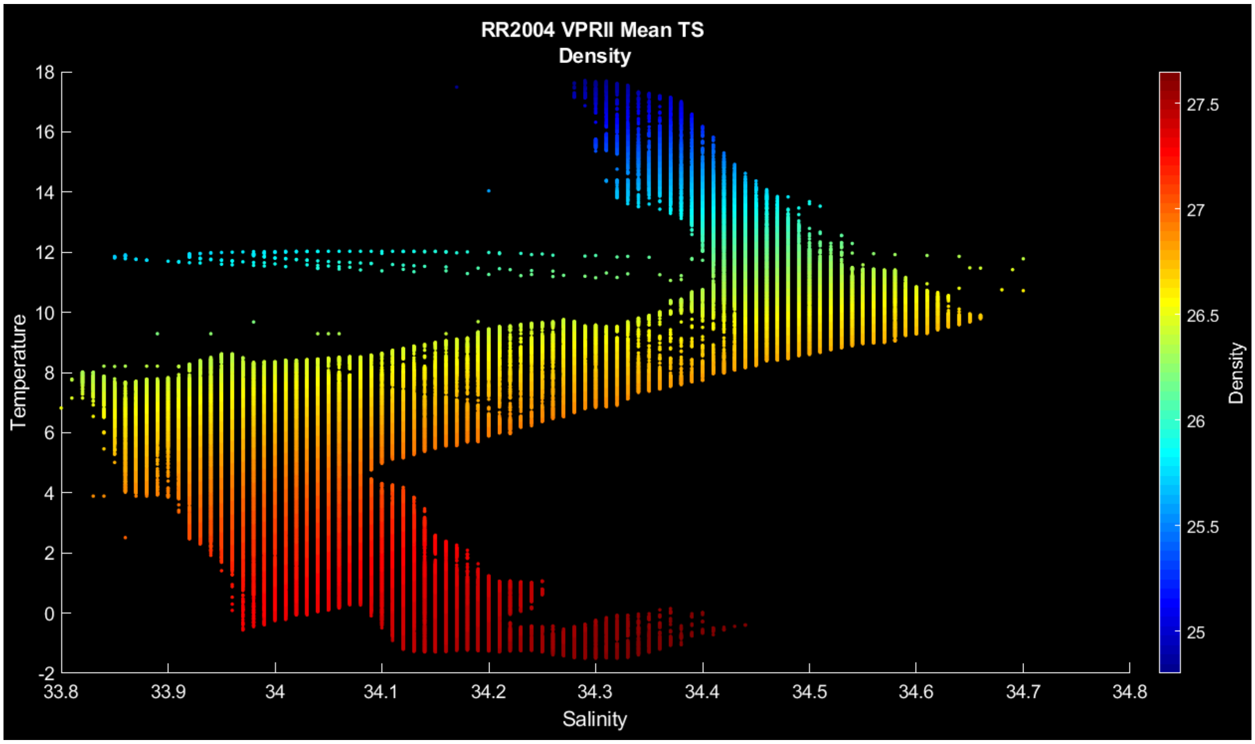
*CNN taxa copes_calanus

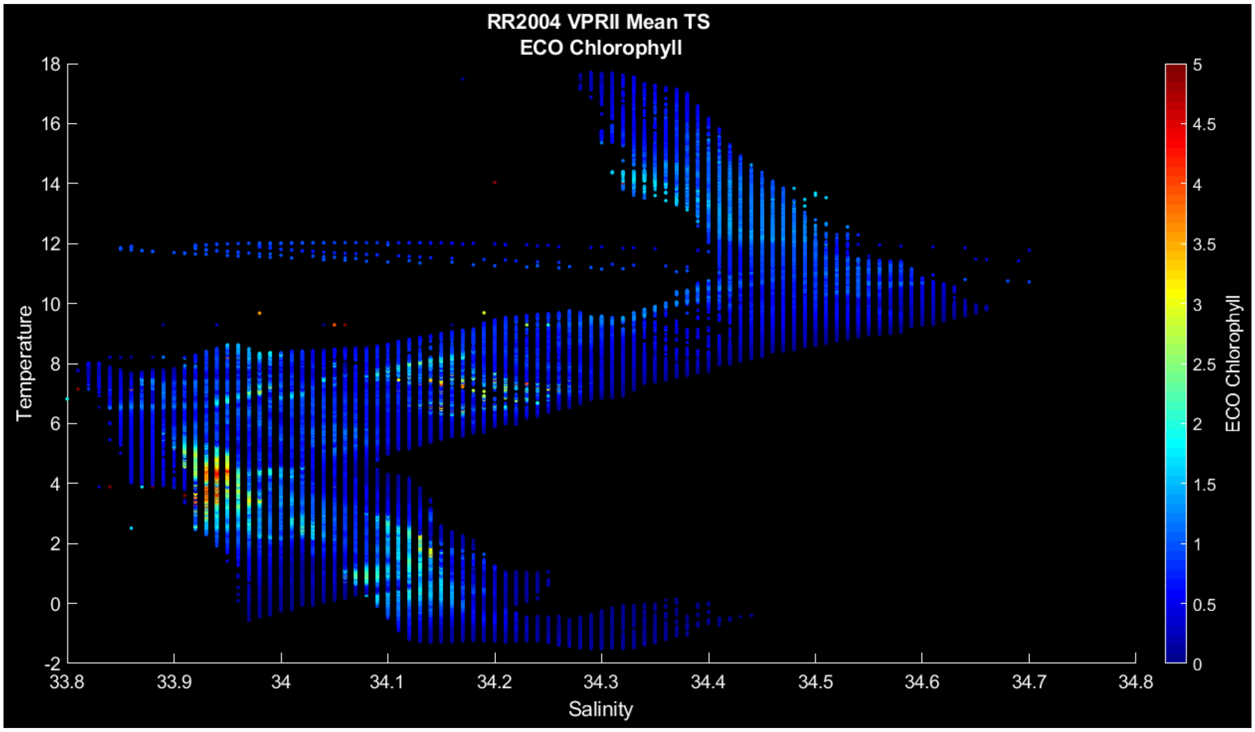


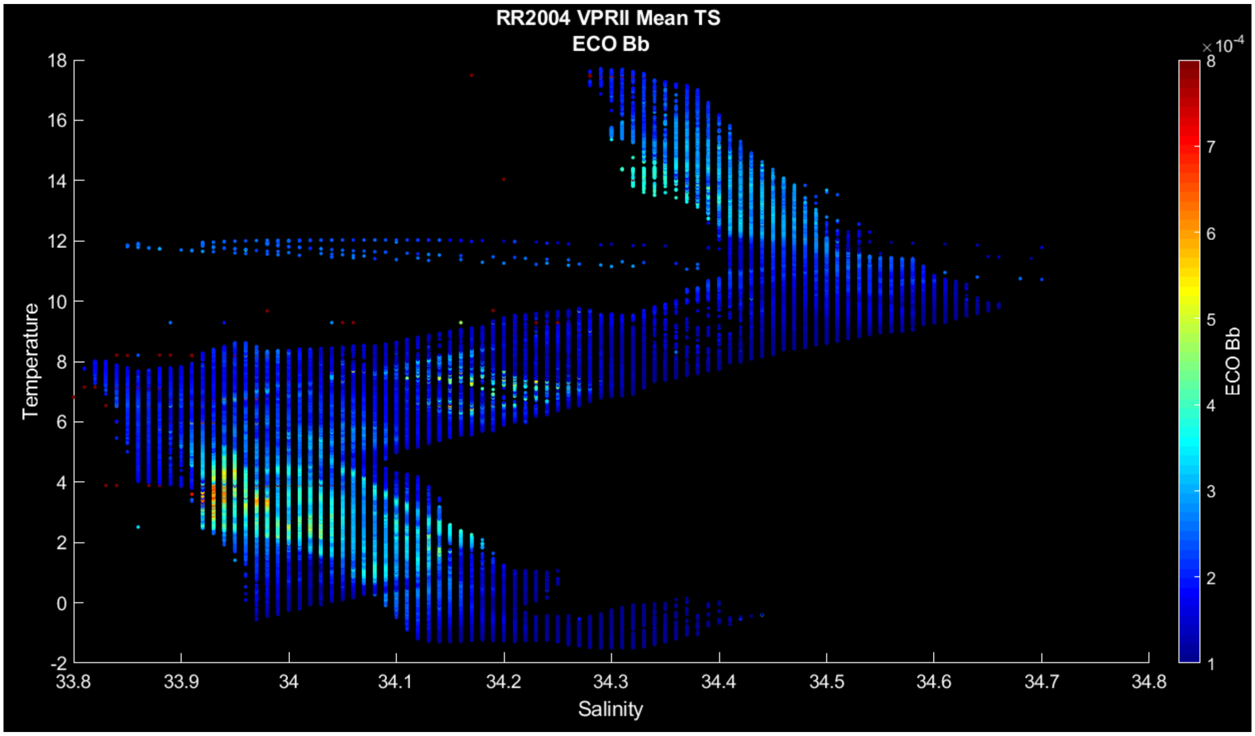
*CNN4(10b) taxa Phaeo_bloom

