3.3 Physical oceanography; submitted by Anthony Amos and Margaret Lavender, University of Texas at Austin, Marine Science Institute.

3.3.1 Objectives: The main objective of the physical oceanography program was to describe the upper ocean water structure around the Elephant Island area in relationship to the observed distribution of biological organisms. This was accomplished by measuring the vertical density profile of the waters to a depth of 750m (where possible) over (1) a coarse grid of 50 stations (Surveys A and D, Figure 3.1.1) around Elephant Island, (2) a finer-scale grid to the north of Elephant Island (Surveys B and C, Figures 3.1.2 and 3.1.3), (3) closely spaced stations along two sections extending across the shelf-break, also to the north of Elephant Island, and (4) by continuously monitoring the meteorological conditions along the ship's track to study mechanisms maintaining the upper mixed layer and pycnocline. The grids and transects were repeated on Leg II of the cruise.

3.3.2 Accomplishments:

CTD Stations: Using a Sea-Bird SBE-9 CTD with a General Oceanics rosette sampler, a total of one hundred-sixty-seven (167) stations were occupied. The CTD had additional sensors attached (a SeaTech 25cm transmissometer, Biospherical Instruments PAR light meter, and SeaTech *in-situ* fluorometer). Thus, real-time profiles of temperature, salinity, beam attenuation, downwelling light, and fluorometry were acquired. Data were displayed as multi-colored plots on a PC monitor, printed on a laser printer, and stored on removable cartridge disks. At each CTD station (on the uptrace), ten 10-liter water samples were collected, one at depth and the others from 100 m to the surface, at depth intervals suitable for chlorophyll-a sampling. Chlorophyll, DNA, HPLC, ABS phytoplankton, floristics and nutrient sampling were done by O. Holm Hansen's group. All water samples were analyzed for salinity by *Surveyor*'s Survey technicians using the ship's Guildline Autosal salinometer. A total of 1723 salinity determinations were made to verify the sampling depths and for *in-situ* calibration of the CTD.

Data were acquired at the rate of 6 scans/sec using the *Surveyor*'s rack-mounted Everex 386 computer and Seasoft software. On all but the first two stations of Leg I, the UTMSI CTD was used. This instrument has the capability of supporting the additional optical sensors. Data were stored on the ship's LAN network disk because our 44 Mbyte 5 1/4" Bernoulli removable cartridge disk system was not compatible with the Everex 386 computer. Over 60 Mbytes of raw CTD data were acquired.

Weather Monitoring System: An continuous weather/navigation system was installed aboard the *Surveyor* to collect environmental data throughout the cruise. Using a Data World 386 computer as a processor, information from the ship's Magnavox 1102/1107 GPS-Transit satellite navigation system, the ship's Coastal Climate Weatherpak anemometer, Weathermeasure air temperature, relative humidity and barometric pressure sensors, and three solar radiation sensors were acquired at 10-minute intervals. A sea-surface temperature probe was towed from the fantail to monitor sea-surface temperature SST data. SST and salinity data were also collected using the ship's thermosalinograph, and merged daily with the information from the UTMSI weather system.

Weathermeasure signal-conditioning units, a Hewlett-Packard model 3421-A data acquisition-control unit, both asynchronous communications ports and an IEEE-488 interface fed the data into the computer. Data were stored in daily files on the hard disk and transferred using 5 1/4" diskettes to the Everex for further processing. Files were closed and re-opened each time a line of data was written to protect from accidental erasure and backed up at 0000 hours (UT) daily. At any interval, comments could have been made (i.e. "CTD SU... START"), at which time a line of environmental and position data was stored. Thus, the system provided a log of all scientific activities for the cruise. Daily log sheets were provided to each scientific group on the ship, and to the Field Operations Officer and Navigator. Log sheets listed positional and environmental data on the hour and whenever an event occurred, and a daily summary of the cruise progress and mean and extreme weather conditions for that day.

Computer Programs: Several computer programs were written during the first leg to facilitate data acquisition and to process, analyze, display and store data. Other programs were modified to customize the systems to the *Surveyor*'s particular equipment set up and to digitize and plot data on polar and Mercator projection maps. A new program to make geostrophic computations more suitable for use with shallow CTD casts was written during this cruise.

