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Report of a chief of an expedition

1. Introduction.

In the 31st cruise at RV "Professor Shtockman" hydrophysical studies were carried out in a north-east part of the Atlantic ocean in a zone of the Azor front. The expedition route scheme and the works area are given on Figure 1.

The expedition took place within the international WOCE program, basic project 3, part "subduction" of projects "Fronts and eddies" and "Razrezy" of the Russian state scientific - technic program. "Complex Research of Oceans and Seas, of the Arctics and Antarctic".

1. Subduction.

As a term of subduction there is understood a set of physical processes which determine the input of waters of a surface boundary layer being directly influenced by the atmospheric effect into the upper part of a main thermocline. The idea of the water masses being formed in the inner ocean area by the way of intrusion and "ageing" of the surface layer waters was first brought up by the end of the 30s by Aiselin and Montgomary on a base of the joint analysis of vertical and horizontal T-S curves for the ocean surface and as a result of this their principal similarity has been shown. Practically up to the latest time this idea had neither experimental nor theoretical development. Beginning with the 1985 mainly by russian as well as by foreign scientists there were taken measurements of thermohaline characteristics in the ocean with high vertical and horizontal resolution. One of those should be first considered the researches in the experiments "Mesopolygon" in 1985, "Megapolygon" in 1987 in the expedition "Atlantex-90" in 1990. As a result mesoscale intrusive formations with anomalous relatively to hum characteristics were found and described. It is shown that intrusions are statically steady formations which shift in quasi-isopicnic layers. Usually intrusive structures were found in the areas of hydrologic fronts.

Recently there appeared rather simple models where an exchange in the ocean is parameterized with isopychic and dynamic exchange differing from a traditional vertical and horizontal exchange. Results of modeling let us understand a number of problems solution of which is related to an understanding of subduction processes.

Nowadays an international program of subduction studies is formulated and carried out and it is a part of a general program "World ocean circulation experiment" (WOCE). Repeated researches of the specifics at subduction processes of different seasons are now carried out in the area of Azor front (AR-II). The Institute of Oceanology of Russ. Acad. Sci. participates in this program and provides this cruise partly covering its obligations.

2. Fronts and eddies in the ocean.

In 1970 soviet scientists conducted a big experiment on research of hydrophysical fields of the open ocean-Atlantic hydrophysical polygon-70. Synoptic eddies of the open ocean were discovered and described in a result of repeated hydrophysical surveys and currents measurements analysis. This discovery stimulated intensive researches of the eddies activity in different regions of the ocean: american experiments MODE I, MODE II, soviet-american experiment POLYMODE, soviet experiments "Mesopolygon", "Megapolygon", "Atlantex-90" and other.

Study of experimental data and results of the eddy-resolution al modeling let us assume that ocean eddies, and first of all-frontal eddies may bring an important input into the exchange of heat, salt and momentum in the ocean. According to this nowadays there are taken active modeling and experimental research in different ocean regions for solution of this fundamental problem of the ocean physics.

3. Main goals of the expedition.

3.1. Taking measurements for description of the geographic location and intensity of the Azor current and of the Azor frontal zone, of meanders and eddies forming due to hydrodynamic instability of a current. Types of measurements: continuous temperature measurements in the near-the-surface ocean layer; discrete sound measurements on a hydrophysical survey of the research region; measurements of currents on ABC in the Azor current rod (programs "WOCE", "Fronts and eddies").

3.2. Taking measurements for study of subduction processes of surface layer waters and the intermediate waters ventilation in the zone of the Azor front. Types of measurement: temperature and salinity measurement with high spatial resolution (horizontal 0,5 -1 km, vertical 0,2-1 m) in the upper 400 meter ocean layer; microstructural measurements of the vertical distribution of temperature, salinity and vertical current shift in a layer of 0-300m; CTD-sounding up to a length of 2000m (program "WOCE", part "Subduction").

