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Variability of the Warm Water Supply off West Greenland and Labrador during Four Decades - 1950 to 1989

by

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Abstract

Based on a data set of about 15,000 oceanographic stations which are extracted from the digital CD-ROM World Ocean Atlas 94 (WOA94), a climatic analysis of the „Warm Water Supply" to the areas off West Greenland and Labador is performed. The analysis is concentrated along the path of the Irminger Current component, a branch of the Gulf Stream system, which follows approximately the 1,500m isobath around the Labrador Sea proper.

A special oceanographic software, the OCEAN-DATA-VIEW 4.0 programme as provided by the Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, was used to achieve a quick analysis of large data sets.

Compared to the climatic background of the data series, 1920s to 1980s, the paper elucidates how the inflow of warm water into the area changed in the decades of the 1950s to 1980s. It is shown that highest temperatures were encountered in the 1960s.

The authors emphasise that the present study might be a first step into a new way of viewing oceanographic data. The software ODV is an easy tool to enable this view on large data sets, and to reveal changes in the distribution of oceanographic properties.

Key words: Climatic variation of water masses, temperature, salinity, Irminger Current, Greenland, Labrador Sea

Background

Oceanographic observations in the area between West Greenland and Labrador, known as the Labrador Sea, have been made from the 1910s onwards (NOAA, 1995). First observations were done by Canada in August, 1915 at the coast of Labrador. In 1921, the United States of America added to the knowledge of the submarine properties off Northeast Labrador, and during August, 1924 a set of oceanographic stations off West Greenland followed, performed by Norway. Denmark started oceanographic work along the West Greenland fishing banks during 1925, a time when the general warming of the Northern Hemisphere led to the establishment of a self-sustaining and very abundant West Greenland cod stock (Hansen and Hermann, 1965; Hermann and Horsted, 1976; Stein and Messtorff, 1990; Stein and Buch, 1991; Stein and Lloret, 1995).

During the following decades, oceanographic investigations were done along Oceanographic Standard Sections crossing the West Greenland and Labrador shelves, and the Labrador Sea at its southern border like the Cape Farewell-Seal Island Section (Stein, 1988). As shown in literature, the area between West Greenland and Labrador attains heat through solar radiation and advective subsurface heat transport by the Irminger Current component which enters the Labrador Sea south of Cape Farewell and leaves the area to the east off

Labrador/Newfoundland (e.g. Stein and Wegner, 1990; Stein, 1996; Templeman, 1975; Trites, 1982). Until present only the section approach was performed in literature to show the variation of the current constituents along the path of the West Greenland Current system and the Labrador Current system.
By means of a modern oceanographic software, and based on the large amount of oceanographic data as contained in the WOA94 CD-ROM data set, it is now possible to *follow* the Irminger component along its path from entering the Labrador Sea south off Cape Farewell and leaving the Labrador Sea at its western side, east off Labrador/Newfoundland.

Material and Methods

To reveal changes in the „Warm Water Supply“ to the areas off West Greenland and Labrador, data were extracted from the World Ocean Atlas 94 (WOA94) which is provided by the National Oceanographic and Atmospheric Administration (NOAA, 1995) as a set of CD-ROM. To achieve a good station cover for the region around and in the Labrador Sea (Fig. 1), all PTS-data from WMO rectangles 7504, 7505, 7506, 7604, 7605 and 7606 were downloaded from the CD-ROM. In total, about 15,000 oceanographic stations (bottle observations) were used for the present analysis.
Realisation of the WOA94 data extraction and graphical evaluation of the variability aspects were performed by means of the OCEAN-DATA-VIEW 4.0 software (ODV). This software product was provided by R. Schlitzer from the Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany through the INTERNET (www.awi-bremerhaven.de/GPH/ODV). During a visit to the Marine Research Institute in Bergen, Norway, V.A. Borovkov was first informed on the existence of the ODV-software. He brought this to the attention of an oceanographic workshop, held in Hamburg, Germany, in April, 1997 (Stein and Borovkov, 1997).

