HINDCAST MODELLING OF UPWELLING SITUATION IN SEPTEMBER 1989

INTRODUCTION

A three - dimensional σ - coordinate model based on the Princeton Ocean Model code (Mellor, 1993) was applied to study wind - induced upwelling in the Southern Baltic Sea. The aim of this note is to reconstruct a strong fall of sea surface layer temperature in September 1989 at the Polish Baltic coast described by Malicki in (Malicki and Miętus, 1994).

The model simulations were performed for the whole Baltic with its main basins: the Gulf of Bothnia, the Gulf of Finland, the Gulf of Riga, the Belt Sea, Kattegat and Skagerrak. Presentation of results is limited to the Southern Baltic Sea.

Model was forced by realistic wind fields estimated from atmospheric surface pressure charts. At the sea surface, temperature and salinity fluctuations are modelled with a method of “relaxation to climatology” (e.g. Oey and Chen, 1992; Lehmann, 1995). Climatological fields of sea water temperature and salinity were estimated from monthly mean surface charts (Bock, 1971; Lenz, 1971). The surface pressure data were taken from (BED, 2000).

Developping of intensive upwelling in some region along the southern coast of the Baltic as a response of a stratified sea to an onset of variable winds in September 89 was presented. The results of calculations of time series of temperature in two grid points were compared with the observed values of temperature taken from (Malicki and Miętus, 1994). To complete the picture of variability of termohaline parameters time series of calculated sea water salinity in these points were depicted.

DESCRIPTION OF UPWELLING SITUATIONS

Malicki described the anemobaric situation (Malicki and Miętus, 1994) which was realated to strong fall of sea surface layer temperature observed along the Polish coast of the Southern Baltic Sea in September 1989. Example time series of the sea surface layer temperature at the stations: Kolobrzeg and Władysławowo, taken from figure presented in Malicki and Miętus (1994) are shown in Fig. 1. Location of the stations in the Baltic Sea are depicted in Fig. 2.

Fig. 3 presents the pressure fields related to the strong fall of the sea surface layer temperature along the Polish Baltic coast (cf. Fig. 1). The pressure field are taken from Internet (BED, 2000) and are almost the same as shown in (Malicki and Miętus, 1994).