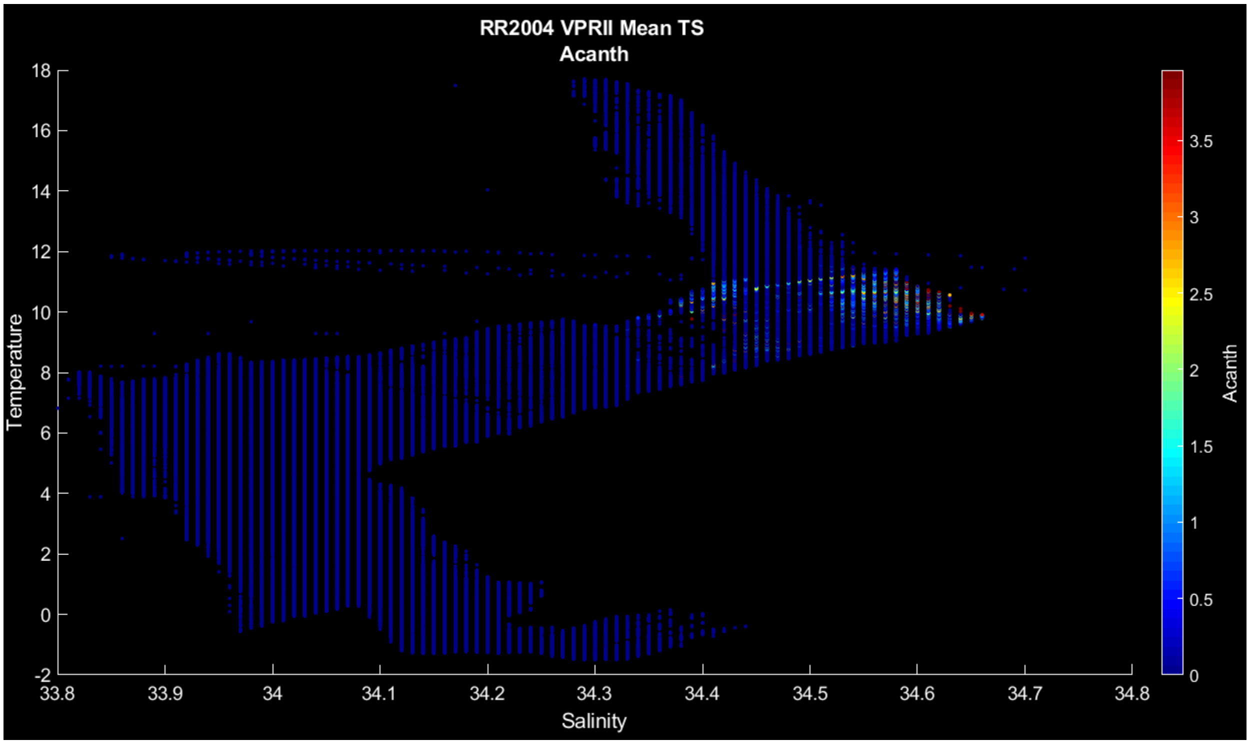

RR2004 VPRII
Diatom Chains
Depth
0
-50
-100
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude
Diatom Chains
0
2
4
6
8
10
12