Results

Based on all available data from the above mentioned WMO rectangles the climatic background plot is constructed from station data with bottom depths between 1,000m and 2,000m (Fig. 2). The path of the Irminger water mass along the rim of the Labrador Sea region follows approximately the 1,500m isobath. Therefore the spine of the section swath is superimposed on the track of this isobath, and the stations within this swath are taken for the section plot. The upper left two panels of Fig. 2 give a scatter plot of the temperature and salinity profiles. The lower left panel indicates on a contour map the location of the section swath and the extracted station positions. The two right hand panels reveal the temperature and salinity sections of the upper 2,000m along the „Irminger“ section. The distance scale starts with 0 km at the meridian of Cape Farewell (44°W) and ends at 2,750km at about 50°N, 50°W (note that the ODV-programme uses 360° longitude labelling, starting at Greenwich in an eastward direction).
Since the original plots are multi-colour prints, the reader of this paper is either referred to the oral presentation which uses colour slides, or she/he has to live with the black and white surrogates. The authors feel, however, that it might be timely to mention that the use of coloured figures is nowadays state-of-the-art, since else this kind of information as presented here would not be transferable.

Climatic background

Temperatures range from above 1°C to about 6°C, salinities are between 33 and 35.5 psu. The colour bar at the right side of Fig. 2 is trimmed in a way that gradient layers become clearly visible [also in the black and white version].
A tongue of warm water crosses the meridian of the Cape Farewell and enters the Labrador Sea at its southeastern border. The depth of the warm water core (Irminger

Water mass) is situated at about 500m depth, however, the warmer than 4°C water is traced down to 700m depth. On its way around the Labrador Sea the Irminger Water mass loses heat to the surrounding water layers, and off Labrador temperatures have decreased to less than 3.75°C, which is the temperature of the thermal layer (yellow [white in the b&w plot]) surrounding the Irminger Water layer at the top and bottom of this warm water tongue.
The upper 250m layer is characterized by cold (< 3°C), low saline (< 34.5 psu) waters which refer to the polar waters originating from the East Greenland Current component off West Greenland, and to the cold waters of the Baffin/Labrador Current off the Labrador/Newfoundland coast.
Below the Irminger Water the transition zone to the Labrador Sea Water emerges from Fig. 2, and in the deep layers at about 1,500m to 2,000m depth, the North Atlantic Deep Water inhabits the lower parts of the section (Stein and Wegner, 1990).

1950-59 Thermohaline Conditions along the Irminger Section
For the 1950s, data off the northeastern Labrador coast are scarce. Thus, Fig. 3 gives only a biased picture, based mainly upon the West Greenland conditions. It can be seen, however, that the warm water conditions reached further north than shown in the climatic background picture (Fig. 2). The halocline inhabits about the same depth layer as in Fig. 2.

1960-69 Thermohaline Conditions along the Irminger Section
The 1960s reveal warming in the subsurface layers of the Irminger Water (Fig. 4). Throughout the length of the section, temperatures are > 3.75°C, and the upper and lower thermocline indicated by the yellow [white in the b&w plot] zone, are nearer to the surface, and deeper than normal. Also the surface layer off Labrador/Newfoundland is warmer than normal. The vertical extension of the low saline surface waters has decreased, showing less influence of the polar water masses, both off West Greenland and off Labrador

1970-79 Thermohaline Conditions along the Irminger Section
For the 1970s the section swath had to be enlarged (Fig. 5) to include at least some stations along the path of the Irminger Water component. In contrast to the previous decade of the 1960s, the cold low saline surface layer indicates cooling and dilution which was brought about by the anomalous climatic conditions in the early 1970s (e.g. Borovkov, 1982; Stein, 1982; Trites, 1982). The core of the Irminger Water mass has cooled as compared to the mean climatic situation (Fig. 2) and the 1960s situation. There is no light red [white in the b&w plot] area in the core region, indicating that temperatures in this layer decreased by about 1°C during the 1970s.

1980-89 Thermohaline Conditions along the Irminger Section
As for the 1970s, also for the 1980s data cover the section swath had to be enlarged, since especially off West Greenland data coverage was very scarce for the Irminger Water path region (Fig. 6). Off West Greenland and off Labrador/Newfoundland a cold diluted surface layer with a vertical magnitude of nearly 500m was encountered during the 1980s. Below this cold layer, only in the slope region off Labrador a small area surrounded by a yellow zone (temperature > 3.75°C) [white in the b&w plot] is visible. Also salinities decreased in the layers below 500m depth.

Discussion

1. Some General Remarks on Oceanographic Data Analysis.
Analysis of oceanographic data has undergone considerable changes during past decades. Was it normal in ICNAF times to analyze mostly oceanographic sections,

e.g. the standard sections in the ICNAF area by hand, spine and paper drawings, the use of computers more and more altered the way of data analysis. Following during the times of the 1980s and early 1990s mostly the classical way of analyzing section or time-series data by a suitable software with graphic interface, thus realizing in a much faster way similar results as previously performed by hand, the approach of most recent oceanographic software enables the skilled analyst - most probably a versed oceanographer - to select from the entirety of a data set the most suitable products.

