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CRUISE REPORT

Environmental investigations in the Greenland Sea and northern Norwegian Sea. June- July 2004.

By

Francisco Rey[1], Kjell Arne Mork[1], and Magnar Hagebø [2].
[1] Research Group for Oceanography and Climate
[2] Chemistry Laboratory

with a contribution from
J-C. Gascard, C. Rouault and N. Martin
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Toktrapport/Havforskningsinstituttet/ISSN 1503-6294/Nr. 4 – 2004

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CRUISE NUMBER: JH2004208

VESSEL: R/V "JOHAN HJORT"

DEPARTURE: Bergen, Norway on June 13, 2004

ARRIVAL: Bergen, Norway on July 6, 2004

PARTICIPANTS:

Francisco Rey	Institute of Marine Research	Chief Scientist
Kjell Arne Mork	Institute of Marine Research	Scientist
Magnar Hagebø	Institute of Marine Research	Chief technician
Julio Erices	Institute of Marine Research	Technician
Anita Nybak	Institute of Marine Research	Technician
Linda Fonnes	Institute of Marine Research	Technician
Jan Erik Nygård	Institute of Marine Research	Chief instrument
Ole Sverre Fossheim	Institute of Marine Research	Instrument op.
Jean-Claude Gascard	LODYC, Paris, France	Scientist
Catherine Rouault	LODYC, Paris, France	Computer Engineer
Nicolas Martin	LODYC, Paris, France	Technician

The cruise had several major objectives:

1) To carry out physical, chemical and biological oceanographic observations at the standard Norwegian sections Gimsøy-NW and Bjørnøya-W as part of IMR`s own monitoring activities.

2) To carry out a detailed oceanographic study of convective "chimneys" in the Greenland Sea. Recovering of floats deployed in 2003 and deployment of new ones.

3) To collect water and sediment samples for the determination of diverse radionuclides in the northern Norwegian Sea and Greenland Sea, including monitoring activities at the site of a sunken Russian submarine.

4) To carry out a detailed survey of nutrients close to the bottom at selected sections along the Norwegian Sea continental slope.

Figure 1 shows the cruise track and the positions of the oceanographic stations where sampling was carried out. Not all the objectives of the cruise were achieved due to delays caused by technical problems with the CTD probe.

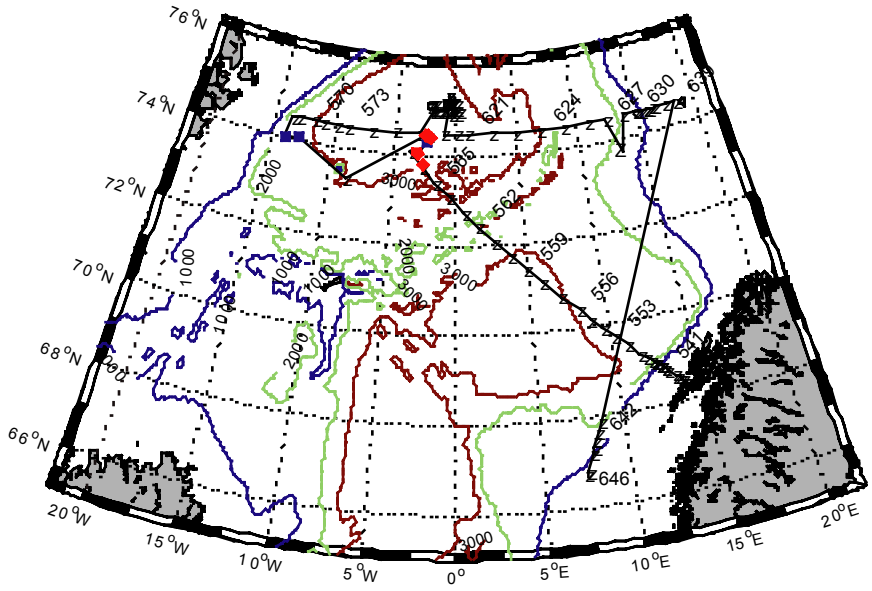


Fig.1 The cruise track of R/V"Johan Hjort" Cruise JH2004208. June 13 to July6.

Material and methods.

Hydrography

The hydrographic work was carried out with a CTD-water sampling package from SeaBird Inc. with data being collected both during down- and upcast. The package consisted of a SBE 911plus CTD with double sensors for temperature and conductivity and a SBE43 Oxygen sensor. All sensors were calibrated at the factory one month before the cruise. An oxygen sensor of new design, Aanderaa Optode 3830, was also mounted on the CTD as external voltage for testing. Unfortunately, in the middle of the cruise water leakage in the Optode sensor lead to shortcircuiting and disturbances in the CTD data acquiring system. At the end the sensor housing exploded while the CTD was on deck. Two LADCP-profilers (RD Instruments), down- and uplooking, were mounted on the CTD in order to obtain vertical current profiles (see Figure 2).

Fig.2 CTD probe used during the cruise

The CTD was also equipped with a 12 position SBE 32 Caroussel with 10 liter sampling bottles. At all stations water samples for calibration of the conductivity sensors were collected at the deepest sampling level. At selected

stations samples at all depths deeper than 1000 db were also collected. The samples will be analysed ashore.

Nine floats of the RAFOS type were deployed in three packages at different distances from the center of a convective chimney in the Greenland Sea. The floats were also deployed at three different depths (500, 1000 and 1500 m). The floats will drift at the same programmed depth for about one year. After that, they will pop up to the surface and transmit the data (positions, pressure and temperatures) via satellite (Argos system). The positions of the floats are found by tracking the floats with sound sources on moorings that were deployed last year.

Chemistry

Oxygen concentration was measured using the Winkler method with potentiometric determination of the titration end-point. Titration was done on whole samples (about 120 ml) using two 1 ml automatic burette (716 DMS Titrino, Metrohn) with a dispensing precision of 0.001 ml. The Titrinos were controlled by an own developed program (LabView) that permitted the analyst to analyze two samples simultaneously (see Fig.3). Calibration of the thiosulfate solution (about 0.1 N) was done on each run. The reproducibility of the method estimated as the standard deviation of six replicates was better than 0.3 µmol kg^{-1} at an oxygen concentration of about 300 µmol kg^{-1}. Sampling procedures, reagents preparation and analyses were done following WOCE recommendations as stated in Culberson (1991). Conversion of volumetric to weight concentrations were done as recommended by WOCE using potential temperature from the CTD bottle file.

Fig. 3. Chemists at work at the OxyLab on board R/V"Johan Hjort"

Seawater samples for the analysis of nitrite, nitrate, phosphate and silicic acid were collected just after the sampling for oxygen. After rinsing three times, samples were drawn into 10 ml high-density polyethylene test tubes with screw caps with O-rings, and kept dark and refrigerated at 4 °C. Analysis of the samples were carried out less than 12 hours after collection. At selected stations extra samples were collected in the same type of container for analysis of ammonia.

The analyses of nitrite, nitrate, phosphate and silicic acid were performed using a Flow SOLUTION IV automatic system from Alpkem with reaction units of own design and fabrication (see Fig. 4). The methods used were adaptations of standard methods (Strickland and Parsons, 1972) slightly modified to the autoanalyzer system (Føyn *et al.*, 1981). The precision for the different analyses (ten samples drawn from the same water sampler) at full scale was less than 0.2% for nitrite, nitrate and silicic acid and less than 2 % for phosphate.

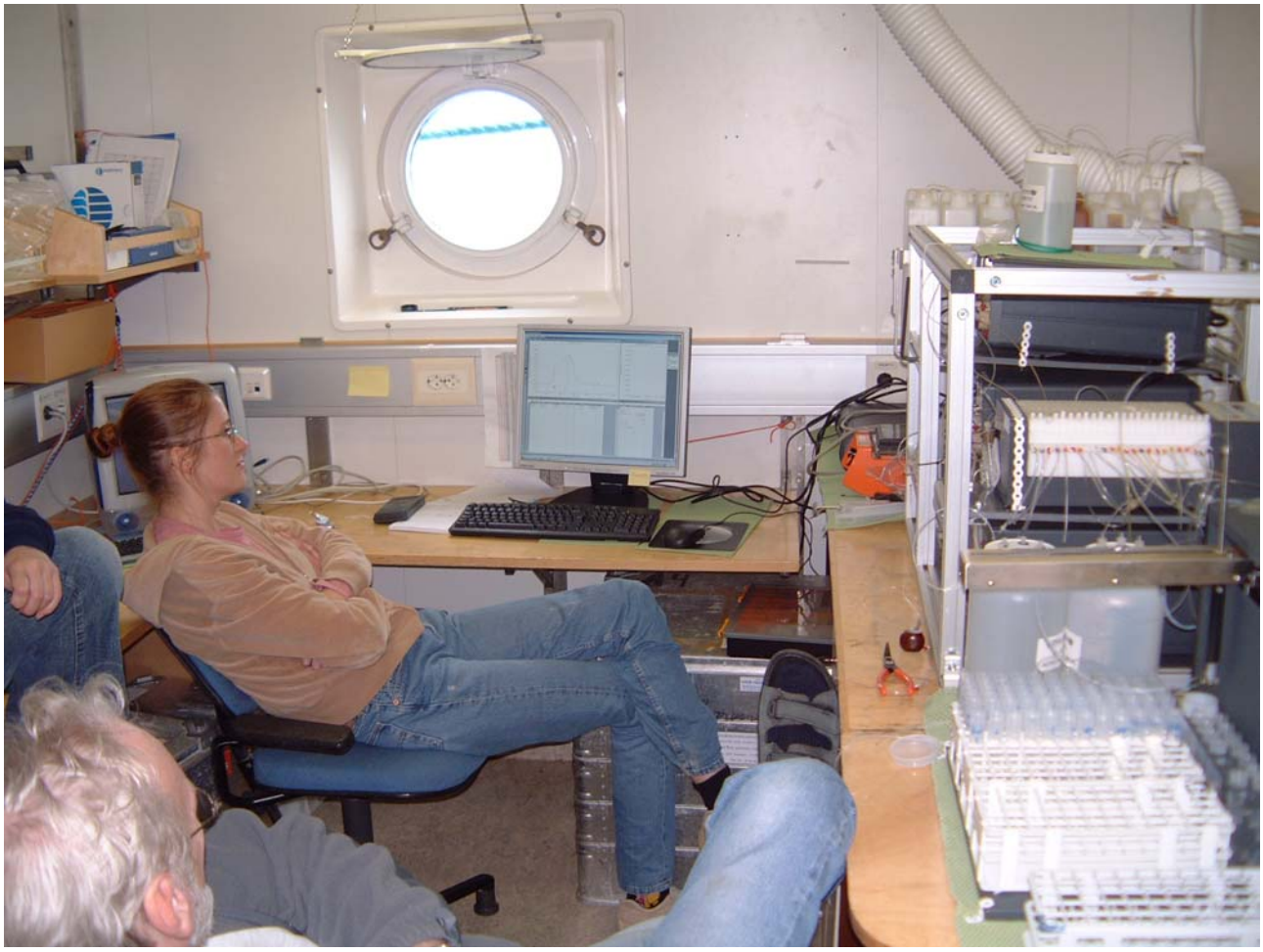


Fig. 4. Chemists at work at the NutrientLab onboard R/V"Johaqn Hjort"

Ammonia analyses were carried out by a fluorescence method described by Kérouel and Aminot, 1997. They were performed with a Flow SOLUTION IV automatic system but the sensor unit was a DFL-10 Fluorescence Detector

from D-Star Instruments. The precision of the method was about 1% at a 1 µM level.

At selected stations samples for iodine analyses were also collected. The samples will be analyzed ashore in France.

Samples for chlorophyll analyses were collected in 263 ml plastic bottles and filtered through glassfiber type F filters. The filters were inmediately frozen for analysis ashore.

