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Subduction in the Subtropical Gyre

Seasoar Cruises: Data Report

May 1991 - May 1993

Technical Report WHOI-95-13

by

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ABSTRACT:

The overall objective of the Subduction Accelerated Research Initiative (ARI) was to bring together several techniques to address the formation and evolution of newly formed water masses. The Seasoar component provided surveys of temperature and salinity to help determine the spatial variability of the temperature, salinity and density fields in both the active frontal regions and in the vicinity of subducting water tagged by bobbers. Data were collected in the Eastern North Atlantic Ocean in Spring 1991, Winter 1992, Winter 1993 and Spring 1994. "Star" patterns were used to study the mesoscale variability. Temperature, pressure and thickness for each pattern were objectively mapped on potential density surfaces of 26.5, 26.7 and 26.9 kg/m^3. Acoustic Dopler Current Profiles (ADCP) maps were also created for the two shallower density surfaces. We describe the Seasoar data collected during the four cruises. A CD-ROM includes 1 and 3 second CTD, cruise navigation, ADCP and Seasoar engineering data, as well as color figures of these data. This data report can also be viewed using an internet information browser (i.e. Mosaic, Netscape) using the provided CD-ROM.

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Subduction in the Subtropical Gyre: Seasoar Cruises Data Report

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1. INTRODUCTION

Seasoar CTD data were collected during the Subduction Experiment in the Eastern North Atlantic during the period of May 1991 - May 1993. The Seasoar work is part of the Subduction Accelerated Research Initiative (ARI) supported by the Office of Naval Research. The overall objective was to bring together several techniques to address the formation, evolution and subduction of newly formed water masses over a two year period. Other activities include synoptic mesoscale sampling of tracers, including potential vorticity in the upper pycnocline, and direct tagging of water parcels with bobber floats, as well as independent Eulerian velocity and meteorological measurements from surface moorings. The Seasoar provides well-resolved surveys to help determine the spatial variability of the temperature, salinity and density fields in both the active frontal regions and in the vicinity of subducting water tagged by the bobbers.

The Seasoar, manufactured by Chelsea Instruments, Ltd., is a towed vehicle equipped with impeller-forced wings that can be adjusted to undulate in the upper ocean. The wings are controlled by signals from the ship, and moved by an hydraulic unit. The Seasoar undulates between 0-450 dbars while being towed at about eight knots, cycling to the surface approximately every 12 minutes. The Seasoar group participated in four cruises during the experiment (Table 1). On the initial cruise in May 1991, 18 bobbers were deployed, three mesoscale surveys ("star patterns") and a frontal survey were completed (Luyten, 1991). In Feb 1992, a second frontal survey was completed (Rudnick, 1992). The following November, six star patterns near bobbers and two long transects were executed (Joyce, 1992). The final cruise, May 1993, surveyed near four bobbers and towed along three long transects (Luyten, 1993); (Fig 1, Table 2). In conjunction with four star patterns (two on the first and two on the last cruise), a series of closely spaced CTD stations, using a profiling CTD, were made overlaying the star pattern in an L-shaped pattern for the tracer studies. We used the CTD data from these stations to augment the Seasoar dataset. All cruises were on the R/V Oceanus.

Table 1: Dates corresponding to the cruises during the Subduction Experiment.

Subduction 1 (OC240 Leg 2)-	5 May 1991 - 3 June 1991	- J. Luyten
Subduction 2 (OC250 Leg 3)-	2 March 1992 - 20 March 1992	- D. Rudnick
Subduction 3 (OC254 Leg 4)-	24 November 1992 - 16 December 1992	- T. Joyce
Subduction 4 (OC258 Leg 3)-	18 May 1993 - 16 June 1993	- J. Luyten

Table 2: This table includes the mean locations, start and end times for all the star patterns surveyed on the Subduction cruises. In addition, it includes the start and end locations and times for the sections presented in this data report.

Cruise	**Star**	**Start time**	**End time**	**Latitude**	**Longitude**
1	1	05/16/91	05/20/91	22.8655 N	-27.0472 E
1	2	05/23/91	05/27/91	29.0139 N	-23.5313 E
1	3	05/31/91	06/02/91	29.9845 N	-21.6587 E
3	1	11/28/92	11/30/92	20.3393 N	-29.6893 E
3	2	12/01/92	12/02/92	22.8685 N	-27.0472 E
3	3	12/02/92	12/04/92	22.7953 N	-28.6941 E
3	4	12/04/92	12/06/92	23.2972 N	-29.4279 E
3	5	12/08/92	12/11/92	25.1120 N	-24.4478 E
3	6	12/11/92	12/12/92	26.9678 N	-24.9349 E
4	1	05/24/93	05/27/93	18.9862 N	-31.9748 E
4	2	05/30/93	05/31/93	24.2855 N	-37.4544 E
4	3	06/02/93	06/03/93	23.5120 N	-31.6550 E
4	4	06/05/93	06/08/93	28.1707 N	-26.3902 E

Cruise	**Sect**	**Start time**	**End time**	**Start**		**End**	
				Latitude	**Longitude**	**Latitude**	**Longitude**
3	1	12/06/92	12/08/92	23.2020 N	-29.0249 E	24.6882N	-24.6651E
3	2	12/12/92	12/14/92	26.8574 N	-24.8574 E	32.6342N	-24.7439E
4	1	05/27/93	05/30/93	19.0518 N	-32.0232 E	24.6200N	-24.6200E
4	2	06/04/93	06/05/93	26.3285 N	-28.2048 E	27.8200N	-26.1847E
4	3	06/08/93	06/09/93	28.9257 N	-25.8696 E	28.8426N	-23.0890E
4	4	06/09/93	06/10/93	28.8509 N	-23.0497 E	30.4189N	-23.8573E
4	5	06/10/93	06/11/93	30.4394 N	-23.8296 E	32.9475N	-21.5498E

