Variations of Acoustic Noise Intensity Accompanying Internal Wave Soliton

Boris Katsnelson
University of Haifa
Haifa, Israel
bkatsnels@univ.haifa.ac.il

Oleg Godin
Naval Postgraduate School
Monterey, USA
oagodin@nps.edu

Qianchu Zhang
University of Haifa
Haifa, Israel
zqcouc@163.com

***Abstract*— Acoustical noise intensity fluctuations recorded by single hydrophones (SHRUs) in the Shallow Water 2006 experiment are studied. It is shown that appearance of irregular wideband sound field (amplitude by up to 20-40 dB greater than noise background) takes place when train of NIW is passing through location of the corresponding SHRUs.**

Keywords—acoustic noise in shallow water, nonlinear internal waves

I. EXPERIMENT SHALLOW WATER 2006

Multiinstitutional experiment Shallow Water 2006 (SW06) was carried out since June till September of 2006 in area of USA Atlantic Shelf. It included set of oceanographic equipment (thermistor strings, ADCPs etc) and acoustic sources and receiving systems. The area of experiment (New Jersey Atlantic shelf) is characterized by remarkable activity of internal waves; in particular approximately twice per day trains of nonlinear internal waves (NIW) consisting of up to ten separate peaks with the amplitudes about 10-15 m and wave front parallel to the coastal line move toward the beach. During its motion trains of NIW cross positions of five SHRUs, and L-shaped array (horizontal and vertical parts -HVLA), located about 5-8 km to each other along line perpendicular to the coast as well as thermistor's strings (Fig.1), which allow us to estimate shape and evolution of trains while they are propagating.

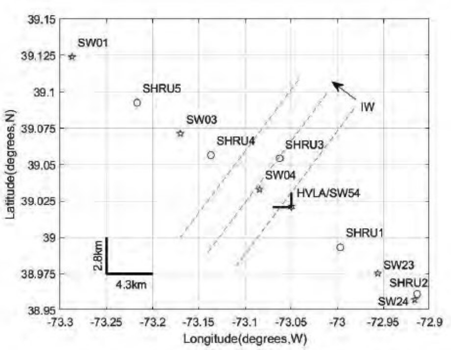

Fig.1. Layout of Shallow Water 2006 experiment

Using thermistor strings it is possible to find positions of wave front of NIW during their propagation. Goal of given paper is to study noise signals recorded by mentioned receiving systems in the presence and in the absence of NIW

One of events of generation and propagation of nonlinear internal waves in SW06 experiment took place 17 of August. In the Fig.2 two positions of the corresponding NIW fronts are shown.

In the Fig.4 the noise intensity, accompanying NIW passage on 17[th] August is shown: intensity of the noise measured by SHRU3 as a function of time (time interval 22:30 – 22:50 GMT). During this time behavior of internal waves can be understood using cluster of thermistor strings deployed in this area (see Fig.2).