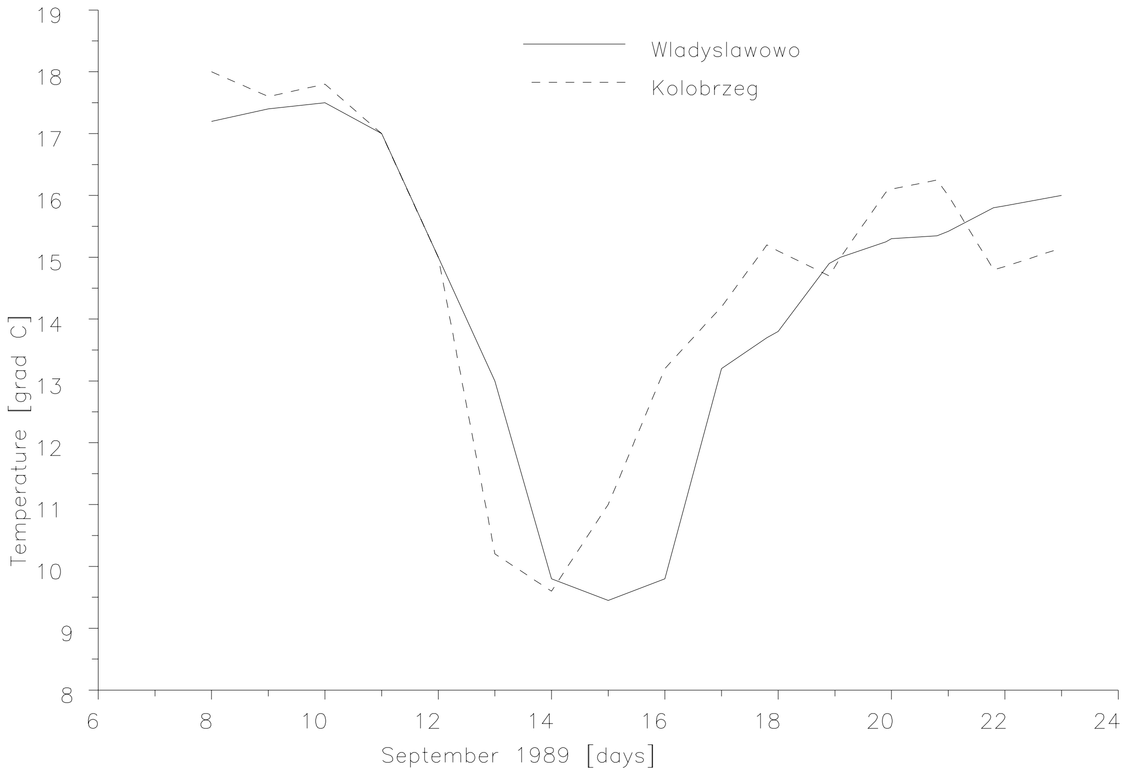

Fig. 1 Example of strong fall of sea surface layer temperature [^{o}C] at two points at the Polish coast of the Baltic Sea in September 1989 (Malicki and Miętus, 1994).

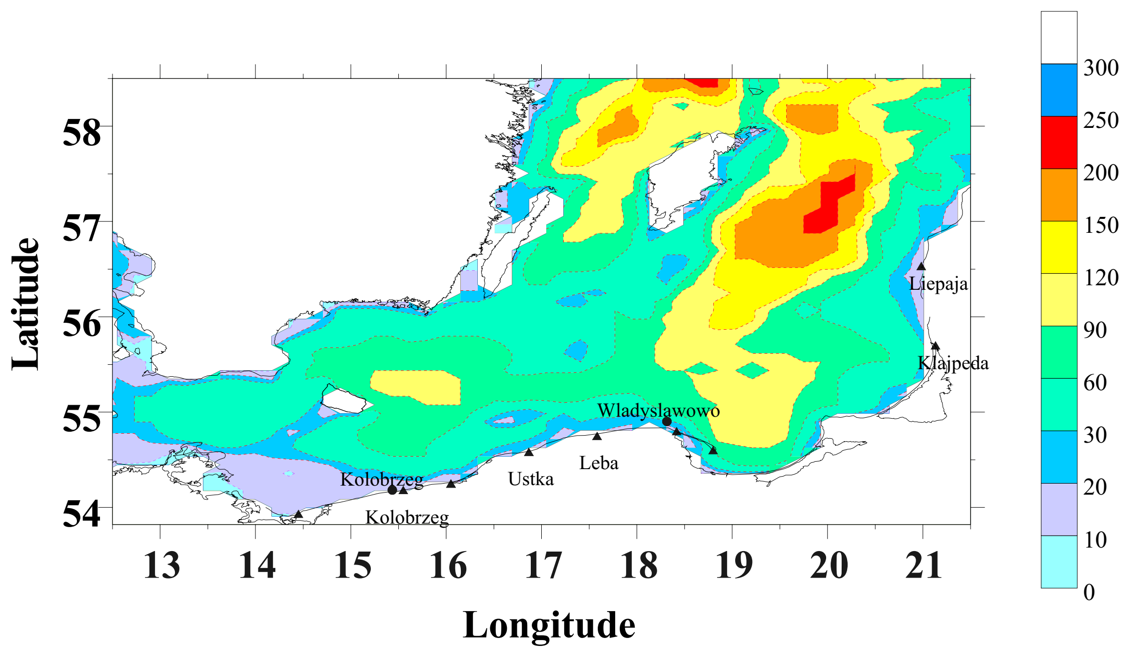

Fig. 2 Location of hydrometeorological stations and numerical grid points used for visualization of time evolution of calculated hydrological parameters. Numbers on isobaths indicate sea depth of the Southern Baltic Sea (data from Seifert and Kayser (1995)).

