DETAILED REPORTS

1. Physical oceanography; submitted by A. F. Amos, M. K. Lavender, and J. K. Heimann, University of Texas at Austin, Marine Science Institute.

1.1 Objectives: The physical oceanography component of the AMLR program provides information on the hydrography of the upper water column with the objective of assessing its influence on the observed distribution of krill (*Euphausia superba*). By making closely spaced CTD/rosette casts, the water masses of the Elephant Island region can be identified, and the mean current flow deduced. This component also records the meteorological and sea surface conditions continuously while the *Surveyor* is in the study region to study the effect of atmospheric conditions on the upper-water-layer structure. AMLR 1992 is the third field season for the collaboration of physical measurements with biological studies.

1.2 Accomplishments:

CTD/Rosette Stations: One hundred and eighty-eight (188) CTD/rosette casts were made during AMLR 1992. The cruise was divided into two legs; stations done during Leg I were re-occupied during Leg II about one month later. The large-area survey of 72 stations (Figure 2--Introduction), which was on a quarter degree latitude by half-degree longitude grid, was the major CTD survey of AMLR 1992. Due to medical emergencies diverting the ship, only 64 stations of the grid were done during Leg I; the eastern-most line on meridian 53°30'W was omitted. Two cross-shelf transects of closely-spaced CTD stations were made north of Elephant Island on each leg to define the boundary of the shelf-break oceanographic front discovered on previous AMLR cruises (Figure 3--Introduction). Time allowed us to complete two additional cross-shelf transects to augment the planned cross-shelf study. Finally, eight CTD/rosette casts were done in conjunction with the MOCNESS tows.

Following the convention established on previous AMLR cruises, the large-area survey stations were designated "A" (A01 through A64) on Leg I, and "D" (D01 through D72) on Leg II. Cross-shelf transects and any extra stations were designated "X" (X01 through X16 on Leg I, and X17 through X44 on Leg II). The fine-scale MOCNESS sampling stations were designated "M" (M02, M04, M06, M07, M10, M12, M15, and M18 on Leg I only).

Almost two thousand water samples were collected from the rosette bottles. Water samples were collected for determination of micronutrient, phytoplankton, chlorophyll, and salinity content. Salinity data were analyzed on board (using a Guildline Autosal) by *Surveyor's* survey technicians to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor. On both legs, expendable bathythermographs (XBTs) were deployed during the acoustic surveys where time did not permit CTD/rosette casts to be made. Additional XBT drops were done across the

Drake Passage on both southbound transits to provide the Servicio Hidrográfico y Oceanográfico de la Armada with information on the Antarctic Polar Front. Some XBTs for these projects were provided by the University of Texas Marine Science Institute (UTMSI) and some by *Surveyor*.

Underway environmental observations: Sixty-three days of weather, sea temperature, salinity, clarity, chlorophyll, and solar radiation data were continuously collected during AMLR 1992. Augmented with the ship's navigational information, these data provided complete coverage of surface environmental conditions encountered throughout the cruise. A University of Texas Zeno (Coastal Climate Co.) weather station was installed by the Seal Island party on the hill above the Seal Island camp. Records have been recovered from the instrument for the period 14 Dec 1991 through 06 March 1992 (83 days). The weather station was left in place on Seal Island to provide a year-round record of weather conditions there. Data were provided to *Surveyor* whenever the ship visited the island to provide comparison with ship's underway weather data.

1.3 Methods:

CTD/Rosette: The water column was sampled continuously with a Sea-Bird Electronics SBE-9 CTD. CTD/rosette casts were limited to 750 meters (m) depth (or to within a few meters of the ocean floor when the depth was less than 750m). A Benthos 12-kHz pinger was attached to the rosette frame. A Sea-Bird dissolved oxygen sensor, Seatech 25-cm beam transmissometer, a Biospherical Instruments PAR sensor, and a Seatech *in situ* fluorometer provided additional water column data on each station. A standard General Oceanics RMS Mk VI rosette sampler with eleven 10-liter bottles was used to collect the water samples. The space usually occupied by the twelfth bottled was used to mount the PAR sensor which requires a clear field of view of the downwelling light. All Niskin bottles had teflon coated springs to minimize contamination of the sample. CTD data were collected using a Data World 25 MHz 386 PC and stored on Bernoulli 44 megabytes (MB) removable disk cartridges.

The CTD was lowered at a rate of 50m/min with a sampling rate of 24 scans per second and raised at a rate of 60-75m/min with a sampling rate of 6 scans per second. Rosette bottles were triggered at the bottom (usually 750m) and then at pre-determined levels as the instrument was brought to the surface. Triggering the rosette did not interfere with the flow of CTD data as a three-conductor electromechanical cable was used. Data from each sensor are recorded on "Mark" files at the moment the bottle is triggered. At stations shallower than 750m, the pinger was used to guide the instrument to within 5-10 meters of the ocean floor. The cross-shelf transect stations were taken to the bottom or 2000m, whichever was shallower. For these, the fluorometer and PAR sensors had to be removed due to their pressure-case limitations.

CTD data were processed on board ship using Sea-Bird's software to produce files with data averaged over 1-m depth bins. A series of programs developed by the principal investigator were then used to perform dynamic computations, generate Temperature/Salinity (T/S) curves and property-property diagrams, and conduct a preliminary analysis of the data. These data were provided to other AMLR scientists for their initial analyses. No attempt was made to apply salinity corrections to these data. Comparison of the Autosal salinities with those from the CTD showed an offset of about 0.020 $^{o}/_{oo}$. Many of the sample depths are within high temperature and salinity gradients and are not suitable for this type of calibration. A detailed analysis of these differences must be done before the final corrections are made.

Underway data: Data from twelve environmental sensors were collected, multiplexed, and combined with the GPS navigation information. Ship's position and environmental data were acquired from the *Surveyor's* ETHERNET LAN using a program (LOGUNDER) and the ship's Everex 386 computer. This provided GPS position, ship's course and speed, relative wind speed and direction, air temperature (from a Coastal Climate Weatherpak), and sea temperature and salinity from the ship's Sea-Bird SBE-21 thermosalinograph. Using a Weathermeasure signal-conditioning unit, barometric pressure, air temperature, relative humidity, and sea-surface temperature (from a towed thermistor) data were sent to a Hewlett-Packard 3421A data acquisition unit where they were multiplexed and sent to the Data World computer via IEEE-488 GPIB interface.