3.3. Measurements for description of structure and dynamics of the upper ocean level. Types of measurements: repeated drift measurements of temperature and salinity profiles with discreteness of 3 hours during 36 hours; measurements of currents velocity in the upper quasi homogeneous layer and seasonal thermocline with discreteness of 28 sec.; measurements of microstructure of vertical distribution of temperature , salinity and velocity gradient of the horizontal current component (programs "WOCE", "RAZREZY").

3.4. CTD-sounding on a special program in case of finding lenses of mediterranean origin for description of thermohaline structure in a "body" of the lens and in its periphery)Program "WOCE", "Fronts and eddies").

4. Methods and means of measurement and data processing.

Metrological supply of measurement equipment.

For description of a large scale structure and a synoptic scale disturbance there was undertaken a CTD-survey in 4 sections, oriented normally to the Azor front. Distance between the sections-60 miles, and measurement discreteness on sections 10-20 miles. CTD-sounder "Mark-3" has been used for measurements.

Mesoscale structure measurements in a frontal area were taken on transfrontal sections by the way of tugging at a speed of 4 knots of CTD-sounder with the depth scanning. That provided a high measurement resolution as to horizon (discreteness < 900 meters). Scanning CTD-complex "Fish" with a measurement sounder modulus "Mark-3" on tug has been used for measurement.

Microstructural measurements were taken at a daily station with discreteness of 3 hours up to the depth of 250 meter. Measurements were taken by a falling microstructural sounder "Baklan" with two sensors of velocity, conductivity, temperature, pressure and vibration.

At the same daily station there were taken current velocities from aboard of a ship in the upper ocean layer and vertical profiles of temperature and salinity. Measurements were taken from aboard of a ship by current meters "POTOK" with a time discreteness of 38 sec. at 10 horizons and OHS -sounder (optical hydrophysical sounder constructed by SKB MHI) every three hours.

Mentioned above the measuring complex at a daily station was undertaken, m order to describe the dynamic and thermohaline-structure of the upper boundary layer and its daily evolution.

Processing of sounders "Mark-3", OHS and current meters - "POTOK" was provided according to standard algorithms. Program maintenance of the registration and processing of the tugged complex "Fish" was provided by employees of the Atlantic division: engineer-programmer V.A.Maslov; senior scientist Dr. N.N.Golenko.

Meteorologic measurements were taken at standard terms 4-times a day. During polygon works meteorologic measurements were carried out every 3 hours. Measuring complex included standard equipment: thermometer for the air temperature measurement, psychrometer, thermometer for the water temperature measurement, aneroid barometer.

Standard processing of meteorologic information and calculation estimation of heat, humidity and momentum fluxes was provided by GGO methodic. Operative facsimile synoptic maps and ocean surface temperature maps were received and analyzed.

Metrologic maintenance of measuring equipment is given in the metrologic commission act (the act is supplemented to the expedition report).

5. Estimation of the technical state and of the scientific

Equipment usage during the cruise.

The ship's echo sounder acts unstably and only on drift. Under condition of sharp changes of the bottom relief the signal practically is not registered. That made considerably difficult the installation of two ABC. That was the reason of a decision to stop the following settlement of the anchored autonomous stations.

CTD-sounder of the company "Neil Brown" - "Mark-3" was used in a regime of measurement on drift and a regime of scanning in hydrophysical complex "Fish". The sounder was working without failure during measurement taking on drift. During the work in the scanning regime there were malfunctions in the connection lines due to the winch collector corrosion. Another type of malfunction happened due to occasional plankton ingress into the conduction sell (despite of the special protection grid). In case of detecting of deviation in the conductivity data the sounder has been upraised and the sell was washed by the fresh water. Usually malfunctions have been removed during the data processing without considerable information loss.

Continuous measurements by the complex "Fish" were few times disconnected due to blocks break. Blocks pulley has been split and needed to be changed because of bad slip under high load. For normal functioning of this complex it is necessary to use blocks fitted for a high load with pendulum bearings.

Technical state of the sounder "Baklan" did not allow to use it for work on each station as it has been supposed to do. Wear of the cable line, corroded collector, damages of the sounders body anodic surface often brought to breaks and loss of information. That is why it was necessary to repeat the sounding.

