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SHORT AND LONG TERM PROGNOSING OF THE CONDITIONS FOR THE SOUND PROPAGATION IN THE BALTIC SEA

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The aim of the paper is to characterise the acoustic conditions in the Baltic Sea, pointing their specific features and showing their impact on short and long term prognosis for the sound propagation. The paper contains the results of experimental and theoretical research based on a large number of in situ measurements. The acoustical climate of the Baltic Sea is difficult to characterise because of many factors influencing it. Seasonal changes in vertical sound speed distribution, typical for upper layer in shallow water, are the main factor influencing the wave propagation. But the difficulties in specifying the acoustical conditions are augmented by the appearance of anomalies as well as short term local phenomena changing considerably the sound speed distribution in certain areas.

INTRODUCTION

It is known that sound propagation in shallow water depends on water depth [18, 10], sound speed profile [6], sea surface and bottom roughness [2], and bottom sediments distribution [8, 18]. Changes in the sound speed distribution in shallow water are the main factor influencing the wave propagation [5, 13]. This fact is often taken into consideration since the range of action of the devices used in underwater investigation is greatly dependable on it [1, 12, 14, 16]. Numerous publications treated that problem in several aspects thus confirming its importance. The phenomena having the impact on the wave propagation in the sea are considered in several fundamental monographs, for instance [3, 4, 17]. The matter of acoustic conditions of the Baltic Sea is examined in [9]. Numerous underwater investigations conducted concurrently with measurements of the sound speed distribution testify to the recognition of the importance of that problem. However there are very few publications devoted to the general characteristics of the acoustic conditions in the Baltic Sea [6, 7, 11].

1. SEASONAL CHANGE OF SOUND PROPAGATION IN THE BALTIC SEA

The acoustical conditions in the Baltic are fully dependent on hydrological conditions. Generally in the Baltic Sea two main layers can be distinguished: the upper layer and the deep water layer. The acoustical conditions in the upper one are influenced by the inflow of solar energy into the sea surface and its transportation into the deeper parts of the sea, while the acoustical conditions in the deep water layer depend on inflows of highly saline water from the North Sea through the Danish Straits. Though the mechanisms of both of those phenomena are well known, they are not fully predictable. The meteorological phenomena influencing processes occurring at the ocean - atmosphere border as well as the deep water inflows are carefully observed and monitored. The general trend in their changes during the year is stable, but the casualistic factor modulating them plays significant role in forming the hydrologic-meteorological situation [14]. Additionally the dynamics of dense bottom currents is strongly dependent on numerous physical factors and also the specific bottom topography. Therefore the long-term as well as the short-term predictions of the conditions of the acoustic wave propagation are burdened with a certain error.

The influence on the changing of acoustical conditions during the year of main physical phenomena: heating and inflows of saline water could be imaged in the form of a diagram showing the vertical distribution of the sound speed as a function of time. Such graphs obtained for the Bornholm Deep and the Gdańsk Deep are presented in Fig. 1. The averaged distribution of the sound speed was estimated for each month separately for every station.