These oceanographic products like map plots of properties, scatter plots, section plots with coloured figures as a final product - in a gridded version or in the more honest way of presentation, the dot-colour plot - enable a much better view on characteristics of the ocean than it was possible prior to these integrated software solutions.

By means of this modern software it is now an easy task to analyze randomly distributed data, and data sampled e.g. along a section.

It is easy to show with this modern software the deficiencies of international data sets, like the Digital World Ocean Atlas (WOA94).

As every data set, institute's, national or international data sets, data sets contain errors despite all the sophisticated data checking software. The integrated oceanographic data analysis software makes these errors visible, supposed a skilled specialist looks at the output plots.

No matter how big a data set is, the results are attained in acceptable time-frames. Following events in a given region of the world ocean, e.g. the NAFO area between Greenland and Canada, is a task which can be fulfilled on short time.

2. Detection of Climatic Events within the Domain of the Irminger Water Mass.

The original scope of the above mentioned workshop was to analyze ICNAF/NAFO Standard Sections in the Davis Strait/Labrador Region. Due to the availability of the ODV-software this was, however, enlarged to the definition of *an „Irminger Water Section"* since it was clear to the authors that this peculiar water mass is the essential „Warm Water Supply" to this arctic/subarctic region, and changes in this water supply might be vital for the climate of the region.

We find that a section like this is much more informative than the classical Oceanographic Standard Sections. This does, however, not mean that in future time sampling of oceanographic information on Standard Sections is obsolete. As our example shows, only the systematic sampling along the standard sections as done in the past, enable us now to provide these types of analysis and extract from the data this kind of information. This is possible since the ICNAF/NAFO Standard Oceanographic Stations cover the path of the Irminger Water mass.

The most informative result of this paper is to our mind the top right panel in figure 2: About 2,000km from Cape Farewell, after nearly completing its path around the Labrador Sea, the water mass characteristics of the Irminger Water fade out at 55.4°N, 55.7°W (304.3 in the lower left panel of fig. 2). During the 1960s when the arctic regions experienced considerable warming, our analysis shows warming along the entire path of the Irminger Water with a remarkable increase in the vertical extension the warm water supply.

Atmospheric cooling which started in the early 1970s in the West Greenland/Labrador region, led to considerable cooling of the surface waters especially off the Labrador coast. This cooling did not yet effect the subsurface conditions in the Irminger layer. However, during the continued cooling throughout the 1980s, also this water mass revealed considerable signs of cooling effects.

The present study is a first step into a new way of viewing oceanographic data. The software ODV is an easy tool to reveal changes in the distribution of oceanographic properties.

As a next step a view on the horizontal distribution of oceanographic data (e.g. temperature, salinity, nutrients, derived properties) should be made for the same area. This gives a more comprehensive view on climatic changes in the region of the Davis Strait/Labrador Region.

