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Institute of Oceanographic Sciences
Deacon Laboratory

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INTRODUCTION

RRS Discovery Cruise 198 (Fig. 1) was a joint cruise with the James Clark Ross, part of the BOFS Community Research Project, to survey the development of the spring bloom in the vicinity of the ice edge in the Bellingshausen Sea. A transect across Drake Passage was also undertaken as a contribution to the UK WOCE CRP. This report describes the SeaSoar data collected on that cruise.

The SeaSoar system used was that belonging to RVS, comprising a Neil Brown Mark IIIb CTD (serial number 01-1181) fitted with a new oxygen sensor (serial number 1-8-27) and 16 light sensing channels (Jim Aiken6), a Chelsea Instruments aquatracka fluorometer (serial number SA240) with 600m of Fathom faired cable on a horizontal axis winch.

Three surveys were undertaken (Table 1).

One day after sailing from Port Stanley, Falkland Islands, the SeaSoar was deployed (12/11/92) for a trial run in the passage south of the Falklands and north of Burdwood Bank. However, as it functioned perfectly, the first survey line, across Drake Passage (Fig. 2), was run without a break. The cable length outboard was shortened from 600m to 200m during the transit across Burdwood Bank from 1830Z/12/11 to 0440Z/13/11, and was again shortened to increase the ship's manoeverability in poor visibility and in the vicinity of ice from 0940-1040/14/11 and 1630/14/11-0707/15/11.

The second deployment began as an exploratory run from 65°40'S at 85°W south towards the ice edge. It was soon decided to convert the run without a break into the first ice edge survey (Fig. 3). After a dogleg to move the southward track westward to 86°20'W, a survey of 8 legs at 8 n.m spacing (20' longitude) from 66°30'S to 68°S was planned. The central leg down 85°W is labelled A. The first six legs (W, X, Y, Z, A and B) were completed without major incident, although there were detours to avoid icebergs and it was occasionally necessary to drop the speed below the optimum 8 knots in poor visibility.

Weather conditions were poor throughout the first ice edge survey, and on the 7th leg (C), running south along 84°20'W it was impossible to keep to the track (Fig. 2). It was also found that a boom attached to the stern gantry had sheared several bolts and was in danger of falling onto the SeaSoar cable. Because the SeaSoar could not safely be recovered until the boom was secured, and the boom could not be secured until the weather abated, the ship steamed slowly into wind on a northwestward track from 2000/27/11 and later east of north until repairs could begin at 0930/28/11. Although the survey was officially abandoned at the end of leg C, the last run across the middle of the survey area has been processed and is presented here as 'stormleg'.

The first attempt at a second survey (2230/30/11 - 0300/1/12) was aborted because of forecast severe weather, and the ship remained hove to for 24 hours until 0200/2/12, when SeaSoar was again successfully deployed. Thus the second survey (Fig. 4) began nearly 4 days after the first had ended. The intention was to run north-south at the same longitudes as in the first ice edge survey, but from

67°S to 68°30'S, later extended to 69°S. Also, the lines were worked upstream from east to west, as the first ice edge survey had repeatedly crossed a strong front with an eastward flowing frontal jet.

The first four legs (D, B, C and A, using the same labels as for the first survey) were completed without incident. Shortly after the end of leg A along 85°W, the signal from the CTD was suddenly lost. On recovery the cable was found to have parted some 20m from the SeaSoar, so the SeaSoar and all instrumentation was lost. After a delay, and transfer of the PML Undulating Oceanographic Recorder (UOR) from the James Clark Ross, the survey was completed with surface chemistry and UOR tows (not reported here) in 8-hour segments.

PROCESSING

SeaSoar data were logged in the usual way through the RVS Level A/B/C computer system, then transferred into the IOSDL PSTAR system on another workstation. Data were split into 4-hourly sections, for the convenience of watchkeepers, who processed, applied initial calibrations, plotted and edited the data. The major task, as always, was to examine the data for offsets caused by biological fouling, usually requiring an offset in salinity to recover to a good calibration relative to data before and after the fouling event. While this procedure is time-consuming, the great merit of the Neil Brown conductivity cell is that, once the fouling clears, it recovers its calibration reliably, and calibration drift is rare.

Towards the end of the Drake Passage survey, it was realised that the Level A software, which had been rewritten, no longer obeyed the correct algorithm for matching the time constant of the temperature sensor to that of the conductivity sensor in order to calculate salinity without bias and with minimal spiking. The value allowed for pressure spiking had also been set too small, resulting in good data being discarded whenever the climb or dive rate exceeded 2 m s-1, which commonly occurs shortly after each turn. The software could only be corrected by RVS at Barry. While this was being done, the entire Drake Passage survey was replayed from the backups of raw 8-hz data maintained by the RVS electronics division. A PSTAR program to reduce the data from 8 hz to approximately one sample per second using the correct algorithm was revived, and very clean data with the 16 light channels correctly demultiplexed were retrieved. The time base was retrieved by setting the start time, which was logged on the backup tape, and calculating the time between samples so that the resultant plots matched those originally processed through the Level A. This revealed that the CTD sampling rate was 8 samples in 1.02413 sec.

Revised Level A software was received and tested in time for use in the ice edge surveys. It was not perfect, particularly in regard to demultiplexing of the light channels, but the time constants of temperature and conductivity could be correctly matched, so the normal Level A route was used for the remainder of the cruise.

The 4-hourly sections were appended and contoured either every 12 hours (Drake Passage) or for each leg (ice edge surveys). Final calibrations were derived and applied as described below.

CALIBRATION

Initial calibration was done by PSTAR program 'ctdcal', for which the calibration file is shown in Table 2. Further calibrations were applied later, as described below.

Temperature

The calibration supplied by RVS was used throughout:

$$T = 0.00274 + Traw * 0.0005 * 0.9996194$$

Experience has shown that the temperature calibration is precise and very stable, and cannot be easily checked, as it is more accurate than any other sensor onboard ship. Any shift would manifest itself as a probably severe offset in salinity, which was not observed. No bias could be detected when our T/S plots were compared with those of other investigators who had recently worked in similar areas (R Peterson, Burdwood Bank, September 1992, personal communication; J Swift, Bellingshausen Sea along 67°S, February 1992, personal communication). We therefore take the SeaSoar temperatures to be absolutely correct to within perhaps 0.003°C, with relative drift during the survey no more than that.

Salinity

The SeaSoar salinity was first given an approximate calibration by use of a conductivity ratio that gave reasonable answers for the area being surveyed. Bias between down and up profiles caused by the different time constants of the temperature and conductivity cells was minimised by choosing a time constant by which the temperature was speeded up (for the calculation of salinity only) to minimise the hysteresis between down and up T/S profiles. The value chosen was 0.35 s, on the large side for the Neil Brown platinum resistance thermometer.

Relative calibration was maintained by comparing T/S profiles four at a time with a master T/S plot which was gradually developed for each survey area. Fouling of up to 0.2 or larger in salinity could occur, with frequent offsets of order 0.010 to 0.050. These were not always easy to spot, but the contour plots proved to be sensitive indicators of offsets (maintained for a profile or more) of as little as 0.010. Despite the care that was taken, there were occasions, in particular when the T/S relation changed rapidly across the front that lay across the ice edge survey area, when determination of the timing and magnitude of an offset proved almost impossible to correct with 100% confidence. Thus there may be occasions when the salinity is in error by as much as 0.030, but we expect the calibration to be within 0.010 more than 99% of the time.

Absolute calibration was subsequently achieved by comparison with hourly samples drawn from the sea-water supply to the thermosalinograph. The taking of the samples was timed to coincide with the SeaSoar surface turn, however, later comparisons between the time the bottle sample was drawn and the corrected SeaSoar time showed that the two rarely coincided. However, the seasonal mixed layer was sufficiently horizontally homogeneous that interpolating between SeaSoar profiles gave a good comparison with the bottle samples, except across fronts where the surface gradients were higher. These latter data were ignored in assessing the salinity correction.

The SeaSoar conductivity cell proved very stable for most of the cruise and straight offsets were applied for the first two deployments to bring the surface data within +0.010 of the salinity samples. Across the Drake Passage salinity was corrected by +0.015 (Fig. 5a) and for the first ice edge survey the correction increased to +0.024 (Fig. 5b). On the second ice edge survey the conductivity cell displayed a previously unobserved, aberrant behaviour, oscillating wildly over a 0.04 salinity range (Fig. 5c). The cause of this is unknown but it was most likely some kind of fouling, possibly by krill, as it recovered eventually. The oscillation in salinity made it very difficult to identify offsets due to fouling, or to ascertain the relative calibration. Comparison with discrete salinity samples showed that the deployment began with a +0.024 offset, but after the conductivity cell started oscillating this was masked by a larger and more variable offset which appeared to jump randomly between two values about 0.030 apart. Together with the 0.024 offset, we estimate the correction to be 0.044+0.015. About half way through the deployment the conductivity cell appeared to recover and relative calibration of the potential temperature/salinity plots left a correction of only +0.010 to be made.

Oxygen

Oxygen is calculated for the Beckmann oxygen sensor attached to the CTD by

$$O2 = rho * oxyc * \exp(-alpha * temp + beta * press)$$

where

$$temp = a * TCTD + b * oxyt$$

with

$$a + b = 1$$

where 'oxyc' and 'oxyt' are the oxygen current and temperature values, and 'press' is the CTD pressure. For deep CTDs, normal practice has been to choose 'a', the ratio between the CTD temperature (which has a short time constant) and the internal Beckmann unit temperature (oxyt) to reduce hysteresis between down and up casts. The constants rho, alpha and beta are then chosen by a least squares fit to all available oxygen data from one or many CTD casts. This procedure did not significantly reduce the hysteresis when tried on the sensor in the SeaSoar, because (a) there was very little temperature variation with depth south of the Polar Front and (b) the SeaSoar cycles through the oxygen gradient much more rapidly than a CTD.

A new procedure was therefore adopted on Cruise 198. The oxygen current OC was speeded up by the formula

$$OCtrue\ (t0) = OCobs\ (t0) + tau\ [OCobs\ (t1) - OCobs\ (t\text{-}1)]/(t1 - t\text{-}1)$$

where t-1, t0 and t1 were successive 1-second values, and the oxygen temperature was ignored (b = 0). Several values of tau were tried until hysteresis was minimised. It was found that the value of tau depended on the depth of profiling, and two values which improved the fit were chosen as 15 sec for the Drake Passage section, and 10 sec for the ice edge surveys (Fig. 6b).

The least squares fit to determine the remaining constants also could not be applied because (a) oxygen samples obviously cannot be drawn at the SeaSoar position, (b) the least squares fit equations tend to be ill-conditioned. This is so because both pressure and temperature tend to vary monotonically with depth, so the fit is sensitive to errors in bottle values caused by sampling problems or samples not carefully matched to the SeaSoar values in space and time.

Oxygen samples available consisted of (a) those drawn from CTD casts along 85°W between the first and second ice edge surveys and (b) two-hourly surface samples during SeaSoar runs. The latter were used to choose rho with a typical value of alpha (-0.036), but exhibited rather wide scatter with some obviously bad sample values possibly caused by difficulties in sampling off the non-toxic supply. However, it had been noted that the percent saturation of the calibrated CTD oxygens correlated well with patches of high and low productivity, ranging from 1.04 (104%) in the major bloom, through 1.00 in smaller blooms to 0.98 where the bloom was absent. By choosing rho = 1.472, alpha = - 0.036, these percent saturations were closely matched by the SeaSoar oxygens in and out of the bloom areas. The pressure coefficient beta does not affect the fit at zero pressure.

To approximate the vertical profiles of oxygen, we made use of the samples drawn on CTD casts at 300m. T/S profiles from the CTD casts along 85°W were compared with SeaSoar T/S profiles from the 4-km gridded file (averaged over down and up casts) for the 85°W run during the first ice edge survey. As this survey crossed and recrossed the front, where the T/S relation changed rapidly, profiles could be matched within a few km of similar features. Applying rho and alpha given above, with a nominal value of beta = 0.00014, it was found that the SeaSoar values were too low. By adjusting the value of beta to beta = 0.0003965, the 300m values were brought in line with the sample values to within 0.02 + 0.10 ml l-1, where 0.10 is the standard deviation over 10 samples. This is equivalent to a near-linear stretching of the oxygen values with pressure, because exp (beta * press) = 1 + beta * press

for beta * press << 1.

In the thermocline, accurate calibration is impossible because of the oxygen sensor hysteresis (Fig. 6b).

In summary, we expect that our calibrated oxygen values will be correct within about 2%, and are more likely to be low than high (if the 98% surface saturation values should be increased to 100%, say).

Chlorophyll

The Chelsea Instruments fluorometer has a range of 4096 counts for 0 to 10 volts. Conversion of counts to volts is thus

volts = 0.002441 * count.

Hourly samples drawn from the non-toxic supply were used to calibrate fluorescence values. The following calibrations have been kindly supplied by G Moore. For the values presented in this report, no quench correction has been applied, and only dark values have been used to calculate the calibration factors.

For The Drake Passage section, the calibration from volts to mg m-3 was

Chl = exp (-2.5607 + 1.1071 * volts).

For the ice edge surveys, the calibration was

Chl = exp (-4.8823 + 1.8957 * volts).

Light

Two channels in the CTD data stream were multiplexed over 8 samples to record 8 upward and downward looking light values at different wavelengths. These were demultiplexed and then split off from the main CTD processing stream. Their calibrations and values will be presented elsewhere.

DESCRIPTION OF PLOTS

For each of the three surveys, a T/S scatter plot for the whole survey is given and a series of contour plots, eight for each section. Six of the eight are plots against pressure of potential temperature, salinity, density sigma0, oxygen, chlorophyll converted to mg~m-3, and across-track geostrophic velocity (positive eastwards) relative to 404 m. The remaining two contour plots are of temperature and temperature and thickness plotted against density as the vertical coordinate. The salinity shows where boundaries between water masses occur. Thickness, defined as the pressure difference between isopycnals 0.02 apart centred on the reference isopycnal, shows how a component of potential vorticity varies isopycnically.

ACKNOWLEDGEMENTS

These data were collected on the first cruise of the rebuilt *RRS Discovery*. The weather was occasionally less than perfect and we would like to acknowledge the dedication and skill of the Master, M Harding, officers and crew which made the cruise so successful. We would like to thank the Principal Scientist, Dr D Turner for allowing us time to complete the section across Drake Passage.

TABLE 1

SeaSoar deployments

Run	Deployed	Recovered	Duration	
1	12/11/92 1330	15/11/92 0707	2 d	18 h
2	23/11/92 1430	28/11/92 1000	4 d	20 h
3	30/11/92 2308	1/12/92 0415		5 h
4	2/12/92 0253	4/12/92 1034	2 d	8 h
		TOTAL:	10 d	3 h

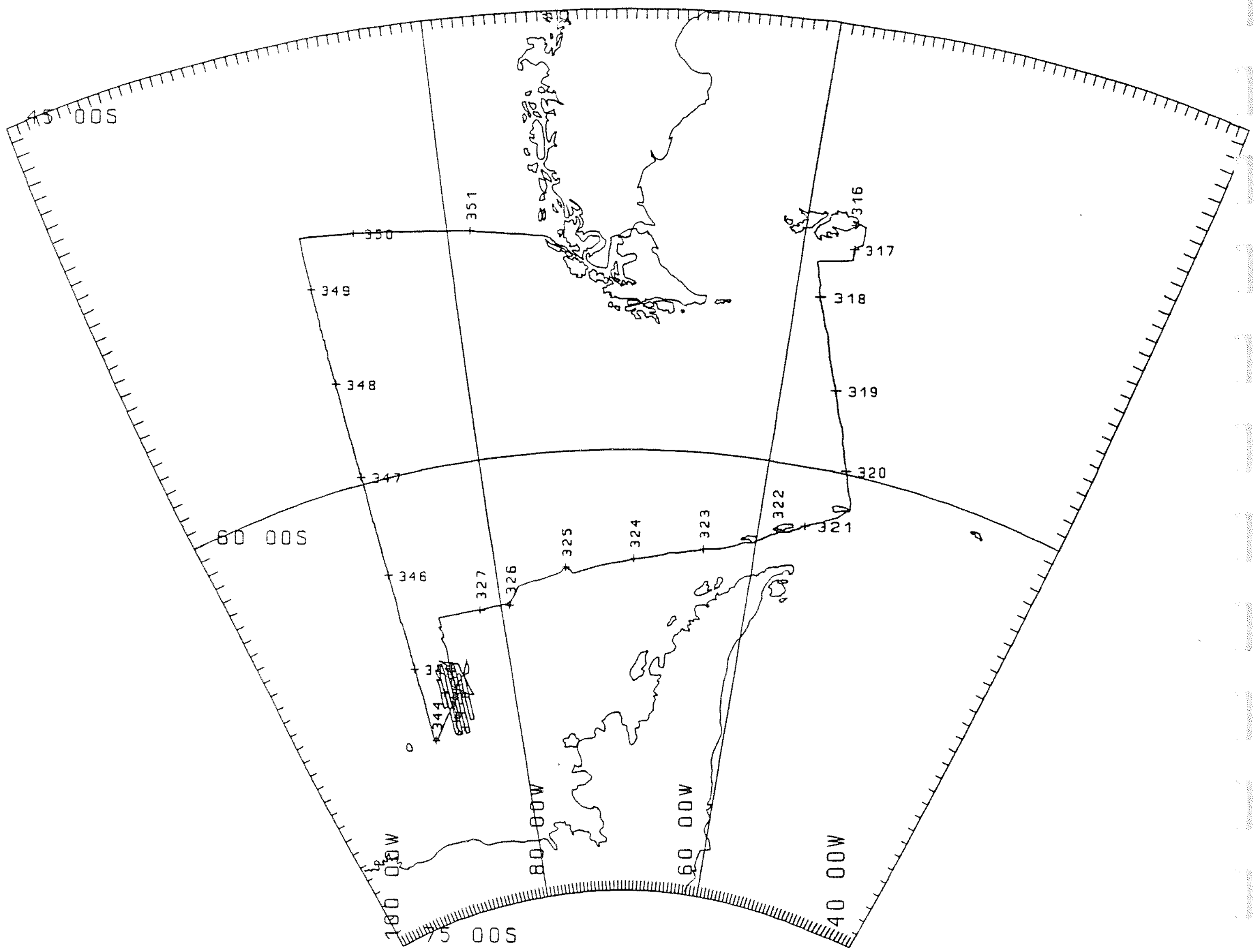
TABLE 2

shalctd.cal

:calibration file for shallow ctd
:this version for Di198 rvs ss_light ctd

press	.01	-0.824	2.496522	0.	0.
temp	.0005	.00274	.9996194	0.	0.
cond	.001	0.	1.	0.	0.
:fluor rubbish cal as yet					
fluor	.001	-3.7	4.14	0.	0.
:oxygen cals applied later, equivalent to					
oxyc	.001	0.	1.472	0.	0.
oxyt	.128	0.	1.	0.	0.
oxyfrac	-.036	0.0003965	1.	0.	0.
oxygen	.0	0.	0.	0.	0.
deltat	.35	0.	0.	0.	0.
fvolts	.002441	0.	1.	0.	0.