Samples for taxonomic and quantitative analysis of phytoplankton were drawn from the sampling bottles into 100 ml brown glass bottles and 20 % neutralized formaldehyde was added for conservation.

Zooplankton

Samples for zooplankton biomass and species composition were collected by vertical tows at selected depth intervals by means of a 56 cm opening WP-2 plankton net with a 180 µm mesh size. The samples were split into two, one part being preserved with formaldehyde for later determination of species composition. The other part was passed through three different meshsize nets, 2000, 1000 and 180 µm, and the fractions collected into preweighted aluminium containers, dried at 60°C and then frozen. Determination of zooplankton dry weight in these samples will be done later ashore.

Underway measurements

Chlorophyll *in vivo* fluorescence (WebStar Mini fluorometer), temperature and salinity (SBE 21 Thermosalinograph, Seabird Inc.) were continously monitored on water from the ship´s water intake at 5 meters depth.

PRELIMINARY RESULTS

The hydrographical conditions along the section from Gimsøy and northwestwards are shown in Figs 5 to 7. As in previous years it was easy to identify the main watermasses in the area, the Atlantic water ($t>0.5°C$; $S>35.0$) and the Greenland Sea water ($t<0.5°C$; $S<34.9$) in the upper 500 meters. The area between these two water masses is called the Arctic Front. The Front is topographically controlled by the Mohns Ridge. This year it has also the same location from the surface to about 600-700 m depth, as seen from the salinity (Fig. 6.). The Front is relatively sharp and from the thermosalinograph (Fig. 8) it is, at least in the surface, only 1-2 km wide. Underneath the Atlantic Water lies the Arctic Intermediate Water ($S<34.9$ and $-0.5<T<0.5$). A salinity cell ($S>34.905$) on the western side of the Front suggests that there are some kind of eddy activity there.

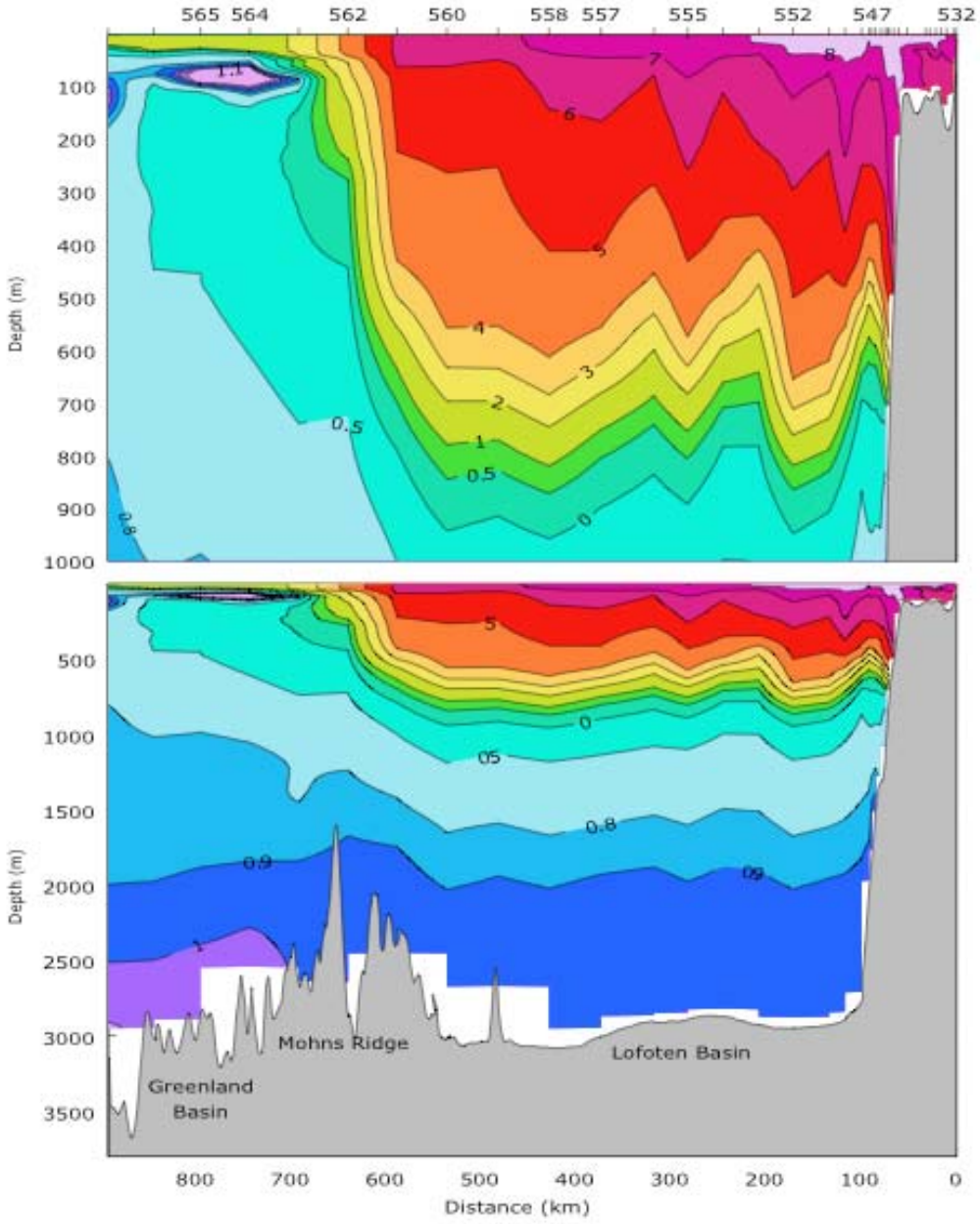


Fig. 5 Vertical distribution of potential temperature (°C)at the Gimsøy-NW section

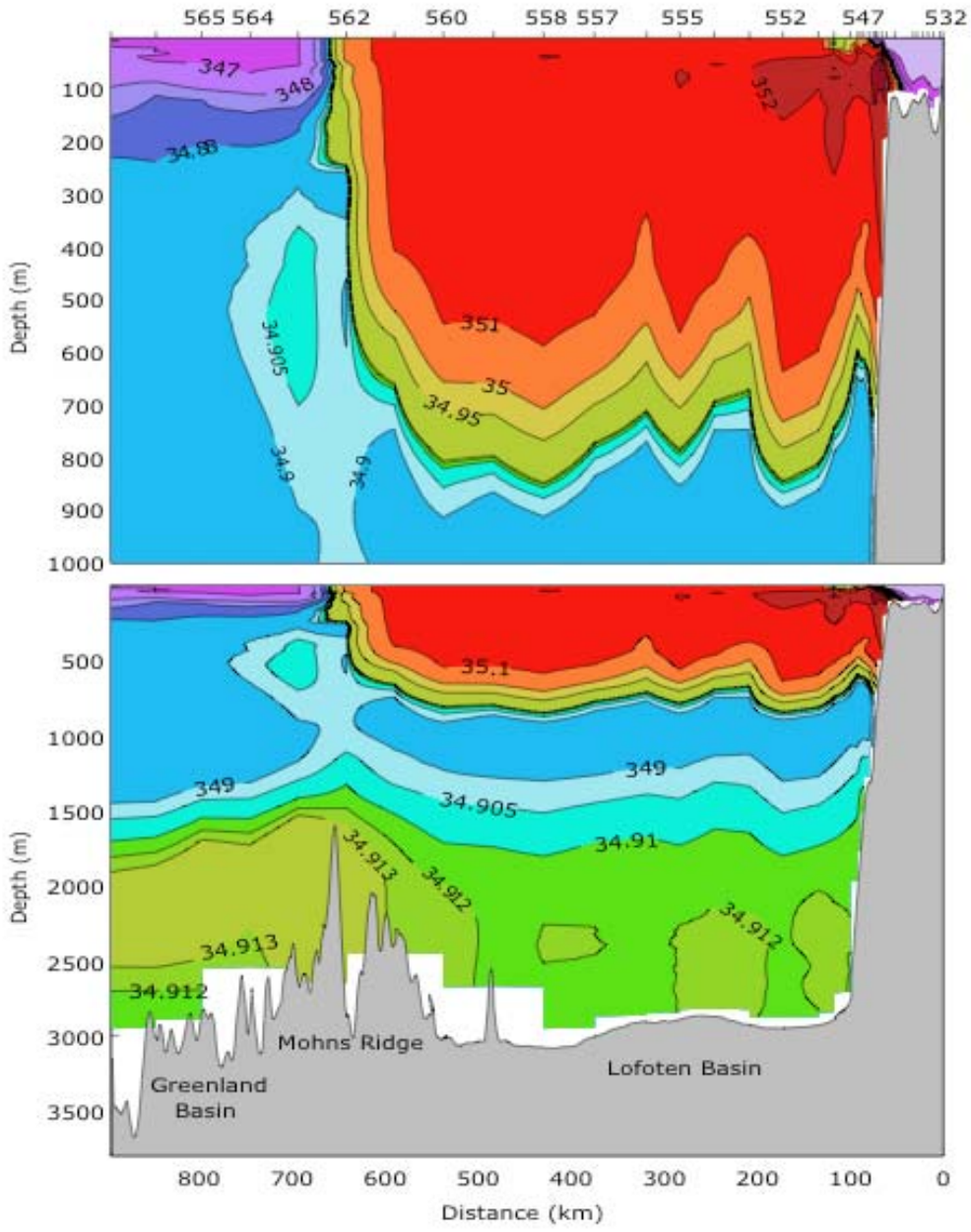


Fig. 6 Vertical distribution of salinity at the Gimsøy-NW section.

