Dovetail

N. B. Palmer 97-05
31 July to 08 September 1997

Cruise Report
Arnold L. Gordon

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I Objectives:

The objectives of Palmer Cruise 97-5 is: 1. to set out the array of Dovetail moorings which is designed to monitor for a period of 8 to 16 months the highly variable circulation within the Weddell-Scotia-Confluence region; 2. to deploy drifters for monitoring of sea ice response to wind and the sea ice divergence; and 3. to investigate ocean thermohaline, oxygen, velocity profile and tracer chemistry stratification in the region separating the circumpolar water masses from those of the Weddell Gyre and intervening Weddell-Scotia Confluence. Of specific interest is: 1. the outflow of dense bottom water from the Weddell Sea; 2. the spill-over and spreading of dense Weddell waters across the South Scotia Ridge; and 3. nature of the winter mixed layer and its relationship to the pycnocline and WDW t-max. A more general objective of the Dovetail program is to establish a design for a cost effective, long term monitoring strategy for the bottom water outflow from the Weddell Sea and secular variability of water column stratification.

The observational program includes: CTD/Oxy and Lowered ADCP sensors; water samples for salinity, oxygen, nutrients, CFC, Tritium/Helium, stable isotopes; 12 moorings; 6 ice drifter. Besides basic navigation, the underway observations included hull ADCP, SeaBeam as required for mooring site survey, meteorological monitoring.

The packet of figures attached to this report shows the station positions, the mooring and drifter deployment sites, plus a selections of data displays.

II Watches:

DOVETAIL Personnel and Watch System

A. Gordon, Chief Scientist
R. Muench Co-Chief Scientist

[A] CTD/Oxy/salinity/LADCP (midnight-noon)

Watch A (midnight->noon)	Watch B (noon->midnight)
B. Huber- Head	P. Mele- Head
J. de Bettencourt (LADCP)	M. Visbeck (LADCP; hull ADCP)
A. Orsi (salinity)	R. Iannuzzi
S. Green (Oxy, nutrient)	S. Ma (salinity)
	S. Peacock (nutrient; Oxy)

[B] Chemistry

Manfred Mensch (CFC)
Guy Mathieu (CFC)
Sally Mathieu (CFC)

Dee Breger (Tritium/Helium)
Lois Breger (Tritium/Helium)
Benjamin Gordon (Tritium/Helium)

[C] Mooring / Drifter: R. Muench (hull and LADCP)
R. Iannuzzi (drifters)

III Status Reports:

[A] Palmer 97-05 Dovetail Project Status Report 1
Arnold L. Gordon, Chief Scientist, DOVETAIL

Friday, 8 August 1997; TIME: 1300 local (1700 Z)

LAT/LONG 60 deg 10'S; 44 deg 15' W starting CTD #15

Ship departed Punta Arenas around 3:10 PM local on 31 July. Moderate seas along a line from the eastern entrance to St. of Magellan to the first CTD station at 57.5 deg S and 45 deg W. From there worked our way south mostly along 44.5 deg W, with CTD stations, more closely spacing once south of 59.5 deg S to better resolve the northern front of the Weddell-Scotia Confluence and the deep waters in the deep trough north of the South Orkney Islands. First ice bands near 58.7 deg S. Full cover of ice south by 59.5 deg S. South winds have moved ice front northward, but generally thin, new ice, as we are in an ice shadow from the Orkneys. Thicker ice expected as we move southward east of the Orkneys.

Completed CTD #14 station at 60 deg S, 44.31 deg W. All CTD, LADCP operation and water sampling for chemistry and CTD calibration going fine, except for a problem with the oxygen titration unit. The data clearly define the strong isopycnal stirring of Weddell waters with Circumpolar water, as well as the spill-over of dense water from the Weddell into the southern Scotia Sea.

Mooring deployment ran into problems during the first attempted deployment at 58.7 deg S, 44.5 deg (anchor first method was used because of ice floes). It was aborted, and mooring site 2 deployment at 59.50 deg S, 44.40 deg W was postponed, as line handling and deployment methods had to be reconsidered. The modified deployment method (see ASA report for details) was applied with success at mooring site at 60 deg S and 44.31 deg W, which at 4800 m is the deepest of the Dovetail moorings. We will deploy the moorings at the first two sites later in cruise as we head west from the completion of the 40 deg W line. SeaBeam surveys of mooring site (all three sites were 'SeaBeamed') proceeding nicely, even in ice the SeaBeam views are useful in selection of exact site for deployment.

[B] E/mail problem: The following assessment was sent to ASA and NSF on 15 August:

"During first few days of the Palmer 97-5 cruise we were able to receive, but unable to send e-mail communications. This was corrected on 6 August, apparently there was a problem at the ASA Denver site. On 11 August our ability to send and receive e-mail ceased. Eventually we were able to receive mail, but not send. Finally on 14 August we transmitted messages via a Lamont server, which clearly demonstrated that the problem was again located at ASA Denver.

"E-mail communication is a cost effective link for cruise participants to the global internet. The ability to access e-mail is essential to the success of a scientific expedition: receipt of ice charts and weather helps steer the field program; exchange of technical and science information with the home office or colleagues maximizes the ability of on board scientists to exploit their field presence; exchange of official business keeps the scientists in touch with their many other commitments in a timely fashion; and, one should not underestimated the importance of personal e-mail exchange as an effective moral booster. I place reliable e-mail communications at very high priority. I'm not one of those that go to sea to get away from communications.

"I was very surprised to find that the Palmer e-mail services are not dependable. I thought by now

ASA after supporting the science programs on Palmer for 5 years, would have worked out the best procedures to maintaining reliable e-mail communications. I officially voice my displeasure with the present situation and I strongly urge ASA to place Palmer e-mail services at the highest state of reliability as quickly as possible.”

[C] Palmer 97-05 Dovetail Project Status Report 2
Robin Muench, Co-Chief Scientist, DOVETAIL

Friday, 15 August 1997; TIME: 1000 local (1400 Z)
LAT/LONG 64°15’S; 40°00' W, at CTD #32

Our DOVETAIL cruise is proceeding well and “on schedule”. The ship is making reasonably good time through nearly total ice cover capped with several inches of new snow. The shipboard scientific equipment is operating well. We have now completed the first meridional CTD transect along about longitude 44 W across the plateau surrounding the South Orkney Islands. This transect veered eastward toward its southern end, culminating with cast #32 in the deep basin near 64.25 S. Nominal station spacing along this transect has been 10-15 n m, generally closer over the shelf and steep slope regions. A preliminary look at the data show the deep plume of Weddell Bottom Water paralleling isobaths deeper than about 3600 m. Additionally, we have identified a high oxygen, high CFC water mass near 1500 m on the southern slope of the South Orkney Plateau. This water mass, not seen before, is of uncertain origin. Additionally, the Weddell temperature maximum is significantly warmer than seen in the historical data. We are now preparing to jog eastward and commence a northward transect along about 40 W.

The lowered ADCP (LADCP) continues to provide invaluable results on the deep currents. These data show a significant near-bottom counterclockwise circulation around the South Orkney Plateau and around a smaller bank just north of the Plateau, and eastward near-bottom flow in the Bottom Water plume south of the Plateau. These results are being used to estimate the barotropic currents, and preliminary computations suggest large eastward volume transports in the northern Weddell that are consistent with published estimates of western boundary transport.

Four of the six Argos-tracked ice buoys have been deployed, to date, over a grid having length scales of order 100 km.

Finally, five of the 11 planned deep current moorings have been successfully deployed - all along the 44 W meridional transect. Moorings deployed were at sites 7, 8, 9, 11 and 12 (site 10 - a shallow site containing a single current meter, was deleted). The remaining two moorings along this transect - at sites 13 and 14 - will be deployed during the westward transit toward 48 W from the north end of the 40 W CTD transect. These deployments required design by shipboard ASA personnel of a hydraulic winch-based system by which the moorings can be spooled directly off the stern anchor first. This system has proven to be robust, relatively safe, and fast. A thorough pre-deployment check of the current meters has suggested that they are functioning per design and should yield high quality datasets. The earliest data returns are scheduled to begin on 1 March 1998 - the estimated time of greatest ice retreat.

[D] Palmer 97-05 Dovetail Project Status Report 3

Status Report of Palmer 97-05
Friday, 22 August 1997; TIME: 0900 local (1300 Z)

Enroute from 58°30'S, 40°W to the Dovetail mooring site at 59°00'S; 44°15'W

[A] Accomplishments:

We have completed two sections consisting of closely spaced stations along 44°W and 40°W between 58°S (average) and 64°20'S, they share a common southern station. A total of 50 stations have been obtained usually at 15 to 20 nm separation. The 44°W section crosses the South Orkney Plateau; the 40°W section crosses a gap in the South Scotia Ridge which channels the major overflow of dense Weddell Sea into the Scotia Sea. A station includes CTD, with Lower Acoustical Doppler Profiler (LADCP), water samples for salinity; oxygen; nutrient; CFC-11,12,113; Helium; Tritium; stable isotopes. Underway data includes navigation, hull ADCP, meteorology.

The two completed sections extend from the southern limits of the circumpolar regime into the Weddell Gyre. They provide an excellent view of the transitional fronts and zones between these regimes, including the Weddell-Scotia-Confluence, the outflow of dense bottom water from the western Weddell Sea and the interaction of the Weddell and Scotia Seas.

3. All six ice drifters have been deployed, all south of 62°S. They vary in separation from 80 to 150 km.

[B] Science topics:

1. Benthic layer of Weddell Sea Bottom Water (WSBW) is often thick, well mixed, other times thin and stratified. Some relationship to bottom topography is observed. However, as we sometimes see a mixed mode, there also may be a sporadic nature in that the well mixed benthic layer is formed locally and then lifted off the bottom by the surrounding, denser stratified layer. A series of such event would eventually mix all of the WSBW into the water column.

2. The effective depth of the 40°W controlling sill for Weddell overflow into Scotia Sea is 3150-3300 m, located near 60.5°S and 41.5W.

3. The Weddell Deep Water (WDW) t-max water sampled by the Dovetail sections is derived from the Weddell western boundary current. The WDW t-max is substantially warmer than observed in previous years. The t-max observed south of the Scotia Ridge is near 0.7°C, 0.15°C warmer than that measured by Palmer in 1992, and by earlier cruises to the region. Weddell Gyre t-max warming over the last 2 decades has also been reported for the area west of Maud Rise.

4. As mentioned in the last status report, the South Orkney Plateau bottom water (around 1000 m) consists of a well ventilate water mass, which either formed locally (unlikely) or spreads from

the west ‘floating’ over a interval of denser water.

[C] Plans: After deployment of the two remaining moorings along 44°W we will head west to deploy the last 5 Dovetail moorings along 48.5°W. The station section along 48.5°W will extend across the Powell Basin. We will attempt to reach the position of the German moorings off Joinville Island, then into the eastern Bransfield Strait. The array of Dovetail stations will define the ocean stratification and velocity profiles along several slices of the Weddell-Scotia-Confluence, allowing inspection of the changing form of the fronts, zones and Weddell Sea outflow, as they cross the complex topography of the South Scotia Ridge.

[D] Comments:

1. The ship officers and crew, the ASA team and the science grantees are all performing in an excellent manner.

2. The e/mail problems seem to have been solved, as we are presently back to using Glacier ASA Denver server, with a commercial internet server as back up. We are following a twice daily e/mail exchange. While I am pleased that e/mail problems have been tended to, I would hope that a reliable e/mail service becomes the norm for all future cruises abroad Palmer.

Arnold L. Gordon...Friday, August 22, 1997

[E] Palmer 97-05 Dovetail Project Status Report 4

Robin D. Muench
Thursday, 28 August

The DOVETAIL cruise is progressing well.

We have completed 63 CTD/rosette/LADCP casts to date, and scientific systems are performing well. Our progress is being aided at present by favorable ice conditions, light winds and surface air temperatures near freezing. We are now working our way southward on a transect that extends along approximately 48 W starting at about 59.5 S, and are nearing the midpoint of the Powell Basin at about 62 S. Our course of action at the southern end of our present transect, near 63 S, will depend somewhat on local ice and weather conditions. Our plan is to work along a track from that point that extends west to Joinville Island thence north across Bransfield Strait, effectively closing a “box” that encompasses the source waters for the DOVETAIL study region.

Ten of the eleven planned moorings have been successfully deployed. Mooring 15, at the northern end of the 48 W transect, was attempted under less than ideal conditions of heavy swell passing through a rubble field. A particularly large sequence of swells parted the line when the mooring was about 70% deployed, causing the loss of one current meter, an anchor and some line. It was not feasible to wait for conditions to improve. The remaining components are being used to construct an additional mooring that we plan to deploy at the northeastern end of Bransfield Strait near the end of the cruise, allowing measurement of currents from the Strait into our study area.

Very preliminary analyses of results to date along the 48 W transect reflect the general conditions seen farther east. A cold, saline bottom water layer was present near 3000 m along the northern periphery of the Powell Basin. This provides evidence that at least some of the newly formed bottom water enters and circulates around the Basin rather than simply flowing eastward past its entrance farther south. Additionally, we have detected layers of cold, low salinity, high oxygen water between 1500-2500 m depths in the northern Powell Basin. These reflect input of shelf waters.

We continue to enjoy the Palmer's unique combination of Chilean, Philippine and Cajun cuisine, and are looking forward to new discoveries during the coming week.

[F] Palmer 97-05 Dovetail Project Status Report 5

Final Weekly Status Report of Palmer 97-05, DOVETAIL
Thursday, 4 September 1997; TIME: 1:30 PM local (1730 Z)
62°30'S; 57°47'W
Arnold L. Gordon, Chief Scientist

I first present my comments, then comments from various participants concerning their responsibilities.

[A] Accomplishments:

We have completed 94 stations (anticipate a total of 97 for the cruise, just beginning 95) stretching from the central basins of the Bransfield Straits eastward to 40°W, east of the South Orkney Islands. In the meridional the sections extend from the Circumpolar water column of the Scotia Sea across the Weddell-Scotia-Confluence, the outflow of Weddell Sea Bottom Water, into the interior regime of the Weddell Sea.

A station includes CTD, with Lower Acoustical Doppler Profiler (LADCP), water samples for salinity; oxygen; nutrient; CFC-11,12,113; Helium; Tritium; stable isotopes. Underway data includes navigation and bathymetry, hull ADCP, surface water temperature and salinity, meteorology. We deployed 11 current meter moorings and 6 satellite tracked sea ice drifters. The drifters were deployed south of 62°S along the 44W and 40W sections. Reports of the other programs are included below.

[B] The Science:

The Dovetail CTD/LADCP/Tracer data set is very extensive and a number of research topics pertaining to Weddell Sea forced ocean ventilation can be pursued. The primary topics and questions are:

• Warmer Weddell Deep Water t-max: The Weddell Deep Water warming of the last few decades, continues. This trend may result from decrease of deep water heat loss to the atmosphere and cryosphere or increase of injection of warm circumpolar deep water into the Weddell Gyre. What is the cause of the WDW warming? What is the relationship of the t-max warming to sea ice distribution, glacial ice melting, Weddell Sea Bottom Water production and to the Weddell Polynya?

• Benthic Layer: The Dovetail CTD/tracer data along with the 1992 Weddell Ice Station data set nicely define the stratification and spatial pattern of the Weddell Sea Bottom Water benthic layer in the western and northwestern Weddell Sea. The Dovetail LADCP provides a glimpse of the velocity field associated with the WSBW. The WSBW benthic layer takes on varied forms: thick well mixed layer; a thin stratified form. Often (mainly on the 40°W section) a more complex form appears with attributes of both types. What is the relationship of the Benthic layer type to the sea floor depth, slope and bottom roughness; to the water column temperature and salinity stratification and stability; and to LADCP measured bottom current and shears? What is the WSBW transport? What is the role of the Powell Basin in governing the downstream form of the Benthic layer? Does benthic mixing receive positive feedback from thermobaric effects?

• W-S-C Low Salinity Deep Water: Within the Weddell-Scotia-Confluence over the South Scotia Ridge west of the South Orkneys, there is a well ventilated low salinity deep water, which may be referred to as Weddell-Scotia-Confluence Deep Water. It advects eastward to provide the bottom water on the southern, deeper parts of the South Orkney Plateau and then passes northward into the Scotia Sea. The Dovetail data clearly shows it is coming from the Antarctic Peninsula eastern shelf. It may be considered as a less dense form of Weddell Sea Bottom Water. It rides the 'outer-rim' of the Weddell Gyre, to feed into the Weddell-Scotia-Confluence. The Weddell-Scotia-Confluence Deep Water spreads on density surfaces into the Powell Basin and Scotia Sea, over-riding the Weddell Sea Bottom Water and may influence the thickness of the benthic layer. How much Weddell-Scotia-Confluence deep water is formed? What is it's relationship to the formation of Weddell Sea Bottom Water? Where is the specific source of the low salinity shelf water? Is there a Larsen Ice Shelf contribution? and what is its role in larger scale ocean ventilation?

Concluding Remark: The western Weddell continental margins form freezing point water with a wide range of salinity that ventilate the neighboring ocean from the sea floor (southern Weddell Sea) to the pycnocline (Bransfield). This water then reaches into the deep and bottom layers of the global ocean.

[C] Plans: As of this time we still need to complete sampling within the Bransfield Strait, which I believe provides the pycnocline waters of the Weddell-Scotia Confluence. We also will determine the renewal of the trapped water in the deep basins, with the first modern tracer coverage in the Strait.

[D] Comments:

1. The ship officers and crew are excellent. They handled the ship very effectively in the ice. I particularly appreciated their positive attitude towards the frequent change of plans forced by the

ice, weather and “real-time” disclosures in the data stream. The ASA team were invaluable, and also have that positive ‘can-do’ attitude towards their responsibilities. The science grantees are all performing in an excellent and cooperative manner.

2. Reliable e/mail is a real problem on Palmer, as discussed in previous e/mail exchange. Considering the importance of good communication the correction of this problem should be placed on high priority. Reliable e/mail service must become the norm for all future cruises abroad Palmer.

3. SeaBeam is a valuable tool for physical oceanographic research (in addition to MG&G). The detailed bottom bathymetry SeaBeam images are very helpful in the analysis of ocean stratification and currents. Even in the presence of sea ice (where the raw data looked hopeless) with heavy editing the SeaBeam data provide clear views of the sea floor. Because of contractual issues involving ASA and SeaBeam, on Dovetail we were limited in its use to survey of mooring sitings, these surveys proved to be very important. However, further use on Dovetail would have been an asset. The present SeaBeam system makes data editing very labor intensive. Whatever can be done to more streamline this process with computer assisted editing routines should be done. In view of the poor quality of Southern Ocean bathymetric maps, I recommend that SeaBeam data be obtained as routinely as possible on as many Palmer cruises as feasible. Speaking for physical oceanographic studies, detailed bathymetric data will also help re-analysis of archived data sets. Unless a more streamlined data editing procedure is developed the science party members should be advised that they will be asked (to volunteer) to help edit the data during the cruise.

4. Accurate information flow from ASA to the science grantees prior to the cruise should be improved. Besides an unexpected problem I encountered, I understand that there were minor misunderstandings, mostly to do with the Palmer computer facilities.

REPORTS:

——————————————————— Moorings Current Mooring Deployments Robin Muench (co-chief scientist)

Eleven arrays of moored current meters were deployed successfully during the cruise. Of these, ten were positioned as specified in the DOVETAIL proposal and one was repositioned based on field conditions. Nominal depths for current meters on the arrays are 200 m, 500 m and 50 m above the seafloor. Seven arrays were deployed along a meridional transect, coincident with the initial CTD transect of the cruise, crossing over the South Orkney Plateau near 44 W. Four moorings north of the Plateau will measure deep and bottom water flow in that part of the Scotia Sea expected to be impacted by Weddell Sea Bottom Water. Three moorings are situated south of the Plateau in locations optimal for measuring deep and bottom water flow in the northern Weddell Sea. Three additional arrays were deployed along a second meridional transect, also coincident with a CTD transect, along about 48 W. Two of these are located to measure flow in the vicinity of a gap in the South Orkney Plateau through which Weddell Sea water can flow, while the third is located to measure along-isobath flow near the base of the continental slope in the Powell Basin. The eleventh and final mooring was deployed partway down the western continental slope of the Powell Basin near 52 W, at the end of a short CTD transect that extended southeast into the Basin. CTD, bottle and LADCP data acquired at the site of each mooring deployment substantiated that most were situated in regions of particular interest with respect to deep and bottom water movement.

Deployment of the moorings proceeded, with one exception, exceedingly well and without untoward incident. The initially planned method, based on use of a brailing head, never worked because the head proved unusable for this purpose. An alternate deployment scheme was devised that used the seismic gun winch. This method proved to be relatively safe, trouble-free and rapid. One 3000-m deep mooring was deployed in less than 1-1/2 hours. The single mishap occurred in attempting to deploy a northernmost mooring along the 48 W transect. Conditions at the time were a broad swell passing through a rubble field. The rubble prevented an anchor-last deployment which would normally have been used in the presence of swell, and the mooring line parted upon passage of a particularly heavy set of swells with the mooring about 70% deployed. It was decided to use the remaining components to deploy a relocated mooring which was finally emplaced in Powell Basin at the site near 52 W. This very successful set of deployments could not have taken place without exceptional performances by ASA shipboard personnel, especially Rhonda Kelly, Mark Talkovich, Gary Osborne and Melissa Iszard-Crowley. These individuals designed the highly successful deployment method, spent many cold hours on deck and were extremely helpful, cooperative and pleasant during all phases of the operation.

The Palmer proved highly suitable for the mooring deployments. The heated fantail deck provided an excellent preparation area, and the stern A-frame and associated winches were more than up to the task.

Use of the SeaBeam system proved essential for the success of the deployments. A short survey, typically covering a 100 square kilometer region and requiring 3-4 hours time, was made of each site prior to the start of deployment. A target deployment site was then selected based on the detailed local bathymetry. Wind, ship and ice drift were assessed, and a scheme devised so that the ship could be at the site by the time the mooring was fully in the water and ready to be released. Many of the deployments occurred in areas of extremely steep and poorly charted bathymetry, and the ability to chart and plan the deployments proved crucial. Finally, thanks are due to Suzanne O'Hara, who spent long, irregular and uncomplaining hours operating the SeaBeam system and led a number of us cheerfully through the onerous process of editing the data.

CTD, Computer and underway operations. Bruce Huber

CTD Operations: The package used during DOVETAIL consisted of an ASA SBE 9plus CTD with dual sensors, 24-position SBE Carousel water sampler with 10-liter bottles, a bottom pinger and bottom contact switch. The CTD cable is in excellent shape. The cable was already terminated when we boarded, and was not reterminated. A Lowered Acoustic Doppler Current Profiler

(LADCP) was provided by Lamont. ASA support personnel mounted the LADCP components on the CTD frame using materials from both shipboard ASA stock and Lamont. The secondary CTD temperature sensor was found to be faulty during initial checkout of the CTD, and was replaced. Some minor adjustments were made to the sensor plumbing to improve flow.

After some initial minor problems with leaky bottles and recalcitrant carousel triggers, the water sampler performed very well with a minimum of trouble. Most annoying of these minor problems was the tendency for the endcap o-rings to become loose, sometimes resulting in lost samples. It appears that some of the end caps were not machined to close enough tolerances, resulting in sloppy o-ring fits. These should be relegated to the spares drawer, and replaced with endcaps with properly machined o-ring grooves.

Both conductivity sensors were replaced early in the cruise due to sediment fouling after impacting the bottom on station 2. ASA is to be applauded for maintaining an extensive stock of CTD sensors, most of which had been recently calibrated.

Lamont computer and peripheral equipment was used for the CTD data acquisition and some processing operations. The ASA support personnel were very helpful in rearranging existing computer equipment in order to meet our needs. Some of the shipboard CTD computer equipment is quite old and should be upgraded or replaced. Some of the monitors are so old the phosphors are dimmed to the point of causing eyestrain.

Over the side CTD operations were for the most part smooth, especially in the pack ice. In open water, with only moderate swell, operations are a bit dicey. A faster boom would reduce the risk to the package upon deployment and recovery in moderate to rough conditions.

Water samples were analyzed for dissolved oxygen and salinity. The shipboard salinometers were used for the latter analysis, and many problems were encountered. One unit, reportedly just returned from factory calibration, was found to be unusable. The other performs well as long as the ambient temperature doesn’t fluctuate, and when there is minimal vibration due to ice breaking (which means not often working well on this cruise).

Oxygen titrations were initially done on a Lamont automated titrator. This unit eventually failed, and the ASA optical endpoint titrator was set up and used. There were only minor problems with this unit (including a cracked UV source lamp) and it has overall performed well. Again, thanks to the ASA support team for assistance. It should be noted that during the planning phase of DOVETAIL we had requested the ASA titrator be made available as a spare, so proper planning paid off.

Computer support and underway data logging: The ASA computer support personnel were very helpful in getting us set up, including putting some of our computers on the network. Equipment was moved when necessary, and every effort was made to give us what we needed within the constraints of the systems installed. Email is not so great and should be completely revamped. In fact, the entire network of networks should be reevaluated and streamlined. The concept is great, but there are surely better ways now to implement multi-platform networks. The underway data collection system is a great idea too, but the implementation requires too much maintenance. The meteorological display is unreliable - the data should be median filtered before averaging to avoid contamination by serious outliers and gps flake-outs. The TSG appears to be working well, even in the ice, in welcome contrast to earlier experiences.

Lowered Doppler Current Profiler (LADCP), Martin Visbeck

The goal of this project was to obtain top to bottom velocity profiles by using two ADCPs attached to the CTD frame. The LADCP-2 system was recently developed by the PI and this cruise was the first scientific application of the new system. I staged the LADCP operation in the dry lab next to the Baltic room. The ASA staff help during the setup phase and designed an efficient mounting system using parts that I brought along. Two RDI WH-150 ADCPs and one battery pack were mounted on the CTD frame, one ADCP looking upward and the other one downward.

We were able to operate the LADCP system at every station.

The procedure was fairly simple and required no extra station time. The ASA team helped to set the data logging and data processing computer system up. Once everything was running we were able to provide full ocean depth velocity profiles about 15-30 minutes after the CTD was on board. The quality of the data set was very good and interesting scientific conclusions could already be drawn. To my knowledge this was the first extensive survey of near bottom currents in the Weddell-Scotia confluence zone.

This project would have benefited from more SeaBeam data throughout the cruise. Bottom currents are obviously directly affected by the bathymetry and the charts available are insufficient to say the least. To me it seemed that we have wasted an opportunity to improve on the quality of bathymetric maps by not using a sounding system which could have been available.

Overall we have demonstrated that the LADCP system has great scientific payoff for a minimal extra investment and should be part of the standard hydrographic package. Aside from the at times terrible e-mail situation I want to thank the captains and crew of the N.B. Palmer and the ASA support team for making this cruise a worthwhile operation.

Tracer Chemistry Manfred Mensch

Tracer Sampling (D. Breger, L. Breger, B. Gordon, G. Mathieu, S. Mathieu, M. Mensch)

Tracer samples were collected to supplement the information derived from the standard hydrographic parameters temperature, salinity and dissolved oxygen.

CFC samples (PI W.M. Smethie) were taken at all stations and with very few exceptions at all depths where Niskins were tripped. The analyses were performed within less than 12 hours of the sampling. Frequently, air samples were analyzed to establish the atmospheric CFC concentrations. They will be used to calculate the CFC saturation of the surface waters.

Helium, oxygen isotopes and tritium samples (PI P. Schlosser) were collected at about every third station. The samples will be shipped back to Lamont-Doherty Earth Observatory where they will be processed at the Noble Gas and Stable Isotopes Laboratories.

The water sampling package used during the cruise performed very well. No mistrips were encountered and the total number of leaky Niskins was very small. At the beginning of the cruise, all O-Rings on the Niskins were replaced with BUNA-N O-rings that were baked under vacuum at 80°C for one week to minimize the danger of CFC sample contamination. Unfortunately, the test and shake down station did not sample CFC free waters so that the blank levels of the Niskins could not be established. Replicate samples that were frequently drawn throughout the cruise do not exhibit any suspicious variability. Therefore, we are confident that the Niskins did not contaminate the CFC samples.

The ASA personnel on board as well as ECO's officers and crew members provided excellent support. All our requests and needs were answered in a prompt and friendly manner. We were very pleased with their expertise, efficiency and cooperation that helped making our part of the cruise a great success.

IV Data Sharing Policy:

As is my normal policy, any Dovetail researchers or member of the Palmer 97-5 science staff can receive preliminary forms of the data obtained during the cruise. However, it must be recognized that the data are in preliminary form and are released only as an aid in interpretation of the specific data program of the Dovetail researcher or as an educational tool. The data set is not to be shared by people outside of the Dovetail program.

For each data set there is an "owner". Use of data for science analysis requires approval of the "owner". "Ownership" expires two years after the end date of the cruise or in the case of mooring and drifter data, two years after the data are recovered from the field.

I assume all of this is clear, but a more subtle point is as follows: if one uses the data for a routine procedure that would have been done by the "owner", that does not buy collaboration (co-authorship). "Owners" invite collaboration.

OWNER DATA SETS: CTD (Gordon); bottle: salinity (Gordon), oxygen (Gordon), nutrient (Peacock), CFC (Mensch/Smethie), Trit/He (Schlosser), stable isotope (Schlosser); LADCP (Visbeck); eventual data from moorings (Muench) and drifters (Martinson).

GROUP DATA SETS: Navigation; weather; hull ADCP; underway T and S; bottom bathymetry; SeaBeam at survey sites.

