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ON THE INFLUENCE OF A WARM ANTICYCLONIC EDDY OF THE KUROSHIO SYSTEM ON THE ACOUSTIC SIGNAL PROPAGATION

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Presented are results of experimental studies for the acoustic field structure at sound propagation through a synoptic anticyclonic eddy formed in a system of the Kuroshio Current on a boundary of the front division between subarctic and subtropical water masses. Experimental data are compared with the modeling calculations carried out with a method of normal modes and parabolic approximation.

Acoustic methods of investigating spatial-temporal variations of water mass in various parts of ocean allow us to expand essentially the notion on the physical processes occurring in the World Ocean. To obtain information by direct methods is quite difficult and expensive. Even satellite data on superficial changes of the water temperature may not coincide with the boundaries of subsurface variations caused by the presence of unstable dynamic processes in depth. In this case, the information received by direct methods, with the help of traditional oceanographic devices, becomes not sufficient as the measurements of the physical parameters variations should be carried out within quite extended ocean areas. One of the regions of dynamic variability is an area between water masses in a system of the Kuroshio Current. In the given area of the subtropical and subarctic waters boundary it is annually formed 7-8 quasiperiodic cold cyclonic and warm anticyclonic eddies moving with the average speed of 2-8 cm/sec [1].

The given study is aimed at researching the influence of the warm anticyclonic eddy formed on a boundary of subtropical and subarctic fronts on the transformation of a sound field structure. At the acoustic expedition carried out in summer of 1988 on the R/V "Akademik A.Vinogradov" and R/V "Akademik M.Lavrentyev" [2] it was investigated two traces: A - crossing a warm anticyclonic eddy in its centre, and B - passing on its edge. Traces length made more than 430 km. Tone signals with the frequencies of 232Hz and 696 Hz were emitted by means of the acoustic system towed along the traces on the depth of 100m. In case of Trace A, the emitting vessel located in the eddy centre, in a point of 38˚30´N, 149˚09´E, was moving away from the receiving system northward, to a point of 42˚30´N, 147˚09´E. For Trace B the receiving systems were located on the eddy periphery in a point of 42˚04´N, 151˚40´E, and the acoustic signals emitter was moving away from them south-eastward to a point of 38˚58´N, 148˚52´E. Signal was received by the vertical antenna with the sensing elements located on the depths of 100, 250, 500 and 1000m. After the termination of the acoustic experiment it was carried out hydrological survey of traces to the depths of 1500m. Distance between hydrological

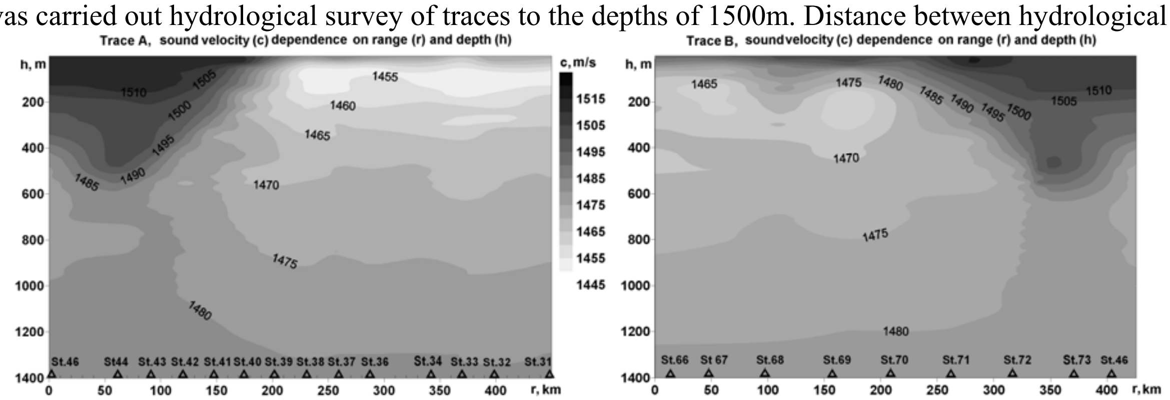

Fig. 1. Sound speed distribution through depth on Trace A and Trace B.

stations was 25-30km. Bathymetric survey of the bottom was carried out during the acoustic experiment from the emitting vessel. Bottom depth on the traces varied from 5300m to 6500m. Experimental data on the sound speed variation through depth and distance for Trace A and Trace B are presented in Fig. 1. In the bottom part of the figures the numbers of hydrological stations and distance between them are shown. In a southern part of Trace A it is observed the basic thermocline