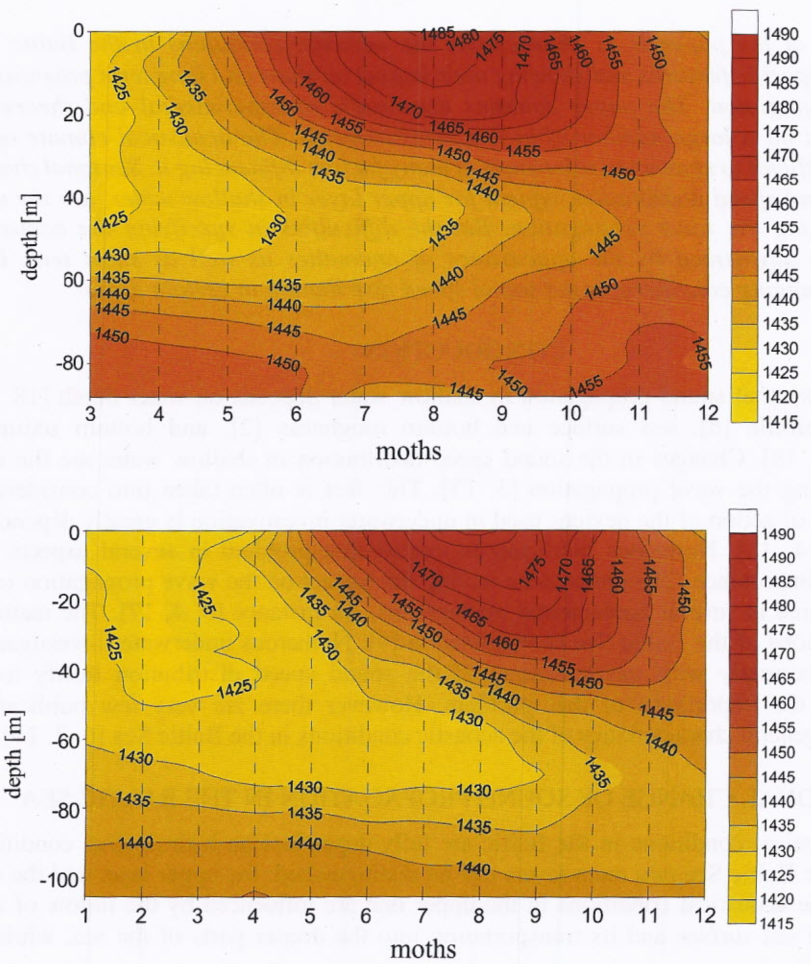

Fig. 1. Annual change in vertical sound speed distribution in the Bornholm (a) and Gdańsk Deep (b)

The characteristics shown in Fig. 1 were obtained using values of sound speed averaged for each month in years 1979-1999. Comparing the data illustrated in the figures we can state that the general trends in changes in the sound speed distribution are similar at both of the stations, however their individual characteristic features could be noticed. In distribution determined for both stations seasonal changes characteristic for the southern Baltic are visible. In winter-months distribution in the upper layer is almost uniform. The sound speed increases with the growth of the depth, reaching at the Bornholm Deep values about 7-8 m/s greater than at the Gdansk Deep. It is the result of greater salinity in the deep layer of about 5-6 PSU. Greater values of the sound speed at the bottom in the Bornholm Deep region influence the vertical sound speed distribution during the whole year. There the minimum occurs practically from May to November at depths of about 50 m at the Bornholm Deep and about 60-70 m at the Gdansk Deep. The minimal value in both cases increases during the year and it is greater at the Bornholm Deep than at the Gdansk Deep from about 2 m/s in May to 10 m/s in September.

2. ACOUSTICAL ANOMALY IN SEASONAL DISTRIBUTIONS

The graphs in Fig. 1, which are based on the averaged sound speed distributions, could be treated as an attempt to characterize the acoustic climate of the Southern Baltic. They provide data for long term prognosis of sound wave propagation in selected areas as well as in all Southern Baltic Sea. The next step in the search for the specific features of the Baltic treated as a complex environment of sound propagation was to find out how does the particular synoptic sound speed distribution differ from the averaged one and how does it influence the acoustical conditions. To get the answer several synoptic distributions established in different seasons are compared with the averaged distribution.

An example, illustrating a positive and a negative anomaly of acoustical conditions in June and their impact on the transmission losses diagrams, is shown in Fig. 2. The diagrams are predicted for the same source positioned at the 20 m depth in the Bornholm Deep area. Calculations were done for the averaged vertical speed distribution characteristic for June as well as for the distributions measured in May 1986 (positive anomaly) and in May 1987 (negative anomaly). Transmission losses were predicted taking into account geometrical spreading loss, absorption loss and bottom interaction loss.

3. SHORT TERM CHANGES IN ACOUSTICAL CONDITONS

Characteristic for the Southern Baltic is appearance of short-term local phenomena changing considerably sound speed distribution in certain areas [10, 15]. They cause difficulties in prognosing the acoustical conditions influencing the range of hydroacoustic devices. The examples of such phenomena involving short term local anomaly can be observed in the upwelling near Rozewie and in the Gulf of Gdańsk as a consequence of the influence of the Vistula water on acoustical conditions.

