Seasonal changes of acoustical propagation properties in the Southern Baltic.

Przemyslaw Soszynski, Eugeniusz Kozaczka
Naval University of Gdynia, ul. Smidowicza 69, Poland
e-mail: soszynski@amw.gdynia.pl, ekoz@amw.gdynia.pl

The effectiveness of the acoustic equipment working in the water environment, characterized by variable sound speed distribution, is largely dependent on the changing characteristic of the directionality of acoustic rays caused by the refraction phenomenon. This fact is especially significant in case of shallow water environment where the seasonal changes of hydrological properties are especially high. In this article, the results of analysis of sound speed profile changes resulting from a seasonal influence for the Baltic Sea are presented. Basing on this analysis the effective range of operation of hydrological equipment can be approximated.

The range of operation of the acoustic equipment working in the water environment is largely dependent on the changing characteristic of the propagation of sound. One of the main contributing factors that affect the way sound propagates in the water environment is the distribution of sound speed. Different locations are characterized by its peculiar sound speed profiles which are determined by factors that are subject to temporal and spatial changes. The temporal changes are related to the annual and diurnal alterations of the meteorological conditions (air temperature, wind, waves) and the spatial changes are determined by the specific location of the sound source.

The subject of this paper is to examine the properties of sound propagation for the Baltic Sea, therefore it is helpful to describe shortly this water environment. There are a number of factors that make Baltic Sea a unique water environment. One of them is a fact that it is a sea with one of the smallest levels of salinity (a factor influencing the sound speed distribution). Another feature is that Baltic Sea is quite shallow so it is more easily affected by the changing meteorological conditions than seas of a bigger depth. It is also more susceptible to local and seasonal anomalies. Because of this uniqueness of the Baltic Sea a lot of time is devoted by scientists for the research of the influence of the meteorological and hydrological conditions on the propagation of sound in this area.

Generally, two distinct layers can be discerned in this sea that have a different characteristic of sound distribution and sound propagation and are differently dependent on external conditions. The acoustical conditions in the upper one, called the surface layer, depend on the exchange of the solar energy between water and the atmosphere and transferring of this energy into the water environment. The propagation conditions in the lower layer, called the deep water layer, are typically subject to changes in a minor manner, however in the Baltic Sea they depend on the influx of waters from the North Sea which have much higher level of salinity. Although the general mechanisms of both phenomena are well known it is still difficult to predict its outcome, therefore the short and long term prediction of acoustical conditions is influenced by certain errors.

In order to characterize the seasonal changes of propagation conditions the averaged sound speed profiles for years 1960-1997 have been used (Fig 1. and 2.)

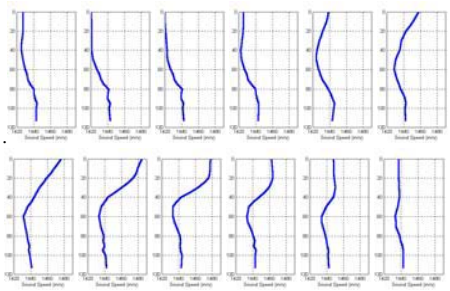

Fig. 1. Averaged sound speed profiles for Gdansk Deep for consecutive months of the year

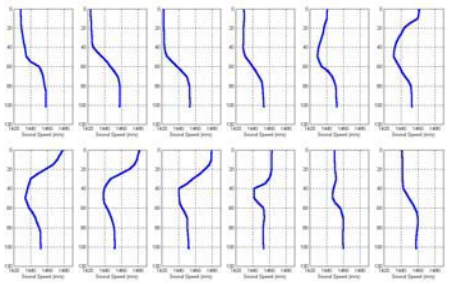

Fig. 1. Averaged sound speed profiles for Bornholm Deep for consecutive months of the year

It can be seen that there are similar seasonal changes of the profiles at both locations. In the surface layer the sound speed has a tendency to by much higher for the summer months (due to higher air temperatures), where it changes from about 1420 m/s in January to about 1480 m/s in August (for both locations). In the colder months because of the winter storms and a larger amount of waves the water in the surface layer gets mixed up and the temperature, which is the dominant factor for the sound speed in this layer, becomes approximately equal. The slightly positive sound speed gradient may be due to the increasing pressure. As far as the deeper water layer is concerned, there is a distinct minimum speed in the profiles for the months from May until November which exists approximately at depth

of 60 m for the Gdansk Deep and at about 45 meters for the Bornholm Deep.