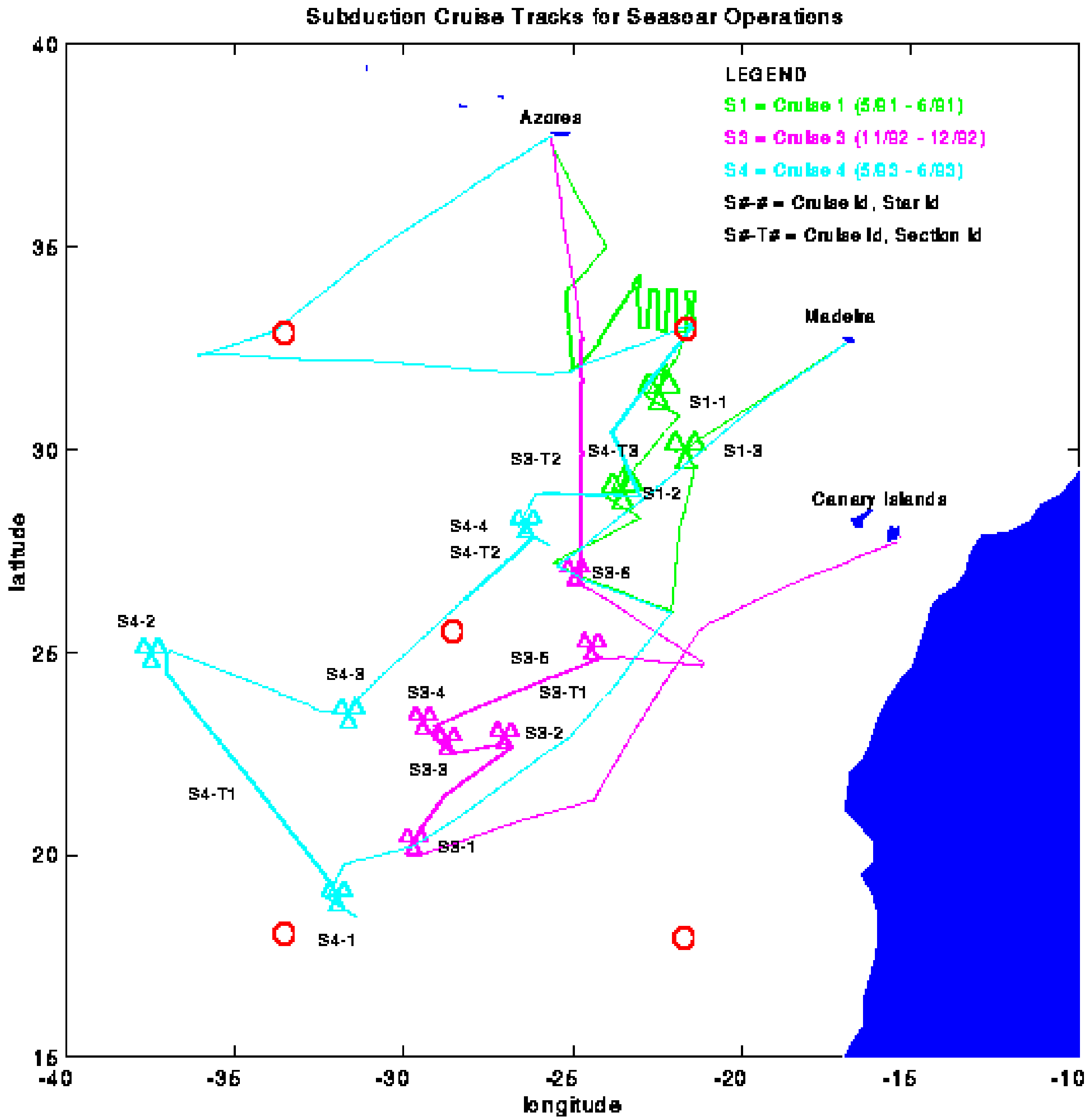

Figure 1: Seasoar Cruise Track: May 1991 - May 1993. Heavy lines denote when seasoar was actually being towed. Heavy Circles are location of subduction moorings.

2. METHODS

A: Temperature, Conductivity and Pressure

The Seasoar CTD is a Sea-Bird model 911 with redundant sensors for conductivity and temperature and a single oxygen sensor. Data were telemetered to the ship at 24 Hz. The CTD sensors are openly mounted on the top cover of the vehicle, the temperature sensors are located behind and slightly above the conductivity cells (Fig, 2). Peak flow rates past the sensors typically reached 5 m/s, with occasional extremes of 7 m/s. Flow rate exceeded the capabilities of the standard pump on Sea-Bird CTD's and therefore no pumping of sea water through the sensors was done. Seasoar sensors were exchanged with those on a pumped profiling CTD, also a Seabird 911, for calibration purposes where they could be compared with rosette samples directly. The 24 Hz data were logged and displayed on a personal computer (PC) or a Sun Computer.

B: Location of Bobbers

In May 1991, 18 bobbers were launched during Oceanus Cruise 240, Leg 2. The bobbers are sound fixing and ranging (SOFAR) floats which control their buoyancy to cycle every other day between prescribed isotherms. (J. Price, personal communication) Bobbers transmit a swept 250 hertz signal for 80 seconds, precisely 12 hours apart on a preset schedule. The range to the float can be derived from the travel time and the speed of sound in the water. While at sea, onboard tracking was done using shipboard listening stations and SOFAR receivers. Either special hydrophone arrays or a Sonobouy float was used at these stations to listen for the bobbers. In addition, drifting SOFAR receivers (DSRs) and ALFOS floats, which were deployed from the ship earlier, relayed the times of arrival (TOAs) of bobber signals to WHOI via ARGOS satellite. The TOAs and receiver position were then transmitted to the ship via INMARSAT FAX where the range from the drifting receivers to the bobber was calculated. Range information from two or three receivers was combined to locate the bobbers by triangulation. On the final cruise, the moored Autonomous listening stations (ALS), which had been recording TOAs from the bobbers since May 1991, were recovered. The ALS data were decoded and actual positions were determined for the bobbers for the times of the Seasoar surveys (Fig. 3a - Subduction 3, Fig. 3b - Subduction 4).

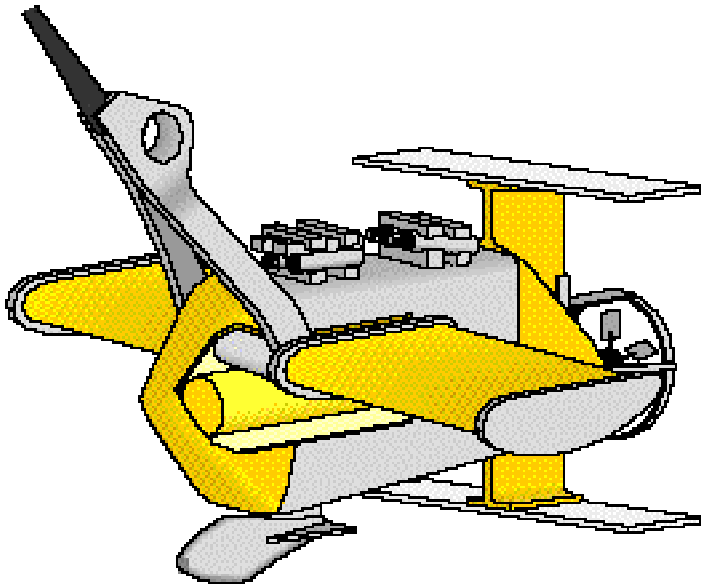

Figure 2: Seasoar vehicle with sensors.