Three optical sensors, an Eppley PSP pyroheliometer, a Bisospherical Instruments PAR sensor, and an Eppley TUVR sensor, were mounted on the flying bridge to sense solar radiation relatively unobstructed by *Surveyor's* superstructure and masts. These data were fed directly to the HP multiplexer. Finally, a plumbed sea-water flow-through system provided bubble-free water for a Seatech 25-cm transmissometer and a Turner Designs fluorometer to monitor sea-surface water clarity and chlorophyll fluorescence. The inputs were also fed to the HP 3421A.

Because of problems with the direct GPIB interface, these underway data were sent to the computer using a National Instruments GPIB/RS 232 controller (Leg II only). Data were collected at one-minute intervals throughout both legs. On Leg II, a Hewlett-Packard 7475A plotter was used to provide real-time graphical representation of environmental conditions. Daily logs and plots of the data were provided to AMLR investigators and the ship's navigator.

1.4 Preliminary Results and Analysis:

Water masses: From previous AMLR cruises we have recognized several water mass types in the Elephant Island region, designated types I through V. They have been classified by their T/S curve from the surface to 750m.

TYPE I — Drake Passage water: warm, low salinity water, strong sub-surface temperature minimum ("Winter Water," approximately -1°C; salinity 34.0 ppt.), a temperature maximum at the core of the Circumpolar Deep Water (CDW) near 500 meters.

TYPE II A transition water: temperature minimum near 0°C, isopycnal mixing below T-min, CDW evident at some locations.

TYPE III Weddell-Scotia Confluence: little evidence of a temperature minimum, mixing with Type II, no CDW, temperature at depth generally > 0°C.

TYPE IV Eastern Bransfield Strait water: deep temperature near -1°C, salinity 34.5 ppt, cooler surface temperatures.

TYPE V Weddell Sea water: little vertical structure, cold surface temperatures (near or below 0°C).

These are broad classifications involving the entire water column as shown in the insets of Figure 1.1, which also shows the approximate boundaries of the water masses from Leg I of this cruise. In assessing the relationship between these water mass types and the distribution of krill, it may be that the upper 50-100m of the water column is the most important vertical zone. In this case, the major feature in the AMLR area is the abrupt transition between Drake Passage (oceanic) water and Bransfield Strait (shelf) water.

Oceanographically, the Elephant Island zone is bisected by this front. To the north and west, waters of the Drake in summer show the influence of summer warming with surface temperature above 2°, salinity less than 34 $^{o}/_{oo}$ (from melting ice), and a deep mixed layer (often >50m) from the strong winds which prevail in the region. Below the mixed layer, the remnants of the previous winter's surface water form a strong temperature minimum which weakens as the summer progresses. Under this layer, temperature and salinity increase to a maximum of near 2° around 500m, and then slowly decrease to the bottom. The T-max near 500m is the CDW, a water mass which is circumpolar around the continent and is the result of upwelling of water whose origins lie far to the north in the Atlantic Ocean. This year, a dissolved oxygen sensor provided additional information on water mass characteristics; the CDW is depleted in oxygen.

In contrast, the water on the Elephant Island side of the front shows no evidence of CDW, little winter water (although there is a sharp T-min), and higher oxygen despite the depth of almost 1200m at station X39. The transition zone in the front is characterized by mixing of CDW with the more coastal water. Temperature and salinity inversions fall along isopycnal surfaces thus permitting CDW to mix up into the water column. This may be an important mechanism for the vertical transport of krill eggs and larvae north of Elephant Island.

Temporal changes: Leg I took place in the late austral summer and Leg II in the early fall. The contrast was evident in the cooling of surface waters as summer progressed into fall (Figures 1.2a and 1.2b), and in the weakening of the temperature minimum associated with the winter water at depths which ranged below 100m on Leg I to 75m on

Leg II. The change in salinity from $<34^{o}/_{oo}$ in the Drake to $>34.3^{o}/_{oo}$ west of Clarence Island, is the most evident expression of the front at the ocean surface. On Leg I, a broad area of low salinity extended almost to Elephant Island, and the frontal boundary was diffuse (Figure 1.3a). By late February, the higher salinity water had pushed north and westward, intensifying the salinity gradient along the shelf break (Figure 1.3b). To illustrate the differences in water mass characteristics between the two surveys, miniaturized T/S curves have been plotted on the AMLR 1992 station locations (Figures 1.4a and 1.4b). These "worm" diagrams clearly show the contrast between Drake Passage water to the north of Elephant Island, and Bransfield water to the south. The intrusion and mixing of water on the shelf during Leg II (Figure 1.4b) can be seen in the shape of the T/S curves between 60°30'S and 61°S, west of 56°W. In both seasons, a transition zone is evident at the extreme north of the area, perhaps showing a meander in the Weddell-Scotia Confluence (WSC).

Dynamics: Figures 1.5a and 1.5b show the streamlines of the flow implied from the dynamical calculations from the large-area surveys of Legs I and II. To illustrate, we have used the slope of the sea surface relative to the 500 decibar (db) level. The main axis of the geostrophic flow is from southwest to northeast both in the Drake and the Bransfield. By early March, the flow becomes more complex with meanders and a more easterly component. A concentration of streamlines shows intensified flow between Clarence and Elephant Islands during both legs. It must be emphasized that these are preliminary examinations of the data only, and additional analysis remains to be done.

1.5 Disposition of Data: The CTD/rosette, underway, weather station and XBT data have been stored on Bernoulli 44MB disks. The raw data will be taken to the University of Texas Marine Science Institute in Port Aransas, Texas, U.S.A. Copies of preliminary data, both 1-m averaged CTD and underway data, have been provided to the acoustics and phytoplankton groups.

