ACOUSTICAL OBSERVATION OF INTERNAL WAVES ON THE SHELF OF THE BLACK SEA

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In October, 2007, the Acoustics Institute performed complex acoustical and oceanological studies on a fixed experimental path in the Black Sea, near the Golubaya Bay. Sound signal with linear frequency modulation were used in the experiment. The processing of the experimental records consisted in computing the envelope of the correlation function of the received and transmitted signals and the time dependence of the correlation maxima. A characteristic change in arrival times of the rays is observed for the period of the income of cold near-bottom waters on the path. The quasi-harmonic variation in the arrival times of the ray groups allows one to correctly define the parameters of short-period internal waves accompanying the bore.

INTRODUCTION

In the earlier experiment of 2004, we in detail studied the effect of the coastal anticyclonic eddy on sound propagation along a fixed path at the shelf of the Black Sea, near the Golubaya Bay [1]. Here, we present data of experiments performed on a similar path in the same region. Those experiments were focused on the influence of short-period internal waves on the structure of propagating sound signals.

1. EXPERIMENTAL TECHNIQUE

The experiment was performed on October 11—14, 2007. It comprehended complex hydrophysical and acoustical measurements on a 1.3-km path oriented along the 30-m isobath. The transmitting and receiving systems were bottom-moored, with 70 and 40-cm heights over the seafloor for the transmitter and receiver, respectively. The tripod with the receiver was equipped with a line temperature sensor, 20 m in length, whose data were recorded during the entire experiment. The lower end of the sensor was at 0.5 m from the bottom surface. In addition, the acoustical experiments were accompanied by surveying with the CTD from a launch. With CTD NXIC Auto-500M (manufactured by FSI), vertical profiles of salinity and temperature were obtained. The number of soundings varied from 8 to 21 in different days of experimenting.

Sound signals with linear frequency modulation were used. The frequency varied from 1500 to 8000 Hz during 2 s. The pulses were separated by about 6 s. The received signals and those fed to the transmitter were continuously recorded. In signal processing, the envelope of the correlation function for the received and transmitted signals was computed, and the pattern of time variations of the envelope was obtained.

2. DATA OF MEASUREMENTS

During the observations, sound propagation along the path was mainly affected by the income of cold near-bottom waters onto the coastal zone under the influence of the wind-driven up and down welling. Figure 1 shows two profiles of the sound speed that illustrate two typical types of water stratification on the path, (A) a quasi-uniform water column and (B) that with a developed near-bottom sound channel.