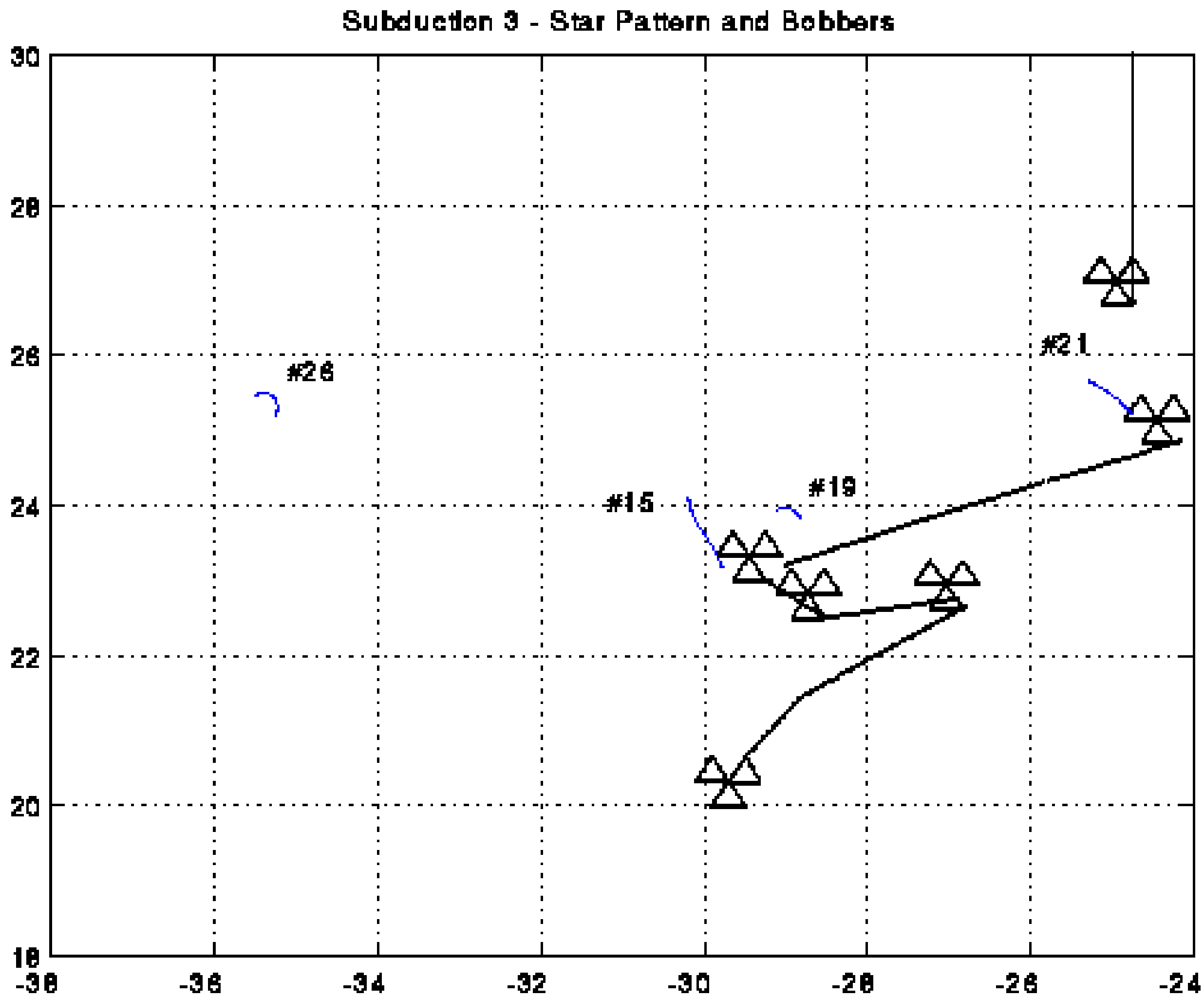

Figure 3a: Subduction 3. Bobber location at the time of Seasoar mesoscale survey determined from ALFOS data.

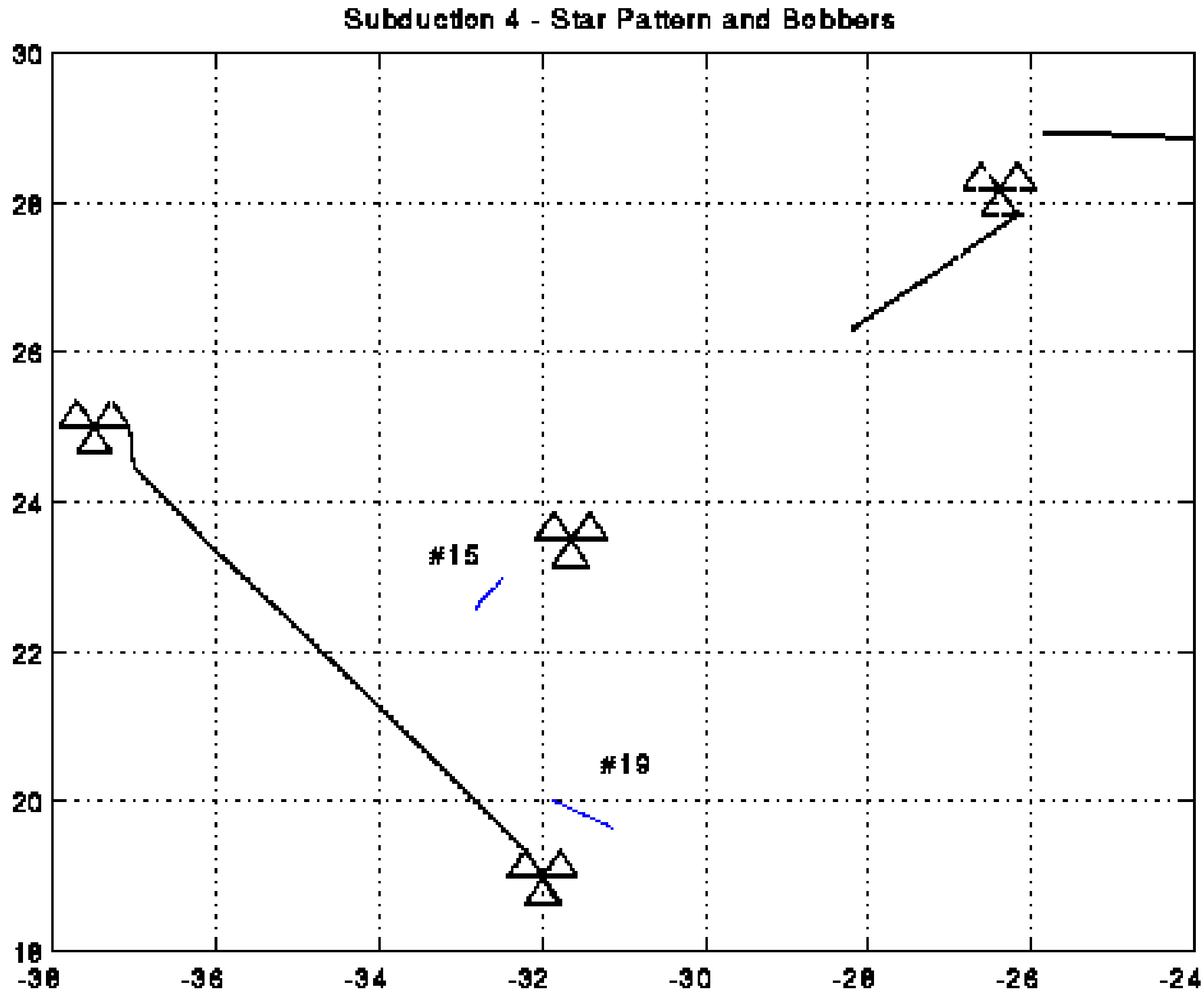

Figure 3b: Subduction 4. Bobber location at the time of Seasoar mesoscale survey determined from ALFOS data

C: Data Processing

The CTD temperature and conductivity sensors were calibrated for each cruise using a combination of lab calibrations (done by Sea-Bird at the North-West Calibration Center) and comparisons with water samples collected on a profiling CTD. All sensors were calibrated before the initial cruise and following all subsequent cruises.

The temperature sensors were corrected for drift based on the lab calibrations alone, by assuming a linear change in time between two calibrations. Corrections to the lab calibrations were +/- 0 to 2 mK (offset) and 1 +/- 0 to 0.15 mK/K (slope).

Using the corrected temperatures, water sample salinities from approximately seven deep stations per cruise were converted to conductivity for comparison with the conductivity sensors. The calibration for conductivity in shallow water where the vertical gradients are large and spatially variable is particularly difficult. The profiling CTD maintained one sensor pair (primary) throughout a cruise, the secondary sensors were swapped with the Seasoar's for calibrations. Thus, the primary sensor pair had the greatest number of water samples to use for calibration. For cruises one and three, we determined the Seasoar sensor calibration by performing a water sample calibration for the primary CTD sensors, and then fit the secondary sensors to the primaries using data from the complete cast. The bottle data for the secondary sensors then served as a consistency check for the obtained calibration values. For Subduction 4, however, this approach generated a correction to the pre-cruise lab calibration that largely exceeded the post-cruise lab calibration. This can not occur if the sensors drift essentially linearly in time. We therefore relied only on the direct bottle comparison to calibrate the Seasoar conductivity sensors. Additionally, the vertical conductivity gradient during this cruise was at times so strong that the vertical separation of 1.5 meters between bottles and sensors introduced an error large enough to affect the calibration. To correct for the spatial difference, a polynomial fit of the conductivity gradient was determined for each station, and an offset was applied based on the polynomial and the distance between bottles and sensors. The conductivity gradients from the other cruises were not large enough to require this correction. Conductivity corrections ranged from -1.7 to +0.7 mS (offset) and 1 +/- 0 to 0.6 mS/S (slope). The remaining differences between calibrated CTD conductivity and bottle conductivities were of the order of 0.2 mS/m (deep samples) to 0.5 mS/m (shallow samples), corresponding to salinity differences of 0.002 to 0.005 psu.

The calibrated 24 Hz data were then screened for anomalous points using a 9-point median filter. To determine the proper relationship between temperature and conductivity sensors influenced by their physical separation and sensor response times, salinity was calculated for various lags of temperature and pressure relative to conductivity. A lag of 4 scans (1/6 second) was found to minimize salinity spiking across sharp gradients. This lag was consistent over the course of the experiment. The data were edited further by excluding data shallower than 1 dbar. This excludes salinity spikes due to air in the conductivity cell when the Seasoar breaks the surface. Summary Figures for quality control were produced (Fig. 4). The data were then binned into 1 and 3 sec datasets (available in ASCII and matlab format on CDROM) of time, pressure, potential temperature, salinity, and potential density. Salinity and potential density were calculated after binning.