3.3.3 Preliminary Results and Discussion: Data from the downtrace of each CTD station were averaged to 1-meter intervals and recorded on disk. It is these 1-meter data that are used to produce the diagrams presented here. No attempt has been made to adjust the salinity based on the sample salinities.

The study area encompasses several bathymetric and oceanographic regimes. The bathymetry of the Drake Passage rises north-to-south, from below 4,000 m in the trench-like Shackleton Fracture Zone to the continental slope and the shelf of the South Shetland Islands. The Elephant Island group is the northernmost of the South Shetland Islands. Based on last year's results (AMLR1990), the grid was expanded to the south of King George Island, to the west in the Drake Passage, and to the east of Clarence Island. South of Elephant Island, the station grid crosses the deep (below 2,000 m) basin of the northern Bransfield Strait, and in the east, reaches the slope of the Weddell Sea Basin.

North of Elephant Island, surface waters are those of the Continental Water Zone and its boundary (Nowlin and Clifford, 1982)[1], characterized by a shallow mixed layer beneath which a strong temperature minimum ("Winter Water") separates surface water from the deeper Circumpolar Deep Water (CDW). The core of the CDW rises to nearly 500 m close to the continent. Surface flow is generally to the east in the Drake Passage, but immediately adjacent to the South Shetlands, flow is westward as water from the Weddell Sea moves around the northern tip of the Antarctic Peninsula. Within the Bransfield Strait, Weddell Sea Water is recirculated and returns along the northern boundary of the Strait, mixing with Bellingshausen Sea water. A frontal zone separates the Bellingshausen from the Weddell-type water. During AMLR1991, this zone ran parallel to the shelf-break north of Elephant Island and appeared to be associated with high concentrations of krill.

The complicated hydrography around Elephant Island that represents the westernmost boundary of the Weddell-Scotia Confluence (WSC) and its interaction with the oceanic waters of the Bellingshausen can be revealed by plotting T/S diagrams from each vertical CTD profile. This region of water mass boundaries is thought to be favorable for krill in the Elephant Island area. Five water mass types similar to those encountered in 1990 were identified during Legs I and II of AMLR1991. Modified descriptions with additional comments are given below:

TYPE I: Drake Passage water; warm, low salinity surface water, strong sub-surface T-min ("Winter Water", approx. -1°C, salinity 34.0 ppt), CDW near 500 (Figure 3.3.1).
TYPE II: A transition water; T-min near 0°C, isopycnal mixing below T-min, CDW evident at some locations. There were some dramatic examples of transition water during this cruise, showing considerable mixing along isopycnals (Example Station A7, Figure 3.3.2).
TYPE III: Weddell-Scotia Confluence (WSC water; little evidence of a T-min, mixing with Type II, no CDW, temperature at depth generally > 0°C (Figure 3.3.3).
TYPE IV: Eastern Bransfield Strait water; deep temperature near -1°C, salinity 34.5 ppt, cooler surface temperatures (Figure 3.3.4).
TYPE V: Weddell Sea water; Little vertical structure, cold surface temperatures (near 0°C), limited to extreme SE corner of study area (Example Station D24, Figure 3.3.5).

Tentative boundaries for the study area are give in Figure 3.3.6 for Leg I and Figure 3.3.7 for Leg II. Uncertainties in the boundary between Type II and Type III water will be resolved as the data analysis progresses.

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[1] Nowlin, W.D. Jr. and M. Clifford (1982) The kinematic and thermohaline zonation of the Antarctic Circumpolar Current at Drake Passage. J. Mar. Res. Suppl. 40:481-507.

The most distinct feature of the AMLR1991 hydrography was the front separating Bellingshausen Sea water from Weddell/Bransfield water. Its surface was marked by a meandering salinity gradient separating water of 33.5 ppt in the northwest from >34.3 ppt water over much of the southeastern part of the study area (Figures 3.3.8 and 3.3.9). Subsurface, an abrupt end to the <-1°C temperature minimum separated the stratified water column in the northwest from the generally well-mixed interior in the southeast.

Much of the study period during Leg I was dominated by a strong westerly airflow with a large high pressure dome over the southeast Pacific Ocean and low pressure systems to our south over the Palmer Peninsula. Figure 3.3.10 shows the surface winds, sea and air temperature conditions encountered. Air temperature exceeded sea temperature for the most part. Only when a ridge of high pressure passed to the south did southerly winds from the continent cool the air below the sea temperature (see Figure 3.3.10, 5-7 February).