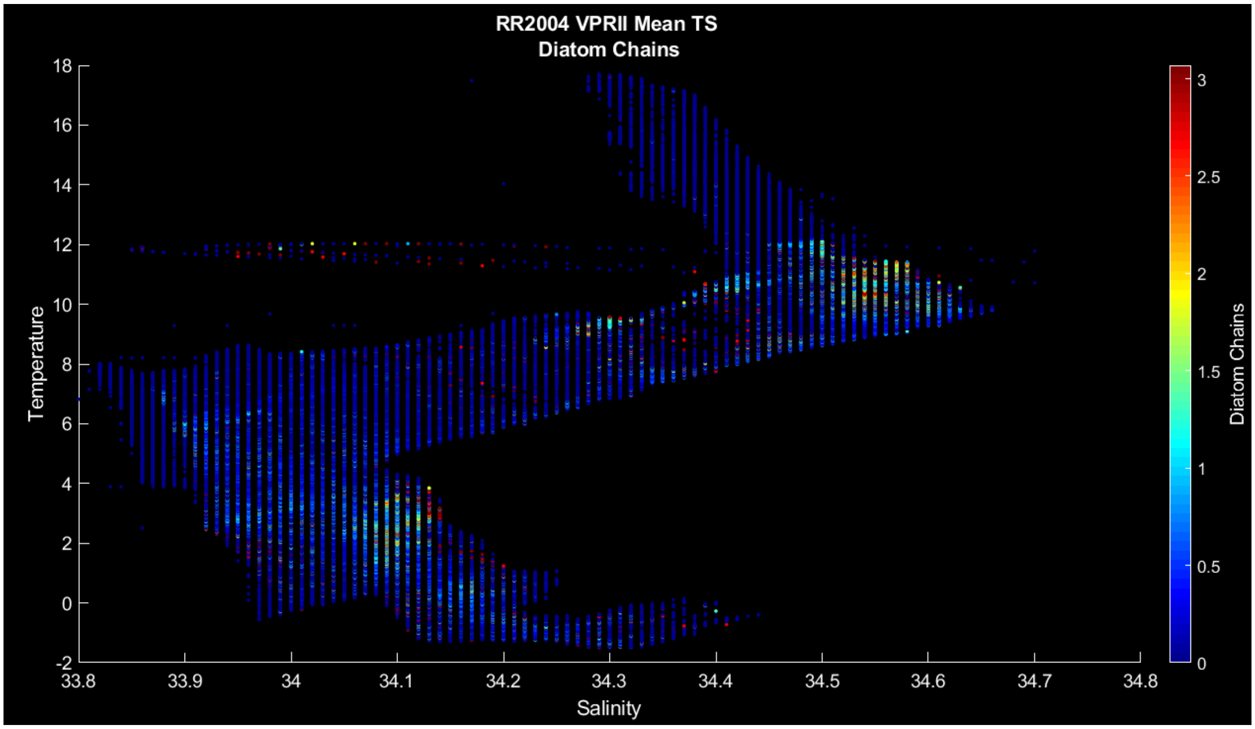

RR2004 VPRII
Marine Snow
Depth
0
-50
-100
-44
-46
-48
-50
-52
-54
-56
-58
-60
Latitude
-150
-148
-146
-144
-142
-140
-138
Longitude
Marine Snow
0
2
4
6
8
10
12
14
16

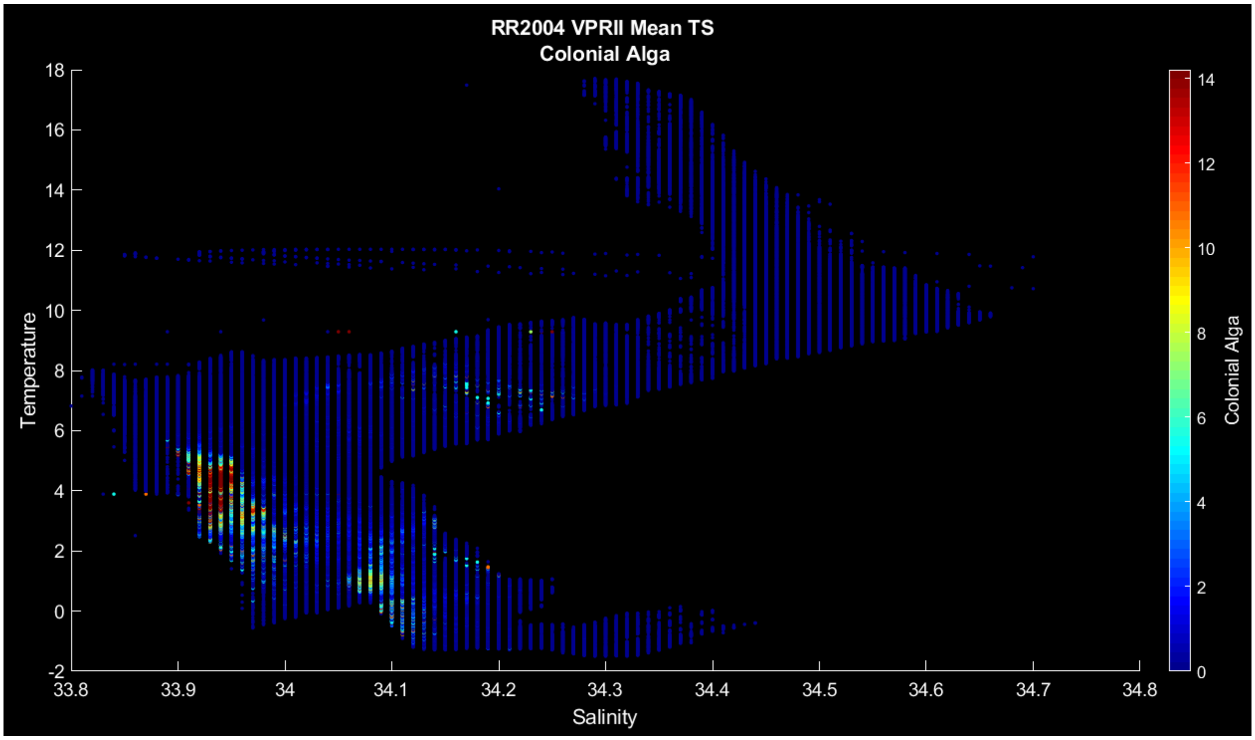

RR2004 VPRII Mean TS
Density
Temperature
Salinity
Density
18
16
14
12
10
8
6
4
2
0
-2
33.8
33.9
34
34.1
34.2
34.3
34.4
34.5
34.6
34.7
34.8
27.5
27
26.5
26
25.5
25


RR2004 VPRII Mean TS
ECO Chlorophyll
Temperature
Salinity
ECO Chlorophyll
18
16
14
12
10
8
6
4
2
0
-2
33.8
33.9
34
34.1
34.2
34.3
34.4
34.5
34.6
34.7
34.8
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