As the "Owner" of the CTD and associated bottle data, I make plots available to Dovetail researchers and Palmer 97-5 science staff. A. L. Gordon

V CTD List; Dovetail Mooring and Drifter Deployment Sites:

• CTD

CTD	Date	Time (Z)	Latitude			Longitude			Bottom Depth	Comments
1	8/4/97	12:01	57	30.070	S	44	59.468	W	3090	test station.
2	8/4/97	18:02	57	59.994	S	44	30.180	W	2781	hit bottom at 30m/min
3	8/4/97	22:26	58	21.096	S	44	30.462	W	2801	primary co sensor changed before this station
4	8/5/97	11:08	58	42.975	S	40	30.097	W	2431	large ice floes in belts and strips
5	8/6/97	00:29	59	05.820	S	44	29.754	W	1208	
6	8/6/97	09:14	59	30.660	S	44	22.810	W	2211	40 m off bottom
7	8/6/97	14:48	59	45.510	S	44	21.120	W	4406	
8	8/6/97	19:41	59	53.369	S	44	20.206	W	4727	
9	8/7/97	00:52	60	04.192	S	44	17.647	W	4821	
10	8/7/97	04:49	60	07.800	S	44	16.540	W	5088	
11	8/7/97	09:59	60	07.795	S	43	53.865	W	4771	
12	8/7/97	15:11	60	07.455	S	43	30.977	W	4994	
13	8/7/97	22:05	60	03.612	S	43	59.442	W	4962	no bottles
14	8/8/97	03:37	60	00.223	S	44	18.631	W	4819	mooring site 12
15	8/8/97	17:08	60	10.800	S	44	15.216	W	5326	
16	8/8/97	22:39	60	19.902	S	44	00.214	W	4626	sensor chg co 2nd
17	8/9/97	07:05	60	28.920	S	44	11.760	W	1489	mooring site 11
18	8/9/97	18:43	60	56.929	S	44	07.333	W	246	6 bottles
19	8/9/97	23:08	61	11.520	S	44	02.939	W	376	6 bottles
20	8/10/97	07:56	61	33.226	S	43	59.397	W	519	near mooring 9
21	8/10/97	22:51	61	59.228	S	43	55.891	W	912	
22	8/11/97	05:58	62	16.800	S	43	38.360	W	1171	
23	8/11/97	11:09	62	26.460	S	43	20.878	W	1450	mooring site 8
24	8/11/97	20:40	62	40.216	S	43	11.077	W	3237	
25	8/12/97	04:48	62	49.375	S	42	55.637	W	3463	ice buoy
26	8/12/97	14:50	63	00.559	S	42	32.291	W	3743	mooring 7
27	8/13/97	12:09	63	09.975	S	42	07.127	W	3757	
28	8/13/97	21:11	63	22.873	S	42	01.656	W	3796	near possible small seamount
29	8/14/97	03:20	63	31.378	S	41	47.094	W	4560	near site of UK mooring
30	8/14/97	13:57	63	50.203	S	41	01.134	W	4501	Ice Buoy
31	8/15/97	00:51	64	04.871	S	40	25.066	W	4628	
32	8/15/97	11:05	64	16.017	S	39	59.650	W	4703	ice buoy w/ thermistor
33	8/16/97	02:05	63	50.161	S	40	07.846	W	4623	
34	8/16/97	14:10	63	05.060	S	40	02.474	W	4228	
35	8/17/97	02:06	63	13.475	S	40	04.628	W	4371	Ice Buoy
36	8/17/97	19:41	62	55.547	S	40	02.848	W	4286	rough bottom
37	8/18/97	02:52	62	35.856	S	40	08.074	W	2695	
38	8/18/97	08:32	62	20.047	S	40	02.252	W	3354	Ice Buoy
39	8/18/97	15:20	61	59.525	S	40	07.770	W	3377	
40	8/18/97	22:33	61	44.454	S	40	03.497	W	3421	
41	8/19/97	09:40	61	25.084	S	39	56.356	W	3190	
42	8/19/97	19:54	61	11.142	S	40	04.194	W	2775	
43	8/20/97	00:55	61	08.788	S	39	43.520	W	2852	
44	8/20/97	05:25	60	59.977	S	39	30.271	W	4021	
45	8/20/97	13:18	60	42.119	S	40	01.039	W	5449	Orkney Deep

46	8/20/97	22:21	60	18.007	S	39	59.435	W	1331	
47	8/21/97	05:17	59	53.490	S	39	58.244	W	1618	
48	8/21/97	11:40	59	29.839	S	39	59.453	W	1909	
49	8/21/97	17:31	58	59.827	S	40	00.092	W	2341	
50	8/22/97	00:41	58	28.986	S	40	00.697	W	3353	station aborted due to high wind, seas and ice
51	8/23/97	02:12	58	38.272	S	44	32.334	W	2931	Mooring site 1 (m14)
52	8/23/97	13:41	59	30.696	S	44	24.444	W	2255	Mooring site 2 (#13)
53	8/25/97	01:10	59	48.960	S	48	13.458	W	4362	
54	8/25/97	07:45	59	59.856	S	48	14.920	W	4386	
55	8/25/97	19:14	60	17.468	S	48	15.647	W	5280	near mooring 10 (#16)
56	8/26/97	02:16	60	30.085	S	48	04.762	W	1358	
57	8/25/97	10:30	60	33.026	S	48	17.208	W	1968	mooring 12 (#17)
58	8/27/97	03:57	60	44.970	S	48	19.554	W	2481	
59	8/27/97	10:38	61	02.090	S	48	19.252	W	2759	
60	8/27/97	20:27	61	18.410	S	48	18.034	W	2876	
61	8/28/97	02:46	61	30.000	S	48	32.400	W	3084	
62	8/28/97	09:05	61	44.965	S	48	41.713	W	3255	
63	8/28/97	15:42	61	59.844	S	48	59.034	W	3317	
64	8/28/97	21:47	62	14.779	S	49	14.438	W	3347	
65	8/29/97	04:04	62	30.160	S	49	22.153	W	3386	
66	8/29/97	13:03	62	46.470	S	49	41.255	W	3398	
67	8/29/97	18:15	62	56.221	S	49	54.029	W	3409	
68	8/29/97	22:48	63	04.580	S	50	00.348	W	2660	
69	8/30/97	11:08	63	04.776	S	50	40.614	W	1519	
70	8/30/97	18:11	63	05.814	S	51	29.382	W	1581	
71	8/31/97	01:28	63	03.676	S	52	09.293	W	550	
72	8/31/97	06:34	63	05.900	S	52	54.094	W	444	
73	8/31/97	10:40	63	06.193	S	53	37.199	W	323	
74	8/31/97	14:06	63	05.650	S	54	18.070	W	395	
75	8/31/97	18:46	63	06.047	S	54	59.830	W	511	Near Joinville Is.
76	8/31/97	22:15	62	47.933	S	54	50.716	W	179	
77	9/1/97	01:33	62	29.946	S	54	45.229	W	275	
78	9/1/97	04:16	62	17.916	S	54	35.983	W	529	
79	9/1/97	06:48	62	09.077	S	54	23.740	W	803	
80	9/1/97	09:43	61	59.923	S	54	14.850	W	578	
81	9/1/97	12:10	61	44.556	S	54	06.870	W	344	
82	9/1/97	15:28	61	31.470	S	54	02.106	W	918	
83	9/1/97	20:00	61	14.504	S	53	50.623	W	1319	
84	9/2/97	00:39	60	53.926	S	53	30.180	W	663	
85	9/2/97	03:20	61	04.498	S	53	20.644	W	1902	
86	9/2/97	21:46	61	39.790	S	51	59.662	W	2170	near mooring site
87	9/3/97	04:48	61	39.104	S	52	30.016	W	471	
88	9/3/97	09:11	61	35.848	S	53	00.775	W	422	
89	9/3/97	12:56	61	32.926	S	53	29.916	W	694	
90	6/3/97	18:14	61	30.218	S	54	29.712	W	1540	
91	9/3/97	21:27	61	38.970	S	1	00.148	W	2173	
92	9/4/97	01:44	61	47.968	S	55	31.066	W	2642	
93	9/4/97	06:41	62	00.098	S	56	06.000	W	1789	
94	9/4/97	11:38	62	14.736	S	56	58.788	W	1600	
95	9/4/97	17:25	62	30.799	S	57	47.734	W	1650	
96	9/4/97	23:35	62	44.898	S	58	58.189	W	1460	
97	9/5/97	15:07	61	36.006	S	56	48.271	W	500	

• Moorings:

ID	Latitude S	Long W	Depth	Deploy Date	Release Date
7	63-00.0	42-29.4	3680 m	8/12/97	4/1/98
8	62-26.7	43-17.3	1476 m	8/11/97	4/1/98
9	61-39.0	43-55.9	591 m	8/10/97	4/1/98
10	CANCELLED				
11	60-29.8	44-09.7	1460 m	8/9/97	5/1/98
12	60-00.7	44-17.7	4830 m	8/8/97	5/1/98
13	59-31.0	44-23.7	2360 m	8/23/97	8/1/98
14	58-41.4	44-32.8	2630 m	8/23/97	8/1/98
15	ABORTED DURING DEPLOYMENT				
16	60-13.3	48-13.4	2657 m	8/26/97	3/1/99
17	60-33.3	48-18.2	2001 m	8/26/97	4/1/98
18	61-18.2	48-18.6	2870 m	8/27/97	4/1/98
19	61-39.6	52-01.9	2012 m	9/2/97	4/1/98

• Drifter:

	1	2	3	4	5	6
Beacon #	4897	4893	4894	4895	4898	4896
Date Deploy (GMT)	97/8/11	97/8/12	97/8/14	97/8/15	97/8/17	97/8/18
Time Deploy (GMT)	0:12	8:05	17:53	14:48	5:45	12:05
Ship Latitude	-61.988	-62.814	-63.835	-64.253	-63.252	-62.298
Ship Longitude	-43.919	-42.890	-40.968	-39.984	-40.096	-40.019
Air Pressure (mb)	979.4	988.27	981.79	983.8	-986.47	988.03
Air Temperature (C)	-6.54	-18.83	-4.26	-11.87	-13.86	-20.14

VI Science- Preliminary data analysis: [See the packet of figures attached to this report which include maps of station, the mooring and drifter deployment sites, plus a selections of data displays.]

These observations are mainly based on CTD/Oxy data. CFC info and Lowered Acoustical Doppler Profiler (LADCP) data are often worked into the story, but usually not to great detail. The LADCP and tracer chemistry information will be incorporated during the data analysis phase of the program in collaboration with appropriate PIs, as will the mooring and drifter data when obtained.

The CTD/oxy data provides the basic water mass presence information upon which the other data may be referenced. Temperature and salinity with their link to the density field, and oxygen are fine integrators of advective, stirring and mixing patterns and processes. Much of my focus is on the upper kilometer (mixed layer, pycnocline and Weddell Deep Water t-max) and the benthic layer at station spacing (generally 10 nm) or greater spatial scales. It is noted that there is much variability between up and down traces of CTD with T/S expression reflecting quasiisopycnal fine structure or stirring processes. Such features are relevant to cross front lateral fluxes research, which are of interest to the Dovetail program, but not discussed in these initial impressions. The LADCP data provide a direct look at the velocity fields of the water column and when coupled to CTD is a powerful new tool that can be used for direct investigations of mixing processes. But this too are the subject of future analysis.

The comments are presented by regions followed by a summary. A packet of figures are attached, but not cited in the text. The topics discussed do not include all aspects of the data, just those that caught my attention. Each station contributes to the story, but I will not point out each intrusion or inflection. The narrative reflects a evolution of thought about the data. (Read the “Closing Statement and Primary Research Topics & Questions” and “Concluding Remark” first.)

For background: Previous research defines a Weddell-Scotia-Confluence (W-S-C) as a zone separating the circumpolar from the Weddell Gyre stratification. Within the W-S-C zone the water is very cold, t-max is generally less than 0°C. It may be viewed as continental margin waters, including some Bransfield Strait waters, injected into the deep ocean at the tip of Antarctic Peninsula.

[A] 44°W Section- This section shows the W-S-C form across the South Orkney Plateau.

Scotia Sea & South Orkney Island Plateau (Station 1-21):

• W-S-C: Stations 1-5 are in Pacific CDW water with t-max of >1.0°C; between station 5 and 6 is a front across which the t-max drops from greater than 1.4°C to less than 0.9°C. The front occurs over the southern flank of the topographic high, called Parie Bank. Stations 6-14 define the transition of the Pacific CDW from the W-S-C water column. On proceeding southward there is shift towards cooler, lower salinity, higher oxygen water for density values less than 27.825 sigma-0. Fine structure is very common, with a particularly intense thin (40 m) feature at station 1 near 875 m with 1°C, 0.07 ppt amplitude. The dovetail stations over the plateau have cold t-max, slightly less than 0.1°C at 350 m at station 20 in about 500 m of water. The W-S-C water column is confined to the shallows over the Orkney Plateau. To the south the t-max increases to over 0.2°C at station 22, as the Weddell water column is encountered, marking the southern limits of the W-S-C, the Weddell Front.

A section along 50°W west of the Orkney Plateau (see southern ocean atlas) shows the cold W-S-C water column occupies a wide region which along the 44°W Dovetail section is ‘filled’ with the Plateau. Does the W-S-C water pass to the east of the Plateau? It would have to do so over the steeper flanks of the Plateau. One might expect that the favored route is along the Plateau’s southern flank, where the LADCP data shows eastward flow (and a strong westward flow over the northern flank). Clockwise flow around basins, with counter clockwise flow around plateaus and banks, seem to be the rule in this strongly barotropic circulation. As the outflow of continental margin waters at the tip of Antarctic Peninsula may be sporadic, so may be its presence around the Orkney Plateau. The Dovetail crossing does not reveal a dominate presence of W-S-C water, except over the Plateau.

• Benthic layer north of Parie Bank: The stations 1-5 are warmer at all depths than 6-14, but in the lower 200 meters, particularly at the deeper stations 1, 2 and 3, the water cools rapidly meeting the station 6-14 temperature profile, coupled to an increase in the oxygen gradient, but without a T/S signature. I suspect that more recent Weddell spill-over (Weddell water that flows northward over gaps in the Scotia Ridge) water is migrating rapidly along the sea floor to the northern edge of the Parie Bank.

• Low salinity upper pycnocline water on the Orkney Plateau: The pycnocline of stations 18 and 19 just southeast of the Orkney Islands indicate the presence of some lateral effects that may reflect shear between Scotia and Weddell water columns. At these stations the pycnocline salinity spans a wide range, while the temperature is nearly constant at -0.6°C. A small t-min at station 19 of -0.85°C occurs at 190 m. The surface layer follows the Scotia Sea water column as revealed in stations 1-5, the deep layer follows the Weddell water column, seen further south; the isothermal layer links the two water columns in T/S space. It appears that over the Orkney Plateau low salinity surface water over-rides denser Weddell waters, with the interface falling around sigma-0 27.75 (200 m on and south of the Plateau; 500-800 m to the north). The source of the upper pycnocline lower salinity water may be sea ice melt, as the northern edge of the seasonal sea ice zone may experience net melting as ice is blown into the margins, where it melts. The melt water diffuses into the warmer water of the pycnocline, which then over-rides denser Weddell water.

Added after Bransfield Stations (3 Sept.)*: It is possible that the low salinity pycnocline water is coming from the Bransfield Strait.*

• Sill Depth: This will be dealt with in the 40°W section. The bottom temperature is -0.598°C, salinity of 34.648 and oxygen of 5.95 ml/l (est.) at the deepest site (station 15) north of the Scotia Ridge. To the immediate south of the ridge these properties are found near 3000 m, but further south they are occur at deeper depths. The 40°W section will point-point the controlling sill depth.

• Mixed Layer: Mixed layer thickness varies from 70 to 120 m within the sea ice fields. Freezing point (around -1.84°C) or slightly warmer surface water occurs at stations 12 and 17 with a salinity of 34.17. As we experienced lots of sea ice north of these stations, ice at these northern sites must be melting, balanced by northward wind drift. On proceeding to the south the surface water remains at the freezing point, while surface water salinity lowers to 34.07 at station 21 over the Plateau. This is a further sign of net melting, but probably earlier in the winter season. South of the Plateau the salinity increases, see next section. Mixed layer oxygen is usually above 8.0 ml/l (7.6 ml/l at St. 21, 90%) well over 90% of saturation, indicating little upward mixing of the oxygen poor deep water.

Southern Slope of S. Orkney Plateau into Weddell Basin
(Station 22-32):

• Low salinity upper pycnocline water: On proceeding southward from station 18 the mixed layer and upper pycnocline becomes progressively colder and more saline. Above it is suggested that the upper pycnocline low salinity of the upper pycnocline is due to net ice melting along the marginal ice zone (ice formed in the south is forced northward by the wind, where it melts). The slow attenuation of this feature on proceeding to the south may be due to a decrease of net melt water, as a greater portion of the regional ice is local in origin. With the formation of sea ice the winter mixed layer is maintained at the freezing point and becomes increasingly more saline. The mixed layer water is subducted into the upper pycnocline to the north.

Added after Bransfield Stations (3 Sept.)*: The attenuation mentioned above may just be that we pass through the Bransfield 'river'.*

• Mixed Layer: The Weddell Gyre's surface layer under the winter sea ice is normally well mixed, with a temperature at or slightly above the freezing point. The winter mixed layer oxygen is undersaturated by 10 to 30 % points, this information along with time under ice since the Fall season advance, is used to determine the amount of entrained low oxygen WDW and its associated heat and salt fluxes. The mixed layer temperature encountered south of station 14 is very close to the freezing mark, around -1.85°C. The mixed layer is generally around 70 m thick, varying between 60 to 80 m. Some minor T/S structure is observed within the mixed layer, with a frequent oxygen gradient, higher at the surface. The salinity of the mixed layer varies from 34.07 to 34.36, with slightly warmer temperatures at the low salinity values (-1.84 vs. -1.86°C). The most saline freezing point mixed layer occurs south of the Orkney Plateau, the lowest over the Plateau. Oxygen values decrease with increasing latitude, 8.1 over the Plateau, 7.3 ml/l well to the south, with saturation values near 90%, reaching to 83% well into the Weddell Gyre.

• Warm t-max: South of the Orkney Plateau the WDW t-max is warmer when compared to 92-2 data and to the climatology. The Dovetail t-max, marking the shallowest approach of the WDW core, is between 0.6° and 0.7°C for the stations south of 24, at depths of 450 m. Over the southern flank of the Plateau values between 0.4 to 0.6°C are found, with slightly shallower depths, 350 m. These values are well above the regional climatic expected values of 0.5°C or less.

The warmest WDW is injected into the eastern boundary the Weddell Gyre near 30°E, though some authors have suggested occasionally warm WDW may enter just east of the South Sandwich Islands, with the Weddell Gyre forming two cells. The cyclonic circulation of the Gyre distributes the warmest t-max, with the greater than 0.6°C t-max confined to the central and southern parts of the Weddell Gyre and within a narrow band along the western boundary current of the Gyre. The t-max would warm if the westward infiltration is more rapidly, or if the processes that cool the t-max (mixing with the winter mixed layer and lateral mixing in the continental margin) have diminished. Since the Weddell Polynya occurrence of the mid-1970s the Weddell Deep Water WDW t-max within the central Weddell Gyre has steadily warmed from values below 0.5°C to well above 1.0°C in the 1990s.

The warmest t-max in the northwest, "Dovetail" region, Weddell Sea is derived via the western boundary pathway. A t-max increase indicates that the western boundary current has 'picked-up' the warmer t-max of the southern limb of the Weddell Gyre and is now rapidly advecting it into the NW Weddell Sea. The decreased t-max at station 30 (63°50'S) of 0.63°C shows that we passed south of the western boundary current extension.

Research Question: is the T-max warming due to decrease in heat loss to the atmosphere or due to increase in injection of warm circumpolar deep water into the Weddell Gyre?

• <u>Ventilated bottom layer on the South Orkney Plateau</u>: At stations 21 (bottom depth of 906 m), 22 (1171 m) and 23 (1453 m) over the gentle sloped southern flank of the South Orkney Plateau there is the a benthic layer with substantially cooler, high oxygen and CFC concentrations relative to the deeper adjacent ocean water columns. At station 17 (bottom depth of 1407 m) along the steep northern flank of the Orkney Plateau this anomalous signature is present in all parameter but weaker and lifted off the sea floor (strongest presence at 1000 m); the CFC is particularly weak, nearly absent. Nothing stands out in the CFC11/12 or CFC11/113 ratios. The Orkney Plateau high oxygen layer falls within the sigma-0 range of 27.825 to 27.845.

The bottom current (LADCP) for stations 21-23 are directed towards the east in the 2 cm/sec range; 7 cm/sec for station 23. At station 17 the bottom current is westward at 7 cm/sec. As characteristic of this region, these currents follow isobaths (counter clock-wise around topographic highs).

The well ventilated benthic feature is too warm (in the 0 to -0.4°C range) to be considered as Weddell Sea Bottom Water (less than -0.7°C) and too shallow (1000 m vs. 3000 m) to be influenced by this water mass via isobath following currents from the deep western Weddell Sea. Inspection of the T/S properties reveals that the Orkney Plateau benthic layer is slightly lower in salinity is about 0.005 less than the surrounding fluid of similar density, which does not bear the high oxygen, CFC signal.

Research Question: What is the source of the Orkney Plateau well ventilated bottom water? Possible source: Continental shelf and upper slope water migrating northward in the western Weddell Sea, unless it goes into the Pacific Ocean (which it does not do, except for a brief recirculation in the Bransfield Strait) it eventually runs out of continental margin. It then spreads along isopycnals within the water column to the east forming the upper layers of the cold W-S-C water column. The ISW data shows that along the freezing point curve the shelf water fills a wide sigma-0 range including that of the Orkney benthic layer. Shelf water with salinity of 34.57 can provide an isopycnal source for the Orkney benthic layer water.

The Dovetail data between South Orkney and Antarctic Peninsula should see water with proper characteristics to supply the Orkney benthic layer water. Inspection of the 50°W section given in Whitworth et al (1994) [see southern ocean atlas for an additional section], I suspect that the source will be found in the 300 to 600 m range of the W-S-C (though the Whitworth et al oxygen values are less than 6 ml/l). Because of the Weddell shelf origin with its glacial melt, I suspect that there will be a low oxy-18 value. What we are seeing is a “hop” of shelf water across a deep ocean gap.

• <u>Benthic layer</u>: An inflection point in the T/S curve is observed for the stations south of the Scotia Ridge at potential temperature somewhere in the range -0.55°C to -0.65°C. For colder water the T/S is steeper (more salinity decrease for given temperature decrease). This characteristics marks it as being drawn from the Weddell Sea Bottom Water (WSBW) formed in the Weddell Sea. I call the layer with this steeper T/S slope as the benthic layer. This is meant in the water mass sense; the relationship of the frictional driven Planetary Boundary Layer to the water mass benthic layer may be studied with the CTD and LADCP data (?). However, it is associated with a change in the profile, generally a thick homogeneous layer or a thinner stratified layer. The benthic mixing processes is of interest in that it mixes WSBW up into the water column, where it can then escape over the topographic confines to the north.

Once off the Orkney Plateau there are two groupings of stations: 24-28 with ocean depth of around 3500 m and 29-32 at depths of 4600 m, an abrupt change in bottom depth occurs between stations 28 and 29 which is separated by only 11 nm. The -0.55°C isotherm marks the top of the benthic layer for stations 24-28. It is found near 2900 m, with the sea floor near around 3800 m, making for a 900 m rather well mixed (but not homogeneous) benthic layer. For stations 29-32 the T/S inflection point is at the -0.65°C isotherm at 4100 m, with the sea floor at 4500 to 4800 m, making for a thinner but sharper, more stratified benthic layer. For these deep stations, at the -0.86°C isotherm near 4500 m, the profiles (vs. depth) reveal another increase in profile gradient: temperature and salinity decrease more rapidly and oxygen increases more rapidly as the sea floor is approached. Within this roughly 200-300 m bottom layer the sigma-0 gradient is unstable, similar to that observed in the western Weddell, the source of the benthic water. The coldest bottom temperature of -1.01°C is observed at station 30. The -1.0°C isotherm is somewhat further east than in climatology, but previous coverage of the lower few hundred meters is weak.

Oxygen within the benthic layer is higher than that at similar depth north of the South Scotia Ridge, as topography blocks its access to the north. Bottom oxygen reaches 6.35 ml/l, nearly as high as that of the WSBW low salinity variety along the western Weddell Sea (6.75 ml/l). Bottom CFC at station 27 is 2.4 CFC-11 (don’t have stations 29-32 yet).

The LADCP bottom tracks in lower 250 m. At station 29, the site of high eastward bottom flow as reported by Barber and Crane, the LADCP confirms high eastward speeds, around 12 cm.sec-1. The LADCP shows that south of the Orkney Plateau the barotropic flow is strongly towards the east, clearly marking the northern limb of the Weddell Gyre. The LADCP barotropic transport between stations 24 and 32 is about 40 Sv (a velocity of 5 cm/sec over a 4000 m water column from 62.2 to 64.2°S delivers to a transport of 44 Sv) about the magnitude of the Weddell Gyre western boundary current.

The division between a thick and thin benthic layer occurs close to station 29, 63.5°S (which has a combination of characteristics). On the 40°W section (discussed in the below) the separation occurs between stations 34 and 35, 63.4°S, though mixed mode benthic layers are observed, in which a mixed benthic is undercut by a stratified benthic layer. Inspection of the Palmer 92-2 data marks the division at 45.5°W between stations 9 and 10, 63.6°S. So it appears to fall at latitude of 63.5°S along the northern limb of the Weddell Gyre. At the Gyre’s western limb the ISW data does not show as thick of a benthic layer as observed to the east, though a lessening of the benthic profile gradient at the northern end of the floe drift near 66.1°S is measured for depths less than 2800 m, which may mark the beginnings of the process leading to the thick benthic layer. The ISW data indicates that bottom water characteristics descend by about 1000 m on making the turn to the east as part of the larger scale gyre circulation.

A research question: what is the distribution of the benthic layer thickness and its relationship to bottom depth, slope and roughness, water column t,s, and LADCP profile, and why?

[B] 40°W Section- This section shows the form of the W-S-C after it slips east the Orkney Plateau.

• Low salinity upper pycnocline: The low salinity upper pycnocline observed along the 44°W section, develops on proceeding northward along 40°W from station 36. Station 36 has the saltiest, freezing point surface water and saltiest pycnocline of all of the Dovetail stations along 44° and 40°W, and hence represents the most "Weddell" station encountered on the Dovetail array, so far. The low salinity upper pycnocline feature extends to a density horizon of 27.77 sigma-0 (120 to 170 m). The nearly straight line in T/S space denotes two end-member mixing between the mixed layer and mid-pycnocline.

There are two possible causes for the low salinity upper pycnocline: 1. net sea ice melting with subsequent mixing downward to around 150 m; and 2. low salinity surface water from the southern limits of the ACC overrides Weddell pycnocline. These are not mutually exclusive, as the low salinity of the over-riding ACC water may also be derived from ice melt.

In the western Weddell the prevailing winds are to the north and east, blowing ice towards the north. When the heat budget allows the ice edge advances, this is a Fall season happening. During Spring the heat budget melts the ice edge back to the south faster than the ice is blown north, and the ice edge retreats. In the nearly equilibrium winter season of maximum ice extent (August and September) a balance is achieved between the northern drift and the net melting. Using station 36 salinity profile as for the 'Weddell' reference, one can estimate the excess freshwater required to convert a station 36 stratification to the observed salinity profile for the Dovetail stations that have a Weddell lower pycnocline form (stations 22 to 41). Lowering salinity by 0.1 ppt over 150 m requires ice melt of 0.5 m, not unreasonable. The heat flux required to melt the ice must also make sense. If the half of a meter of ice melted in 2.5 months (ice reached this latitude in early June), 50 cal/cm^2 day is needed. Realistic? I don't know, but sounds OK.

***Added after Bransfield Stations (3 Sept.)**: It is possible that the low salinity pycnocline water is coming from the Bransfield Strait.*

• Warmer t-max: The t-max exceeds 0.7°C for stations 35-37. Along the 44°W section the t-max exceeded 0.7°C at stations 26 and 27. The wider band along the eastern section is most likely a reflection of the 'fanning' out of the isobath following flow on passing east of the confines of the South Orkney Plateau. Clearly the WDW t-max is substantially warmer in 1997 than in 1992 and warmer than the climatic mean. As noted above this is a Weddell Gyre wide phenomena.

Research Question: The flip side to the question asked in the 44°W section, is: What effect does warming of the t-max have on bottom water production or Weddell polynya susceptibility?

• Benthic Layer: Benthic layer of Weddell Sea Bottom Water (WSBW) is often thick, well mixed, other times thin and stratified. When thin and stratified the linear T/S relationship typical of the water column from the t-max to deeper water extends to colder temperature (nearly to -0.7°C, versus -0.5°C or so for thick mixed benthic layer type), resulting a more abrupt change in T/S slope as the benthic layer is entered. The mixed type benthic layer has a more gentle T/S slope change, as it has mixed into the shallower water to a greater extent. Additionally, the thin stratified benthic is unstable in sigma-0, the thick mixed benthic layer is not.

Some relationship of benthic layer type to bottom topography is observed, the thicker benthic layer is often over a shallower sea floor, but not always. A mixed mode benthic layer is occasionally observed. Initially I thought that the form of the benthic layer is set well upstream, in the western Weddell near the formation site, but the mixed mode benthic layer suggests that there may also be a sporadic nature to the benthic layer. The well mixed benthic layer could be formed locally, over rough topography or where the bottom velocity is large (mean or transient). A mixed, thick benthic layer may be lifted off the bottom by the surrounding, denser stratified layer. A series of such event eventually would mix all of the WSBW into the water column.

An interesting idea: the stratified benthic layer is unstable in sigma-0, thermobaric effects are needed to keep it ‘down’. As the increased compressibility of water decrease temperature is non-linear, might there be a feed-back role for thermobaric effects? A small amount of mixing leads to more rapid vertical mixing; push a little and the pushing gets easier. To test this idea station 32 (a thin stratified benthic layer; bottom 4764 db) is used. The sigma-p (pressure reference is 4665 db, 100 db off the sea floor) difference between the bottom T and S at station 32 and that 120 m above the bottom is 0.011. Next, on blending the bottom 100 db of station 32, i.e. making a homogeneous benthic layer, the sigma-p (p=4665) difference between the blended layer and the water 120 off the bottom is reduced to 0.005. Mixing the lower 200 db leads to a sigma-p (p=4565, 200 db off the sea floor) produces a sigma-p difference of 0.003, essentially neutral stability. So benthic mixing reduces the in situ stability of the benthic layer, and further vertical mixing is made easier because of the diminished thermobaric effect.

Calculation of the depth average salinity and potential temperature of the water column deeper than -0.4°C (the WDW T/S point shared by all stations in Weddell, hence above the Benthic layer) for the ISW and Dovetail data reveal some large scale spatial pattern, but also lots of variability between neighboring stations. If the benthic layer flow is essentially barotropic, and influenced by vertical mixing, a slow downstream warming is expected, reflecting to some degree bottom roughness, bottom velocity. If newly formed bottom water is introduced (near the western Weddell slope) or if there is baroclinic shear or a convergence of adjacent benthic layers with differing stratification, we would see some changes in the averages. Also keep in mind that the benthic layer distribution may not be in steady state, as a seasonal WSBW production is possible.