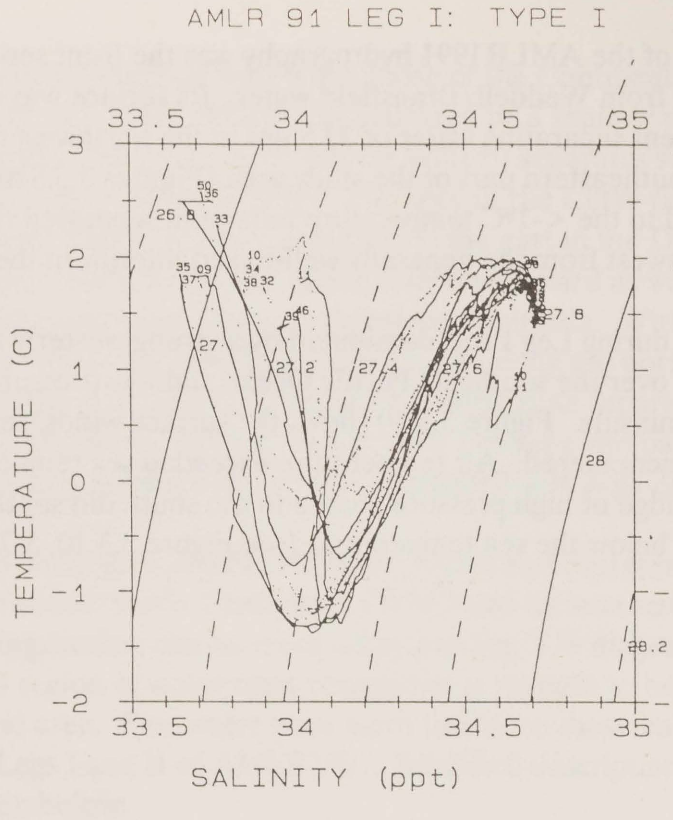

Figure 3.3.1 Temperature/salinity curve; Leg I, TYPE I water.

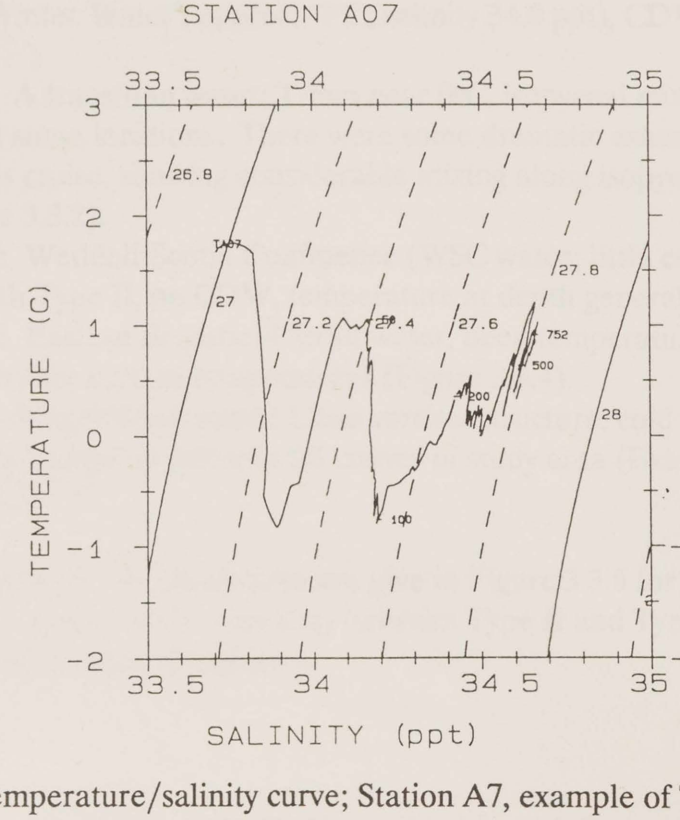

Figure 3.3.2 Temperature/salinity curve; Station A7, example of TYPE II water.