FIGURES



Sterna 92 Discovery Cruise 198 Nov/Dec 1992

Fig. 1

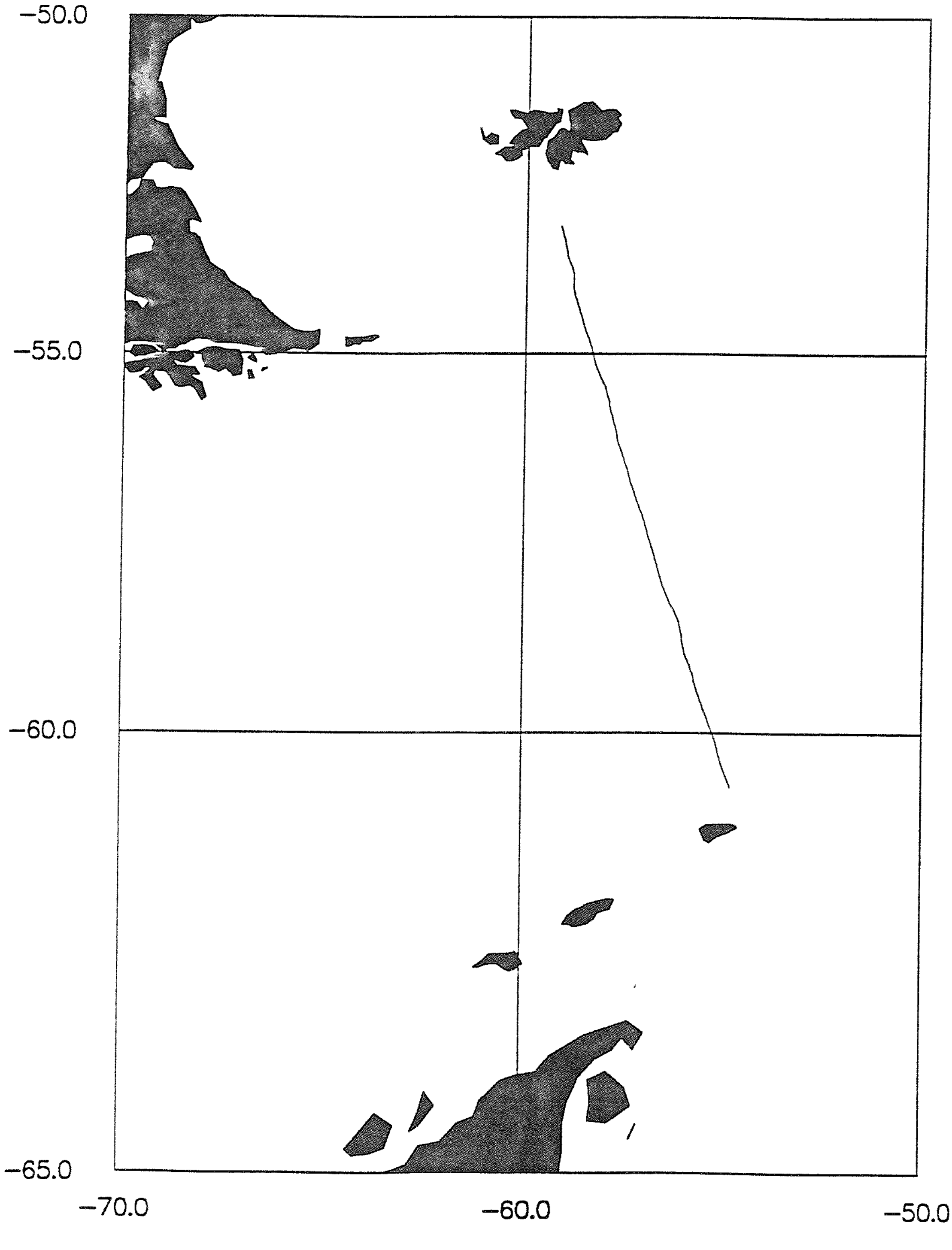


Fig. 2 SeaSoar track across Drake Passage

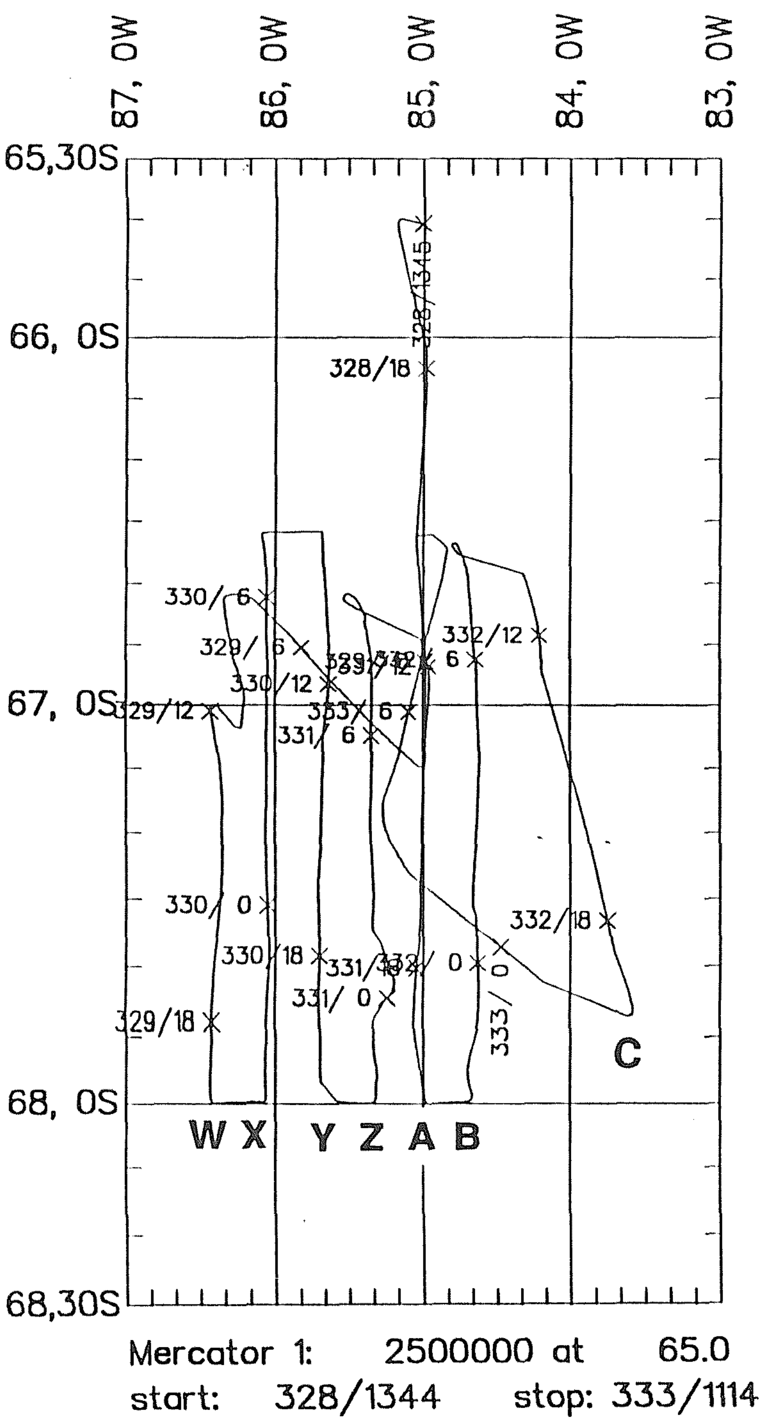


Fig. 3 SeaSoar track for the first Ice Edge Survey

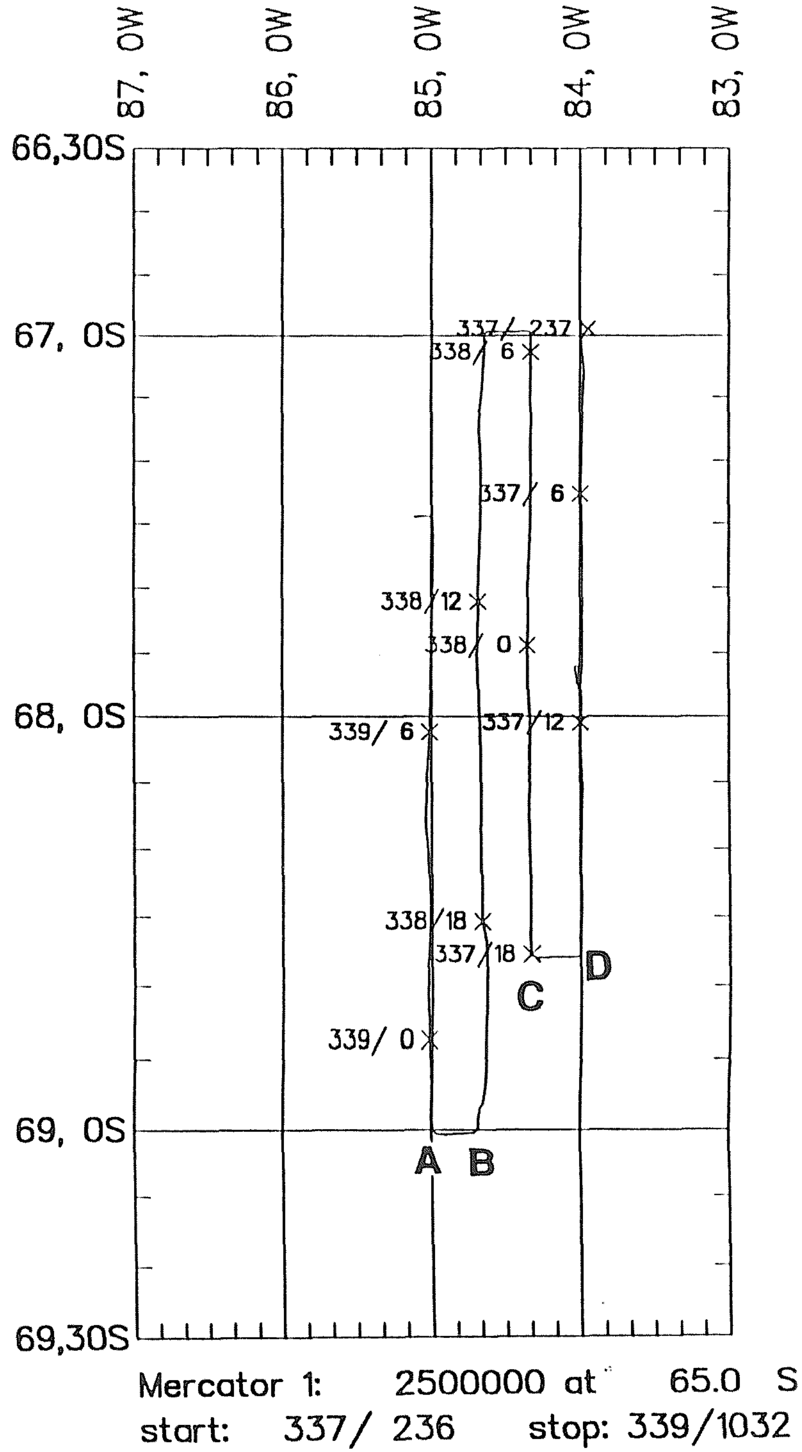


Fig. 4 Seasoar track for the second Ice Edge survey

(a)

(b)

(c)

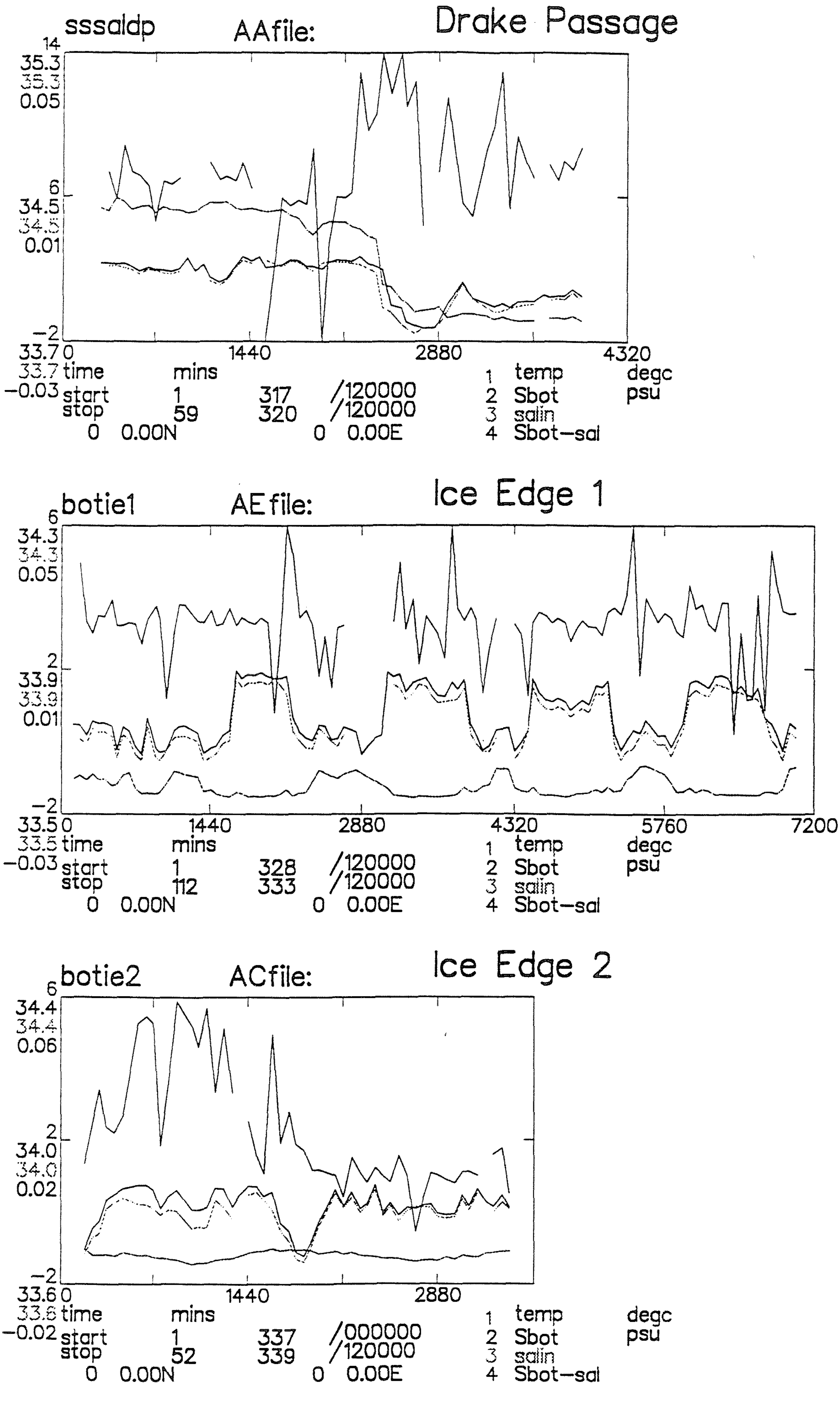


Fig. 5 Plots against time of hourly salinity samples (Sbot), corresponding SeaSoar salinity (salin) and temperature (temp) and the correction to be applied to the SeaSoar salinity to convert it to absolute (Sbot-sal) for (a) the Drake Passage Survey, (b) the first Ice Edge Survey and (c) the second Ice Edge Survey.

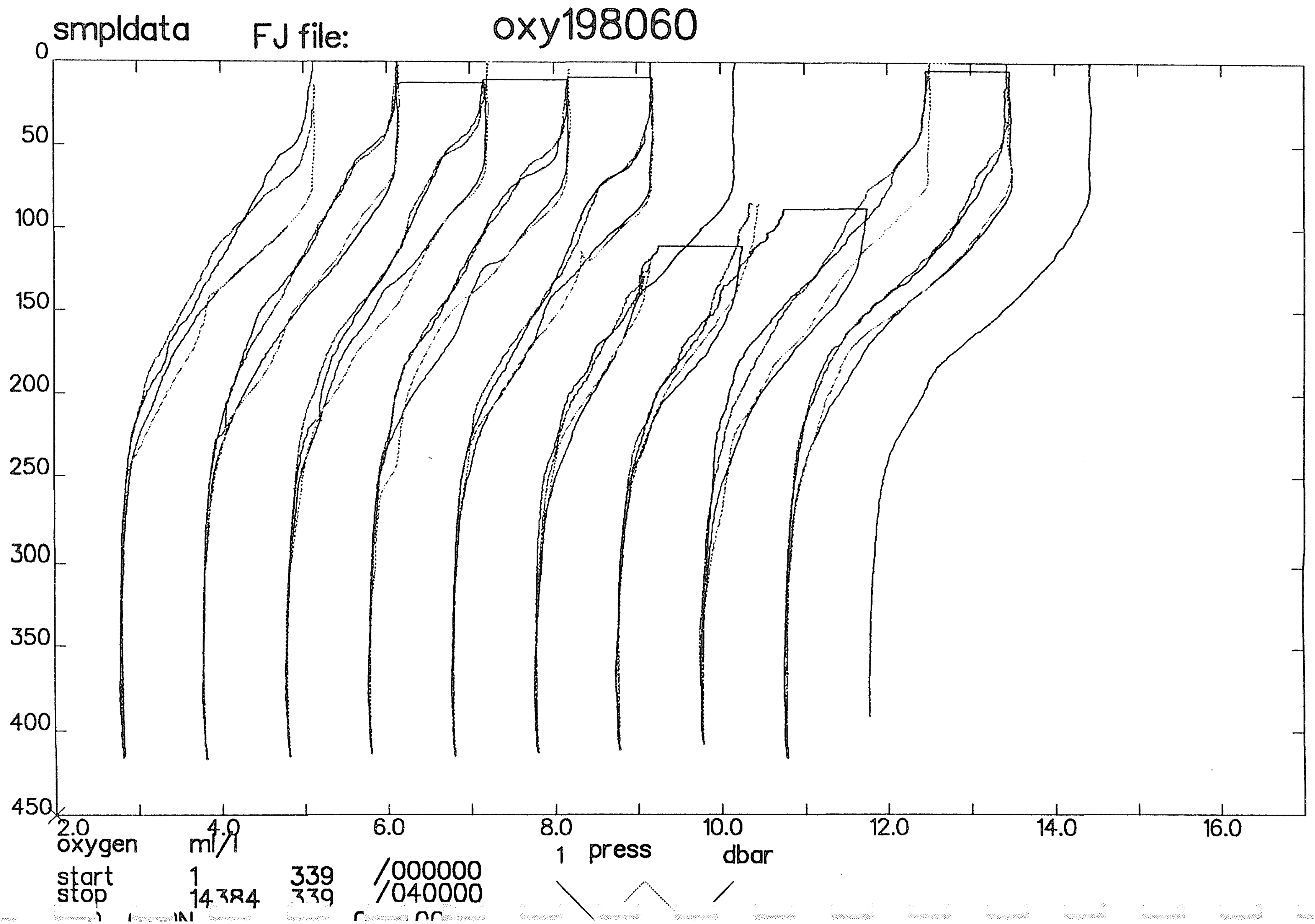


Fig. 6a Oxygen profiles before speeding up the oxygen current.

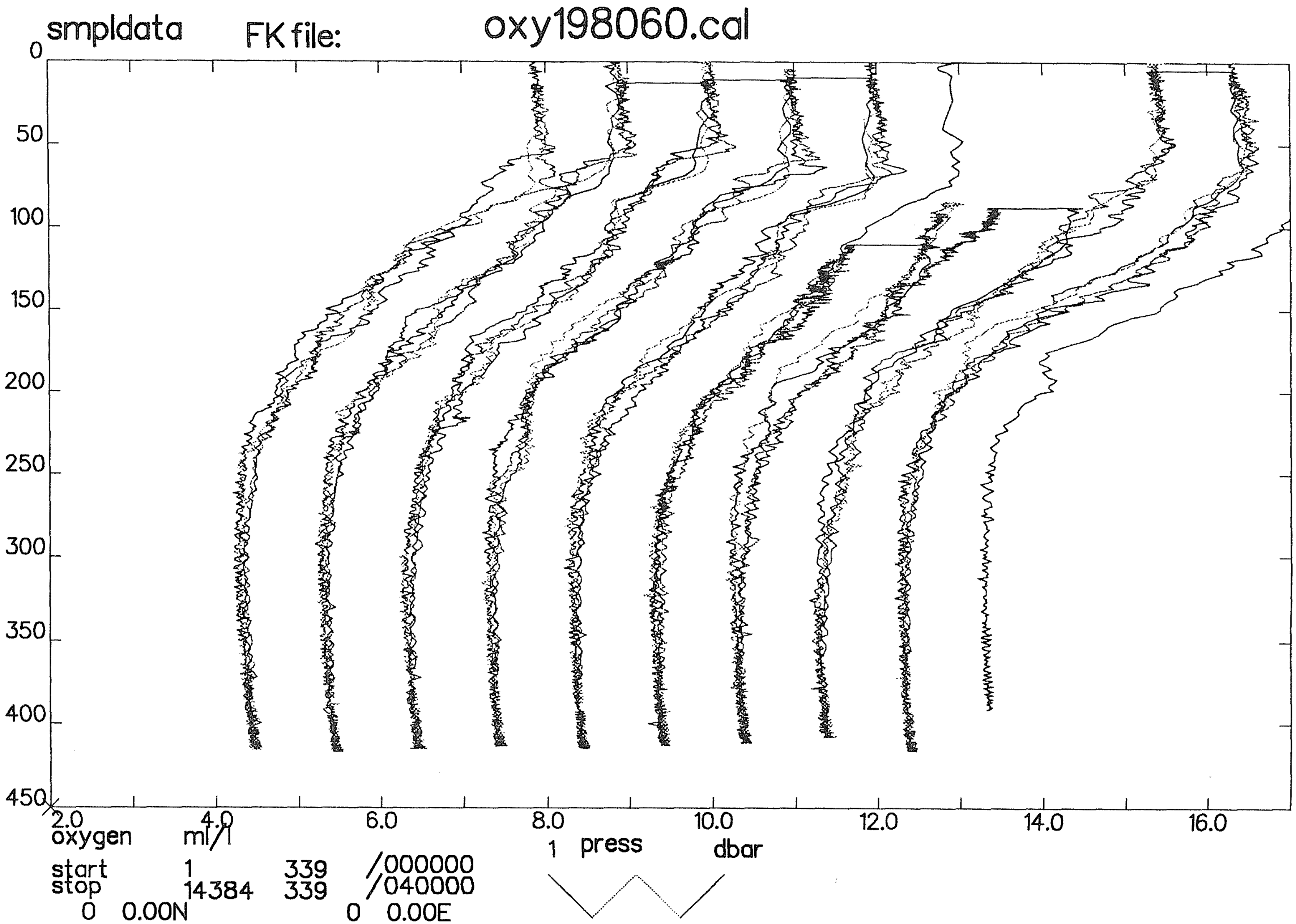
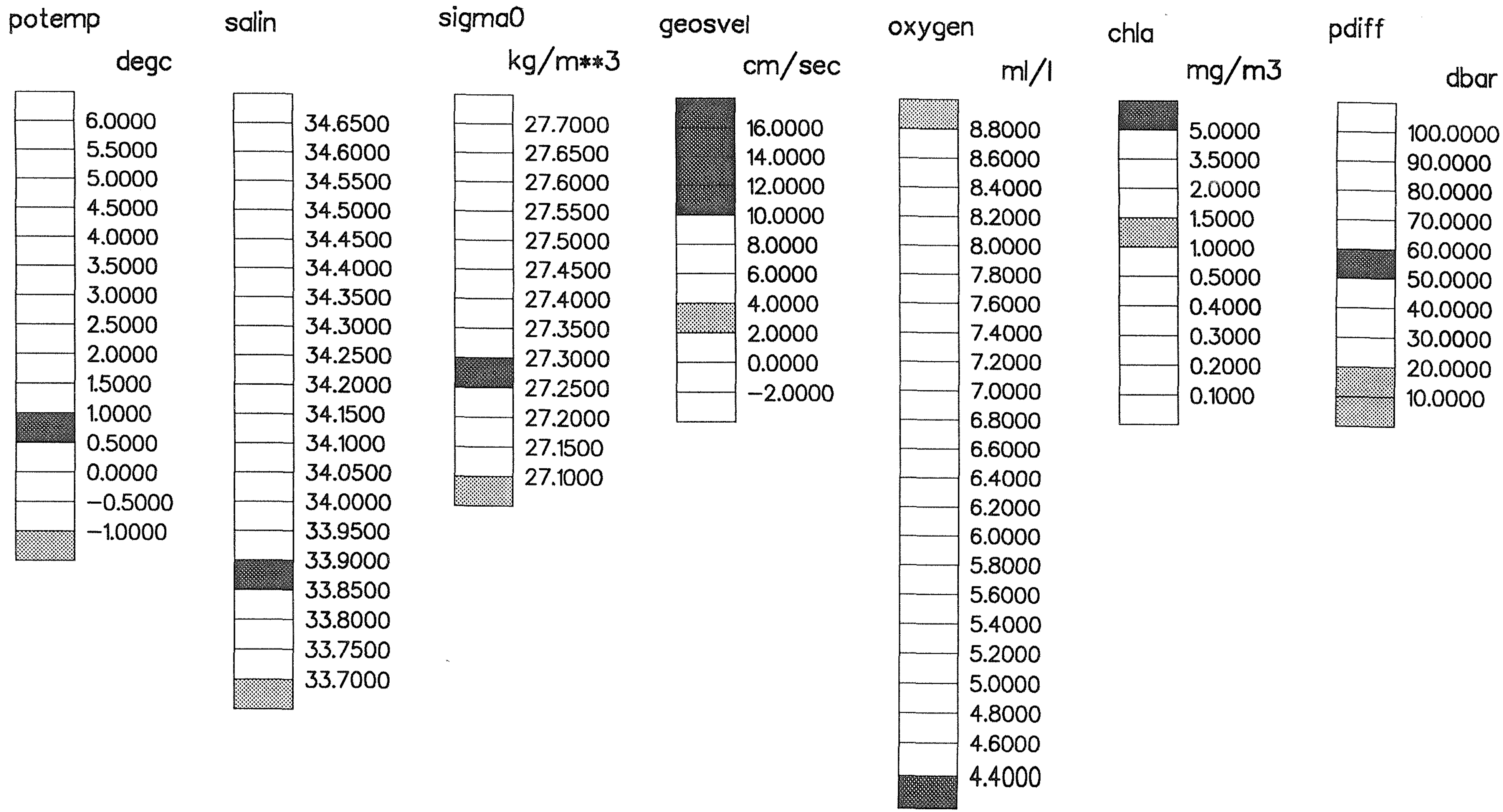


Fig. 6b Oxygen profiles after speeding up the oxygen current with a time constant of 10 seconds.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33.7000
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kg/m**3
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mg/m3
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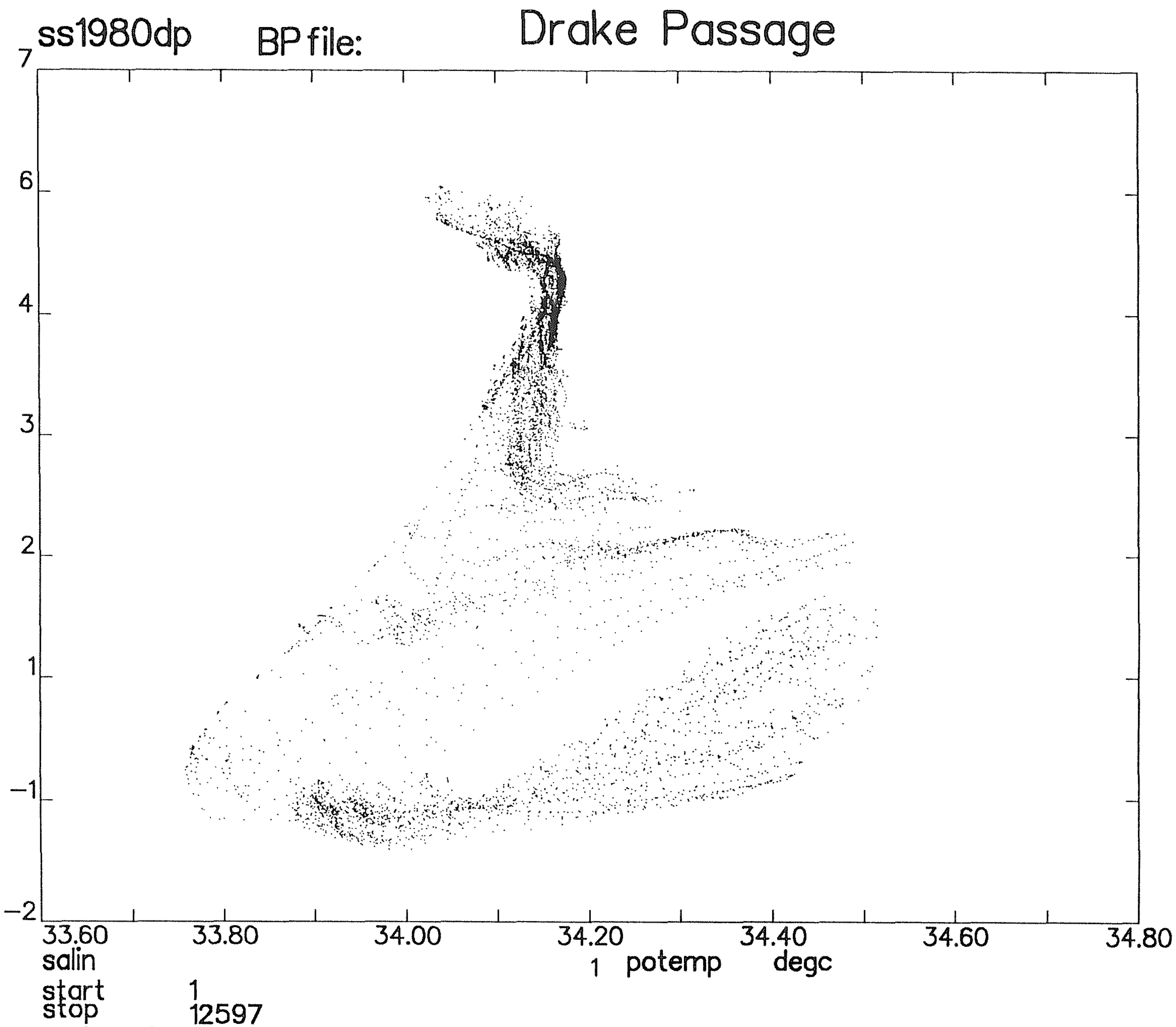

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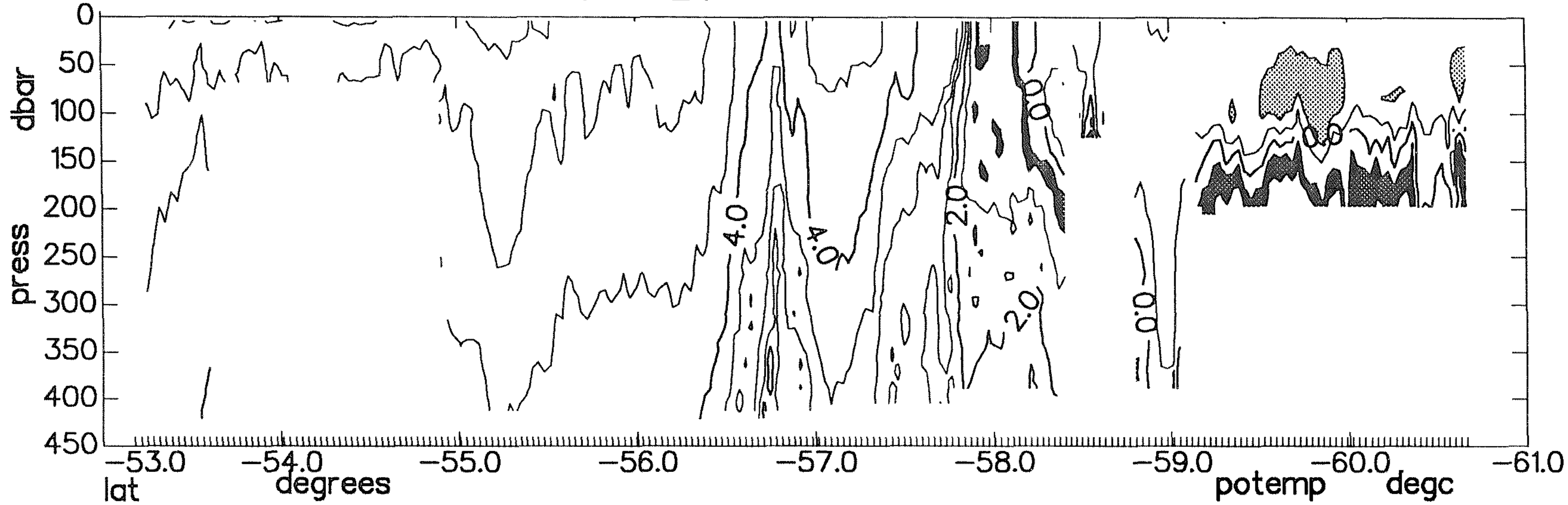