lowering that leads to the formation of a eddy body. In a surface layer of the eddy centre it is observed an area with abnormal low values of the sound speed; further it takes place obvious deformation of a vertical profile, with the sound channel axis rising to the depths of 150-200m, where in a zone of transition from subtropical waters to subarctic ones it occurs a break in the sound channel. Trace B does not cross the subarctic front - it starts and passes, basically, in the waters of an inter-frontal zone.
By the measured data on sound speed distribution the acoustic fields of Trace A and Trace B were calculated with use of the wave [3] and parabolic approximation [4]. In these calculations the hydrology and bathymetry on traces changed in accordance with the experimental data, source depth made 100m, frequency was 232Hz. The spatial acoustic fields obtained at modeling in the presence of a eddy differ from the traditional pattern received for horizontal-homogeneous medium. The picture of a sound field calculated under the wave program, for the extending normal modes, which number varied from 600 to 800 depending on the bottom depth, is presented in Fig. 2 and Fig.4. Fig. 3 shows the distribution of a sound field along Trace A; it is received in parabolic approximation, the source moved from north to south. Calculations vividly demonstrate, that in the beginning of Trace A it is formed a zone structure of the acoustic field; it is highlighted by modes of higher numbers which energy quickly fades with distance [5]. In the area of cold waters separation (distance exceeds 200km), on a distance of a eddy location, the zone structure is transformed; a sound is "pumped" into a narrower channel formed by cold waters of the subarctic front with an axis, sunken down to 200 meters. A reverse picture is observed at sound propagation on the eddy edge (experiment on Trace B). Here, a zone structure formed by extending modes is traced not so distinctly as on Trace A, and in the eddy contact area, sound energy is redistributed and zone structure is destructed. Similar picture is described by the experiment on distribution through a frontal zone [6].

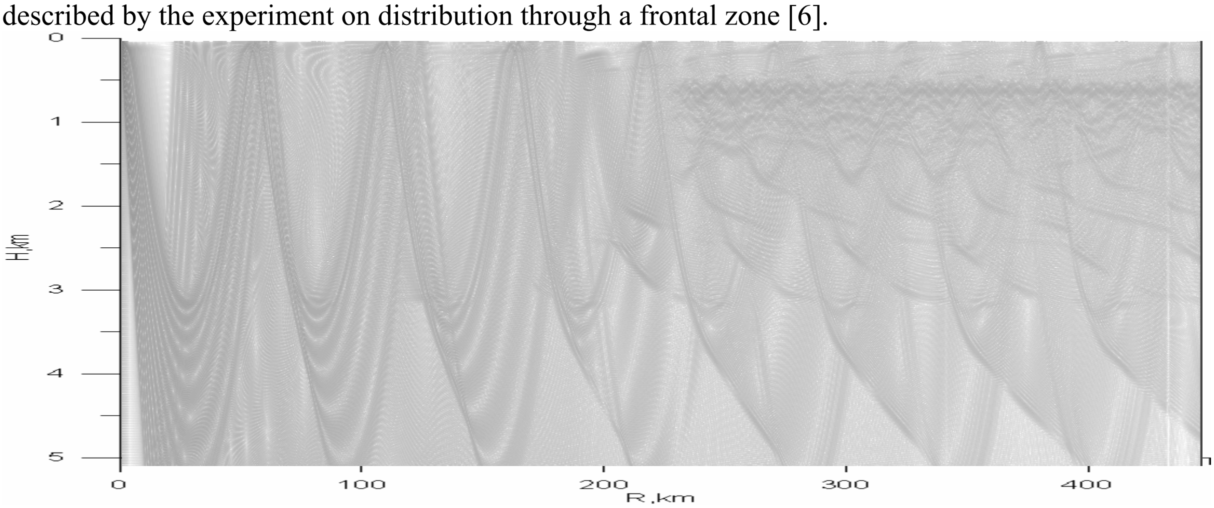

Fig. 2. Transmission loss of the sound on Trace A (radiation frequency F=232 Hz) calculated in wave approximation.

Calculations executed in various approximations have shown acceptable coincidence of results for the given interval of frequencies and scale of changes of the physical parameters of medium on the trace.

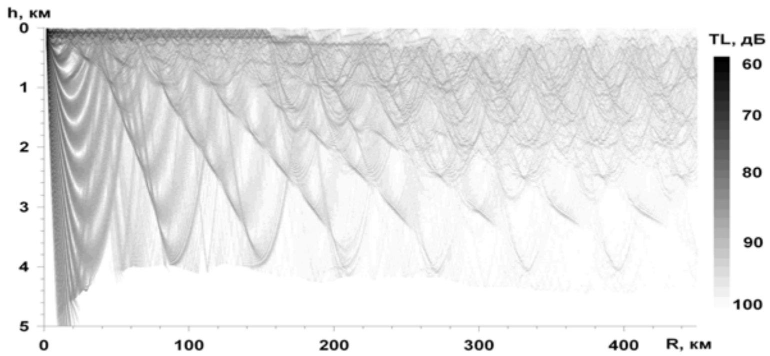

Fig. 3. Transmission loss of the sound on Trace A, F=232 Hz, calculated in parabolic approximation.