1.6 Problems and Suggestions: We experienced problems with the ship's Everex computer and some A/C power problems which caused temporary loss of underway data as well as erroneous information that was at first hard to detect. We would like to see a new computer (with math co-processor) for CTD/underway use on future AMLR cruises. The Everex has historically given us problems, especially in interfacing with the GPIB bus and our Bernoulli disk controller on which we rely to store the mass of data collected by this component of AMLR. The *Surveyor's* LAN was a most useful tool to use for temporary data storage and from which to acquire the ship's position and environmental data. The after part of the chart room provided us with excellent space for the CTD lab equipment.

1.7 Acknowledgements: We are grateful for the excellent support provided by *Surveyor* and her crew. Special thanks goes to the ship's electronics technicians who helped out whenever equipment failed and were not once stumped by a problem. The survey technicians did first class service in preparing and launching the CTD and running the endless numbers of salinity samples. Thanks are also due to the survey technicians for helping us out in running extra samples from another project when the R/V *Polar Duke's* salinometer broke down. The winch operators did an excellent job and often in most inclement weather. Finally, we thank the ship's officers who held station and directed the over-the-side work, in particular, LCDR Fred Rossmann and LT John Humphrey who stood 12-hours watches on deck every day during the surveys.

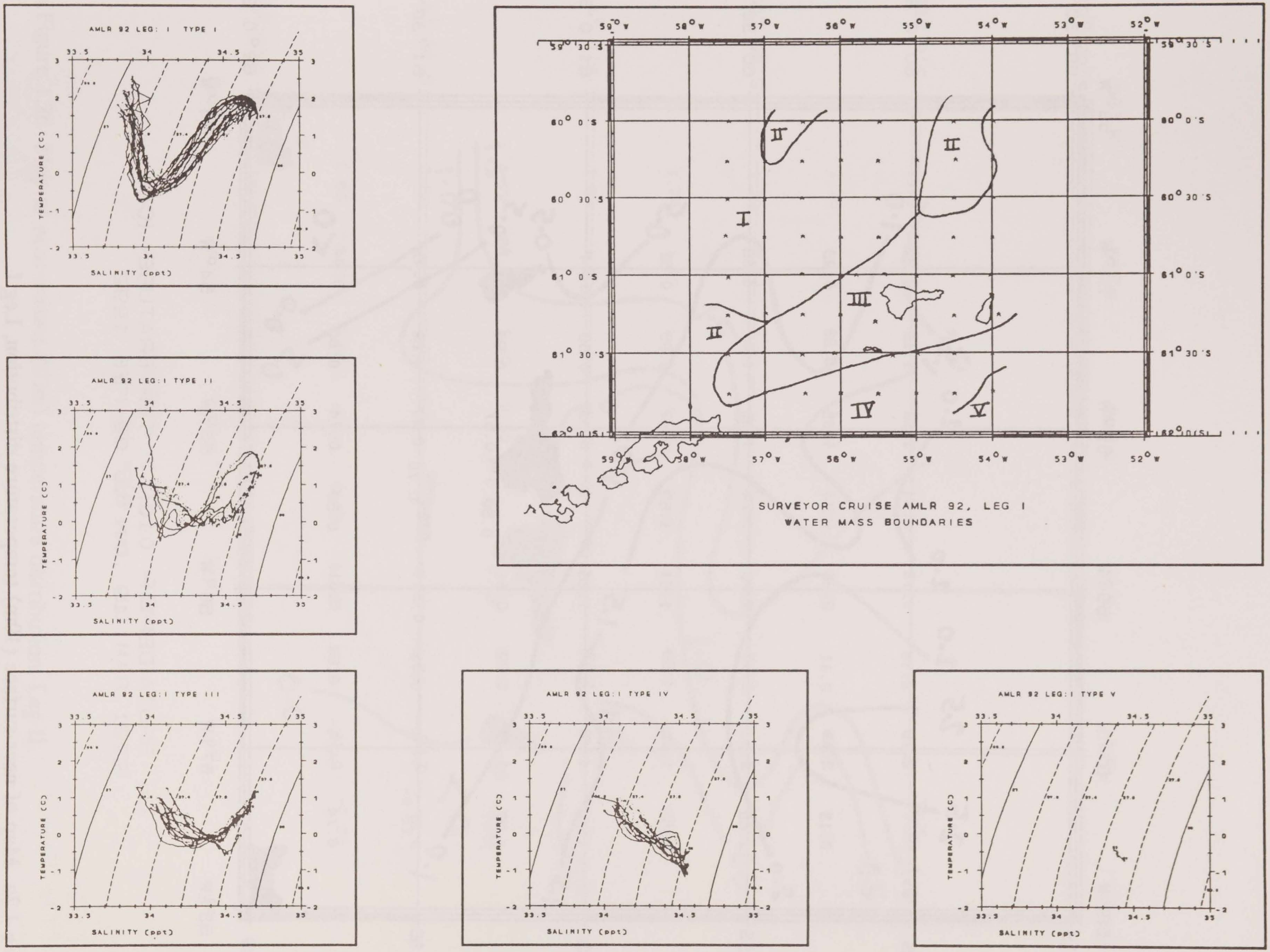

Figure 1.1 Temperature/Salinity characteristics of identified water masses in AMLR study area and approximate water mass boundaries during Leg I.