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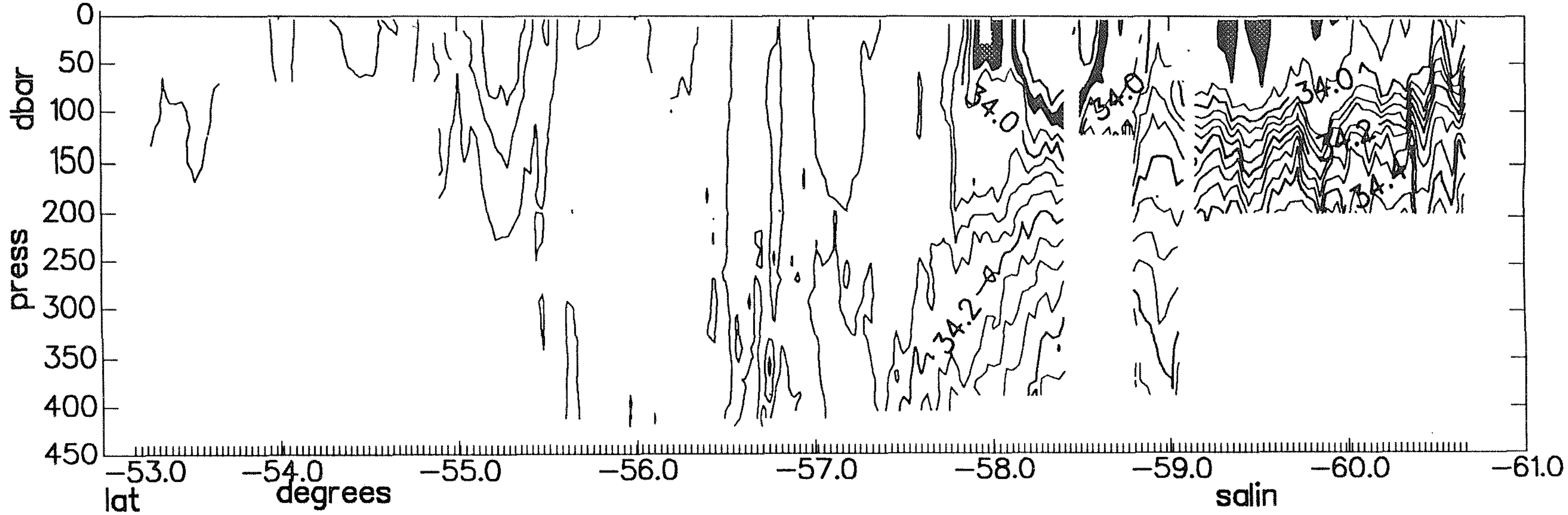

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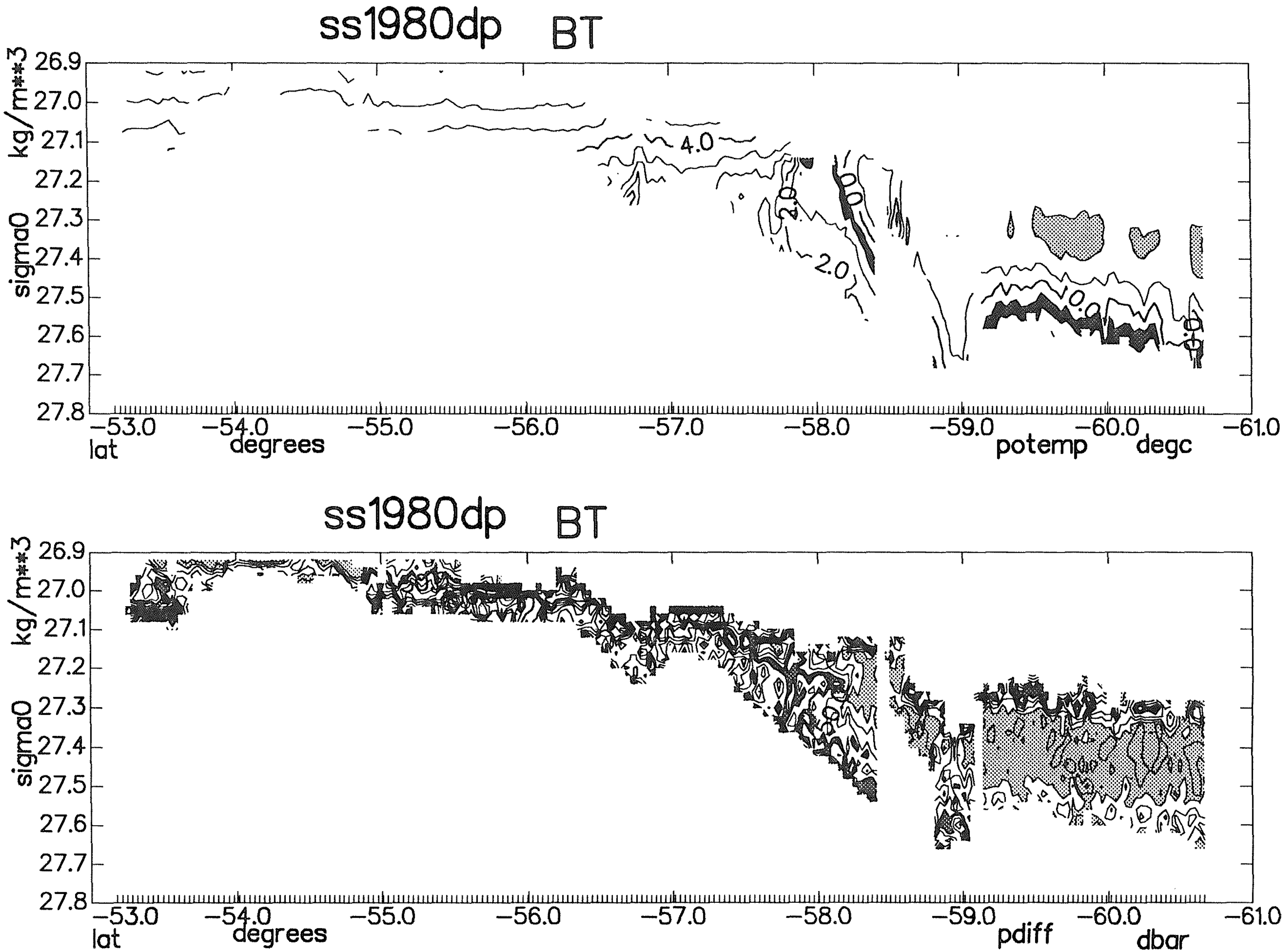

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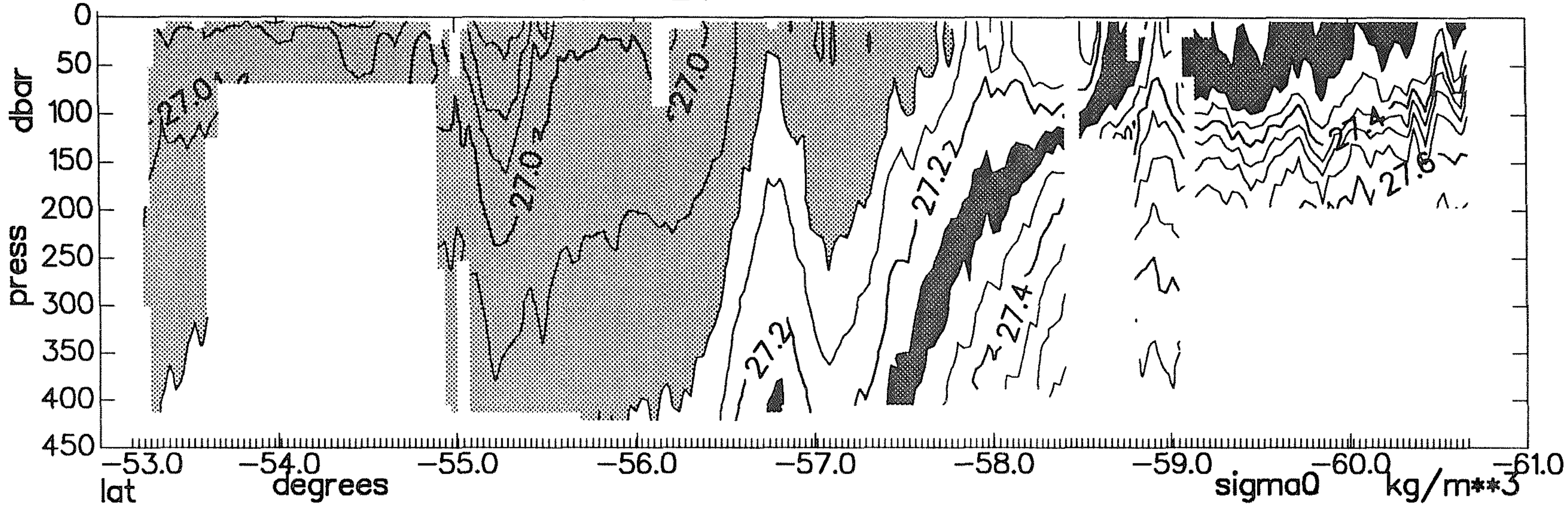

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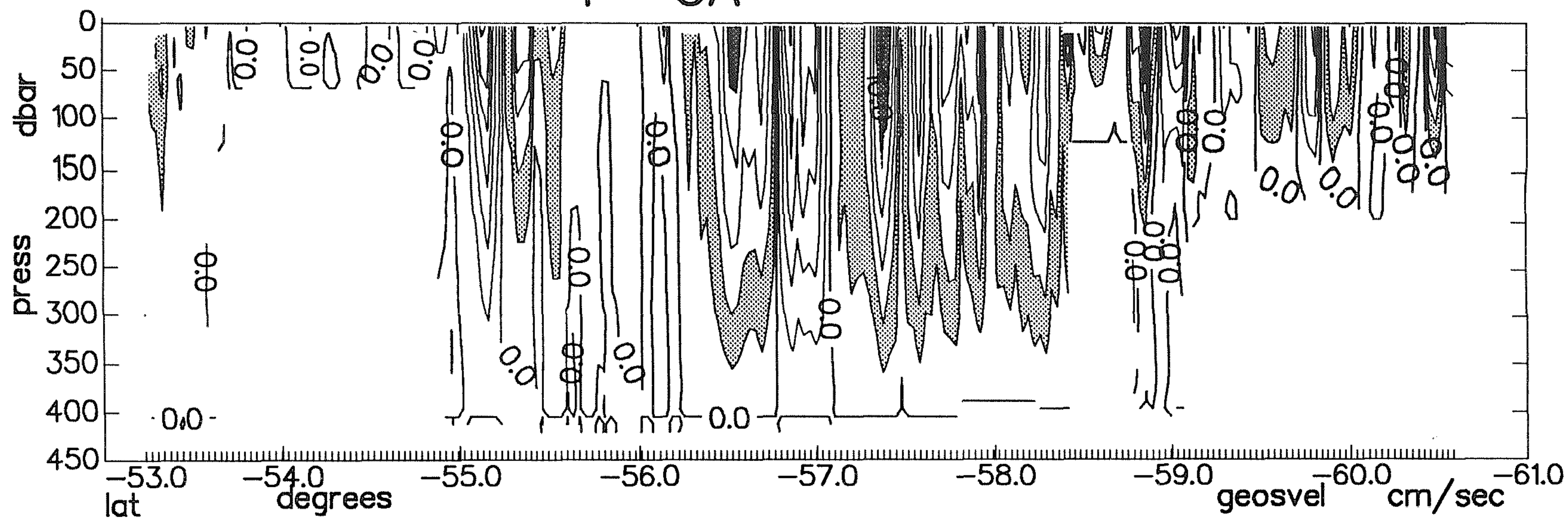

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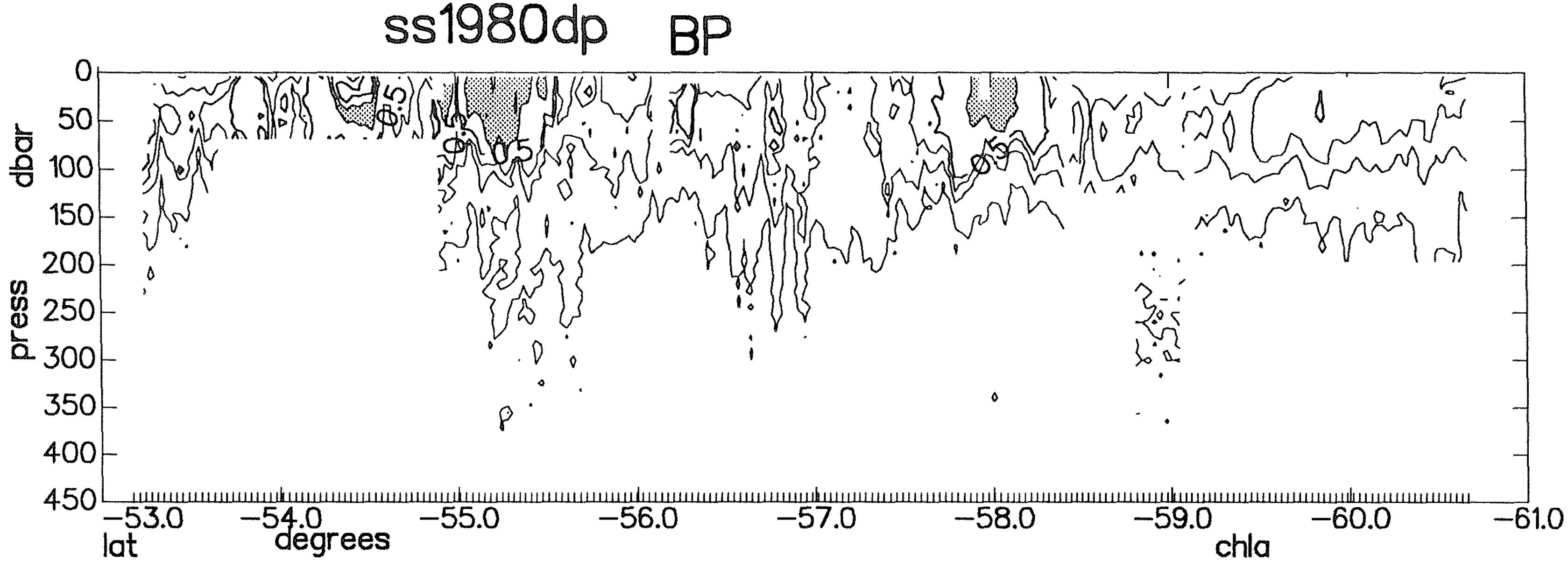