22 velocity and temperature meters "Potok" (6-on ABC-1, 6-on ABC-2 and 10 in string) were used.

Result: - One "Potok" on ABC-1 went out of order because of instable work of the quart generator (the instrument has fallen down on the metal deck at the moment of installation).

- four instruments had small angle of turn of tape pulling of the magnetic information terminal during 1 record cycle (though not all the information has been last);

- one instrument (on ABC-2) has been flowed. (The reason is so far not clear).

Two opticohydrophysical sounders MHI 4112(OFA) were testified in the expedition conditions.

There were dane 7 soundings by each complex at different depths up to 3500 m (the limit of the cable length).

Result:

1. Functioning of complexes satisfactory: sounders measuring pressure, temperature, conductivity attenuation indicator of directed light (measurement error satisfies the passport data).

2. The system of complexes switching of from power works unstably.

3. Barometer operation system works unstably.

Out of a total amount of soundings two failed (there was a discharge of accumulators below the allowance level what made it impossible to pass the information to PC) a 1 sounding (tester) brought to a loss of 5 barometers and a complete switch off of a reserve power what resulted in a loss of information.

List of the expedition participants.
Heading group.

Group of technical supply.		
1. Ivanov Yu.A.	Chief of expedition,	IORAN
	Doc.Phys.mat.sci.	
2. Golenko N.N.	Dep.Chief of expedition,	AD IORAN
	Cand.Phys.mat.sci.	
3. Nikolaeva A.A.	Scientific secretary	IORAN
Group of mathematic processing		
1. Filyushkin Yu.B.	Chief of a group,	IORAN
	Cand. Phys.mat.sci.	
2. Orlov V.S.	Scientist	IORAN
3. Meshyanov S.L.	Scientist,	IORAN
	Cand. Phys.mat.sci.	
4. Aleinik D.L.	Engineer I category	IORAN
Group of technical supply		
1. Onofriychuk S.F.	Chief of a group	IORAN
2. Kondrashev S.E.	Chief engineer,	IORAN
	Cand. Phys.mat.sci.	
3. Pyaterenko S.A.	Electronics engineer	AD IORAN
4. Makeev N.G.	Labs. worker	AD IORAN
Group of measurement equipment.		
1. Zarubin E.P.	Chief of a group	AD IORAN
2. Yakovlev E.A.	Major constructor	IORAN
3. Podufalov A.P.	Engineerconstructor	AD IORAN
4. Arvan M.B.	Electronics engineer	AD IORAN
5. Doronin Yu.E.	Electronics engineer	AD IORAN
Group of physical processes.		
1. Maslov V.A.	Chief of a group	AD IORAN
2. Koohl L.V.	Senior scientist,	AD IORAN
	Cand.geogr.sci.	
3. Artemyeva T.S.	Metrology engineer	AD IORAN
4. Prilyudko L.V.	Engineer	AD IORAN

7. Research program course and detailed description of works

Operation.

Arrived to a polygon on the 11 of October. 11-17 October there was carried a hydrophysical survey for determination of the Azor front and for description of the spatial structure of thermohaline fields. During the same period: 13 and 14 October in a front zone there were set up two autonomous buoys stations (topics 1-4 of the scientific program).

Mesoscale intrusive formations measurements were taken by the tugged hydrophysical complex "Fish" from 17-th up to 20-th October. The ABC N1 has been raised up on the 19-th of October (topic 2 of the scientific program).

On the 20-21-st of October the daily station for the measurement of the upper ocean layer parameters was carried out. There were done: the daily measurements of currents (10 devices) on drift, OGF sounder measurements with discreteness of 3 hours; microstructural sounder "Baklan" measurements with 3 hours discreteness; meteorological measurements complex with the same discreteness (topic 2 of the scientific program).

The ABC N2 has been raised on the 21-st of October; measurements of the intrusive mesostructure in the area of the front were continues on 21-23-d of October (topic 2 of the scientific program).

8. The volume of fulfilled works.

The extent of the expedition itinerary including the polygon works amounts to 4871 miles. The amount of the accomplished stations 41.