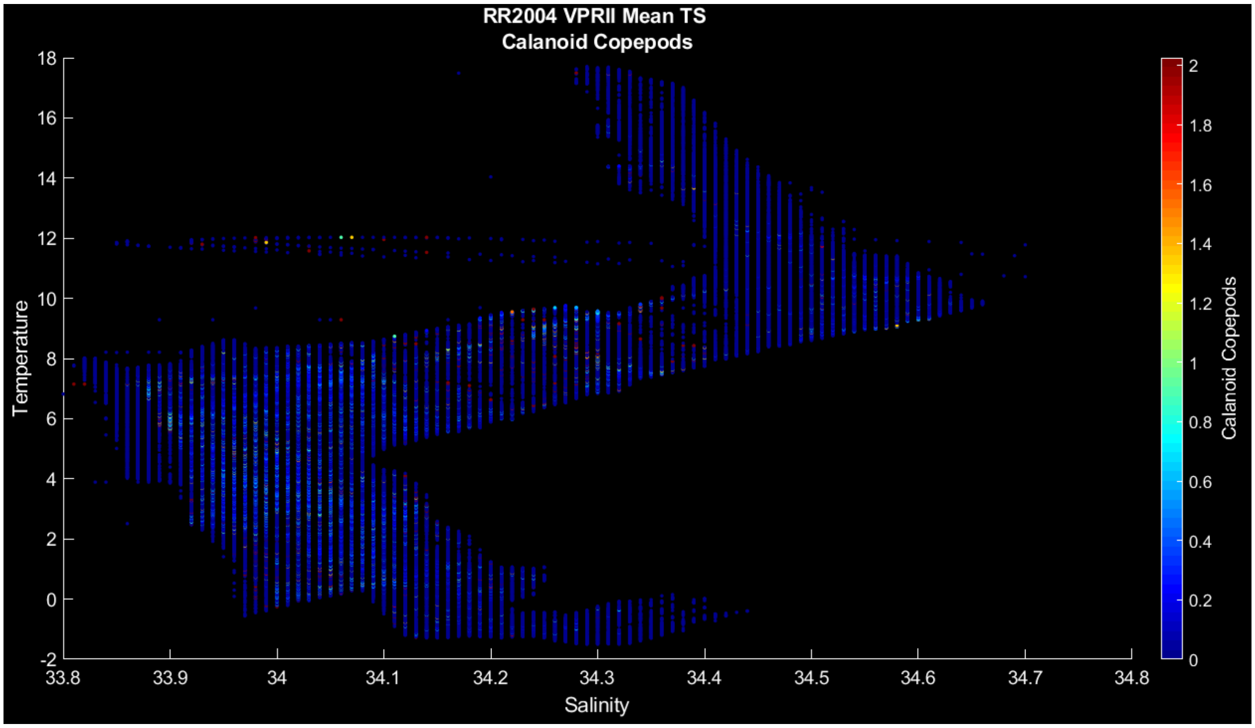

RR2004 VPRII Mean TS
ECO Bb
Temperature
Salinity
ECO Bb
×10^-4


RR2004 VPRII Mean TS
Acanth
Temperature
Salinity
Acanth

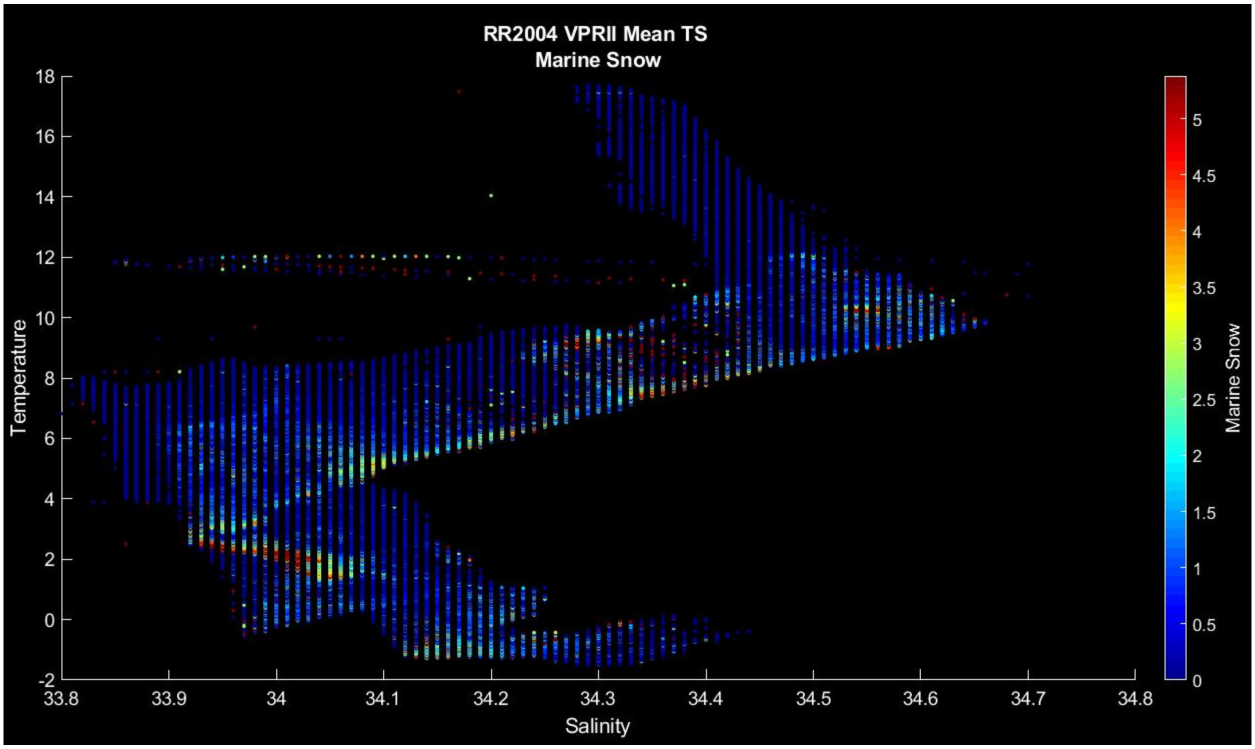




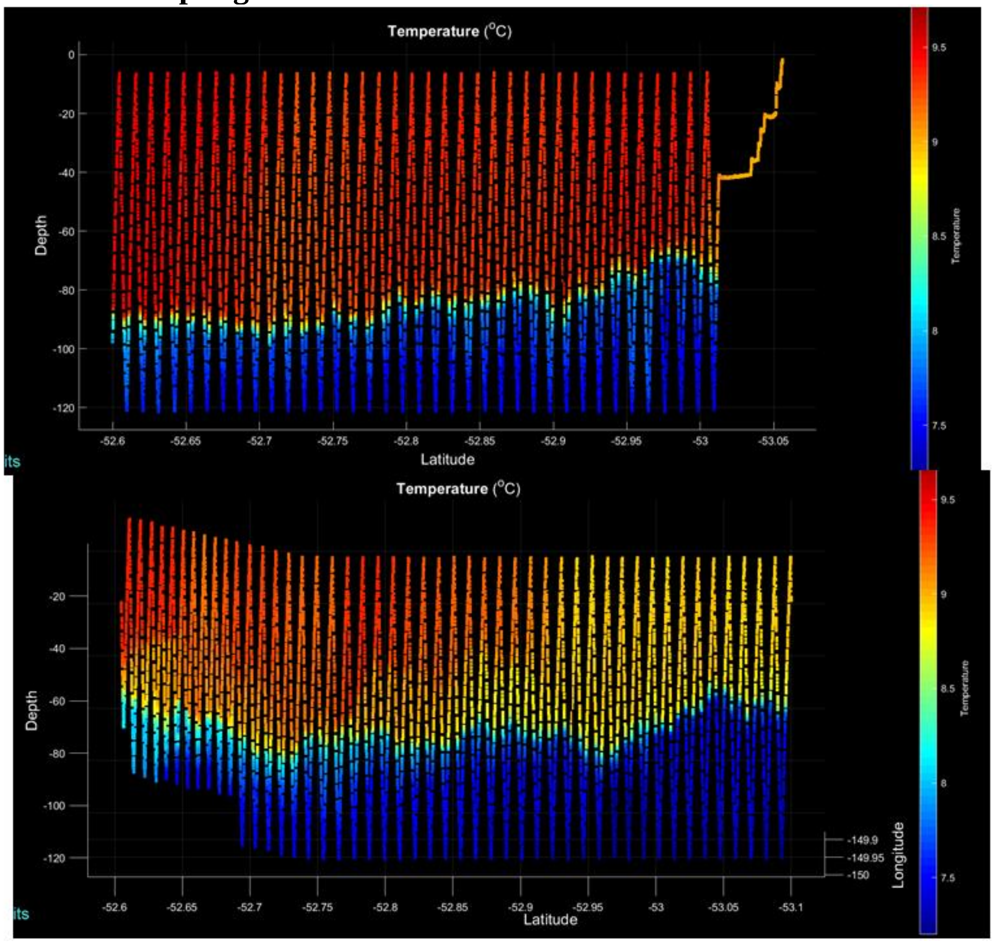
*CNN4(10b) taxa Phaeo_bloom

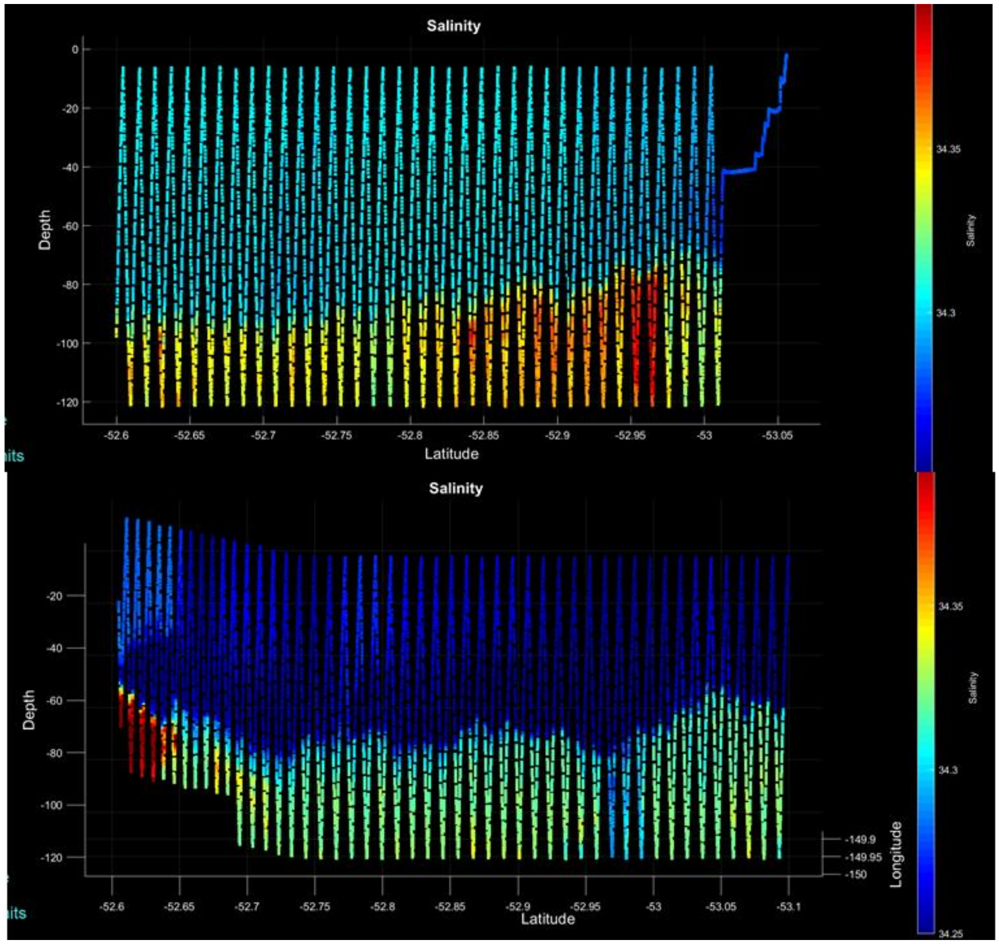


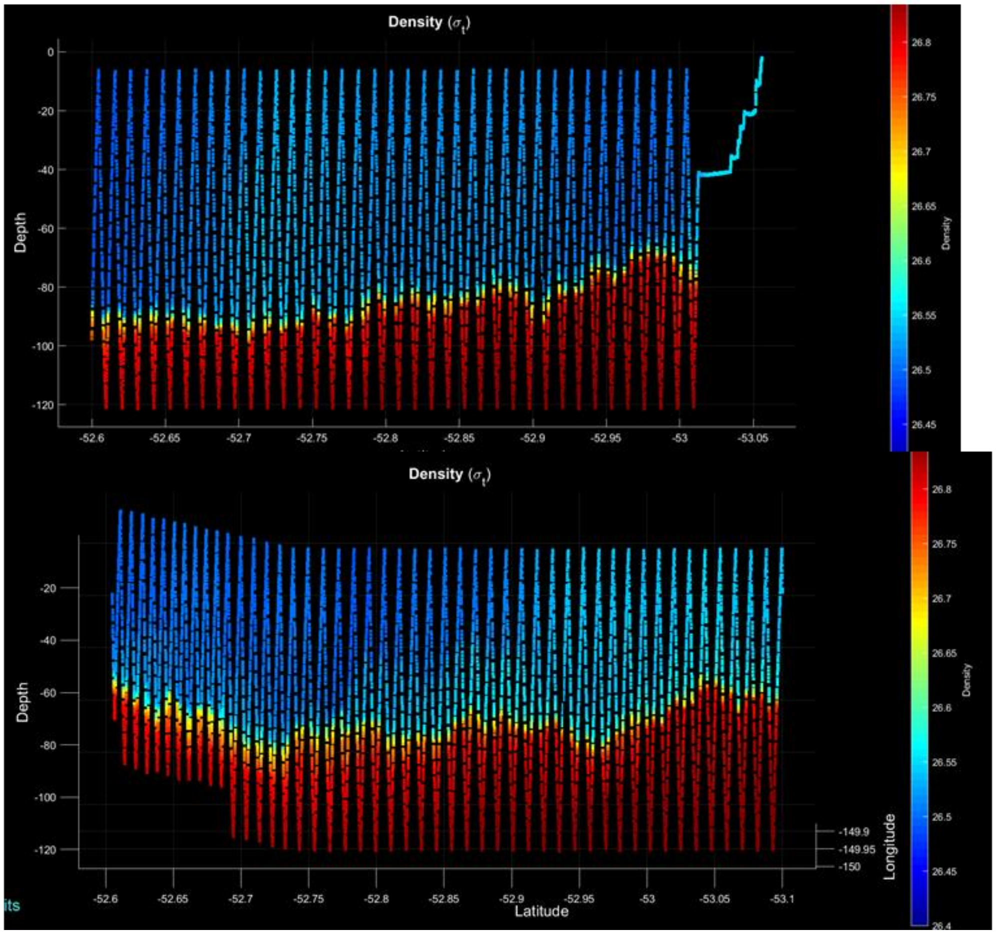