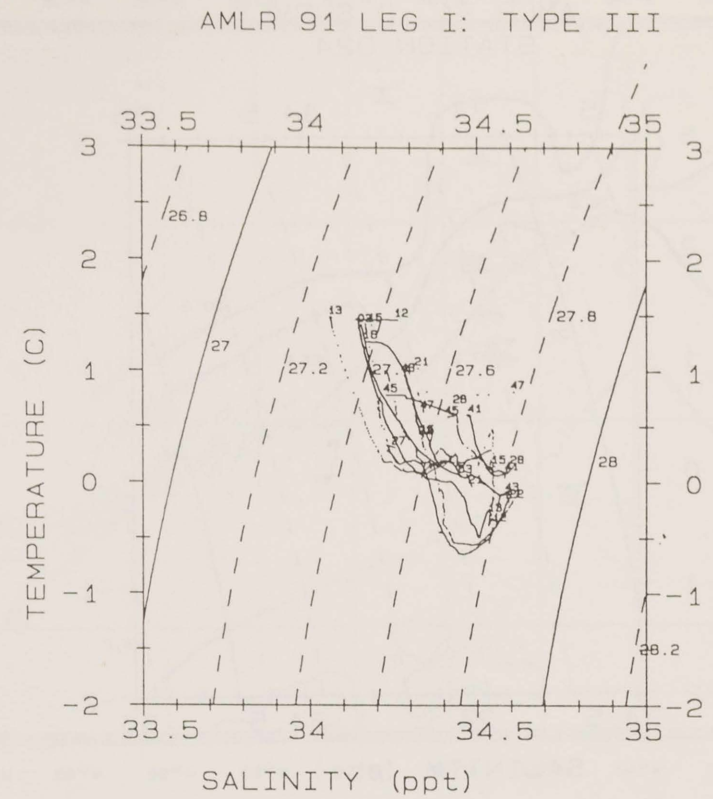

Figure 3.3.3 Temperature/salinity curve; Leg I, TYPE III water.

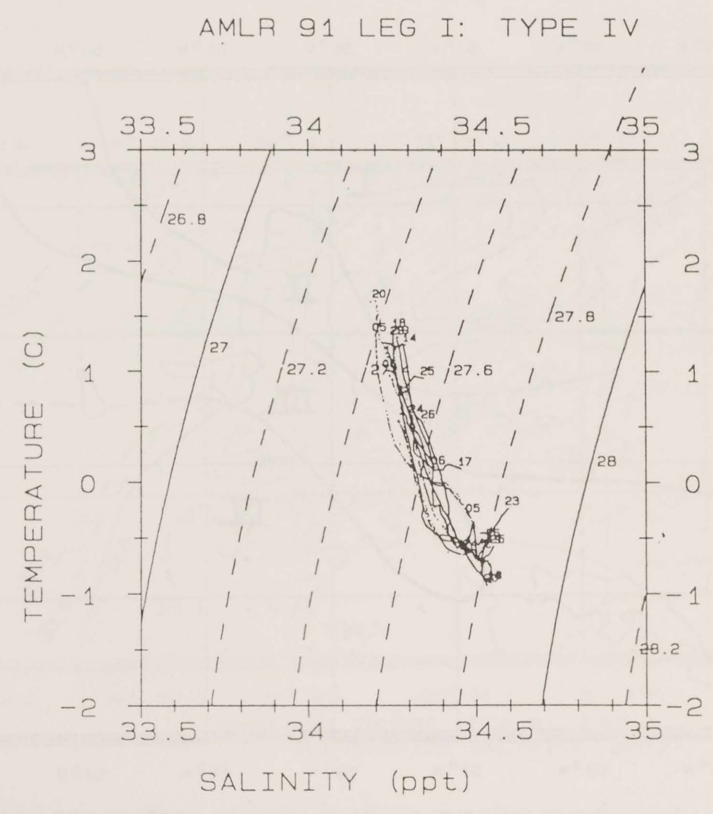

Figure 3.3.4 Temperature/salinity curve; Leg I, TYPE IV water.