The echolot measurement has been provided only on drift due to malfunction of the onboard echolot.

The total amount of the vertical sounding on drift by the sounder "Mark-3" and the sounder OGF - 50.

The amount of soundings by the hydrophysical complex "Fish" on drift 3-4 knots - 612.

Currents measurements on two mooring stations. On the N1 - 6 devices were working during 7 days, on the N2 - 6 devices were working during 8 days.

Measurements by the microstructural sounder "Baklan" - 10.

Measurements of currents on drift in the upper ocean layer during the 24 hours on 10 levels.

The amount of standard meteorological measurements - 132.

The amount of received operative charts of hydrometeorological information - 250.

9. Preliminary scientific results.

Interpretation of preliminary results of the data measurements analysis is presented in each part of the expedition scientific program. Schemes of stations dislocation on hydrophysical survey, of autonomous buoys stations, of daily drift station and of tugging of the "Fish" complex are shown on Figs 2a, 2b.

9.1. The Azor current and the frontal zone.

(projects: "Fronts and eddies", "WOCE", "Subduction", "Razrezy").

Currents computation and the hydrophysical fields analysis on the climatic massive data basis in the region between islands Madera and Azor indicate the existence of a weak current directed to the east [1,2]. Though the accomplish in this area of hydrophysical survey with high resolution (possibly started by expeditions Meteor, 1981, and Poseidon, 1982) allowed to find evident jet (streamed) current with corresponding to it frontal division. Kase and Siedler [3] and showed that this streamed current called Azor is an important part of the anticyclonic cycle of the North Atlantic the following researches showed that the Azor current considerably meanders and changes its location and intensity. Namely these specifics while averaging the data bring to considerable smoothing of hydrophysical and dynamic fields (results received from climatic data).

The up-to-data actual goals of the research of the Azor current and the jointed frontal zone should be considered the determination of the spatial characteristics of variability: transport of frontal zone and current m space, deviation and eddies formation strengthening and attenuation, interaction of the current with eddies.

The research of the frontal zones dynamic is closely connected with the problem of subduction as just in frontal zones, where isopychnic surfaces ascend to a seasonal thermocline and to an ocean surface, the subduction processes are even more intensive. The necessary condition of solution of this problems is taking of longterm or repeated measurements.

Region AR-XI of the international program WOCE is the object of detailed and repeated measurements, including the frontal zone of the Azor current for the research of the frontal zone dynamics and subduction processes.

Hydrophysical thermohaline structure of the frontal zone waters.

Polygon researches were began with the taking of the hydrophysical survey. The scheme of stations location is given on Fig.2a. As to the temperature and salinity the Azor front is definitely distinguished beginning practically with the ocean surface (Figs. 3,4) by sharp strengthening of horizontal gradients across the front. Drop of temperature is 0,9 grades, of salinity 0,23 psu. The front width in the area of research changes from 30 up to 70 miles. As to the distribution of density on the depth of 20 meters the font is not distinguished (Fig.5) what shows to the compensation of the temperature input to the density gradient by the salinity input which has the opposite sigh. On charts of temperature, salinity and density there are visible mesoscale and synoptic disturbances which are not always correlated. For example a cold stain on the east of polygon corresponds to a stain at sealed waters, but as to the salinity in this region there is no any specifics. On the other hand, in temperature distribution in the north-western part of polygon there is visible a stain of cold freshened waters, though in a field of density the anomaly in this region is not registered. Such incoherent structures in the upper layer are the result of unstationary atmosphere effect.