The 3 second averaged data were interpolated onto a uniform grid in depth/distance along the Seasoar track using a second order exponential filter with vertical and horizontal scales of 5 dbar and 4km, respectively. Grid points for which the sum of weights were less than or equal to 0.1 were flagged (Fig. 5). Data were then mapped onto density surfaces at intervals of 0.05 sigma-theta (Table 3, Fig. 6). Where appropriate, CTD data from the L-shaped tracer surveys were combined with the Seasoar data and input into the objective mapping programs. We chose to focus on sigma-theta levels of 26.5, 26.7 and 26.9. The levels correlate with the isotherm boundaries and corresponding average densities of the bobbers when they were initially deployed (Fig. 7). The thickness of each density surface is based on the density gradient centered on the density surface of interest with a fixed density difference of 0.05 Sigma-theta. The mapping technique used a spatial correlation scale of 10 km, and a signal to noise ratio of 50 percent was assumed. Areas with errors exceeding 95 percent were not contoured. Data was objectively mapped for all Seasoar surveys on the above-mentioned density surfaces for potential temperature, salinity, pressure and thickness (Figs. 8a - i).

Despite the variety of shipboard location tools for determination of bobber position, the actual location of bobbers during the experiment was problematic. In some instances, insufficient fixes were available to locate bobbers or two Seasoar surveys were carried out because of possible ambiguities in bobber location. Why post-experiment bobber tracks (using the moored ALS data) seem to be 'offset' from at-sea locations has not been resolved. Thus, the Seasoar maps around bobbers should be considered only to reflect the general characteristics of the water masses at that particular time.

Table 3: Mean and standard deviation of theta, pressure and thickness on density surfaces 26.5, 26.7, 26.9 for all star patterns surveyed. Not enough data were available for density level 26.9 for surveys 3 and 4 during Subduction 4.

SUBDUCTION 1 - STAR PATTERN 1:
DATES: 05/16/91 10:30 - 05/20/91 07:30
BOBBER #: 24,29,22,5,8,21,16,17,18,23,25
MEAN LAT: 31.4729 N
MEAN LONG: -22.4486 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.7702	16.2514	13.9505
Std. Theta	0.0201	0.0680	0.0206
Avg. Press	60.7186	240.5842	364.9566
Std. Press	10.9056	10.0753	4.1349
Avg. Thick	78.4115	31.4357	36.6801
Std. Thick	5.6687	1.5292	1.3638
# grid pts	86	469	223

SUBDUCTION 1 - STAR PATTERN 2:
DATES: 05/23/91 06:00 - 05/27/91 20:00
BOBBER #: 19,14,11,12,26,20,15
MEAN LAT: 29.0139 N
MEAN LONG: -23.5313 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.8185	16.1601	13.9314
Std. Theta	0.1699	0.0929	0.0249
Avg. Press	124.4070	241.9765	366.1262
Std. Press	6.6596	6.3833	4.9197
Avg. Thick	41.0442	30.1820	35.9329
Std. Thick	8.8076	1.6768	1.3890
# grid pts	473	473	346

SUBDUCTION 1 - STAR PATTERN 3:
DATES: 05/31/91 06:30 - 06/02/91 01:30
BOBBER #:
MEAN LAT: 29.9845 N
MEAN LONG: -21.6587 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.7825	16.4236	13.9782
Std. Theta	0.2247	0.1287	0.0264
Avg. Press	51.0511	216.5273	340.1730
Std. Press	4.2587	15.9862	18.1612
Avg. Thick	45.1072	27.1940	36.2476
Std. Thick	5.5786	4.7615	1.0980
# grid pts	418	420	360

SUBDUCTION 3 - STAR PATTERN 1:
DATES: 11/28/92 22:00 - 11/30/92 14:00
BOBBER #: 26
MEAN LAT: 20.3393 N
MEAN LONG: -29.6893 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	17.6773	15.6800	13.5893
Std. Theta	0.1868	0.1361	0.0823
Avg. Press	163.4997	234.0999	342.2342
Std. Press	10.8143	11.4590	10.1150
Avg. Thick	13.0774	22.1654	30.2678
Std. Thick	0.8380	1.6846	1.5926
# grid pts	308	308	304

SUBDUCTION 3 - STAR PATTERN 2:
DATES: 12/01/92 01:00 - 12/02/91 18:30
BOBBER #: 15,25
MEAN LAT: 22.8685 N
MEAN LONG: -27.0472 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.2682	16.0629	13.8362
Std. Theta	0.0742	0.0673	0.0426
Avg. Press	180.6118	262.3036	373.9740
Std. Press	5.6818	5.9471	5.1209
Avg. Thick	14.5908	24.6175	28.2718
Std. Thick	0.6068	1.1954	1.4681
# grid pts	308	308	308

SUBDUCTION 3 - STAR PATTERN 3:
DATES: 12/02/92 19:00 - 12/04/92 19:30
BOBBER #: 19
MEAN LAT: 22.7953 N
MEAN LONG: -28.6941 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.3048	16.0337	13.8438
Std. Theta	0.0858	0.0732	0.0374
Avg. Press	191.6362	271.8771	376.0974
Std. Press	6.4222	5.5544	5.1748
Avg. Thick	14.3554	23.5976	24.8414
Std. Thick	0.7220	0.8780	1.5926
# grid pts	312	312	303

SUBDUCTION 3 - STAR PATTERN 4:
DATES: 12/04/92 20:00 - 12/06/92 01:00
BOBBER #: 15
MEAN LAT: 23.2972 N
MEAN LONG: -29.4279 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.1389	15.8712	13.7206
Std. Theta	0.2898	0.2891	0.1830
Avg. Press	187.0571	268.6239	374.4001
Std. Press	5.9160	8.1597	9.1982
Avg. Thick	14.3723	24.3347	25.0590
Std. Thick	0.8294	1.0564	1.4868
# grid pts	301	301	298

SUBDUCTION 3 - STAR PATTERN 5:
DATES: 12/08/92 09:30 - 12/11/92 13:30
BOBBER #: 21
MEAN LAT: 25.1120 N
MEAN LONG: -24.4478 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.5389	16.2373	13.9424
Std. Theta	0.0331	0.0267	0.0070
Avg. Press	176.1963	268.6849	387.1770
Std. Press	4.8472	4.9632	6.2923
Avg. Thick	18.6155	28.0117	30.1917
Std. Thick	1.3784	0.8609	1.1335
# grid pts	272	272	272

SUBDUCTION 3 - STAR PATTERN 6:
DATES: 12/11/92 13:30 - 12/12/92 18:30
BOBBER #: 20
MEAN LAT: 26.9678 N
MEAN LONG: -24.9349 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.2821	16.1338	13.9678
Std. Theta	0.0512	0.0342	0.0164
Avg. Press	164.3603	256.8055	362.1923
Std. Press	3.9648	4.1351	3.9743
Avg. Thick	19.5107	28.0923	33.5705
Std. Thick	0.7727	1.1078	0.8828
# grid pts	265	265	265

SUBDUCTION 4 - STAR PATTERN 1:
DATES: 05/24/93 07:30 - 05/27/93 12:00
BOBBER #: 19
MEAN LAT: 18.9862 N
MEAN LONG: -31.9748 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	17.8358	15.6538	13.5999
Std. Theta	0.1302	0.0988	0.1453
Avg. Press	199.7486	261.7677	361.3810
Std. Press	10.6113	11.6073	8.3183
Avg. Thick	11.1412	20.6743	28.2127
Std. Thick	0.8561	0.9830	2.1628
# grid pts	306	306	279

SUBDUCTION 4 - STAR PATTERN 2:
DATES: 05/30/93 02:00 - 05.31.93 13:30
BOBBER #: 26
MEAN LAT: 24.2855 N
MEAN LONG: -37.4544 E