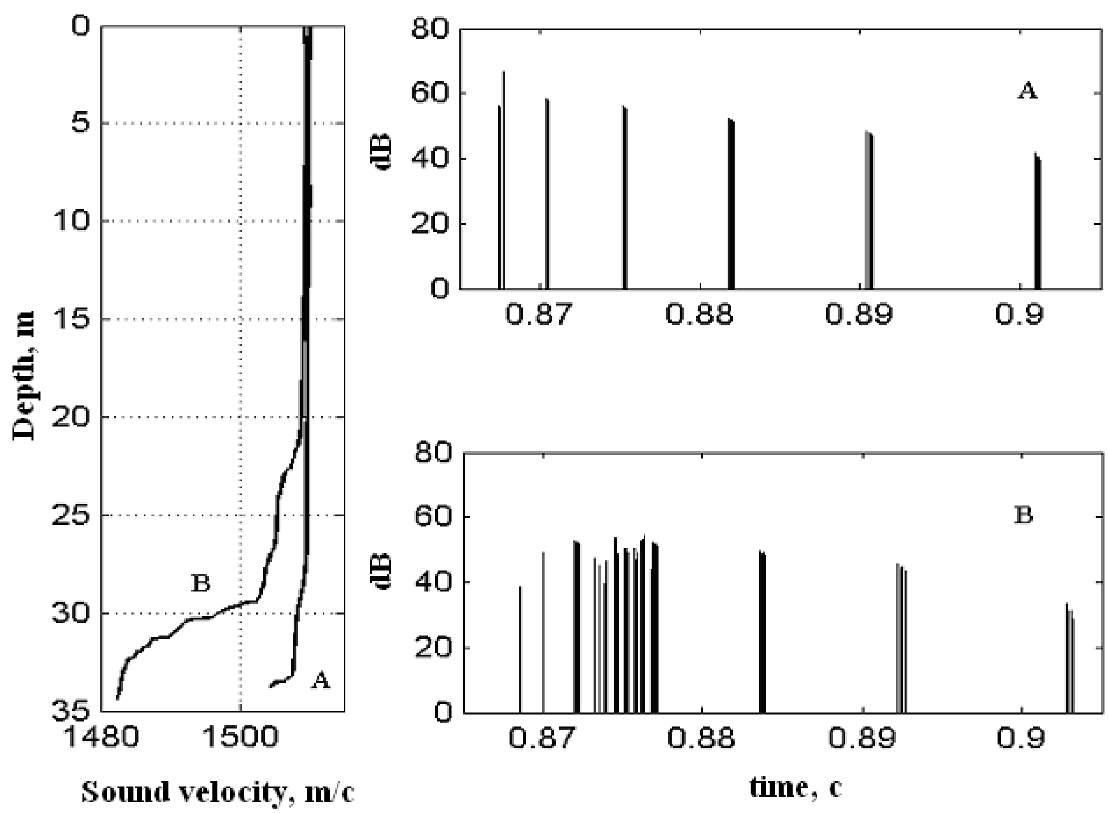

Fig.1. Left: typical profiles of the sound speed. Right: the corresponding ray structures (in coordinates of arrival time—amplitude in dB)

The structure of the received sound signals mainly differed in sharply increased number of the rays propagating within the near-bottom channel in the case of the B profile, with increased time separation of the arrivals (Fig. 1). Those rays are reflected only by the bottom and refracted in the vicinity of the thermocline. The latter feature makes those rays rather sensitive to the passage of internal waves. Such effects are clearly exhibited by the experimental records of time variations of the correlation envelope (Fig. 2 and 3).

It is possible to illustrate the effects exhibiting by the experimental records of time variations of the correlation envelope, observing on variations of maximum of a coefficient of correlation in time relative a signal taken for stable sound velocity distribution on the path (See Fig. 2). Sharp dropping of maximum of a coefficient of correlation takes place in a moment of the first approach of cold bottom water (near 60 min). The next sharp variation takes place in a moment of appearance of internal wave train (near 120 min). It becomes a process of signal fluctuation saturation induced stabilization of level of maximum of a coefficient of correlation in the end of internal wave train propagation.