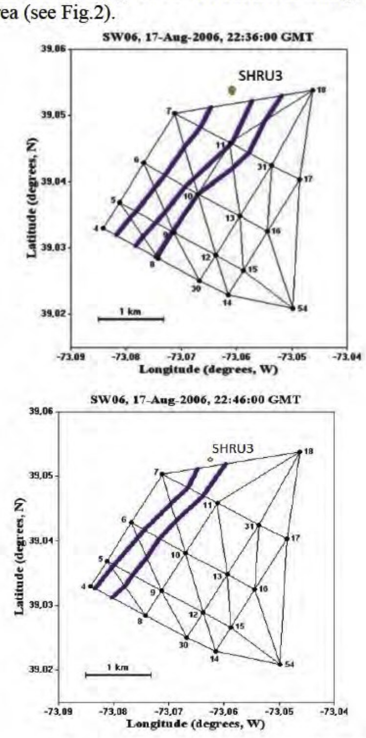

Fig.2 Two positions of wave fronts of NIW 17

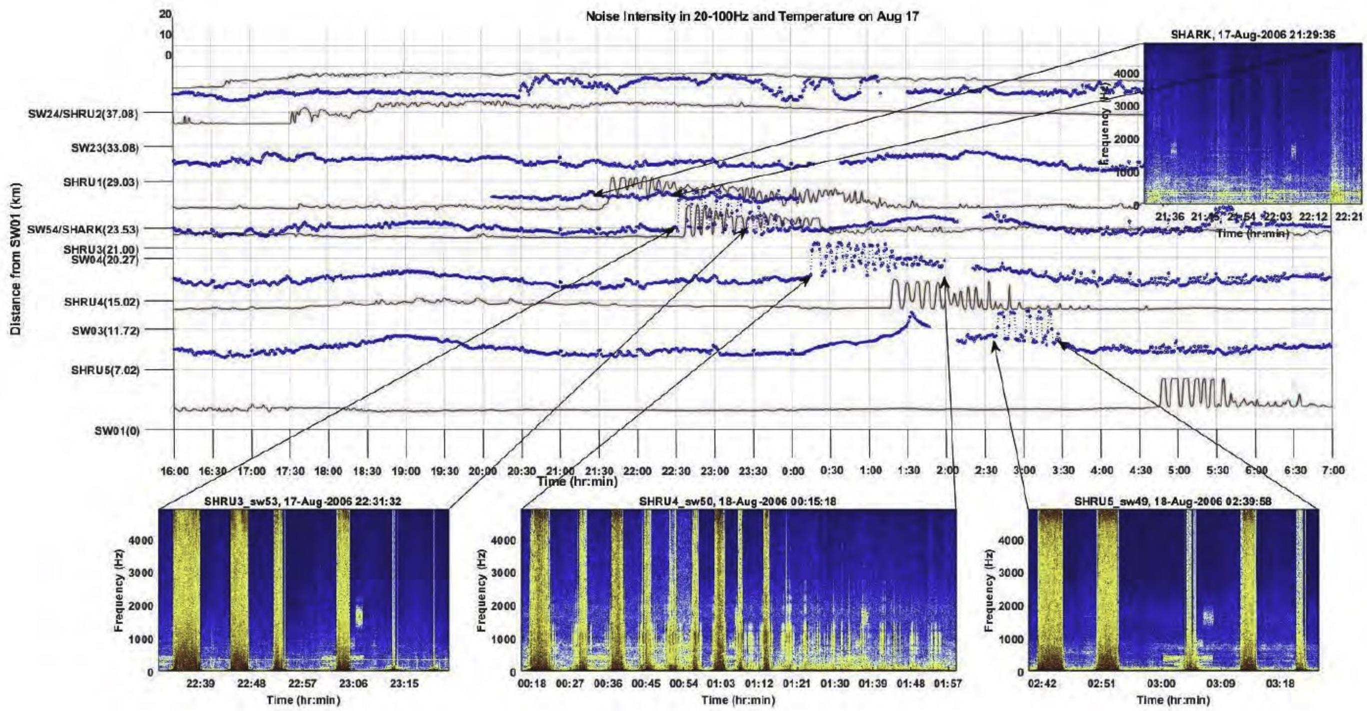

Fig.3. Event of August 17. Motion of NIW and the corresponding spectrograms

In the Fig.4 lines of constant temperature (16°) measured by thermistor strings SW7 and SW11 are shown. In this time interval there are two maximums of noise: at 22:36 and 22:46. The corresponding positions of NIW fronts (lines, corresponding to maximal thermocline displacement), established using all thermistor strings of cluster, are shown in the Fig.2. Sound signal of SHRU3 in the time period between two positions in the Fig.2 is shown in the Fig.4 by red line, where we can see correlation of the noise intensity with variation of temperature due to NIW, crossing thermistor's strings SW7 and SW11 (Fig.2).

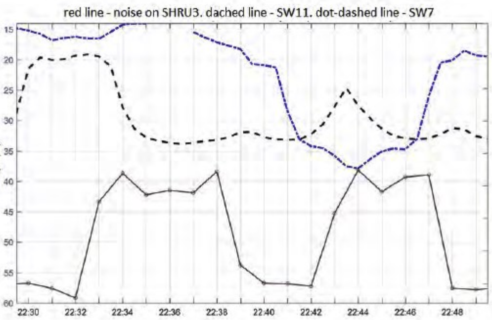

Fig.4 Noise intensity on SHRU3 (red line)

In the Fig.3 event 17 of August is shown in detail. Vertical axis corresponds to the line along positions of hydrophones, where locations of SHRUs and thermistor strings, denoted as SW). Its total length between SW01 and SW24 is ~37 km. Horizontal axis is time starting approximately from moment of NIW formation up to getting out of this train: 16:00 of 17 of August till 7:00 of 18 of August, 15 hours.

Next, in the Fig.3 for each thermistor's string line of temperature for the depth 40 m is shown by red color. We can see appearance of NIW on the thermistor at some moment of time, in accordance with commonly accepted theory, NIW is formed in area between SW23 and SW54, where channel is sharply narrowing, and propagates further with evolving shape. In particular, using this diagram it is possible to estimate speed v of internal waves: distance between SW54 and SW01 is about 23500 m, time interval of NIW passing by is about 7h15 min, so speed of NIW is v~0.9 m/s.

Blue lines denote noise amplitude on the corresponding SHRUs. In spite of positions of SHRUs are rather far from thermistor's strings it is possible to estimate position of NIW as a function of time, using their speed, calculated above. After the corresponding simple estimations it is seen that increasing of noise takes place when train of NIW is passing through location of the corresponding SHRU.