Sigma-Theta	26.5	26.7	26.9
Avg. Theta	18.0407	16.0338	13.9275
Std. Theta	0.0810	0.0271	0.0122
Avg. Press	224.9581	318.8388	389.9046
Std. Press	8.3322	9.2240	4.6894
Avg. Thick	18.3139	27.8029	30.8733
Std. Thick	1.4372	1.4772	1.5640
# grid pts	335	335	132

SUBDUCTION 4 - STAR PATTERN 3:
DATES: 06/02/93 01:30 - 06/03/93 14:00
BOBBER #: 15
MEAN LAT: 23.5120 N
MEAN LONG: -31.6550 E

Sigma-Theta	26.5	26.7
Avg. Theta	18.1924	16.0873
Std. Theta	0.0251	0.0184
Avg. Press	192.4304	281.1632
Std. Press	5.9920	5.0778
Avg. Thick	17.1146	26.1395
Std. Thick	1.3808	1.8345
# grid pts	306	306

SUBDUCTION 4 - STAR PATTERN 4:
DATES: 06/05/93 15:00 - 06/08/93 17:30
BOBBER #: 21
MEAN LAT: 28.1707 N
MEAN LONG: -26.3902 E

Sigma-Theta	26.5	26.7
Avg. Theta	18.4098	16.0449
Std. Theta	0.0979	0.0424
Avg. Press	183.8366	292.0272
Std. Press	11.0004	10.4090
Avg. Thick	31.0742	28.0224
Std. Thick	3.0547	1.4874
# grid pts	366	362

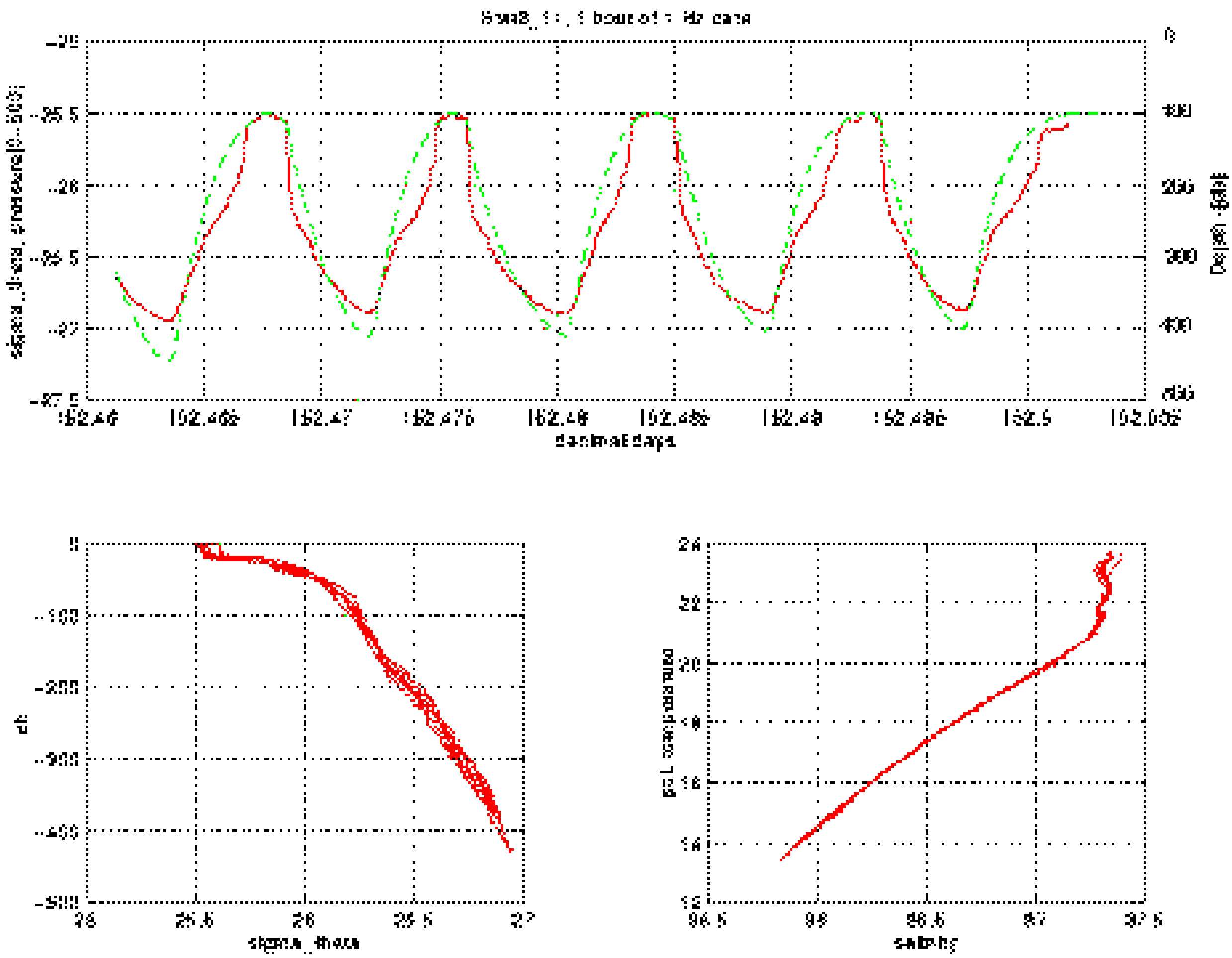

Figure 4: One hour summary plots of Seasoar track. In the upper plot, the dotted line represents pressure over a 0-500 db range vs time. The solid line represent sigma-theta over range of 25 - 27.5.