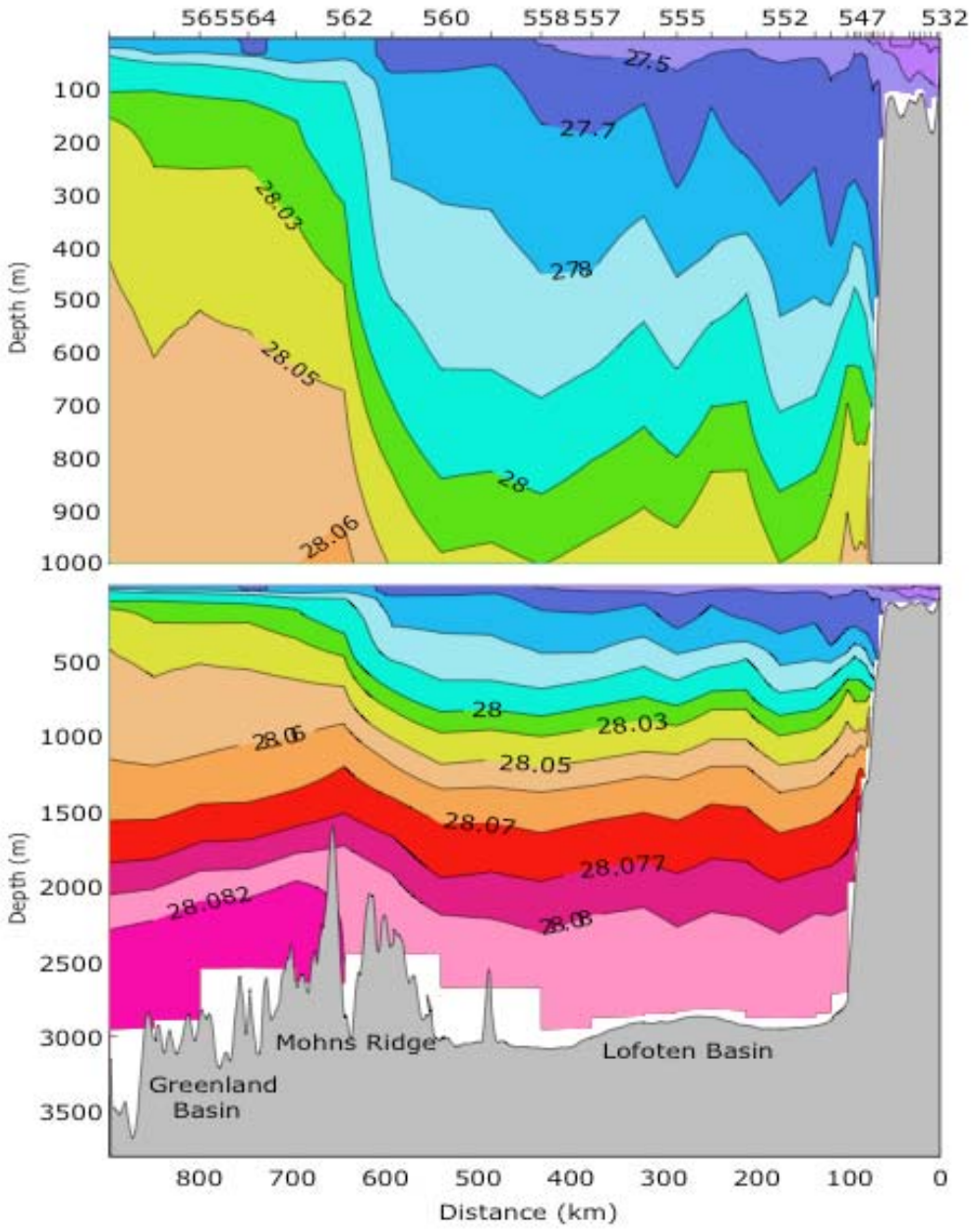


Fig. 7 Vertical distribution og sigma-theta at the Gimsøy-NW section

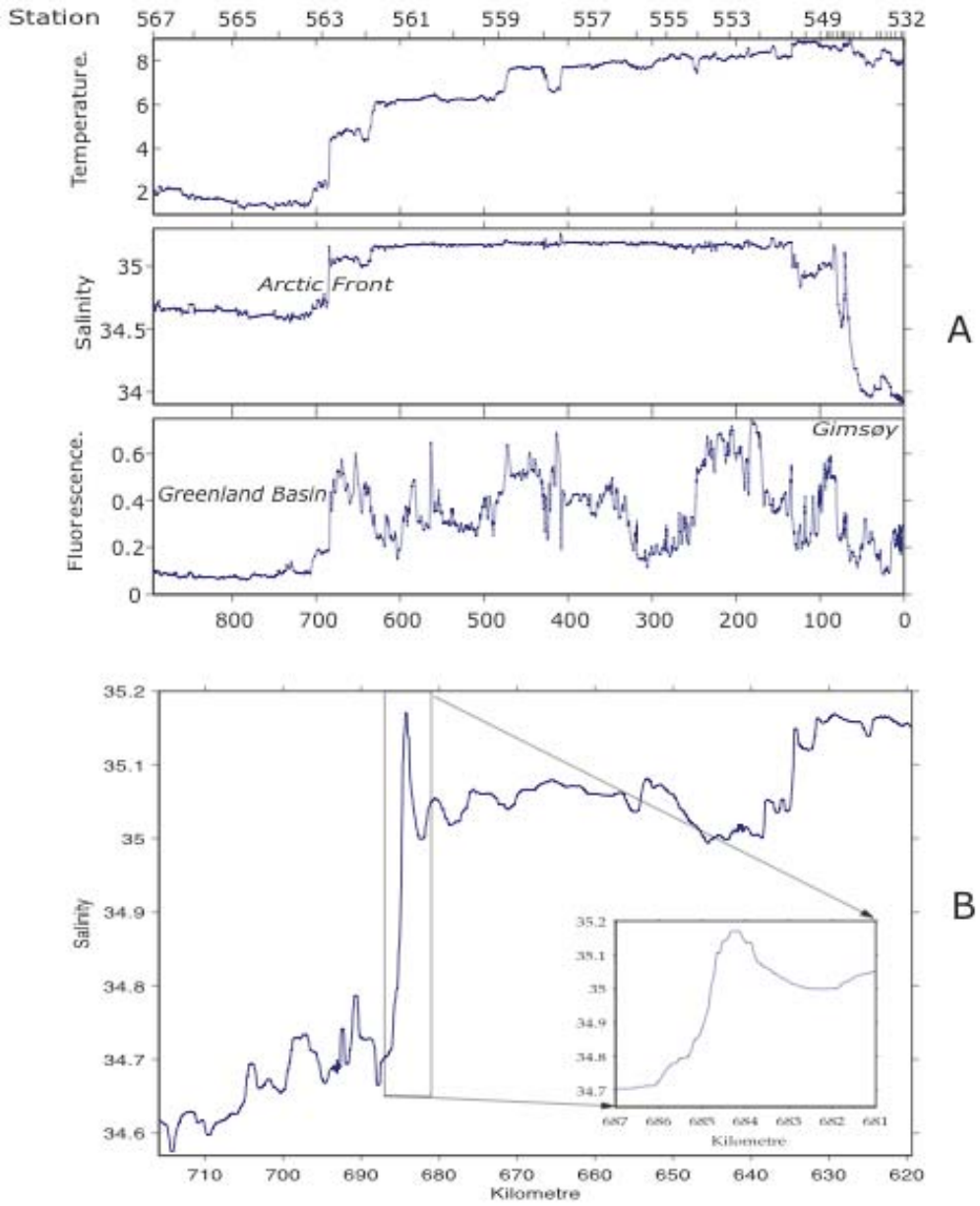


Fig.8 A) Horizontal distribution of temperature, salinity and chlorophyll *in vivo* fluorescence at the Gimsøy section. B) Enhanced view of the Arctic Front.

The oxygen and nutrient distribution along the section is shown in Figs. 9,10 and 11. The cruise was carried out about two weeks later than in previous years and this fact is well reflected in the nutrient distribution. The phytoplankton spring bloom was in full development in the part of the section covered by Atlantic waters and was over on the Norwegian continental shelf.

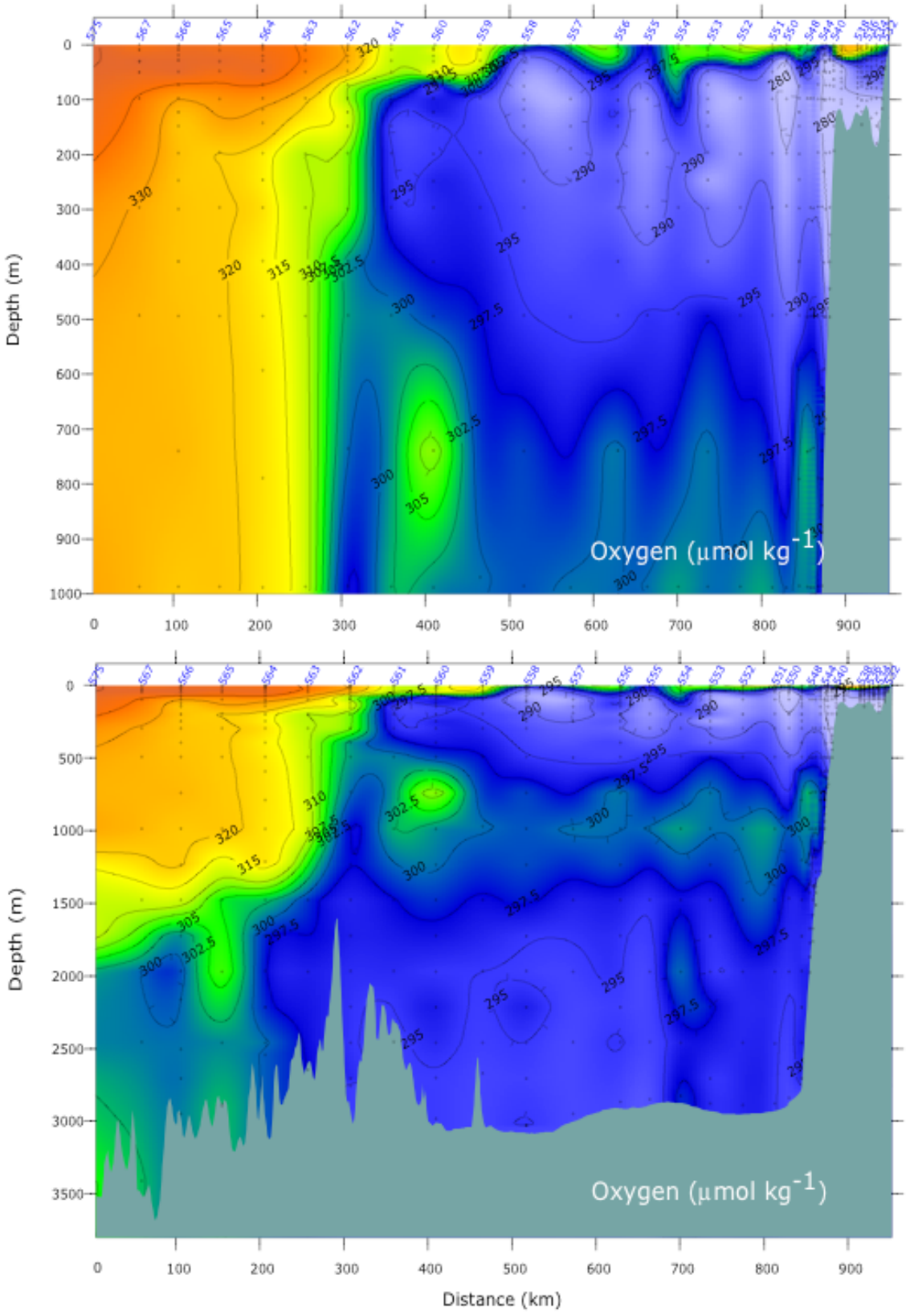


Fig. 9 Vertical distribution of oxygen at the Gimsøy-NW section. June 2004

In the Greenland Sea part of the section the spring bloom was close to termination judging from the chlorophyll fluorescence data (not presented). Along the whole section the almost total depletion in silicate concentrations