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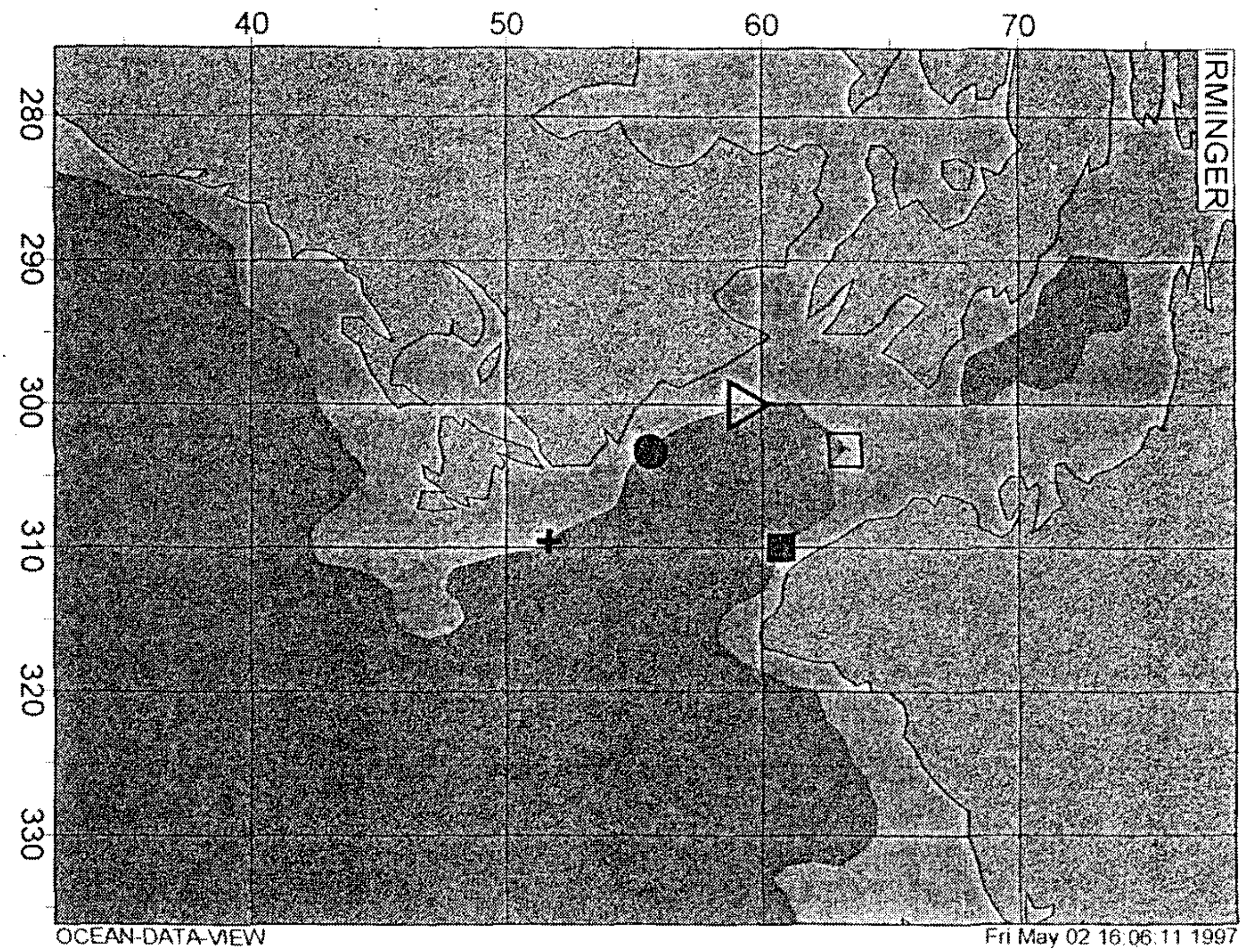

Fig. 1 Location of „Irminger Section" points 500km (■), 1000km (□), 1500km (Δ), 2000km (●) and 2500km (+).