In the Fig.3 spectrograms are shown as well for the time intervals when NIW passes through SHRUs and HVLA locations. First of all, we can see that intensity of noise on the SHRUs is increasing while NIW are moving toward the coast. In the Figs.5 spectra of noise for different hydrophones are shown, corresponding to different distances to SW01. The closer hydrophone to SW01 (the narrower channel) the bigger noise (se for example Fig.5c).

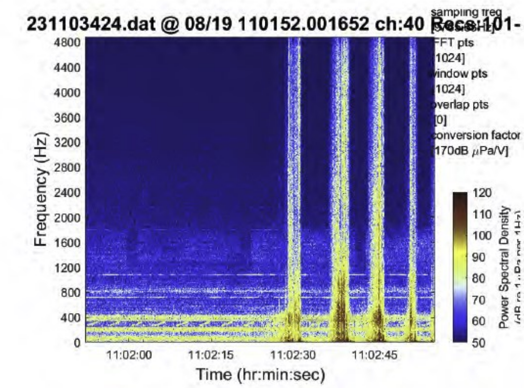

Fig.5a. Spectrogram of noise on the hydrophone of horizontal array, lying on the bottom

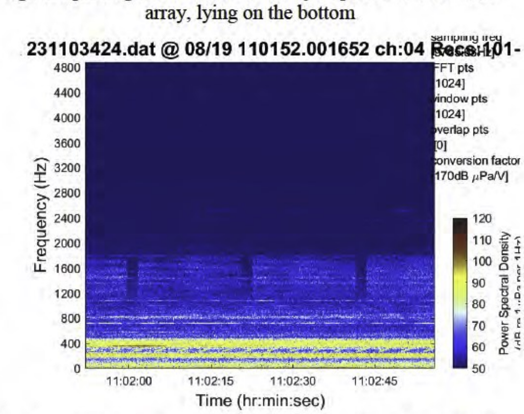

Fig.5b. Spectrogram of noise on the hydrophone of VLA, in the middle of water layer

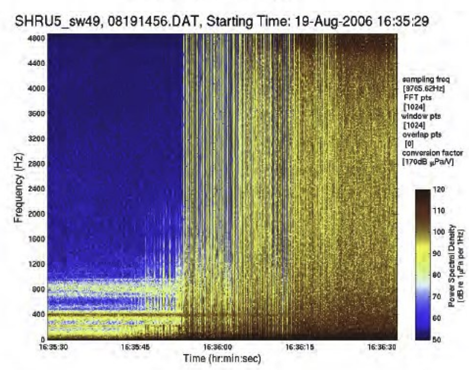

Fig. 5c. Spectrogram of noise on the SHRU 5.

The corresponding spectra of noise, averaged over period of interaction with NIW are shown in the Fig.6.

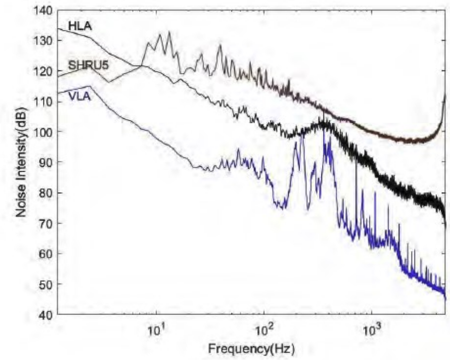

Fig. 6. Spectra of noise for SHRU 5, hydrophone of vertical line array and hydrophone of horizontal line array

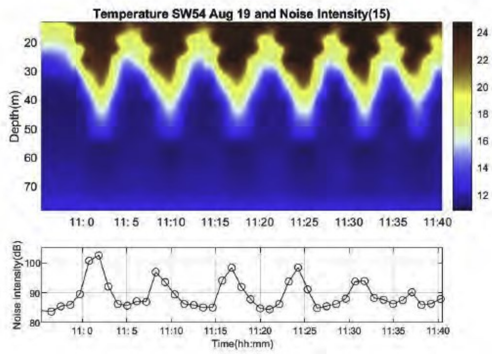

Fig.7. Displacement of thermocline layer at HVLA (upper panel) and noise intensity variations (lower panel)

We can see that (i) noise recorded by SHRU is essentially bigger than on HVLA and (ii) shape of spectrum is different: after some decreasing with frequency red curve (noise on the SHRU) has sharp increasing after about 10 kHz. This behavior of spectrum can be interpreted in accordance with [2], where authors studied noise due to resuspension of sediment produced by hydrodynamic perturbation, for example current in rivers, in our case it is internal wave in narrowing channel. Here NIW propagating toward the coast can reach some place where current of water at the top of NIW touches bottom.

Remark that correspondence of noise intensity fluctuations with displacement of thermocline layer in NIW can be established using those fact that VLA contains set of thermistors, what allows us to find mentioned connection. In the Fig.7 fluctuations of thermocline layer are shown and below there are noise intensity variations.

II. CONCLUSION

So hypothesis about mechanism of noise generation concerned with NIW is sediment resuspension in area of decreasing depth of the sea.

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