On the level of 100 m (Figs. 6,7,8) where direct influence of the atmospheric affect is shielded by thermocline there is evident a considerably close connection between distributions of temperature, salinity and density. Drop of temperature on the front is 1,2 grades, salinity 0,24 psu The width is a little more than in near-the-surface layer. Besides the distinguishly expressed frontal zone on charts of characteristics distribution in the southeastern part of the polygon there are also observed the local formations of cyclonic and anticyclonic type (lower temperature, lower salinity and higher density cyclonic type; higher temperature, higher salinity and lower density anticyclonic type of distribution). The described character of the temperature, salinity and density distribution remains up to level of 600 meters (Figs. 9,10,11). Horizontal characteristics gradients decrease with depth. Anticyclonic and cyclonic type of characteristics distribution can be traced the same evidently easy up to that depth, though having different degree of definition. Thus the cyclonic type is slightly defined as to the density. Already at the depth at 500 meters there happens practically full compensation of density due to temperature and salinity disturbance. Complete destruction of the frontal structure of temperature distribution comes out at the level of 800 meters (Fig.12), at salinity at a depth of 700 meters (Fig.13), of density deeper than 1200 meters (Fig.14).

In eastern part at a polygon beginning with a depth of 700 meters considering temperature and 600 meters as to the salinity up to the depth of 2000 meters (the depth of measurements) there is evident a sharply distinguished abnormal structure with maximal horizontal size of 90 miles at a depth of 1000 meters (Figs. 15,- 16). Maximal positive anomalies of temperature and salinity are located at the same depth and are equal to 3 C and 0,6 .... relatively to hum. As to its thermohaline characteristics (12,0 C, 36. 20 ... maximal values) this structural formation is related to lenses of mediterranean origin. It should be mentioner that according to our information lenses at such a fig size were so far not found in the ocean. Unfortunate a detailed measurement of the whole body of a lens could not have been done because of a lack of time.

Vertical structure of thermohaline fields.

Vertical thermohaline structure of the Azor front zone is characterized by the following specifics: homogeneous upper layer, clearly distinguished during autumn seasonal thermocline, intermediate salinity maximum and destruction of the intermediate temperature maximum at the from crossing. On Fig.17 there are shown curves of vertical distribution of temperature, salinity and density measured at 80 miles to the north of the front. In a layer of 700-1300 meters there are detected intermediate maximum of temperature and salinity. As to thermohaline characteristics these waters should be related to the waters at the mediterranean origin. On Figs. 18,19,20 there is shown the destruction of the temperature maximum and partial wash-out of the salinity maximum in the intermediate layer at crossing of the frontal zone. After crossing of the frontal zone (Fig.20) the temperature maximum in the intermediate layer disappears, and the salinity maximum considerably decreases. Though, episodically mediterranean lenses cross the frontal zone without essential destruction. On Fig.21 there are shown distributions of temperature, salinity and density in a lens described above, based on the analysis of horizontal structure of hydrophysical fields. The vertical thermohaline structure of hydrophysical fields is more detailed characterized on T-S diagram. On Fig.22 there is given a specific T-S diagram for the first meridianal section at hydrophysical survey. In the upper part at the T-S diagram the T-S indexes at each station considerably differ, what is a specific character of distribution at the front crossing. On intermediate depths there is evidently observed a process of destruction of extreme characteristics at mediterranean waters in a zone of the Azor front. All of described specifics of vertical and horizontal structures of thermohaline fields in more detailed form could be analyzed by charts, sections, profiles with T-S curves gives in the atlas (supplement to the expedition report).

Waters circulation in the zone of the Azor front.

Calculations of hydrophysical currents were done from two indication levels 1500 and 2000 meters. Geopotential differences in the Azor current at all levels were invariable. Small deviations of geopotential anomalies at the level of 1500 meters are observed only in disturbances of the synoptic scale (see supplement). On Figs. 23-26 there are given charts of geopotential anomalies on four isobaric surfaces relatively to the 2000 dbar surface. The Azor current has a stream character. The current width in the area at measurements in near-the-surface level (20 dbar) varies from 60 to 80 km. Maximum geostrophic velocity 35 sm/sec. Anticyclonic and cyclonic eddies are observed and traced up to the depths of 1000 meters in northwestern, south-western, southeastern and eastern part of the polygon. Anticyclonic eddy in a central-eastern part of a polygon is observed on all calculated levels up to a depth of 1800 meters. As it was already mentioned above this anticyclonic eddy in a layer of 600-1600 meters contains a water of mediterranean origin. The intensity of the Azor current decreases with the depth and at the level of 1200 meters the current geostrophic velocities are close to a zero. On Fig.27 there are shown velocity isolines on a second section at a hydrophysical survey, geostrophic rate of flow of a current is 15.6010 m /sec, what is 15 sv. On other sections this quantity practically does

not change. Rate of flow calculations of 1500 -dbar and 2000-dbar surfaces give the same result.