Benthic layers of WSBW encountered during the cruise south of the South Scotia Ridge:

Weddell Benthic Layer Types

sta	bottom	type	comments	mean T
25	3500	stratified	weak	-0.617
26	3750	mixed	weak	-0.689
27	3800	both	weak	-0.676
28	3700	mixed	strong	-0.681
29	4600	both	weak	-0.590
30	4600	stratified	strong	-0.605
31	4700	stratified	strong	-0.619
32	4750	stratified	strong	-0.627
33	4700	both	strong	-0.607
34	4800	both	finestructure	-0.578
35	4450	mixed	strong	-0.618
36	4450	mixed	strong	-0.661
37	2700	stratified	strong	-0.510
38	3400	mixed	weak	-0.648
39	3400	stratified	thin mixed	-0.611
40	3400	none	——	-0.629
41	3200	stratified	weak	-0.560
42	2700	none	——	-0.512
43	2900	none	finestructure	-0.556
44	4100	mixed	overflow	-0.609

The stratified benthic layer type is slightly warmer than the mixed benthic layer type, supporting the notion that the mixed type water column experiences displacement upward by inflow of cold stratified bottom. Additional supporting evidence comes from the CFC, the inventory is higher for the mixed benthic layer, as expected if high CFC stratified benthic water slips under the mixed benthic type.

Research Question: What causes the variability in the nature of the benthic layer? Does the concept of sporadic mixing with subsequent lifting of the benthic layer as “unmixed” benthic layer slips below a mixed layer, make sense? Might diminished thermobaric effects provide a positive feed-back to bottom mixing?

• <u>Overflow Sill</u>: Dense Weddell Sea water overflows the South Scotia Ridge into the Scotia Sea. Once in the Scotia Sea spreads northward to eventually exit the Scotia Sea between South Georgia and the South Sandwich Islands, becoming a contributor of unknown importance to the AABW flow in the western Atlantic Ocean. The gap in the Scotia Ridge in the 40°W area controls the overflow, and has drawn some attention inn the literature.

Three stations are particularly useful in resolving the thermometric sill (the “effective” sill depth controlling the water mass overflow) depth between the Weddell and Scotia Seas. These are 44 (bottom temp -0.725°C), 45 (bottom temp -0.662°C), 15 (bottom temp -0.598°C).

Station pair 44/45 gives a 3450 to 3500 m sill, mostly likely near 61°S, 38.5°W. Station pair 45/15 gives a 3100 to 3300 m sill, most likely 60.5S, 41.5W. Salinity gives similar results, but the salinity gradient is small and provides little sensitivity to the sill depth. Therefore dense overflow water fills the deep basin in which station 45 is located across a 3450 m sill. The South Orkney Trough is filled with warmer water drawn from the slightly shallower horizon from the Weddell water column represented by station 44. What is the origin of station 44 bottom water? Station 44 bottom temperature of -0.725°C at 4093 m at is found at 3100 m in the Jane Basin water column. However, the station 44 water column is warmer than the Jane Basin water column below 1500 m and may not be filled from the Jane Basin. It is possible that the route followed by the Weddell water across the Scotia ridge near 40°W may not be along the Jane Basis, but rather via a more eastern channel, along the eastern side of the Endurance Ridge. Using a single station method to determine sill depth (the knee in the temperature profile) a value of 3200 m is estimated for the eastern route thermometric sill depth.

In summary, the effective sill depth between the Weddell and the South Orkney trough is about 3200 m.

• <u>Miscellaneous</u>:

1. Compare stations 6 and 52, both in the same place by separated by 17 days to see how things can change. The Scotia front has moved south, as station 6/52 on 23 August is occupied by circumpolar water. But then compare stations 4 and 51 taken 18 days apart, with 51 about 6 nm north of 4, both 52 nm north of the 6/52 combo. Station 51 t-max is cooler than that of station 4, rich in fine structure. Station 51 indicates increased mixing with Weddell-Scotia-Confluence water. So while the southern pair suggests southward movement of circumpolar water, the north pair shows the opposite, go figure....lots of eddies in the region, the mooring data will be informative.

2. Stations 29-34, the southern apex of the 44° and 40°W sections are within the Weddell Gyre interior. This was detected by the reduction of the t-max as we passed across the outflow of western boundary current water. Another indicator was the WDW oxy-min. The oxy-min of 4.5 ml/l for stations 29-34 falls near 0.44°C. This oxy-min point is about 25-50 m deeper than the 300 m deep t-max, 0.5 to 0.6°C. Within the western boundary extension, the t-max and oxy-min coincide, near 400 m near 0.65°C and 4.75 ml/l. Both points are near 27.82 sigma-0, the lower oxy core is slightly (0.005) more dense. The cooler oxy-min marks the older water of the Weddell Gyre interior.

3. Lowest oxygen mixed layer is 7.12 ml/l at station 35. Salinity is 34.373. Station 36 has slightly higher salinity, 34.391, with oxygen at 7.17 (surface point, at -1.816° slightly above freezing). These stations have the highest percentage of WDW of all the Dovetail stations, so far.

[C] 49°W (stations 53 to 68); This section crosses the W-S-C immediately east of its introduction to the deep ocean and cross the Powell Basin. The LADCP shows the expected clockwise flow in the Powell Basin. The barotropic flow is weak but towards the east between stations 58 and 65, stronger and towards the west across the narrower band from station 66 to 68.

• South Scotia Ridge: Between the Orkneys and the South Shetlands the Scotia Ridge has two limbs, with a deep trench between. Station 55 is in the trench, around 5300 m, it has a homogeneous layer or very low gradient from 2500 m to the sea floor (the top of this layer is set somewhat arbitrary as the temperature profile is quite gentle below 1500 m) with a bottom potential temperature of -0.351°C. North of the ridge the bottom temperature is -0.58°C, a bit warmer but similar to that of the deep trough just north of the South Orkneys. It is likely the Scotia Sea bottom water at 48°W is drawn from a common source, the 40°W gap. The intervening deep trench can be filled from 1800 m from the station 56 and 57 water column. The SeaBeam survey may have included the critical sill north of station 57, it has a depth of around 1650 m. The high bottom current at station 57 suggests that it may be on the Weddell Side of the local overflow path to the north. However, station 57 bottom water (temperature of -0.56°C) doesn't make it over. The complex and poorly defined topography makes it difficult to sort out the local overflow patterns.

• Winter mixed layer: The Powell Basin stations show a saline mixed layer 34.4, which makes for a low stability pycnocline. Entrainment of WDW is likely. However, the salinity gradient across the mixed layer is slightly positive (gets a little more saline with increasing depth), suggesting that recent melting is providing melt water dilution to the surface and that it is mixing downward. The air temperatures we are encountering of -1°C to -3°C makes this explanation more likely. The oxygen concentration in the mixed layer is 7.20 to 7.25 ml/l, 85.7% of full saturation. WDW entrainment may be calculated as done for earlier winter expedition data sets. Unlike the Dovetail stations to the east the melt water is minor and probably a recent occurrence, which have shut down the winter WDW entrainment (at least until the next cold air outbreak).

• W-S-C Low Salinity Deep Water: Over the South Scotia Ridge and along the northern slope of the Powell Basin, an intrusion of low salinity water is observed at depths between the WDW t-max and the benthic layer. I'll refer to this as the "low salinity deep water" (maybe I'll think of a better name, like "W-S-C deep water", but first lets learn more of it's origin), but while it generally does not display an absolute salinity minimum, it usually has an inflection in the salinity profile towards lower salinity and it always displays low salinity as expressed on isotherms, i.e. it has a T/S water mass relationship; additionally it is marked by high oxygen and CFC concentrations. The low salinity deep water observed in Powell Basin has similar characteristics to the bottom water over the Orkney Plateau (stations 17, 21-23). Presumably the deeper segments of the deep s-min that can't spread over the shallower Plateau, are sheared with the more rapid advection along the steep, deeper southern flank of the South Orkney Plateau (e.g. at stations 23 (1428 m) and 24 (3200 m) the eastward directed LADCP measured bottom current is around 8 cm/sec) and were not sampled by during this cruise. As the low salinity deep water was not observed along the 40°W section, it is likely it continues to follow the isobaths of the Orkney Plateau to enter the Scotia Sea.

It's the Antarctic Peninsula stuff that 'floats' to the Orkney Plateau: The low salinity deep water is clearly a well ventilated stratum, though less dense than WSBW, so is not drawn from the dense plume convection of the Weddell Sea. It is proposed that the Powell Basin low salinity deep water advects eastward along the South Scotia Ridge and northern Powell Basin from its source in the northern regions of Antarctic Peninsula, possibility from Bransfield Strait; it's upper part provides the source of the Orkney Plateau bottom water. It's that deep water referred to in the 44W section discussion, that "...spreads from the west 'floating' over a interval of denser water."   The eventual fate of this water and its role in deep water ventilation of the larger scale environment (along with WSBW and AABW) needs to be assessed. The neutral surface approach is useful to tracing the spreading pathways of the low salinity deep water into the deep ocean.

The LADCP bottom tracked barotropic current has an eastward component between stations 58 and 65, with narrower westward flow at stations 66-68, confirming the expected isobath linked clockwise circulation in Powell Basin. Over the South Scotia Ridge the flow seems opposite to the expected relationship to the large scale trend of the isobaths, but the complicated passages across the ridge, may be the primary local guide.

Its best defined within the W-S-C: The first signs of the low salinity deep water is observed at station 54, north of the South Scotia Ridge. There a thin cool, oxygenated, low salinity deep water intrusion occurs at 1900-2000 m. This feature stands out as a sharp spike in T/S space at sigma-2 37.161. While no strong low salinity deep water intrusion or fine structure is seen within the stations 55-58 profiles, the T/S relation reveals the presence of the low salinity deep water within the full deep water column, and may be considered to span the axis of the advective core. That these stations also span the weakest expression of the t-max identifies this zone as the Weddell-Scotia-Confluence.

Spreads into the Powell Basin: The low salinity deep water presence in the profiles of stations 59-60 reveal a bit more structure, reflecting stirring with more saline deep water in the Powell Basin. A thin s-min layer occur at station 61, with a more significant layer at station 62. Station 63-65 near the center of Powell Basin and those further south, do not display the intrusions or low salinity T/S relationship. The low salinity deep water is confined to northern Powell Basin, which suggests a source near the tip of the Peninsula, rather than further south in the western rim of the Weddell Sea. The E-W Joinville and N-S Bransfield mouth sections will help address this issue.

The potential/salinity relationship: It is in the T/S relationship that the unique water mass signature of the low salinity deep water stands out. From the t-max to roughly the -0.5°C isotherm (WSBW begins at -0.7°C) the low salinity deep water is about 0.005 to 0.010 lower in salinity than the surrounding deep water, not much of a difference but clearly two nearly parallel groupings of deep T/S structure are apparent, meaning two water masses. The stations that have significant layers of low salinity deep water are 56-60. The largest separation in salinity between the two groups occurs at -0.35°C, for colder water the T/S suggests mixing of the low salinity deep water with the saline ambient deep water.

[added, Sunday, September 7, 1997: At Joinville Ridge station 71 while the bottom water contributes to the low salinity deep water, but further up in the water column there is a fresher layer, too saline to be pure pycnocline water. I think this is due to mixing of open ocean pycnocline water with less dense deep water just seaward of the slope front. The slope front along the

Joinville section is not well formed, but which may best be located between stations 71 and 72. This same process is observed at other crossings of the slope front around the Weddell Sea, e.g. Fedorov Ice Station stations. Possibly the open ocean pycnocline influence cools and freshens the t-max layer seaward of the slope front, to form the warm end-member of the low salinity deep water.]

The T/S points between -0.35° and -0.40°C defines the most concentrated form of the low salinity deep water observed along 49°W and provides a hint of potential source water sites. The density at -0.35°C is sigma-0 = 27.838; sigma-1 = 32.565; and sigma-2 = 37.175. This puts its source well below the pycnocline. Using the T/S slope for the low salinity deep water, places its source at 34.56 to 34.58 salinity, freezing point water. Such water is found in the low salinity shelf water masses (containing Ice Shelf Water). As this water is also implicated in the formation of the low salinity type of WSBW in the Weddell Sea, a "fine-line" determines whether the low salinity shelf water contributes to bottom water or to deep water.

Oxy and CFC, the signs of ventilation: In the interval from the t-max to -0.5°C, the low salinity deep water is higher in oxygen and CFC-11 than surrounding waters of equal temperature. This is clear indication of a higher degree of ventilation through contact with the atmosphere. The maximum expression of the low salinity deep water in T/S space is at -0.35°C; the oxygen and CFC-11 maximum excess is closer to -0.40 to -0.44°C. The oxygen excess (relative to surrounding water at equal temperature) is slightly over 0.1 ml/l. The CFC-11 concentration is 1.3 units, 0.7 or nearly double that of the surrounding waters. Excess as measured on sigma-0 surfaces are about the same. The oxy and CFC excess along surfaces of constant depth are much larger as the isopleths dome upward in the W-S-C.

Research Question: Where does the low salinity deep water come from and Where does it go? A Larsen Ice Shelf source? Bransfield Strait source? The next part of the Dovetail cruise may provide an answer. As to where it goes. There is not a clear presence of low salinity deep water at the 40 W section. Might it round the South Orkney Plateau clockwise all the way into the Scotia Sea? And from there spread on neutral density surfaces into the deep ocean? It is noted that at station 51 (northern side of Pirie Bank, 45°W) shows a slightly lower salinity in the temperature range of the low salinity deep water. Also as noted above station 17, at the northern slope of the Orkney Plateau, has a trace of the low salinity deep water. As the flow there was towards the west one envisions: a clockwise flow around Orkney Plateau, counter-clockwise around the Orkney Trough, and clockwise around Pirie, a rather long curved pathway which may account for it rapid dilution from the presumed Antarctic Peninsula source. The low salinity deep water spreads into the Scotia Sea, not along the length of the South Orkney Ridge.

That strange Station 60: Station 60 shows low salinity deep water intrusions as discussed above. However, it shows some interesting smaller scale thermohaline structures: below 650 m suddenly, there very small scale fine structure, looks like jitter on the normal scale profiles. Such jitter occurs down to 1600 m. Blown up T/S plots reveal they are parallel to sigma-1 surfaces. The vertical scale of these features is around 10 m (5 to 20 m). Stations 62 and 59 has some of these features, but not over as much of the water column as station 60. As the isopycnal spreading of the low salinity deep water from the W-S-C into the Powell Basin is a 100 km scale process, the very small fine structure is surprising, and not expected to be a product of these larger scales. Another more local process may be occurring. As the saline WDW t-max water is over-riding the low salinity deep water, the salt finger regime density ratio (warm/salty over cold/fresher) for this water column is less than the regional values. From 700 m to 1800 m the density ratio varies from 1.5 to 2.0. It is suspected that salt fingers sporadically occur in the Powell Basin between the t-max and the benthic layer, which alters the local T/S slope. Isopycnal mixing then forms the small scale fine structure. I suspect we are looking at km scale events. This process may be responsible for rapid mixing of the low salinity deep water into the larger mass of WDW, and may account for the general lower salinity (as measured on isotherms) of the WDW relative to its CDW source.

Research Question: Do salt fingers play a significant role in the Weddell Gyre mixing?

• <u>Benthic Layer</u>: In the discussion of the eastern sections, “I call the layer with this steeper T/S slope (top of which is somewhere in the range -0.55°C to -0.65°C) as the benthic layer.” At the top of the benthic layer is a slight increase in temp, sal and oxy profile slope. With this definition in mind the benthic layer within the Powell Basin (stations 58 to 68) thick but very weak (hard to see the top, the temperature profile is essentially linear) in the north, somewhat better defined in the south, at stations 63 to 67.

The water column entering the southern Powell Basin has a thick benthic, not unlike the northern stations of the Ice Station data set. The Powell Basin outflow benthic layer has similar T/S and profile properties as that of the benthic layer of stations along 44°W south of the Orkney Plateau and in the Jane Basin along 40°W, except for the lesser defined top.

The reason for the poorly defined top to the benthic layer in the northern and central Powell Basin seems to be that in the north the T/S slope change marking the top of the benthic layer is blunted by the reduced salinity of the deep water. Mixing (vertical) between the low salinity deep water and the WSBW may occur.

As the Powell Basin water leaves the basin, the shallower low salinity deep water follows the Orkney Plateau isobaths, as discussed above, while the deep benthic layer continues to the east along deeper isobaths to flow under the WDW, re-establishing the distinction of the benthic layer. The WSBW following the Powell Basin path is composing of the outer rim of the bottom water flow from the western Weddell Sea, and thus may account for the relationship (albeit weak) that the thicker, better mixed benthic layer occupies the northern, shallower water, segment of the 44° and 40°W sections.

An additional factor is: as the Powell Basin benthic layer passes south of the Orkney Plateau is converges with the colder thin stratified benthic layer which side stepped the Powell Basin, offering opportunity for the interaction discussed in the 40°W section, which may lead to the complex benthic layers of the eastern sections.

Special Stations: Station 60 which has a thin stratified benthic layer variety. Station 65 (which is the northern most station with a northwest flowing bottom layer) has a bottom s-max, about 60 m below a S-min, though only 0.002 saltier than the s-min. This water mass structure is similar to the WSBW stratification as observed during the ISW expedition.

Research Question: What role does the Powell Basin play in the mixing of the WSBW in the Benthic Layer? Might the thicker Benthic layer be due to a longer path? How much of the WSBW follows the Powell Basin route? The WSBW that enters the Powell Basin follows a much longer path to the 40°W section than does the colder deeper (>3500 m) WSBW that skips across the Powell Basin entrance. The difference is about 600 km, about double the distance from the more direct route from the some common reference site (e.g. 65°S, 50°W). The longer pathway is expected to lead to more vertical mixing of WSBW, more side-wall mixing.

• Powell Basin is not the primary pathway for WDW t-max: The WDW t-max reaches only at or slightly above 0.6°C at stations 63 to 68. This region extends from the central to the southern side of Powell Basin where the barotropic flow is towards the west, drawn from the western Weddell. The t-max in the northern part of the Powell Basin, advecting towards the east, is generally in the 0.5° to 0.6°C range. The Powell Basin t-max water is lower than the >0.7°C t-max observed along the 44° and 40°W sections. Thus the warmest WDW passes out of the Weddell directly to the region south of the Orkney Islands, bypassing the Powell Basin.

[D] Antarctic Peninsula, Western Powell & Bransfield Strait This phase of the cruise looks at the outflow of western Weddell Sea margin water off the northern tip of Antarctic Peninsula and the exchange of water masses across the eastern entrance of Bransfield Strait, in relationship to what we observe in the Powell Basin.

• Joinville Ridge (stations 68-75): a section along 63°06’S, over the northern side of a zonally oriented ridge which deepens from Joinville Island eastward to form the southern boundary of Powell Basin. I’ll call this ridge Joinville Ridge. Besides looking at maps (not all that reliable) we know its the Ridge’s northern slope as the LADCP currents data shows a westward current, fitting for northward deepening bottom topography.

Source of the low salinity deep water: Stations 69-71 show at their 1400-1600 m bottom layer the same and even more concentrated forms of the low salinity deep water. The more concentrated forms fall along the mixing line which passes through the Powell Basin scatter of low salinity deep water to the freezing point at a salinity of around 34.56.

The source of the low salinity deep water within the Powell Basin appears to be from the eastern shelf of Antarctic Peninsula and that it passes around Joinville Ridge entering the southern Powell Basin west of the southern end of the Dovetail Powell Basin section, to be seen again along the northern Powell Basin. It is not from the Bransfield Strait. Any Bransfield Strait influence will effect water layer less dense that the low salinity deep water. The T/S freezing point end-member seems to be the same as for the low salinity WSBW found during the Ice Station.

Further insight is gained by inspection of the Polarstern, September 1989 (PS-89) data set, just south (within 30 nm) of the Dovetail Joinville Ridge section. The PS-89 stations 47 to 50 about 30 nm south of the dovetail 69-71 stations, all show the same extension of the low salinity deep water mixing line towards the temp-freeze value, down to about -0.68°C, same as the dovetail stations 69-71. However, often there is a sharp transition to the more saline benthic layer water. PS-89 station 50 shows such a sharp transition from the low salinity water to the normal benthic layer at 1700 m. Low salinity water over-rides WSBW water. At PS-89 station 47, which is 30 nm due south of the Dovetail Joinville Ridge station 71, the low salinity deep water mixing line passes through colder (-1.2°C) T/S points within a sharp cold intrusion at 800 m, about 180 meters off the sea floor. PS-89 station 46 (492 m sea floor) about 15 nm to the west of St. 47 has similar, though slightly less saline bottom water. The bottom water at station 47 is about -1.15°C, 34.6, placing it on the denser WSBW T/S mixing curve.

It thus appears that dense WSBW benthic layer property water south of Joinville Ridge crest is over-ridden with a lower salinity shelf water, though these two layers then follow some-what different routes, because of isobath pattern, into the Powell Basin. The low salinity water continues into the southern Powell Basin (entering west of the Dovetail Powell Basin section) to form the low salinity deep water observed in the northern Powell Basin (Weddell-Scotia-Confluence). The Dovetail Joinville stations did not 'see' the 34.6 slope water type observed at the bottom of PS-89 station 47, or WSBW, hence WSBW to pass into the Powell Basin would do so further east in deeper water (WSBW is observed within the benthic layer along the southern stations of the Dovetail Powell Basin).

I suspect that the benthic layer at the eastern point of Joinville Ridge may sometimes be able to make the sharp left turn into the Powell Basin, sometimes pass directly to the east. As mentioned above this makes for quite a difference in path length and so relevant to the upward mixing of the benthic layer.

The oxygen and CFC data support the T/S analysis presented above, i.e the low salinity deep water is high in both parameters. This is particularly true for CFC, where the concentrated low salinity water over Joinville Ridge stands away from the Oxy/CFC-11 cloud with its high CFC-11. The CFC-11 is around 2.1 in the station 69-71 low salinity deep water over Joinville Ridge; 1.7 for the low salinity deep water within the W-S-C. In the background data at the -0.6°C isotherm the CFC-11 is 1.3. Higher CFC is encountered in the WSBW benthic, but the low salinity deep water hits a shallower density surface, one more devoid of CFC and oxygen.

Research Questions:
Where does the shelf water contributing to the low salinity deep water come from?
Low salinity shelf water (on the mixing line mentioned above) is commonly revealed in the Ice Station helicopter sections over the continental shelf (including the northern most section at 65°50'S). It is usually associated with the ice shelf water. Might the low salinity water seen near 63°S at stations 69-71 represent the northern spreading of that water? might it contain some melt from the Larsen Ice Shelf?
How do the low salinity and benthic layer WSBW interact (mix) on meeting the Joinville Ridge and within the Powell Basin? Is this relevant to the upward mixing of WSBW?

Shelf Water: On proceeding westward along the Joinville Ridge Section, the water column becomes increasing cool, 0°C is not exceeded from station 72 westward, and is nearly isothermal water column at the freezing point is found at stations 74 and 75. Water as cold as -1.911°C potential at station 74 (375 m) and -1.914 at station 75 (623 m), are 0.002°C colder than the freezing at one atmosphere, i.e. ice shelf (iceberg) melting not needed. This freezing point water, with a salinity of 34.61, is sufficiently dense to reach the deep sea floor. The typical slope front configuration (V-Shaped trough in the isopleths) is not observed.

• Eastern 'mouth' of Bransfield Strait (stations 75-85):

Between stations 79 and 80 the water column changes abruptly. From station 80, north: the t-max is at the sea floor (bottom depths: sta. 80 = 550 m; 81 = 340 m; 82 = 900 m; 83 = 850 m; 84 = 630 m; 85 = 650 m); the pycnocline (mainly the upper layer of the pycnocline with temperatures colder than -0.5°C) is high oxygen and low salinity compared to the pycnocline in the neighboring Weddell Sea. South of station 80 the water column is the same as observed over the western parts of the Joinville Ridge section.

The Bransfield outflow is confined to the most part to the pycnocline within the northern half of the passage between Clarence Island and Joinville Island. It feeds directly into the Weddell-Scotia-Confluence. The main escape path of Bransfield water is south and east of Clarence Island. It is channeled eastward along the southern flank a ridge.

Low salinity pycnocline water is observed within the pycnocline of stations 55 and along the southern flank of the Orkney Plateau well downstream within the W-S-C. The Bransfield may be the source of the low salinity upper pycnocline water of that region.

While one may dismiss a pycnocline export as unimportant, the thickness of the pycnocline in the proposed Bransfield outflow is many hundreds of meters, the t-max in the W-S-C far deeper than it is in the surrounding waters, thus a Bransfield may have a significant effect on the pycnocline, but probably not on the deep waters of the Weddell-Scotia-Confluence.

• Western boundary of Powell Basin (last mooring) (station 86 at 2200 m depth, 87-89): Compare the up and down traces and those raggedy thermohaline steps and the great depth (about 1000 m) of the cool remnants of WDW t-max and tell me what's happening. To me it looks like station 68 (eastern end of Joinville, the entrance to Powell Basin from the south), but with strong isopycnal attenuation of the WDW t-max. I suspect that the source of the cool water stirring into the WDW is the less dense versions of the western Weddell Sea shelf water that contribute to the low salinity deep water in the Powell Basin. Such water was measured at station 71 and 72.

• Bransfield Strait Basins (Stations 90-97)

The basin waters are clearly derived from the freezing point waters that pass from the Weddell Sea around Joinville Island. Source water is observed east of Joinville (stations 73-75) and north of Joinville (stations 76), i.e. it makes the turn into the Bransfield. The saltiest freezing point Joinville water contributes to the basin bottom water, while the less saline Joinville water contributes to the weak salinity minimum at mid-depth. The warm end member for the deep s-min is derived from the pycnocline water probably that coming from the Bellingshausen Sea or southern Drake Passage. The Basin's bottom water is a blend of the saltiest Joinville water with the mix of deep s-min water (a blend of pycnocline and lower salinity t-freeze Joinville water).

Station 96 is most revealing as it has an abrupt t-min/s-min below the more gentle regional deep s-min. Linear fits to both segments point to essentially the same t-freezing water, slightly more saline for the deeper intrusion.

The Bransfield Basin water is very high in CFC-11, about 4.5, nearly as high as the freezing point source (5 CFC-11). The basins are well ventilated. The high CFC of the Bransfield Basins is due to the high CFC of the warm-end member component, pycnocline water rather than WDW.

[E] Summary- ALG Closing Statement and Primary Research Topics & Questions (3 Sept.):

"Dovetail Science Team: The fourth (I think its the 4-th) chapter in my preliminary analysis of the dovetail data will be distributed by e/mail later today. It covers the Joinville Ridge and Bransfield Sections. Unless I find something unexpected in the stations to be collected in the next few days, this is the last chapter that I'll distribute. As before the text deals mainly with the CTD data with some reference to LADCP and CFC data; no figures are included. You may want to see the various pictures in the Dovetail gallery or make some yourself. When I get back to Lamont I'll make a collection of figures (the figures in my computer and those that have been produced by others on the ship) and append these, with credits to originators, to the cruise report text, which would then be available upon request.

"Below I list the primary research topics and questions that Dovetail station data can address. These are broad issues, which are best addressed by a combination of the data obtained during this cruise along with the archived data sets. When the mooring data is returned these topics and others can be further addressed.

"Analysis of the dovetail station data for publication should proceed in a timely fashion. It's good to present results to our colleagues (and program managers) as soon as possible. "Data Owners" are encouraged to coordinate their analysis tasks, involving other collaborators as necessary. I think there are two or three papers that can be prepared within 6 months for such Journals as GRL, Science or Nature. I'll be in touch...

"It not quite over yet, we have the interior of the Bransfield Straits to go, but thanks to all for of your fine work, a lot was accomplished!"

Research/Questions:

• <u>Warmer Weddell Deep Water t-max</u>: The Weddell Deep Water warming of the last few decades, continues. This trend may result from decrease of deep water heat loss to the atmosphere and cryosphere or increase of injection of warm circumpolar deep water into the Weddell Gyre. The apparent acceleration of the t-max warming in the NW Weddell Sea may be caused by the westward migrating interior ‘warm front’ being picked up by the western boundary current.

Questions: Develop a gyre wide t-max time series- what does the spatial/temporal pattern look like, is it a uniform rise? migrating westward? What is the cause of the WDW warming? What is the relationship of the t-max warming to sea ice distribution, glacial ice melting, Weddell Sea Bottom Water (WSBW) production and to the Weddell Polynya?

• <u>Benthic Layer</u>: The Dovetail CTD/tracer data with those of the 1992 Weddell Ice Station nicely define the nature of the WSBW benthic layer in the western and northwestern Weddell Sea. The Dovetail LADCP provides a glimpse of the velocity field associated with the WSBW. The WSBW benthic layer takes on varied forms: thick well mixed layer; thin stratified form. Often (mainly on the 40°W section) a more complex form appears with attributes of both types. The Powell Basin benthic seems to match the thick benthic observed along the dovetail eastern sections. The stratified benthic layer seems to have ‘side-stepped’ the Powell Basin.

Questions: What is the relationship of the Benthic layer type to the sea floor depth, slope and bottom roughness; to the water column temperature and salinity stratification and stability; and to LADCP measured bottom current and shears? What is the WSBW transport? What is the role of the Powell Basin in governing the downstream form of the Benthic layer? Does benthic mixing receive positive feedback from thermobaric effects?

• <u>W-S-C Low Salinity Deep Water</u>: Within the Weddell-Scotia-Confluence west of the South Orkneys, there is a well ventilated low salinity deep water, which may be referred to as Weddell-Scotia-Confluence Deep Water. The less dense versions provide the bottom water on the southern, deeper parts of the South Orkney Plateau. Traces are observed in the Scotia Sea, which may have followed a pathway around the Orkney Plateau. The Dovetail data clearly shows it is coming from the Antarctic Peninsula eastern shelf. It may be considered as a less dense form of WSBW. While the freezing point end-member is the same or similar to that of the low salinity WSBW found in the western Weddell Sea, a slightly fresher warm end-member encountered by the shelf water plume in the NW Weddell seems to be the cause for the low salinity characteristic. It rides the ‘outer-rim’ of the Weddell Gyre, to feed into the Weddell-Scotia-Confluence. The Weddell-Scotia-Confluence Deep Water over-rides the Weddell Sea Bottom Water and may mix with it influencing the benthic layer thickness.