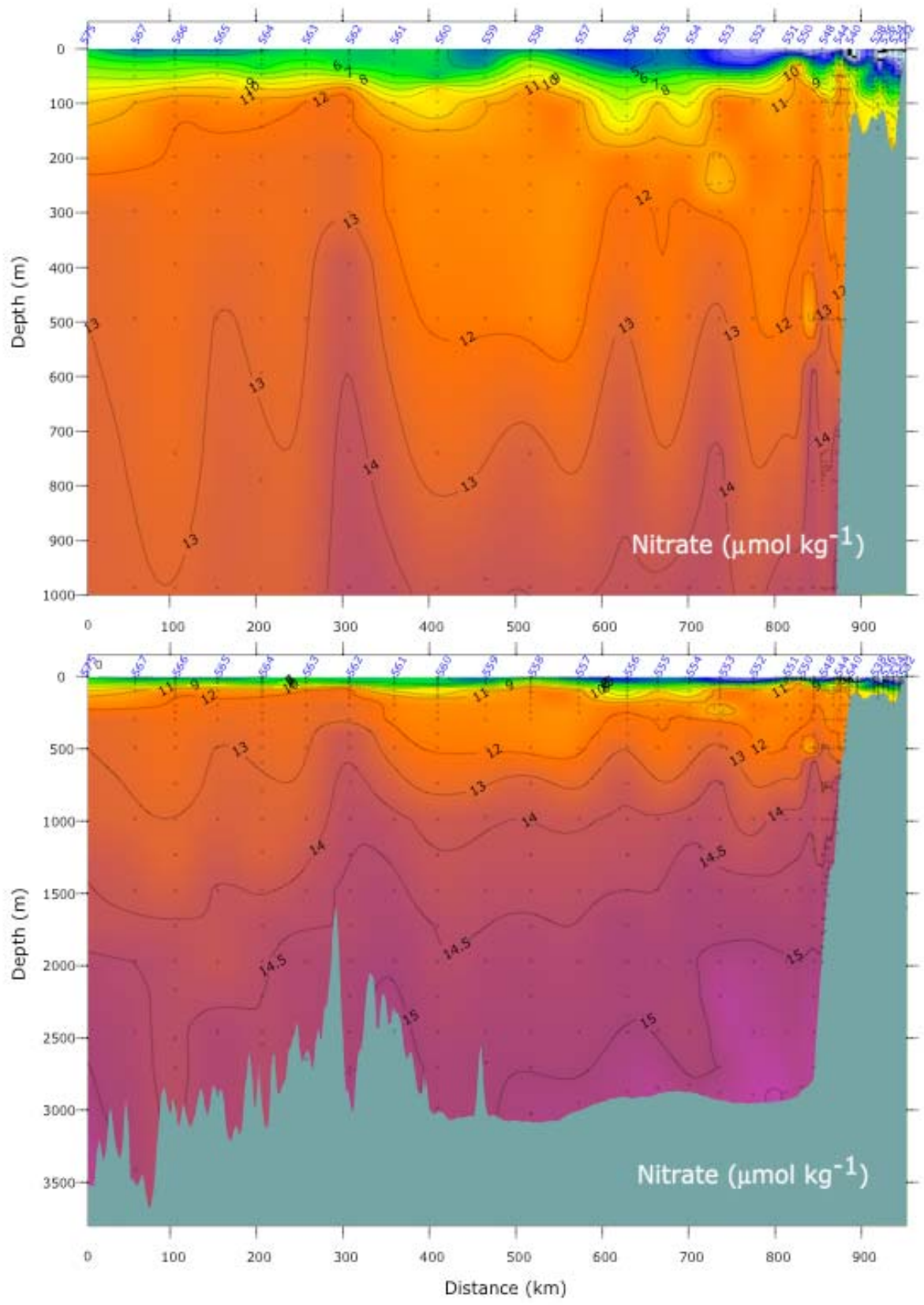


Fig. 10 Vertical distribution of nitrate at the Gimsøy-NW section. June 2004

and remaining moderate levels of nitrate indicates that the spring bloom has been totally dominated by diatoms. Onboard preliminary microscope

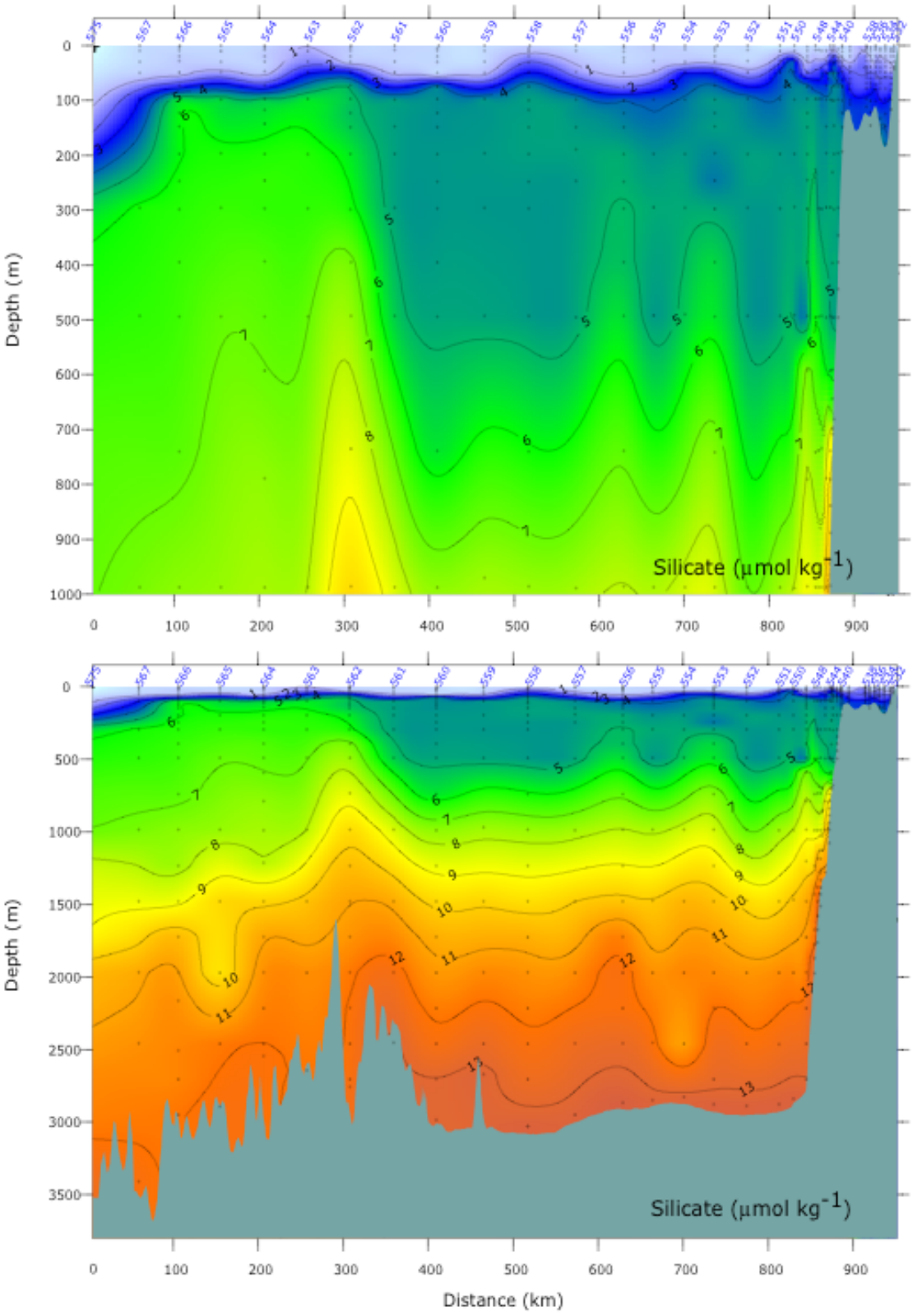


Fig. 11. Vertical distribution of silicate at the Gimsøy-NW section. June 2004

observations confirmed this. Most of the diatoms were large in size and belonged to the genus *Rhisozolenia*, *Thalassiothrix* and *Thalassionema*. On the

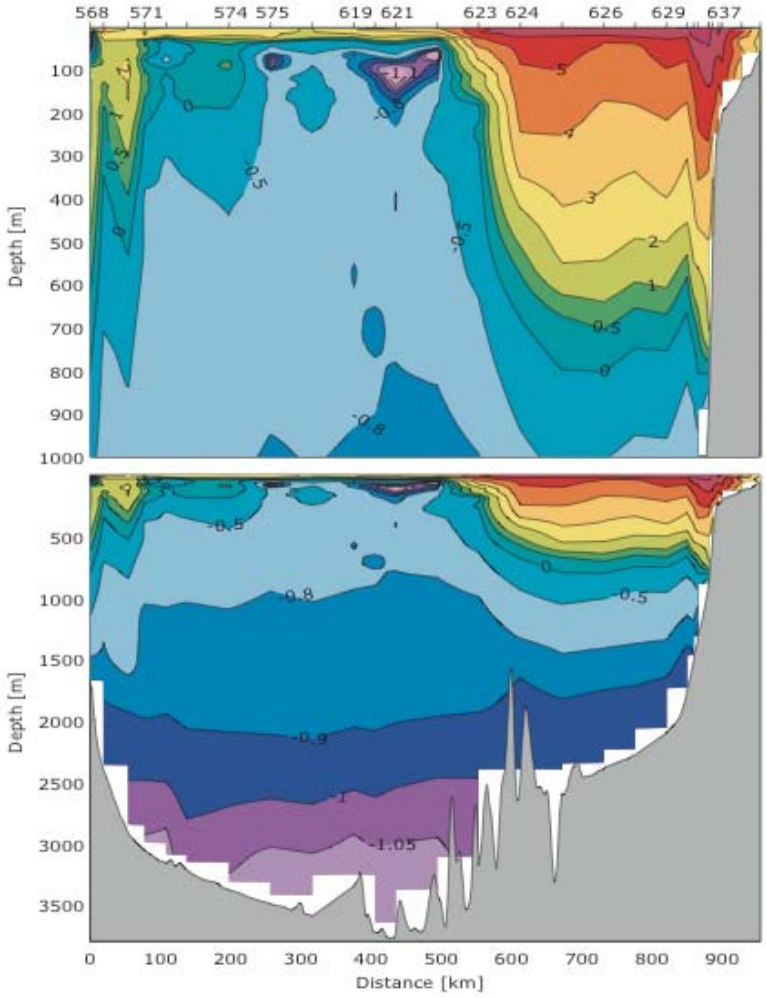


Fig. 12 Vertical distribution of potential temperature at the Bjørnøya-West section

Greenland Sea of the section the decline in silicate was observed down to about 100 meter depth. These facts suggest strongly that the 2004 diatom spring bloom was limited by silicate availability. No signs were observed of *Phaeocystis pouchetii*, another common component of the spring bloom in this area.

The conditions observed at the Bjørnøya-West section are shown in Figures 12 to 17. Atlantic Water in the section has a less westerly and vertical distribution than compared to the Gimsøy section. On the western side of the section, near the Greenland continental slope, the return Atlantic Water is seen at 100-300 m depth with salinity and temperature as high as 34.95 and 2.0 ^{o}C, respectively corresponding with lower oxygen concentrations.

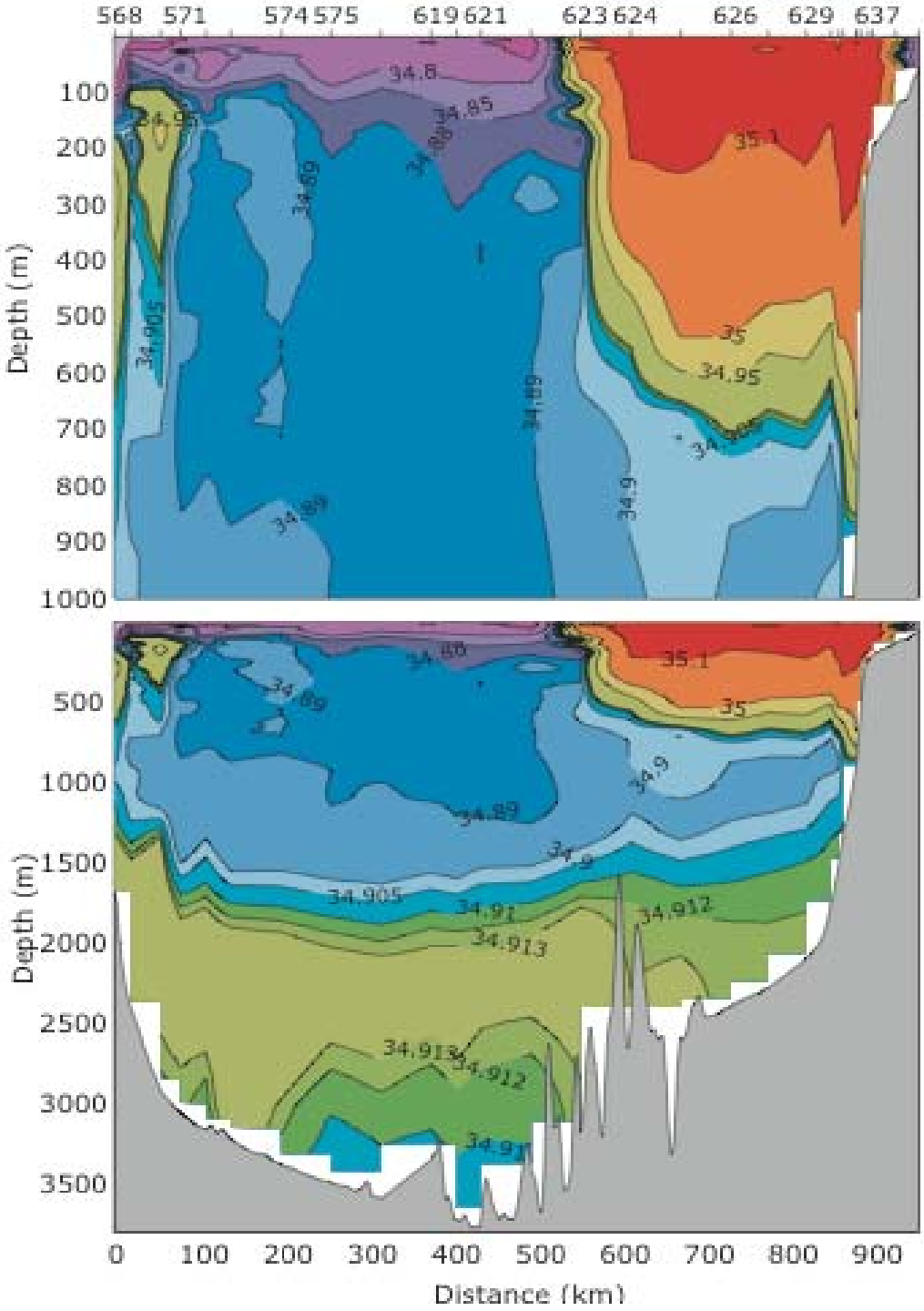


Fig. 13 Salinity in the Bjørnøya-West section during June 2004.