Measurements of the Azor current velocities accomplished at autonomous buoy station N2 on five levels are given in Table 1.

As it could be observed from a table, a direction of currents measured an ABC and calculated on geostrophic relations are close and velocities modules differ by values practically equal to the current velocity measured at a depth of 1200 meters on ABC. Thus the absolute current velocity at each level will be equal to the sum of the barocline geostrophic velocity and velocity measured at the depth of 1200 meters having a meaning of barotropic component. According to this the estimation of the absolute drain of the Azor current could be 25 sv.

Intrusive frontal subduction and ventilation of intermediate waters.
(WOCE project III part "Subduction")

Measurements according to the program "Subduction" were done by hydrophysical complex "Fish" up to the depth of 400 meters with resolution of 0.7 km as to a horizontal. There were carried and three sections parallel oriented to the frontal division. On Figs. 28-30 there is shown the distribution of salinity, temperature and conventional density. Most evident the intrusive subduction is revealed on the right boundary (looking with the stream) of a frontal zone according to the salinity distribution, as most conservative characteristics. Well are observed "tongues" of more salted waters spreading in a front area from the surface layer to the upper part of the main thermocline. Background-corrected to this structure there are observed intrusive spots with a scale of from 15 km up to 1.5 km. Above the frontal zone, below the seasonal shock layer there episodically appear intrusive formations of increased salinity. In temperature distribution in the front zone there are also observed the tongue-type formations spreading from the surface layer into the upper part of the main thermocline. Though there are not detected spots of the increased temperature. On a section at the conventional density in the area of the tongue-type formations of distribution of temperature, salinity and mesoscale structures of increased salinity there are observed only small isopycnal curves. On Fig.31 there is shown the salinity distribution according to data of hydrophysical complex "Fish" on the section 3. Here the "tongue" of the increased salinity is also observed on the right boundary of the frontal division. Intrusive formations are detected slightly, only to the north of the "tongue" there is revealed a well detectable sport of the increased salinity. Though, another particularity in the salinity distribution observed in this section is of great interest. Salted homogeneous waters of the surface layer located in the northern and central parts of a section when spreading to the south penetrate to a seasonal pycnocline and then (in its frontal zone and more intensively at its right boundary) descend into the upper part of the main thermocline.

Polygon works were accomplished during the autumn (October) when the buoyancy flow at the ocean surface is changing its sign. At that period there are considerably increased

the portions of time when consolidation of upper ocean layer and deepening of lower boundary of quasi homogeneous layer take place. Tangential wind stress intensifies and correspondingly the Ekman excitation into a layer of seasonal thermocline. These processes determine the subduction intensification along quasi isopychic layers. Due to unstationarity of boundary conditions at the ocean surface the penetration of the surface layer waters into the seasonal thermocline may occur discretely, by separate portions. Here comes up a question: how does the salted waters transit across a picnocline into the upper part of the main thermocline (picnocline) execute. There could be assumed two physical mechanisms which are probably involved into this process: 1) incidental breaks of seasonal picnocline under the hydrodynamic unstability realization on the frontal division; 2) vertical convection caused by processes of double diffusion.

Ventilation of intermediate waters in the central and eastern parts of the north Atlantic proceeds to a considerable extend due to inflow of mediterranean waters. Because of considerable unstationarity of the flow the main portion of mediterranean waters is being spread in the ocean in the form of lens structures of anticyclonic rotation.