Questions: How much Weddell-Scotia-Confluence deep water is formed? What is it’s relationship to the formation of Weddell Sea Bottom Water? Where is the specific source of the low salinity shelf water? Is there a Larsen Ice Shelf contribution? and what is its role in larger scale ocean ventilation?

• <u>It’s the Warm End-Member</u>: The deep isolated basins of the Bransfield Straits are filled with dense, well ‘CFCed’ water. As with the WSC Deep Water, the cold end-member is similar to that of the WSBW, but with a much fresher (higher CFC) warm end-member derived from the pycnocline water (Bellingshausen or southern Drake Passage). This clearly demonstrates the role of the warm end-member in governing the nature and fate of the cold products from the Weddell Sea.

Question: Why are the two forms of the trapped basin water (deep s-min and more saline bottom water)? What is the residence time of the Bransfield Strait basin water?

Concluding Remark:

The western Weddell continental margins form freezing point shelf water with a wide range of salinity. Variability of the warm end-member salinity adds an additional "degrees of freedom" in governing the nature of the final product. It is clear that the Weddell Sea can ventilate a wide interval of the deep ocean.

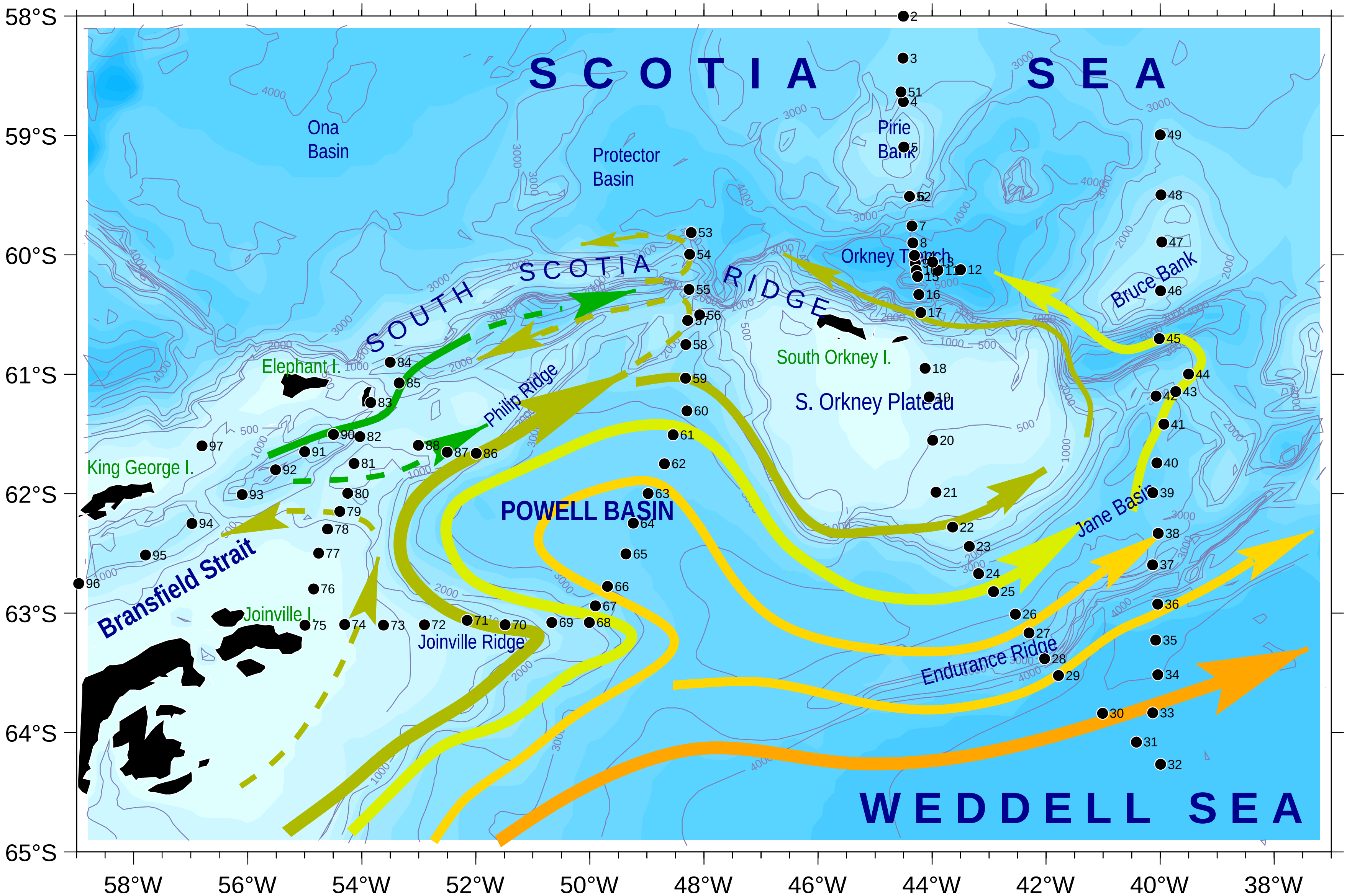
Question: Might the warming of the WDW t-max have important effects on WSBW characterisitcs?

VII Acknowledgments: See III-F "Final Weekly Status Report of Palmer 97-05, DOVETAIL".

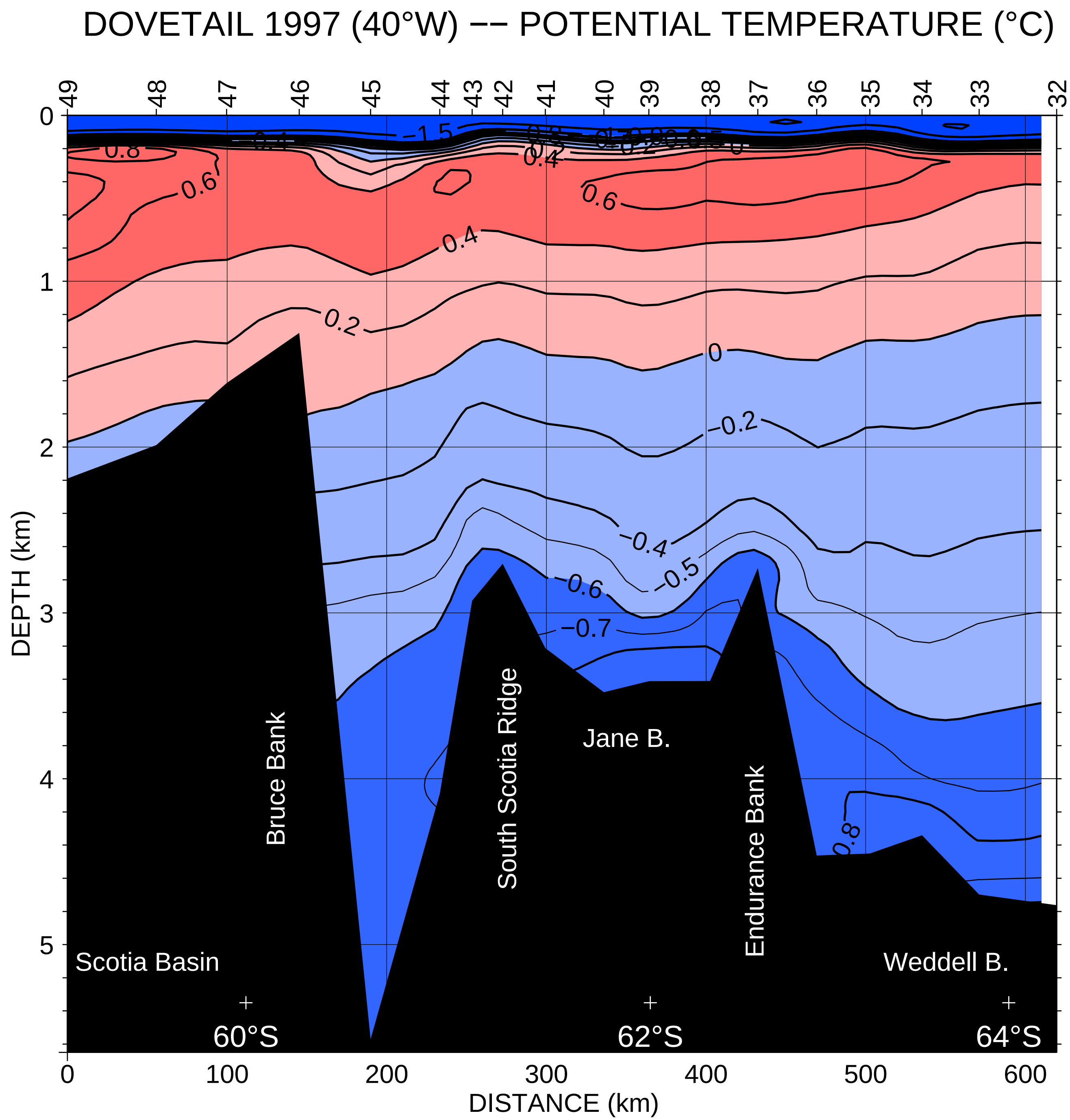
VIII Figures:

Figure Credits: Martin Visbeck produced the Station Map and LADCP Sections; Alex Orsi produced the Sections; and Phil Mele provided the Scatter Plots.

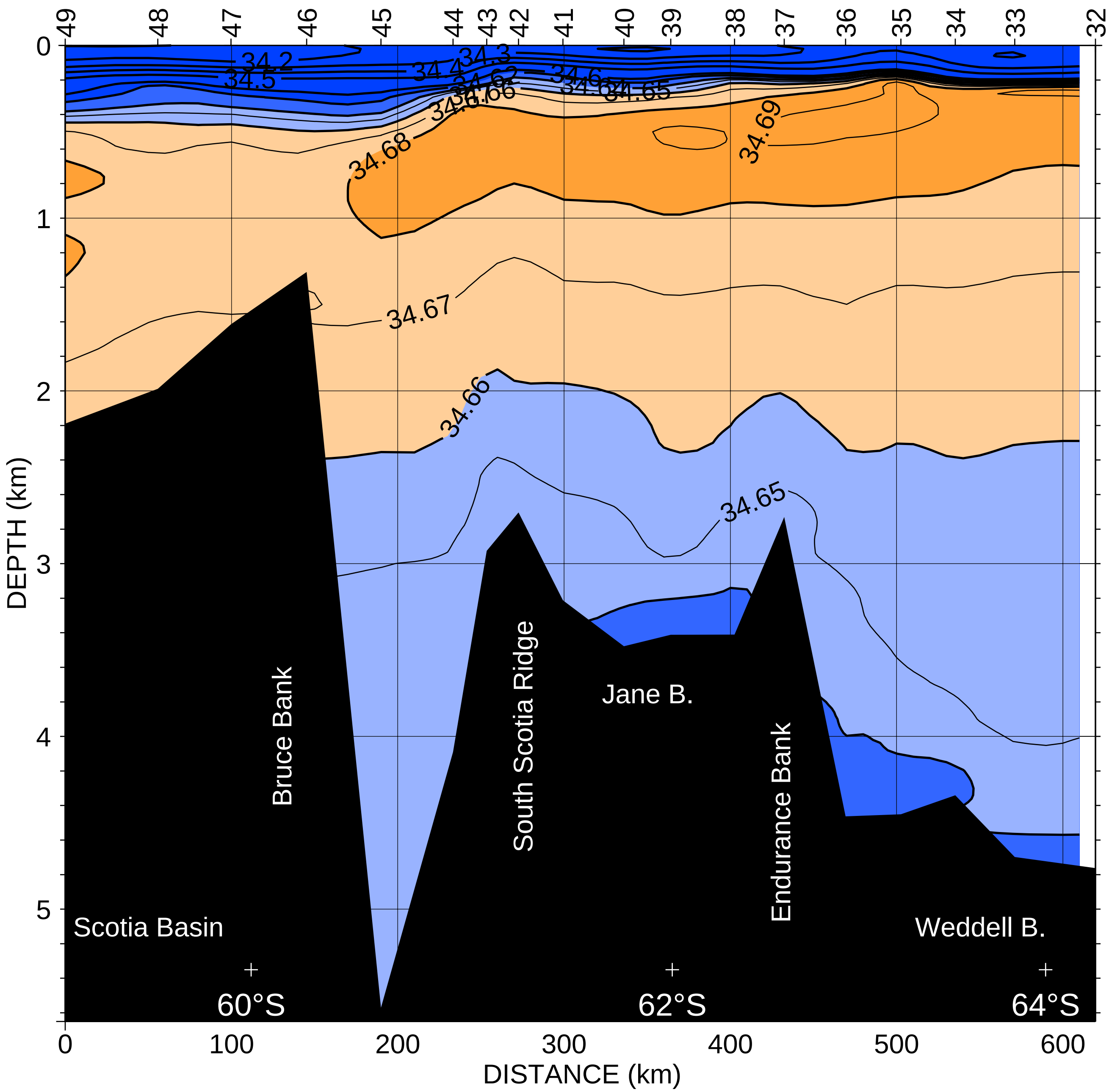
DOVETAIL 1997 Station map and deep circulation



Martin Visbeck, 9/7/9


DOVETAIL 1997 (40°W) −− POTENTIAL TEMPERATURE (°C)
DEPTH (km)
DISTANCE (km)
Scotia Basin
Bruce Bank
South Scotia Ridge
Jane B.
Endurance Bank
Weddell B.
60°S
62°S
64°S

DOVETAIL 1997 (40°W) −− SALINITY



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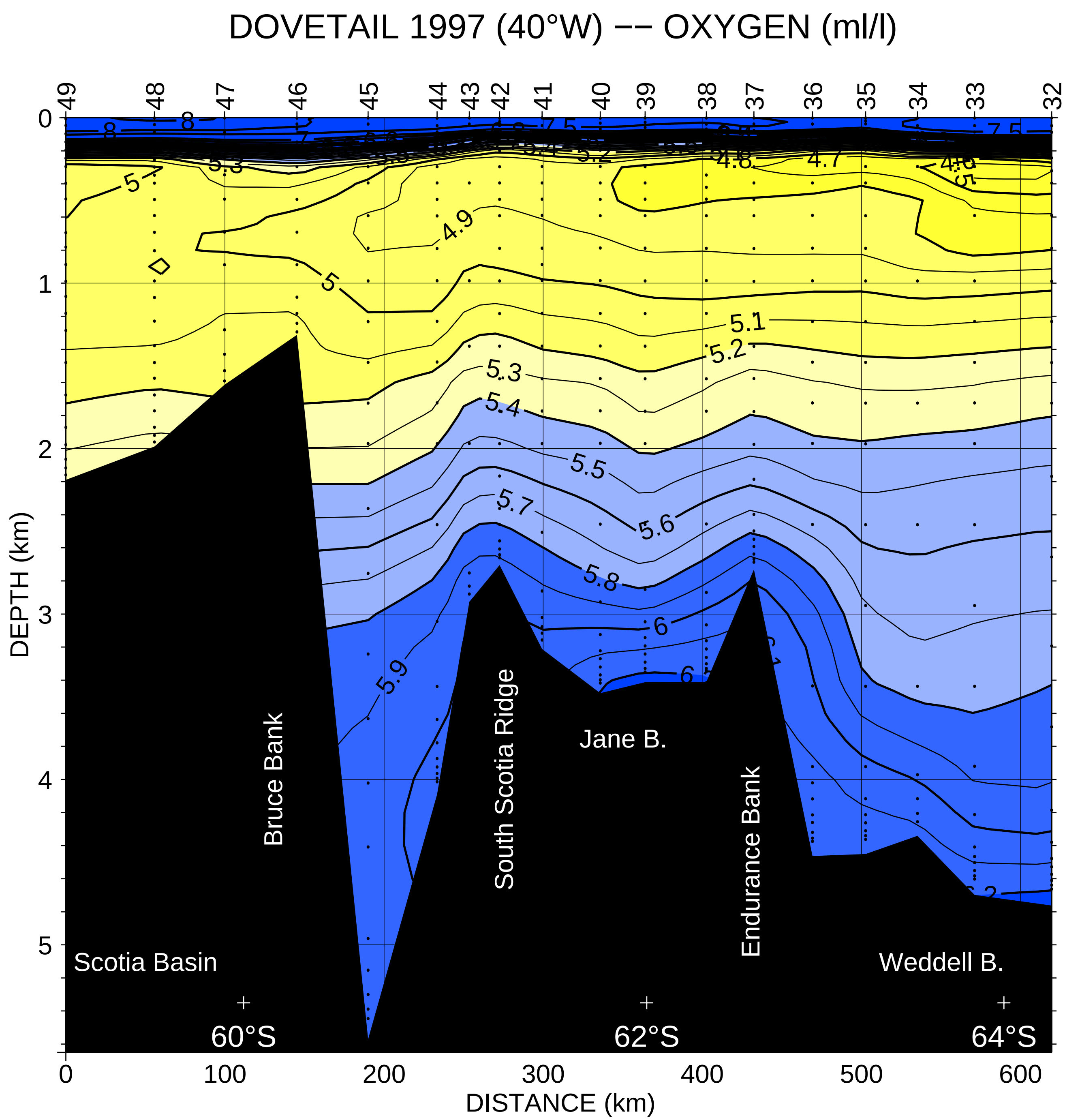

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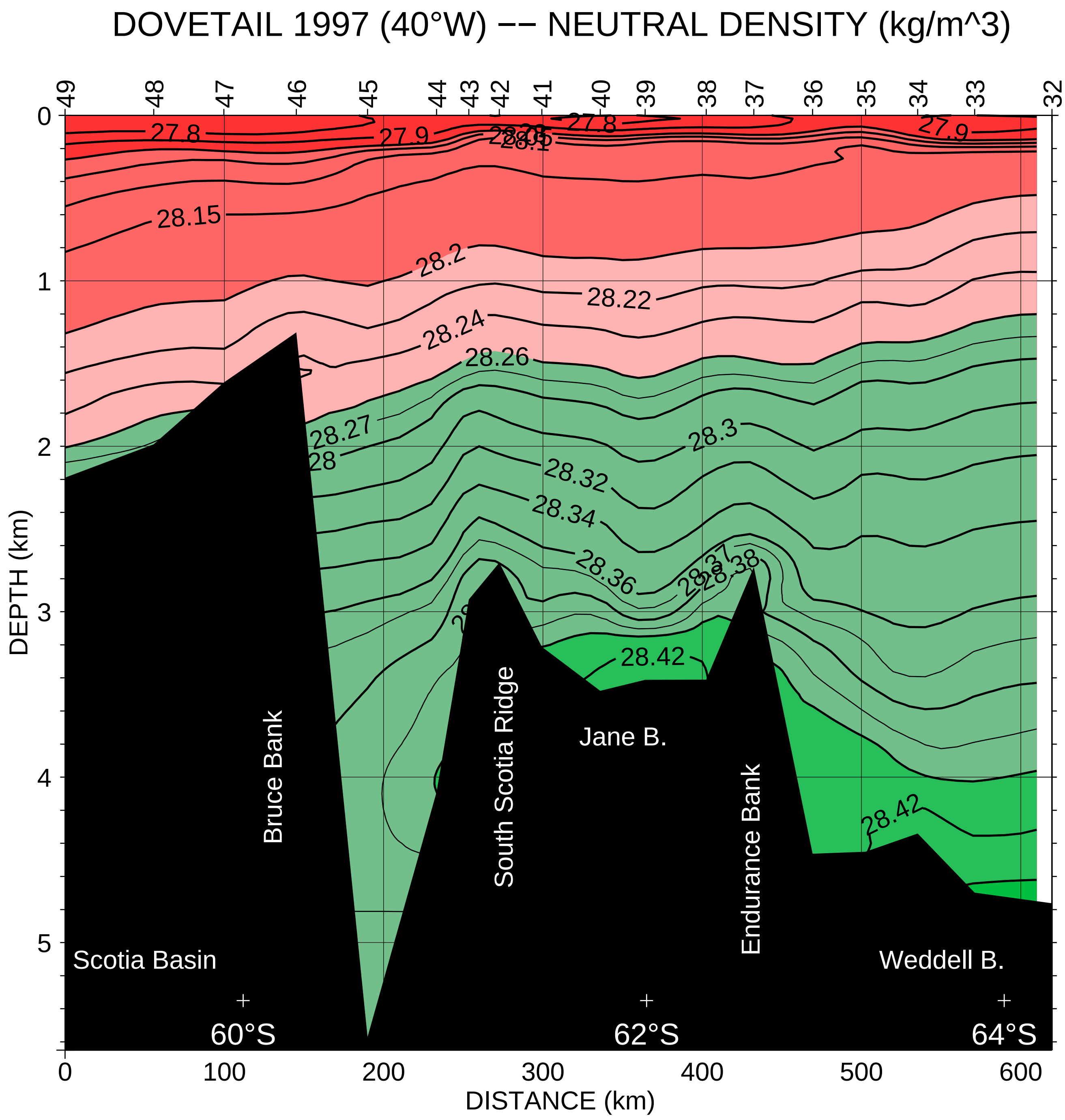

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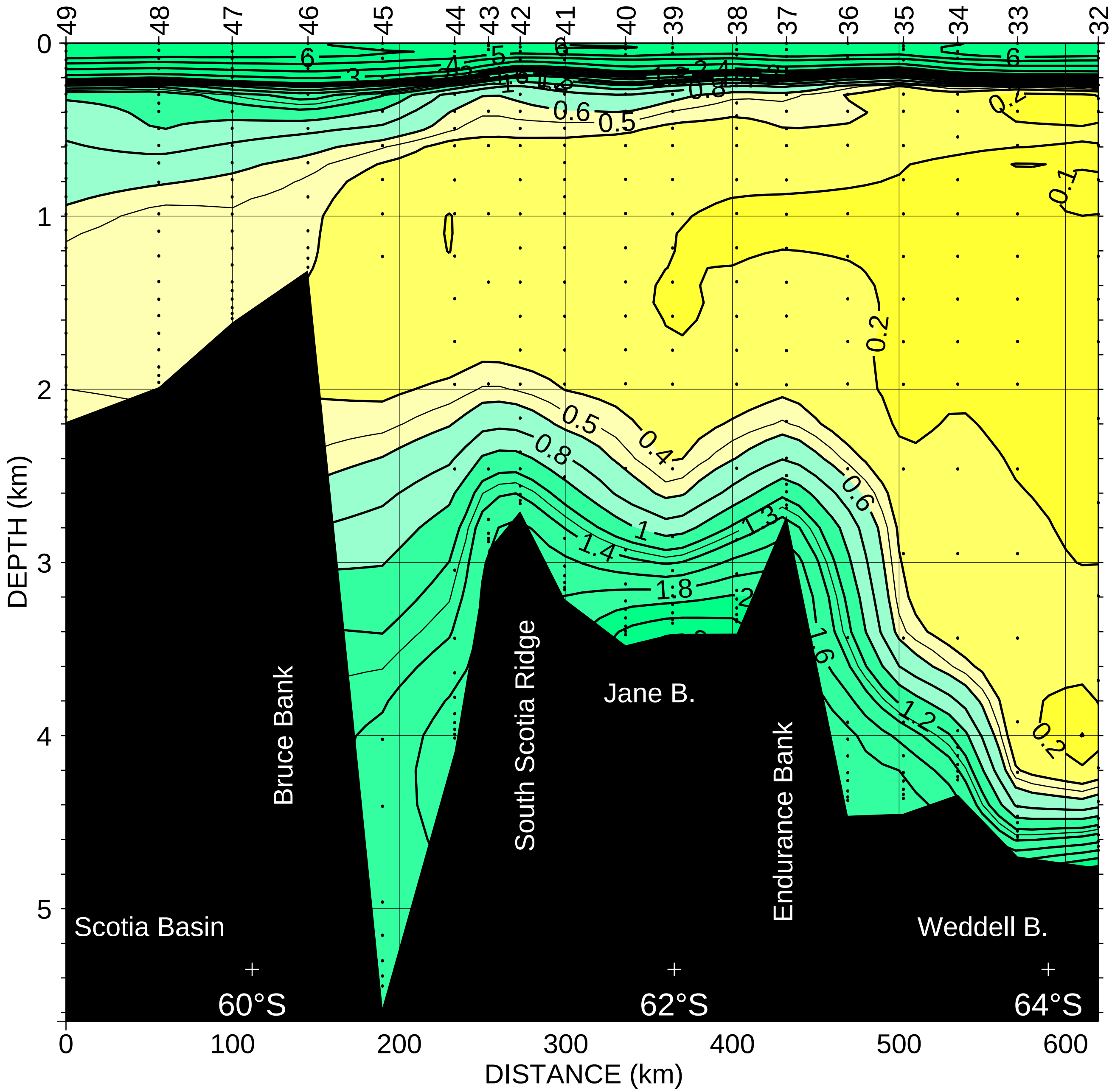
DOVETAIL 1997 (40°W) -- CFC−11 (pmol/kg)



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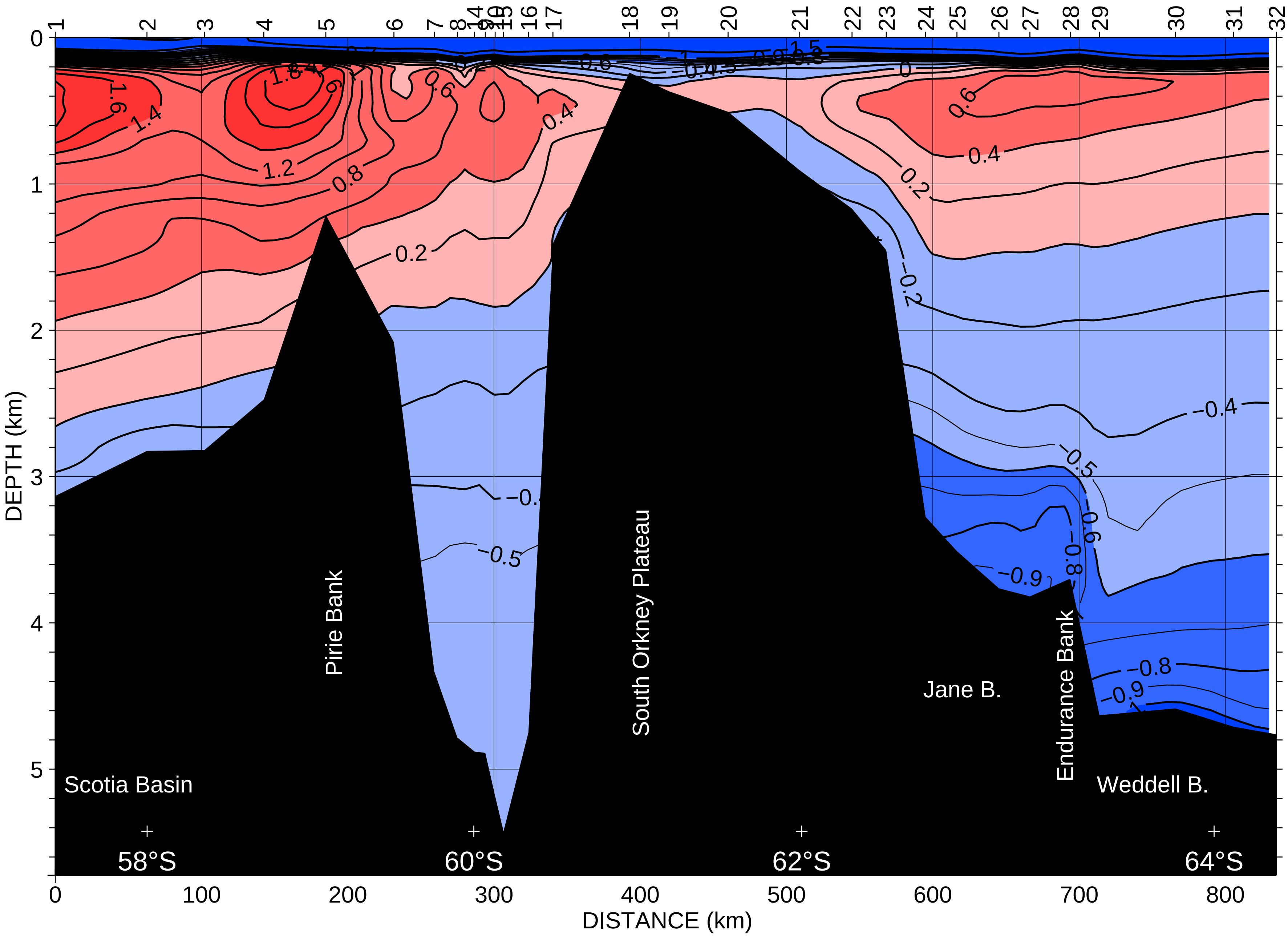
DOVETAIL 1997 (45°W) −− POTENTIAL TEMPERATURE (°C)