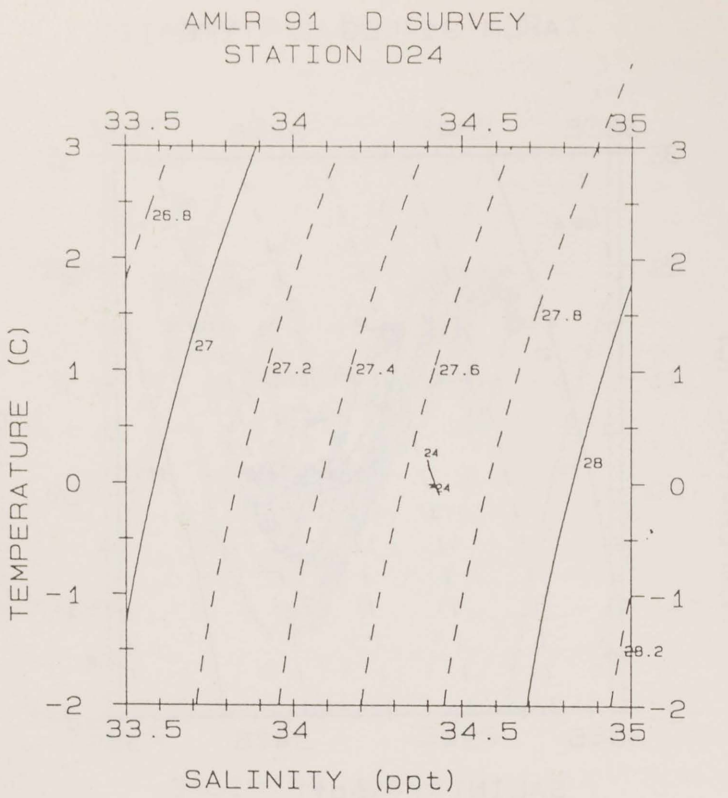

Figure 3.3.5 Temperature/salinity curve; Station D24, example of TYPE V water

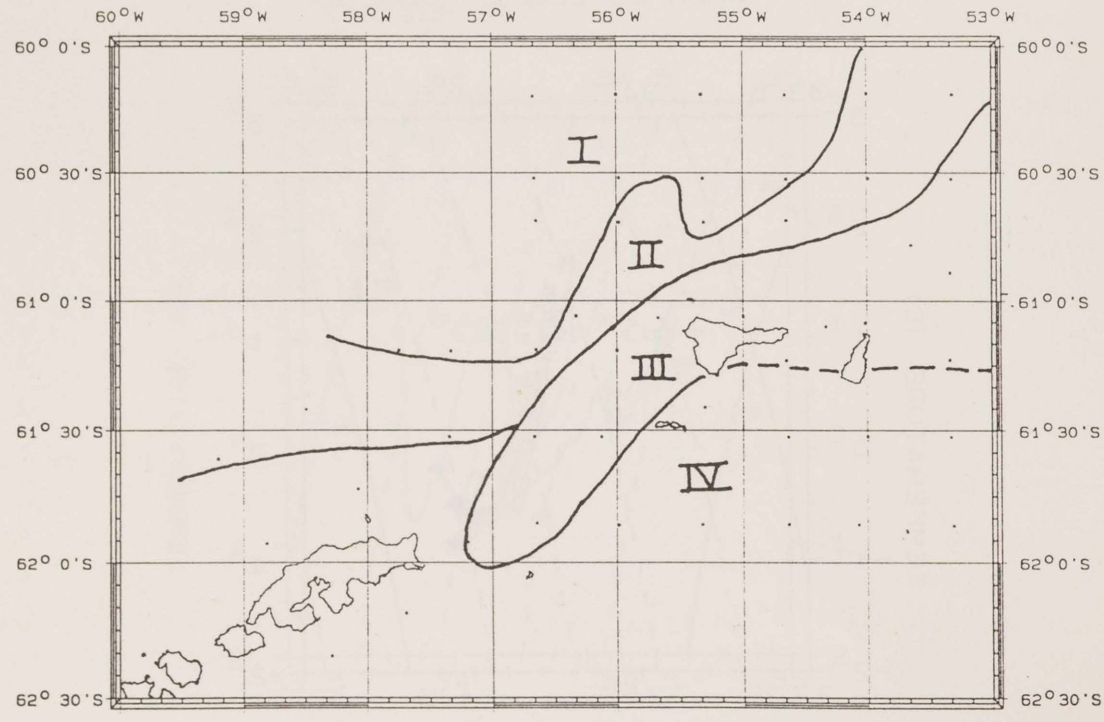

Figure 3.3.6 Water mass boundaries, Leg I.