*CNN taxa copes_calanus

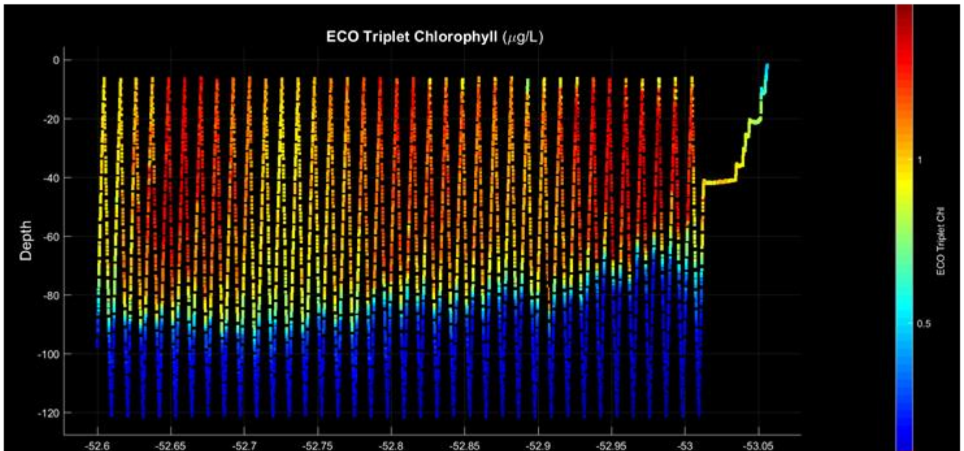


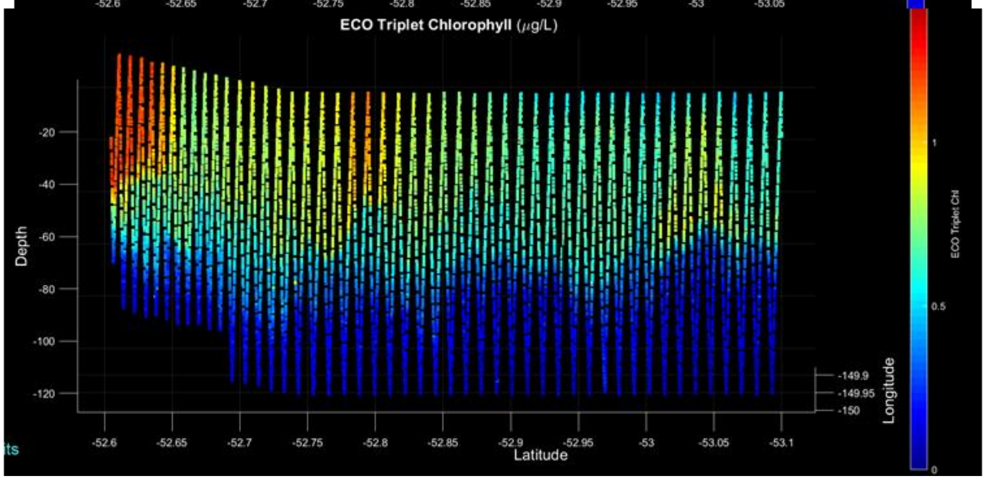
Appendix 4. VPR 3-4 overlap region

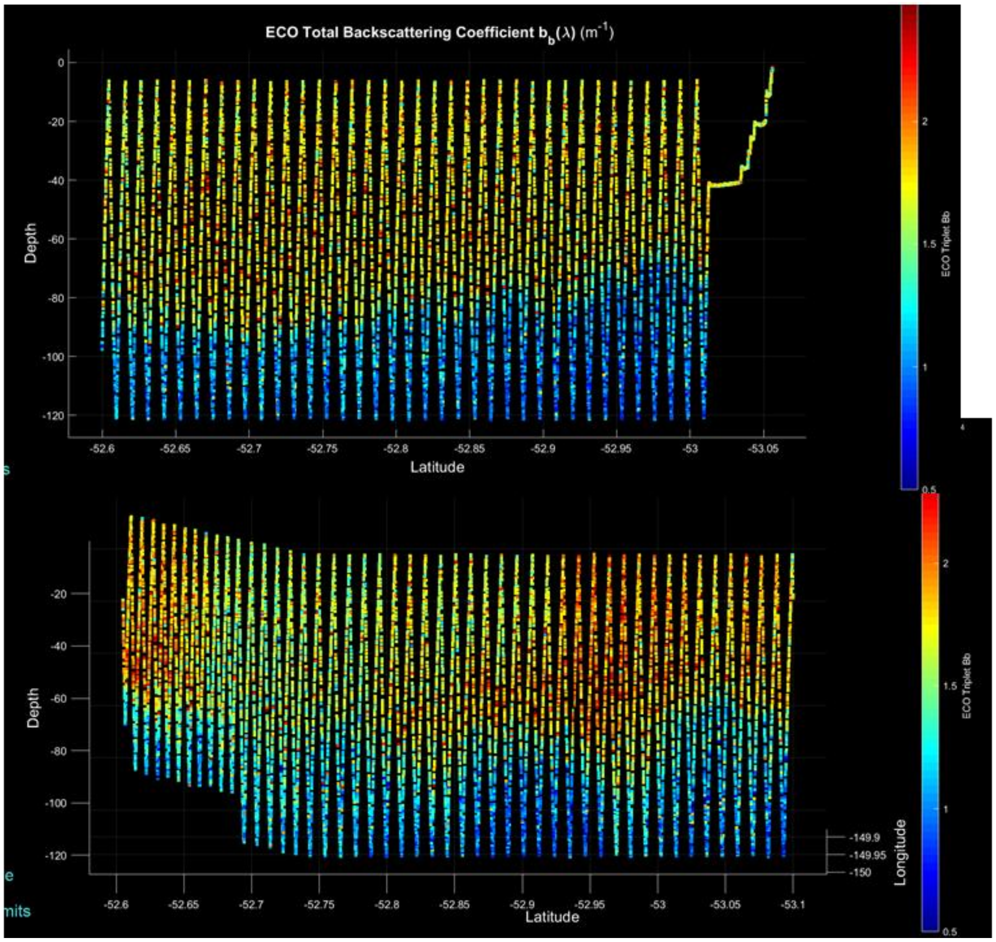



Salinity
Depth
Latitude
Salinity
Salinity
Depth
Latitude
Longitude
Salinity

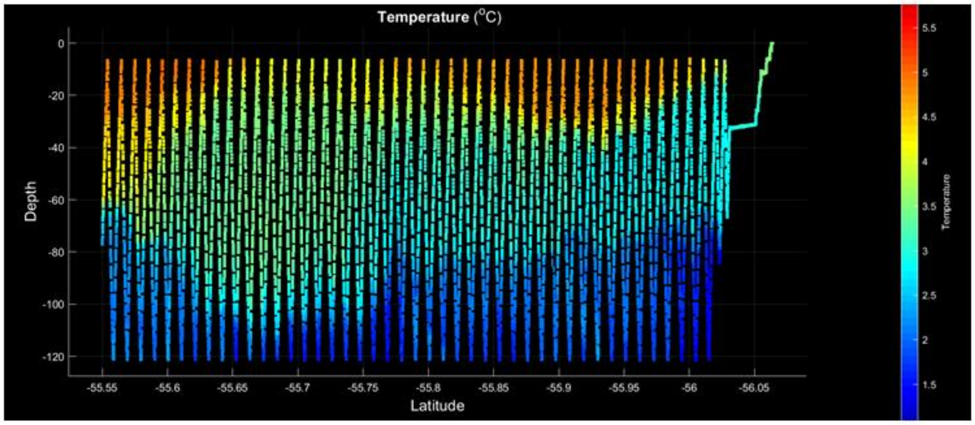

Density (σt)
0
-20
-40
-60
-80
-100
-120
Depth
-52.6
-52.65
-52.7
-52.75
-52.8
-52.85
-52.9
-52.95
-53
-53.05
26.8
26.75
26.7
26.65
26.6
26.55
26.5
26.45
Density
Density (σt)
-20
-40
-60
-80
-100
-120
Depth
-149.9
-149.95
-150
Longitude
-52.6
-52.65
-52.7
-52.75
-52.8
-52.85
-52.9
-52.95
-53
-53.05
-53.1
Latitude
26.8
26.75
26.7
26.65
26.6
26.55
26.5
26.45
26.4
Density