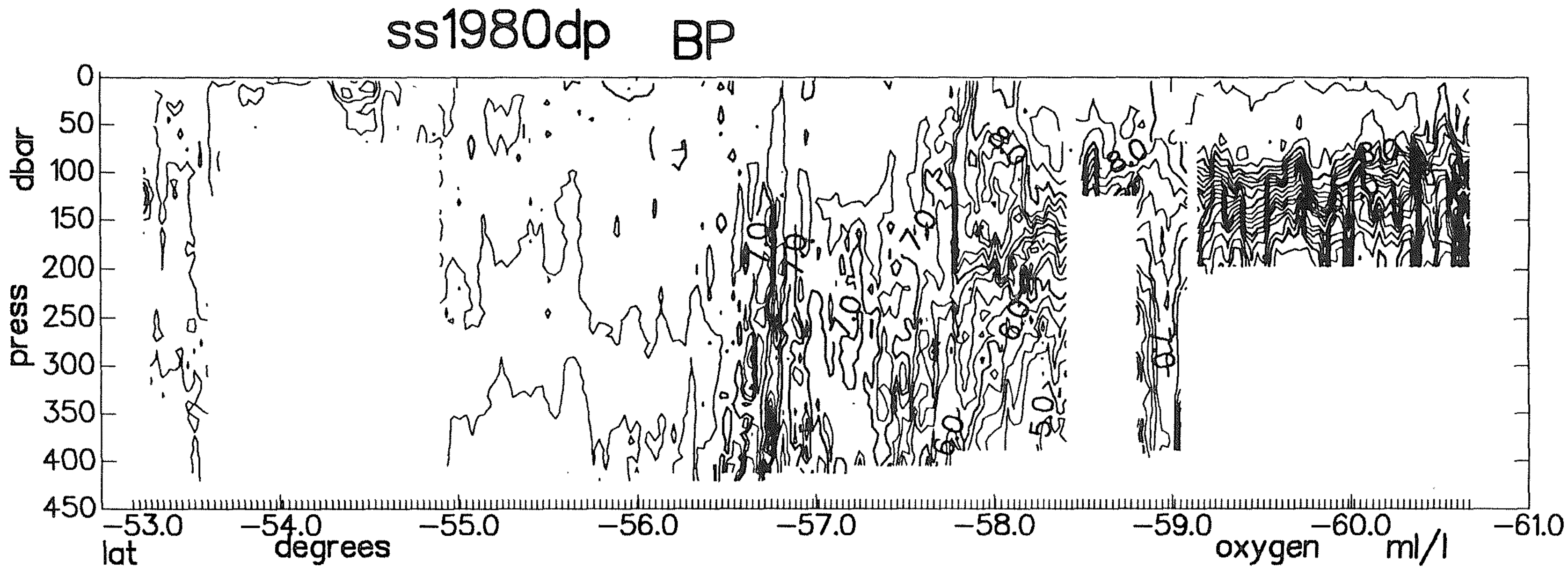

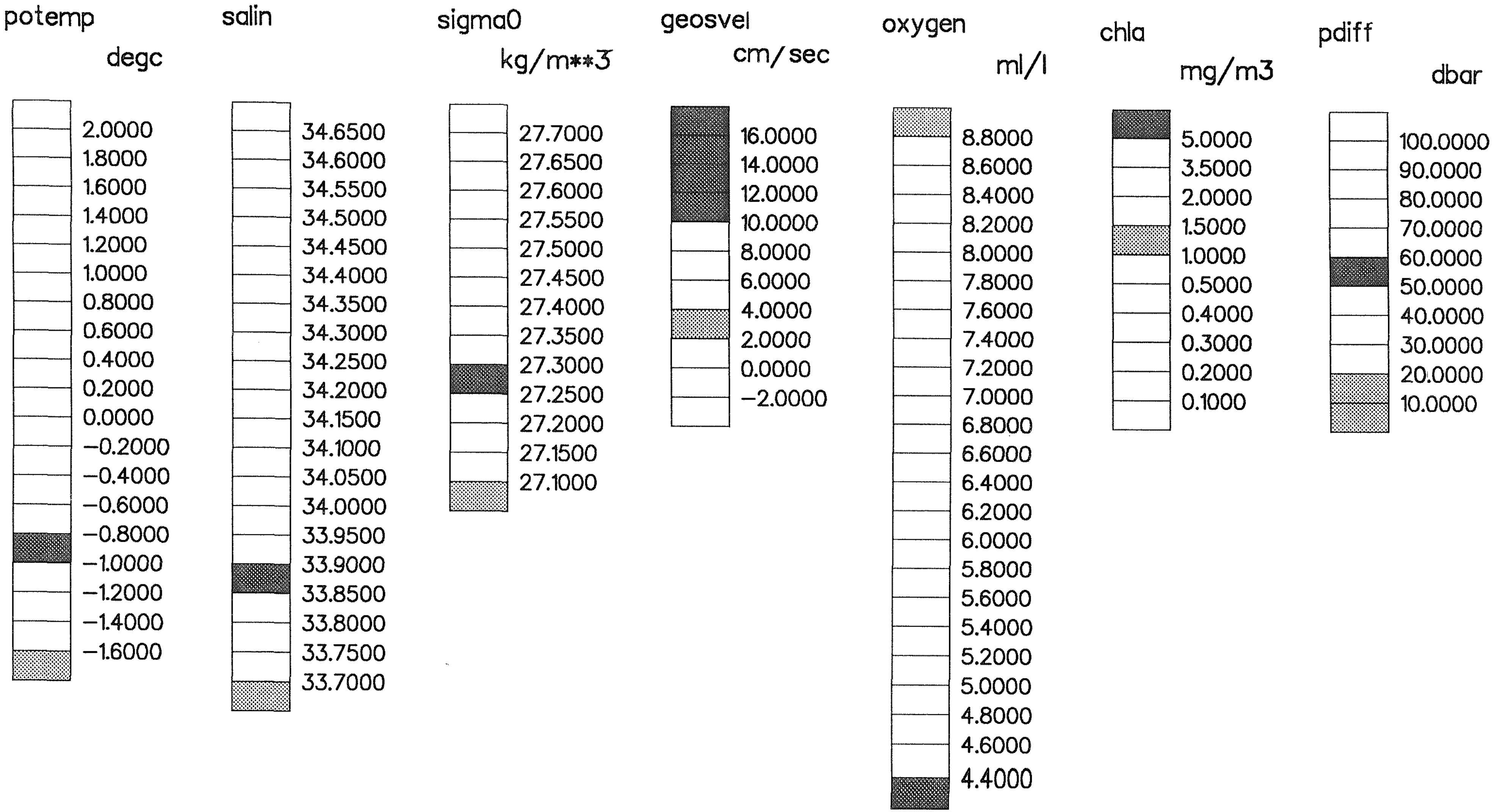

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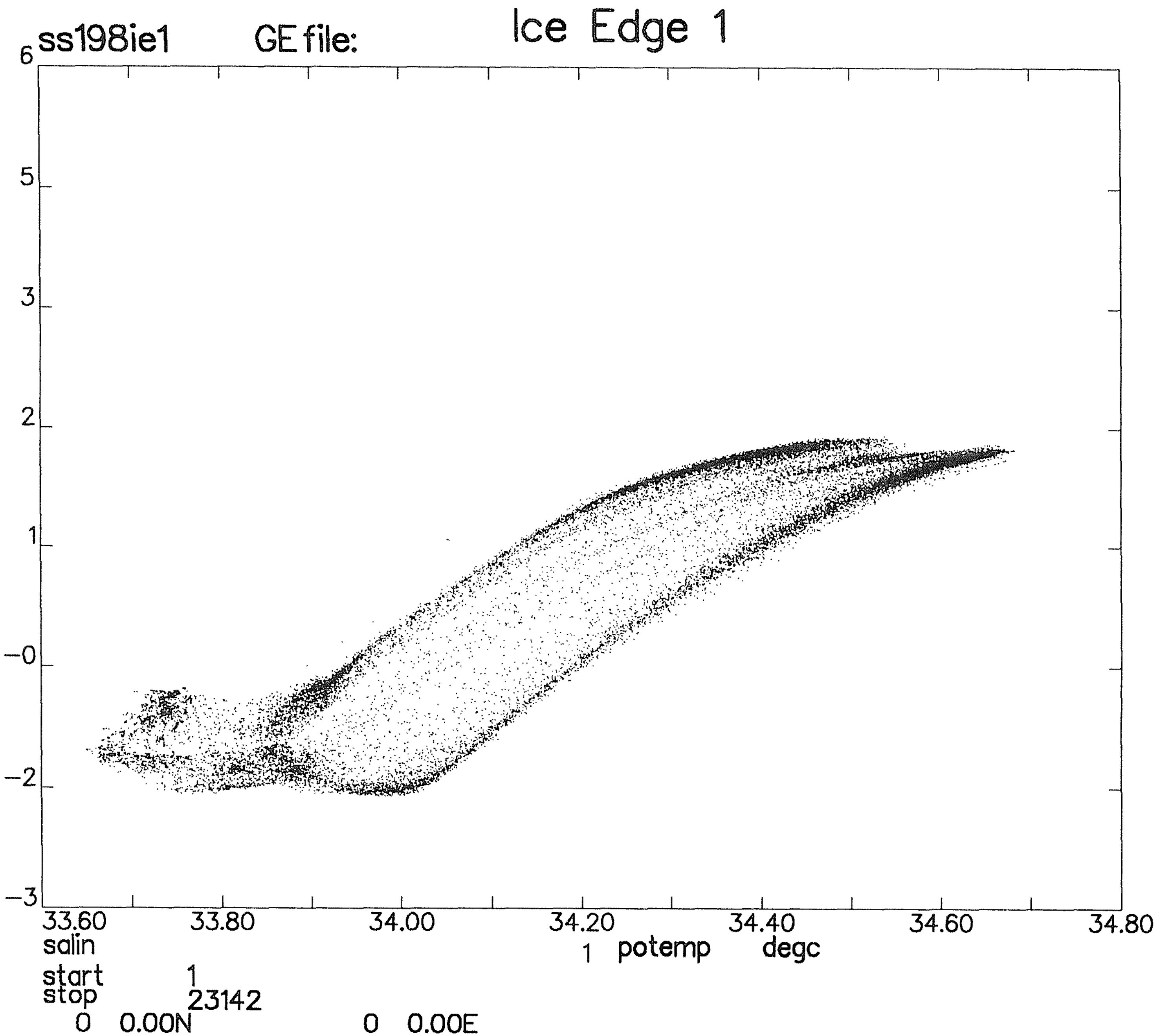
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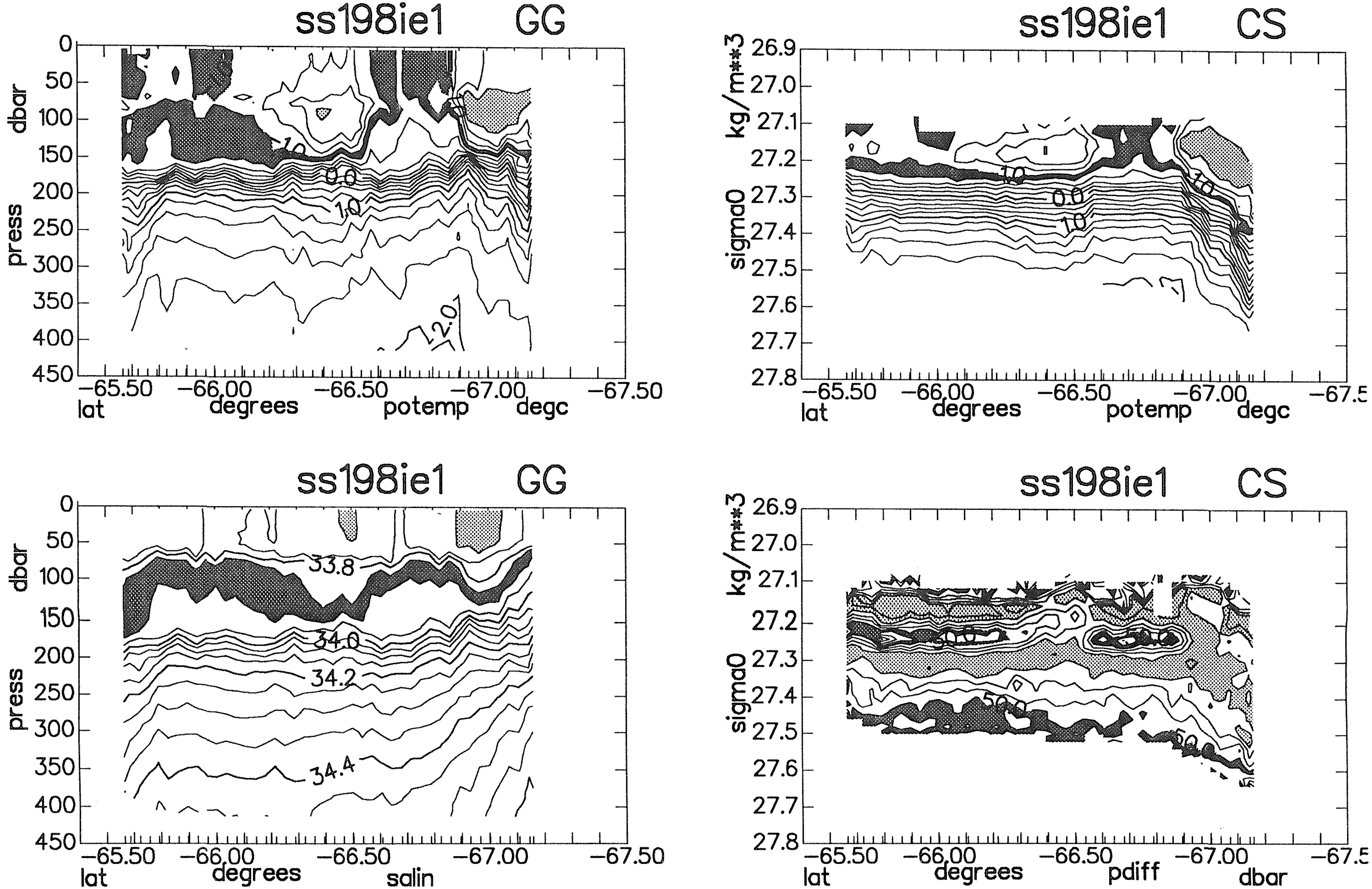
Ice Edge 1 Section An



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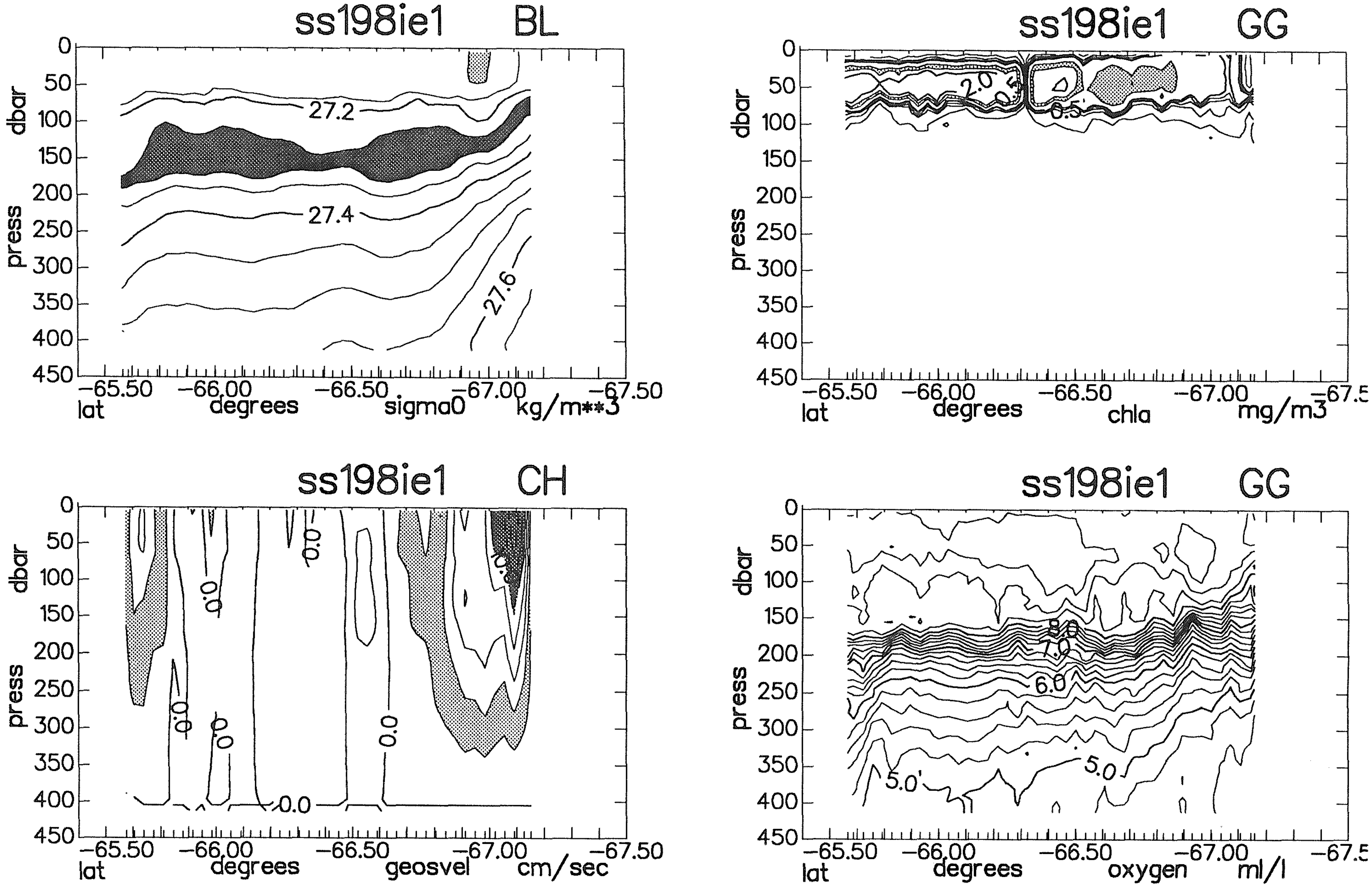

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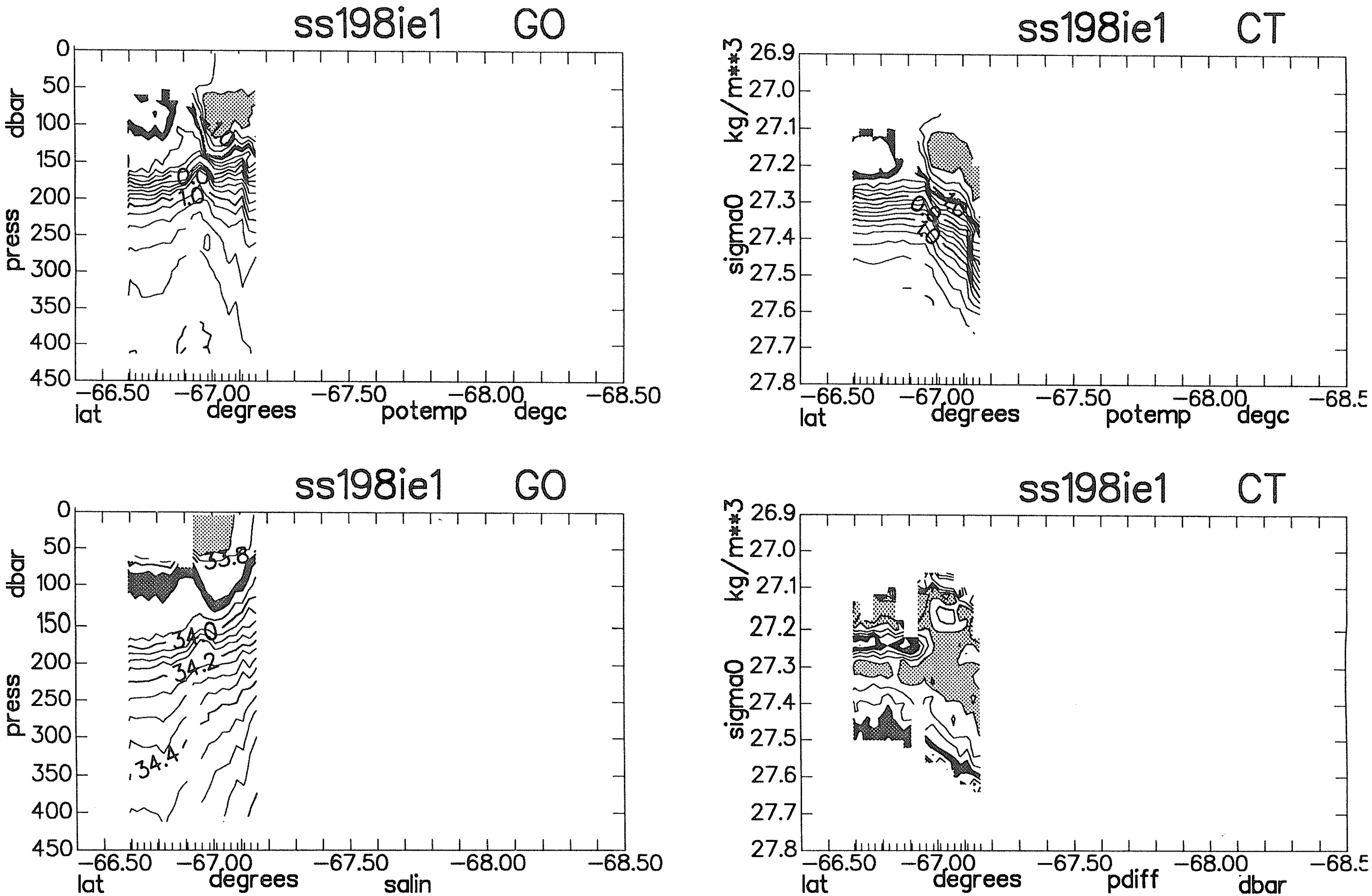

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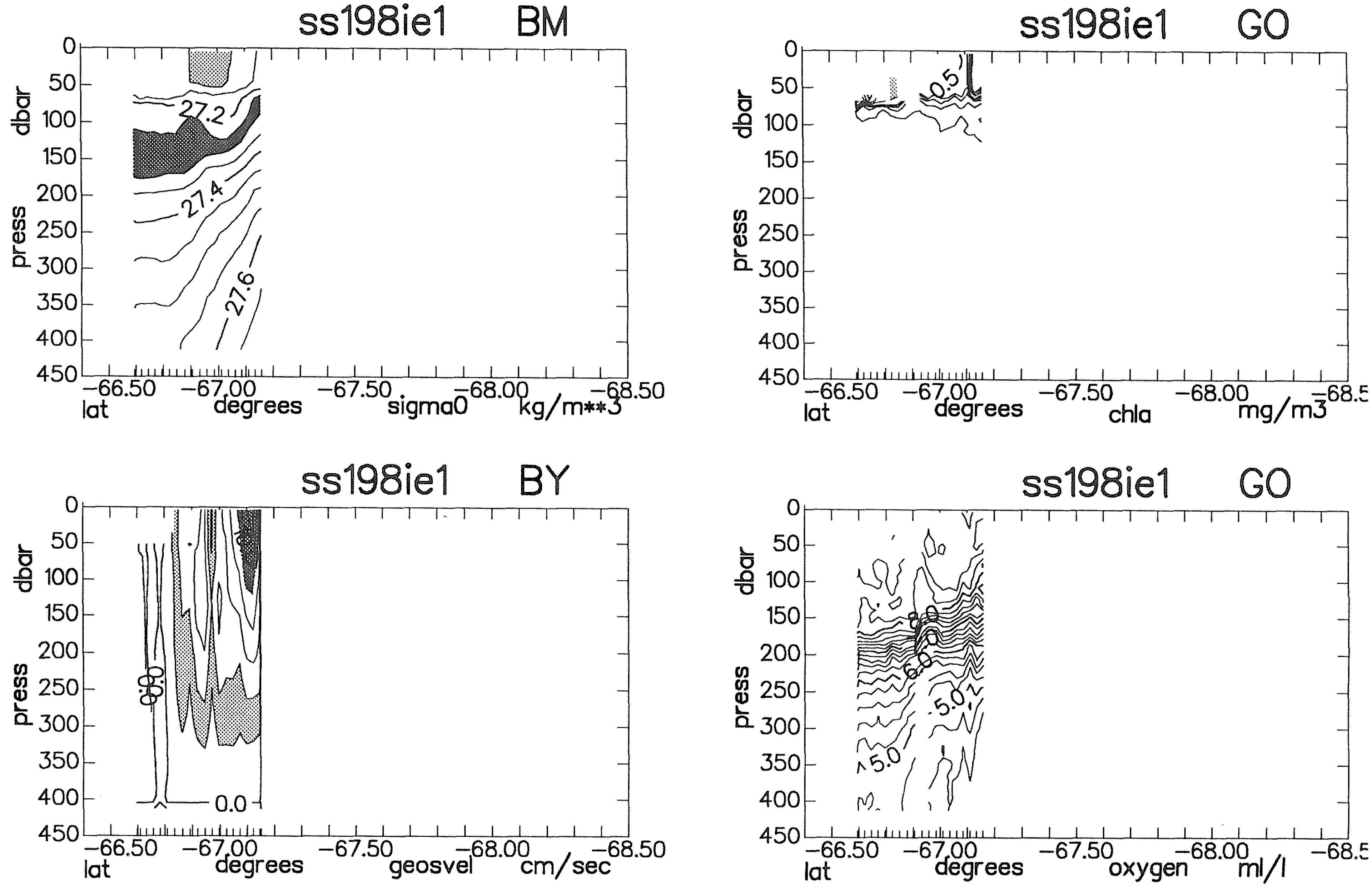

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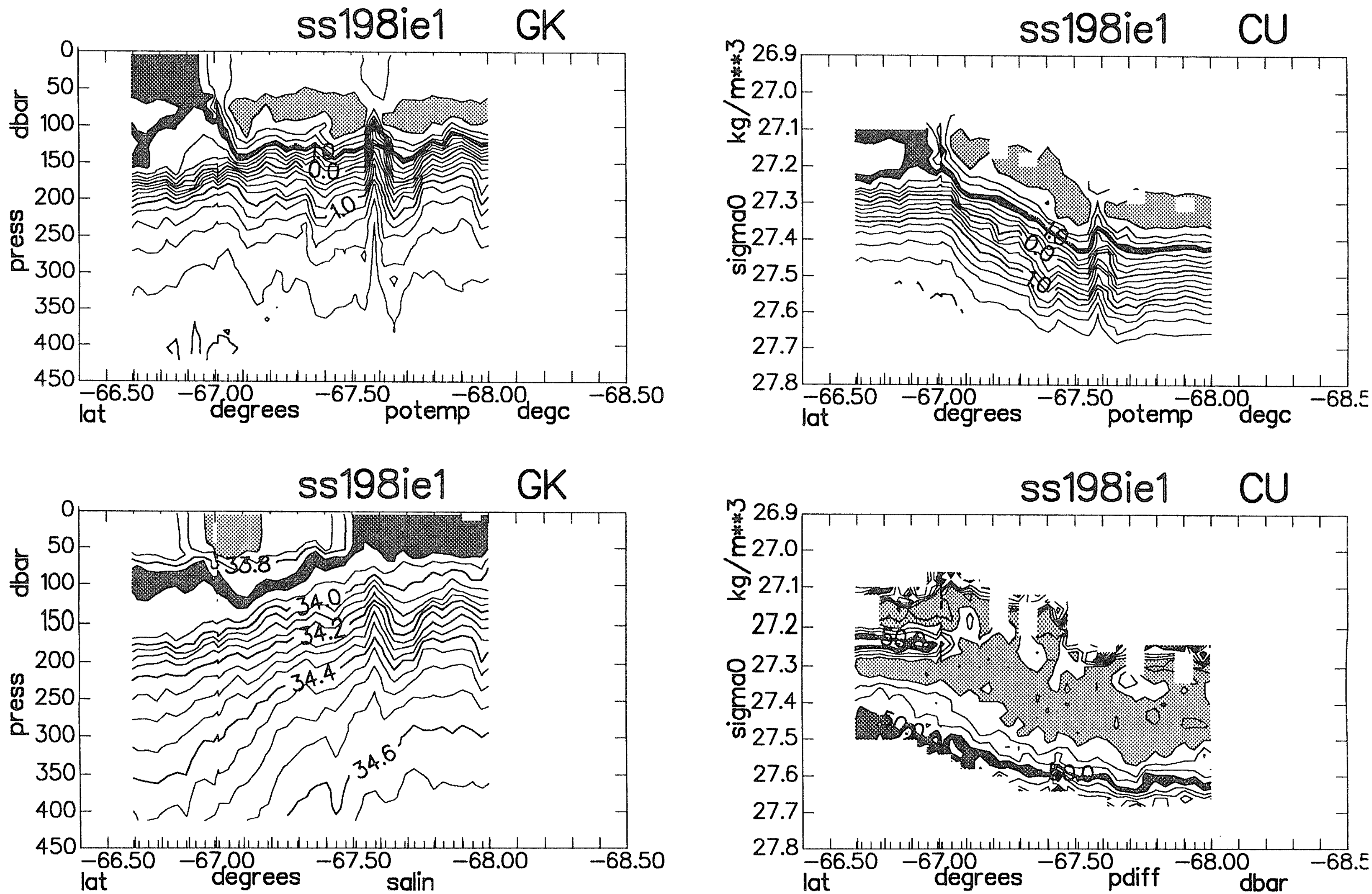

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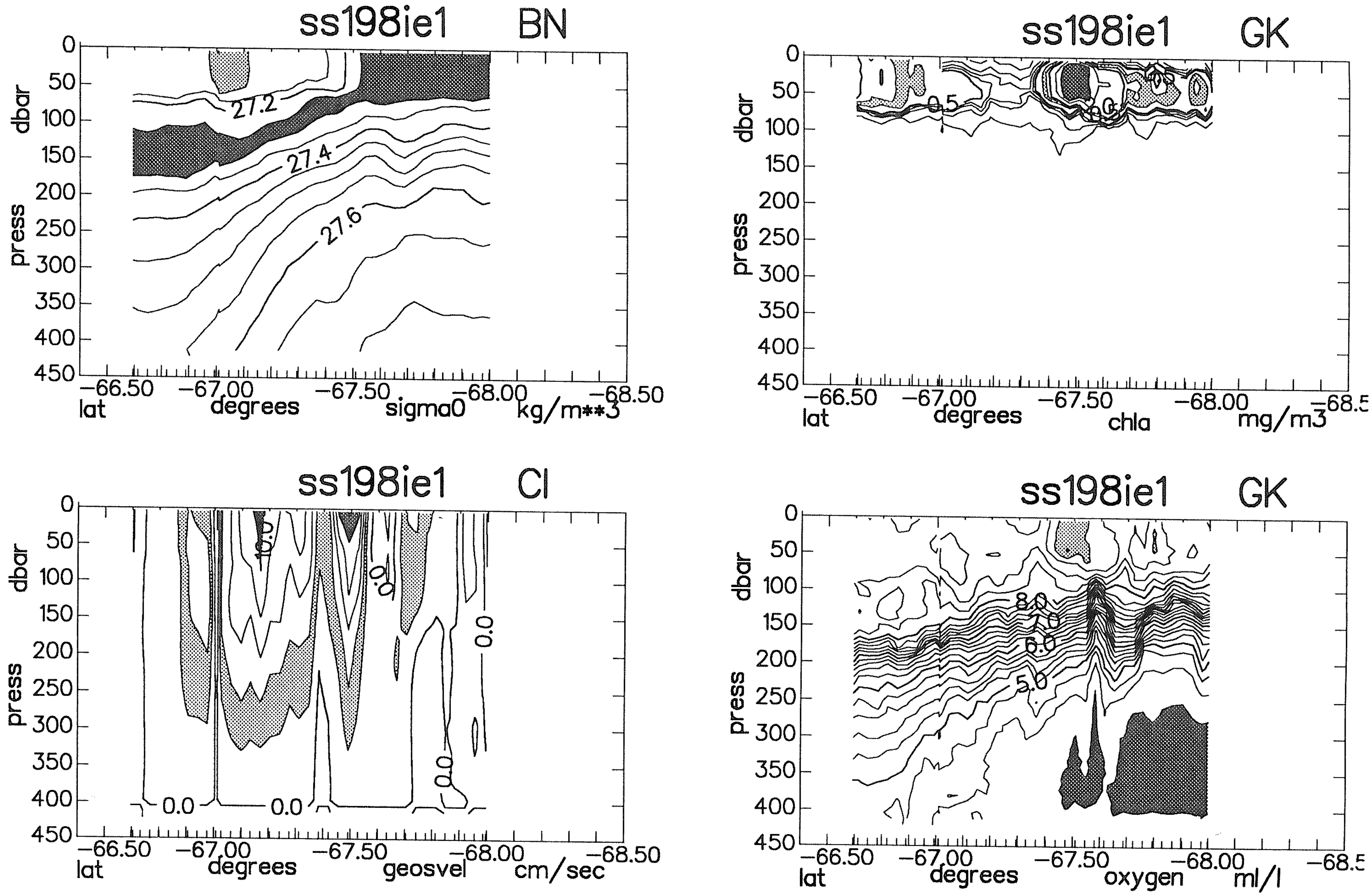

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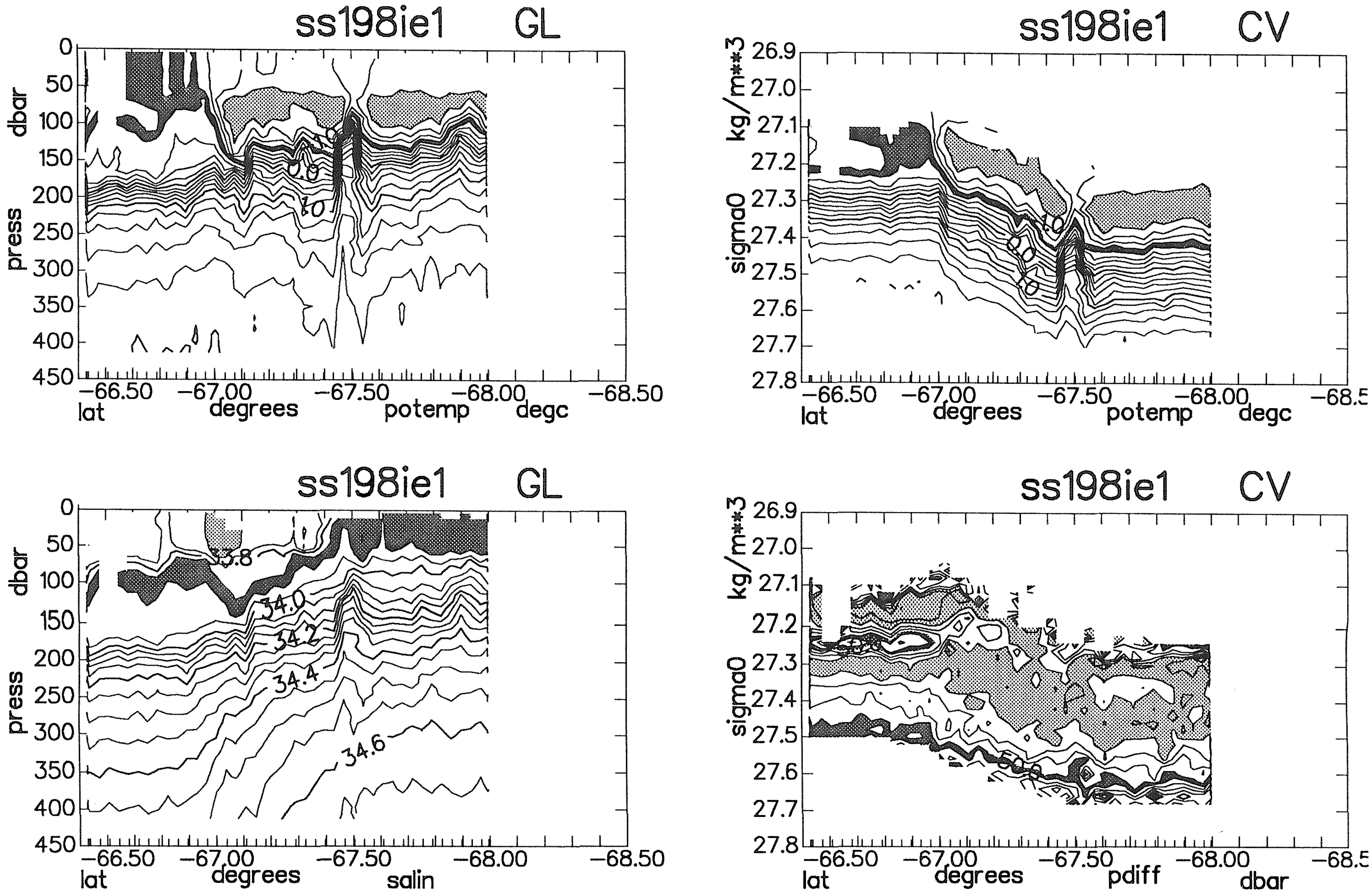