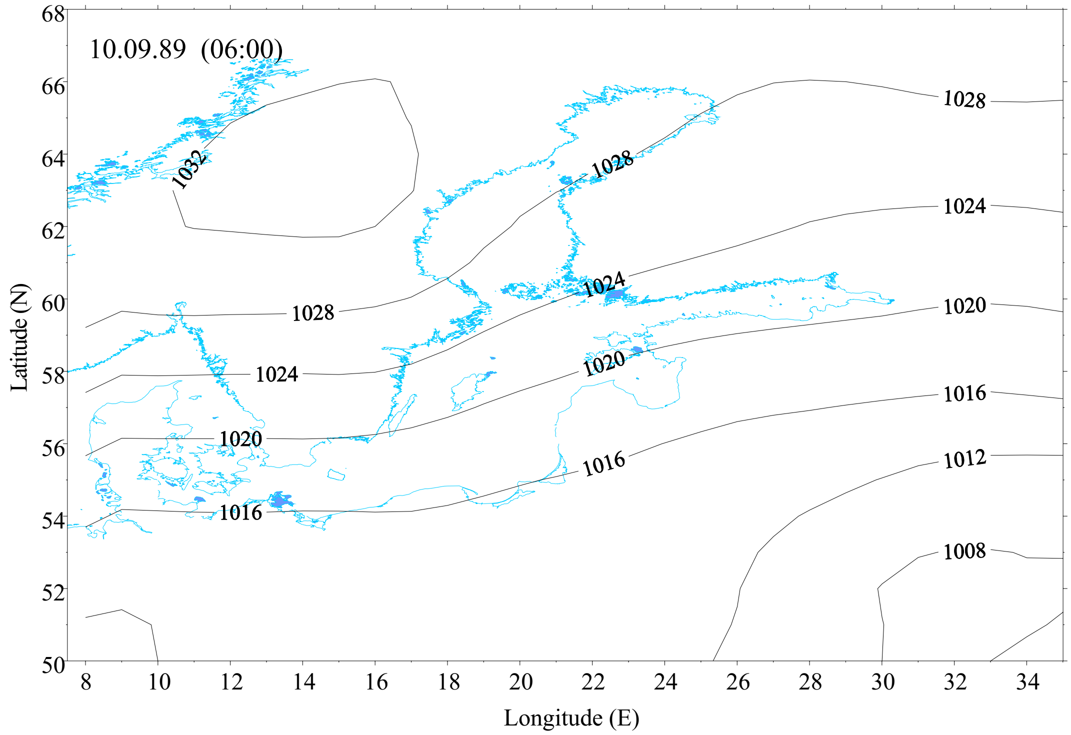

Fig. 3 Anemobaric situation above the Baltic regon related to strong fall of temperature along the Polish Baltic coast shown in Fig. 1 (data from (Bed, 2000)). Isobars in [hPa]. a. 10.09.1989 at 06:00