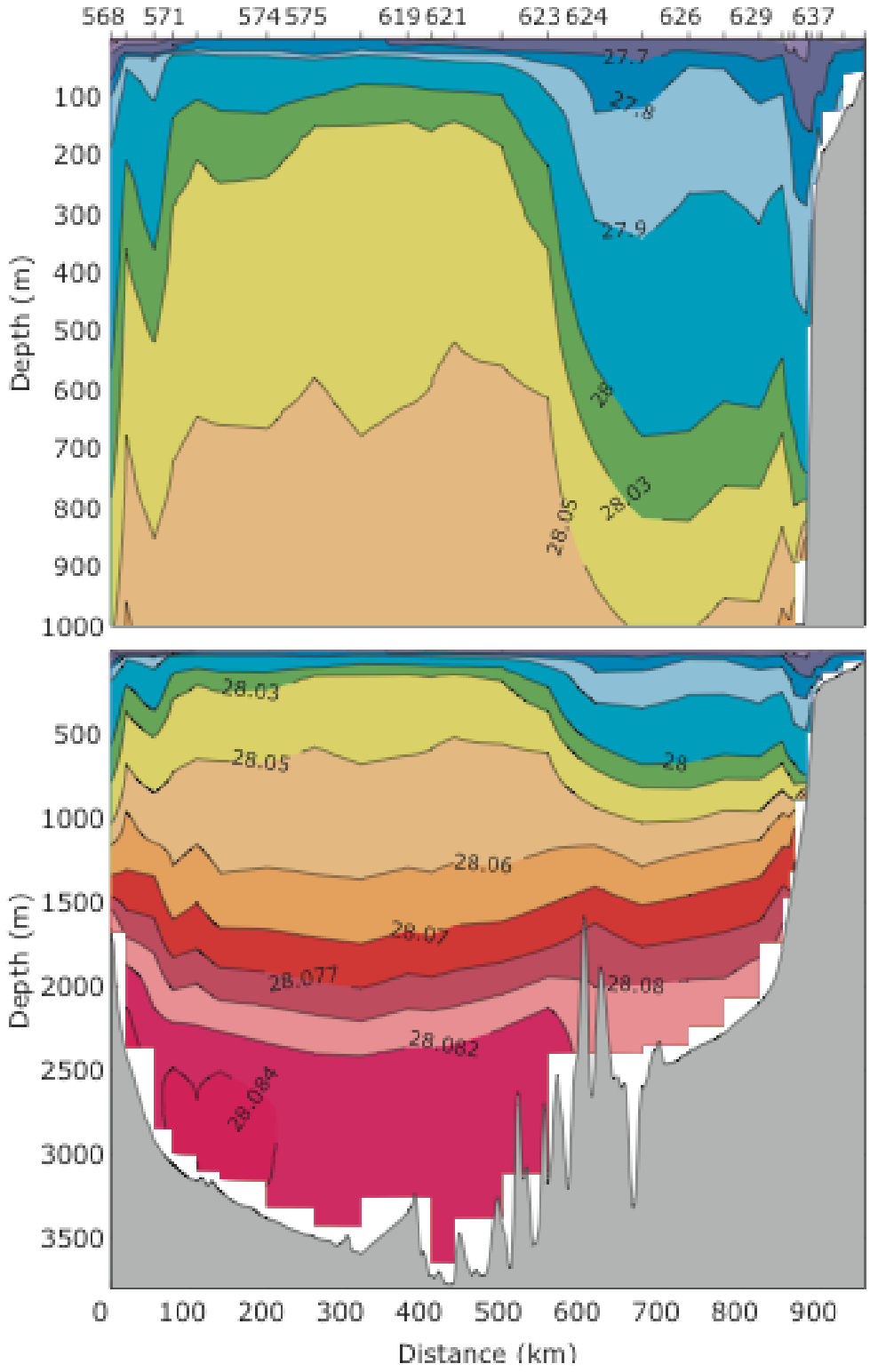


Figure 14 Sigma-theta in the Bjørnøya-West section during June 2004.

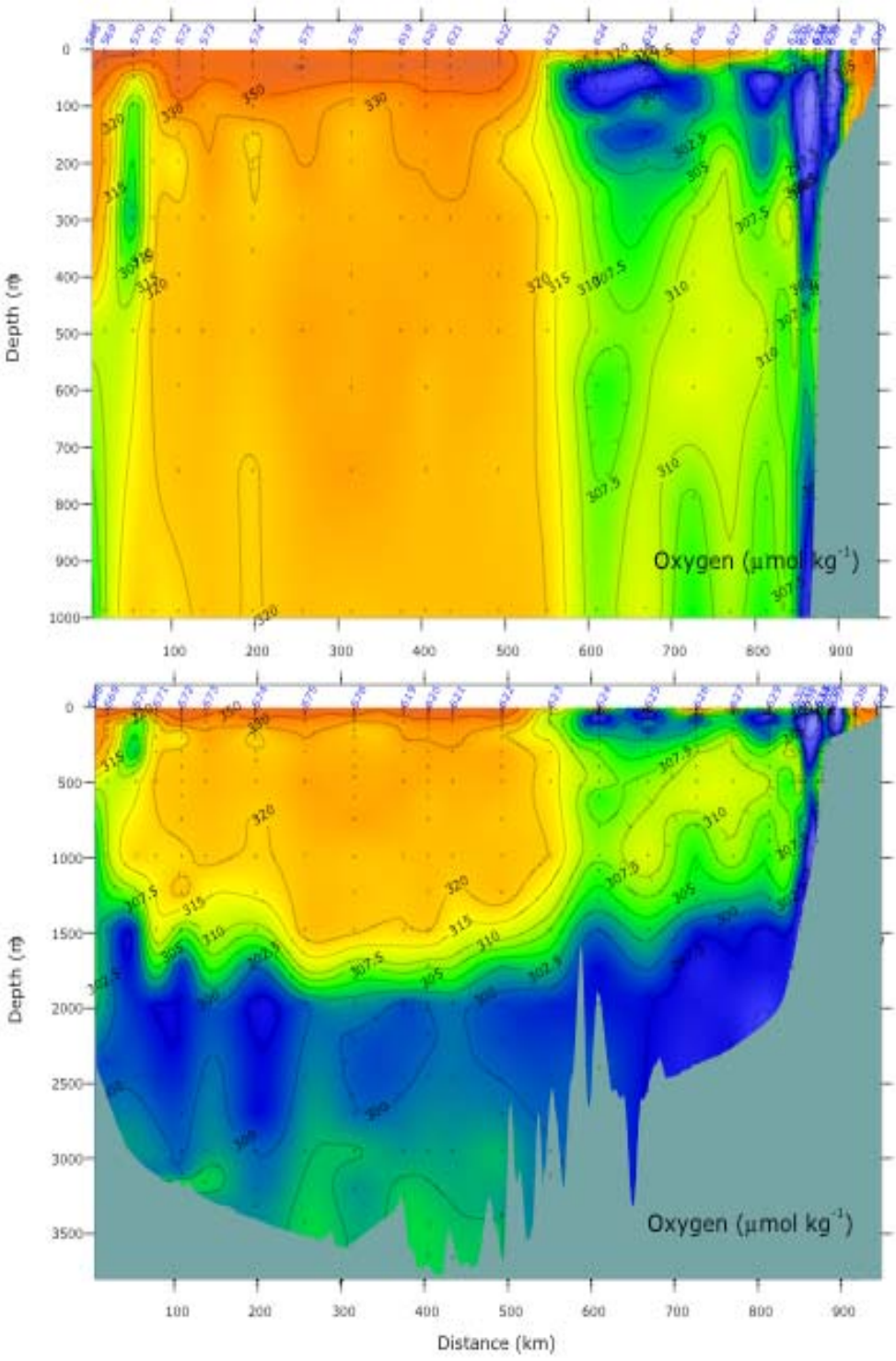


Fig.15 Oxygen in the Bjørnøya-West section during June 2004.

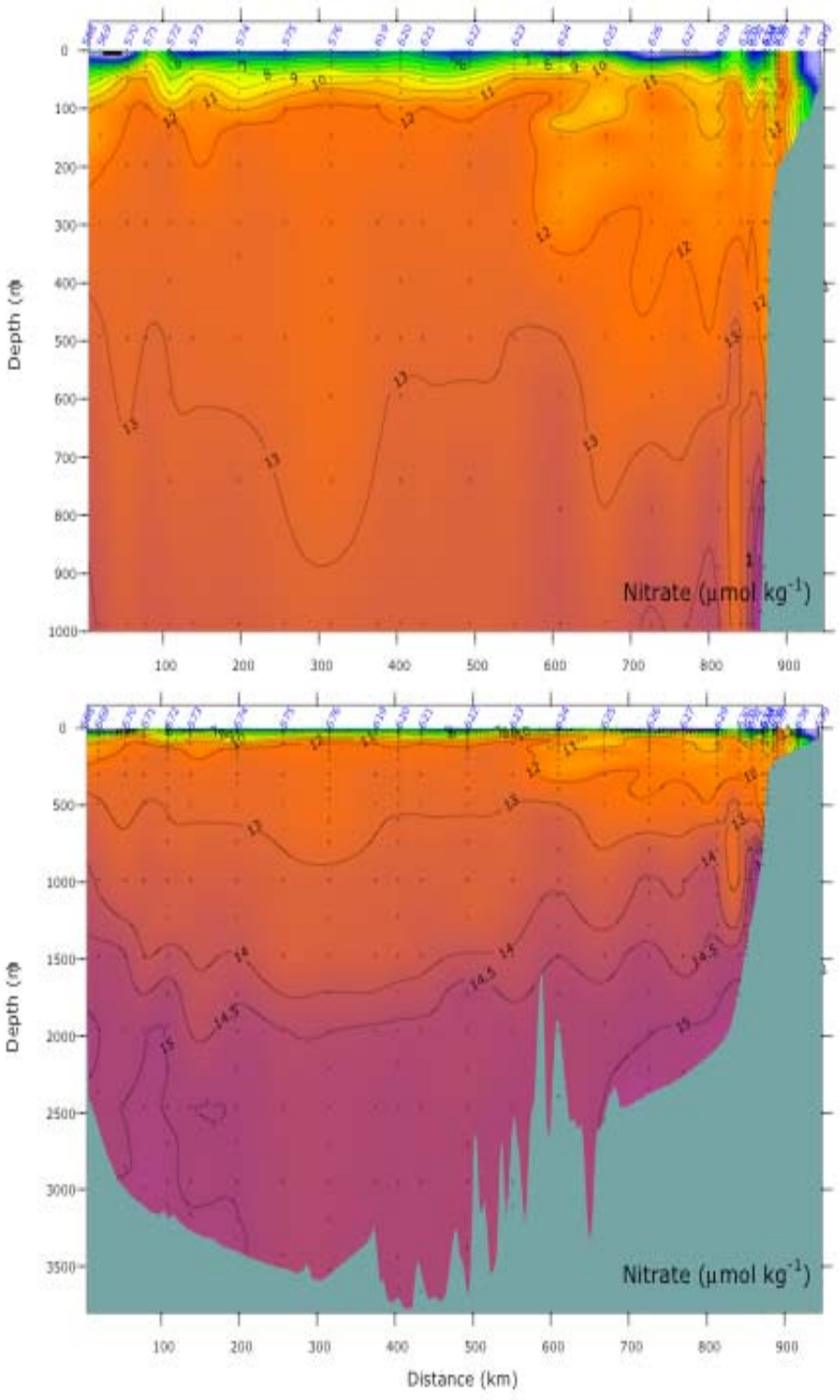


Fig. 16 Nitrate in the Bjørnøya-West section during June 2004.