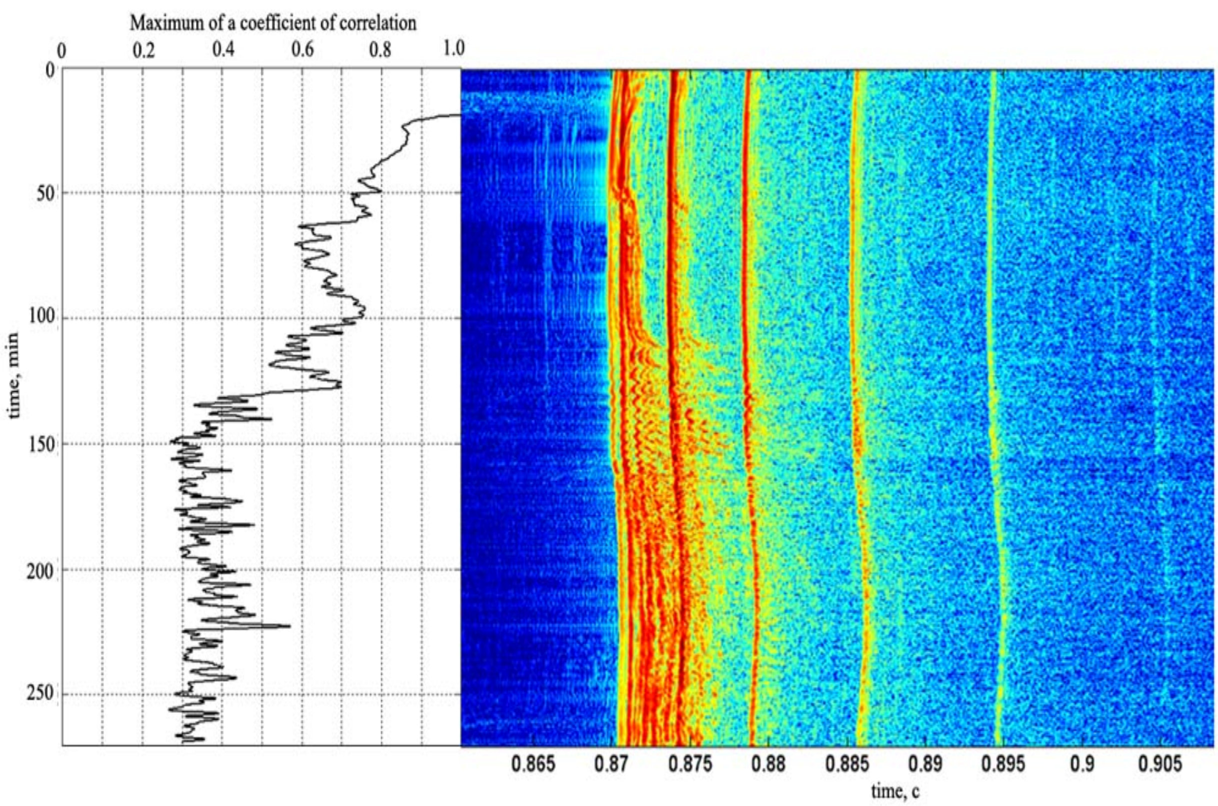

Fig.2. Left: time variations of the maximum of a coefficient of correlation. Right: time variations of the envelope of the correlation function

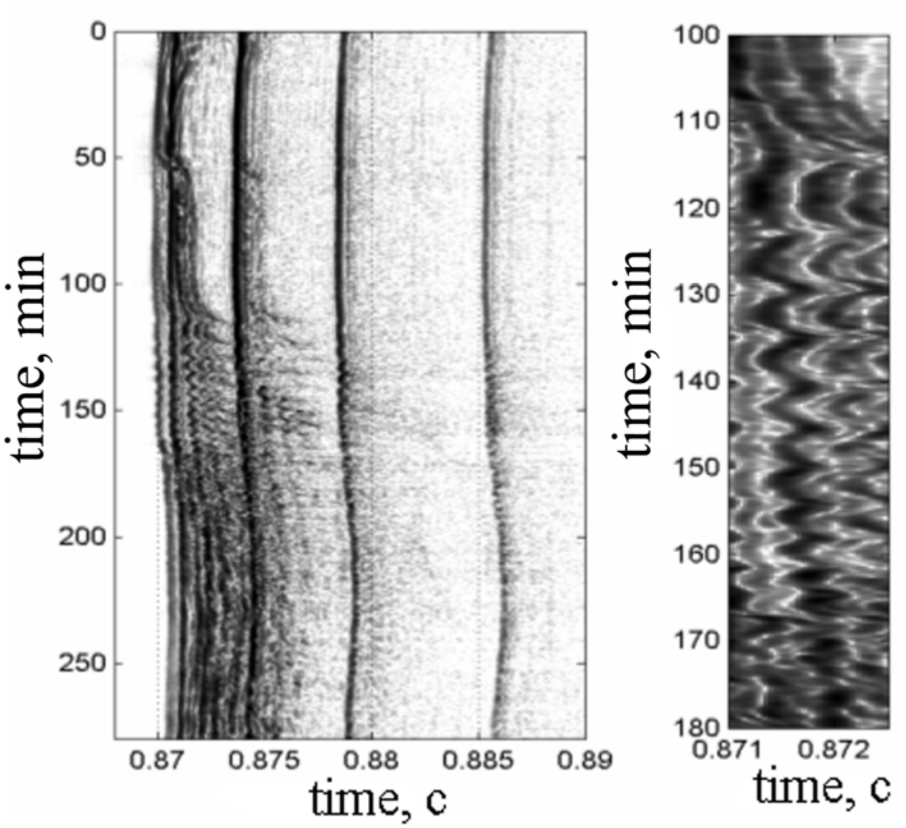

Fig.3. Left: time variations of the envelope of the correlation function. Right: enlarged fragment of the experimental record obtained at the time of passing a train of intense short-period internal waves over the path

