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INVESTIGATION OF THE RELATION BETWEEN THE DISSOLVED ^{137}CS ACTIVITY AND THE SIMULATED SALINITY IN THE LITHUANIAN COASTAL WATERS

Abstract

In May 2000 the hydrodynamic model developed at the Federal Maritime and Hydrographic Agency in Hamburg, Germany was adopted to the Lithuanian part of the Baltic Sea. 1 nm grid is chosen. Comparison of measurements (1999.05.15) with the real time simulations of the particular period showed that in general, in the modelled area, the simulated salinity was higher than measured with most differences in the coastal zone. Average salinity distributions and the distribution of salinity standard deviations were analysed. The coastal area of 15 nm from the seashore, especially to the north of the Klaipėda Strait, is distinguished by the highest variance of the salinity. The relation between the salinity and the dissolved ^{137}Cs activity concentration was observed. However, ^{137}Cs activity bursts 1.5-2 times higher at the coast than the average, cannot be explained and are more likely to be related to the uplifted particulate matter.

1. Introduction

In May 2000 the hydrodynamic model developed at the Federal Maritime and Hydrographic Agency (BSH) in Hamburg, Germany was adopted to the Lithuanian part of the Baltic Sea [1]. It was a part of the IAEA project "Assessment of radionuclide migration in the Lithuanian part of the Baltic Sea environment". The main goals for the modelling were to simulate the evolution of the radioactive contamination penetrating into the Baltic Sea due to the Nemunas river inflow in an ordinary situation and in case of a possible accident (for example) in Lithuanian NPP in Ignalina. The present distribution of radionuclides in the Lithuanian part of the Baltic Sea should also be modelled and the possible causes of the observed uneven distribution, especially on the seashore, should be clarified. For the first approach, the modelling of distribution of the ^{137}Cs activity concentration (AC) was chosen. Its amount in the Baltic Sea is still relatively high compared with the open seas or with the riverine water, and its migration in the environment is of great interest [2]. The chemical properties of ^{137}Cs in fresh and salty water clearly differ: ^{137}Cs in seawater appears mostly in dissolved form. In fresh water it is attached to the suspended matter [3, 4].

2. General information about the model

The area selected for the modelling (with the upper left corner at 19°55'25" E, 56°20'45" N) covers the Lithuanian part of the Baltic Sea including the Curonian Lagoon, part of Latvia and Kaliningrad (Russia) sea area (Fig. 1). 1 nm grid was chosen and the vertical water column was divided into five layers of (8 + 8 + 8 + 26 + 50) m depth. The Curonian Lagoon (average depth 3.7 m) is covered in the model by one layer only and no detailed analysis of the simulations has been made so far. Only one river input is taken into account - the river Nemunas flowing into the Baltic Sea through the Curonian Lagoon. It is the third largest tributary of the Baltic Sea. The river input is considered to be constant.

Meteorological data measured at the ground station in Preila are used for the whole area of the model. Other possibilities are currently under consideration.

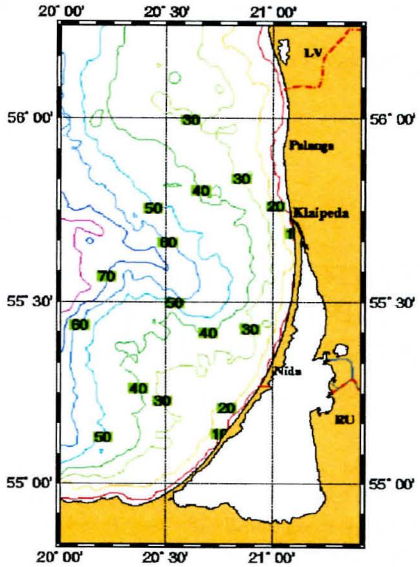

Fig. 1. Hypsographical map

The developed model is dependent on the operational circulation model for the Baltic Sea running at BSH. BSH data of the operational circulation model are used to obtain the distributions of the hydrological parameters at the open boundaries and in the whole area (for the initial distribution) after the interpolation from 6 nm to 1 nm grid.