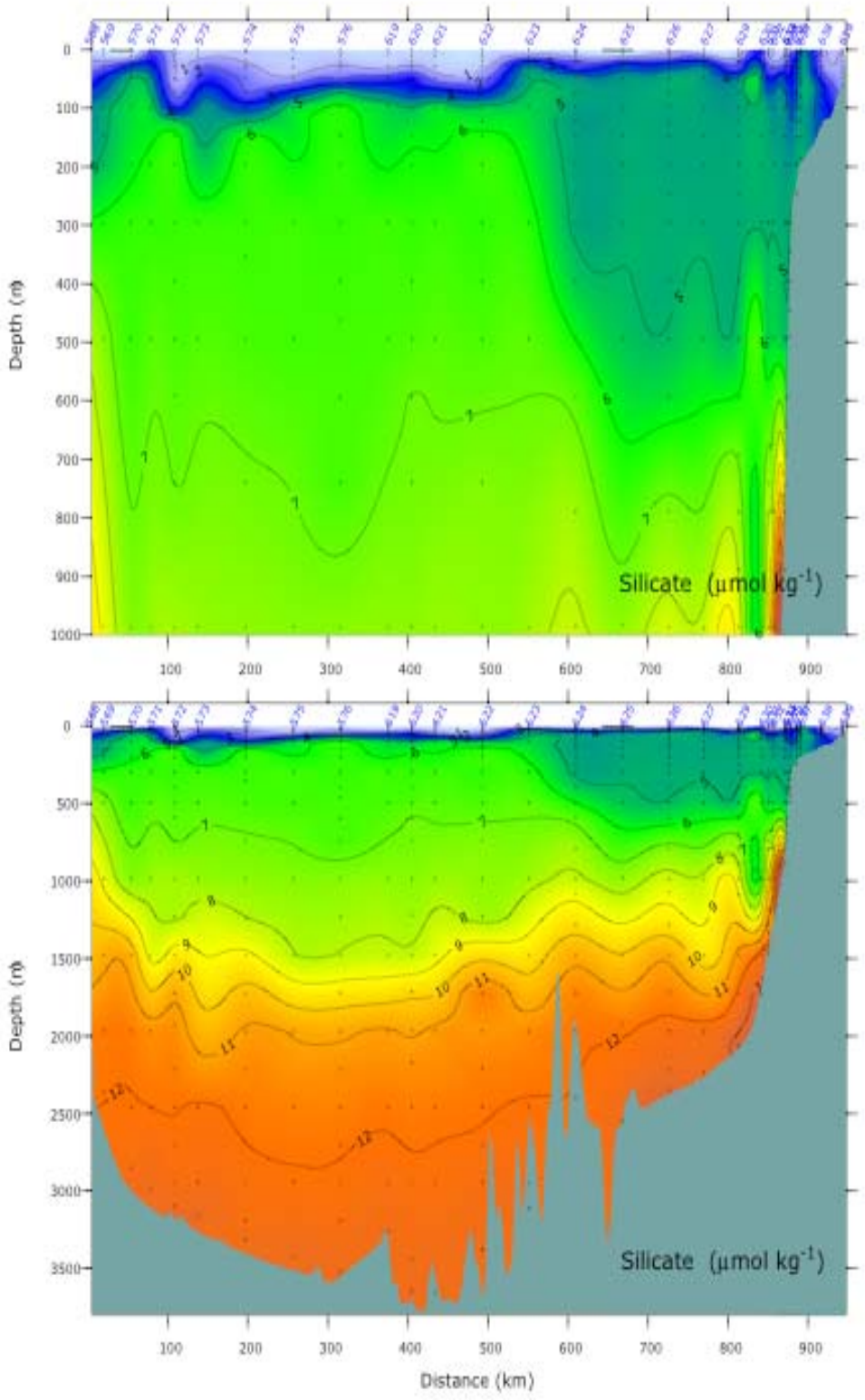


Figure 17 Silicate in the Bjørnøya-West section during June 2004.

One of the other main purposes of the cruise was to carry out detailed studies of convective "chimneys" in the Greenland Sea. During the cruise in 2003 (Rey and Mork, 2003) a "chimney" with deep convection down to about 2500 meters was found at 75° 16.1´N; 000° 38.5´W and drifting buoys from our French partners deployed in its center. The floats surfaced on May 12, 2004 a few weeks previous to the cruise not far away from where they were deployed the year before. The recovered data indicated that the floats were kept moving in an anticyclonic pathway all the year. After recovering the floats a short survey was carried out in order to find the "chimney". This was done almost at the same position as the year before at 75° 17.8´N; 000° 34.3´W. After conducting two sections, one east-west and another north-south with stations at about 1 nautical mile apart, new floats were deployed in the center of the chimney. Figures 18 to 22 shows the hydrography and chemistry of the chimney. The center of the chimney has a homogenous water mass (S=34.886, Pot.T=-1.0^{o}C, Sigma-theta=28.06) with a diameter of ~10 km and reaches down to 2300 m depth. It is surrounded by warmer water, all around. This and the sharp gradient in the salinity between the chimney and its surroundings, below and horizontally (Fig. 23) may indicate that there is no leakage from the chimney to the surroundings. However, the density instabilities on its edges (1500-2000 m depth) can give rise to mixing. As seen from the currents of the L-ADCP the chimney rotates anti cyclonic. The maximum speed is 30 cm/s and is located at the edge of the chimney at about 1700 m depth.

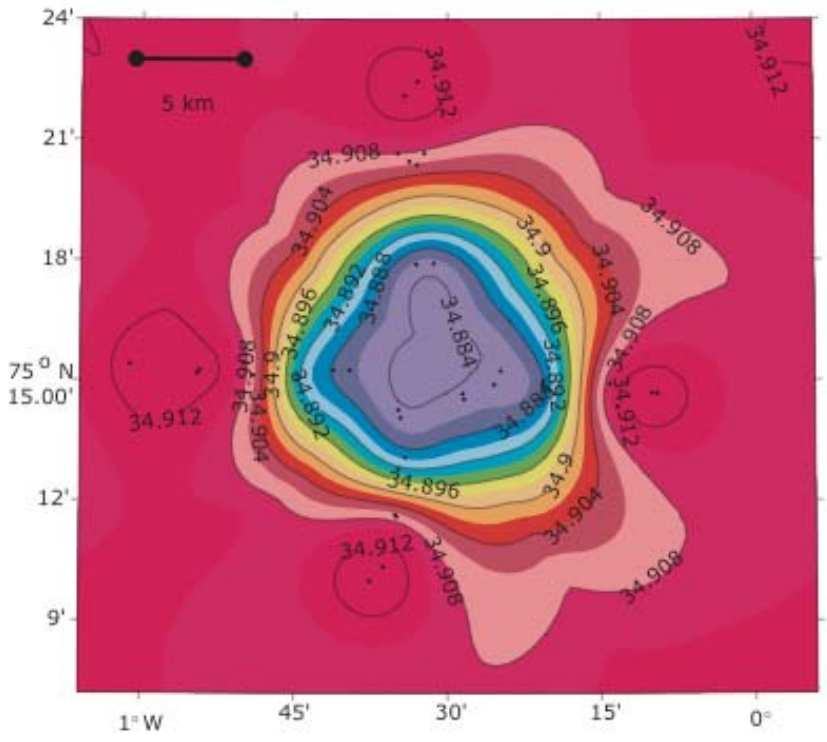


Figure 18. Salinity at 2250 meter depth

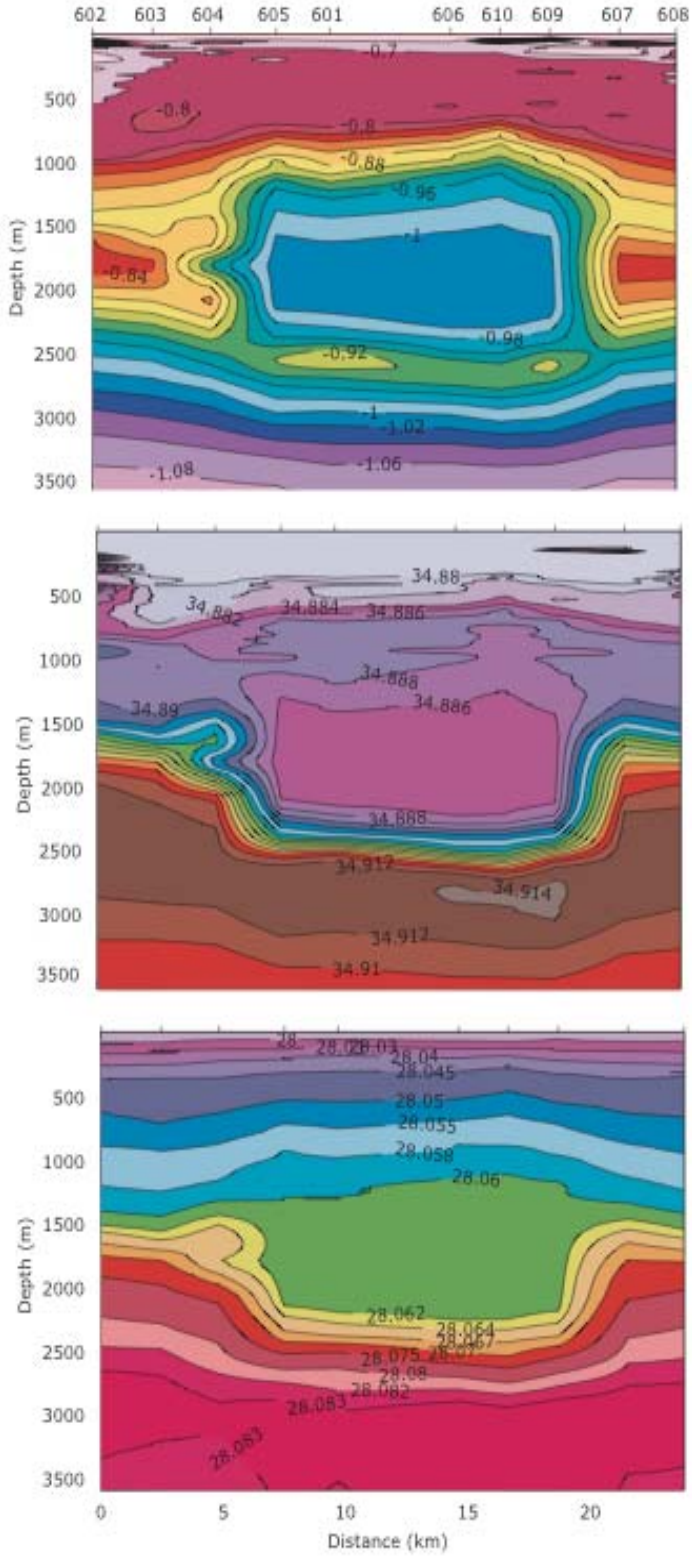


Figure 19. Hydrography across the chimney on an east-west section.