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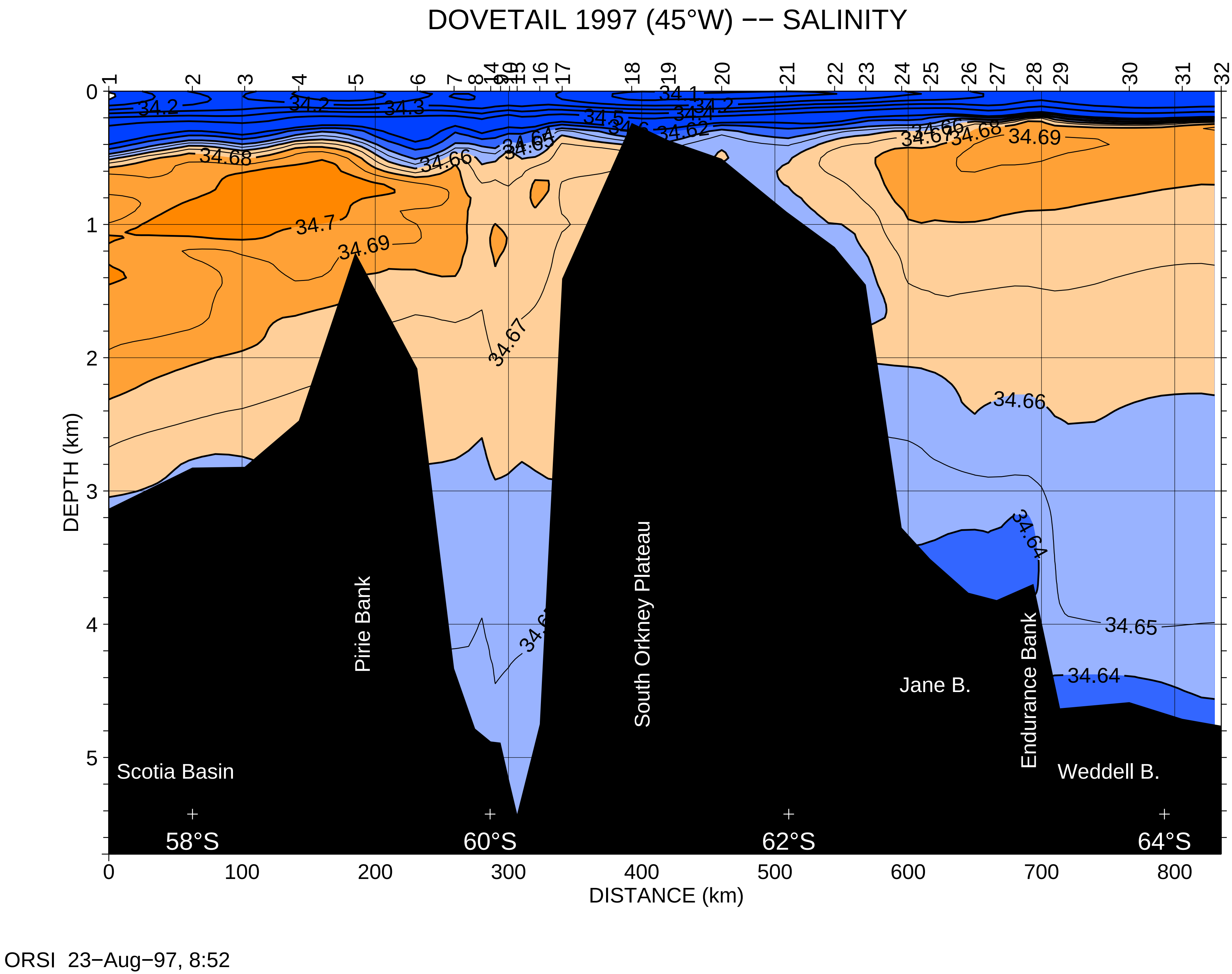
DOVETAIL 1997 (45°W) -- SALINITY
DEPTH (km)
DISTANCE (km)
Scotia Basin
Pirie Bank
South Orkney Plateau
Jane B.
Endurance Bank
Weddell B.
58°S
60°S
62°S
64°S
34.2
34.3
34.1
34.5
34.62
34.64
34.65
34.66
34.67
34.68
34.69
34.7
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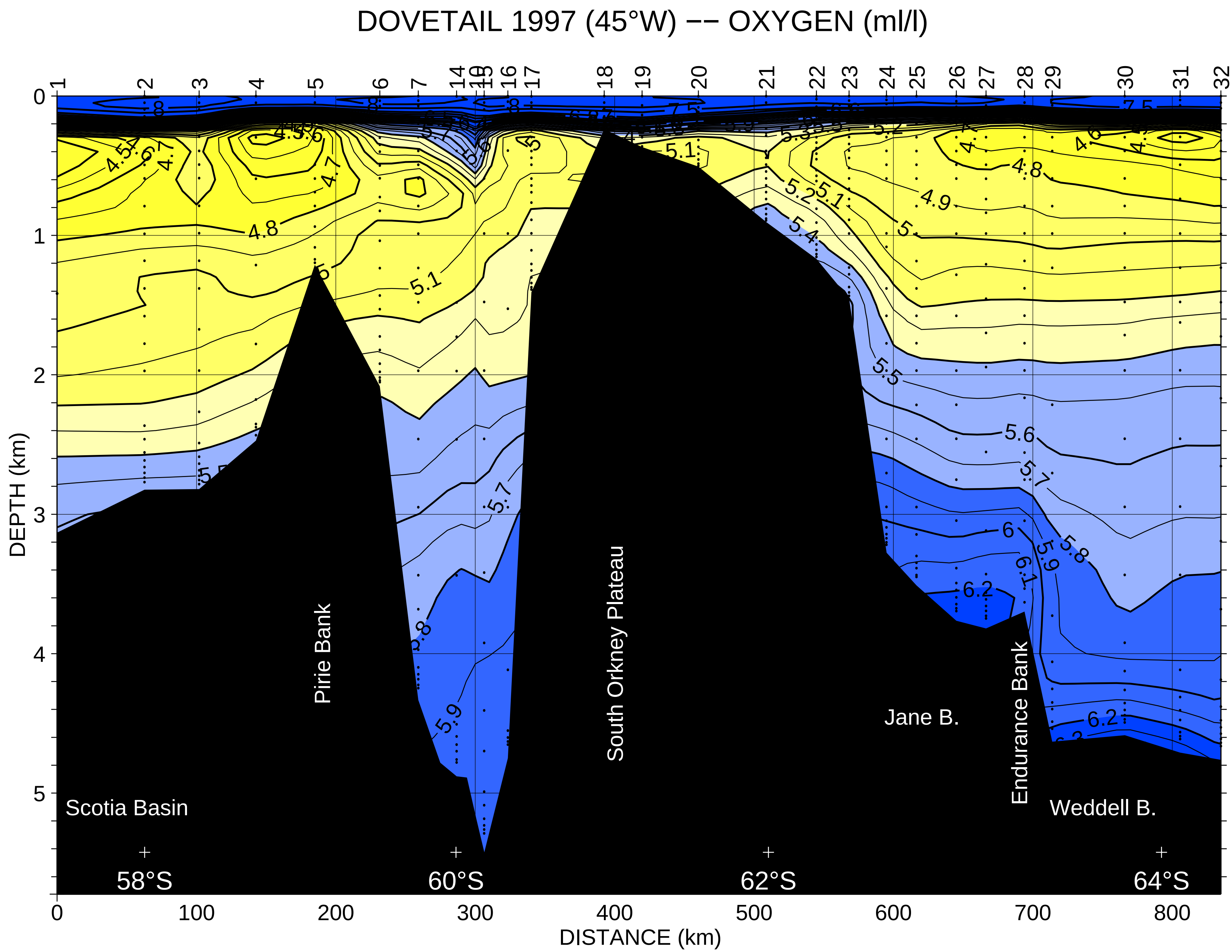

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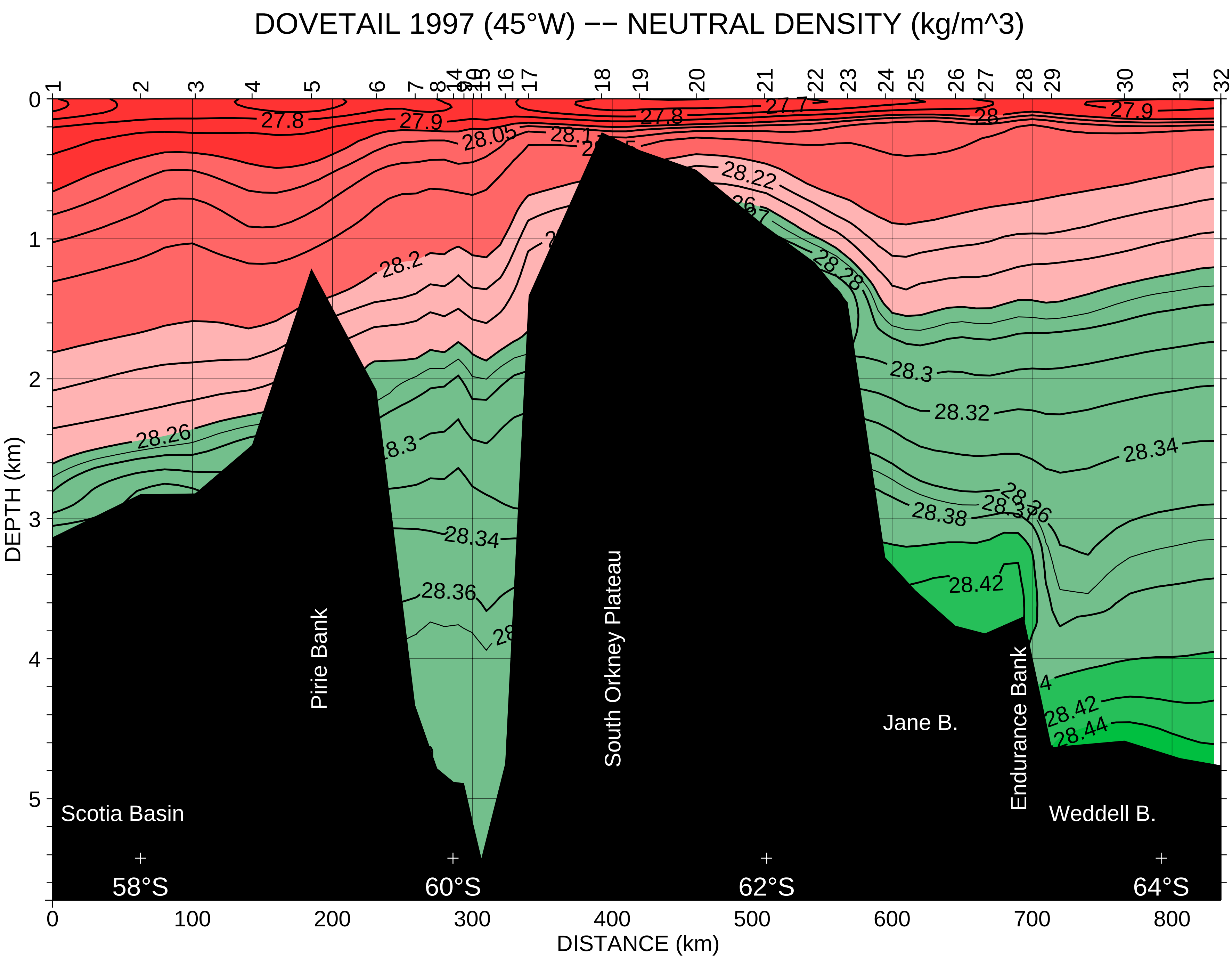

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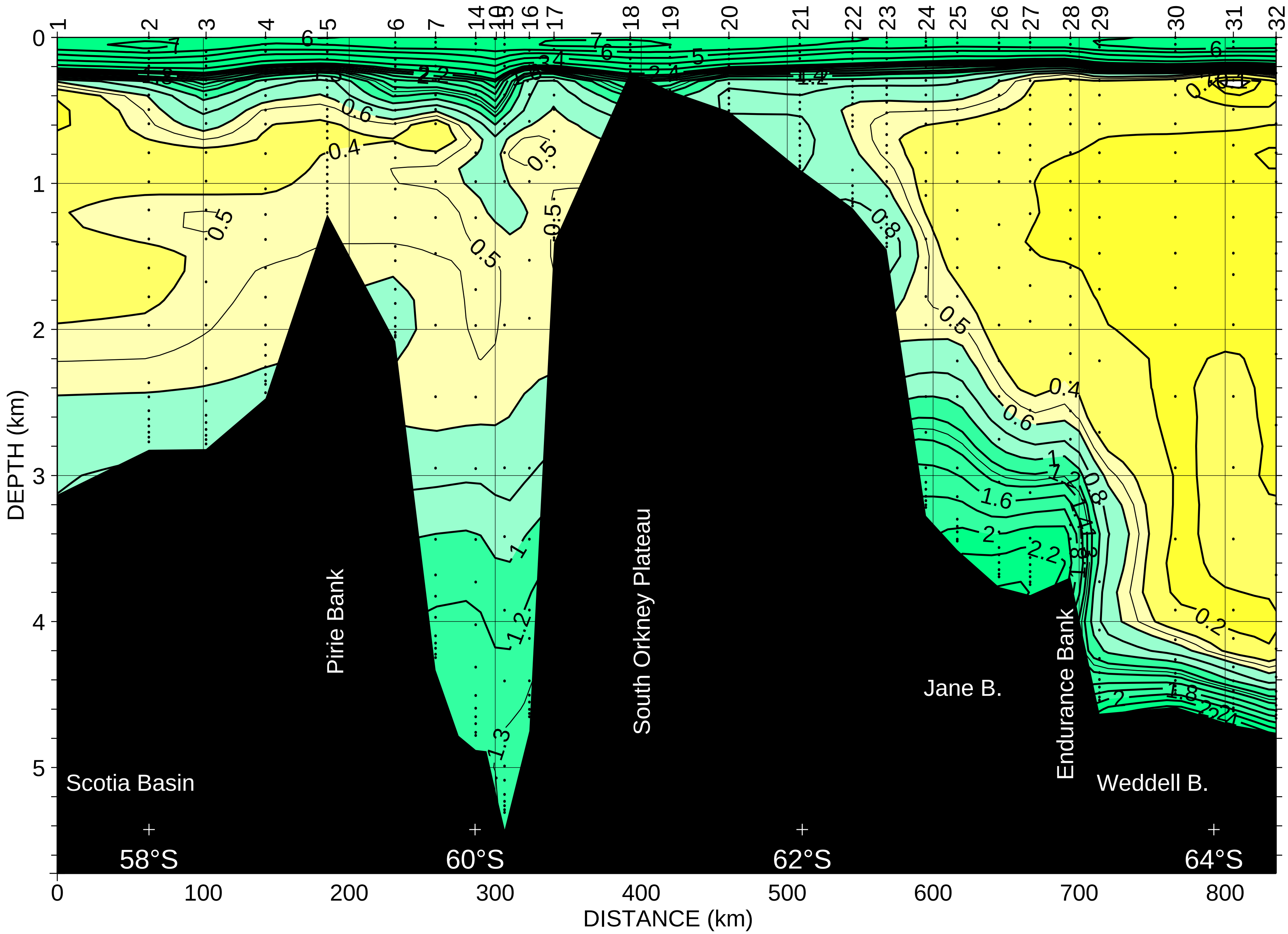
DOVETAIL 1997 (45°W) -- CFC-11 (pmol/kg)



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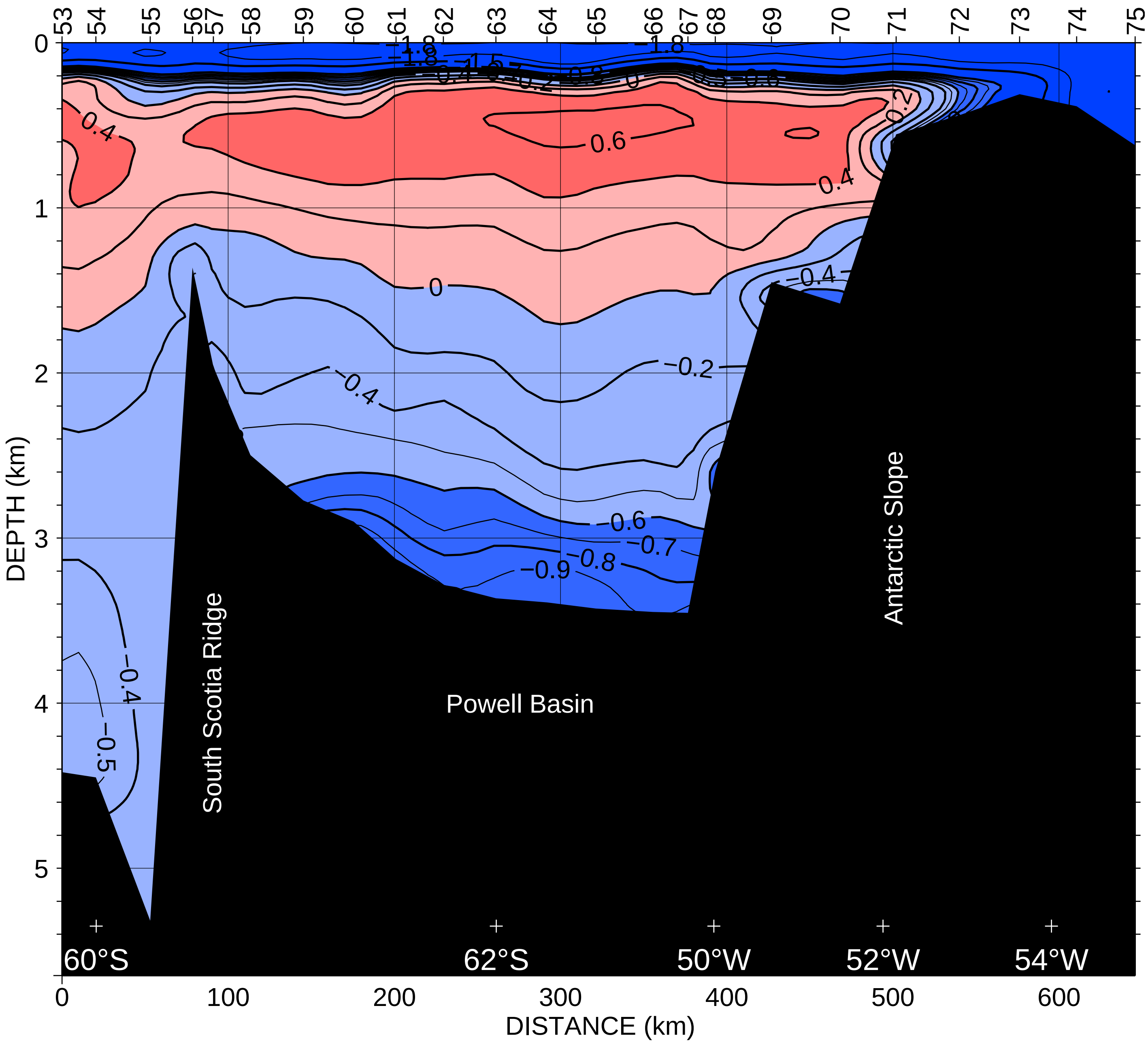
DOVETAIL 1997 (48°W/63°S) −− POTENTIAL TEMPERATURE (°C)



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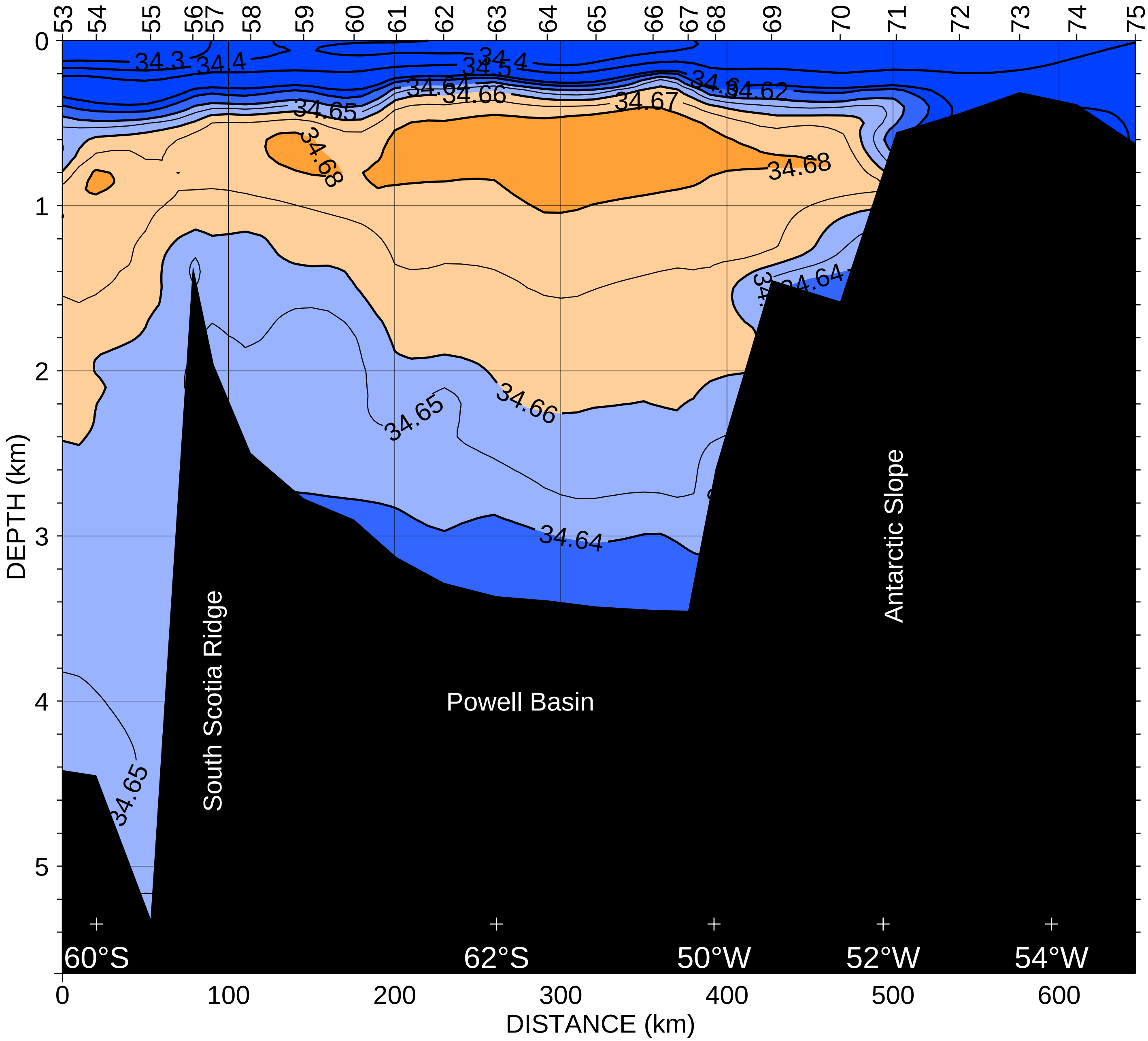
DOVETAIL 1997 (48°W/63°S) −− SALINITY



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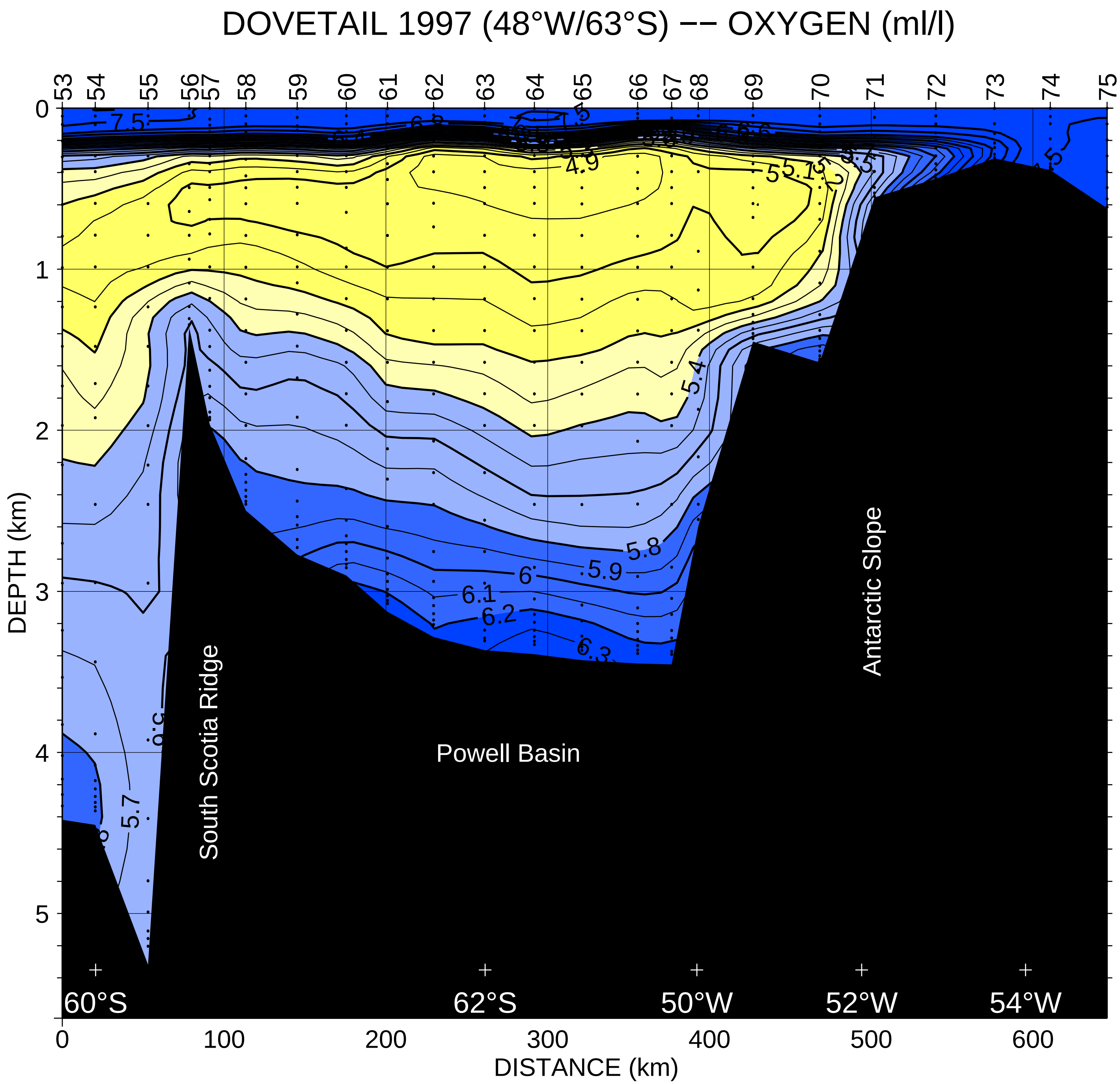

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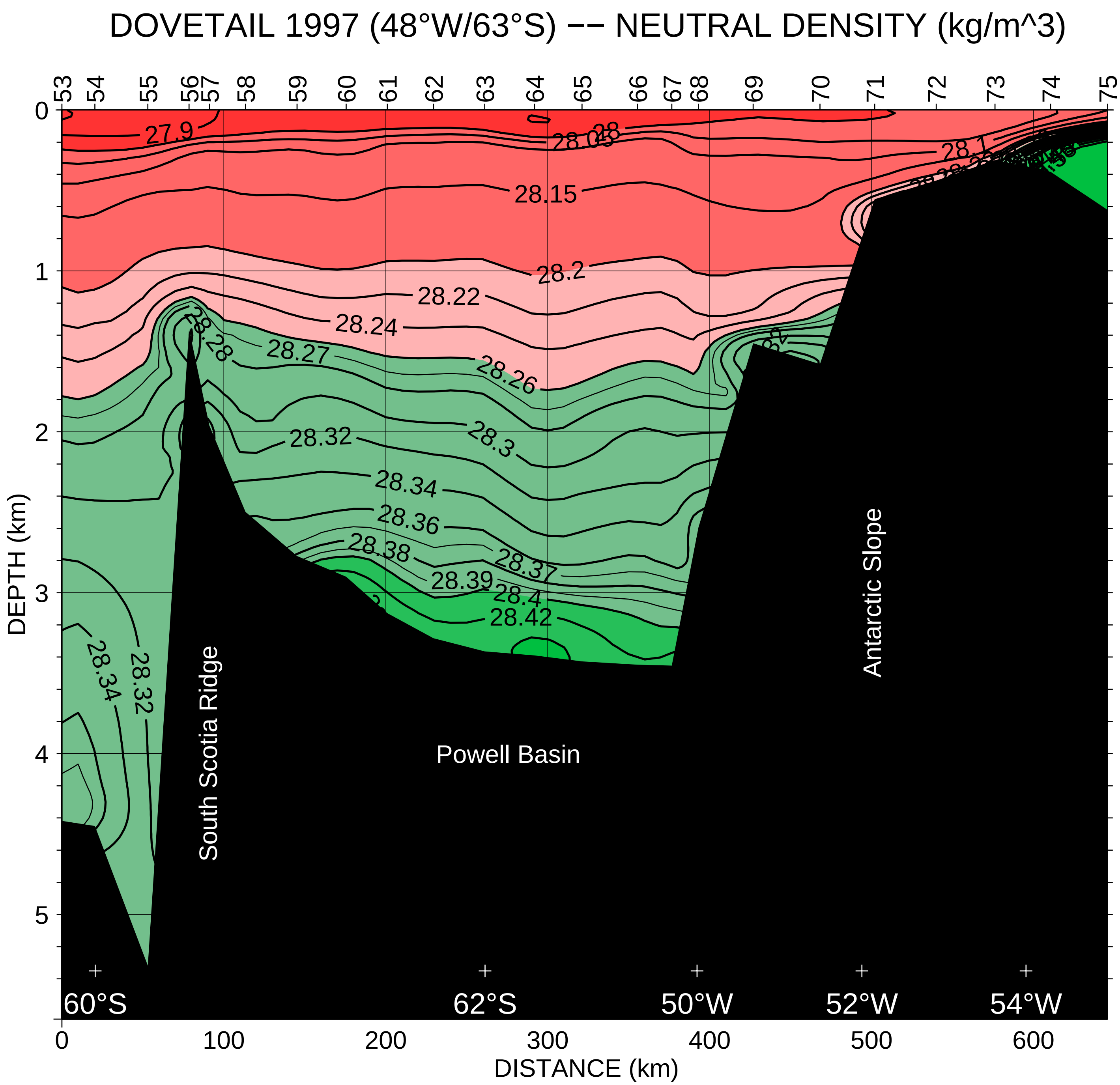