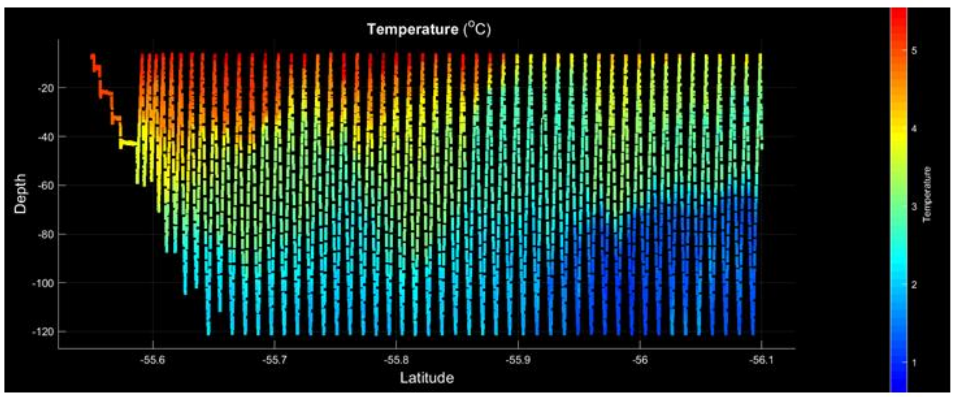

ECO Triplet Chlorophyll (μg/L)
Depth
0
-20
-40
-60
-80
-100
-120
-52.6
-52.65
-52.7
-52.75
-52.8
-52.85
-52.9
-52.95
-53
-53.05
ECO Triplet Chl
1
0.5

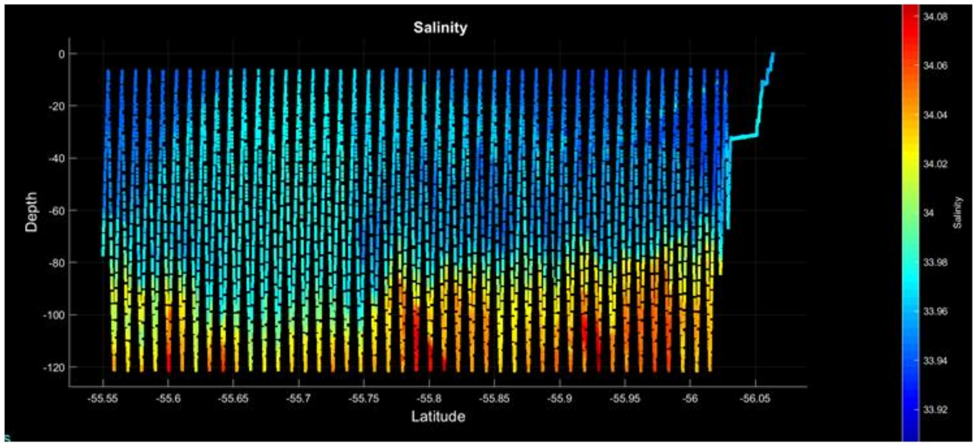

ECO Triplet Chlorophyll (μg/L)
Depth
-20
-40
-60
-80
-100
-120
-52.6
-52.65
-52.7
-52.75
-52.8
-52.85
-52.9
-52.95
-53
-53.05
-53.1
Latitude
-149.9
-149.95
-150
Longitude
ECO Triplet Chl
1
0.5
0

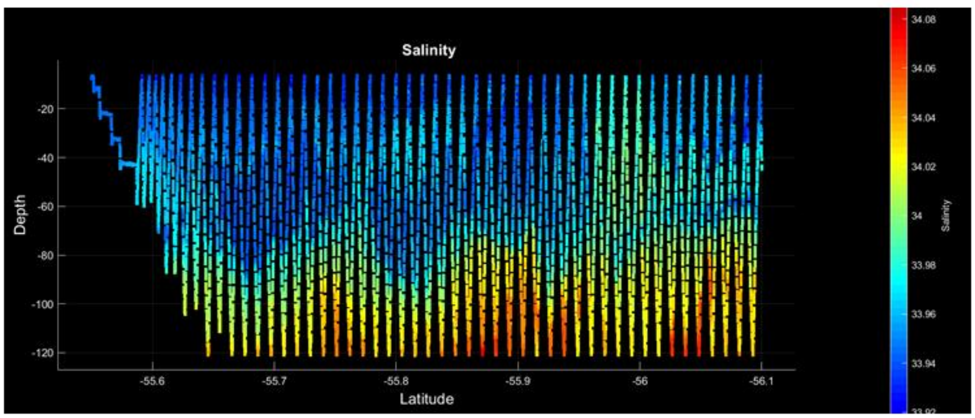

ECO Total Backscattering Coefficient b_b(λ) (m^-1)
Depth
Latitude
ECO Triplet Bb
0
-20
-40
-60
-80
-100
-120
-52.6
-52.65
-52.7
-52.75
-52.8
-52.85
-52.9
-52.95
-53
-53.05
-53.1
2
1.5
1
0.5
-149.9
-149.95
-150
Longitude