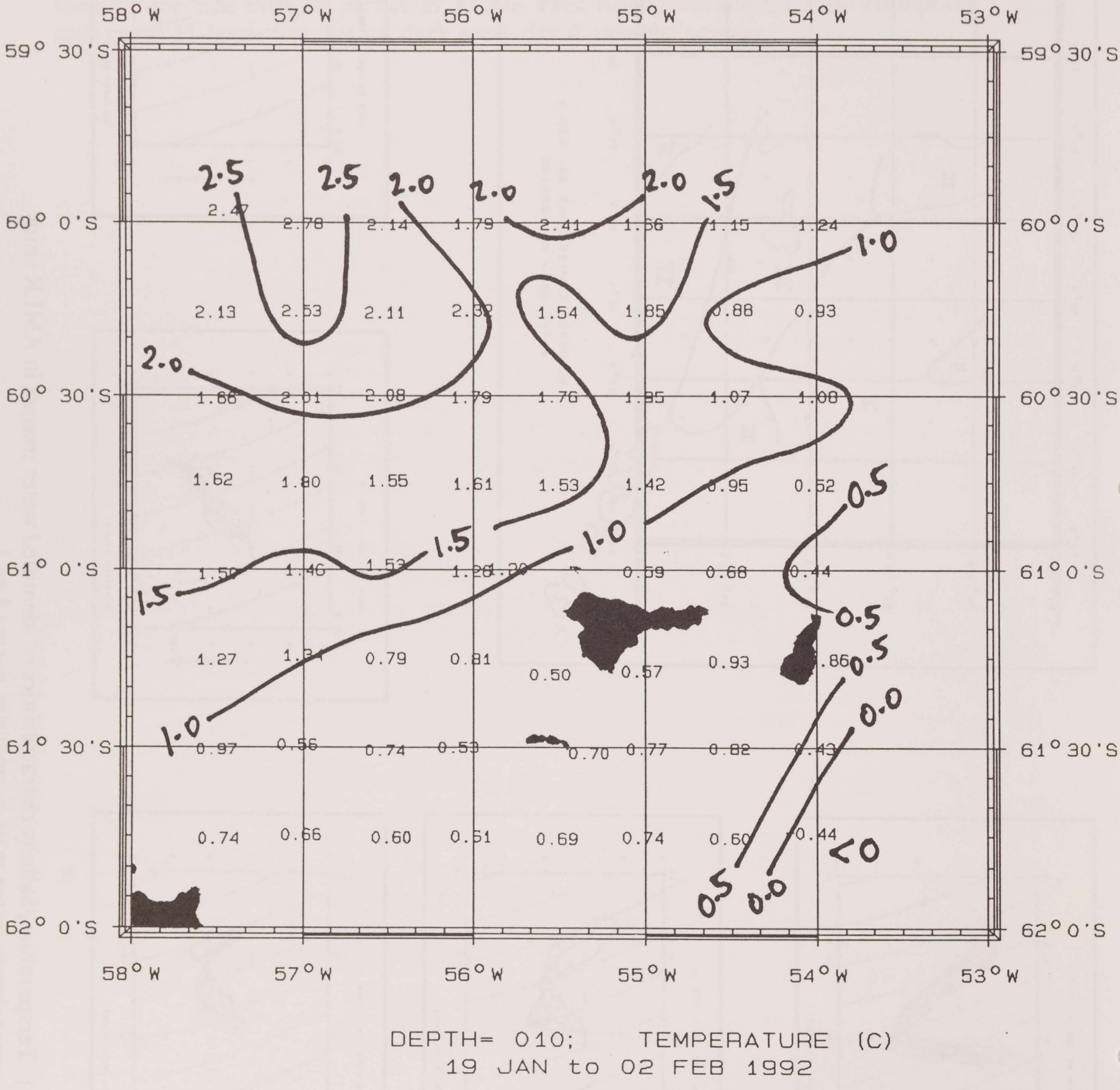

Figure 1.2a Map of near-surface (10m) temperature distribution, Leg I.

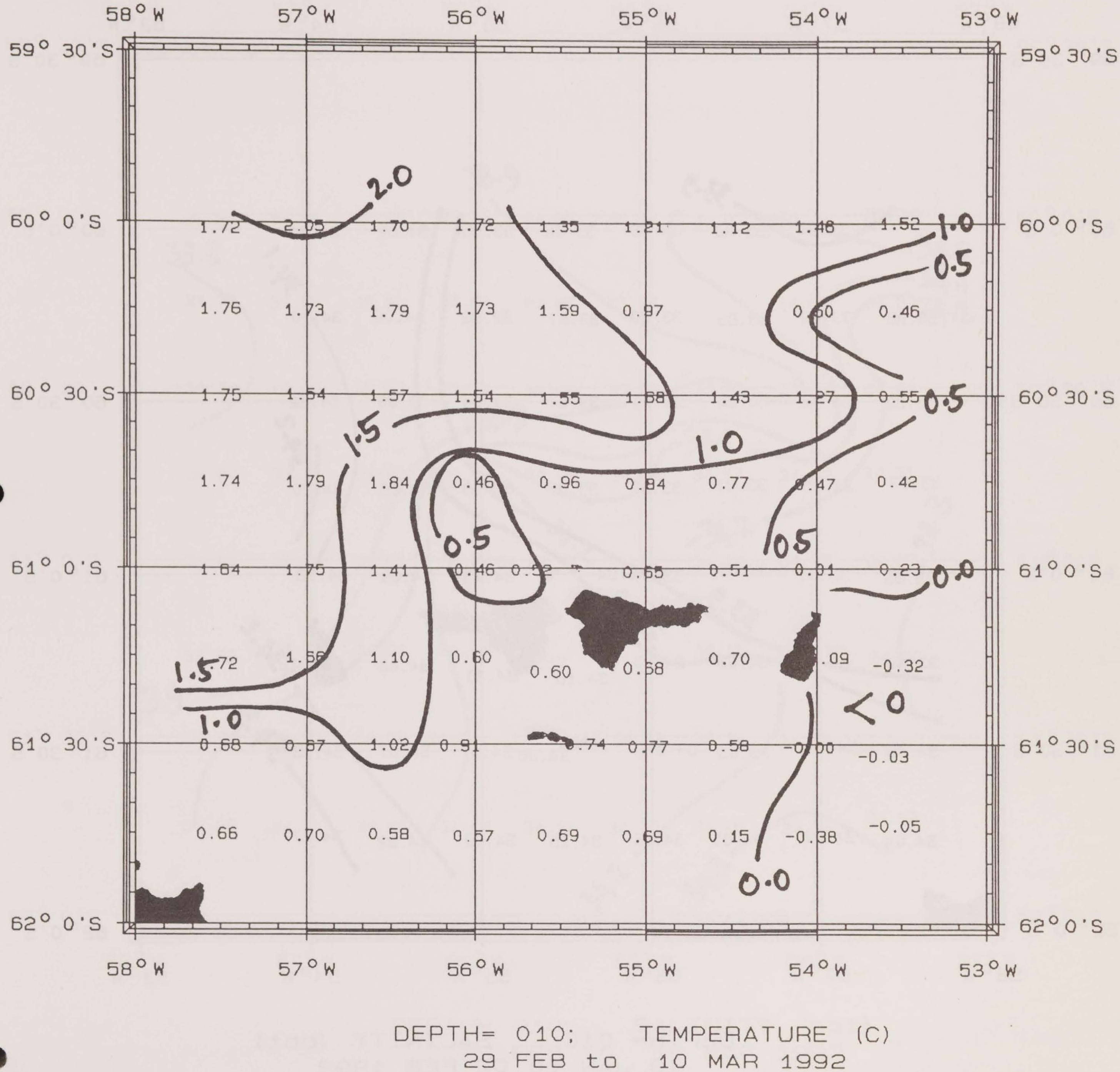

Figure 1.2b Map of near-surface (10m) temperature distribution, Leg II.