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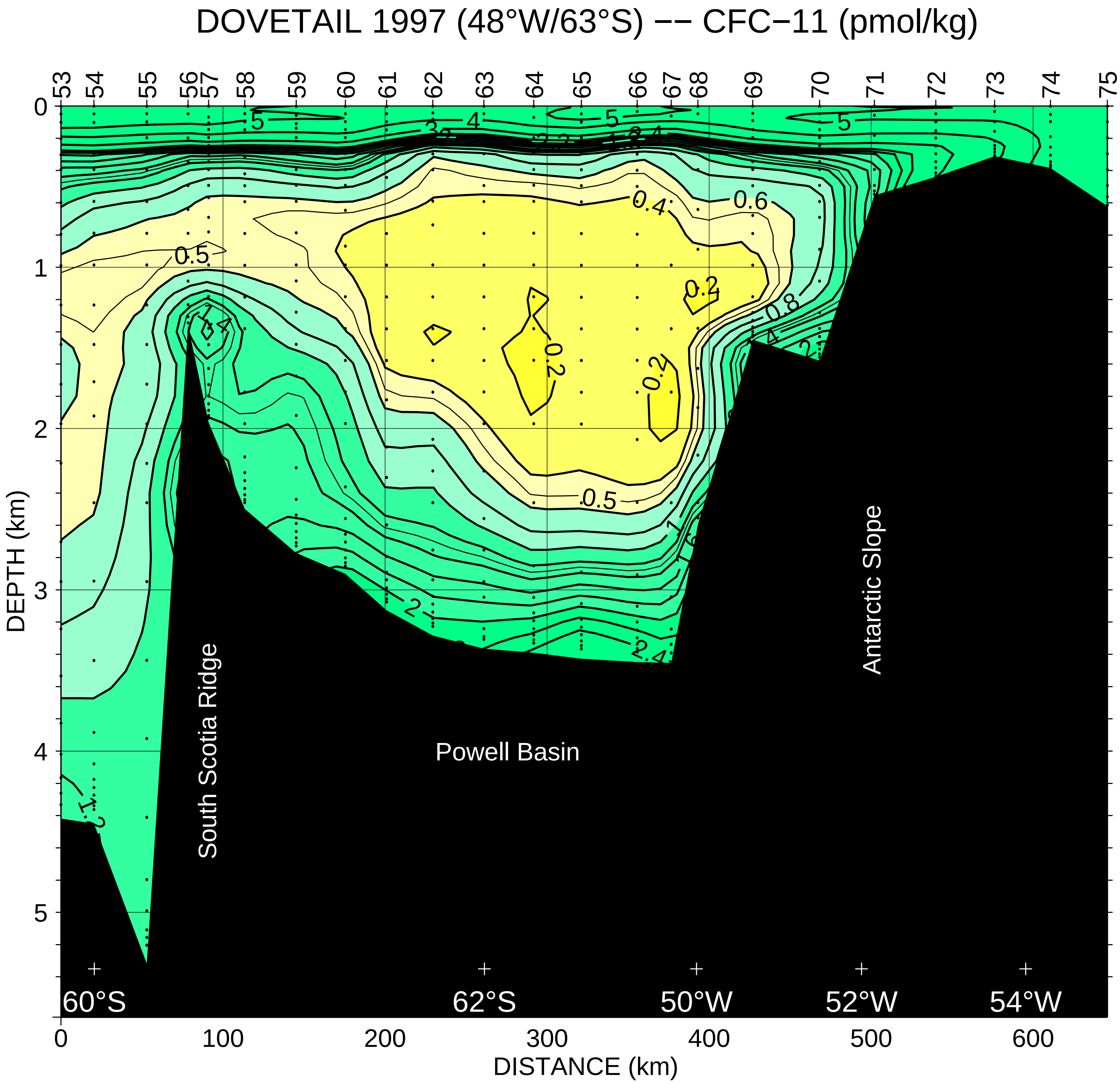

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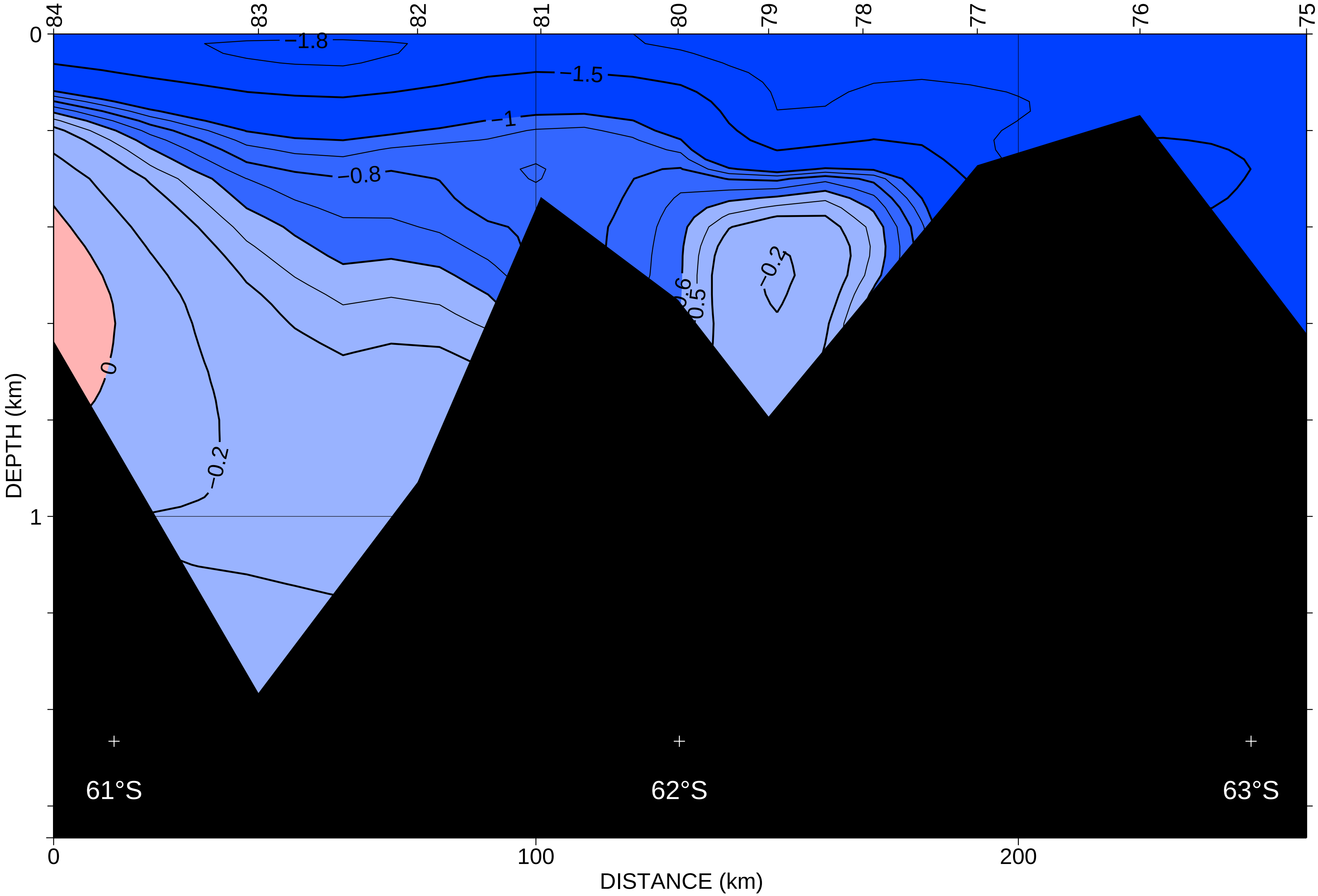
DOVETAIL 1997 (54°W) −− POTENTIAL TEMPERATURE (°C)



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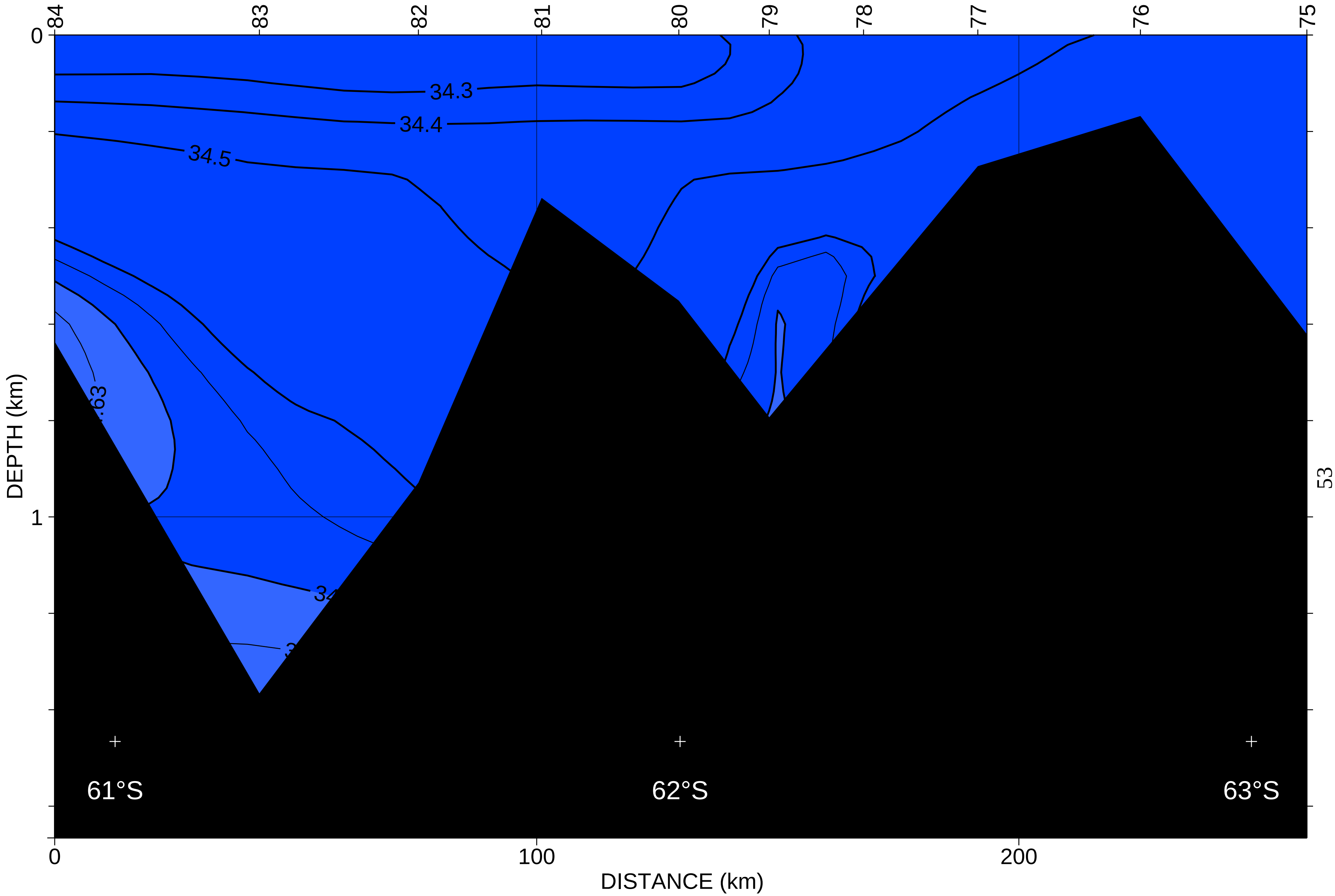
DOVETAIL 1997 (54°W) −− SALINITY



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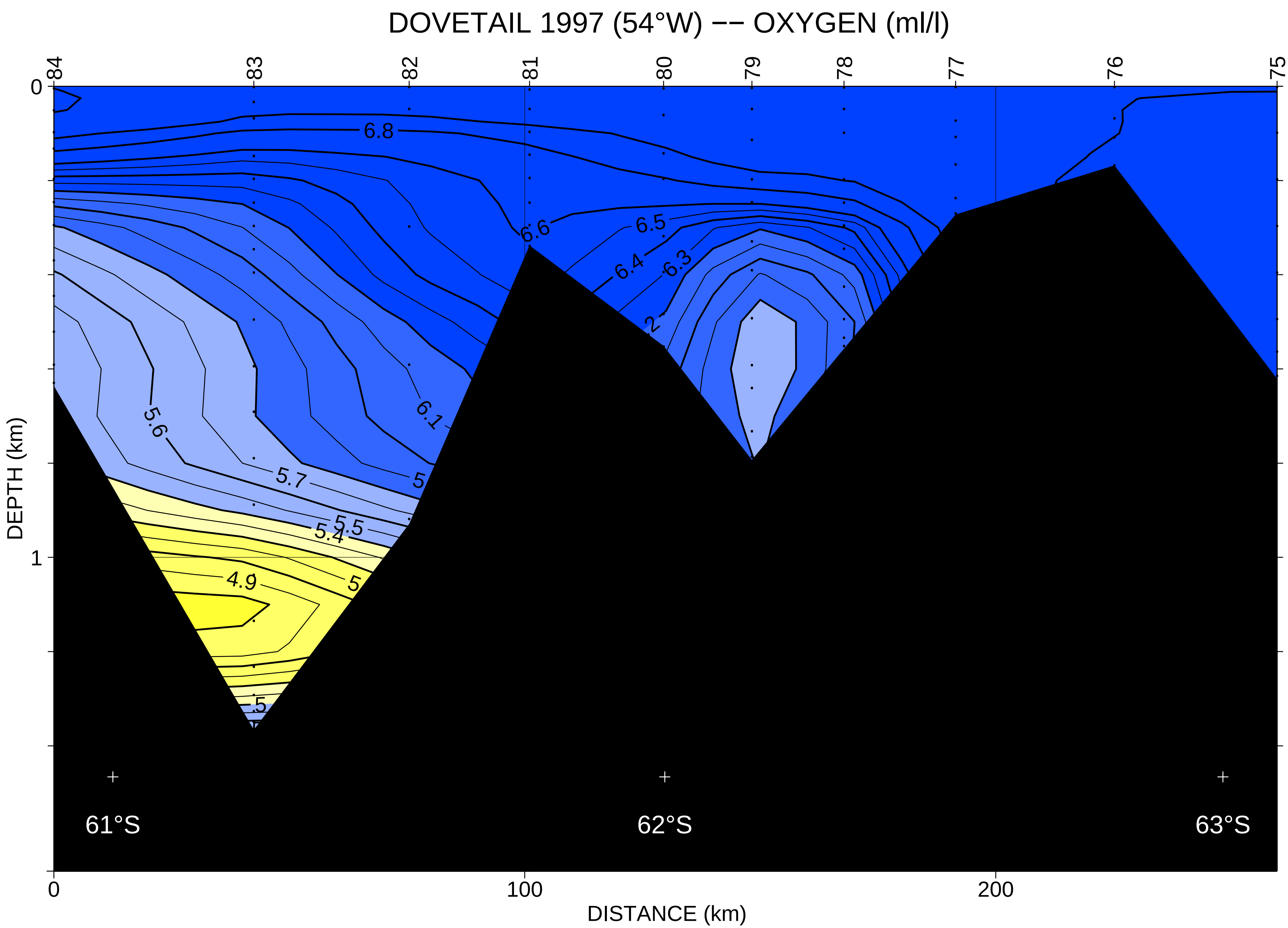

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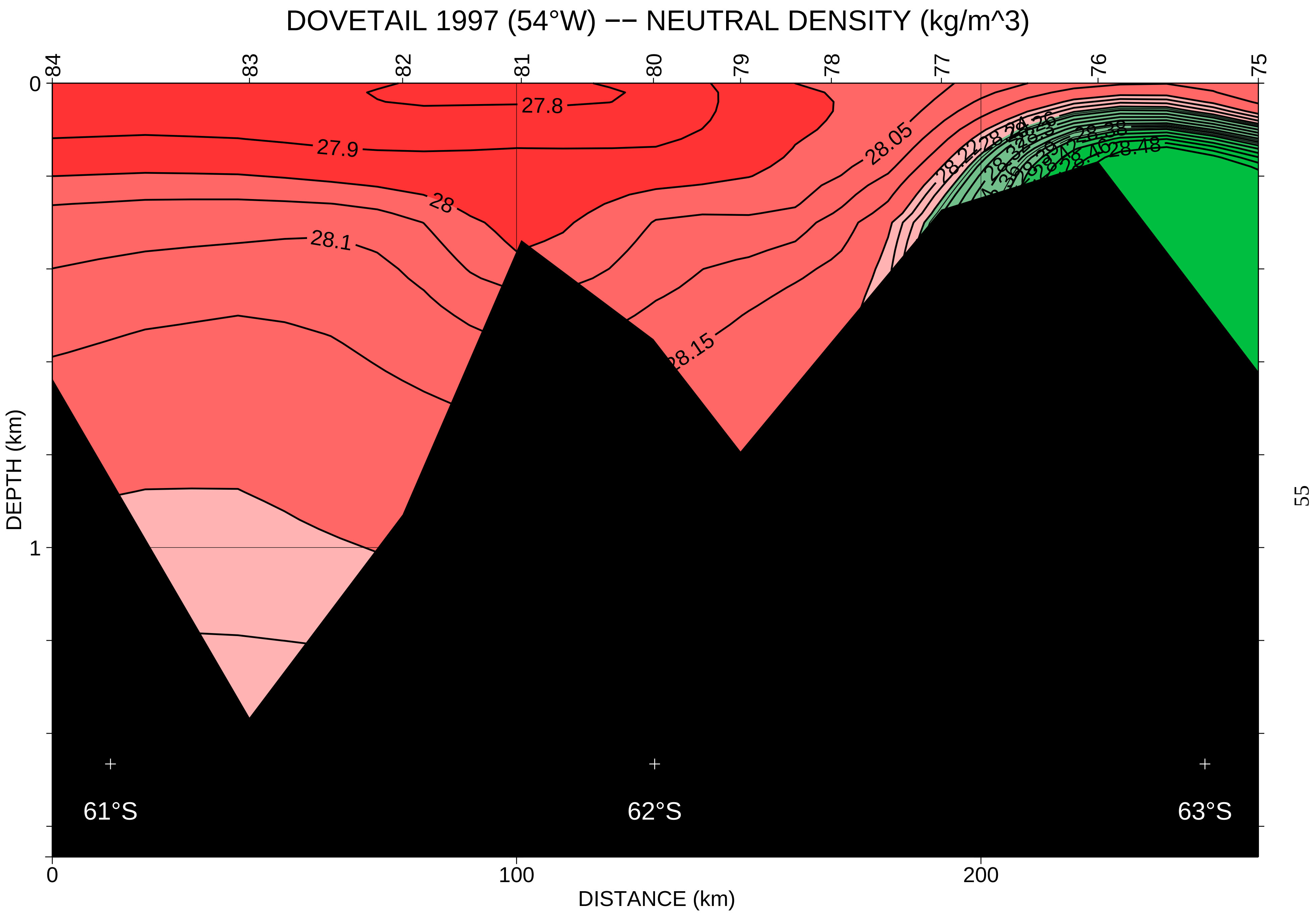

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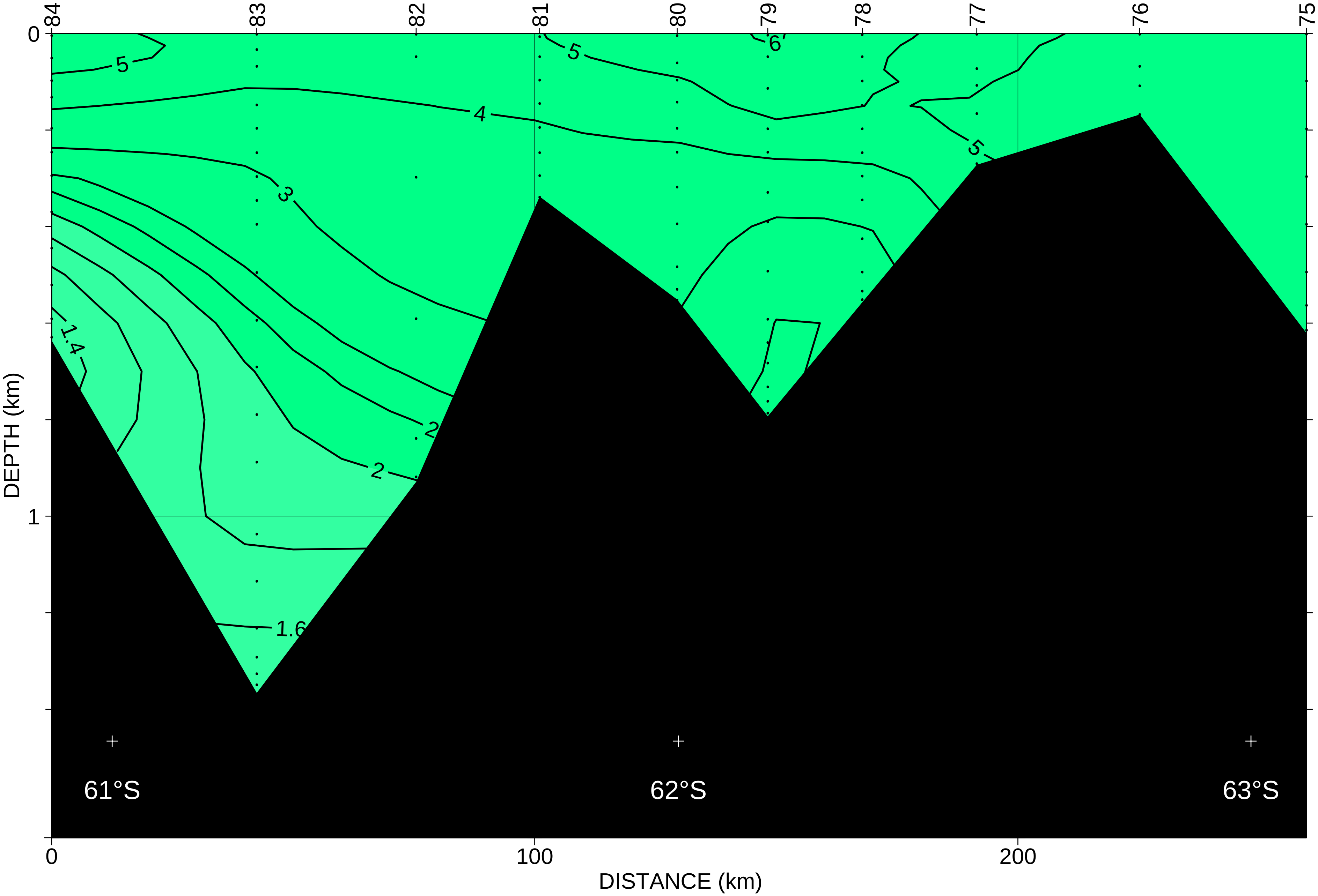
DOVETAIL 1997 (54°W) −− CFC−11 (pmol/kg)



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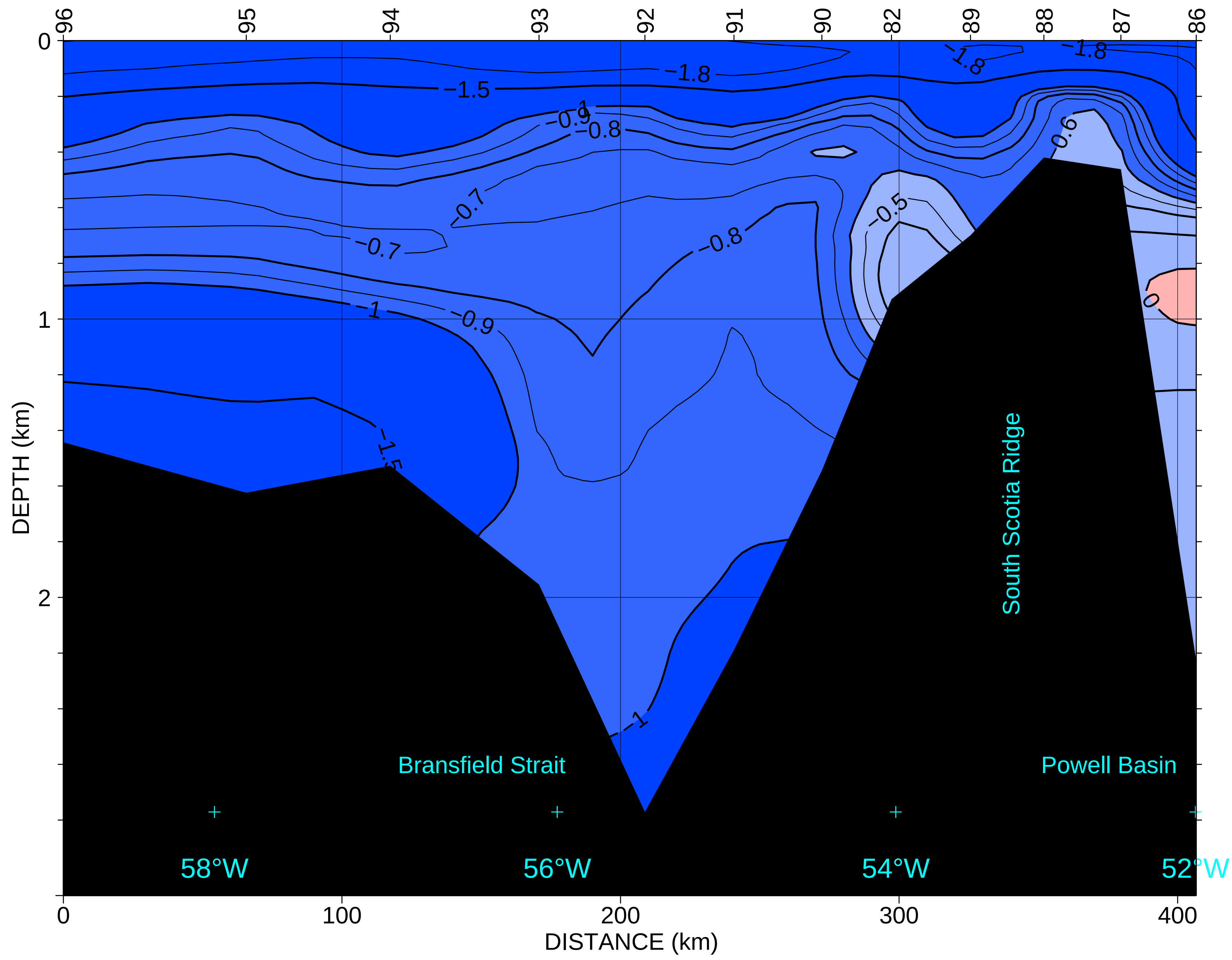
DOVETAIL 1997 (62°S) −− POTENTIAL TEMPERATURE (°C)



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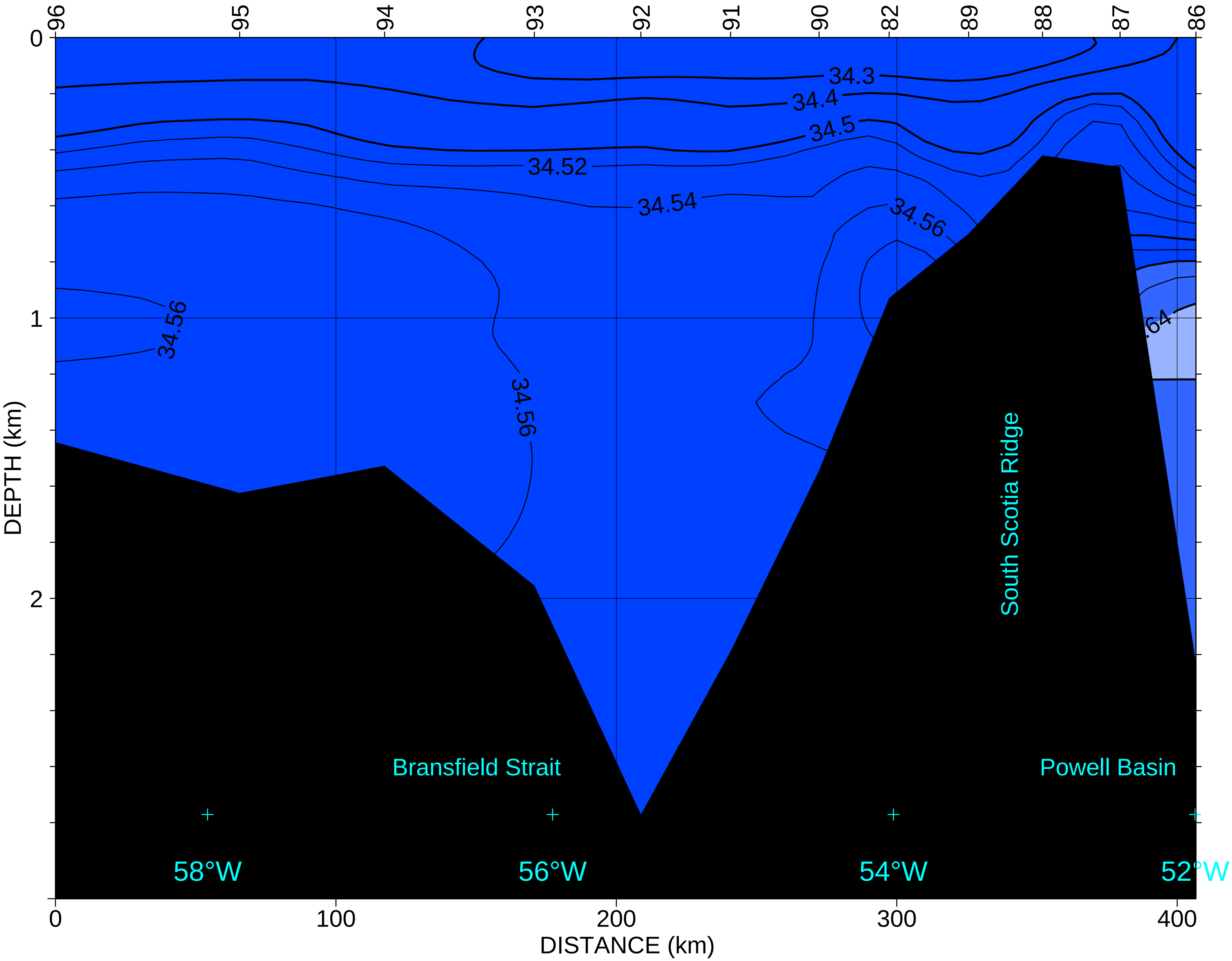
DOVETAIL 1997 (62°S) −− SALINITY