Carrying out of a hydrophysical survey succeeded in detecting of probably the biggest lens so far known by literature [4], and fragments of lens structures on 1-st and 2-nd section. Unfortunately the detailed measurements by the tugged complex "Fish" were possible to be done only in the area of a destroyed lens. On Fig.32 there are given distributions of temperature, salinity and density on section 4. On the section at a temperature distribution and even better on the section of a salinity distribution there are well observed the stains of waters with increased meanings of these characteristics which correspond to the meanings an the periphery of lens found by hydrophysical survey of section 4. On Fig.33 there are shown T-S curves of the lens periphery (st.1022), of intermediate area (st.1023) and at lens core (st.1024) and also T-S diagram for the 4-th section accomplished by "Fish" complex in a layer of 750-1050 meters. T-S curve (st.1022) practically corresponds with T-S diagram in this layer. T-S characteristics in intermediate area of lens and in nucleus correspondingly increase. This circumstance let us assume that observed stains of saline and warm water appeared in result of destruction of the mediterranean lens (close by its characteristics to one observed in the polygon east) in the area of research.

Structure and dynamics of waters of the upper ocean layer
(WOCE project and "Razrezy")

Structure of the active layer at polygon was characterized by homogeneous layer, the width of which varied from 34 to 64 m, and by clearly expressed picnocline. In a western part of polygon the average depth of the mixed layer was 43 m, in eastern part 53 m. The homogeneous layer to the south of the front was an the average by 6 meters deeper.

During a period from 02hrs 00min 21.10.93 till 05 hrs 00 min 22.10.93 a daily drift station for research of characteristics of the upper ocean boundary layer was performed. Measurements of currents were done by devices "Potok" on levels 10, 13, 16, 20, 25, 30,

40, 50, 70 and 80 m with time discreteness 52 see, of the vertical thermohaline structure by OGF-sounder, by microstructural sounder "Baklan" and hydrometeorological parameters (wind, pressure, ocean surface temperature, temperature of the air, humidity) with discreteness of 3 hours.

The average depth of homogeneous layer was 58 m. Amplitude of fluctuations of the lower boundary of homogeneous layer caused by internal gravitation waves did not exceed 10 meters and on the average equaled to 7 m. Weak wind (4-2 m/sec) and vigorous solar warming up permitted to observe building and destruction of daily thermocline. Thermocline started to build up at 11.00 and was observed up to 02.00 of the following day. At 05.00 the day thermocline completely destroyed as result of the night ocean cooling. Maximal temperature difference at the surface and at level of 10 m made up 1 C.

Analysis of currents measurements showed that within the upper homogeneous layer the current vector (modulus and direction) slightly varies (practically within the measurements accuracy). Below the thermocline the velocity vector often differs from currents of the upper mixed layer. That means that in the upper layer homogeneous as to its density the Ekman spiral is not formed, it should by though noted that relatively small wind velocities being present during the experiment could bring to rather big relative errors while measuring drift currents.

Hydrometeorologic researches.

The specific character of the atmospheric circulation and of largescale processes was the meridian type at the air transport above the north Atlantic due to development of blocking processes in the ocean center.

During the period of 12-23 October the baric field in investigated area was anomalous: at a place of climatic center of the atmospheric effect at the Azor anticyclone there were present cyclones for 5 days and ridges of northern anticyclones for 7 days. The polar front was located southward at usual, behind the 40 n.l., waves generation processes in it brought to cyclogenesis within the area of tropical zone. In the research area there were predominating northern (21%) and south-eastern (18%) duration of the wind and velocities 5-10 m/sec (51%).

Turbulent fluxes of heat, moisture and momentum (tangential stress), calculated for 96 observation terms at to the GGO methodics, varied correspondingly from 11 to 39 wt/m , from 6 to 302 wt/m , from 0.01 to 0.45 H/m . Average for 12 days meanings q, LE and t came correspondingly to 12; 127; 0,07. Turbulent heat fluxes, except of 5 situations, were directed from the ocean to the atmosphere. Heat expenditure for evaporation in all the cases directed to atmosphere exceeded averagely by 10 times the turbulent heat fluxes. Most vigorous turbulent exchange was 13, 15, 17 October and the lowest 21, 22, 23 October.