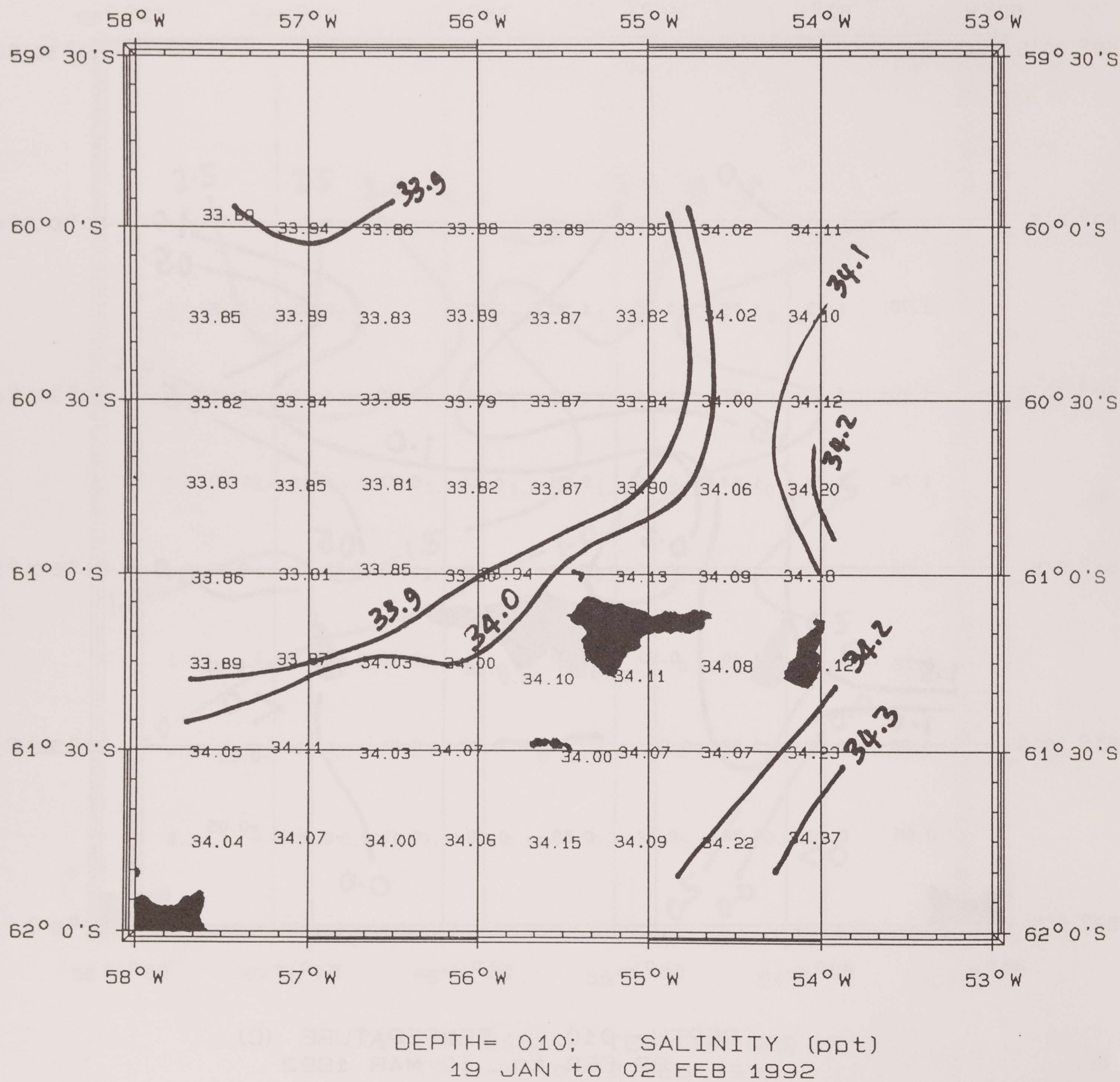

Figure 1.3a Map of near-surface (10m) salinity distribution, Leg I.