Although the profiles presented in the pictures reflect the visible seasonal changes characteristic for the Baltic Sea, the individual features characterizing both locations are also evident. In the winter months the distribution in the upper layer for both locations is similar but in the deep water layer the sound speed is higher for the Bornholm location by about 8 m/s which is a result of the existence of warmer water coming from the North Sea of higher salinity. This increase in the speed of sound causes also that the minimum sound speed is at a smaller depth at this location in comparison to the Gdansk Deep. The effect of that is a creation of a sound channel with an axis at different depths. On the following fig. 3 it can be observed that the sound channel is deeper at Gdansk Deep (about 60m) than in the Bornholm Deep (about 50 m). The poor propagating conditions for the sound source at depth of 50m in Gdansk Deep in November, visible in the figure, is caused by the fact that the speed of sound in the deep water layer at this location is considerably smaller in comparison to the speed of sound in the surface water layer and the sound rays have a tendency get refracted toward the bottom.

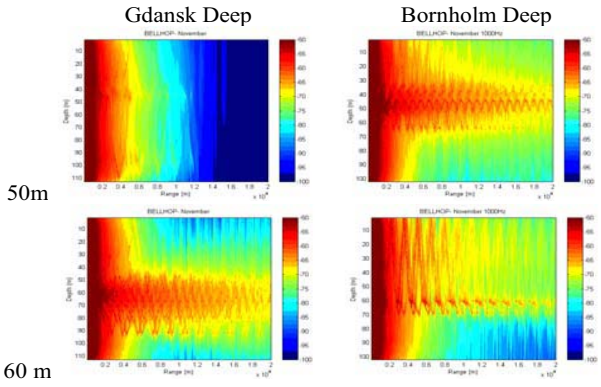

Fig. 3. Average transmission loss for November at given locations

The general sound propagation conditions can be deducted from a careful analysis of the available averaged sound speed profiles however the actual propagation conditions depend on the actual and real sound speed distributions. It is important therefore to study what natural causes affect the distribution of sound speed at different locations and to what extent they influence the change in the sound propagation conditions. The departure from the typical circumstances may be called an anomaly. Lets consider for example an actual sound speed profile for the month of May 1991 at the Bornholm location. The unusually warm winter caused that the sound speed at the surface layer was on average higher by 5 m/s than in the averaged sound speed distribution. In the deep water layer the actual sound speed was lower due to the smaller than typical inflow of saline water in the preceding autumn. This is illustrated in figure 4. Due to the flattening of the sound speed profile for the actual conditions in May 1991 the transmission losses were much higher for sounds originating at small depths.

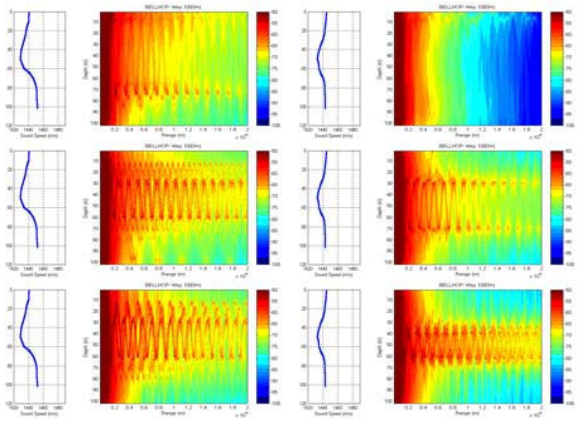

Fig. 4. Transmission loss for an actual sound speed distribution in May 1991 at Bornholm Deep location in comparison to the transmission loss for averaged sound speed profiles for sound sources at depths: 10, 30 and 60 m.

Conclusions

The ability to understand and interpret the sound speed profiles and especially their changes with respect to different seasons have an important effect on the understanding of how they influence the effectiveness of hydrological equipment and especially their range of operation. From the pictures presented in this article it can be seen that there is a definite relation between the speed of sound in the water and the transmission loss of the acoustic signal. The acoustical climate of the southern Baltic is difficult to describe because of the many factors that influence it. The available averaged sound speed profiles can give a general view of the sound propagation conditions in this area and help to see the trends. However, the comparison and analysis of the actual sound propagation conditions leads to the conclusion that it is necessary to constantly update the database of available sound speed profiles as well as concurrent meteorological and hydrological conditions. If possible it is also beneficial to conduct a measurement of the speed of sound in the water before the employment of any hydroacoustical equipment.

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