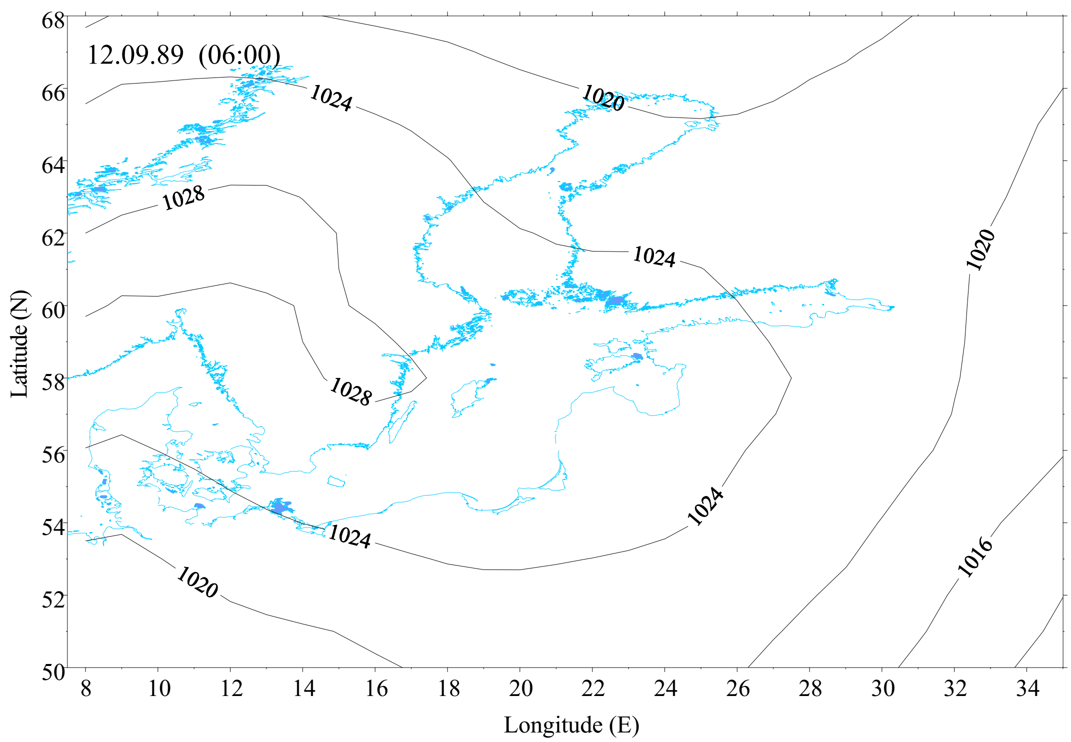

Fig. 3 continued b. on 12.09.1989 at 06:00

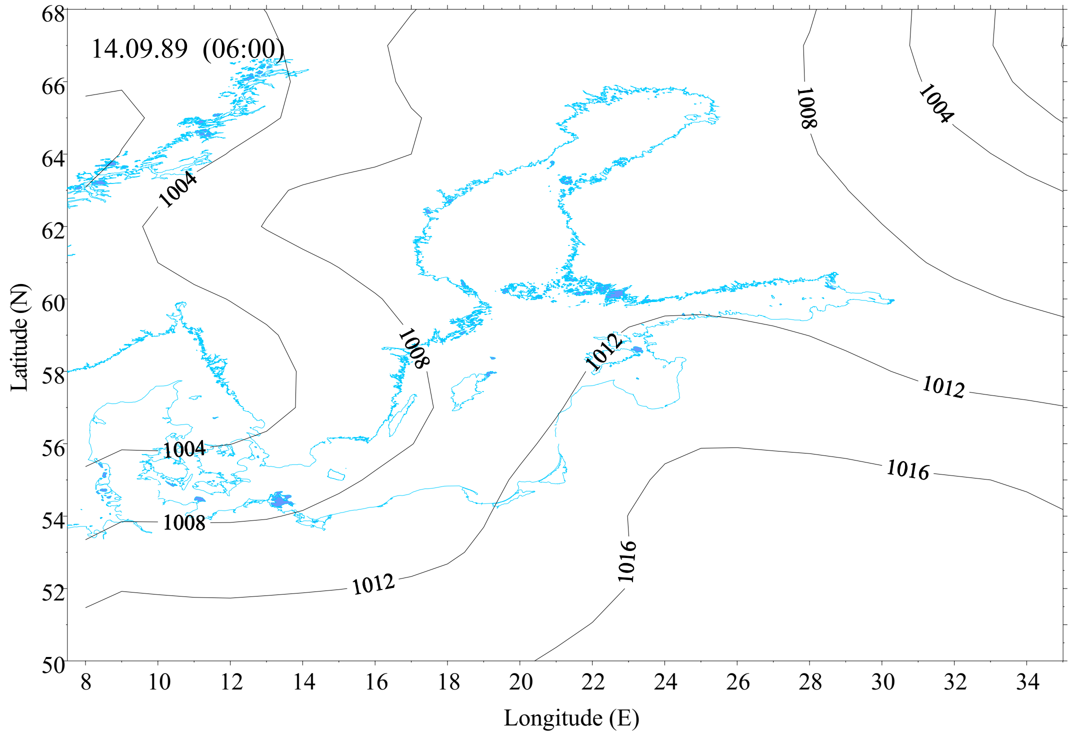

Fig. 3 continued c. on 14.09.1989 at 06:00

RESULTS OF SIMULATIONS

The model computations performed for the whole Baltic with its main basins: the Gulf of Bothnia, the Gulf of Finland, the Gulf of Riga, the Belt Sea, Kattegat and Skagerrak. Presentation of results is limited to the Southern Baltic Sea.

Model was forced by realistic wind fields estimated from atmospheric surface pressure charts. At the sea surface, temperature and salinity fluctuations are modelled with a method of "relaxation to climatology" (e.g. Oey and Chen, 1992; Lehmann, 1995). Climatological fields of sea water temperature and salinity were estimated from monthly mean surface charts (Bock, 1971; Lenz, 1971). The surface pressure data were taken from (BED, 2000).