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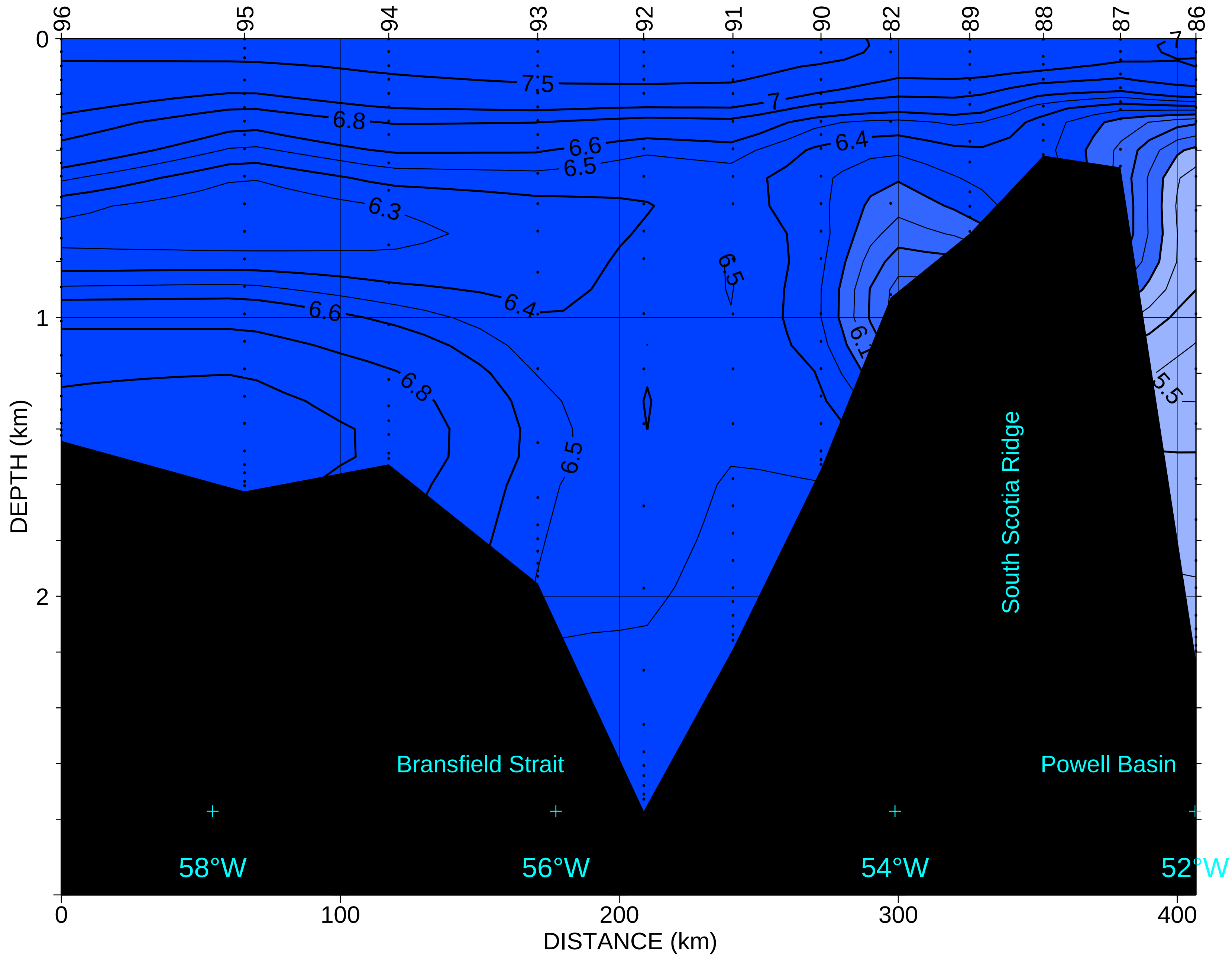
DOVETAIL 1997 (62°S) −− OXYGEN (ml/l)



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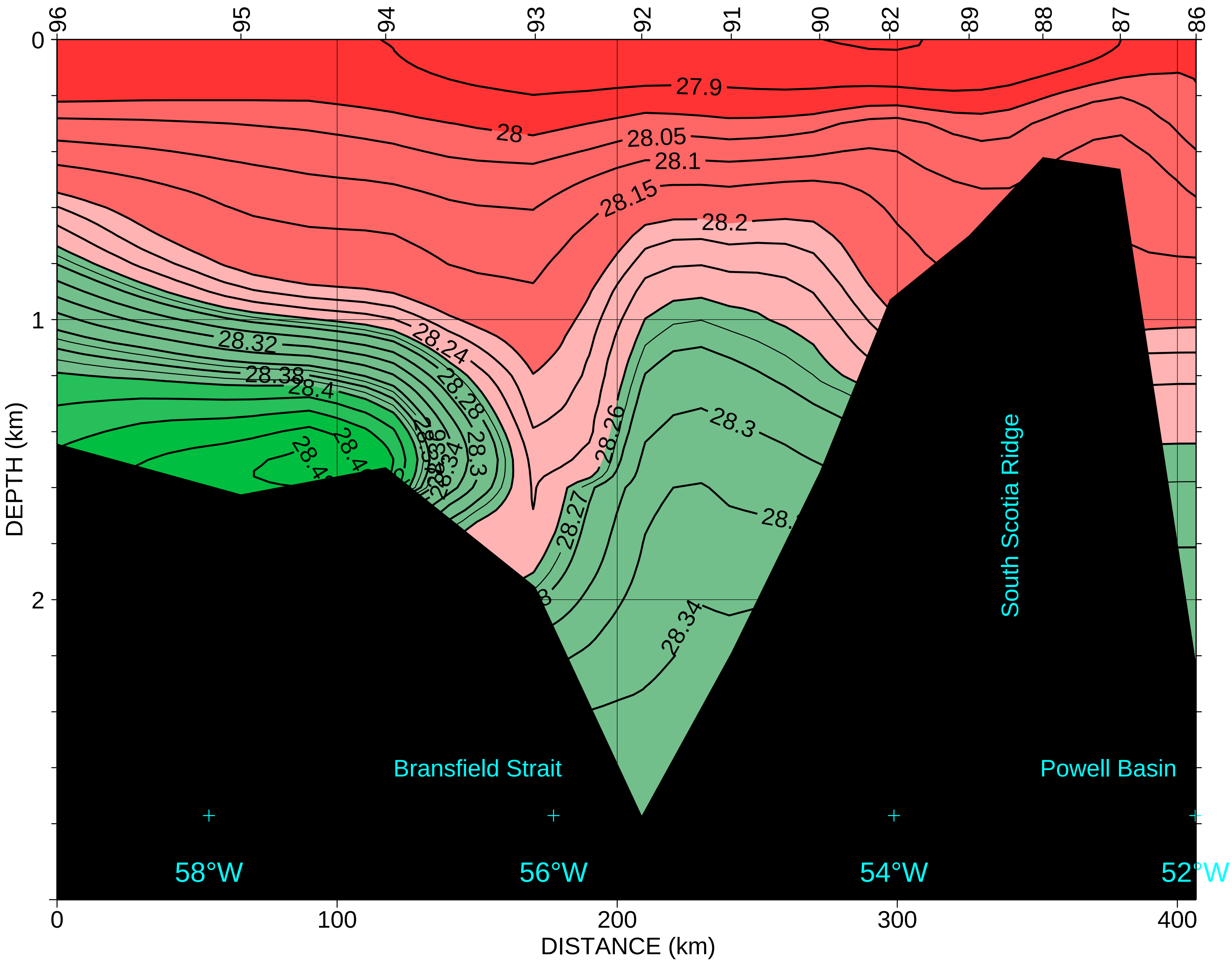
DOVETAIL 1997 (62°S) −− NEUTRAL DENSITY (kg/m^3)



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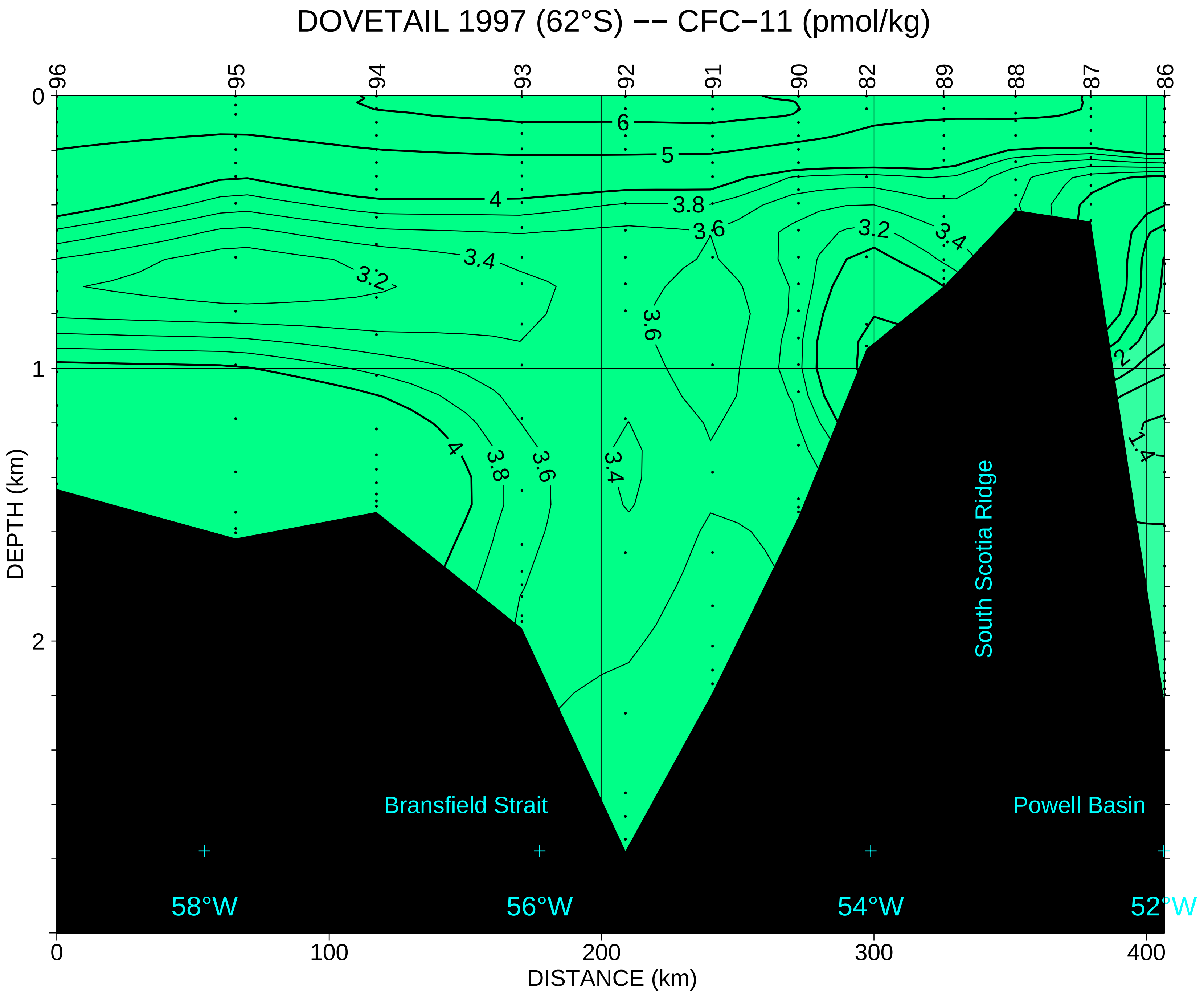

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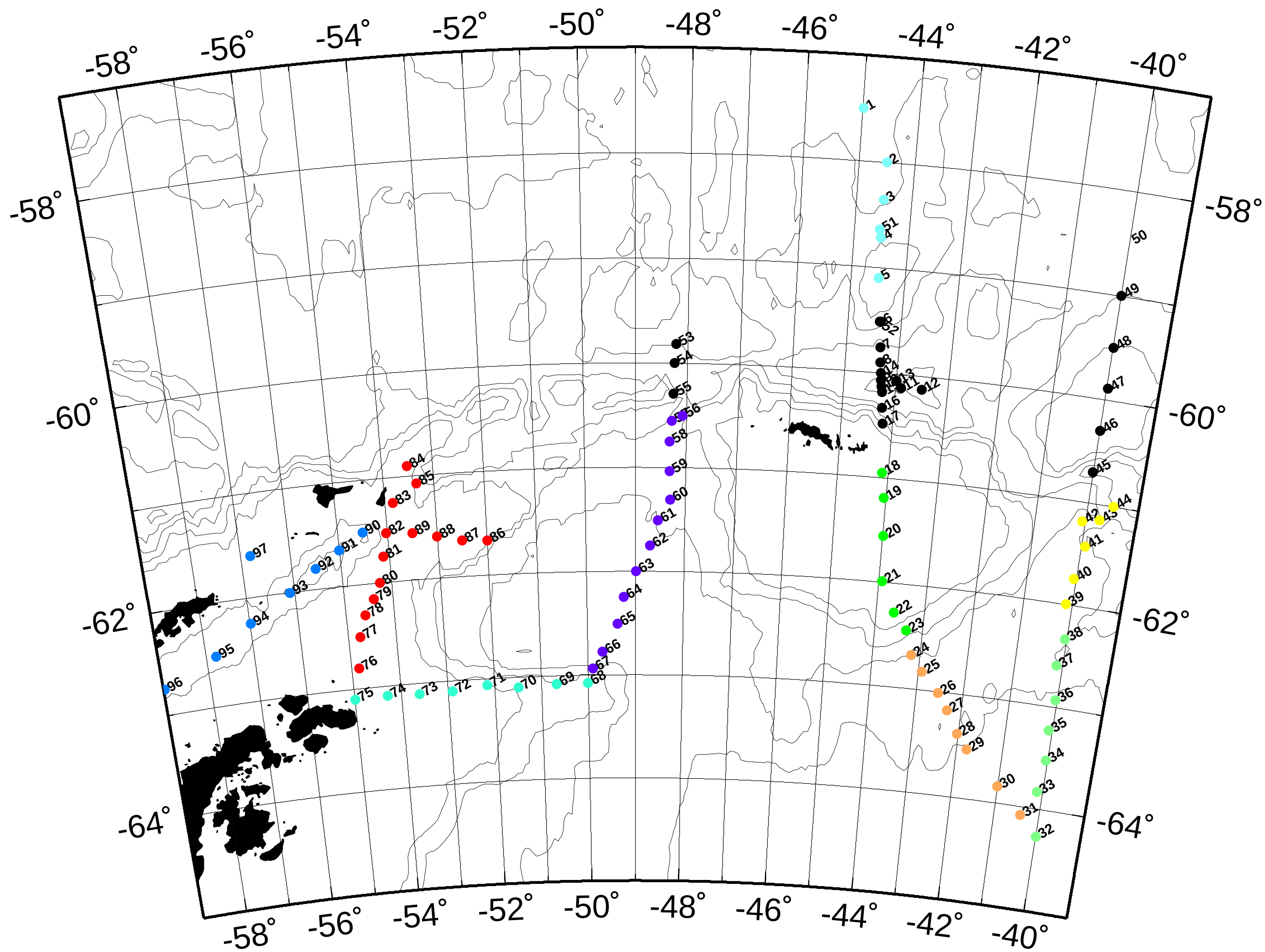
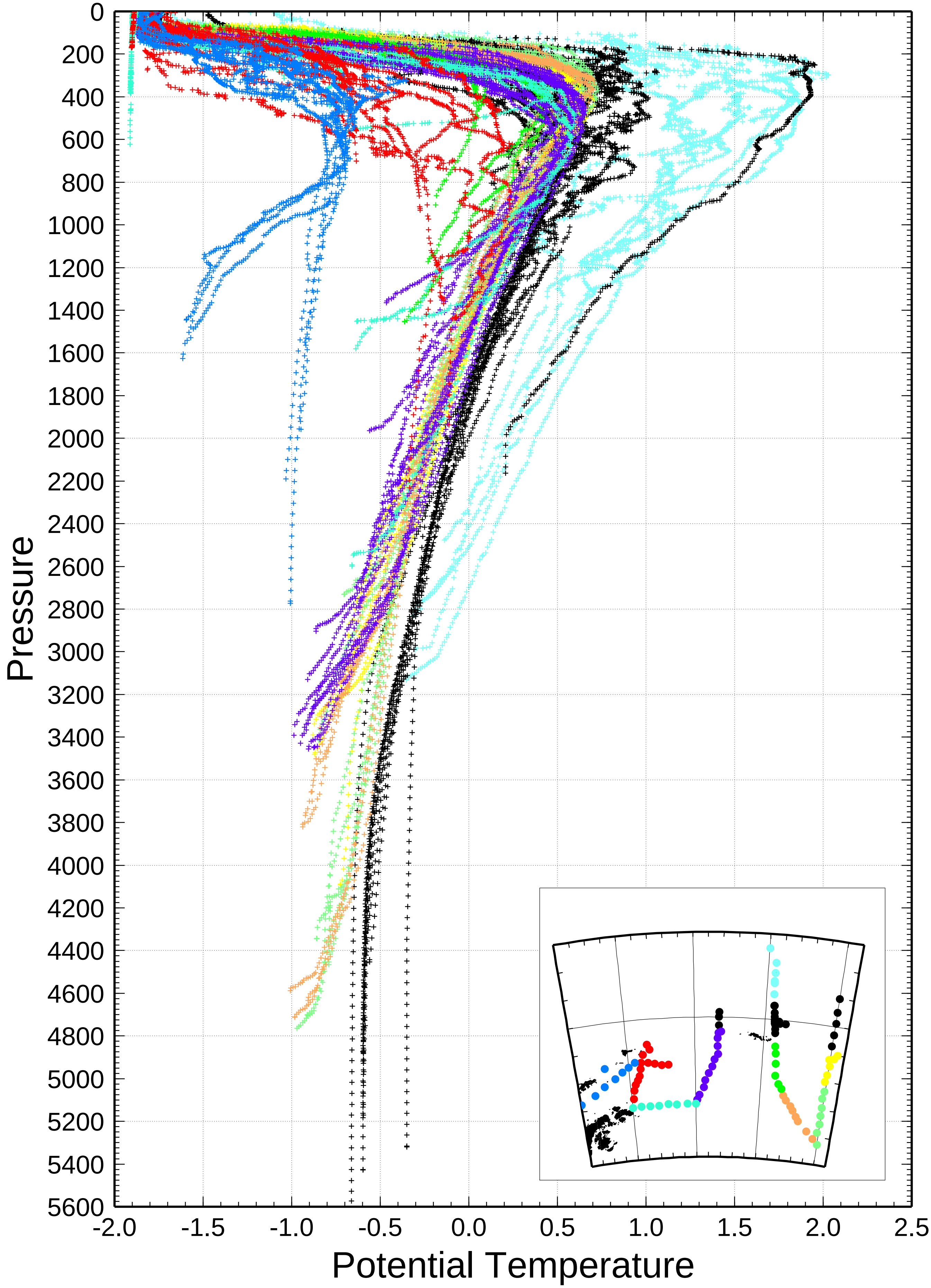
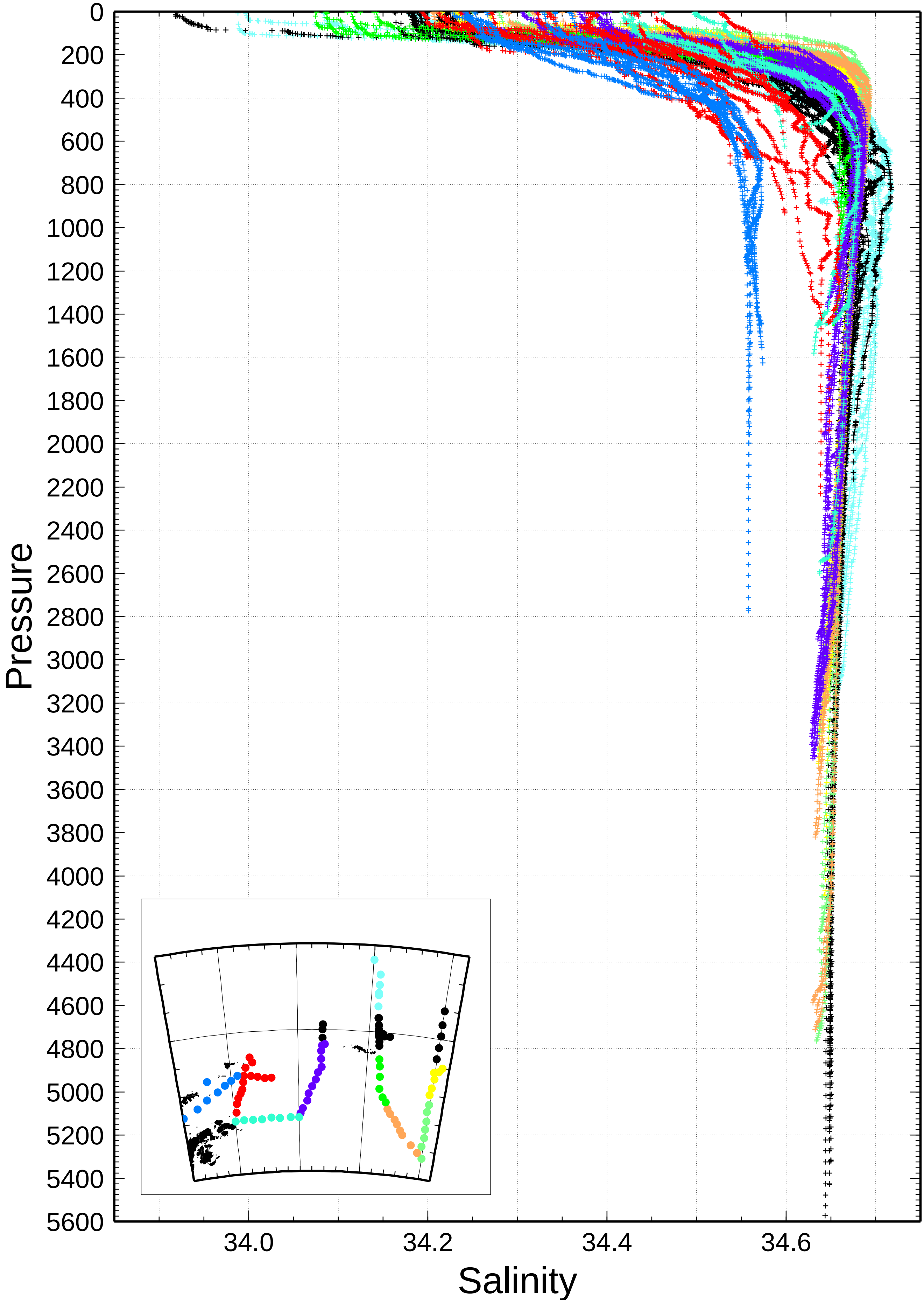
NBP9705 DOVETAIL





Pressure
Potential Temperature
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5



Pressure
Salinity
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
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3200
3400
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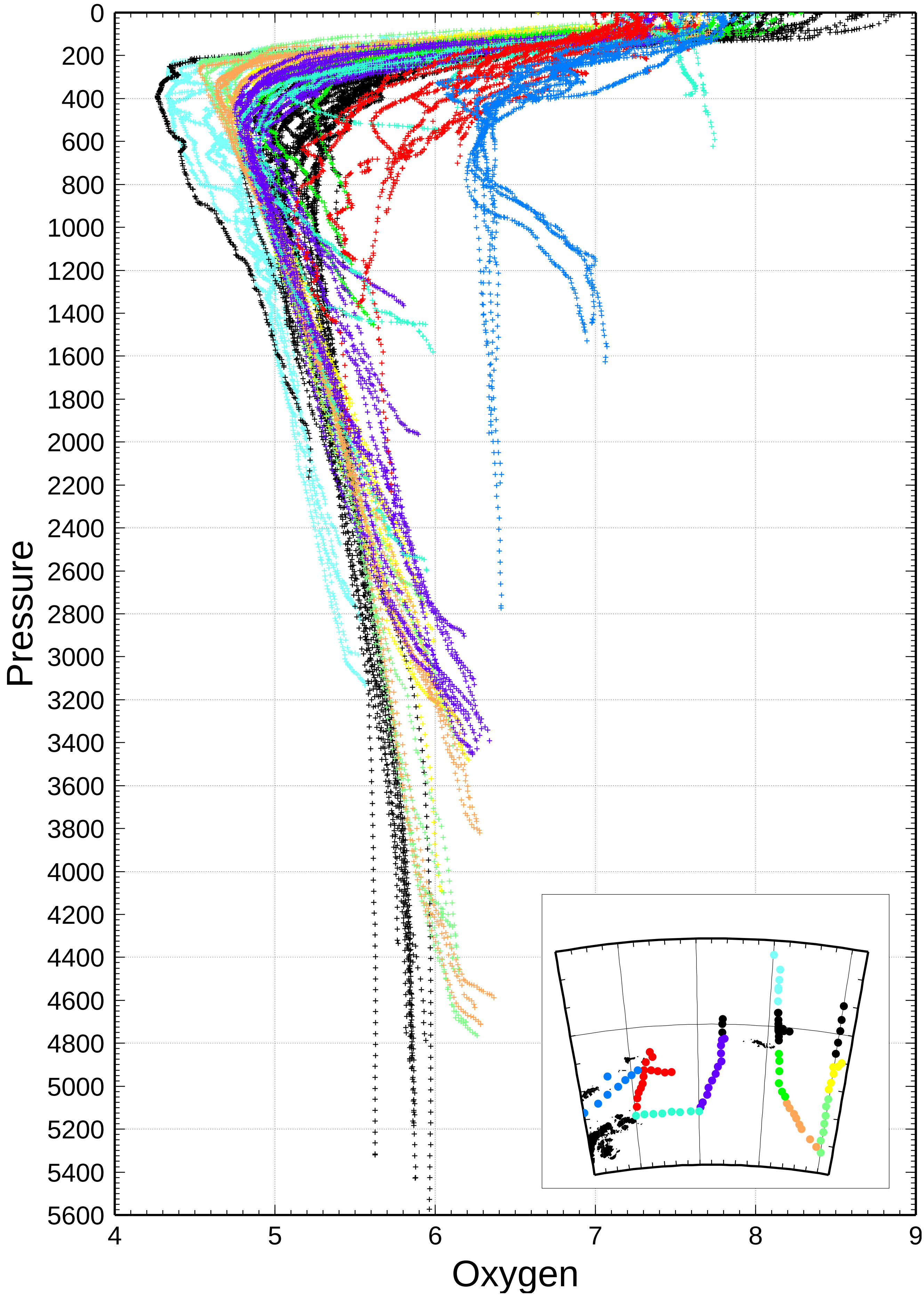
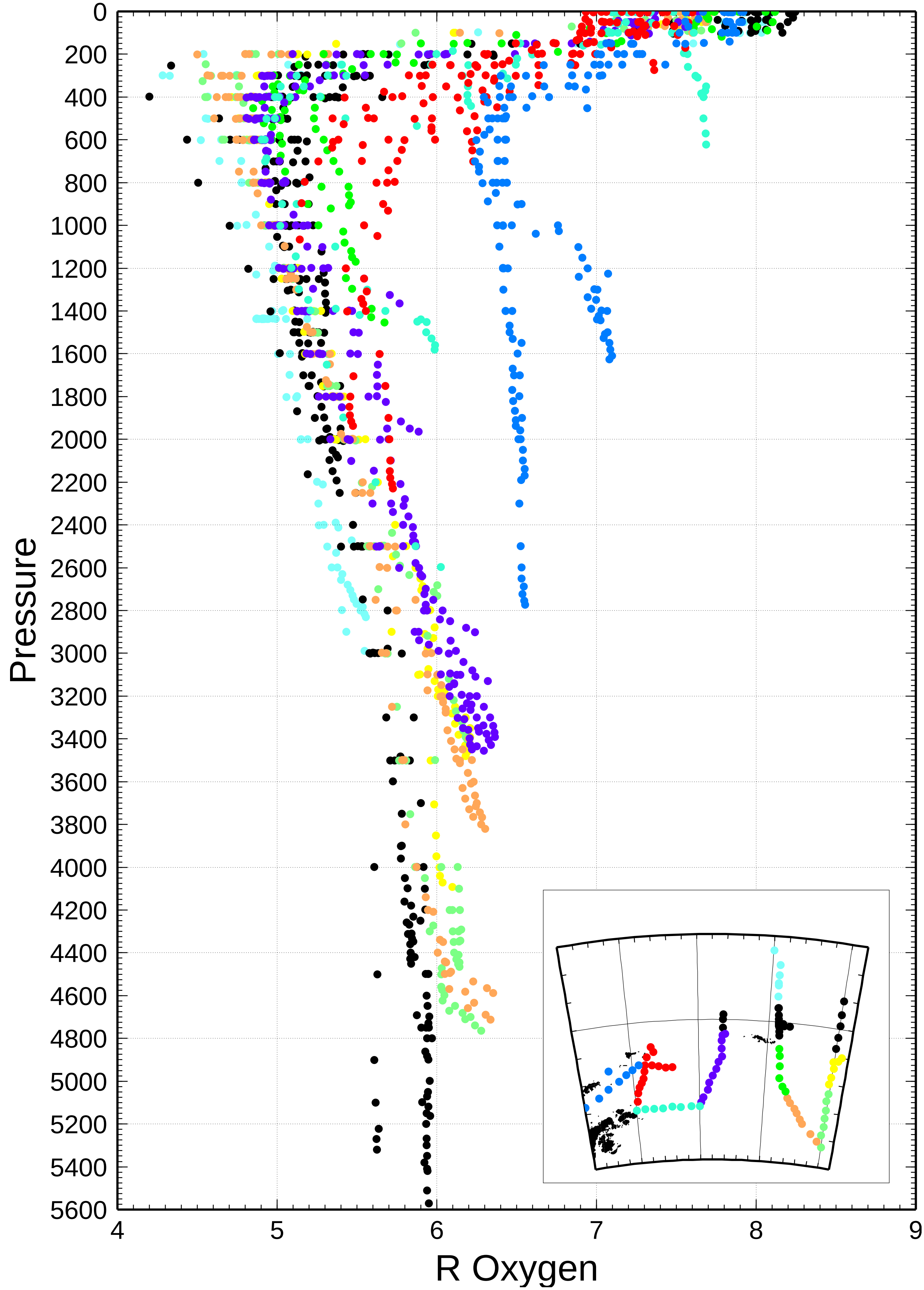
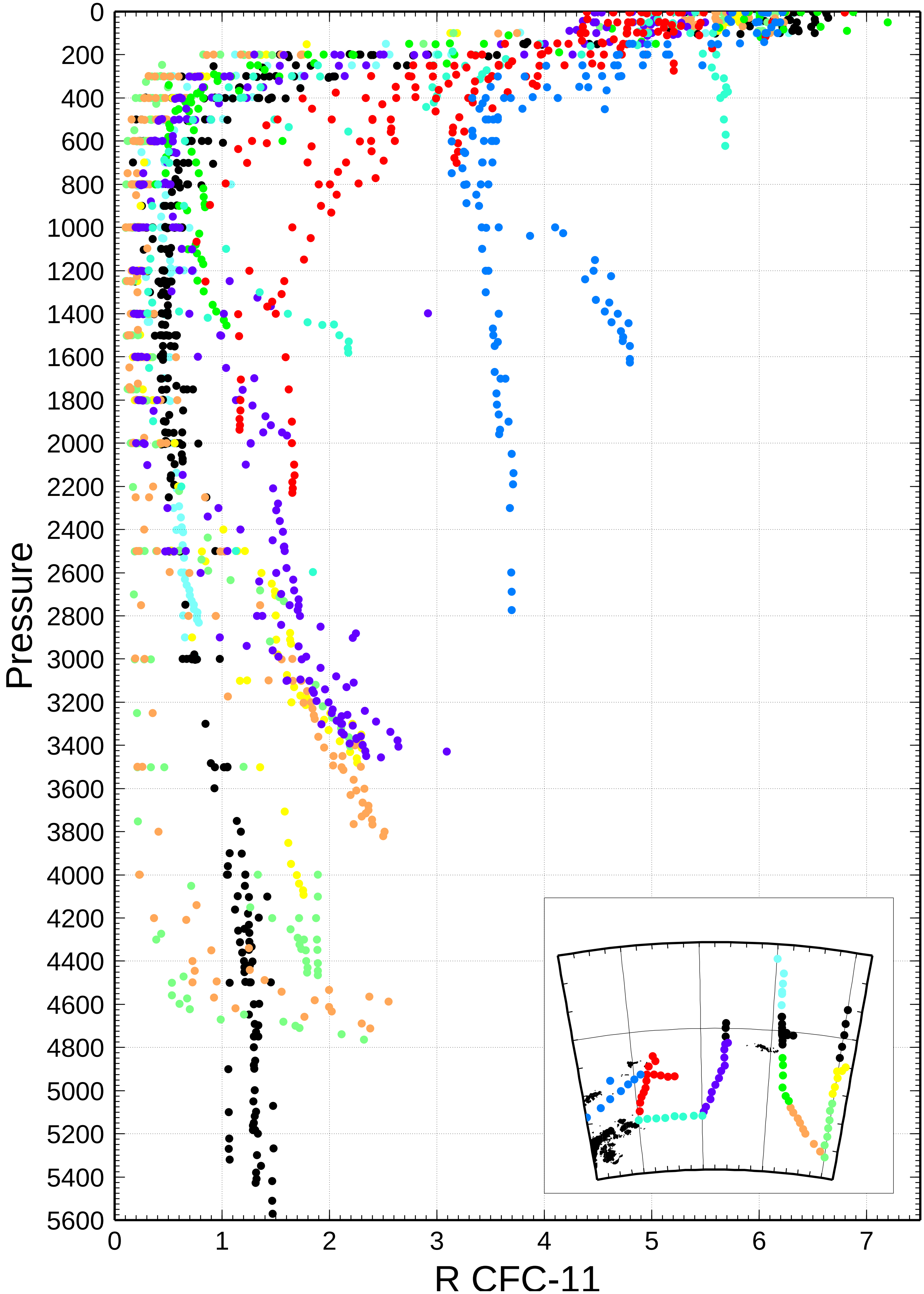
34.2
34.4
34.6