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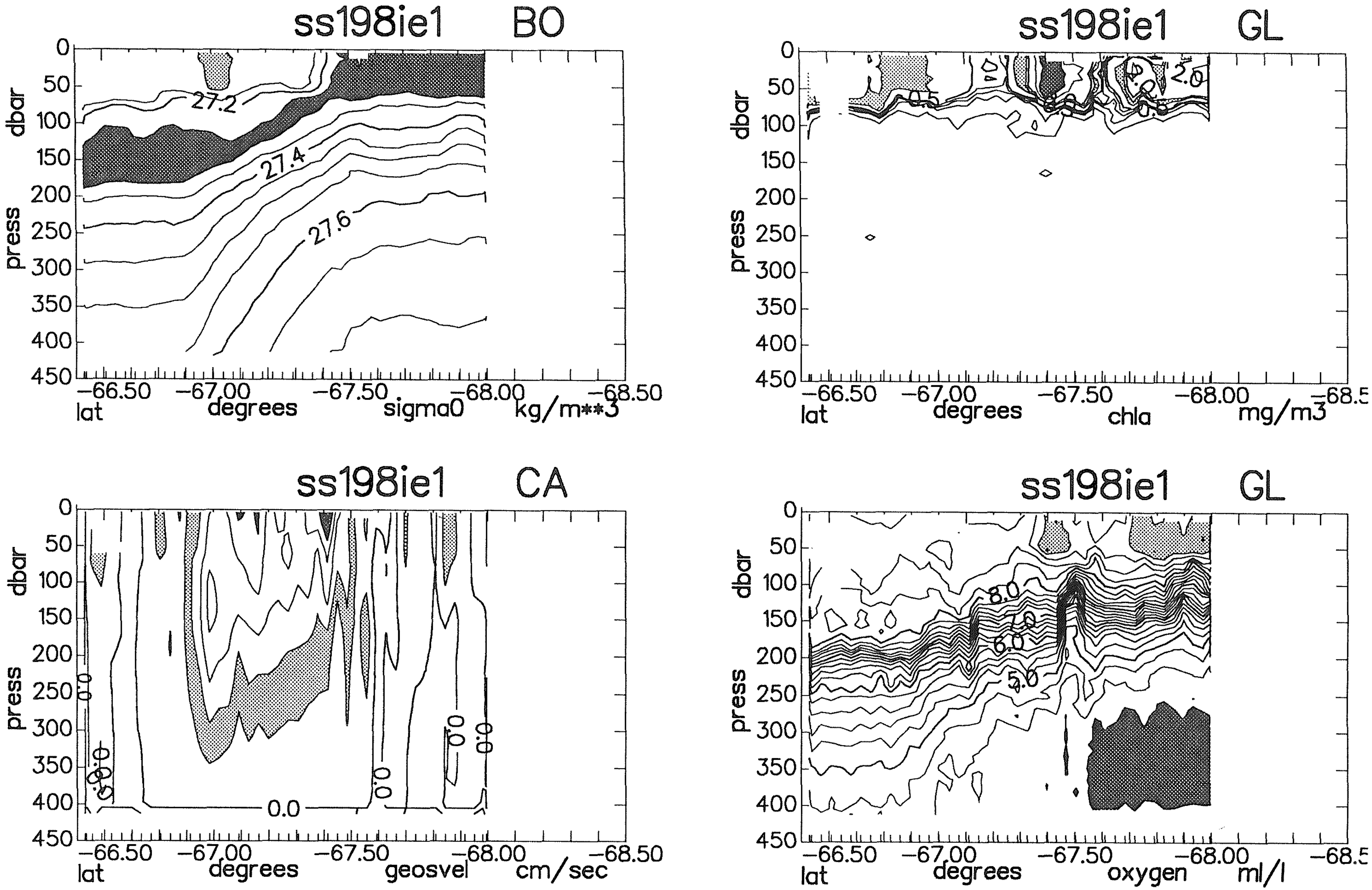

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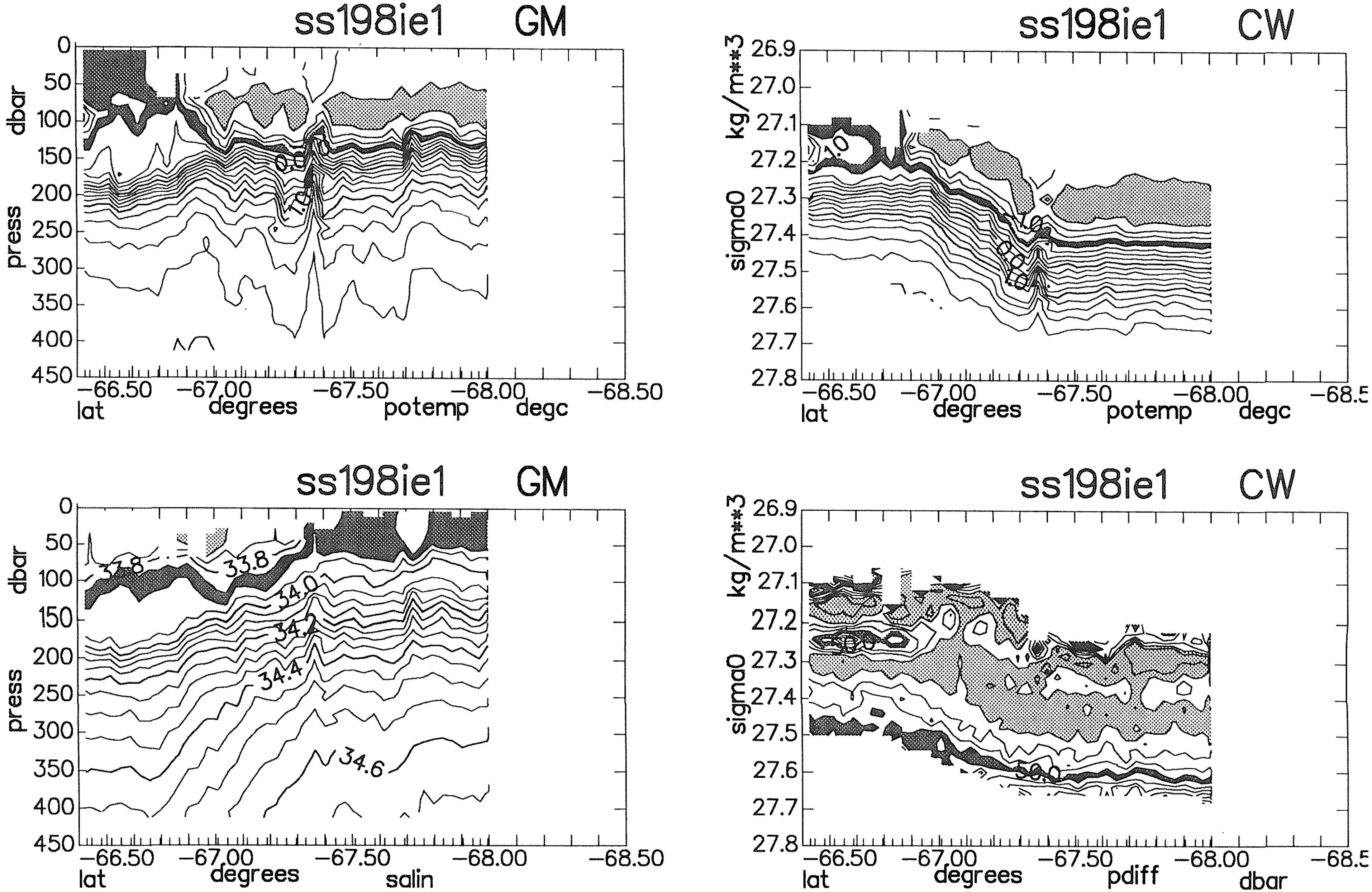

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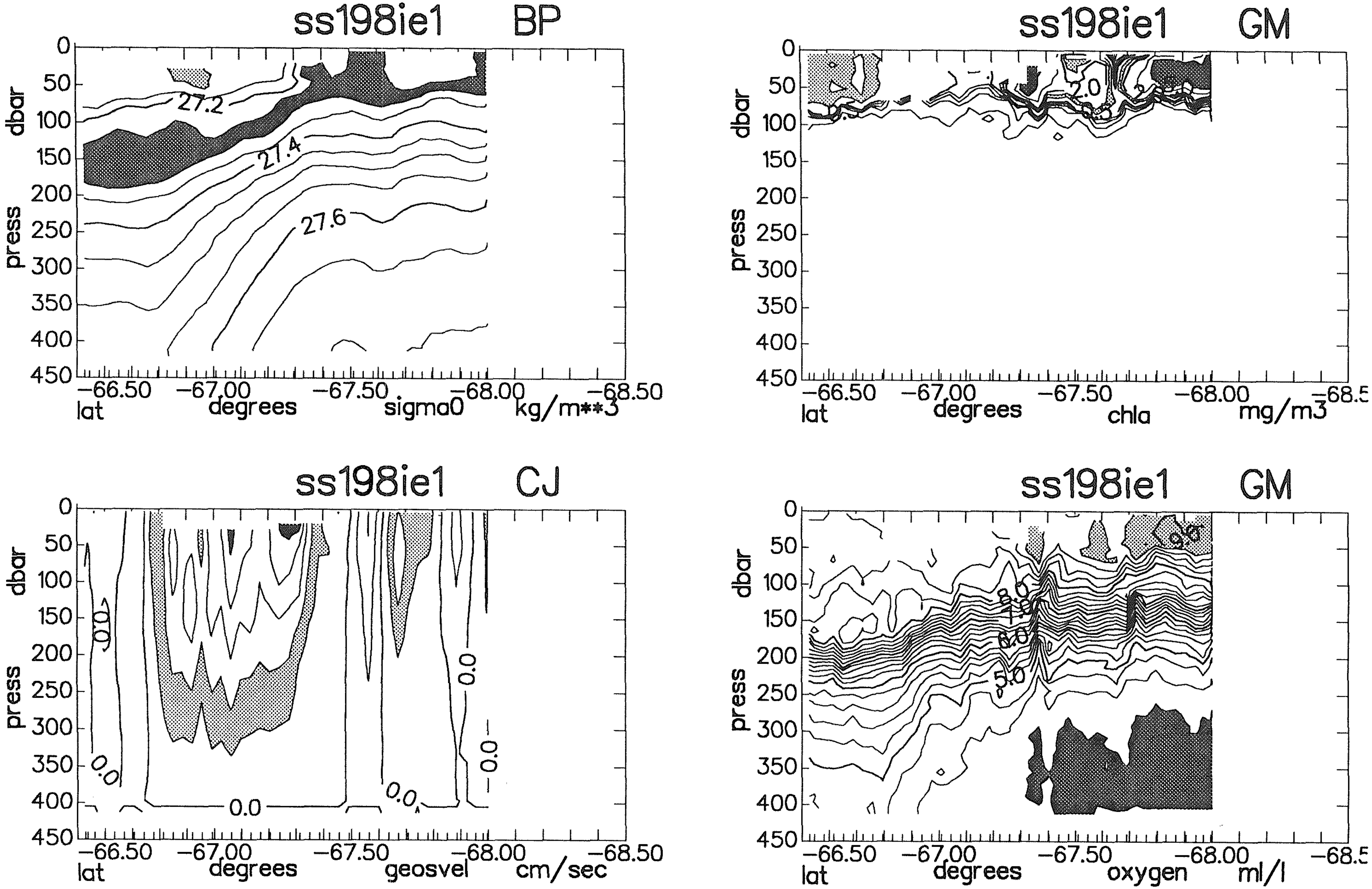

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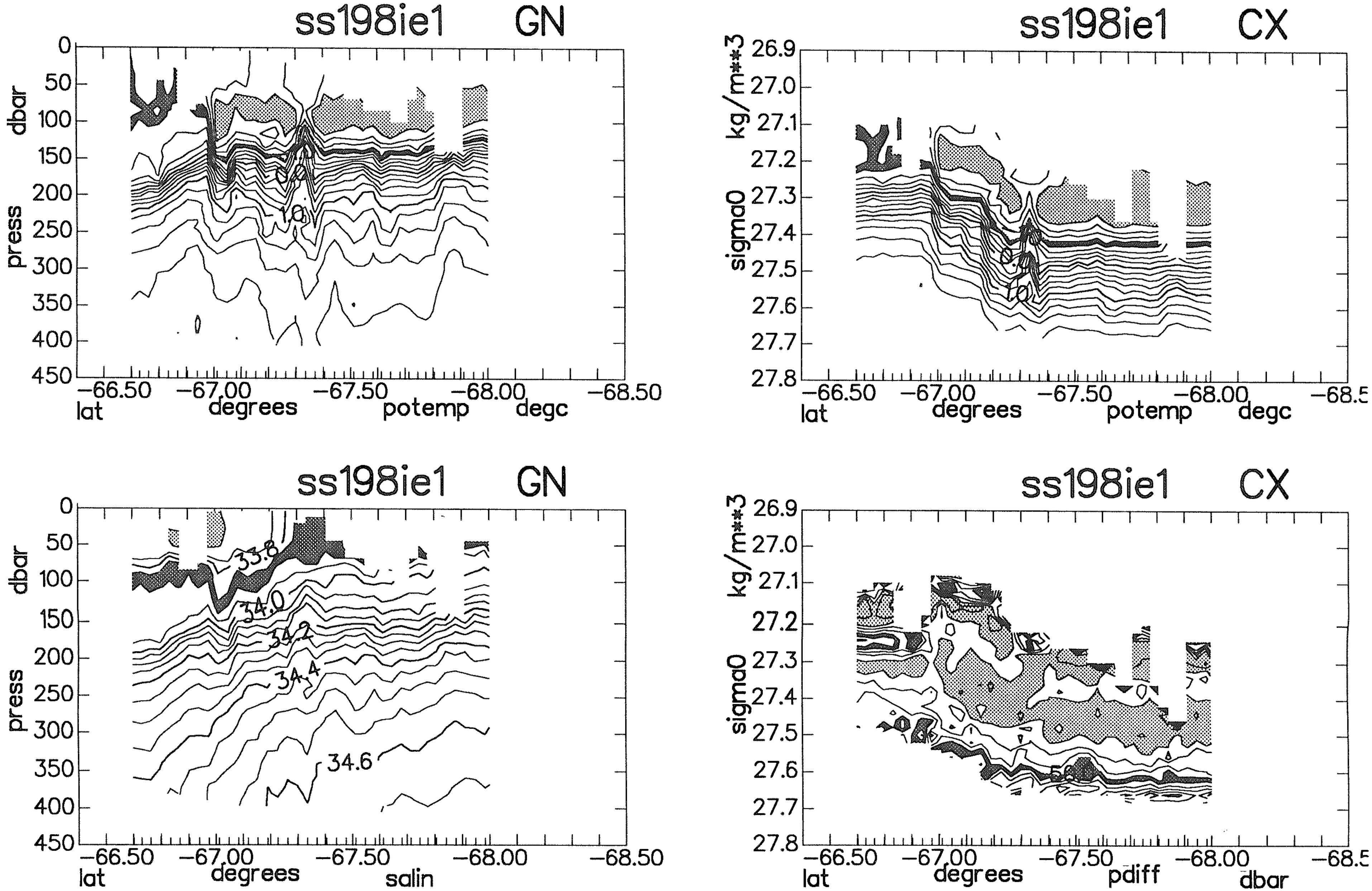

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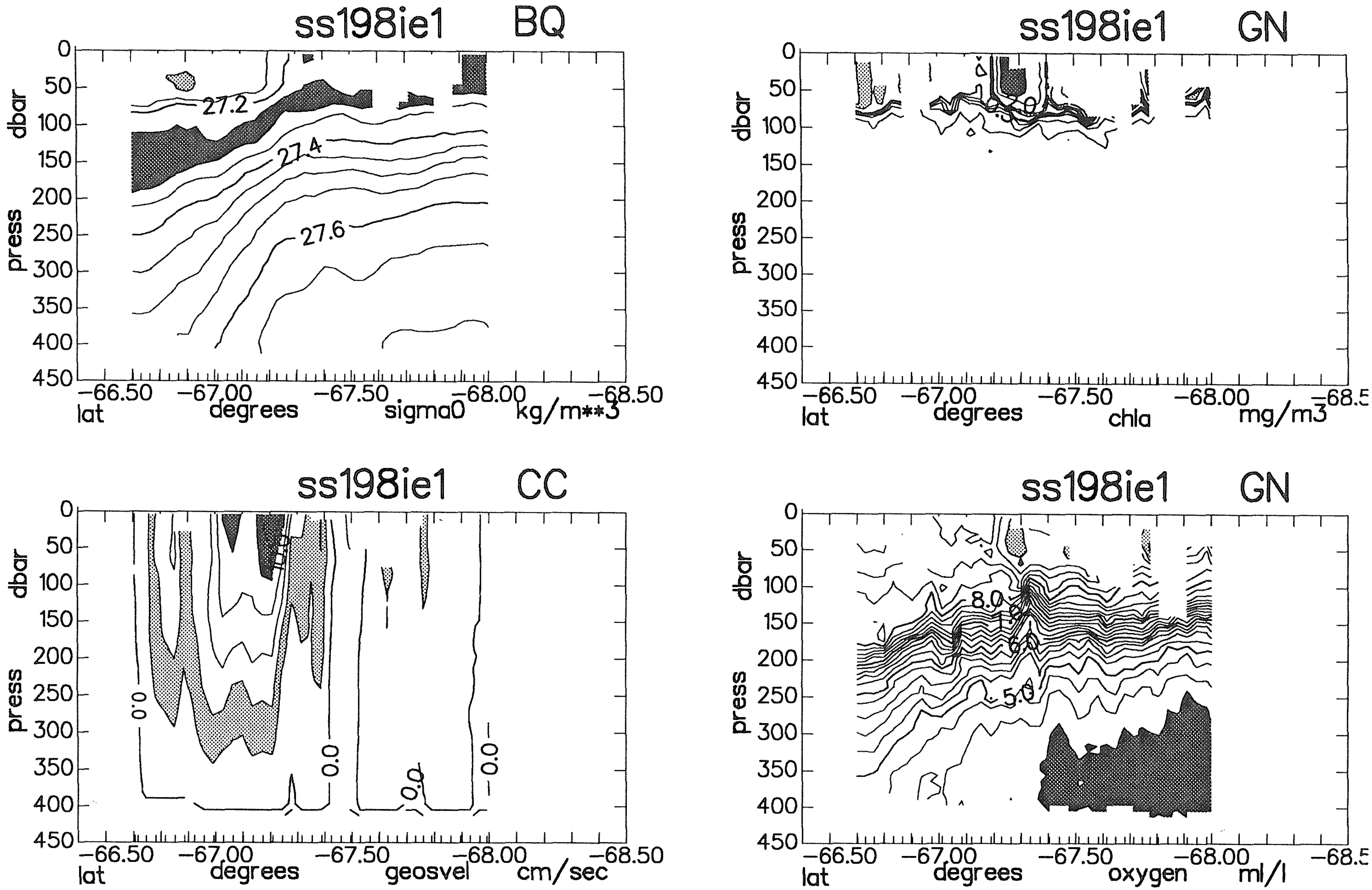

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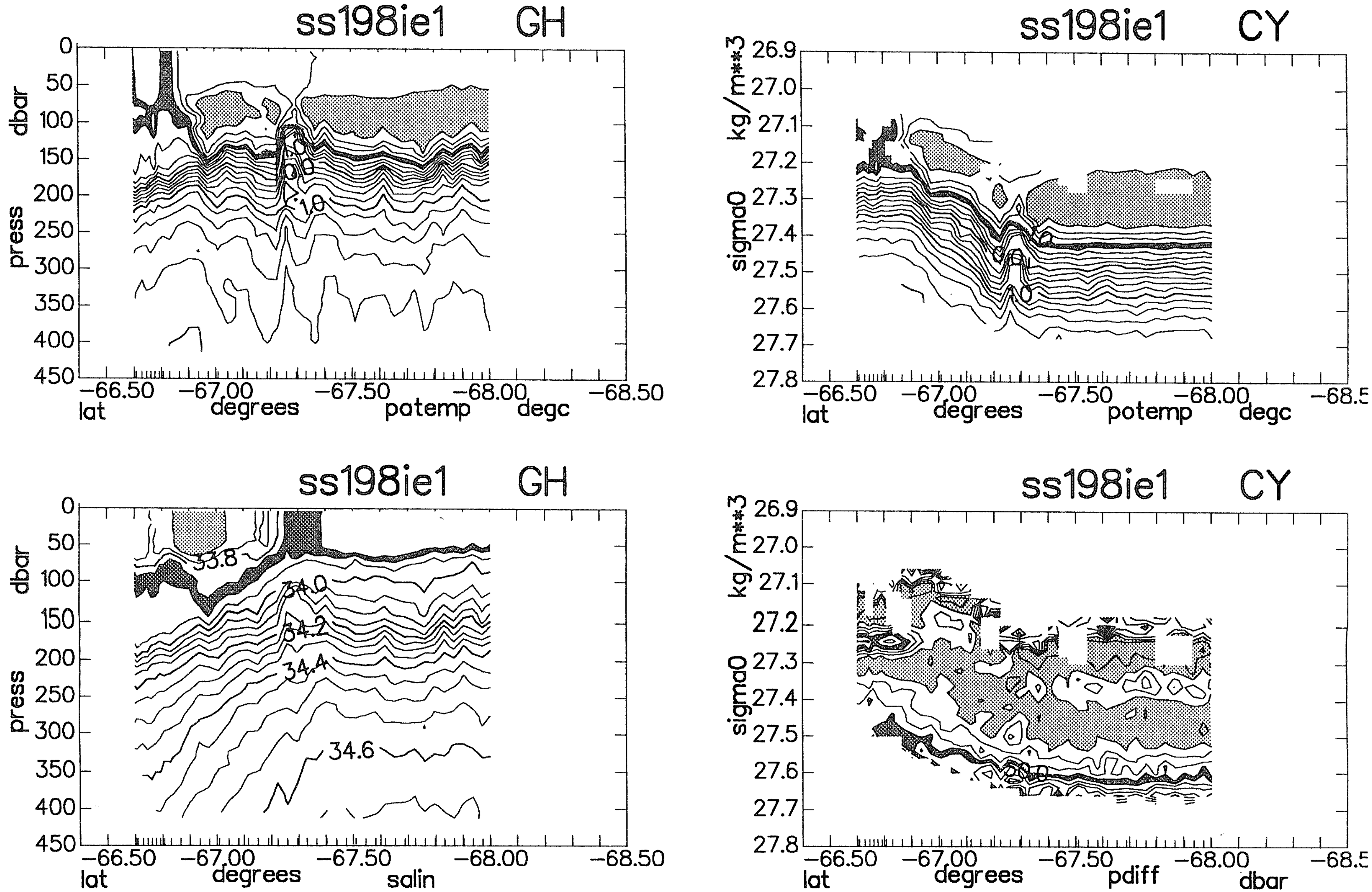