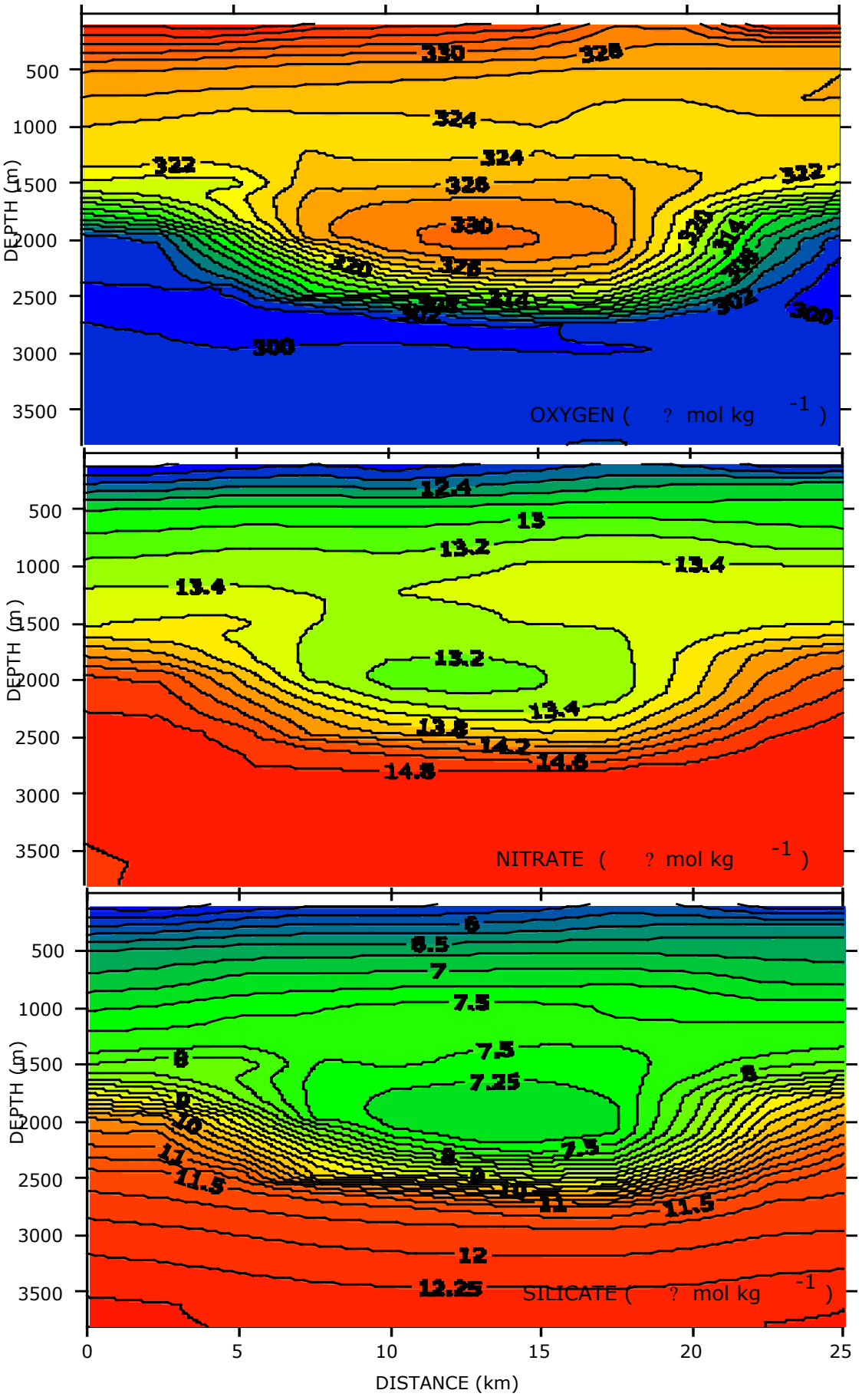


Figure 20. Chemistry across the chimney on an east-west section.

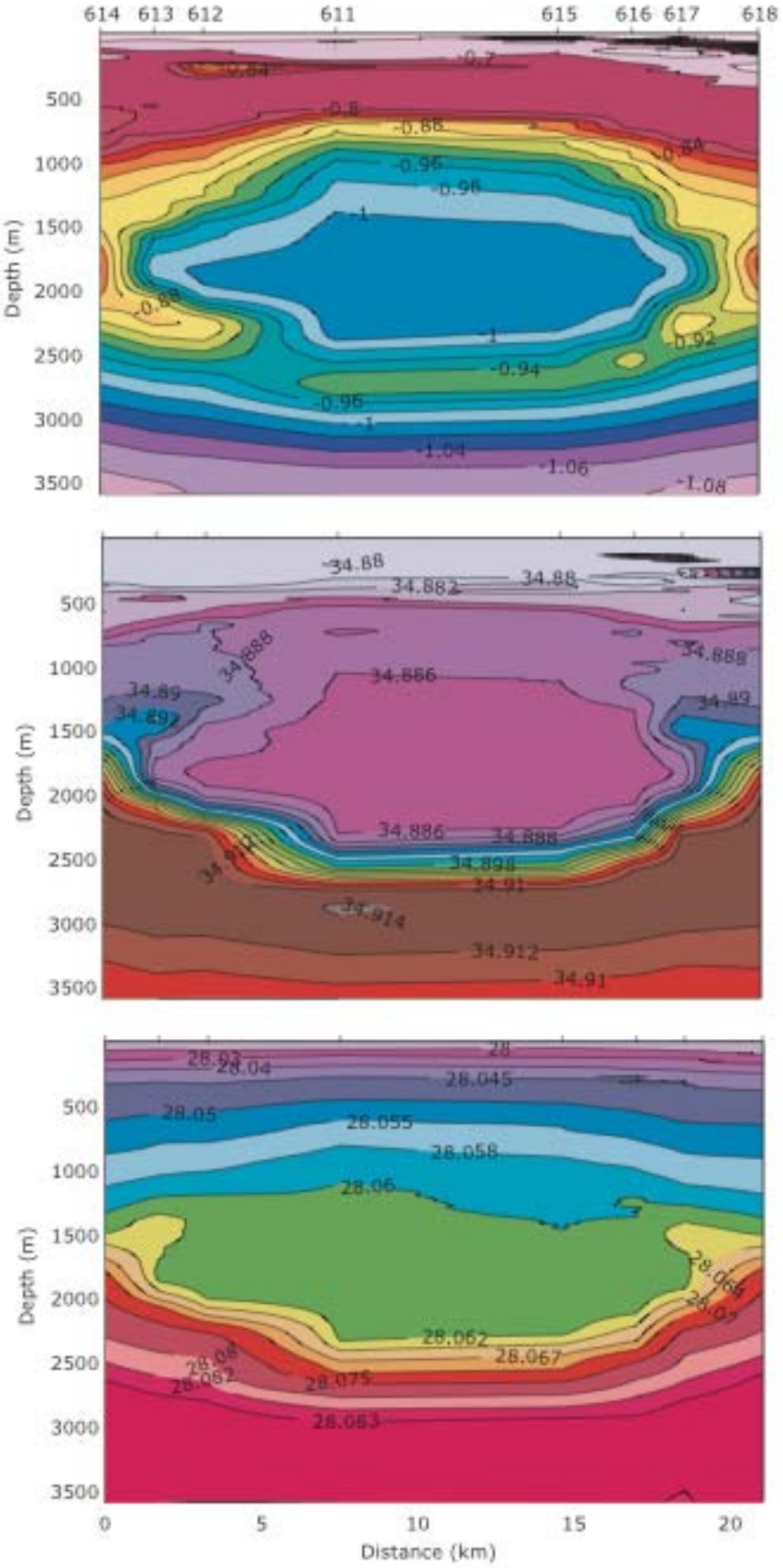


Fig. 21. Hydrography across the chimney on an north-south section.

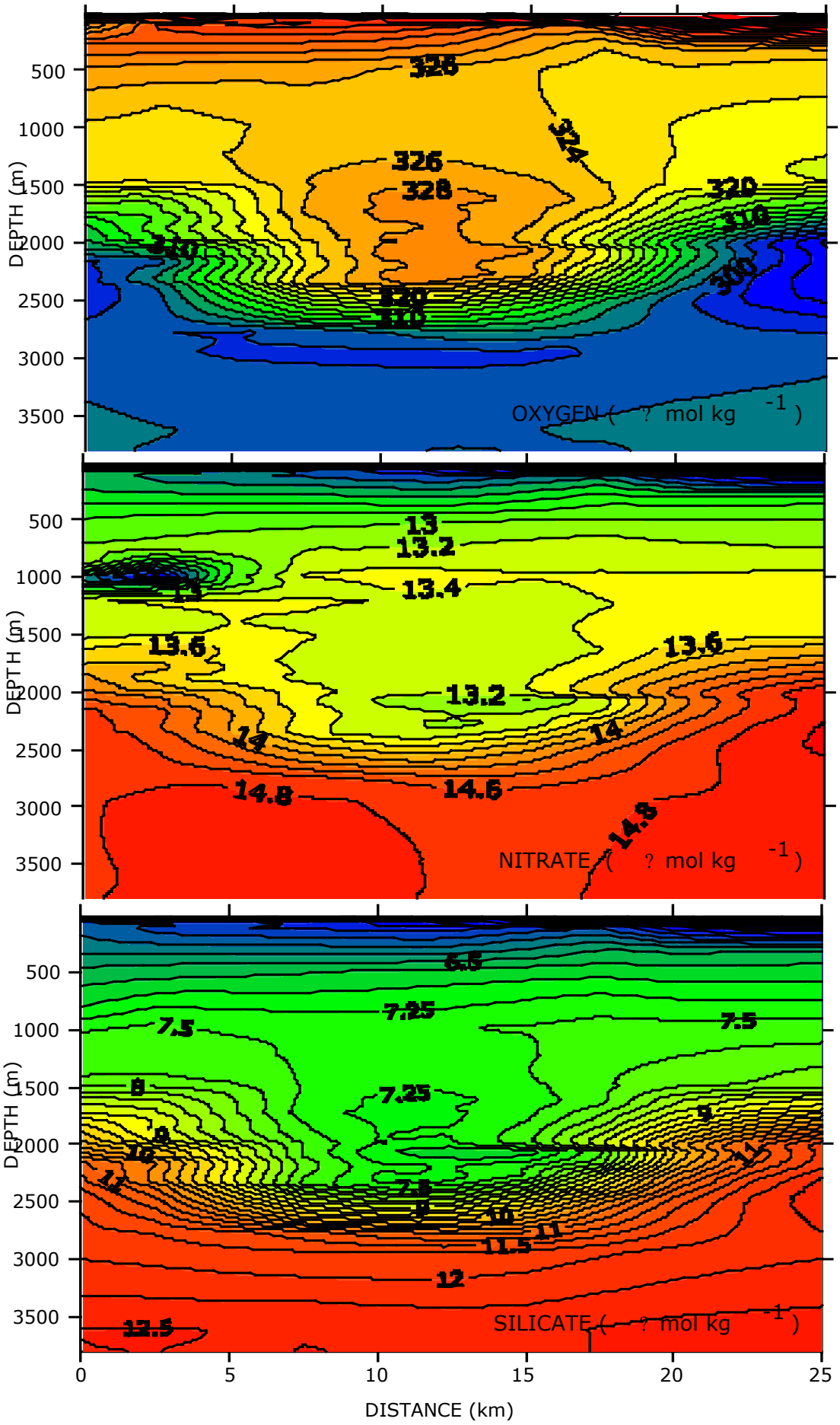


Figure 22. Chemistry across the chimney on a north-south section.