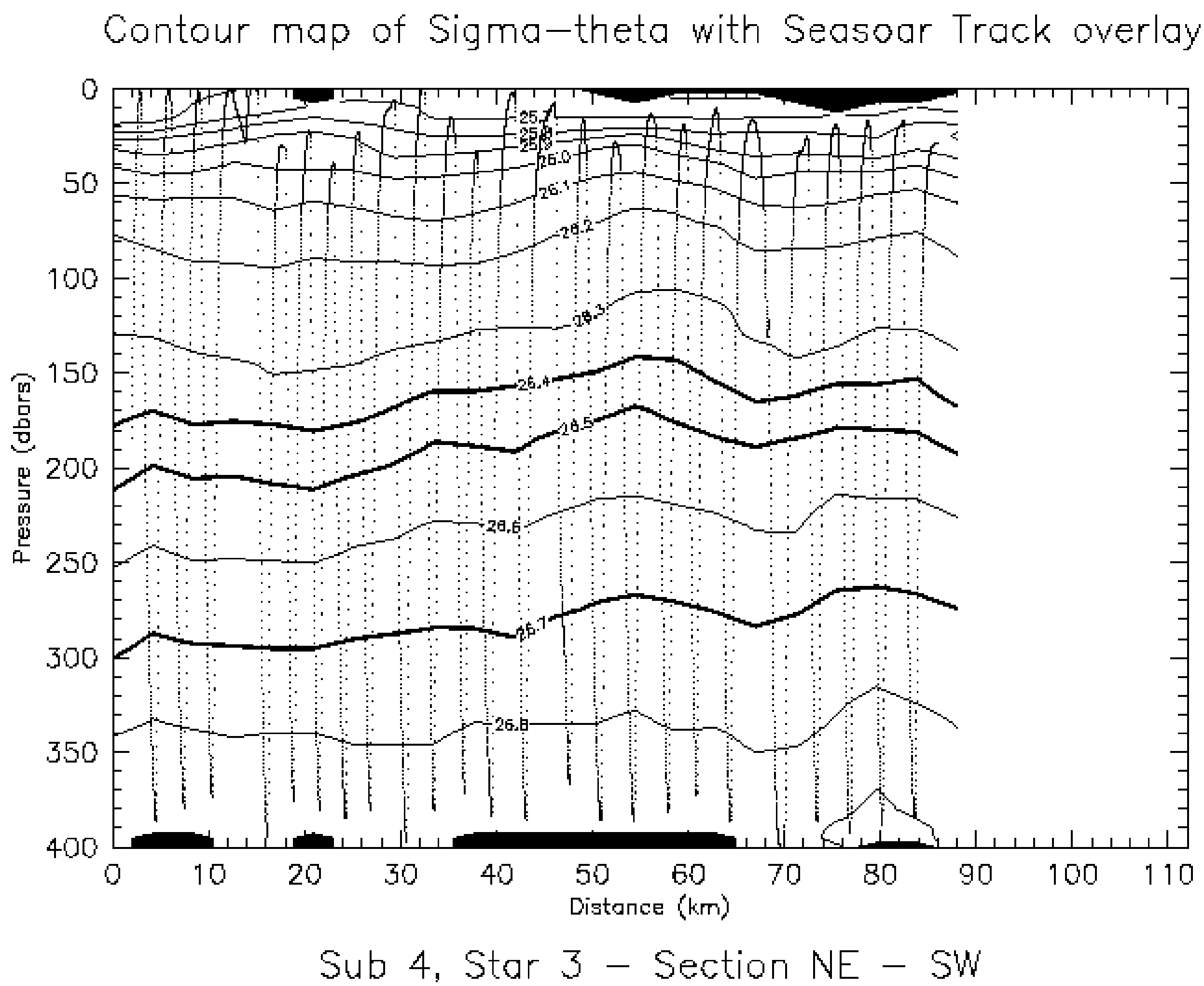

Figure 5: Theta Contour plot of gridded Seasoar data along transect 2 of Cruise 3. Gray areas denote unavailable data. The darker lines represent average sigma-theta, during Subduction 1, where the bobbers were deployed. (see Fig. 7).

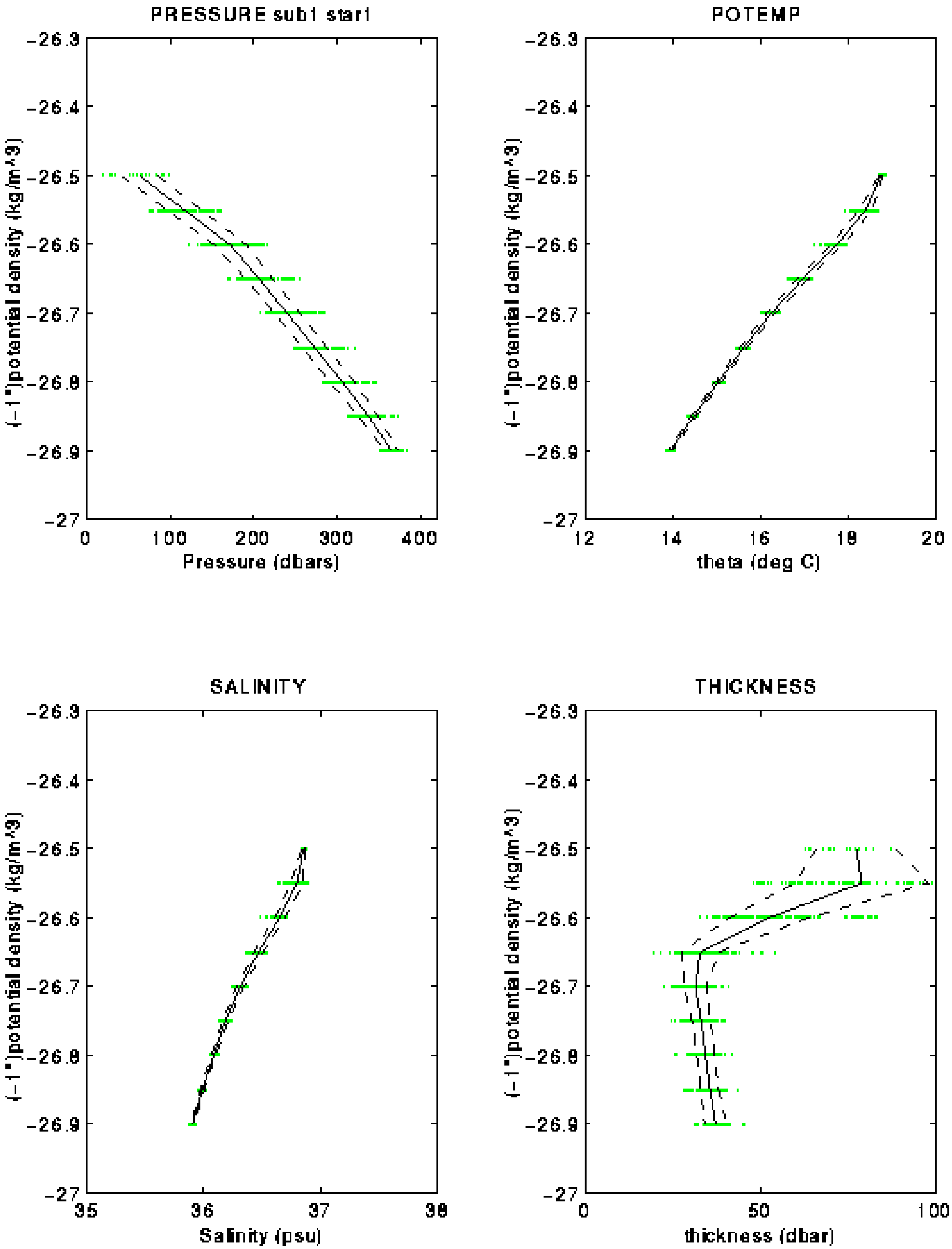

Figure 6: Example Summary plot of Pressure, Theta, Salinity and Thickness vs. Sigma-theta. See Appendix A.