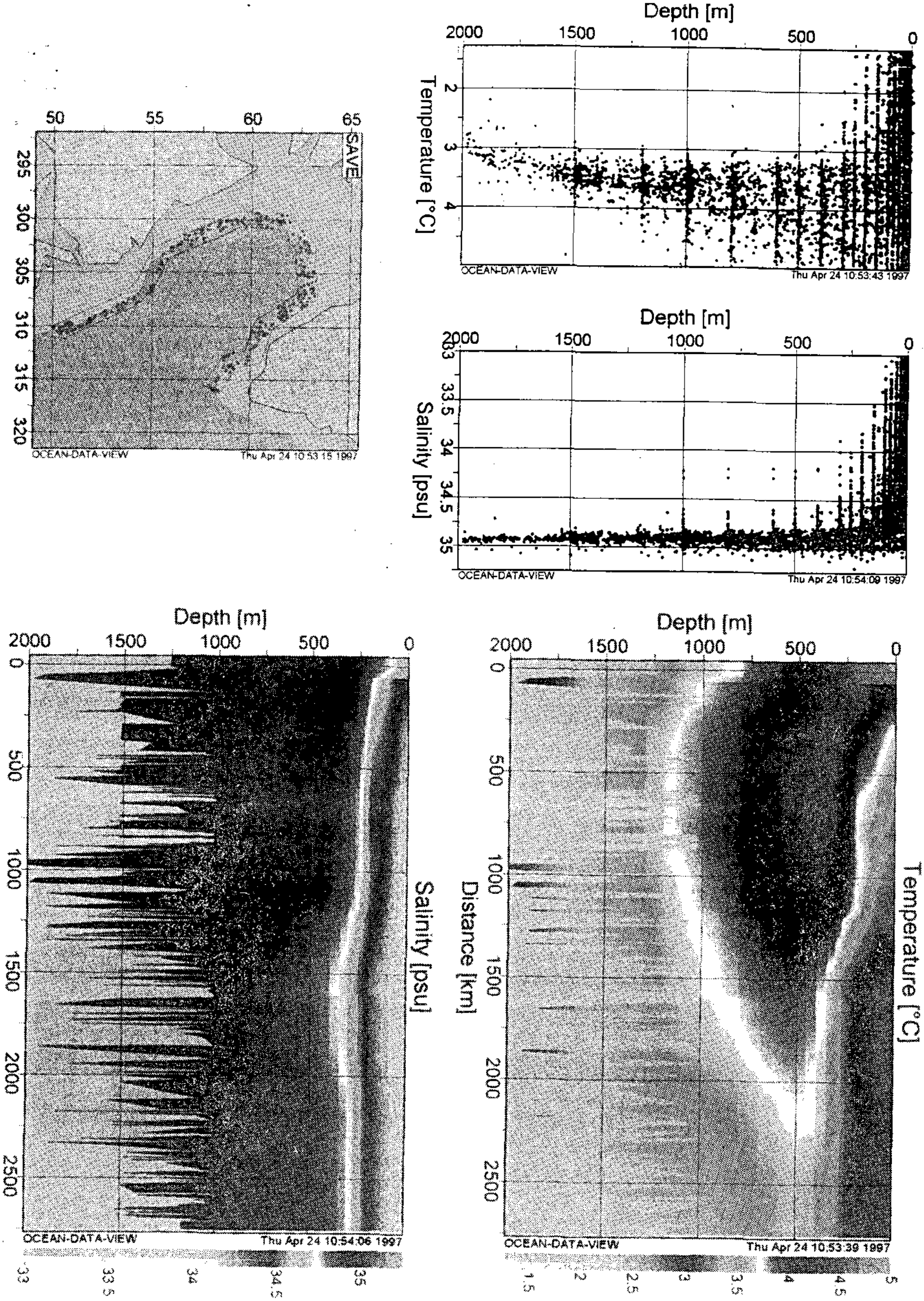

Fig. 2 Climatic background plot of "Warm Water Supply" by the Irminger Water mass; top left panels: temperature and salinity profiles; lower left panel: map showing the path of the Irminger Water mass and position of stations which were used for plotting the temperature and salinty sections as given in the two right panels.