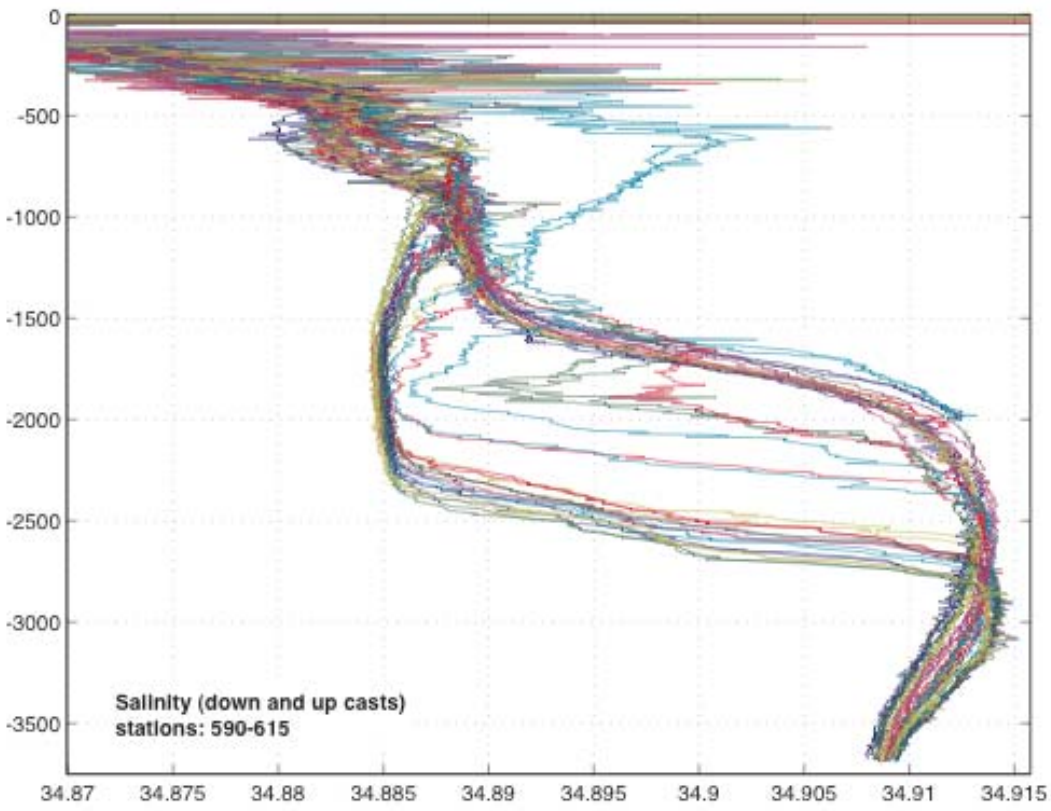


Figure 23. Salinity profiles inside and outside the chimney.

Report from the LODYC group for the Johan Hjort Cruise (June 13-July 6, 2004)

By

Jean-Claude Gascard, Catherine Rouault and Nicolas Martin.
Laboratoire d Océanographie Dynamique et de Climatologie from
Université Pierre et Marie Curie.

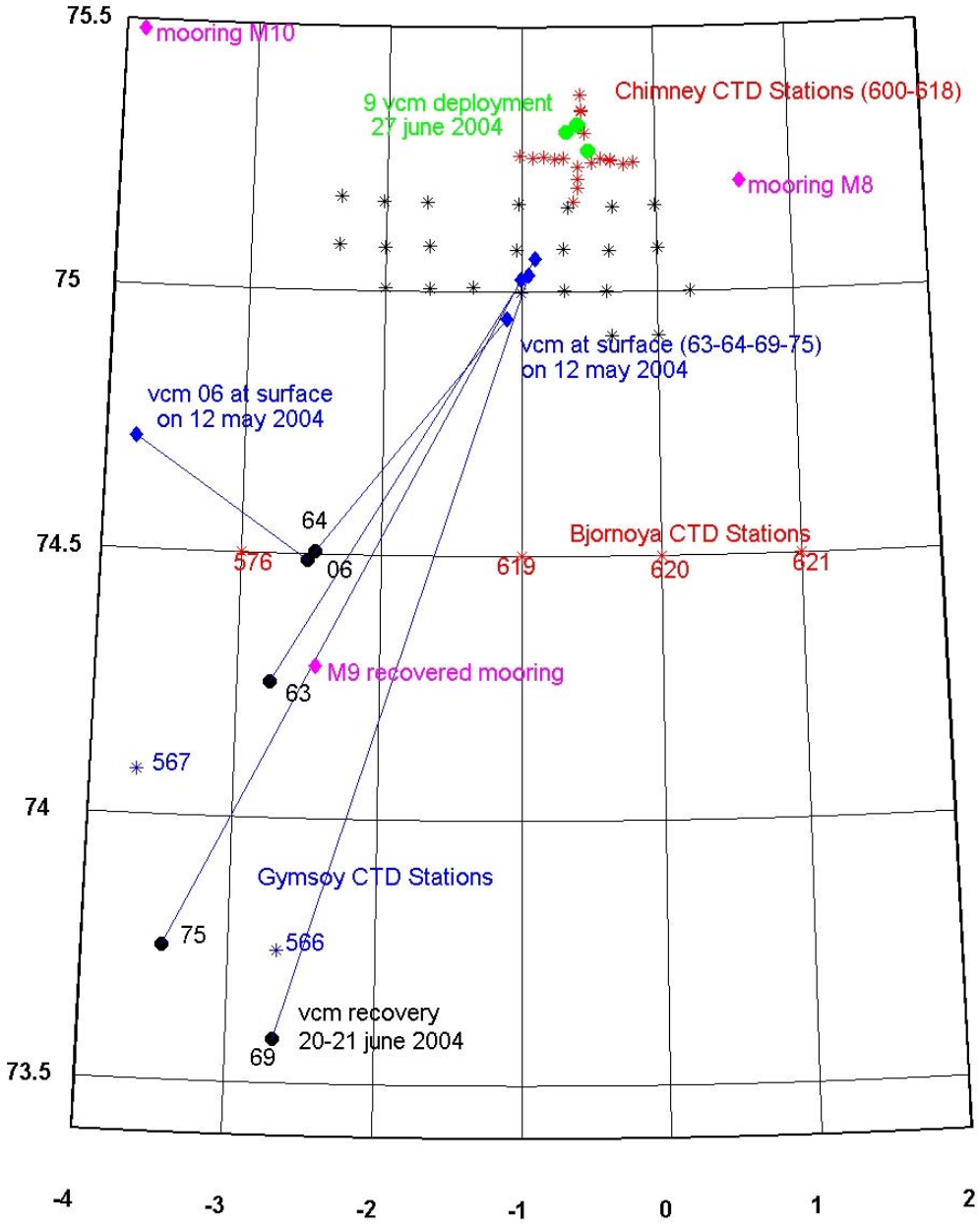
The first two days of the cruise, after leaving Bergen on June 13 and until starting the Gimsøy section on June 16, were mainly used for installing two 300khz RDI workhorse Lowered Acoustic Doppler Current Profilers on the IMR rosette and CTD frame. One LADCP (the "slave") was installed upward looking and the "Master" downward looking, the two LADCPs being synchronised so as to give a full profile of the horizontal currents at all depths and at all CTD stations taken during the whole cruise. It was agreed to lower the CTD at a maximal vertical velocity of 1m/s and to record both up and down casts as well as the GPS ship positions during each casts. A 58 volts battery

package was also installed on the Rosette frame so as to provide the energy to the two LADCPs during each cast. This battery had to be recharged after every deep casts during transit between stations. During this time both LADCPs memories had to be downloaded and reinitialised (approx 5 megabytes for a deep cast > 3500m). The 3 persons from LODYC were shifting watches every 4 hours to take care of these LADCP operations during the whole cruise. Vertical profiles of horizontal currents were produced on board during the cruise. The LADCPs worked quite well during the entire cruise and will provide interesting results in particular to calculate the total water mass transport across the Gimsøy and Bjørnøya sections and compare it with previous years.

In addition we collected 250 water samples (250ml) at many stations along the Gimsøy and Bjørnøya sections and at different depths from top to bottom, for analysing Iodine 129, an anthropogenic isotope released from the nuclear fuel retreating plants in La Hague (France) and Sellafield (UK). Combining Iodine 129 concentrations and water masses transport, we will be able to calculate the total flux of Iodine 129 across the sections. Also Iodine 129 will be analysed on each samples taken for Technetium 99 radioactive measurements. The ratio Iodine 129/Technetium 99 will gave us the time since these radioisotopes have been released in the ocean.

Another major part of the work for which the LODYC group was involved, concerned a deep convective chimney study in the Greenland Sea. This was a similar operation from the one taken last year on board RV Johan Hjort (May 29-June 16), where 6 neutrally buoyant floats had been launched inside one of these chimneys early June 2003 at 3 different depths (500m, 1000m and 1500m) near 75°15N and 000°40W. On May 12, 2004 the 6 floats popped up near 75°N and 1°W (see map below). Four of them (floats #63, #64, #69 and #75) were still very packed when they surfaced indicating that the 2003 chimney had survived for an entire year since June 2003. If not, the floats would have been widely dispersed all over the basin. The main tasks in 2004 consisted in (a) recovering the 6 floats which had been drifting at surface for about 6 weeks between May 12 and June 21, 2004, (during this whole period, floats were transmitting data and were localised several times a day with Argos), (b) recovering one of the 3 moorings (M9) deployed last year in the Greenland Sea near 74°15N and 2°30W because the sound source installed on this mooring and used for tracking floats underwater acoustically, was defective (most of the floats and the mooring being nearby the positions of the last two CTD stations (#566 and #567) of the Gimsøy section, we did not have to spend too much time in transit), (c) remapping the area with CTDs profiles in order to find the new position of the chimney (CTD positions represented by black and red stars on the map), (d) redeploying 9 new floats (green dots on the map) inside the new chimney at 3 different locations and same depths (500m, 1000m and 1500m) for another year (until May 20, 2005). All these operations went very well. We recovered the 6 floats and the mooring in about one day (June 20-21). In order to find the chimney, we surveyed the area north of 75°N for 2 days taking 22 CTD stations (#577 to #599 black stars) limited to 2500m depth in an area where bottom depth is found typically around 3700m.The chimney was discovered at station 600 on June 26 early morning and surveyed along two transects (West-East and North-South) from station 600 to station 618 (red stars near 75°15N). The chimney center was

pointed near 75°17 N and 000°35W, that means 1 to 2 miles away from last year position. Floats trajectories since last year deployments, indicated the chimney had moved no more than 50 km from mooring M8. All the 18 CTDs casts inside the chimney were taken full depth and with the help of the two LADCP, full depth profiles of horizontal currents were obtained revealing the strong anticyclonic vorticity of the chimney. Interestingly peak orbital velocities (>30 cm/s) were found at the periphery of the chimney and at about 1700m depth where the vertical CTD profiles revealed some inversion in the density distribution. It will be quite interesting to investigate thoroughly this new aspect of the Greenland Sea chimney.



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ACKNOWLEDGEMENTS.

We would like to thank the personal from the Chemistry Laboratory and the Instrument Group at IMR as well as the crew of the R/V "Johan Hjort" for a well done job.

Onboard R/V "Johan Hjort" July,6 2004.