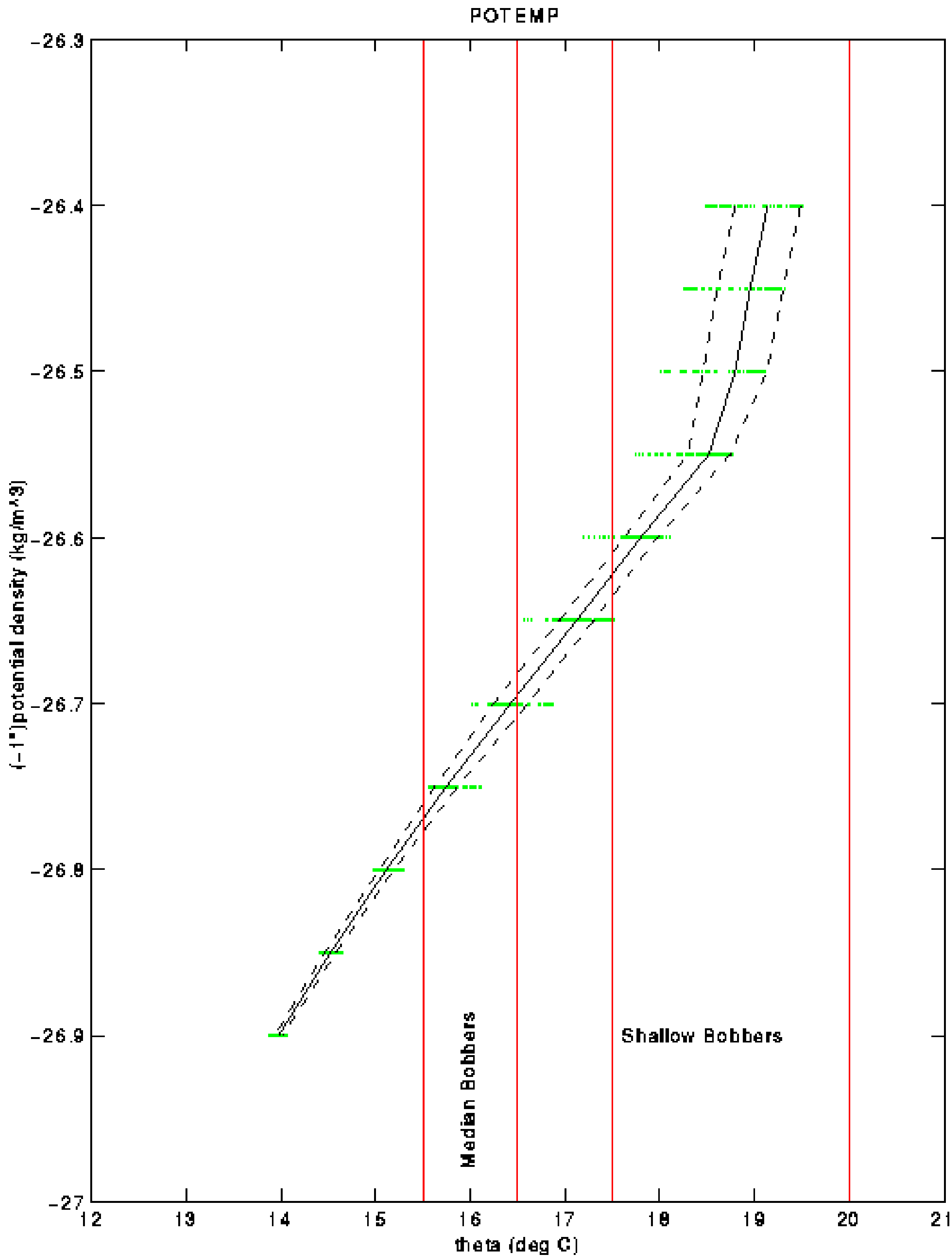

Figure 7: Representative range of bobber movements during Subduction 1.

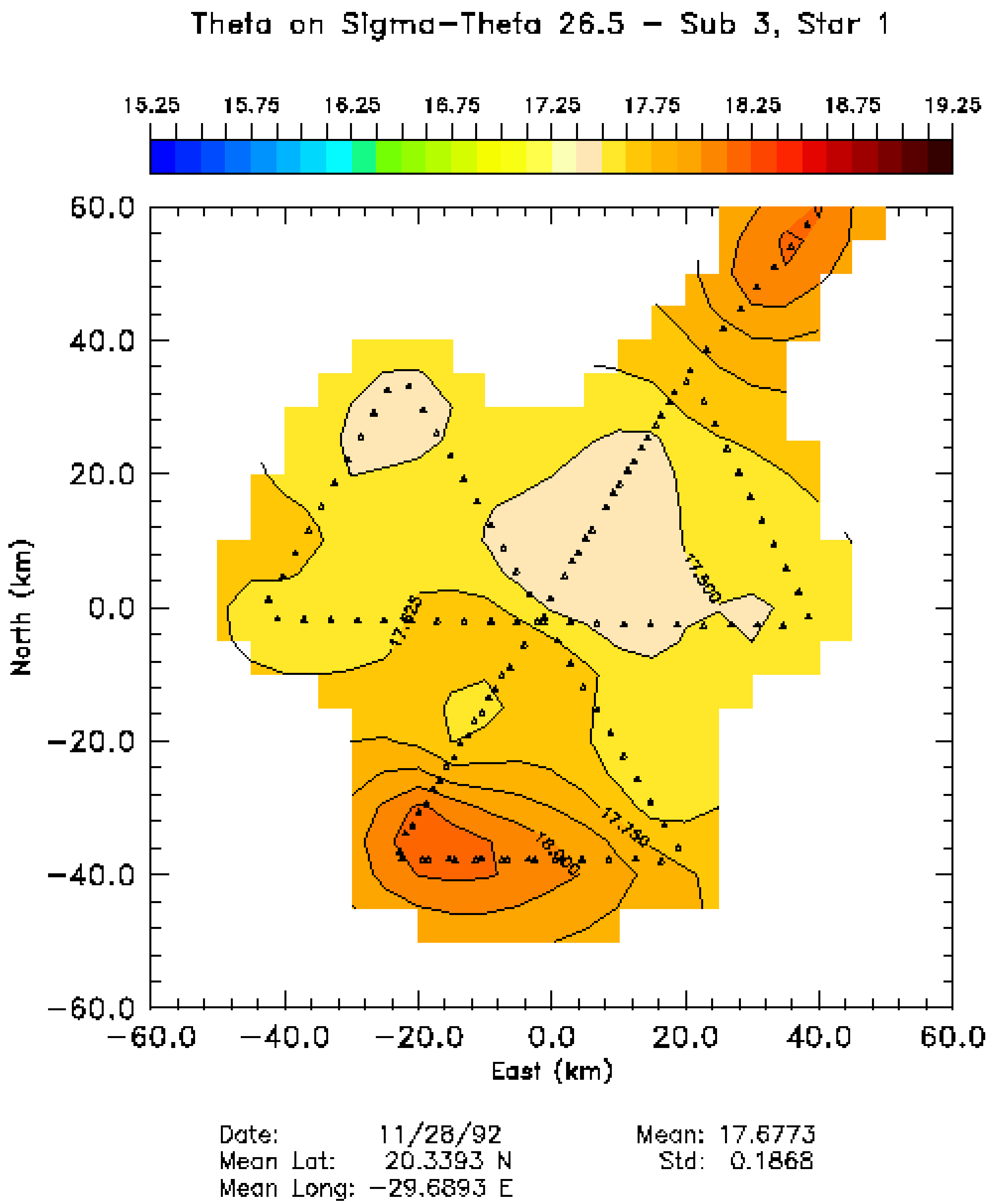

Figure 8a - 8i: Representative contour maps of theta, pressure and thickness for density levels 26.5, 26.7, 26.9. Each map contains a mean and standard deviation (STD) of the observed property over the entire star pattern . See Appendix D.

D: Underway Currents – ADCP

Shipboard Acoustic Dopler Current Profiler (ADCP) data were collected during all four Subduction cruises using a standard 150KHz RD Instruments transducer. The setup used 8 meter vertical bins with 8 or 16 meter pulse lengths averaged over 5 minutes. Bottom tracking data were collected over the continental shelf leaving Woods Hole, and for very short periods over the slopes of the Azores, Madeira and Gran Canaria. One-second navigation data were provided by a Magnavox MX4200 Global Positioning System (GPS) receiver.

The ADCP data were processed with the Common Oceanographic Data Access System (CODAS) software developed by Eric Firing from the University of Hawaii (Bahr et al., 1990). After the data were loaded into a database, the individual profiles were edited for anomalous points based on editing criteria such as large second vertical derivatives of eastward (u) and northward (v) velocity components, large vertical (w) and error velocities, and subsurface maxima of backscatter amplitude. Aside from the usual amplitude warnings triggered by either bottom interference or biological scattering layers, we found occasional interference from the hydrowire when the CTD package had drifted into one of the ADCP beams. Next the GPS fixes were screened for outliers based on number of satellites used and Horizontal Dilution Of Precision (HDOP) values, and then merged with the ADCP data to provide absolute velocities. This step involved the intermediate calculation of the absolute velocity of a reference layer (e.g., Kosro,1985, see Table 4 for layer range). The velocity of the reference layer is the difference between the velocity of the ship over the ground, determined by the fixes, and the velocity of the ship relative to the reference layer, calculated from the ADCP profiles. This initial estimate of the reference layer velocity, which is constant between fixes, was then smoothed by convolution with a Blackman window function (Blackman and Tukey, 1959). The choice of filter width generally depends on the quality of the fixes. For Subduction 1, which occurred shortly after the Gulf war Desert Storm, selective availability (SA) was not in effect, and the fix quality was accordingly good. SA was in effect, however, for Subduction 3 and 4, and the filter needed to be correspondingly larger (Table 4).

Bottom track calibration was performed using mostly the Woods Hole continental shelf data, since the island bottom tracking was often too short. Underway calibrations were done on cruises with many CTD stations. In this type of calibration, velocity differences measured by the ADCP (e.g., when departing from station) are compared with those measured by the satellite navigation. This method has a large uncertainty associated with each individual calibration point and a large number of points need to be taken. Calibration values were computed for each cruise from a combination of bottom track and water track information (Table 4).