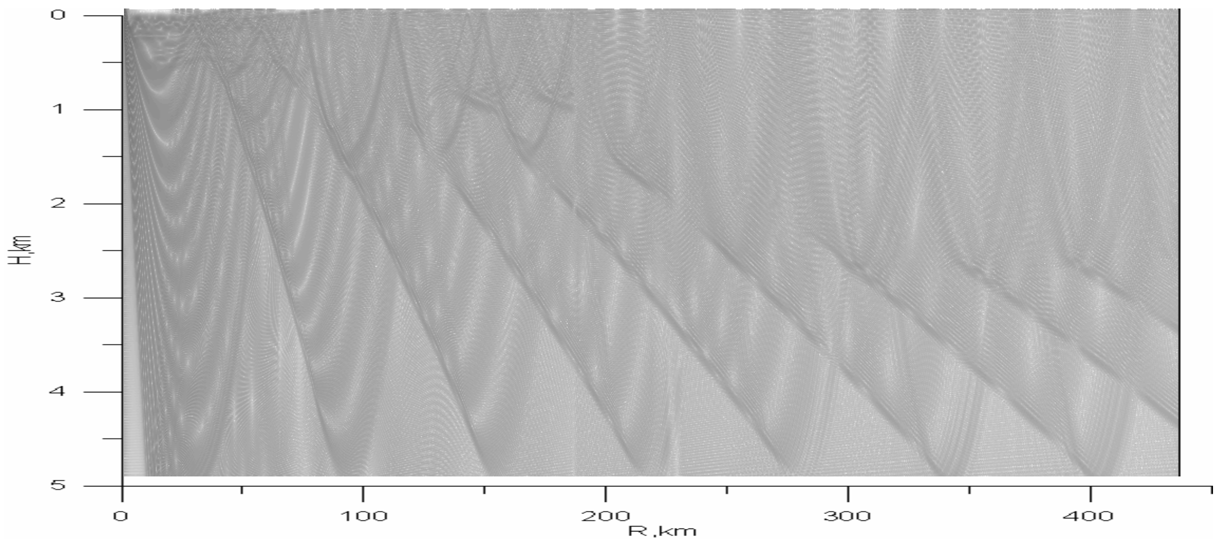

Fig. 4. Transmission loss of the sound on Trace B, F=232 Hz.

Fig. 5 presents experimental and calculated curves for Trace A on various depths of signal reception – 100m and 500m. Eddy presence on a trace of signal propagation resulted in sharp change of transmission loss. For a quantitative estimation of the eddy influence on sound distribution along the trace it was performed approximation of curves of sound volume decay by exponential law separately for the areas of 50-200 km and 200-430 km. In a spatial picture of the acoustic field it is well visible, that the transmission loss for various depths of reception varies to different degree that was proved to be true by the experimental results and executed calculation. For the receiver sunken to 100m, till the distance of 200 km on Trace A, the transmission loss varies under cylinder law, further the exponent changed to -0.4. The reception horizon of 500m appeared to be more sensitive to the eddy crossing, the exponent decreased to -0.6. For Trace B the exponent in the eddy location changed till -0.55. The analysis of curves of the transmission loss for various depths of the receiver allows us to reveal the eddy depth and place of its location, not making use of direct methods of measuring hydrological parameters in the area characterized by unstable hydrodynamic characteristics.

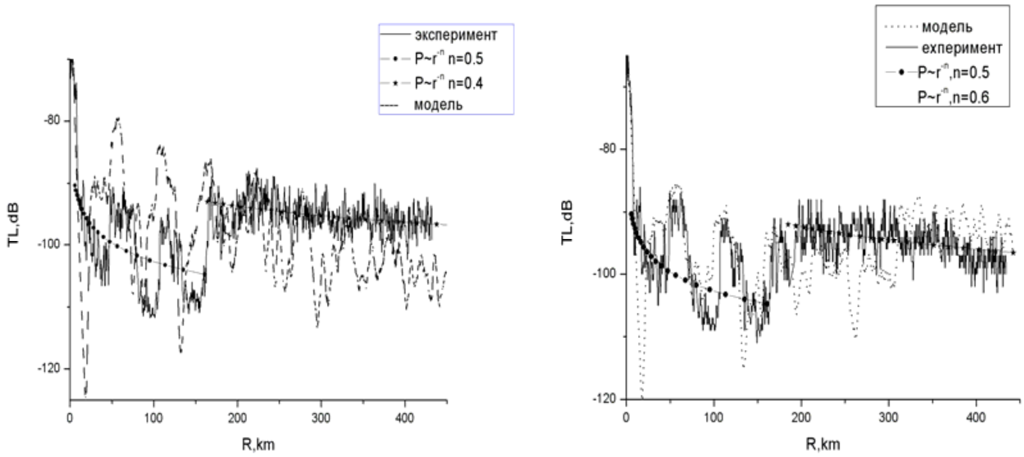

Fig. 5. Experimental and estimated transmission loss on Trace A and exponential law for the receiver H_R =100m, 500m.

The accomplished experiment and calculation allow us to draw a conclusion that the sound field decay through distance, in the areas with unstable hydrodynamic conditions, is sensitive to hydrology variations on the trace. The received experimental curves of the transmission loss for the receivers on various depths of 100, 250, 500 and 1000m well correlate with the calculations. As a whole, the given data illustrate essential changes of the spatial-energetic structure of a sound field in the presence of a eddy, and the received exponents of the sound decay volume allow calculating its depth and extent.

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