The potential time resolution of the signals is about 2/(8000-1500) = 0.00031 s, which is approximately equal to the width of the correlation maximum (from zero to zero). Such a resolution is not sufficient for measuring the parameters of individual rays. Therefore, the time dependence of the envelope of the correlation function allows one to observe nothing but the variations of the parameters of ray groups with close arrival times or individual rays with large amplitudes. The change in the types of the sound-speed profilers, from A (Fig. 3, 0—50 min) to B (after 100 min), leads to a broadening of the interval of arrival times for the near-bottom rays. The fragment of the record illustrating such a broadening is presented in Fig. 3 (right-hand side). A quasi-harmonic variation of the arrival times can be seen for the rays with well pronounced correlation maxima.

The change in the times corresponding to the maxima allows one to estimate the parameters of the train of internal waves that cause the observed short-period oscillations. In particular, the change in the time of the correlation maximum shown in Fig. 4 and corresponding to the passage of the train of internal waves clearly exhibits a characteristic monotonous decrease in the period of internal waves over the train length, from 6.7 to 3.4 min. Such a feature, namely, the decrease

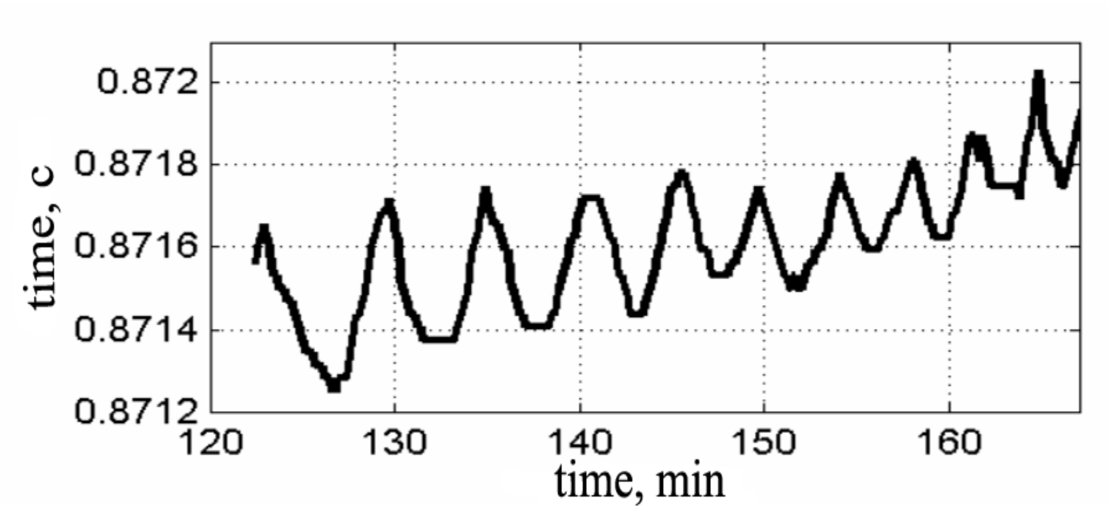

Fig.4. Variations in the time corresponding to the correlation maximum during the passage of the train of internal waves

in the periods and wavelengths, is a characteristic property of the waves in trains that accompany internal bores, both near-bottom (as in our case) [2] and near-surface ones [3]. The record of the time dependence of the correlation maximum also shows a nonlinear character of the internal waves: their crests are sharp and troughs are smooth. The number of waves in the train can be also simply estimated. Within the interval of passing the train, a trend can be seen that evidences for the increase in the mean time of ray propagation under the influence of bore-caused displacing the thermocline afar the bottom.

3. CONCLUSIONS

The experimentally shown high sensitivity of the parameters of sound signals to spatial and time variability of the hydrophysical characteristics of the water bulk under the influence of internal waves allows one to approach the solution of the main problem of acoustically monitoring a coastal sea zone.

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