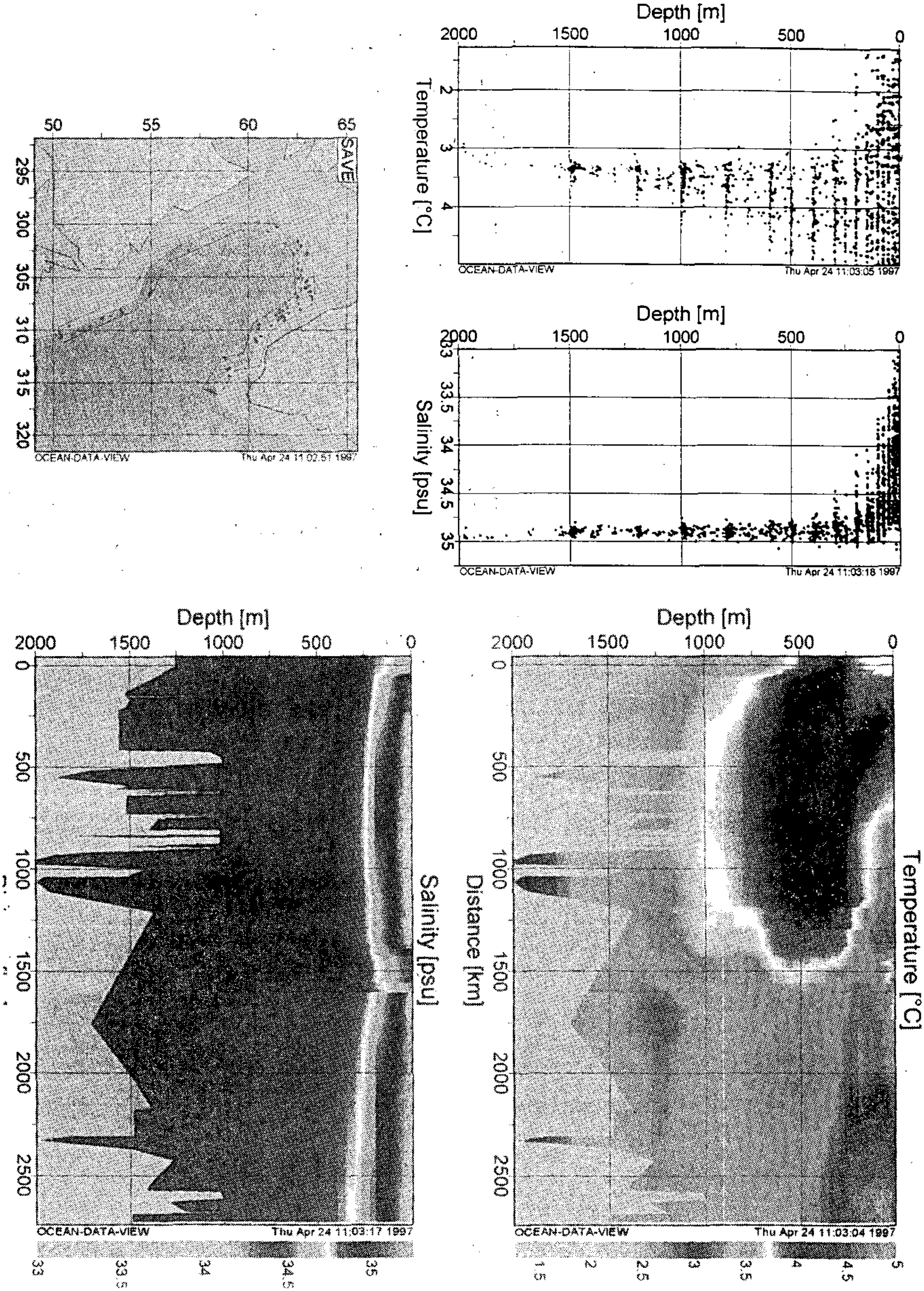

Fig. 3 1950-1959 climatic conditions plot of „Warm Water Supply" by the Irminger Water mass; for definition of panels see fig. 2.