Table 4: ADCP processing parameter settings

	Subduction 1	Subduction 3	Subduction 4
reference	bins 5-20	bins 5-17	bins 5-20
layer range	(50-170m)	(50-145m)	(50-170m)
smoothing filter	20 minutes	30 minutes	30 minutes
half width			
calibration phase	-1.32 degrees	-1.5 degrees	-1.7 degrees
and amplitude	1.007	1.005	1.005

In order to produce maps of velocity on density surfaces, temperature and salinity profiles were generated from 15-minute averages of the Seasoar data. Using this database, the ADCP data were vertically regridded on density, and 30-minute averaged vectors over the two shallower density intervals were calculated (Figs. 9a-b). In addition, 30-minute averages of ADCP velocity along the original depth bins were produced in ASCII format (available on CD-ROM).

4. DISCUSSION

The initial deployment cruise for the bobbers, in May 1991, came just as the water column began to stratify. The remnant mixed layer was deep and reflected the characteristics of late winter conditions. The density modes for the first two star patterns indicated that the initial winter mixed layer depth was between 100 and 150 meters (See Appendix B: Figs. Sub 1, Star 1 - Section SE-NW and Sub 1, Star 2, Section SE - NW). The Subduction bobber cruises were distributed in time in such a way as to cover a two year lifespan. However, due to the concentration in the northern region near the Azores Front on the second cruise (February 1992), no Seasoar data were collected near any of the bobbers. Thus, the temporal sampling between the bobber cruises was uneven, with intervals of 18 and 6 months.

The 'star' patterns were carried out in order to map the variability around the bobber floats. During the initial cruise, the star patterns each consumed about 45 hours of shiptime. The long legs of the patterns were approximately 110 km in length. An analysis of temperature, pressure, and thickness variations on the individual legs indicated that the de-correlation scale was 8-10 km. Error maps made from the objective mapping of the data showed that the star pattern was too large: large areas within the pattern were poorly mapped. In subsequent cruises, the scale of the pattern was reduced so that the long legs of the pattern were approximately 80 km. Not only did this better 'map' the variability, it took less shiptime (27 hrs/survey)!

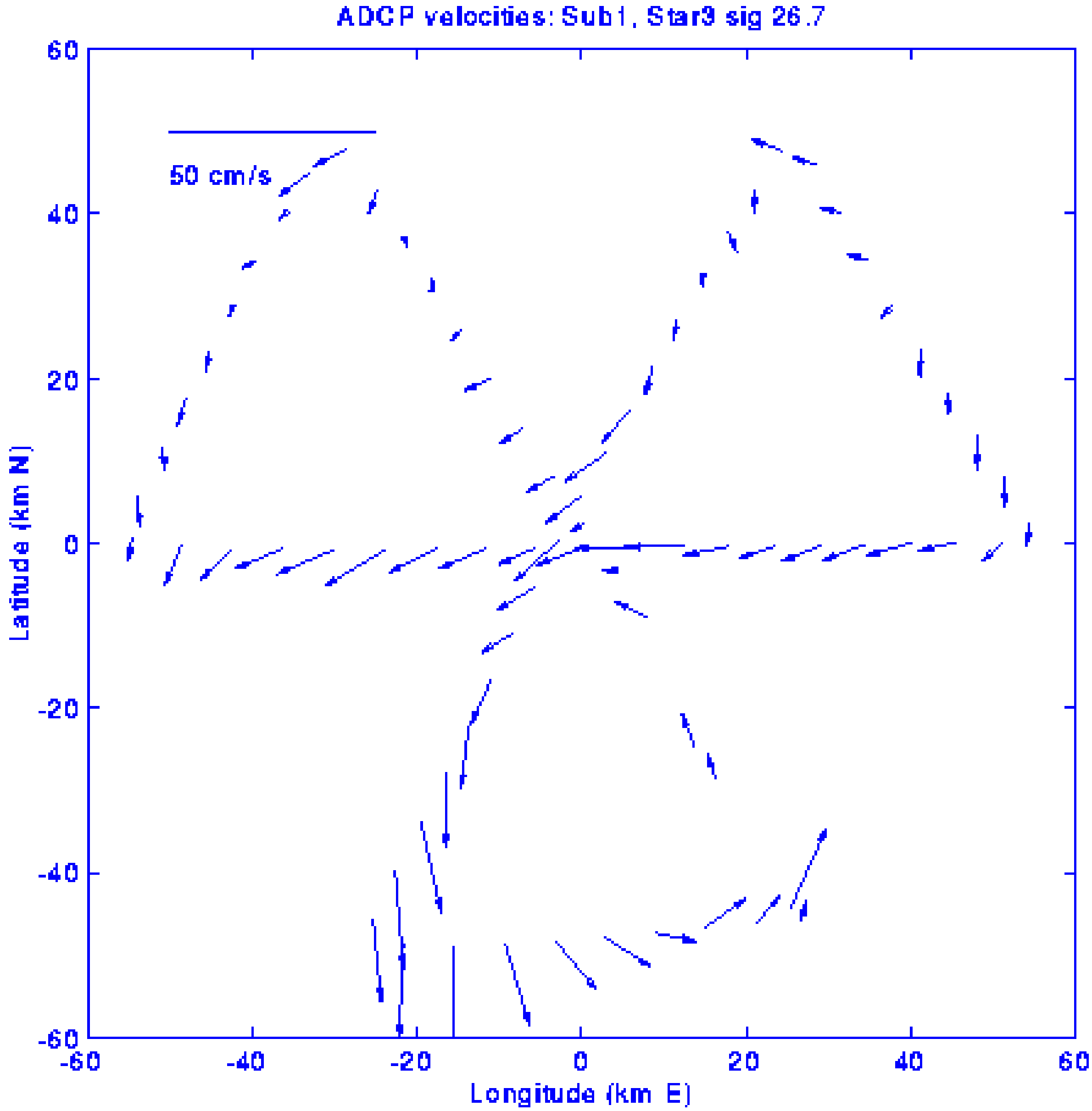

Figure 9: Representative map of ADCP velocities on a star pattern at density levels 26.5 (fig 9a) and level 26.7 (fig 9b). See Appendix E.

5. ACKNOWLEDGMENTS:

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7. APPENDICES (figs. Available electronically from WHPO)

A: Star Pattern - Data Summaries

Seasoar data were summarized for each star pattern surveyed during the subduction experiment. The gridded data were mapped onto density surfaces of 0.05 sigma-theta. Plots of pressure, potential temperature, salinity and thickness vs potential density for each survey are presented in figures A-1 - A-13. Location and time of the survey is described in Figure 1 and Table 2.

B: Section Contour Plots for Star Patterns:

Contour plots of gridded Seasoar data along selected sections of the radiator pattern are shown in figures B-1 - B-15. Each figure consists of a sigma-theta, theta and salinity contour plot for the specified section. Location of the section on the star pattern is highlighted on the star pattern shown in figure B-1. Position and time of the individual star pattern is described in Figure 1 and Table 2. Gray areas denote unavailable data. The darker lines represent the average theta and sigma-theta where the bobbers were deployed during Subduction 1. (see Fig. 7).

C: Long Sections Surveyed between Star Patterns

Contour plots of gridded Seasoar data along several long transects during the Subduction 3 and 4 cruises proceed figures C-1 - C-21. Position and time of the transects can be located on Figure 1 and Table 2. Gray shading denote areas of unavailable data. The darker lines represent the average theta and sigma-theta where the bobbers were deployed during Subduction 1. (see Fig. 7). Color versions of these maps are available on the accompanying CDROM.

D: Star Pattern Objective Maps

Figures D-1 - D-110 present objectively mapped plots of ocean properties on potential density surfaces of 26.5, 26.7, 26.9. Theta, pressure and thickness are individually plotted on the selected surfaces. The triangles on the plots denotes 15 minute averages along the cruise track. Color versions of these maps are available on the accompanying CDROM.

E: ADCP Maps for Star Patterns

Figures E-1 - E-15 show ADCP velocity maps for each star pattern on potential density surfaces of 26.5 and 26.7. ADCP vectors were averaged in density space over 0.05 sigma theta.

F: Contents of Accompanying CD-ROM.