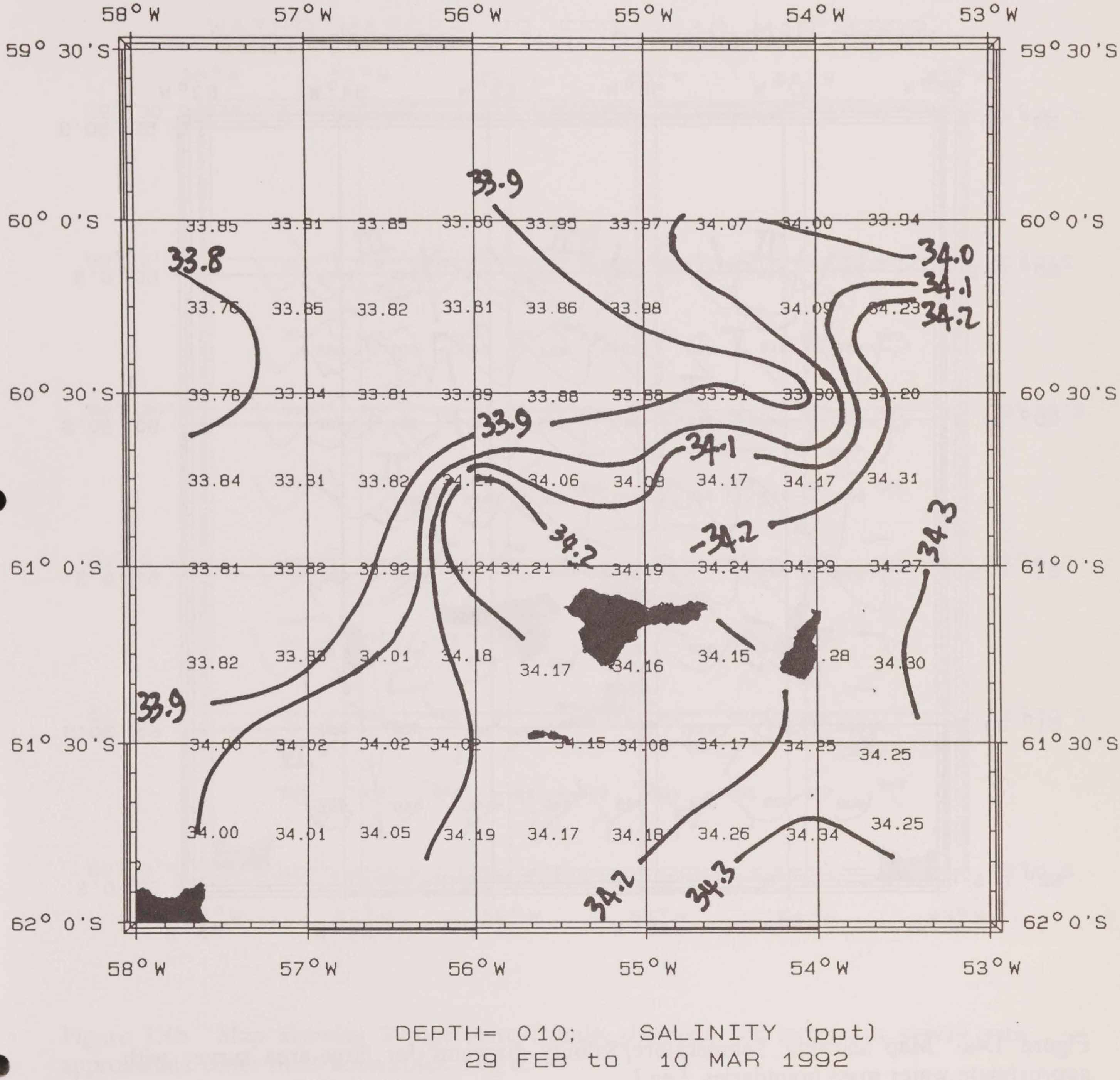

Figure 1.3b Map of near-surface (10m) salinity distribution, Leg II.

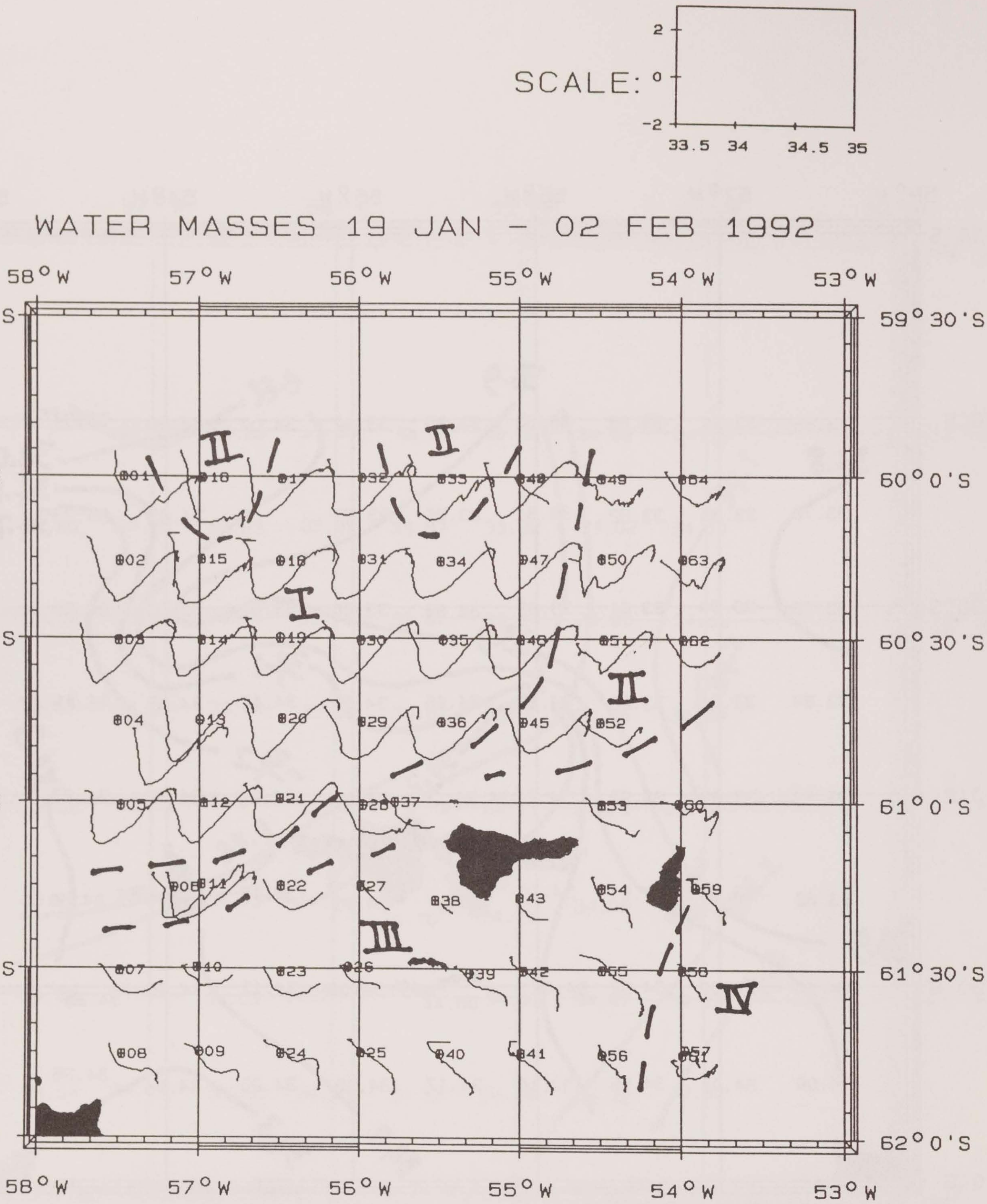

Figure 1.4a Map showing Temperature/Salinity diagrams for large-area survey with approximate water mass boundaries, Leg I.