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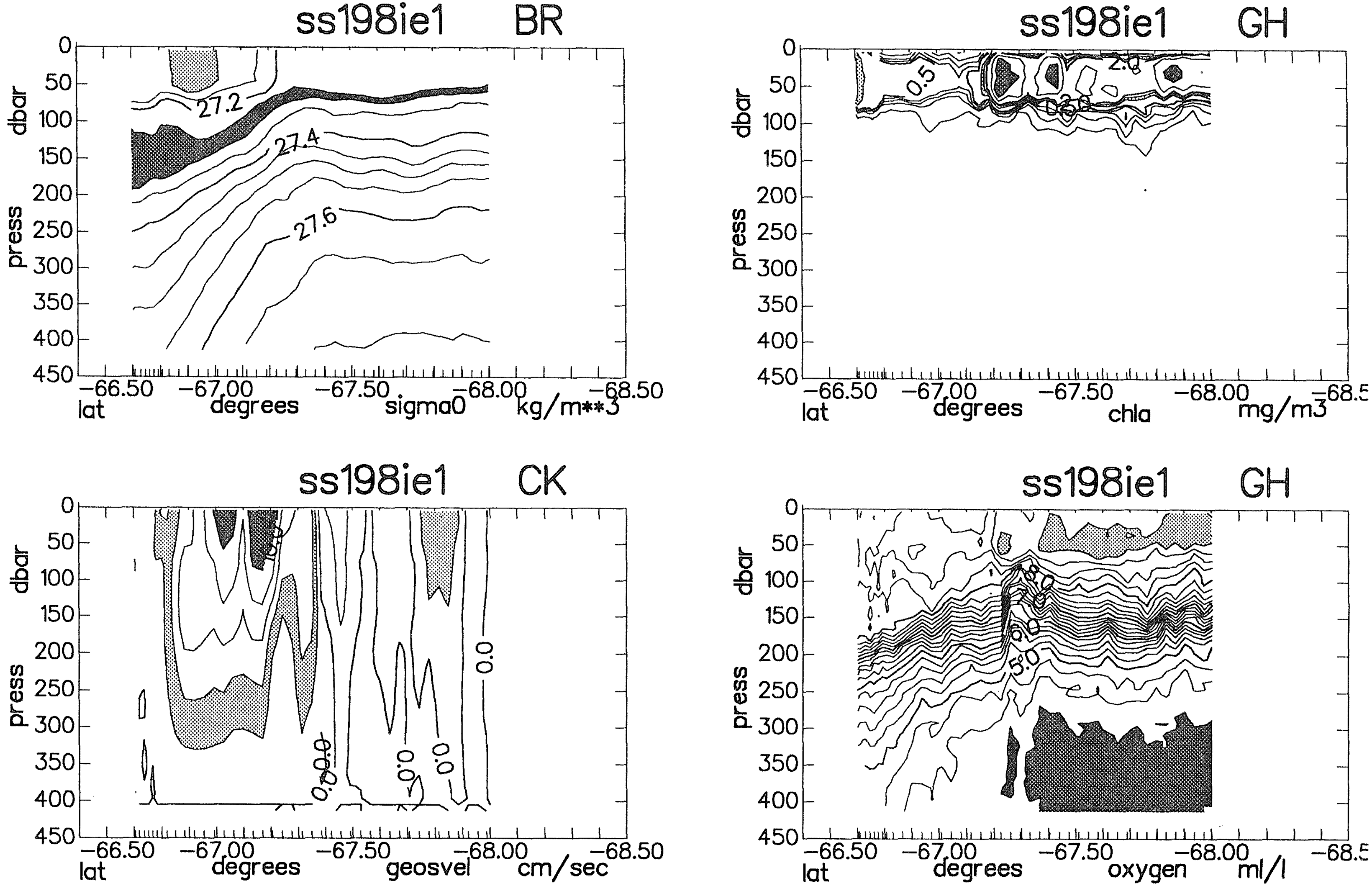

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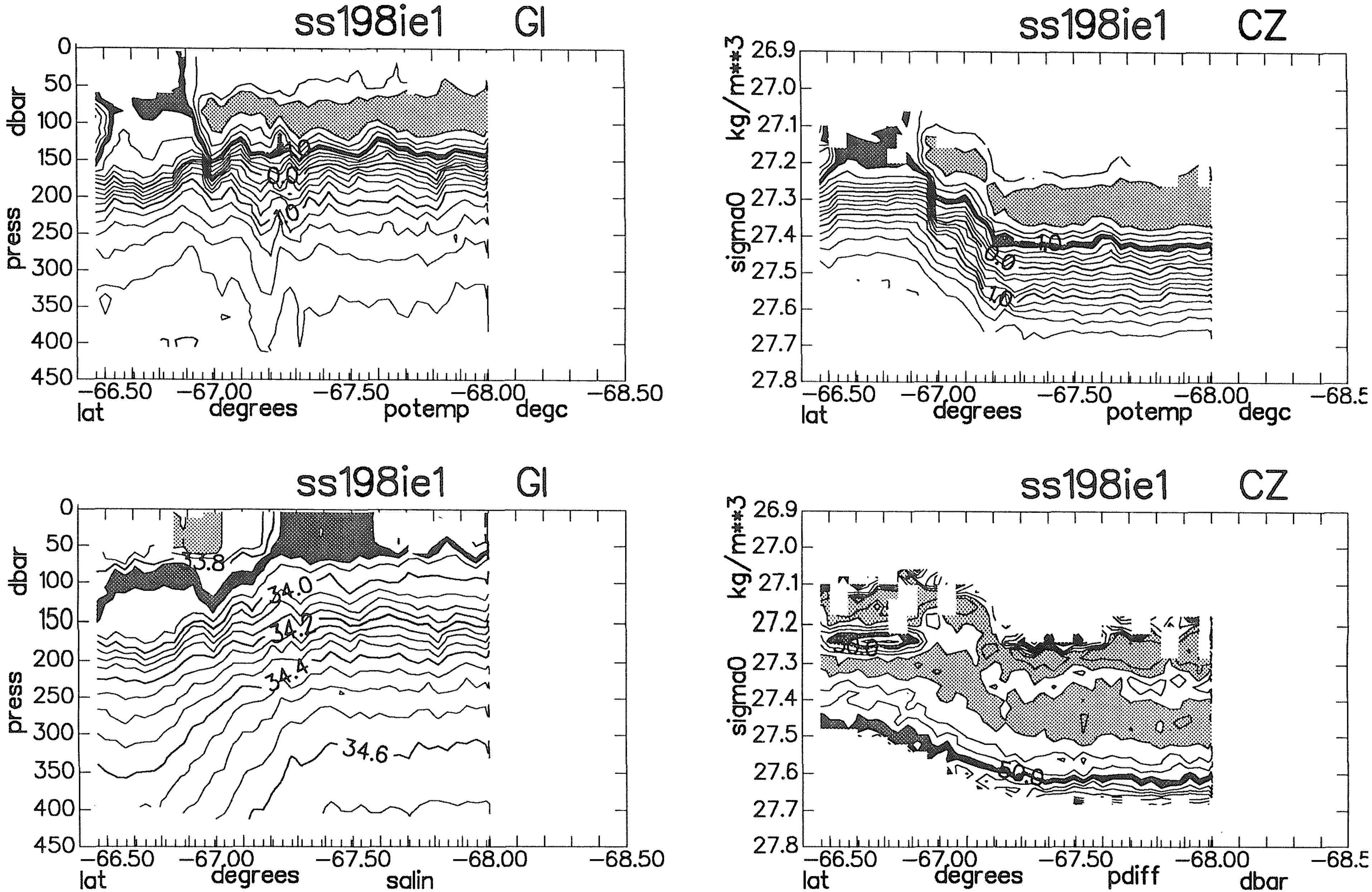

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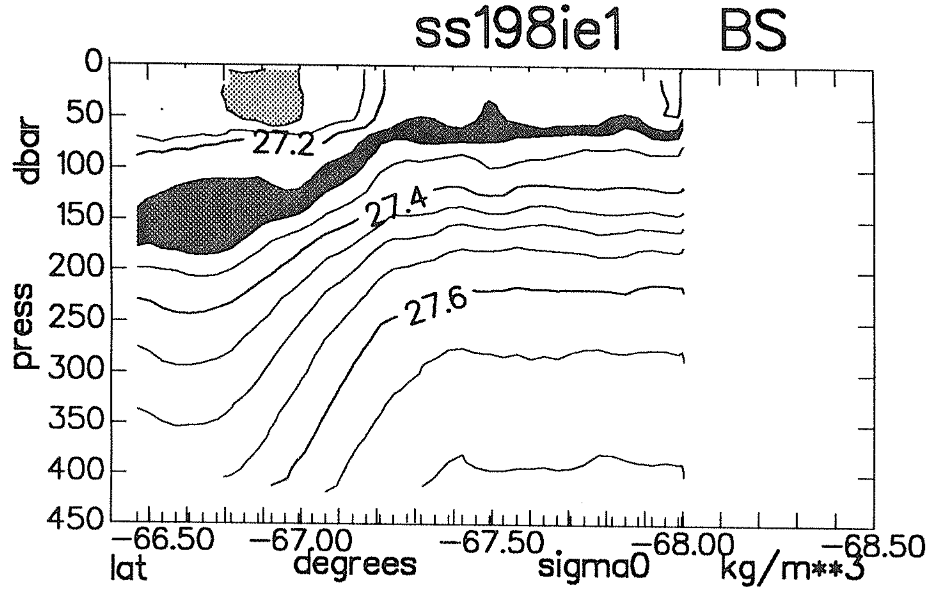

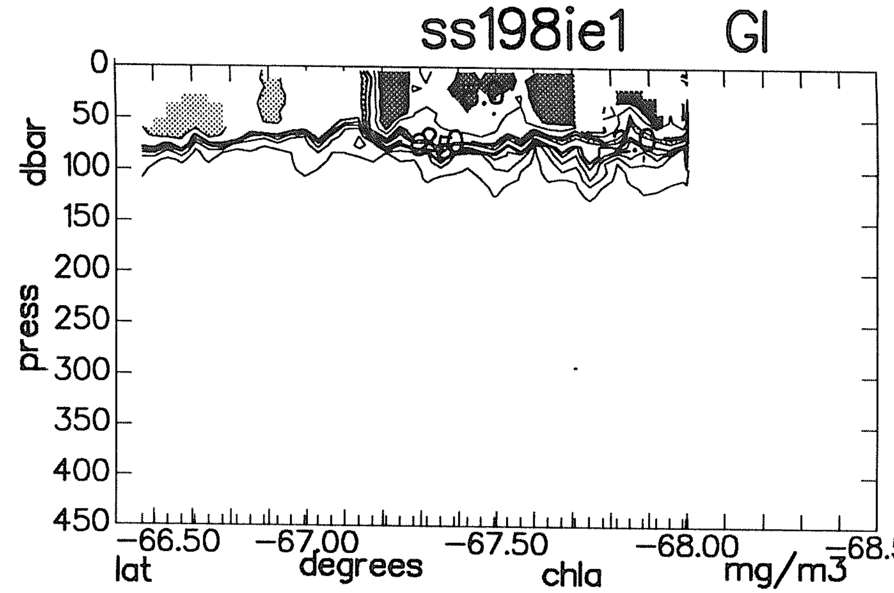

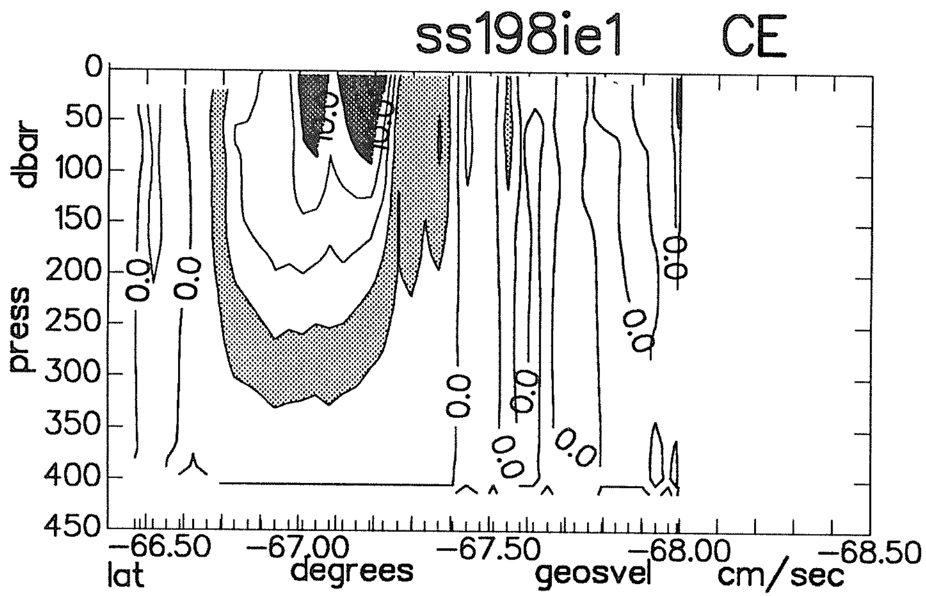

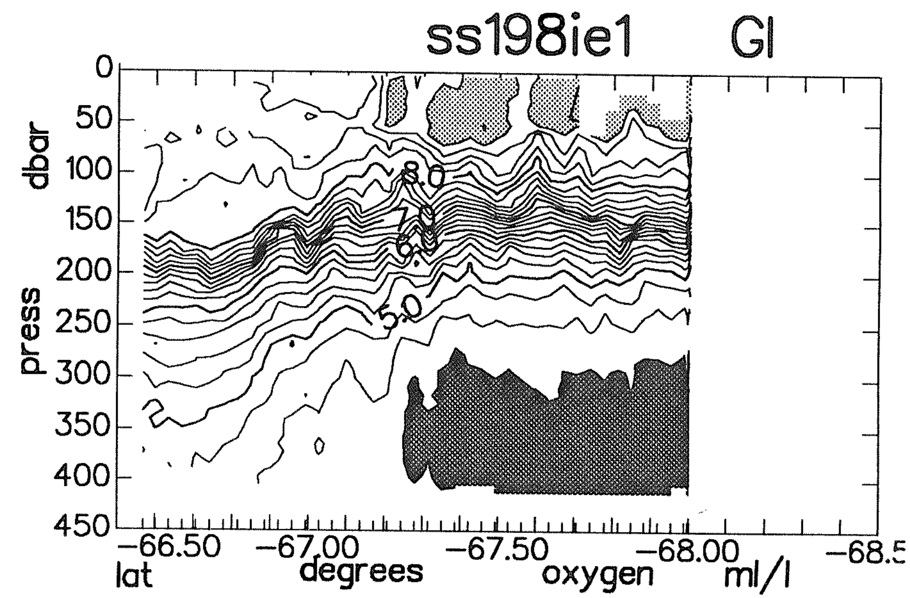

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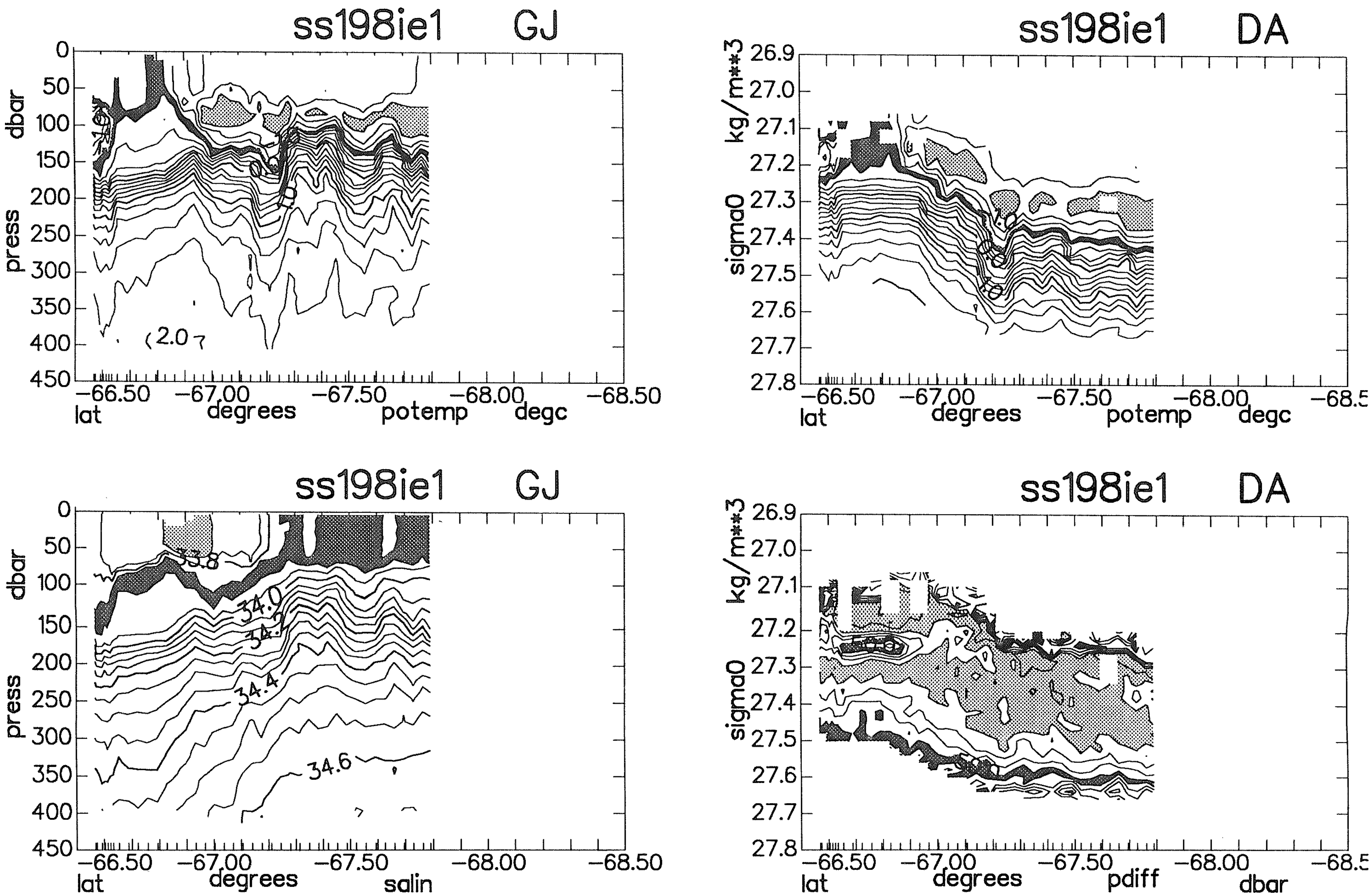

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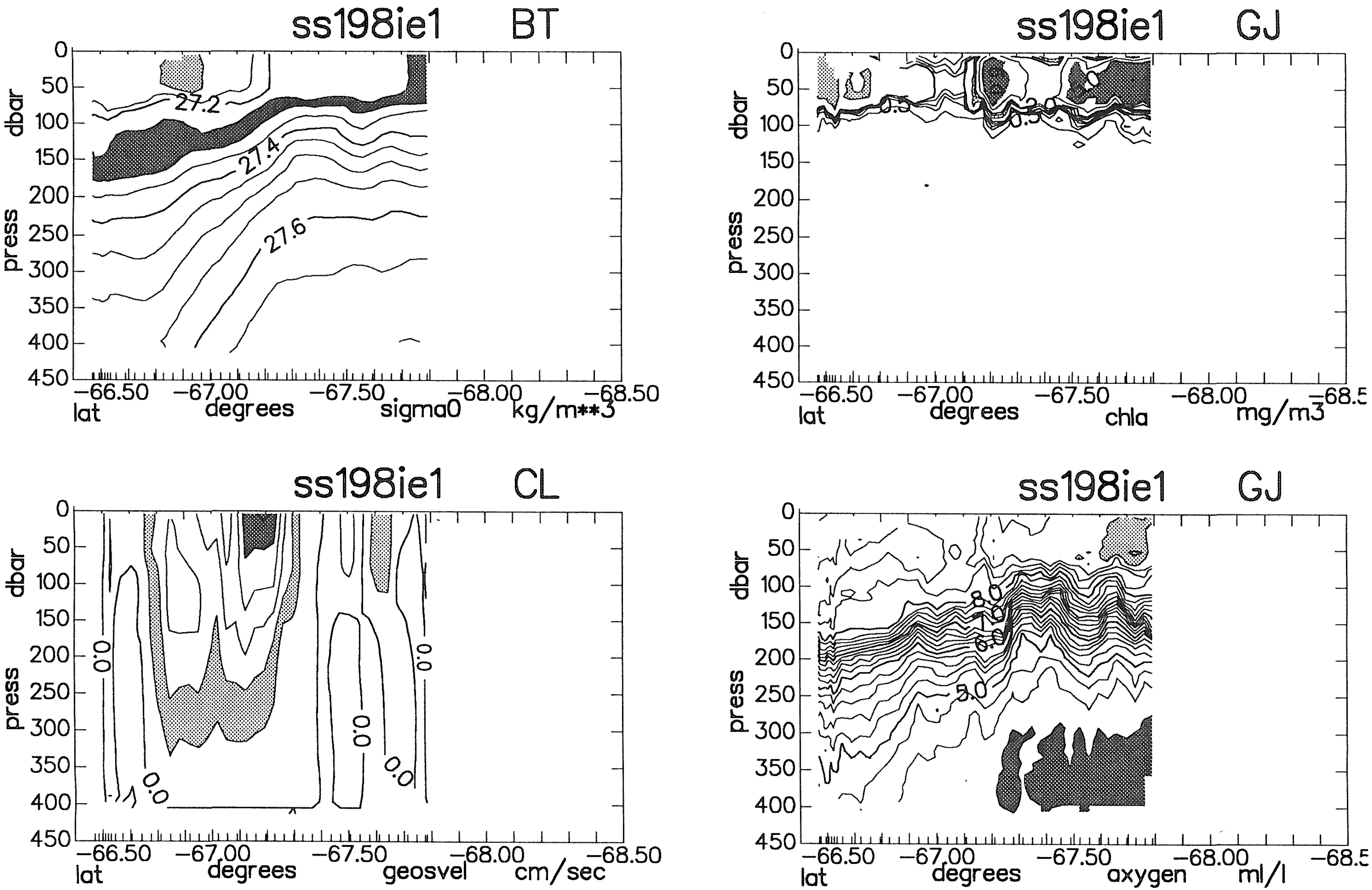

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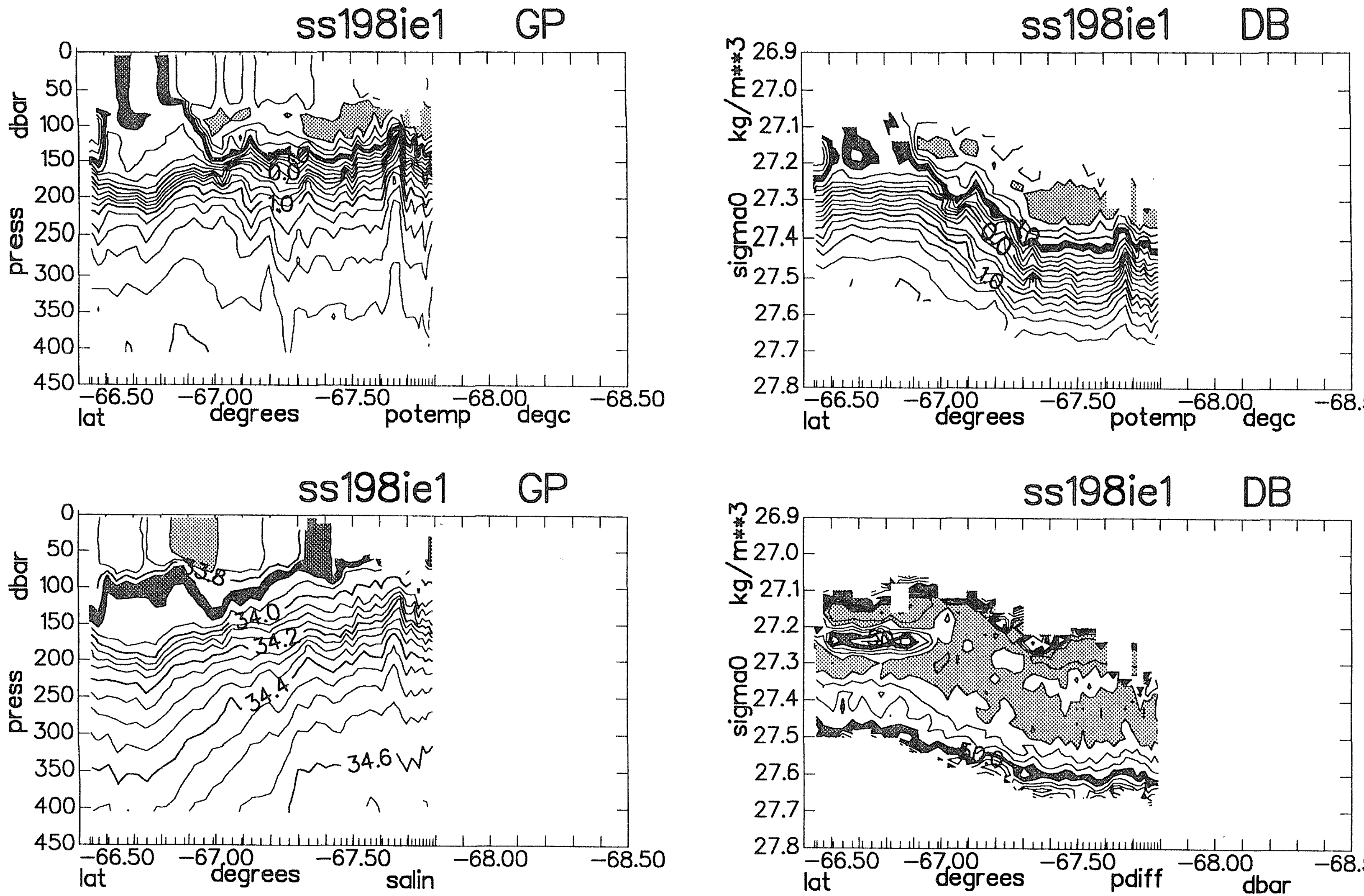