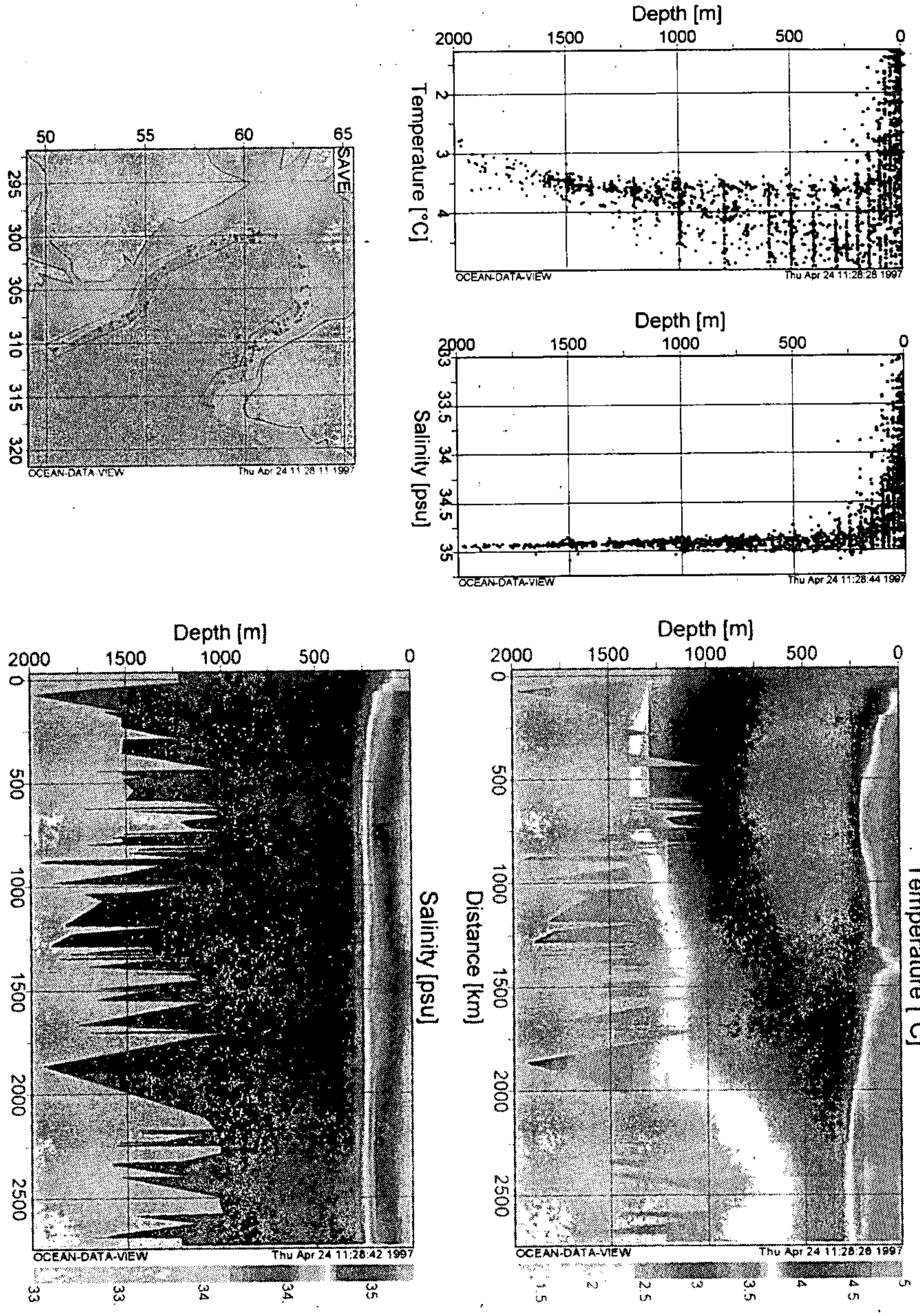

Fig. 4 1960-1969 climatic conditions plot of „Warm Water Supply" by the Irminger Water mass; for definition of panels see fig. 2.

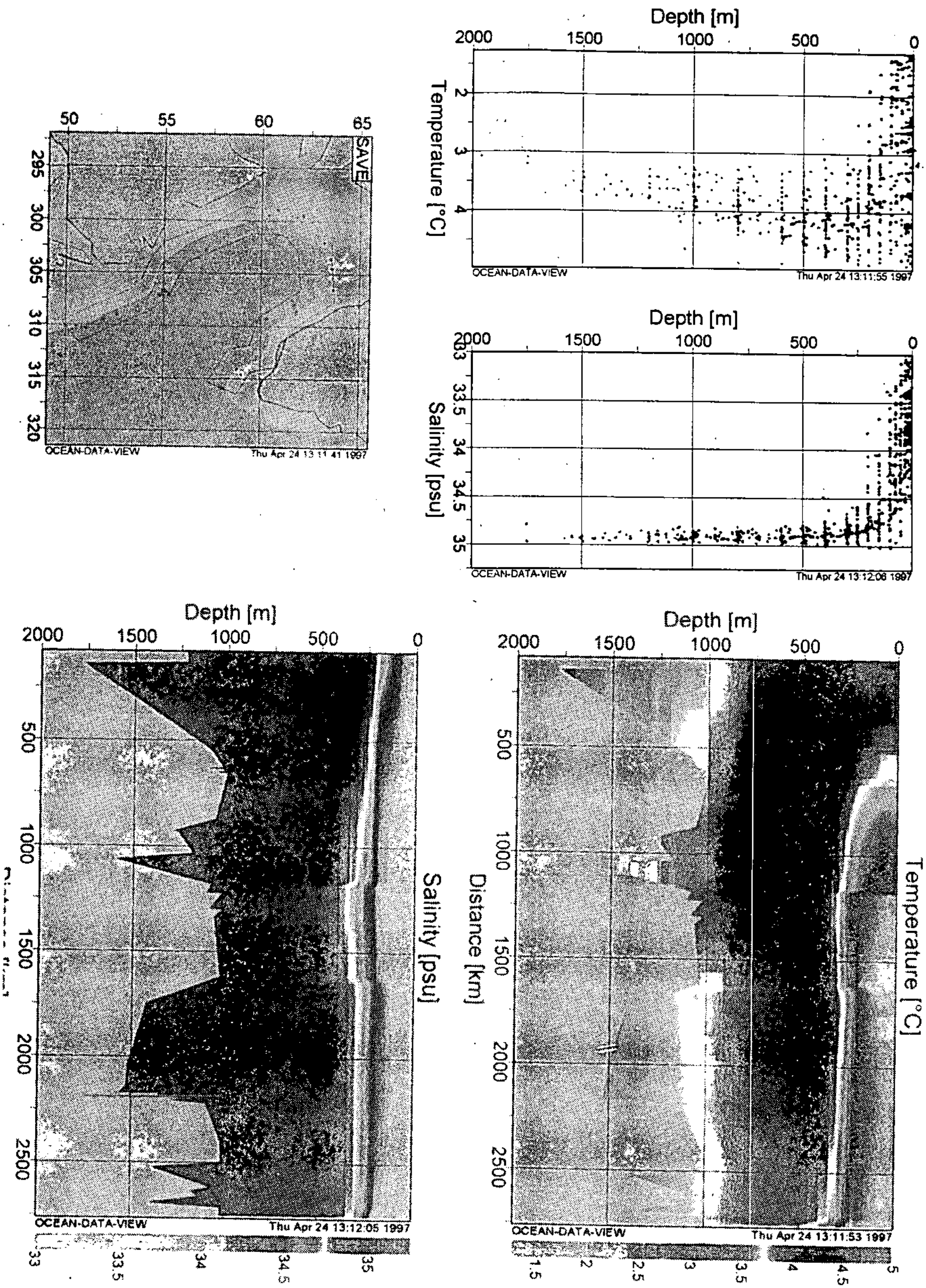

Fig. 5 1970-1979 climatic conditions plot of „Warm Water Supply“ by the Irminger Water mass; for definition of panels see fig. 2.