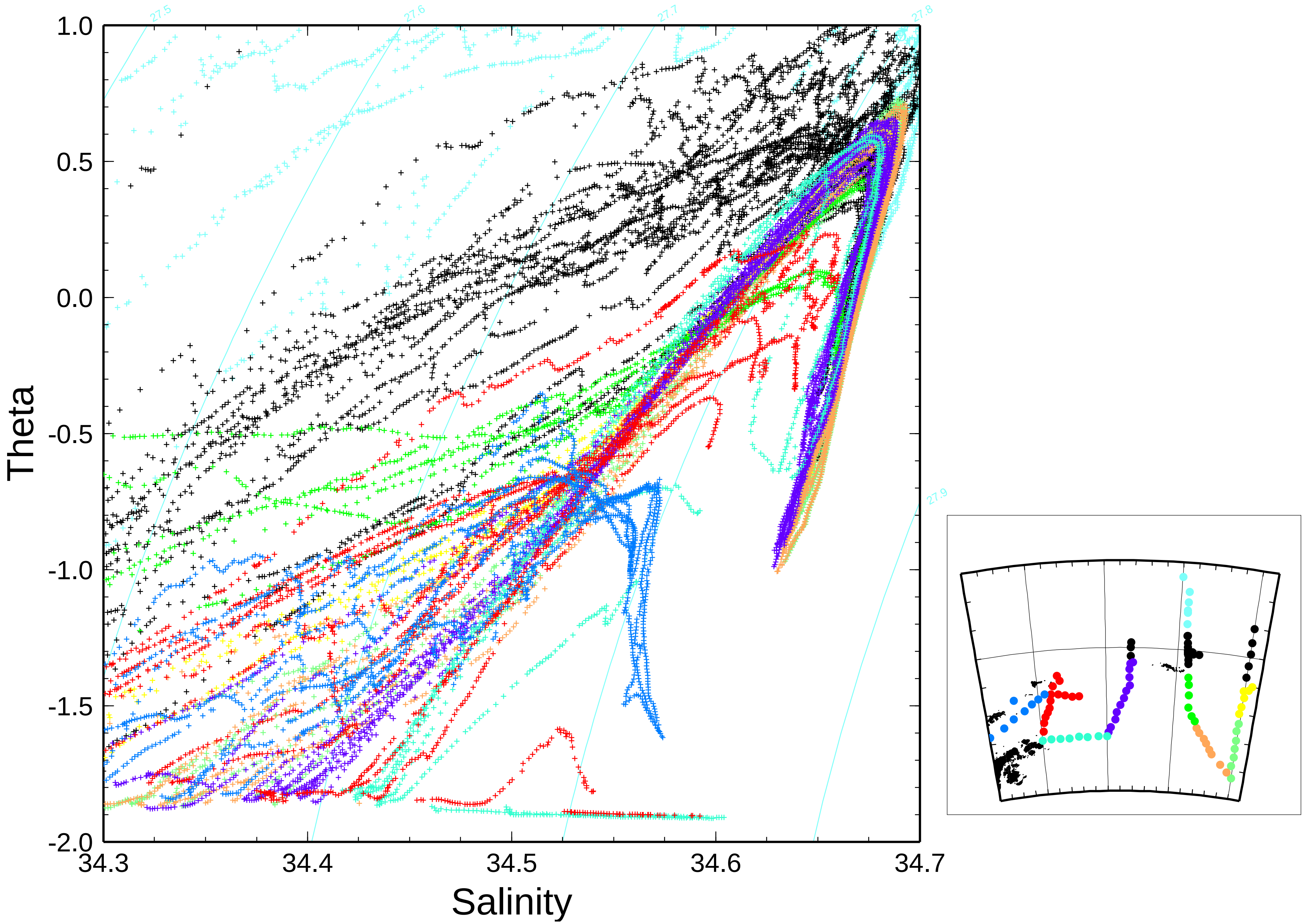


Pressure
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
4
5
6
7
8
9
Oxygen

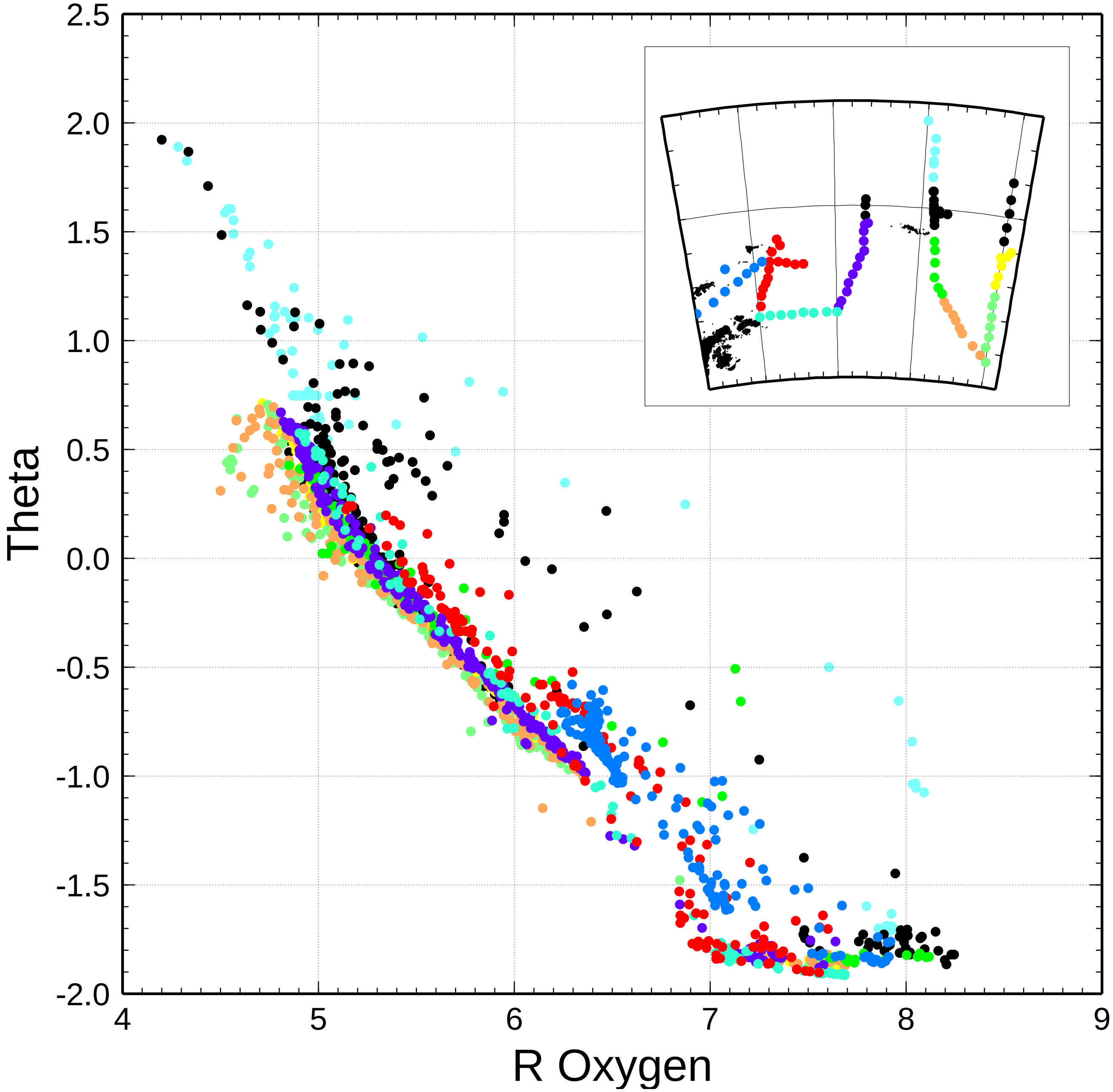


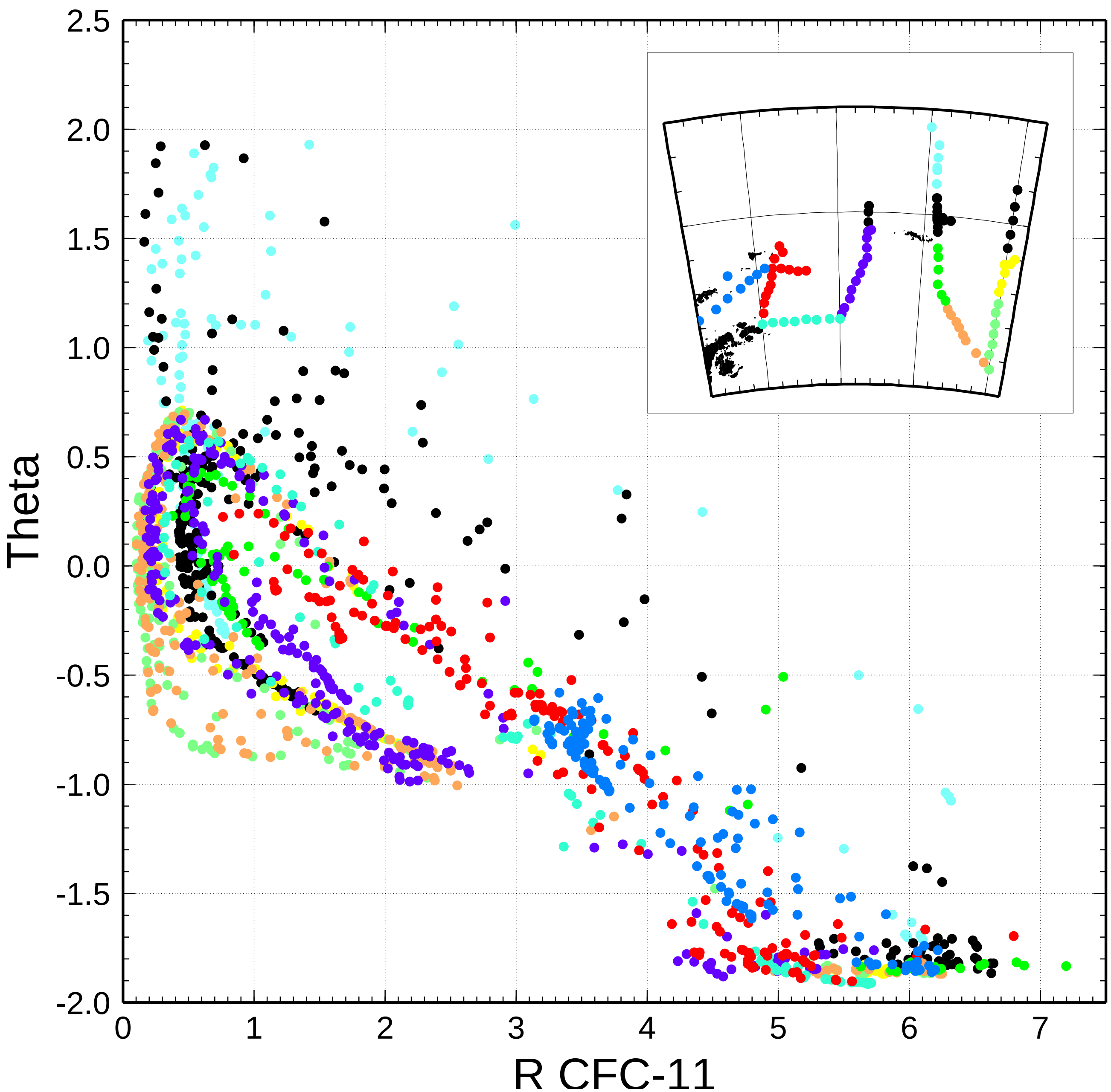
Pressure
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
4
5
6
7
8
9
R Oxygen


Pressure
R CFC-11
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
0
1
2
3
4
5
6
7

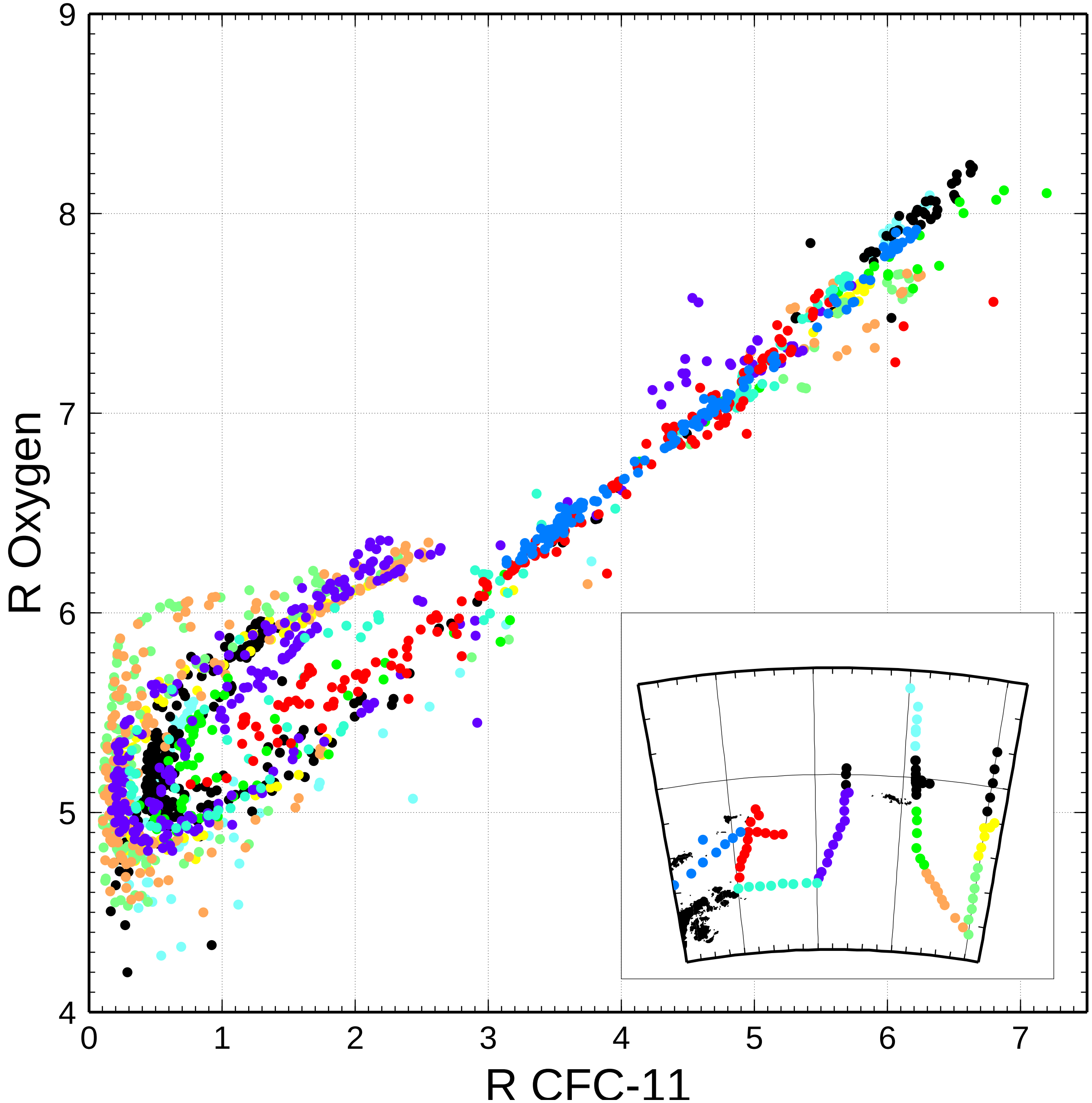


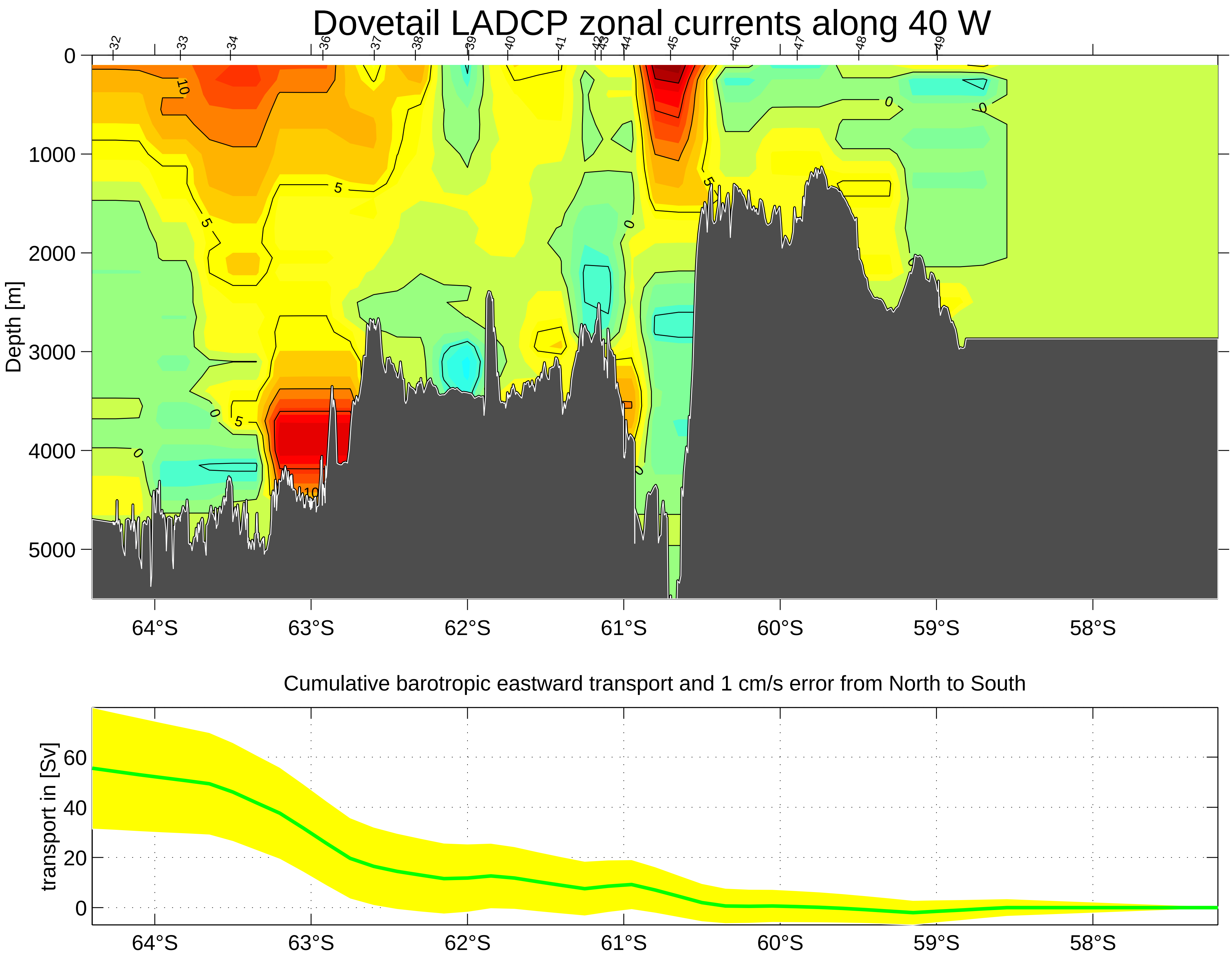
Theta
Salinity
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
34.3
34.4
34.5
34.6
34.7
27.5
27.6
27.7
27.8
27.9

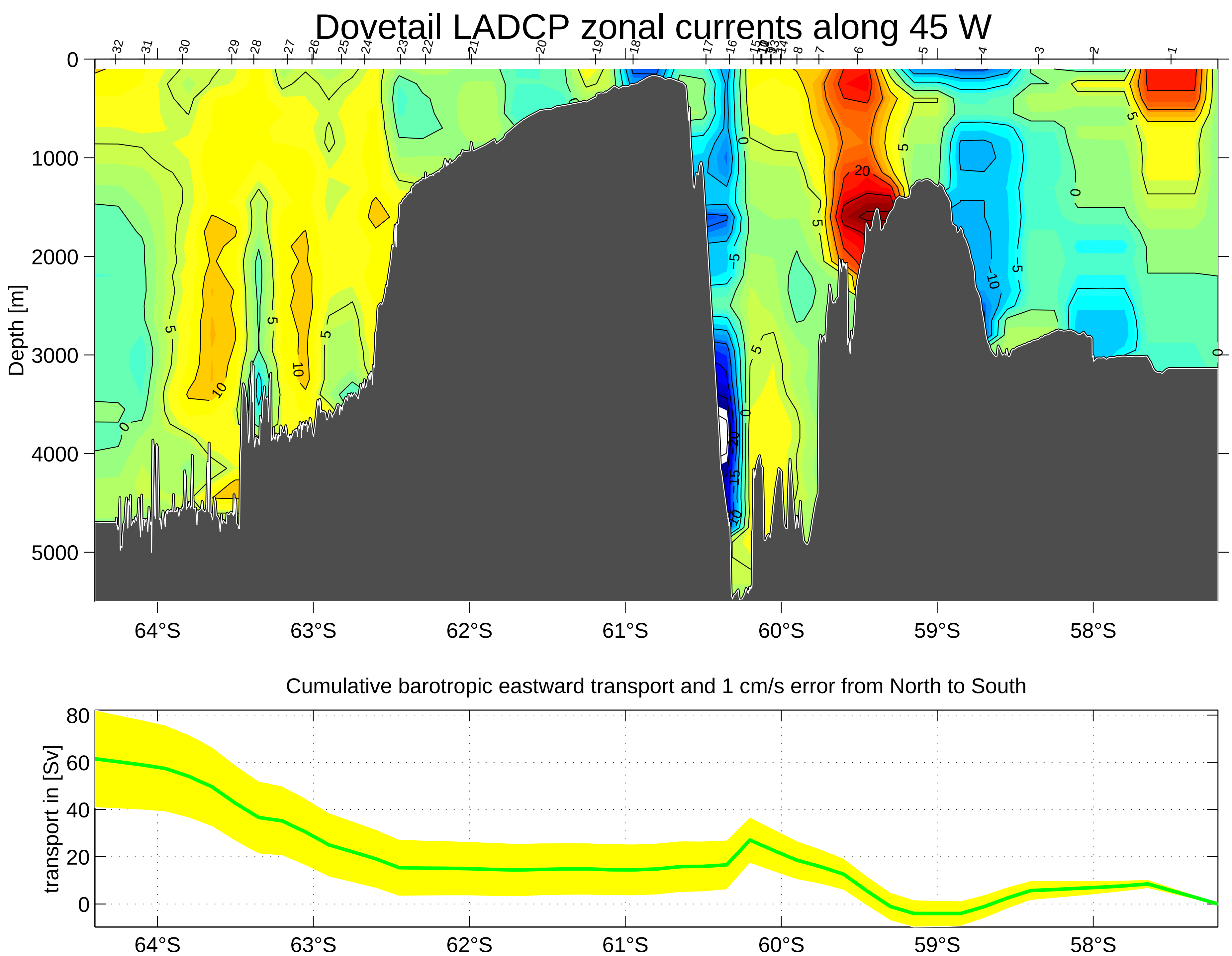

Theta
R Oxygen
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
4
5
6
7
8
9

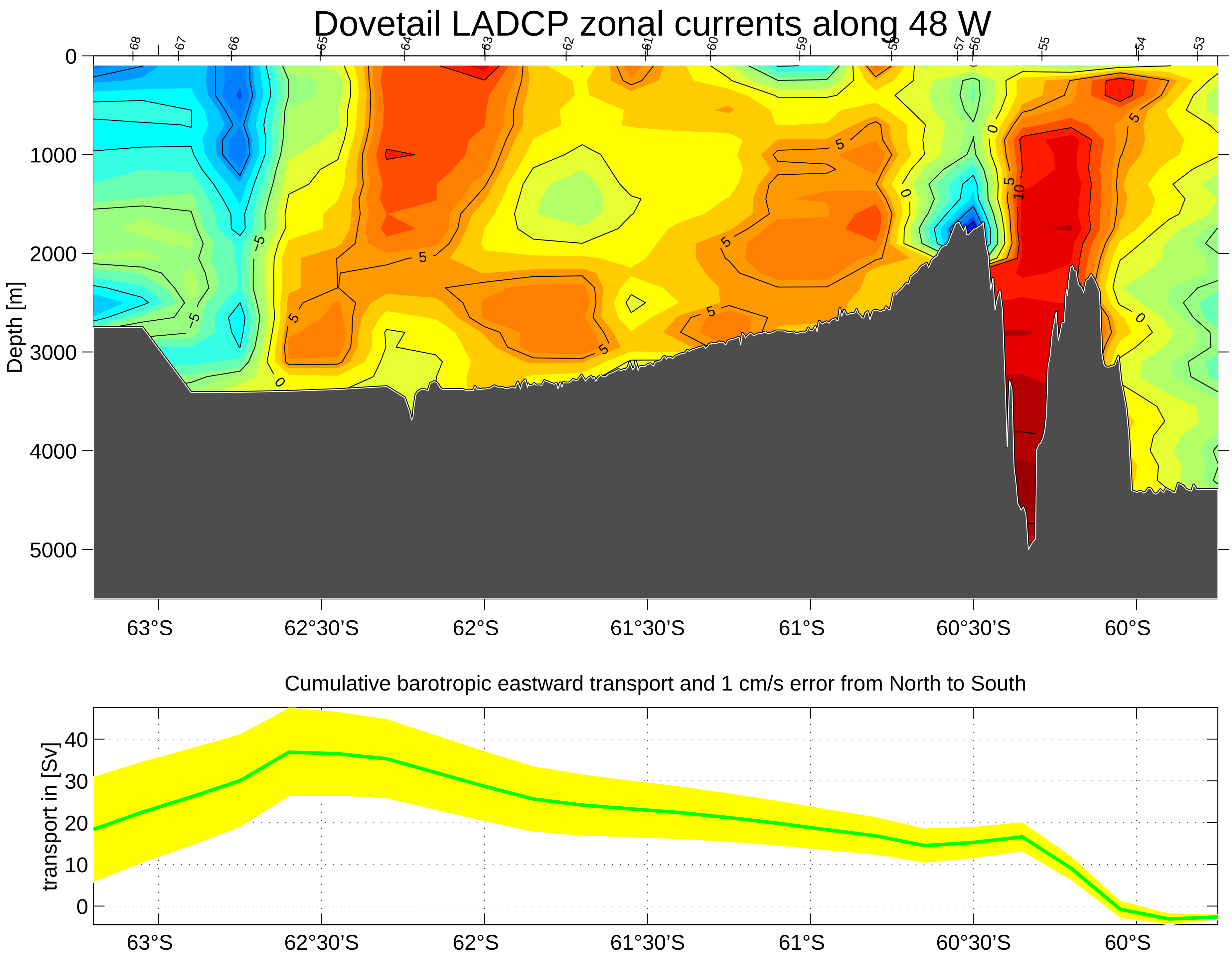


Theta
R CFC-11
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0
1
2
3
4
5
6
7


R Oxygen
R CFC-11
9
8
7
6
5
4
0
1
2
3
4
5
6
7


Dovetail LADCP zonal currents along 40 W
32
33
34
36
37
38
39
40
41
42
43
44
45
46
47
48
49
Depth [m]
0
1000
2000
3000
4000
5000
10
5
0
64°S
63°S
62°S
61°S
60°S
59°S
58°S
Cumulative barotropic eastward transport and 1 cm/s error from North to South
transport in [Sv]
60
40
20
0
64°S
63°S
62°S
61°S
60°S
59°S
58°S


Dovetail LADCP zonal currents along 45 W
Depth [m]
0
1000
2000
3000
4000
5000
64°S
63°S
62°S
61°S
60°S
59°S
58°S
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
8
7
6
5
4
3
2
1
Cumulative barotropic eastward transport and 1 cm/s error from North to South
transport in [Sv]
80
60
40
20
0


Dovetail LADCP zonal currents along 48 W
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
Depth [m]
0
1000
2000
3000
4000
5000
63°S
62°30'S
62°S
61°30'S
61°S
60°30'S
60°S
Cumulative barotropic eastward transport and 1 cm/s error from North to South
transport in [Sv]
40
30
20
10
0
63°S
62°30'S
62°S
61°30'S
61°S
60°30'S
60°S