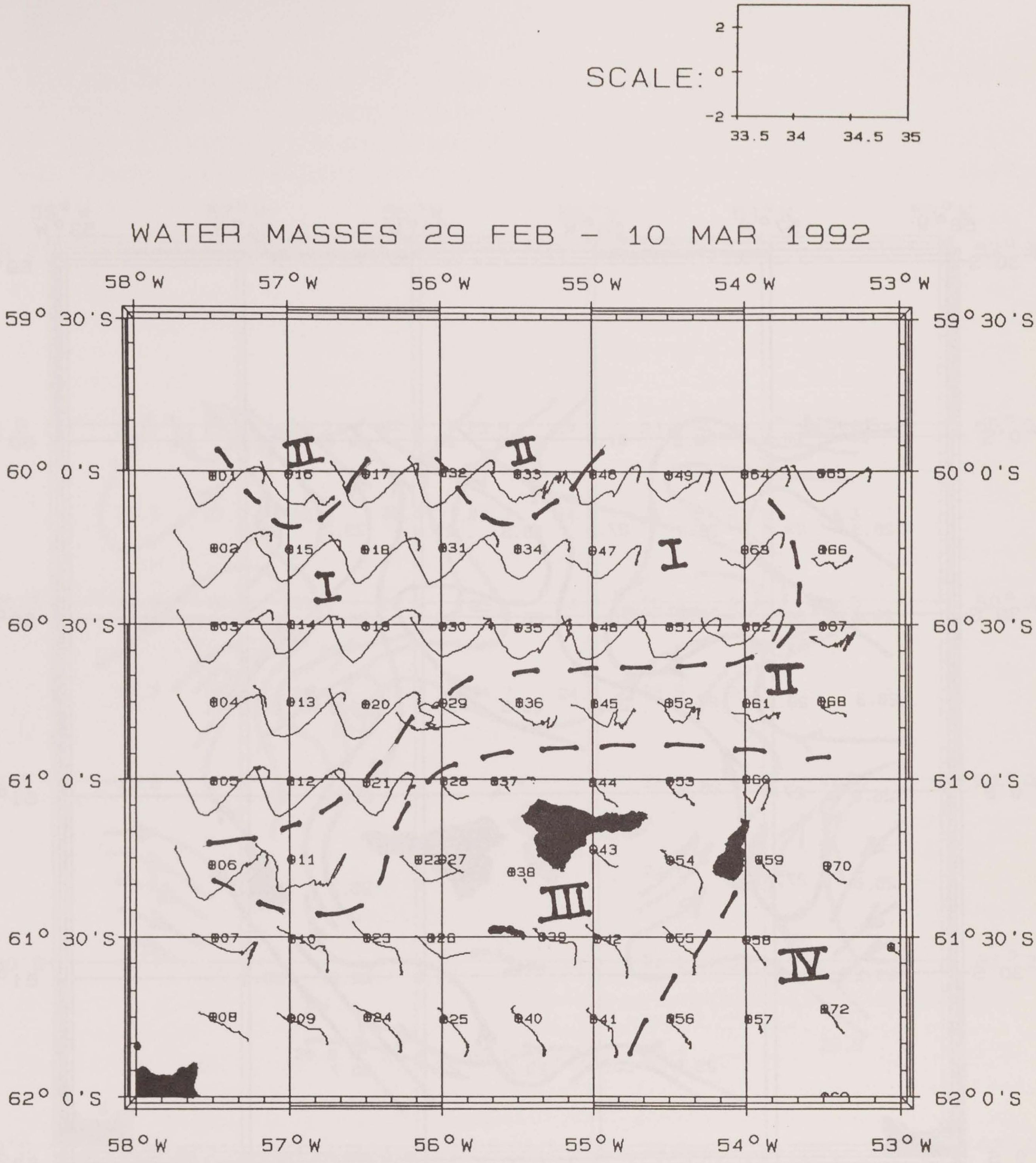

Figure 1.4b Map showing Temperature/Salinity diagrams for large-area survey with approximate water mass boundaries, Leg II.