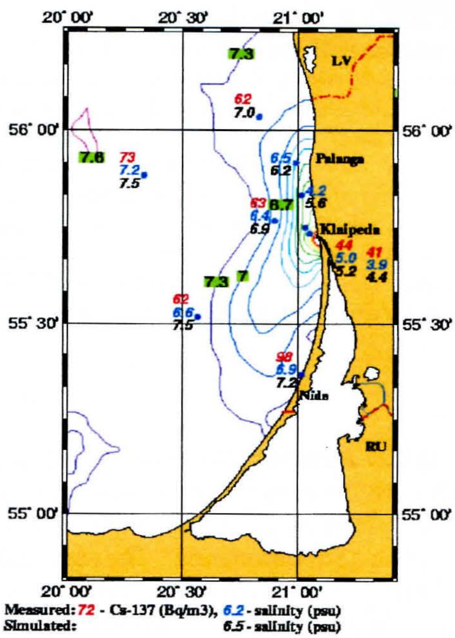

Fig. 2. Measured Cs^{137} activity concentration and salinity on the 15th May 1999 together with simulated salinity distribution

3. Relation between the salinity and the dissolved ^{137}Cs AC

By analysing measurement data of the cruise performed on 15th May 1999 (Fig. 2, [5]) the correlation between the salinity and the dissolved ^{137}Cs AC in the Lithuanian part of the Baltic Sea was found (Fig. 3): the activity concentration of ^{137}Cs has been increasing with salinity. The data measured showed a polynomial relation. As the fresh and marine water mixing starts in the Klaipėda Strait, the minimum of simulated salinity in the Baltic Sea at the Klaipėda Strait is about 4 psu. However, the salinity data of the most measurements obtained by other authors (see, e.g., [6]), falls to the range from 6.5 to 7.5 psu and shows no correlation with ^{137}Cs AC. Therefore to define the relation more precisely the additional combined experimental data, i.e. the salinity measured together with ^{137}Cs AC in the range of the reduced salinity (less than 6.5 psu), are needed. Referring to the relation presented below the distribution of dissolved ^{137}Cs could be related to the salinity distribution in the Lithuanian part of the Baltic Sea indeed. The distribution of the salinity was first analysed to find out stable salinity patterns and to evaluate the fresh water influence. The upper line in Fig. 3 is the result obtained by the Radium Institute for the Gulf of Finland – it is the linear relation [7].

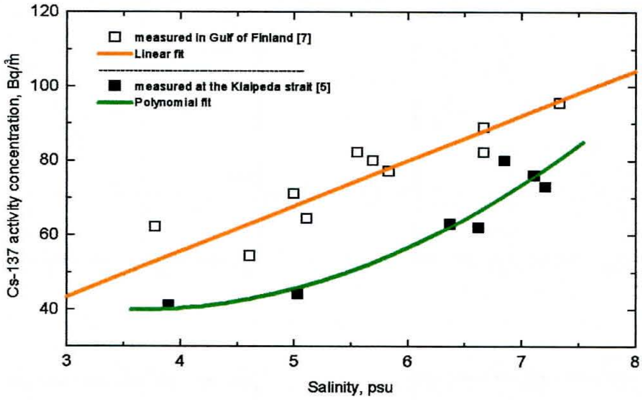

Fig. 3. **Relation between** the salinity and the dissolved ^{137}Cs AC

4. Assessment of fresh water influence

Averaged simulated salinity distributions were calculated for the years 1999 and 2000 (Fig. 4 a, b). Averaging was done over five months, for the period of the "warm" weather and relatively weak winds - from May to September. Wind distributions (wind rose) for these particular periods were also calculated. In the year 1999, westerly, northerly and southeasterly winds were dominant, and in the year 2000, according to the measurements in Preila, only the westerly wind prevailed. As can be seen, in general the obtained averaged salinity distributions look similar - with the most reduced salinity along the seashore to the north of the Klaipėda Strait. As it has also been observed, north is the dominant direction of the water transport from the Klaipėda Strait [8]. The reduction of the salinity (from 7.5 to 7.1 psu) in the southern part of the area in the year 1999 could be clearly related to the bigger probability of northerly wind that caused the reduced salinity water to move in the southwestern direction from the Klaipėda Strait. The minimum salinity value, obtained by the simulations in the southern part of the modelled area, was about 6 psu. Fresh water moved in the southwestern direction but not along the coast (along Curonian Spit) in the southern part of the area. Therefore the fresh water does not have much influence on the average salinity near Nida: the observed average salinity was about 7 psu [9], simulated - 7.2 psu; and the reduced salinity along the seashore to the north from the Klaipėda Strait: the observed average salinity near Šventoji (56°02' N) was 6.6 psu [9], simulated - 6.7 psu.