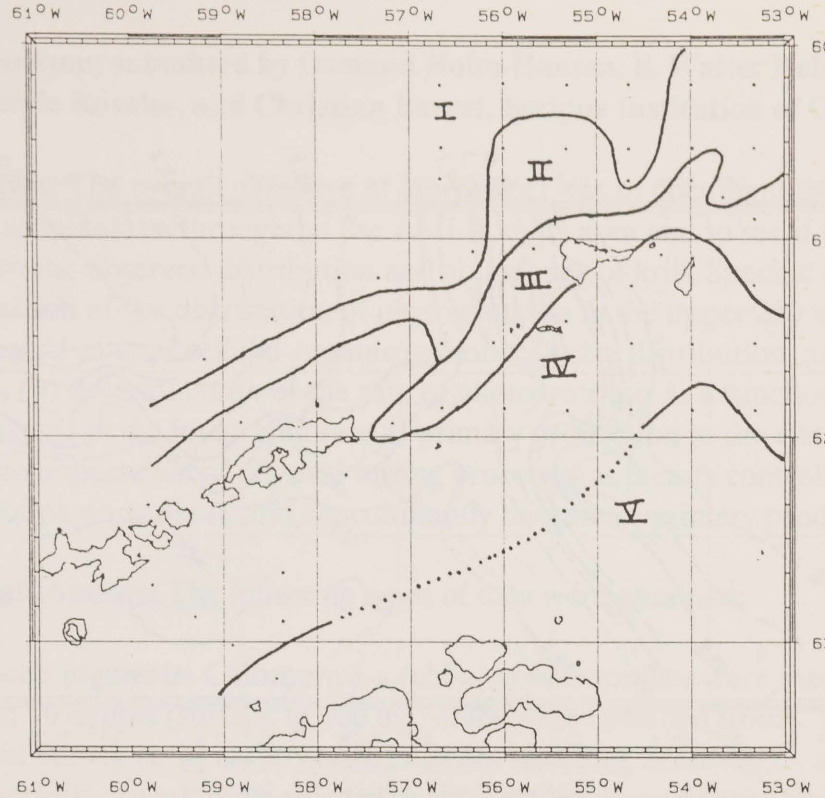

Figure 3.3.7 Water mass boundaries, Leg II.

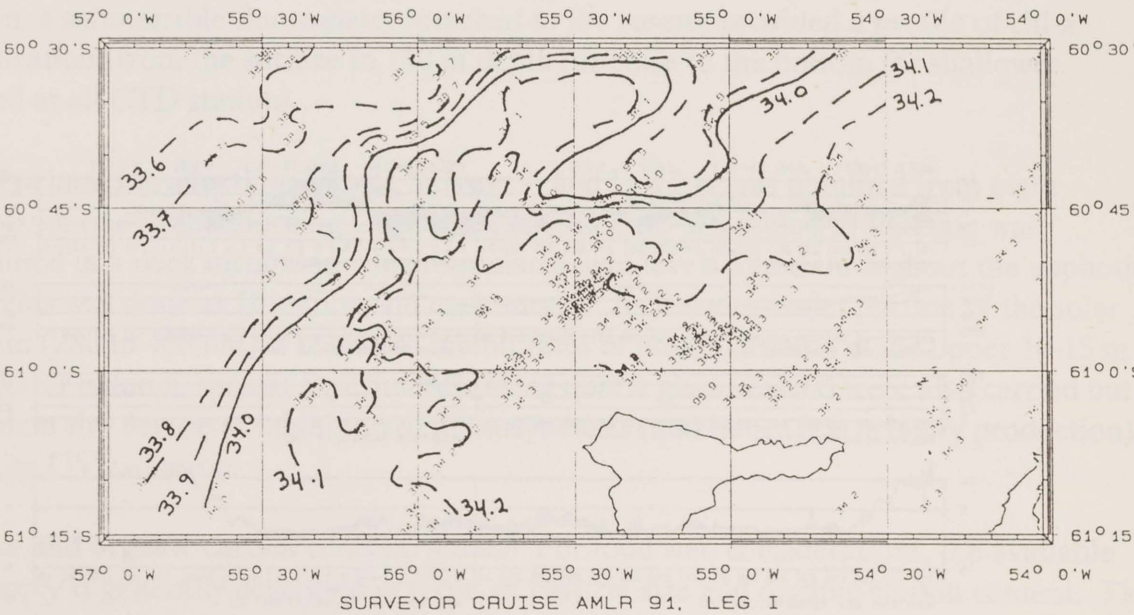

Figure 3.3.8 Leg I sea surface salinity in parts per thousand.