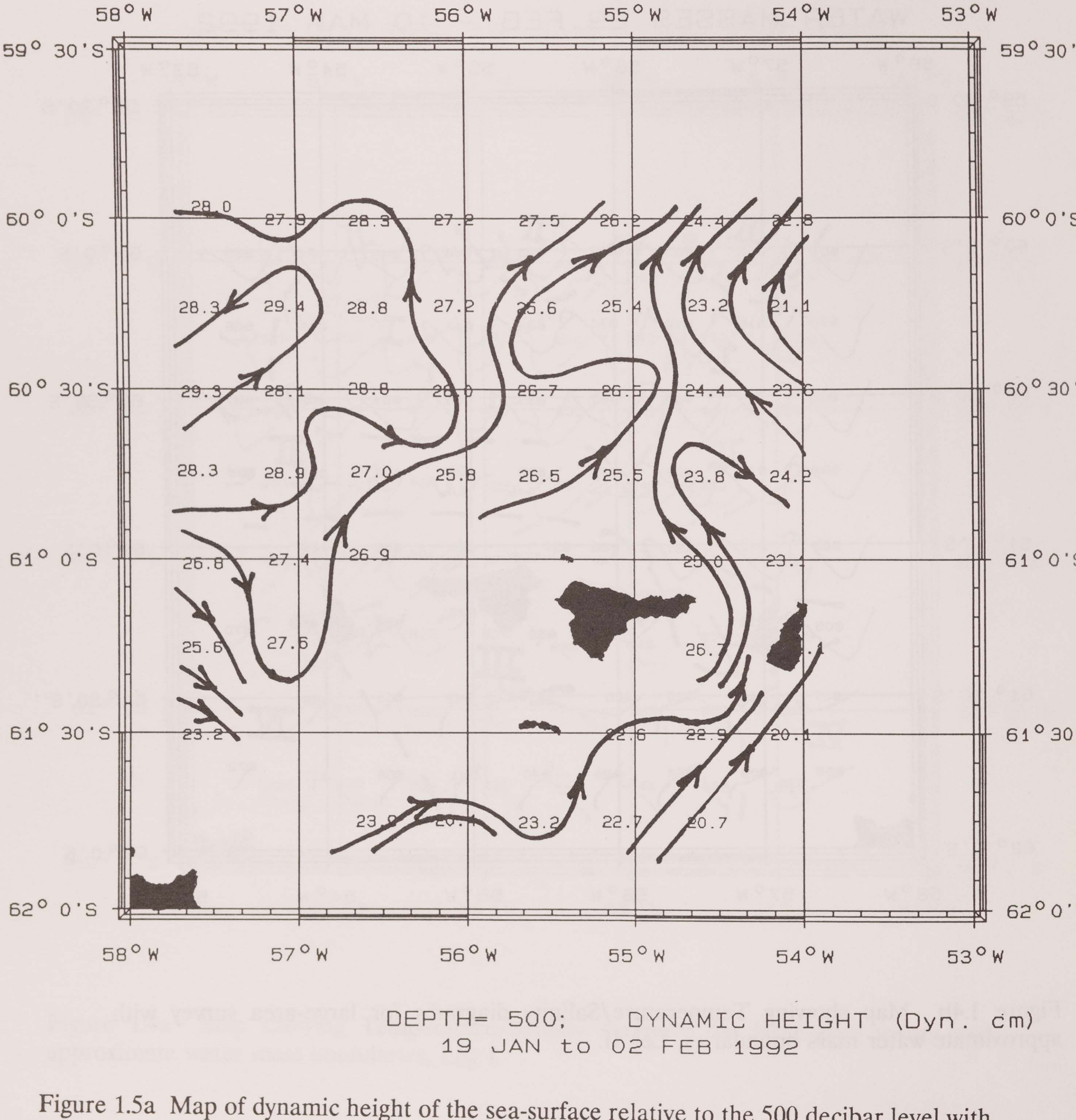

Figure 1.5a Map of dynamic height of the sea-surface relative to the 500 decibar level with streamlines of the geostrophic flow, Leg I.

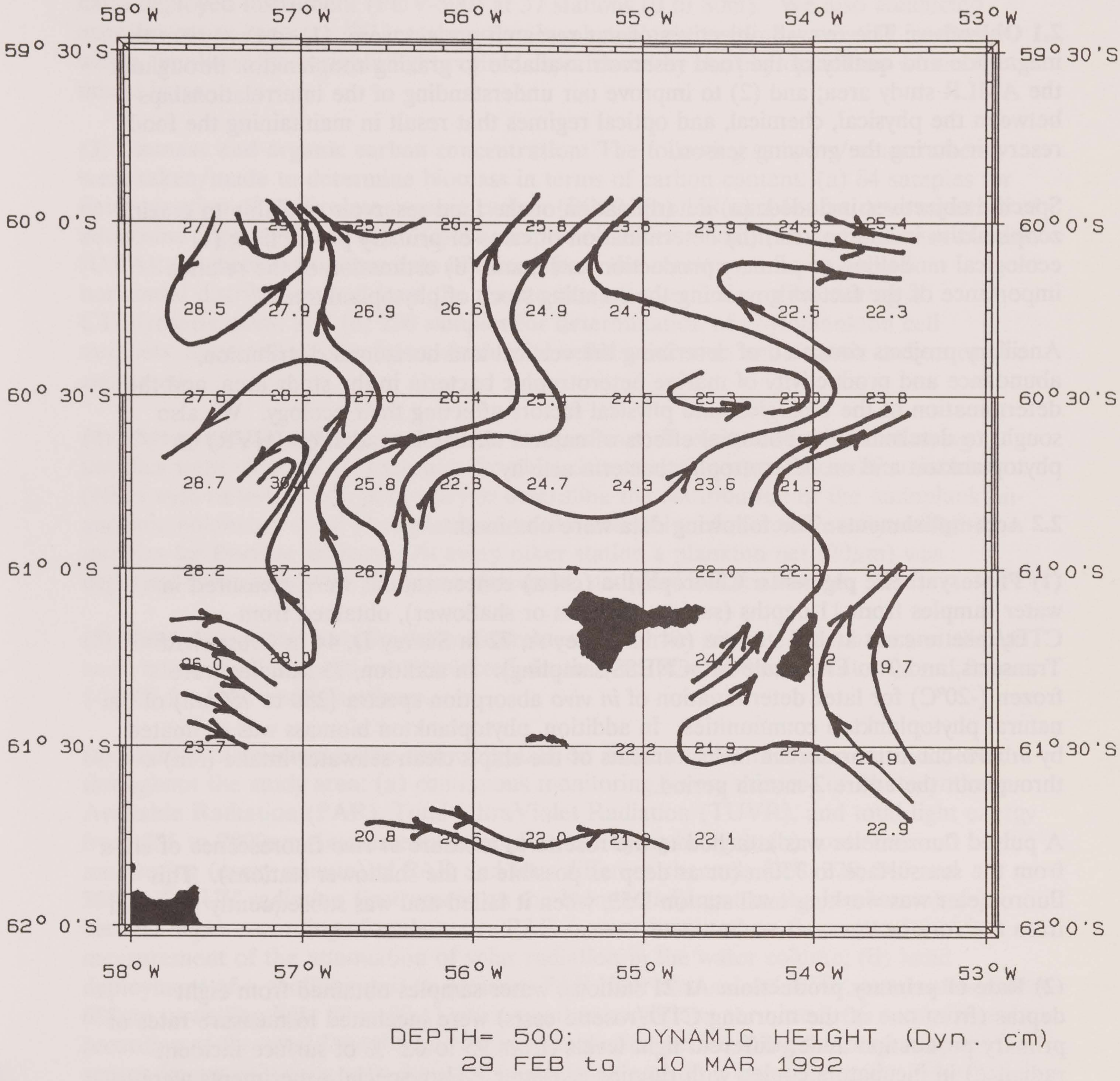

Figure 1.5b Map of dynamic height of the sea-surface relative to the 500 decibar level with streamlines of the geostrophic flow, Leg II.