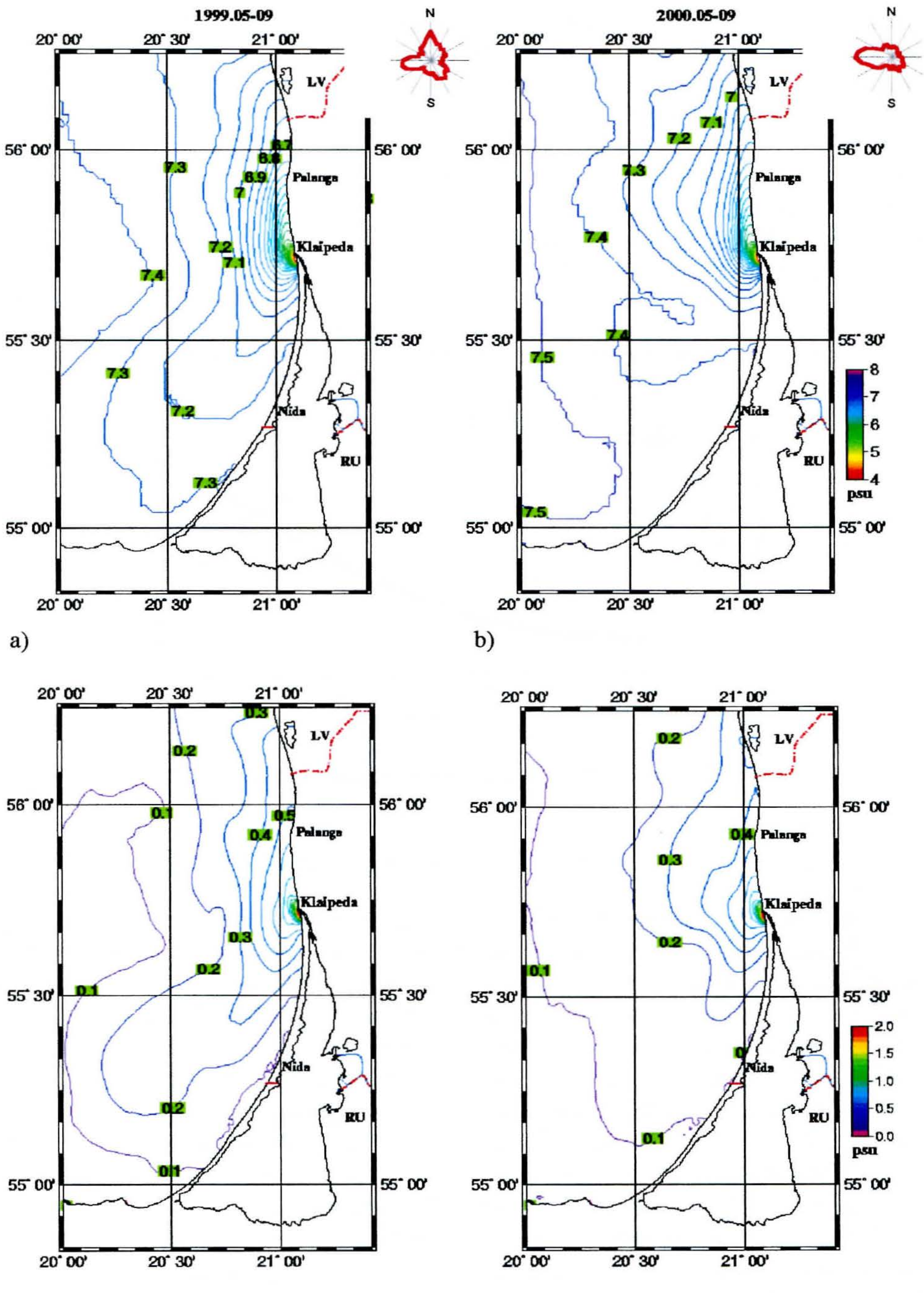

Fig. 4 **a)** and **b)** - averaged salinity distributions for the periods 1999.05-09 and 2000.05-09 with the wind rose (▬); **c)** and **d)** - distributions of simulated salinity standard deviation