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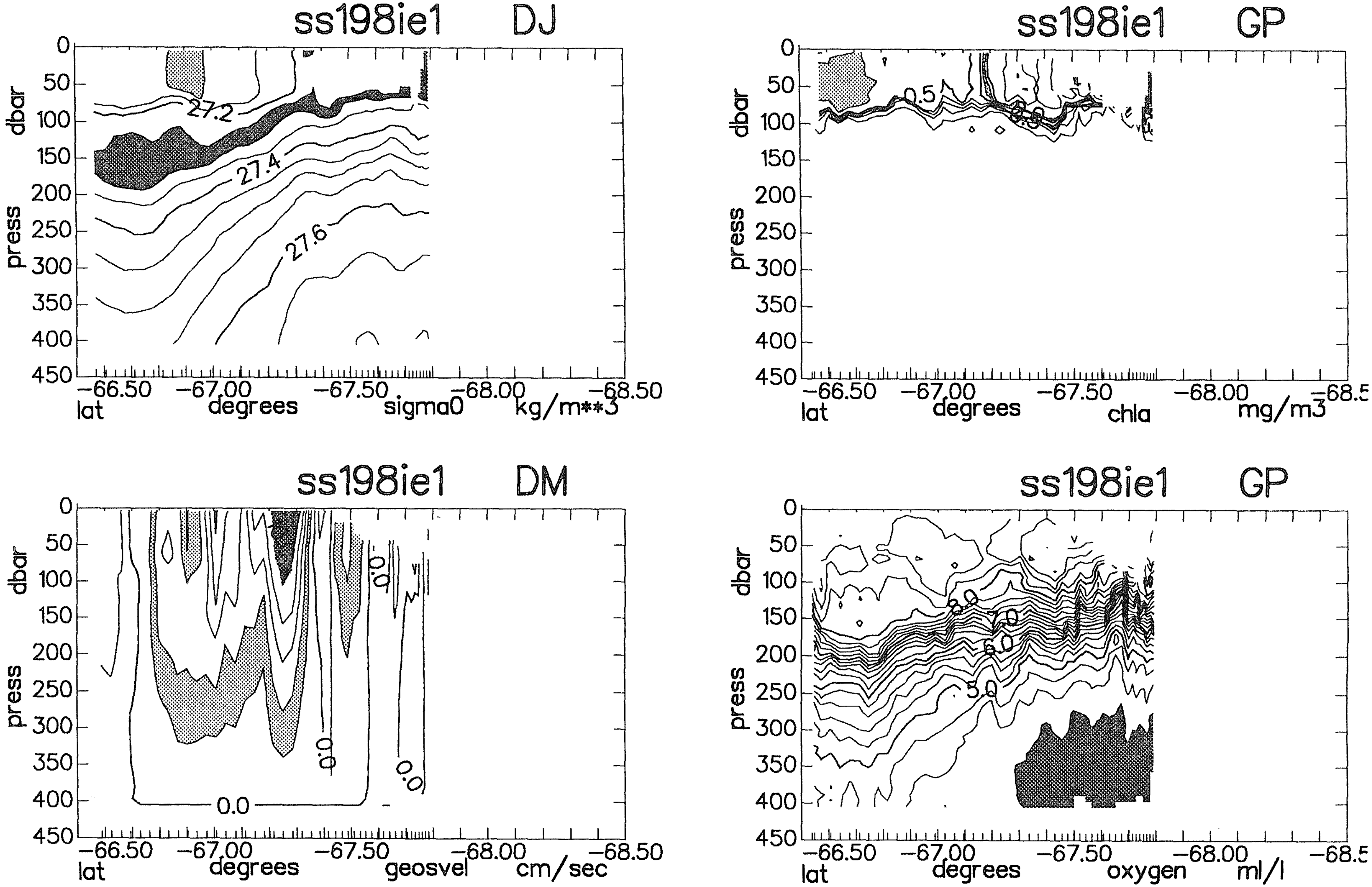

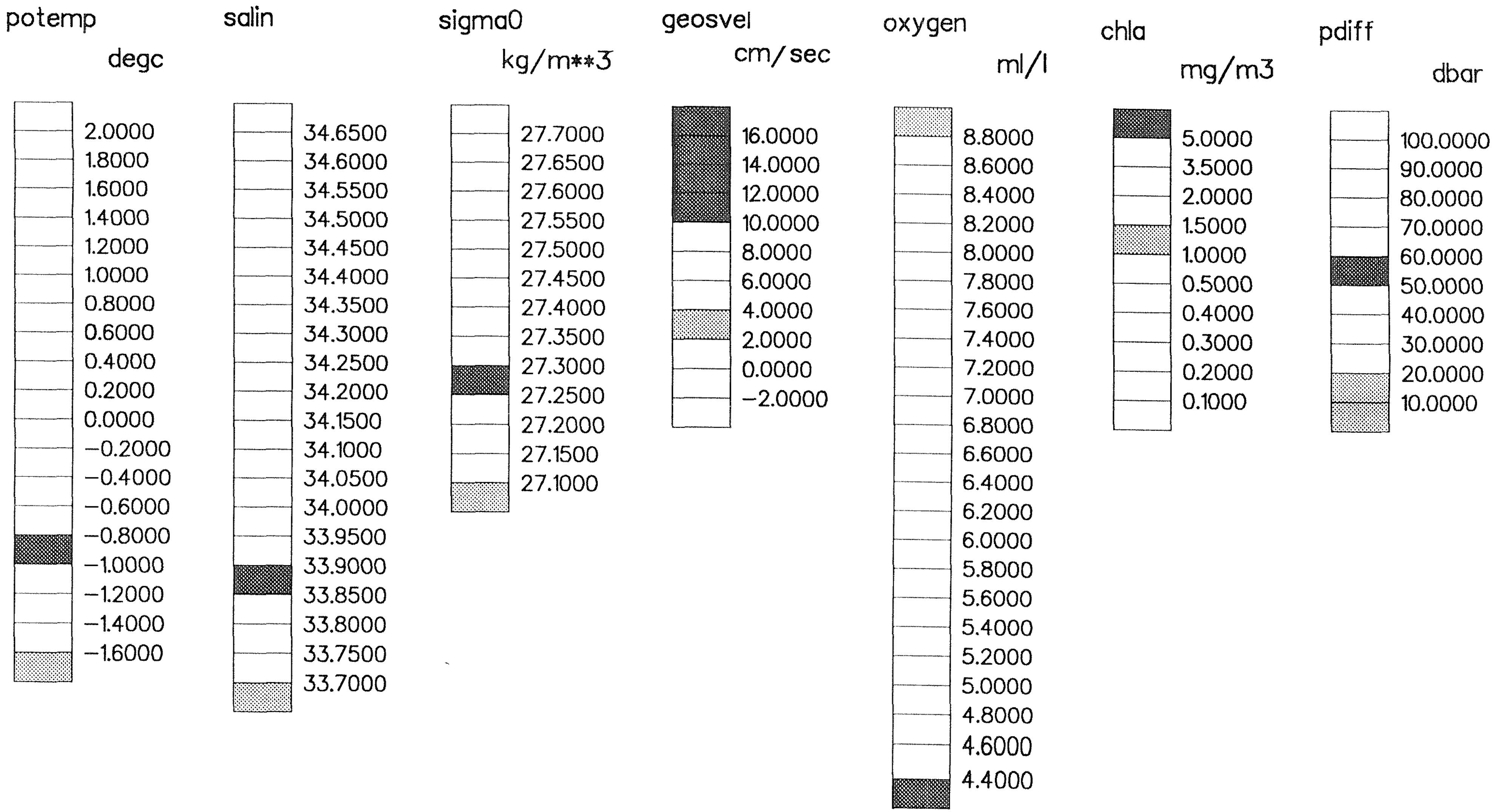
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34.0000
33.9500
33.9000
33.8500
33.8000
33.7500
33.7000
sigma0
kg/m**3
27.7000
27.6500
27.6000
27.5500
27.5000
27.4500
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27.2500
27.2000
27.1500
27.1000
geosvel
cm/sec
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14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
−2.0000
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ml/l
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8.6000
8.4000
8.2000
8.0000
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7.4000
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7.0000
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5.4000
5.2000
5.0000
4.8000
4.6000
4.4000
chla
mg/m3
5.0000
3.5000
2.0000
1.5000
1.0000
0.5000
0.4000
0.3000
0.2000
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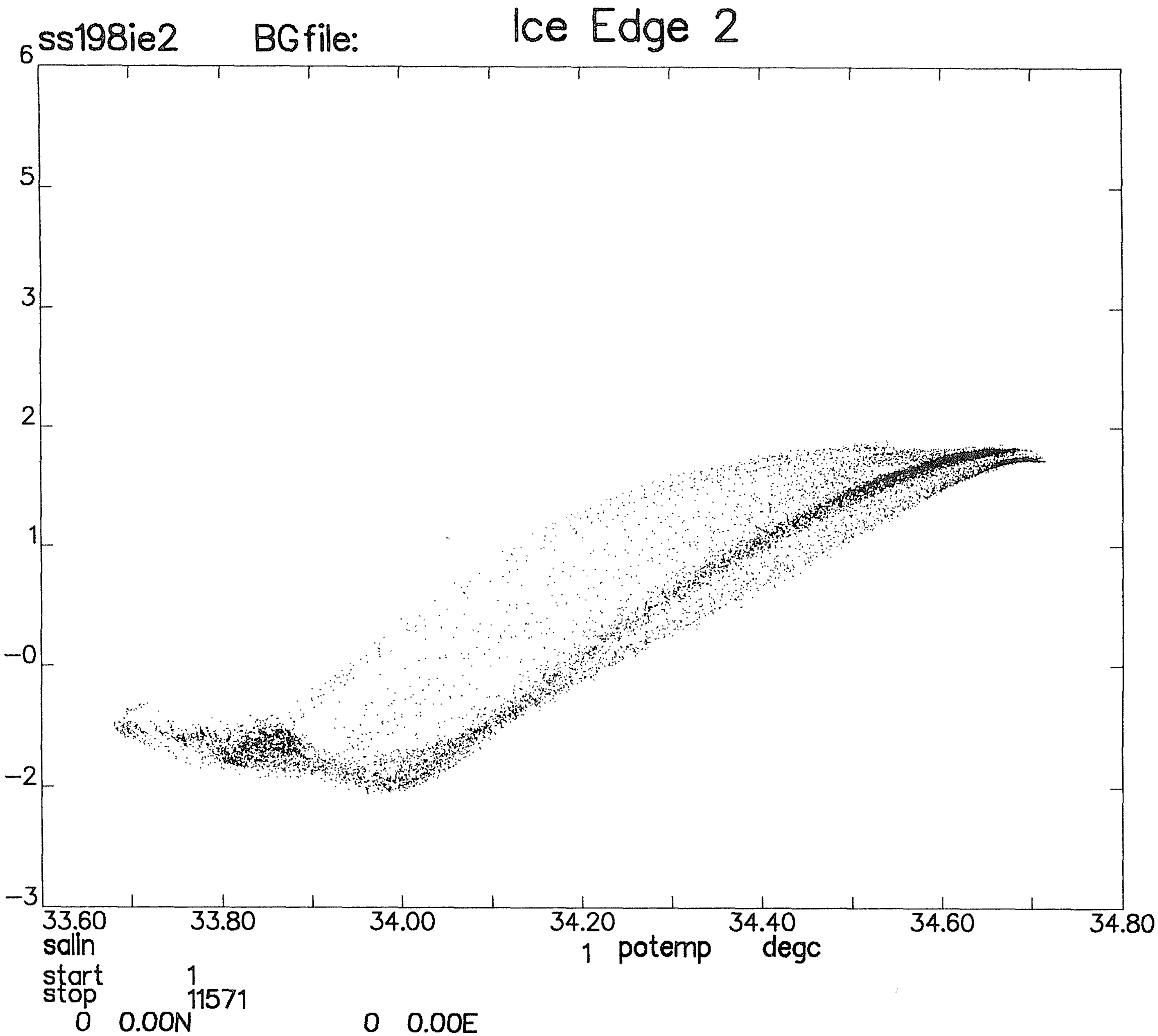
ss198ie2
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−2
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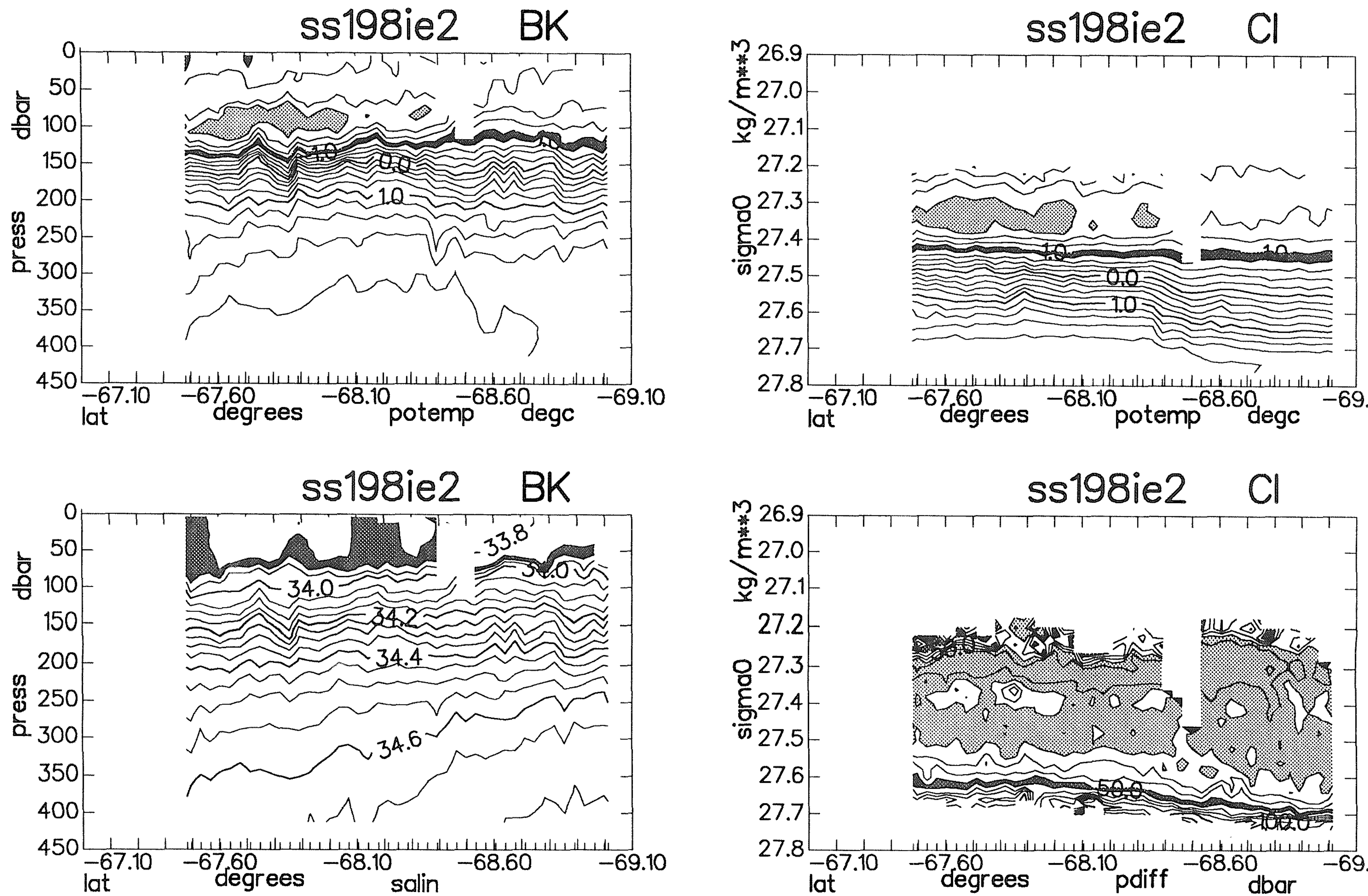

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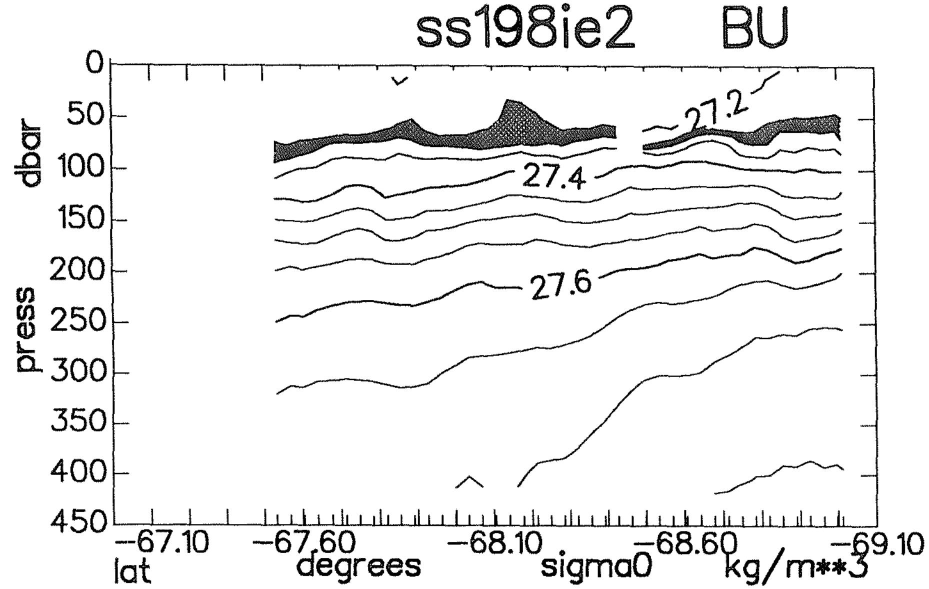

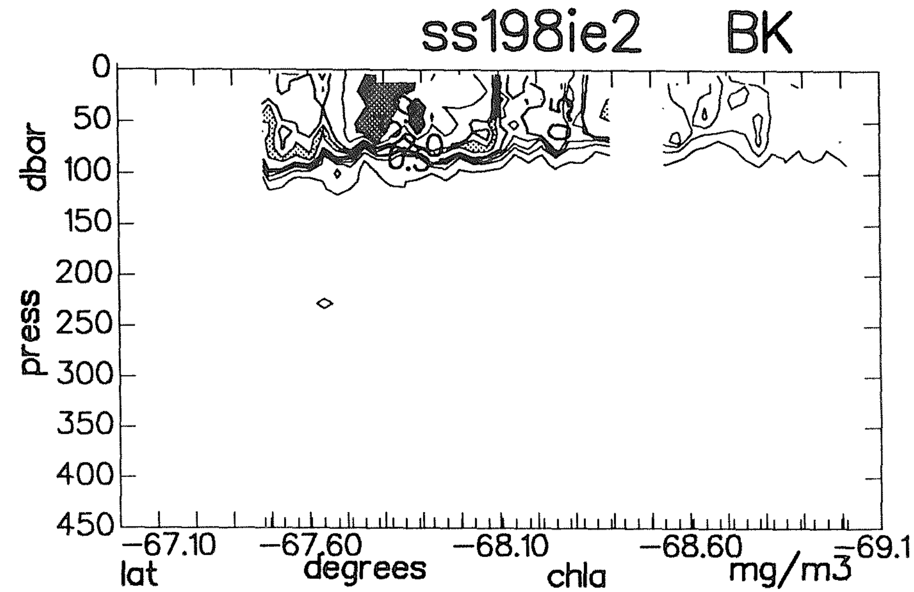

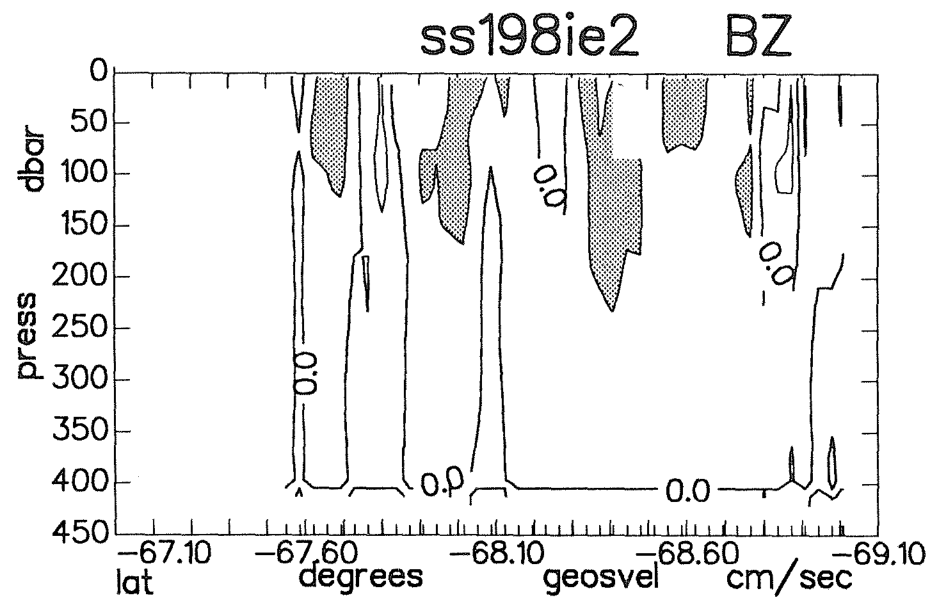

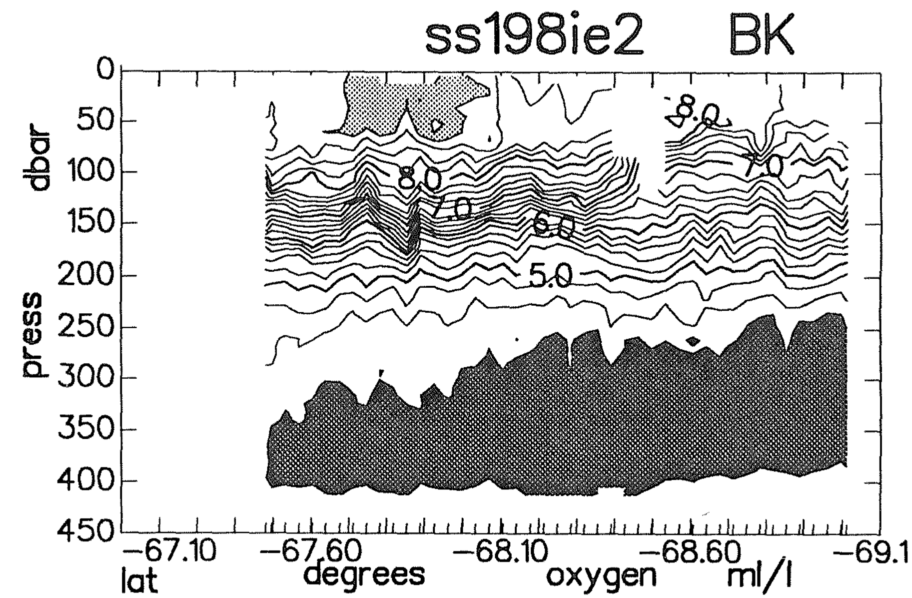

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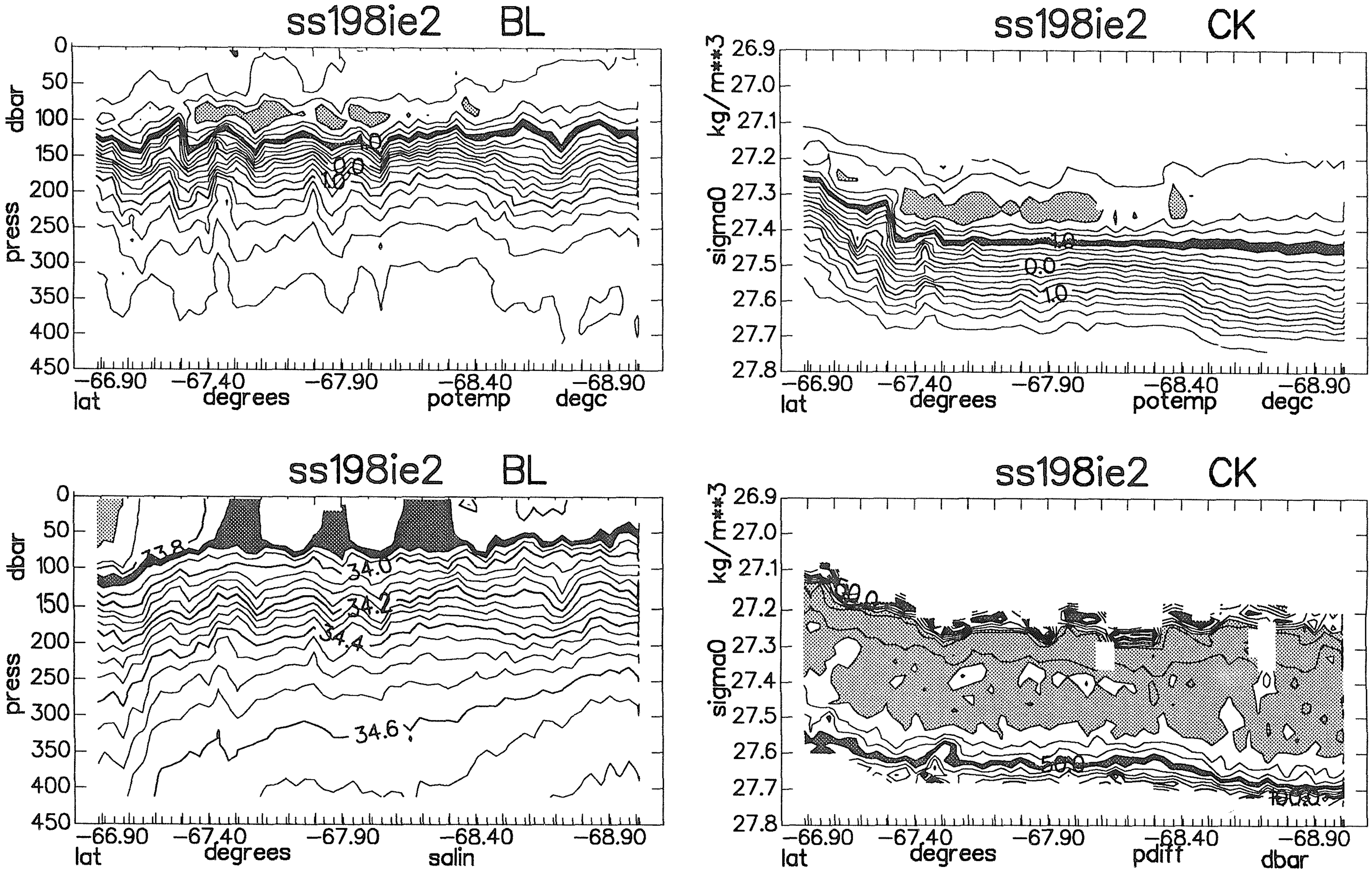