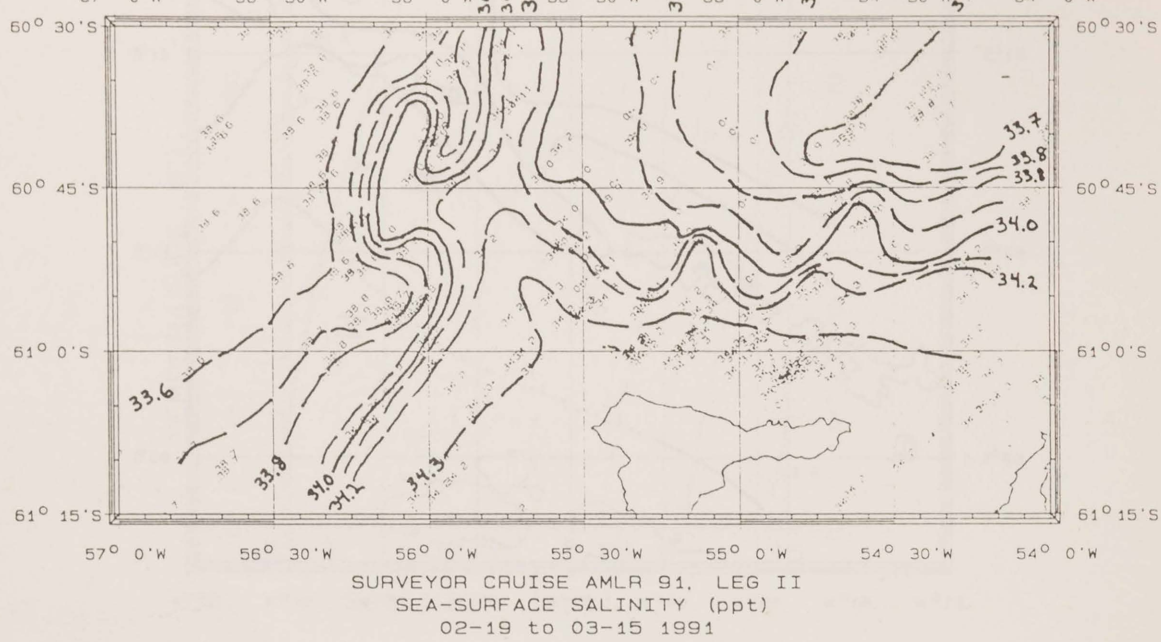

Figure 3.3.9 Leg II sea surface salinity in parts per thousand.

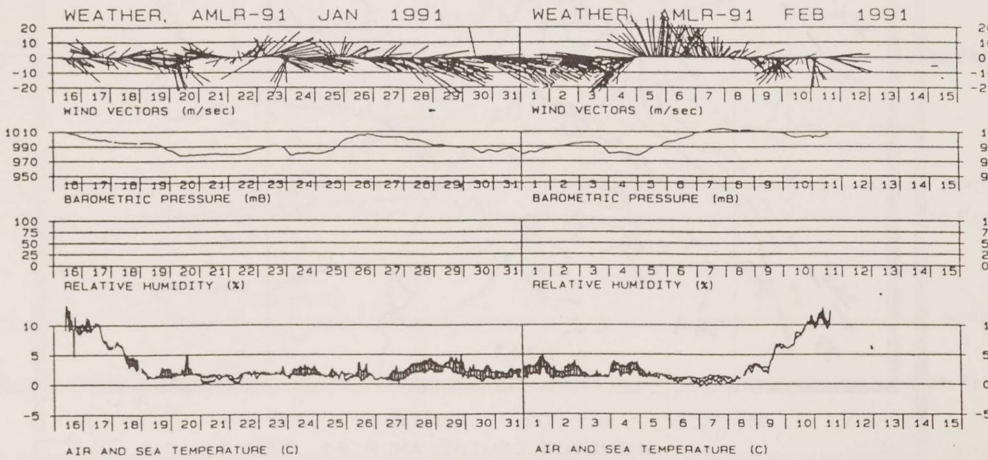

Figure 3.3.10 Leg I surface winds, barometric pressure, air and sea temperature.