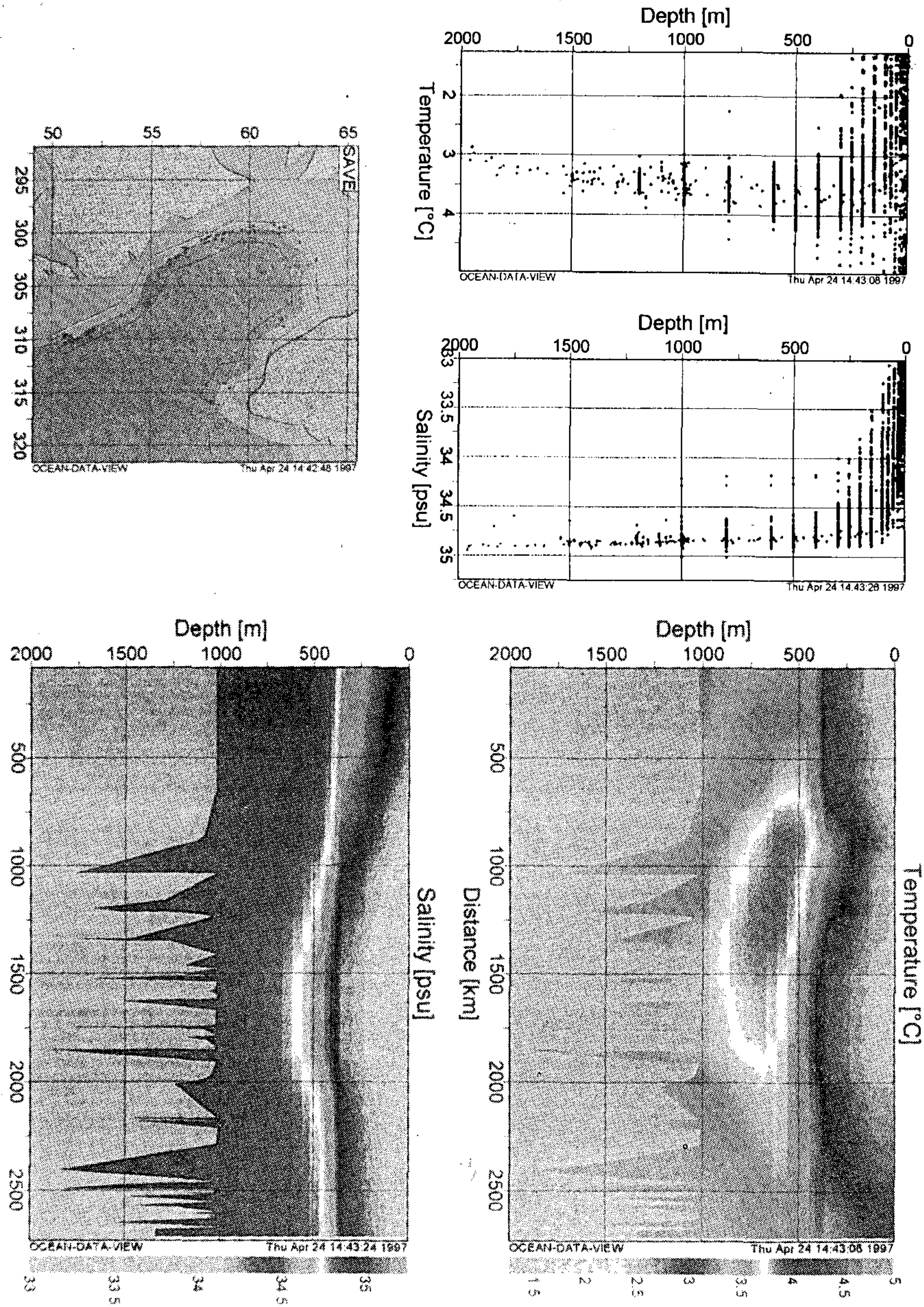

Fig. 6 1980-1989 climatic conditions plot of „Warm Water Supply" by the Irminger Water mass; for definition of panels see fig. 2.