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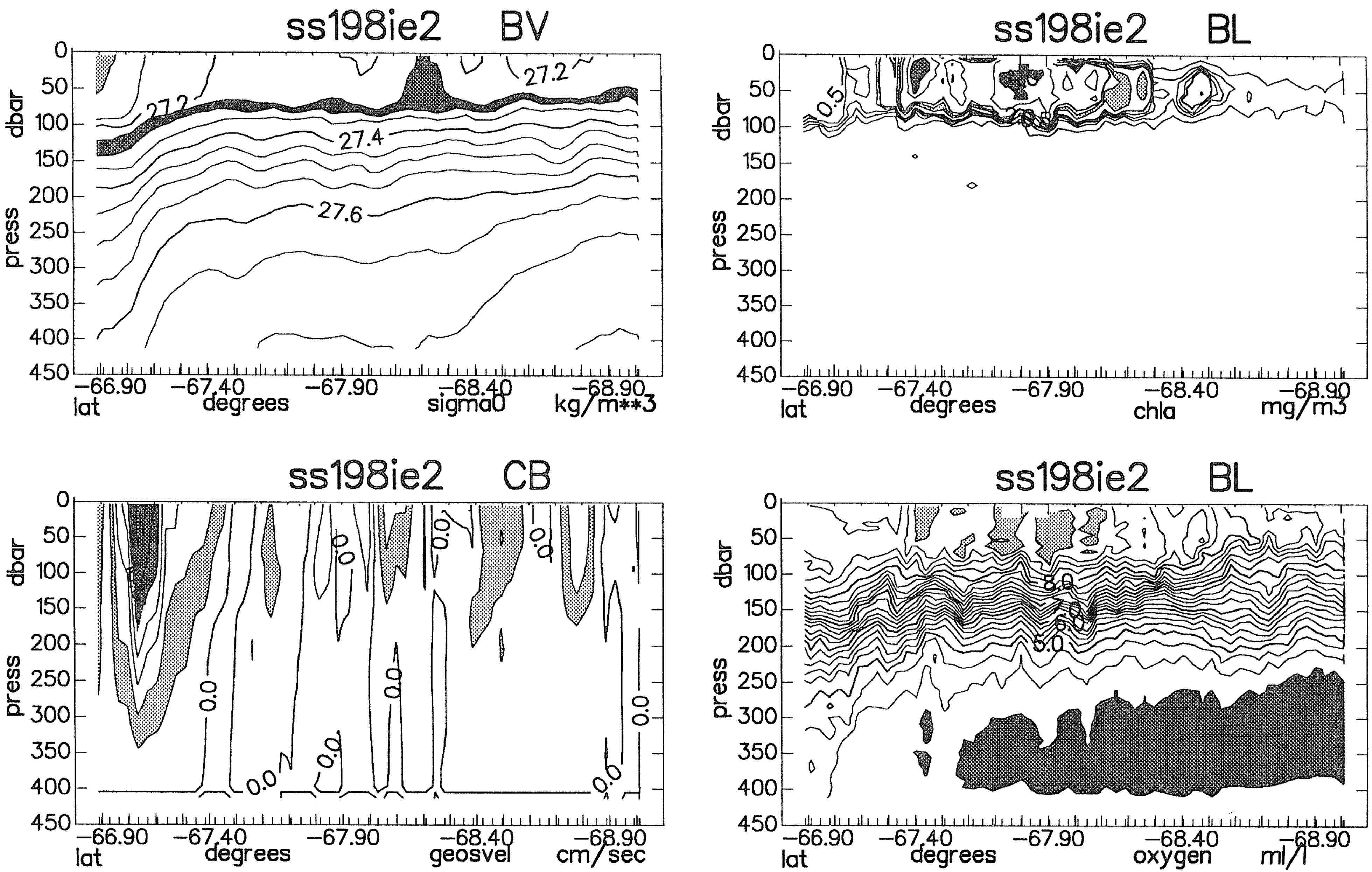

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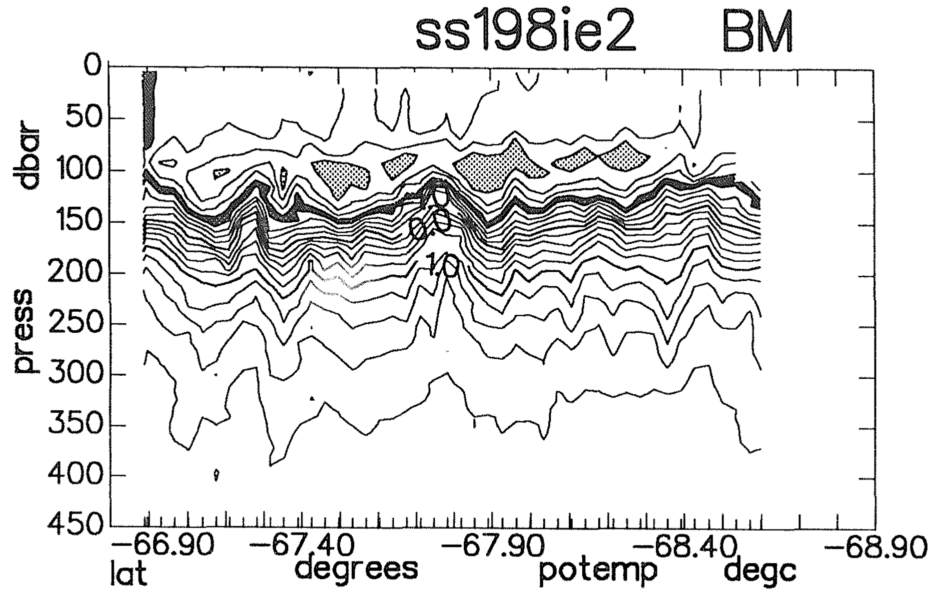

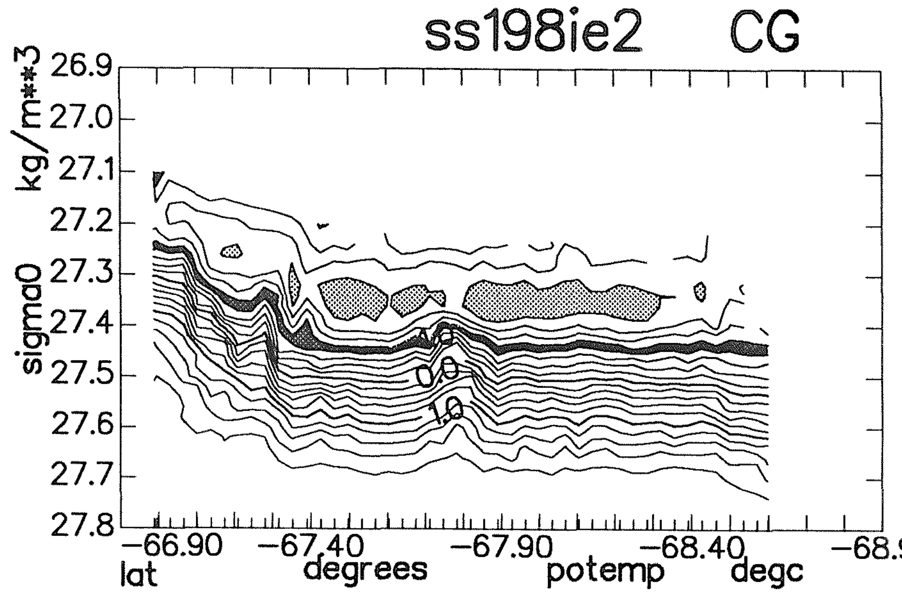

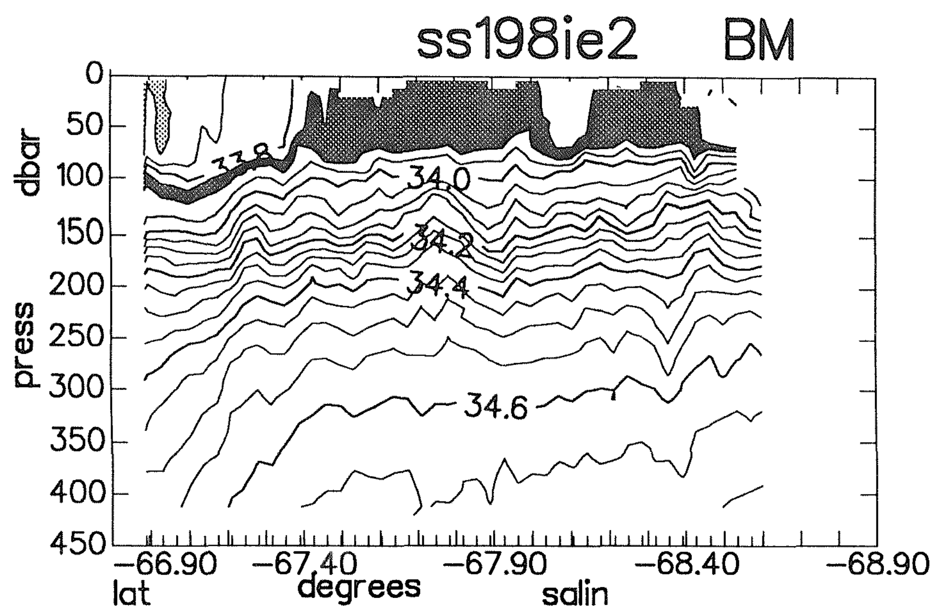

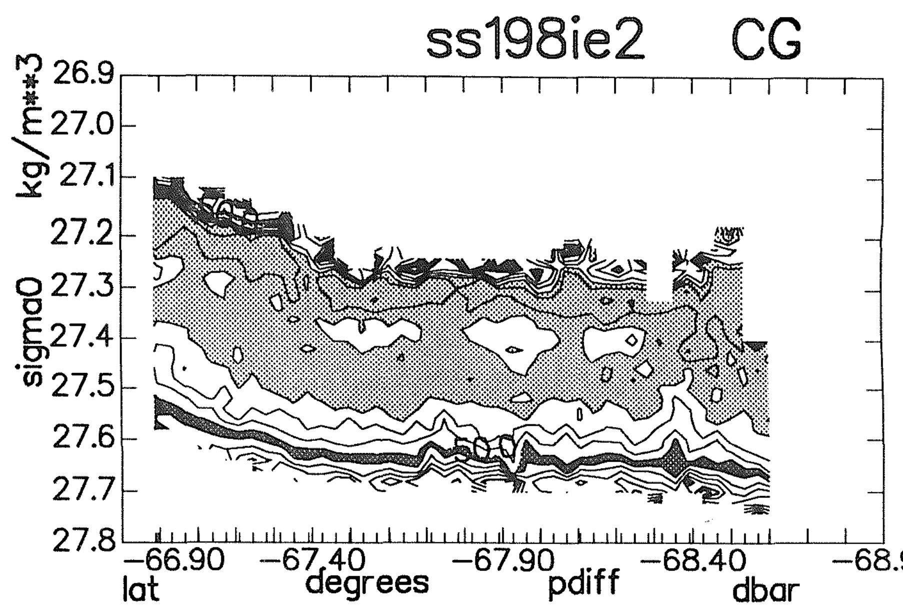

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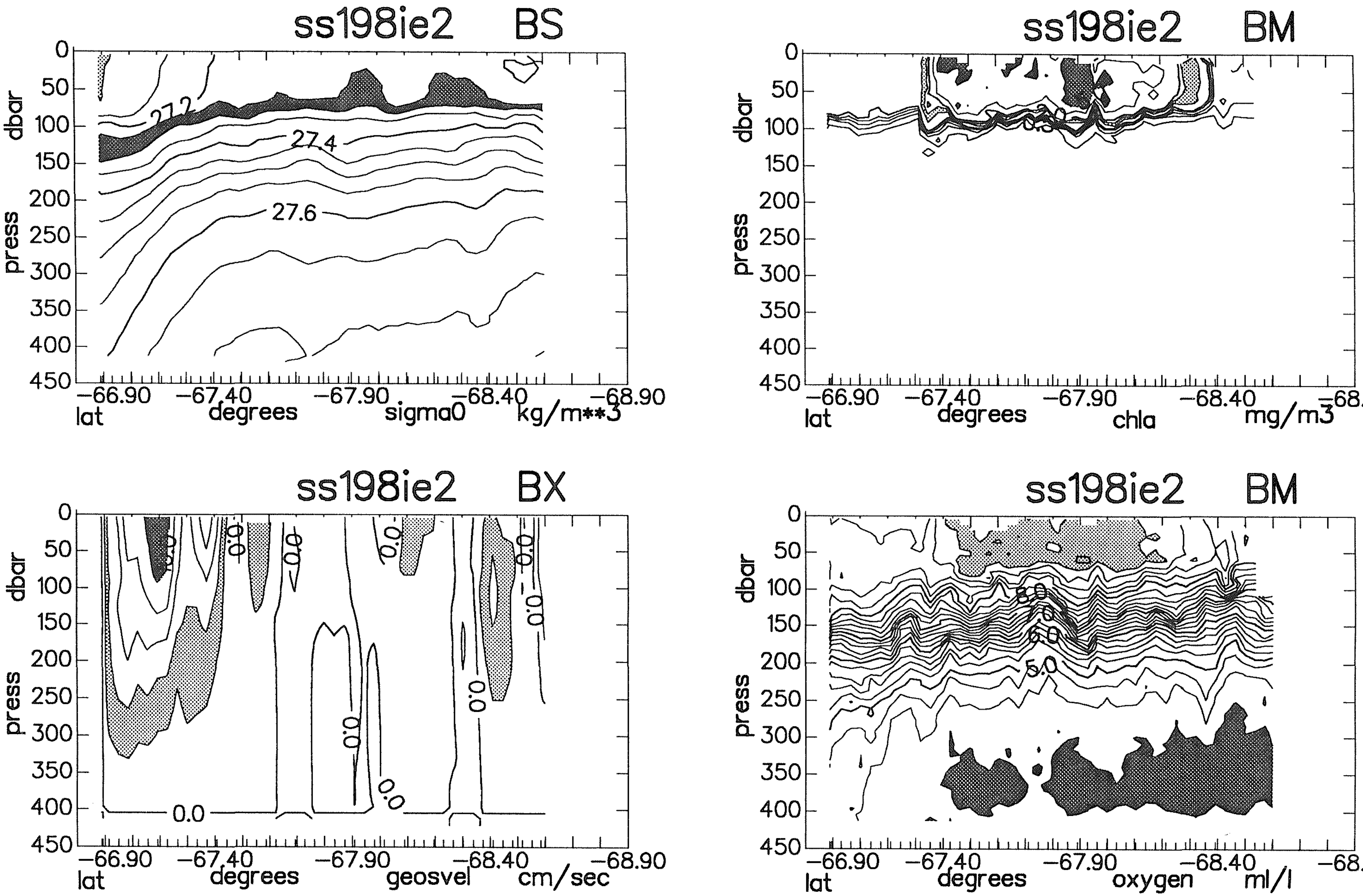
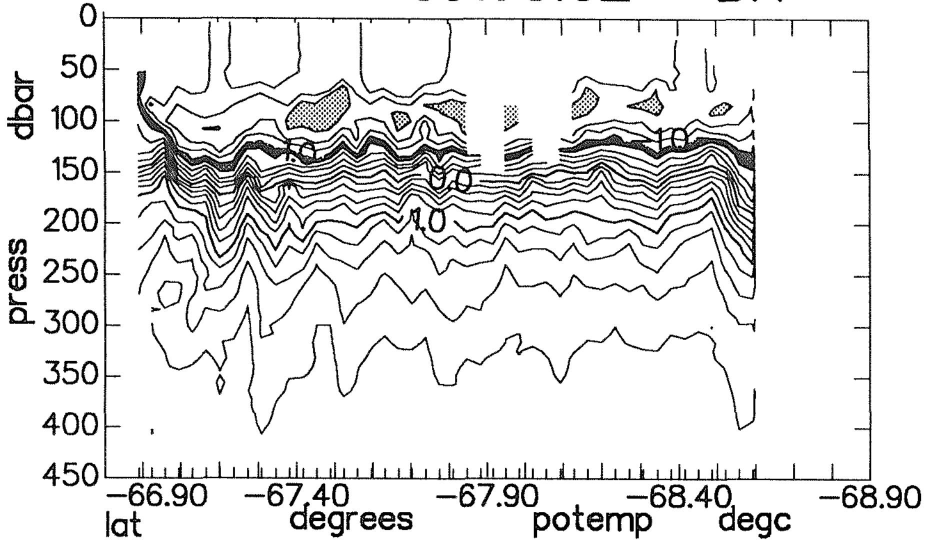


Ice Edge 2   Section D

ss198ie2   BN



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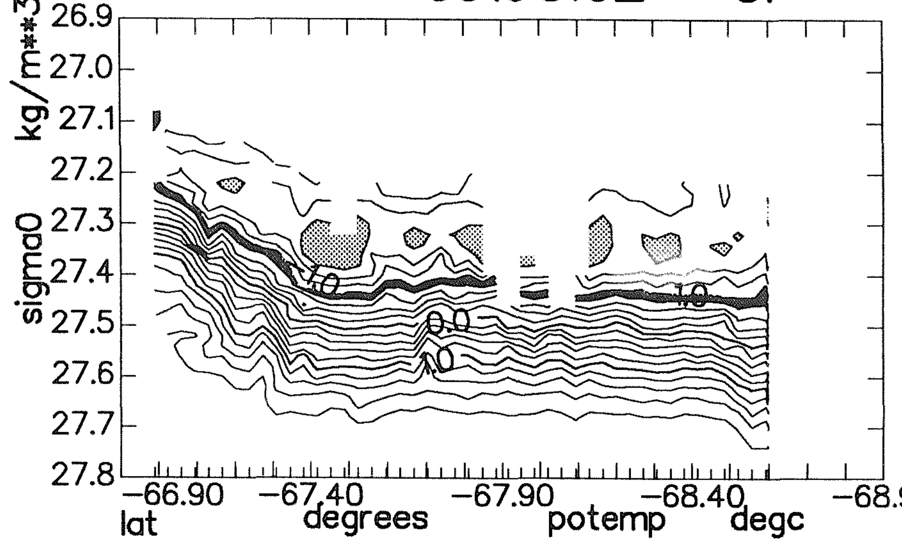

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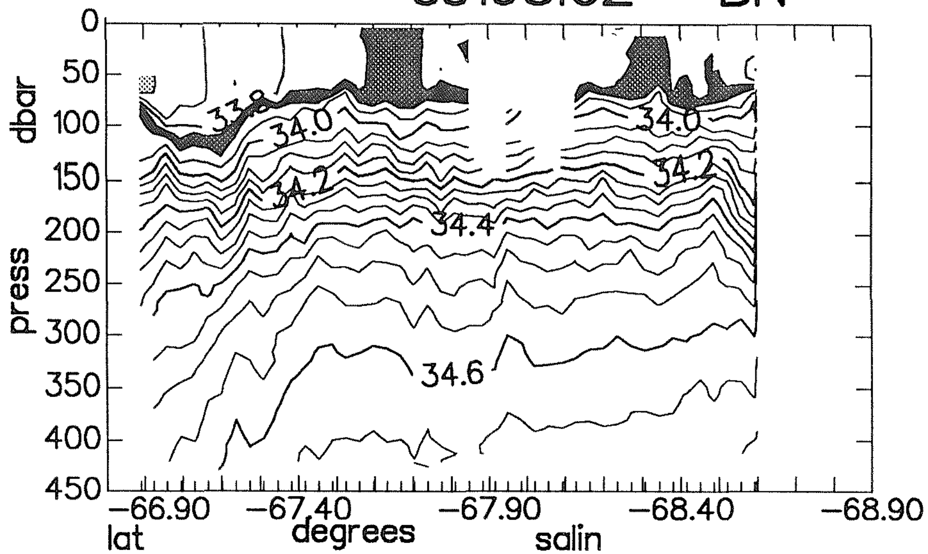

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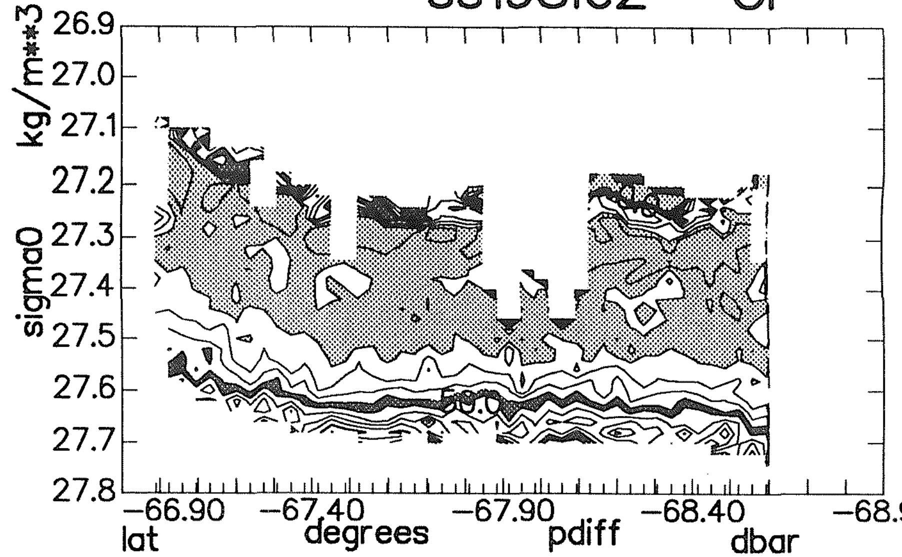
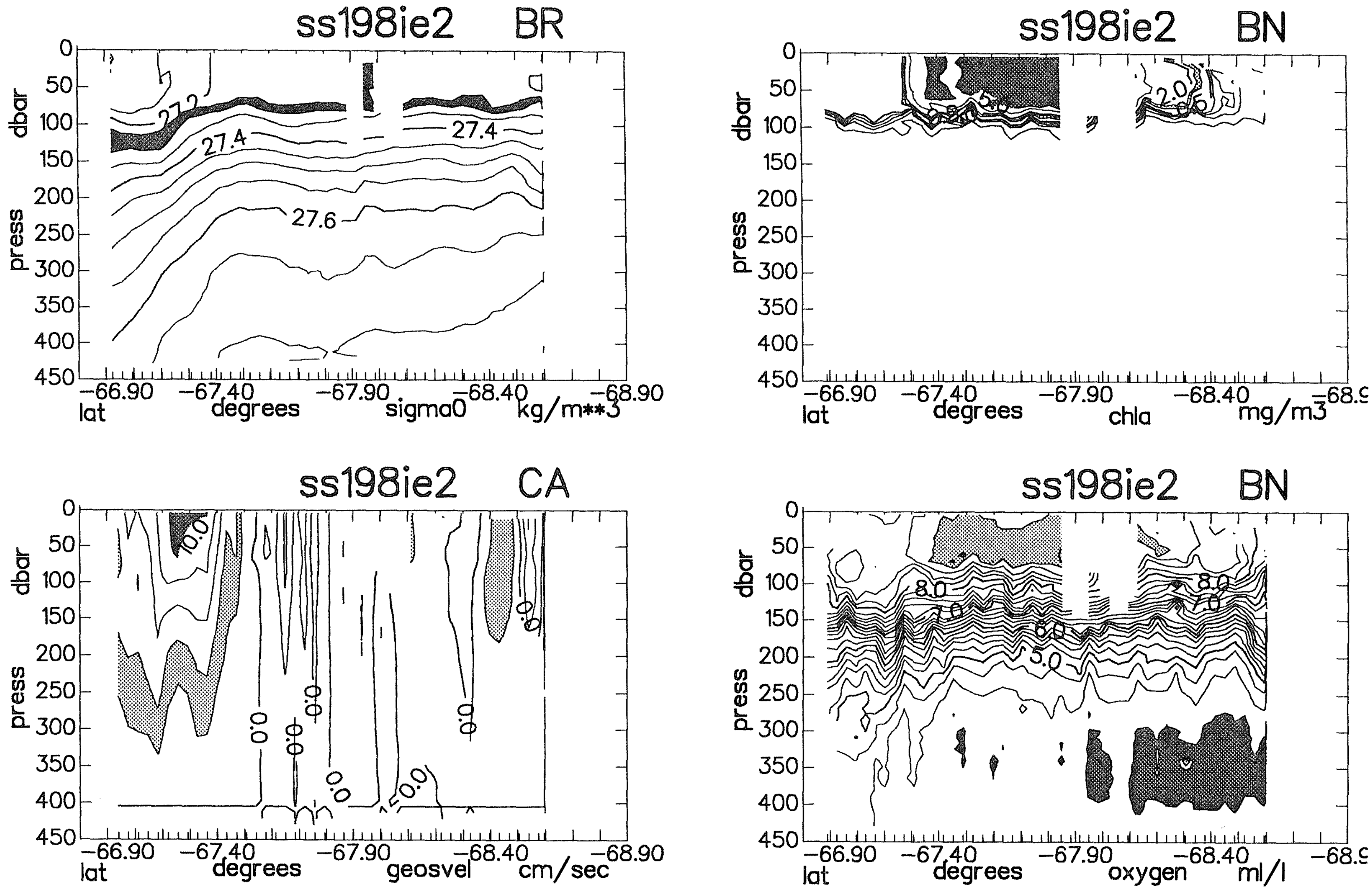


Ice Edge 2 Section D



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