Relations between the components of heat balance estimated by daily average values indicate that from 12 to 20 October the radiation balance was so small that even did not cover the heat expenditure for the turbulent exchange and the heat was coming up to the surface from lower ocean layers, 21-23 October at conditions of less clouds weather and weak turbulent exchange the solar radiation heat excess was transferred from the surface to lower layers, altogether during the whole period of research the heat was coming up the ocean surface from two sources: as a solar radiation (81wt/m , 58% of income) and from the ocean (58wt/m , 42% of income). From the ocean surface the heat was going away as fluxes of evident heat (13wt/m , 9% of expenditure) and of latent heat (127wt/m , 91% of expenditure).

17. Summary of preliminary scientific

Results of the cruise.

Main expedition goals, formulated in the scientific program of the 31-st cruise of RV "Professor Shtokman" according to the international WOCE program, the base project 3 and national project "Fronts and eddies", were accomplished.

1. The Azor frontal zone, the Azor current, meanders and eddies.
(Project "Fronts and eddies" and base project 3 of the program WOCE).

Hydrophysical survey of the Azor front was performed. The exact location of the Azor front and connected to it frontal zone was determined on the basis of processing and analysis of measurement data. Thermohaline structure of hydrophysical fields is described. Geostrophic field of velocity of the Azor current and eddies was calculated. The estimation of geostrophic expenditure of the Azor current was done and it equaled to 15,5010 m /sec.

In the Azor current bar there were set up two autonomous buoy stations with current meters. As a result of analysis it was established that the Azor current has a considerable barotropic component. With considering of the barotropic component the estimation of the total current expenditure comes to 25.0010 m sec. It should be noted that the estimation of total currents expenditure by instrumental data has been done for the first time.

2. Subduction processes in the Azor frontal zone and ventilation of intermediate and deep waters.
(Base project 3 of program WOCE).

The tugged complex "Fish" executed three tacks crossing the frontal zone of the Azor current. As a result there were received three transfrontal sections of the temperature and salinity distributions in a width of 0-400 meters with high horizontal (0.7 km) and vertical (20 sm) resolution. Processing and analysis of these data allowed to describe the two physical mechanisms of subduction process: a) localfrontal subduction which can be related with hydrodynamic inhomogeneity of gravitation waves in seasonal thermocline and convection processes caused by double diffusion; b) penetration of surface waters

into seasonal thermocline in the area to the north at front and there spreading in thermocline "body" up to a frontal zone where they episodically break thermocline as a result of effect of the above described mechanisms. Due to unstationarity of boundary conditions and instability processes realization the thermocline break is often accompanied by generating at mesostructural intrusions formations.

For research at waters ventilation at intermediate depths the data of three tacks (4-th and 6-th), were taken by complex "Rybka" in a layer of 750-1050 m. It is shown that at these depths there are present "young" mediterranean waters with higher salinity and temperature in a form of lens and at "fragments" of lens structures.

3. Structure and dynamics of upper active layer of the ocean.
(Program WOCE, project 3, "Razrezy").

For analysis of structure and dynamics of the upper ocean layer there were used data at hydrophysical survey measurement and complex of measurements from diurnal drift station (currents of 10 levels with discreteness of 52 sec., profiles of temperature and salinity, temperature pulsations, electric conduction and velocity shift, meteorologic changes each 3 hours). There are given variability characteristics of the upper layer parameters in space and in time. It is shown that in a layer homogeneous for its density the vector of drift current practically does not change with depth, namely the Ekman spiral is not formed in this layer.

4. Interthermocline lenses of mediterranean origin
(Project "Fronts and eddies", project 3 of WOCE program).

Under conducting of hydrophysical survey in the eastern part at a polygon there was found a large bus of mediterranean origin. The lens was 150 km in diameter and extended from 700 up to 2000 m by vertical. The lens was in a stage of destruction, what was evidenced by a considerable roughness of a lateral surface and inhomogeneity of temperature and salinity distribution in the lens nucleus. As to the survey data and "Fish" complex measurements in the width of 750-1050 m of the western part of polygon there were found "fragments" of lenses structures in a form of intrusive water stains with temperature and salinity meaning increased relatively to hum.

References

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