Plots of salinity standard deviations could distinguish the variability of the salinity over the analysed period (Fig. 4 c, d). The largest salinity variations (minimum ±0.3 psu) were found at the Klaipėda Strait, where the fresh and marine water mixing is most intensive, and then on the strip of 15 nm by the coast to the north of the Klaipėda Strait. Over 30 nm from the coast, the minor salinity variations were obtained (maximum ±0.2 psu). For the year 1999, in the southern part of the area, major variations of the salinity were obtained along the path of fresh water stream. The averaged salinity and its variation limits in the southern part are dependent on the northern wind probability over the period of the simulation. Minimum salinity obtained in the southerly part of the model area by the northerly wind was 6 psu. In the year 2000, when the westerly wind prevailed, fresh water movement to the north was dominant. Therefore the remarkable salinity standard deviations have only been obtained at the Klaipėda Strait.

The river Nemunas fresh water flow influences all the analysed area to some extent. The fresh water moves mostly along the seashore (to the north and partly to the southwest). The northern part of the area, further than approximately 30 nm from the coast, showed the smallest salinity variation. This area is supposed to be the least influenced by the fresh water. Measurement data obtained there could be used as representative values for the calibration of the salinity and ^{137}Cs AC in the incoming water through the open boundary in the west.

5. Comparison of measurement and simulation

In May 1999, the expedition to the Lithuanian national monitoring stations was organized [4]. The measured ^{137}Cs AC and salinity data, together with the simulated salinity distribution, were compared (Fig. 2). In general, the simulated salinity is higher than that measured in the modelled area. This could be related to the higher salinity values of the input data from BSH used at the boundaries of the modelled area. The largest difference was obtained along the fresh water moving path. As the northerly wind prevailed, according to the distribution of the measured salinity values, the fresh water was moving from the Klaipėda Strait towards southwest. The simulated salinity distribution also shows this tendency but not so apparently. The differences could be influenced by the meteorological data, especially by the wind data used.

The lowest measured ^{137}Cs activity values (about 40 Bq/m^3) and the salinity as well as the simulated salinity, were obtained at the Klaipėda Strait. High ^{137}Cs activity was measured at the seashore - about 100 Bq/m^3 by Preila. The measurements of the ^{137}Cs activity in the coastal zone (in particular in Juodkrante at the Klaipėda Strait) vary in the wide range [10], and sometimes activity concentrations increase to values 1.5-2 times higher than the overall average concentration of the seawater in the southern part of the Baltic Sea, which is about 80 Bq/m^3. The ^{137}Cs activity values, higher than the average cannot be explained or modelled by just using the relation of the salinity and dissolved ^{137}Cs. In the coastal zone and in the fresh - salty water mixing zone at the Klaipėda Strait, the deposition to the sediments, resuspension and sorption - adsorption processes should be taken into account [11]. Therefore a dispersion model should be developed in addition. The transport of ^{137}Cs attached to the particles should be added. The possible sources of particles could be the Klaipėda Strait (fresh water carrying the bottom sediments from the Klaipėda Strait) and bottom sediments in the coastal zone.

This year on 16th and 17th October, a cruise in the Lithuanian part of Baltic Sea was organized. Complex measurements at 9 stations were carried out. To cover the larger area, these stations were organized in the grid 10×12 nm with the upper left corner at -20°20'E 55°50'N. Water and bottom sediment samples were also taken in several additional stations in between (dumping).

Conclusions

1) North is the dominant direction of the water transport from the Klaipėda Strait; the reduced salinity of marine water in all layers was observed.
2) The highest variance of the salinity is distinguished in the coastal area of 15 nm from the seashore.
3) In the modelled area the simulated salinity was higher than measured with most differences in the coastal zone.
4) Bursts of the ^{137}Cs activity at the coast are most likely to be related to the uplifted particulate matter.

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