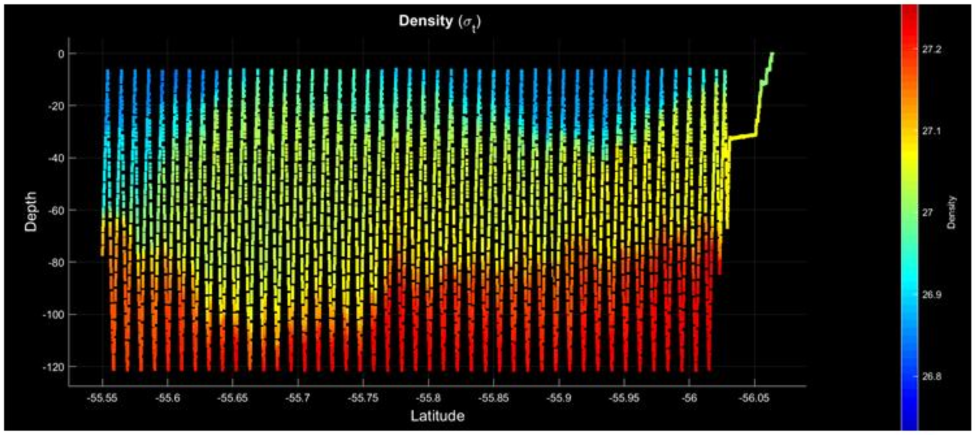
Appendix 5. VPR 4-5 overlap region

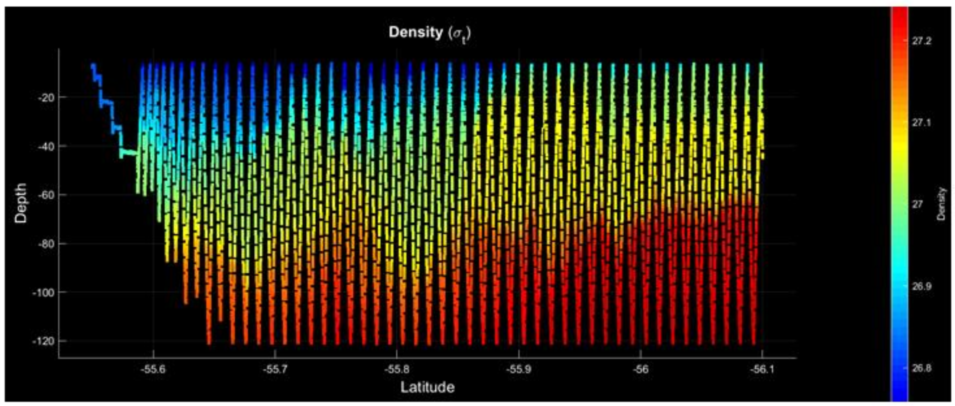


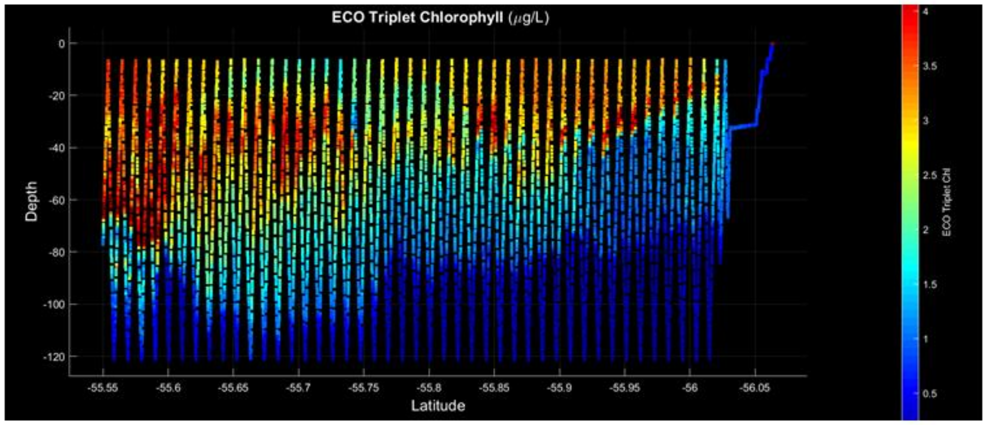


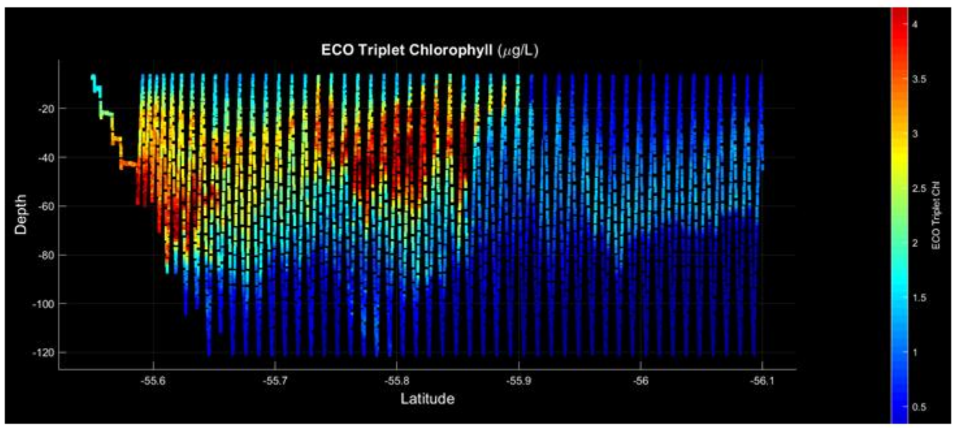

Salinity
Depth
Latitude
Salinity

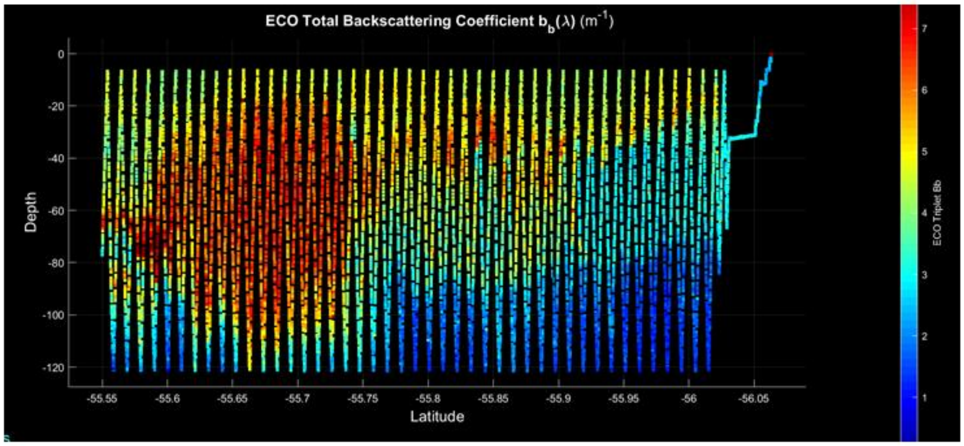

Salinity
Depth
Latitude
Salinity

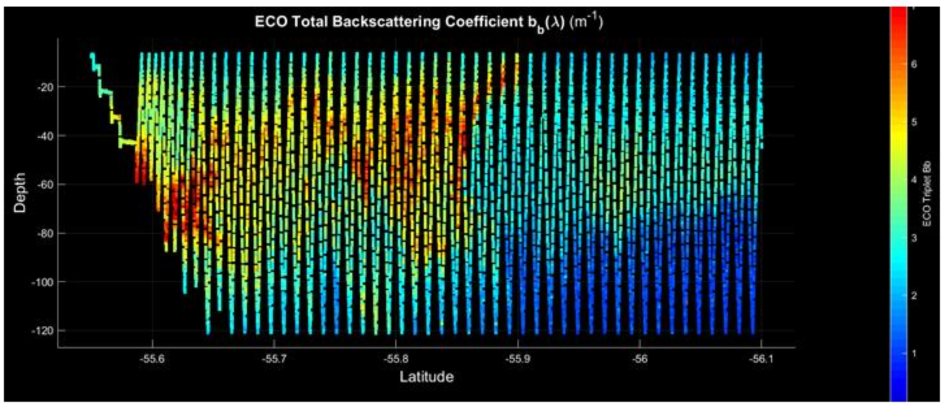

Density (σ_t)
Depth
Latitude
0
-20
-40
-60
-80
-100
-120
-55.55
-55.6
-55.65
-55.7
-55.75
-55.8
-55.85
-55.9
-55.95
-56
-56.05
27.2
27.1
27
26.9
26.8
Density


Density (σ_t)
Depth
Latitude
-20
-40
-60
-80
-100
-120
-55.6
-55.7
-55.8
-55.9
-56
-56.1
27.2
27.1
27
26.9
26.8
Density


ECO Triplet Chlorophyll (μg/L)
Depth
Latitude
ECO Triplet Chl
0
-20
-40
-60
-80
-100
-120
-55.55
-55.6
-55.65
-55.7
-55.75
-55.8
-55.85
-55.9
-55.95
-56
-56.05
4
3.5
3
2.5
2
1.5
1
0.5


ECO Triplet Chlorophyll (μg/L)
Depth
Latitude
ECO Triplet Chl
-20
-40
-60
-80
-100
-120
-55.6
-55.7
-55.8
-55.9
-56
-56.1
4
3.5
3
2.5
2
1.5
1
0.5


ECO Total Backscattering Coefficient $b_b(\lambda)$ (m^{-1})
Depth
Latitude
ECO Triplet Bb
0
-20
-40
-60
-80
-100
-120
-55.55
-55.6
-55.65
-55.7
-55.75
-55.8
-55.85
-55.9
-55.95
-56
-56.05
7
6
5
4
3
2
1


ECO Total Backscattering Coefficient $b_b(\lambda)$ (m^{-1})
Depth
Latitude
ECO Triplet Bb
-20
-40
-60
-80
-100
-120
-55.6
-55.7
-55.8
-55.9
-56
-56.1
6
5
4
3
2
1