Applying the code of the POM version and methodology of numerical simulations described in (Jankowski, 2000a; 2000b) the hindcast calculations were performed.

The calculations which results are presented here were carried out for termohaline conditions of September (multi-year averaged, climatological conditions).

Numerical simulations were performed in two stages. The first stage (days 0-20) was a semi-prognostic pre-processing run and the model was forced only by climatological forcings without wind stress.

At the second stage, the model was forced so by climatological forcings as by realistic atmospheric forcings.

The initial fields of sea level η, currents velocity vector component u, v, w and the mean-depth currents components U, V were set equal to 0. The three - dimensional fields of the sea water temperature T and its salinity S of August, constructed from the montly mean (multi - year averaged, climatic) maps presented in Bock's (1971) and Lenz's (1971) atlases, were used in model runs as initial fields of T, S. The surface distributions of temperature and salinity taken from Bock's (1971) and Lenz's (1971) atlases served as field of climatological forcing.

The climatological forcings were coupled to model by means of so - called method of "relaxtion towards climatology" (cf. Oey and Chen, 1992; Lehmann, 1995) where the surface heat and salinity fluxes Q_T, Q_S can be estimated as follows:

$$Q_T = C_{TC}(T_c - T); \qquad Q_S = C_{SC}(S_c - S). \tag{1}$$

where: C_{TC}, C_{SC} - relaxation constants equal to $C_{TC}^{-1} = 2$ days and C_{SC}^{-1} =20 days, respectively, T, S - calculated values of temperature and salinity at the first σ level, respectively, T_c, S_c - climatological values of temperature and salinity at the sea surface, respectively.

An adaption of the model dynamics to initial fields and climatolgy was achived by a forward integration of the model equations over a period of 20 days when a quasi - stationary state was reached.

At the second stage model was initialized from the previous stage and consisted of a prognostic run when model was forced by both climatological forcings and by realistic atmospheric forcings (winds).

Winds fields were estimated from atmospheric surface pressure charts taken from (BED, 2000), where data were digitalised on grid 1^o x 1 1^o at eight terms: 00, 03, 09, 12, 15, 18 and 21. Example of these data are presented in Fig. 3. Ageostrophic angle was taken equal to 15^o and correction coefficient equal to 0.7. Wind stress components at the surface τ_x, τ_y were estimated by standard relation:

$$\tau_x = \rho_a c_D W_x W_a; \qquad \tau_y = \rho_a c_D W_y W_a \tag{2}$$

where:
W_a, W_x, W_y - absolute value and components of wind speed vectors, respectively, ρ_a - air density and c_D - drag coefficient.

Drag coefficient c_D was computed according to Large and Pond (1981) formula:

$$c_D 10^3 = \begin{cases} 1.14 & gdy \quad W_a \leqslant 10m/s \\ (0.49 + 0.065W_a) & 10m/s \leqslant W_a \leqslant 25m/s \end{cases} \tag{3}$$

Results of simulations of sea surface layer temperature are presented in Fig. 4 for days from 09.09.1989 to 16.09.1989. They depict developping of intensive upwelling in some region along the southern coast of the Baltic as a response of a stratified sea to an onset of variable winds in September 89.

To complete the picture of variability of termohaline parameters time series of calculated sea water temperature and salinity at selected depths in two numerical grid points, near the stations Kołobrzeg and Władysłwowo, were depicted in Figs. 5-8.

The results of calculations of temperature were compared with the observed values of temperature taken from figure in Malicki and Miętus (1994).

The calculations were performed with the help of model with horizontal grid space step ∼ 10 km and with 24 σ - layers in vertical.