The shape of the bottom near Rozewie in specific hydrological and meteorological conditions causes the occurrence of upwelling of the colder water. Data shown in the next figures illustrate the influence of upwelling on sound speed distribution.

CONCLUSIONS

Prognosing of the conditions of sound wave propagation in the Baltic Sea is a complex task because of many factors influencing them. The general mechanisms forming seasonal changes in acoustical climate of the sea are known well, but randomness of factors modulating them cause numerous anomalies of different scope. In long term prognosis the most important role plays the anomaly which is the consequence of long term meteorological conditions. In short term prognosis the local hydrological phenomena are the factor, which must be considered in predictions. Only monitoring of hydrological conditions in chosen area, for which short term anomalies are typical, allow to take them into account in hydroacoustical prognosis.

The averaged distributions allow to assess the general trends, to find specific features for particular seasons. The acoustical conditions in the upper layer, where salinity is almost invariable, depend on the seasonal changes in temperature of water. In the winter temperature in the upper layer is nearly stable down to the depth of about 50 - 60 meters. Therefore the spatial distribution of the sound speed is nearly uniform at that season.

In other seasons temperature of water at the surface is higher than in the deeper layers. It involves the vertical gradient of the sound speed and the appearance of the minimum sound speed in its vertical distribution approximately at the border between the upper and the deep water layer. The value of the gradient is the highest in the summer. During the year the gradient changes seasonally in accordance with the heat exchange between atmosphere and seawater. The thermal conditions in the winter exert an influence on the minimal value in the vertical sound speed distribution during successive seasons, whereas the maximal value of the speed at the surface depends on current conditions in each particular season.

The impact of the inflows of highly saline water from the North Sea causing the increase of the sound speed in the deep water layer usually is visible in the western part of the Baltic Sea in the autumn, and in the Gdansk Deep region in the early spring. The inflow appears as a rule in the autumn and the subsequent course of phenomena depends mainly on when it occurs and the volume of inflowing water.

The differences between synoptic and average distributions demonstrate the strength of the impact that physical factors have on them and confirm the necessity of investigating acoustical conditions when hydroacoustic equipment is used in underwater research.

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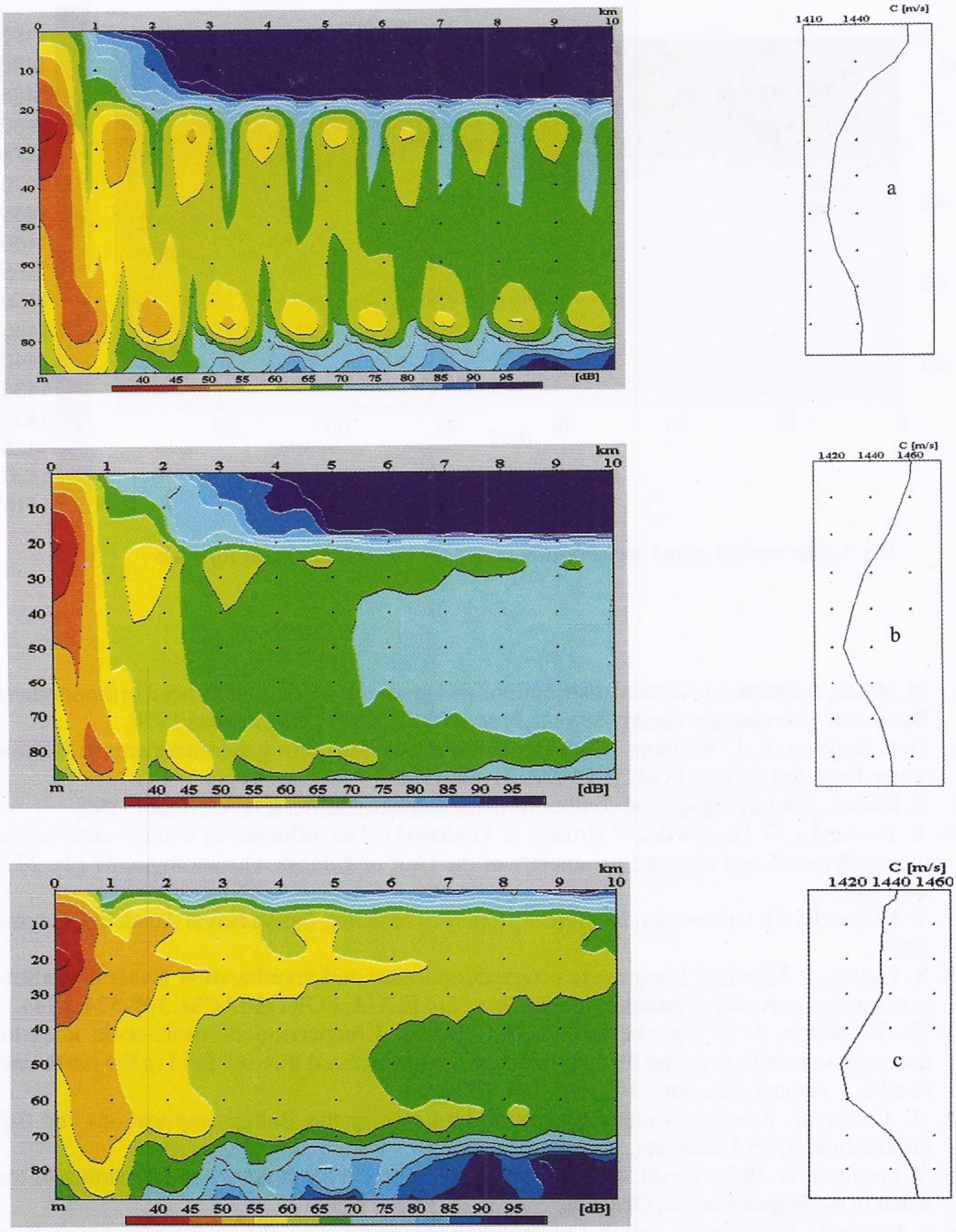

Fig. 2. Transmission losses versus range for frequency of 700 Hz in the Bornholm Deep in June: a) positive anomaly (June 1986), b) averaged distribution in June 1979-1999, c) negaive anomaly (June 1987); depth of a source z=20 m

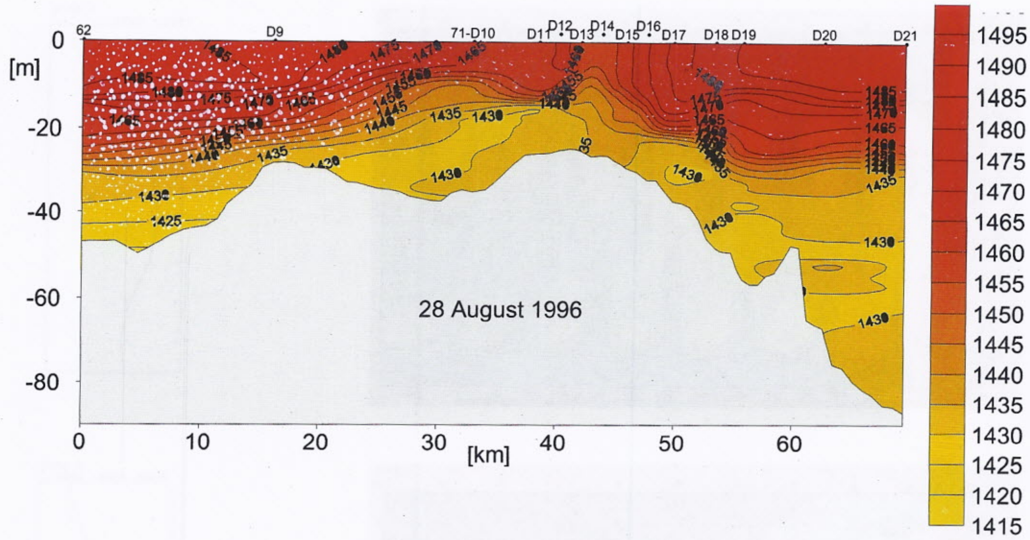

Fig. 3. The vertical sound speed distribution at the cross-section near Rozewie

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