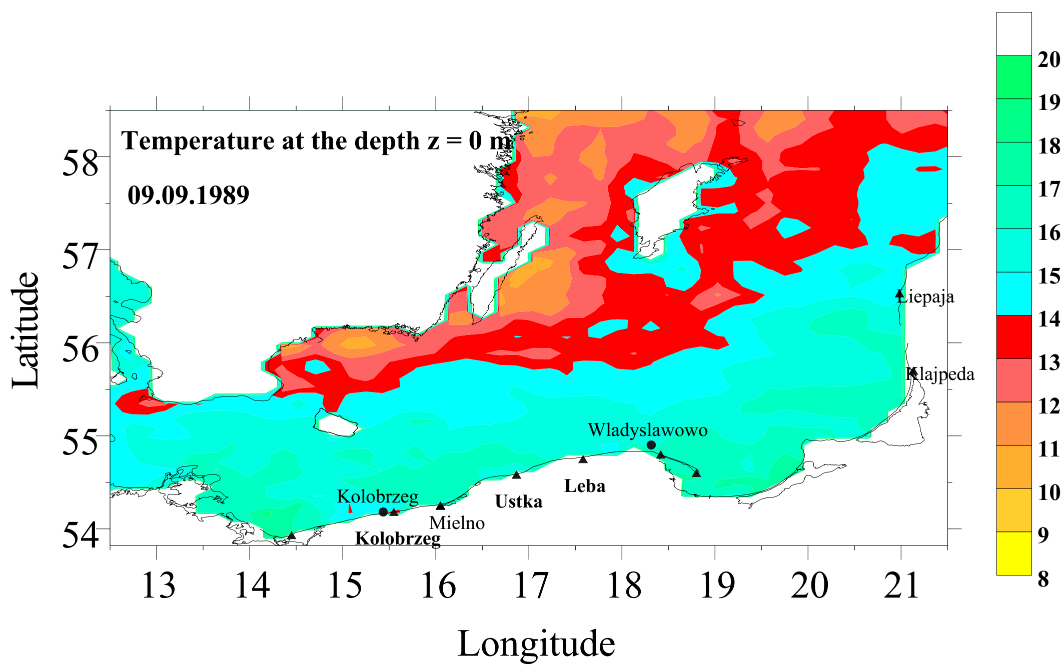

Fig. 4 Sea surface temperature [^oC] calculated by the model (horizontal space steps of numerical grid ∼ 10 km): a. - results on 09.09.1989 at 12:00

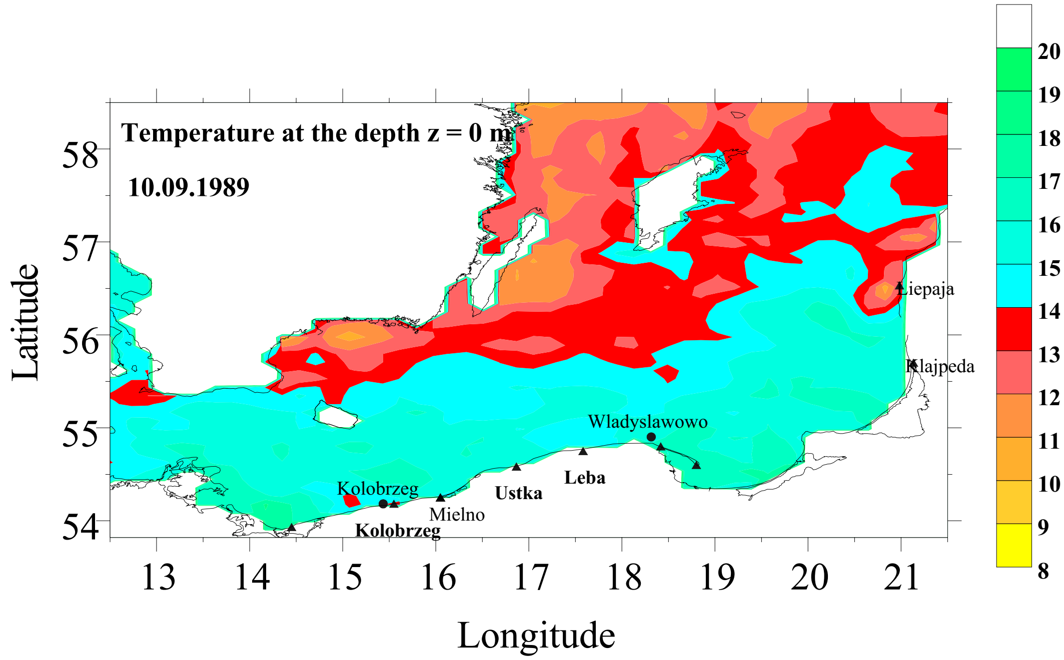

Fig. 4 continued b. - results on 10.09.1989 at 12:00

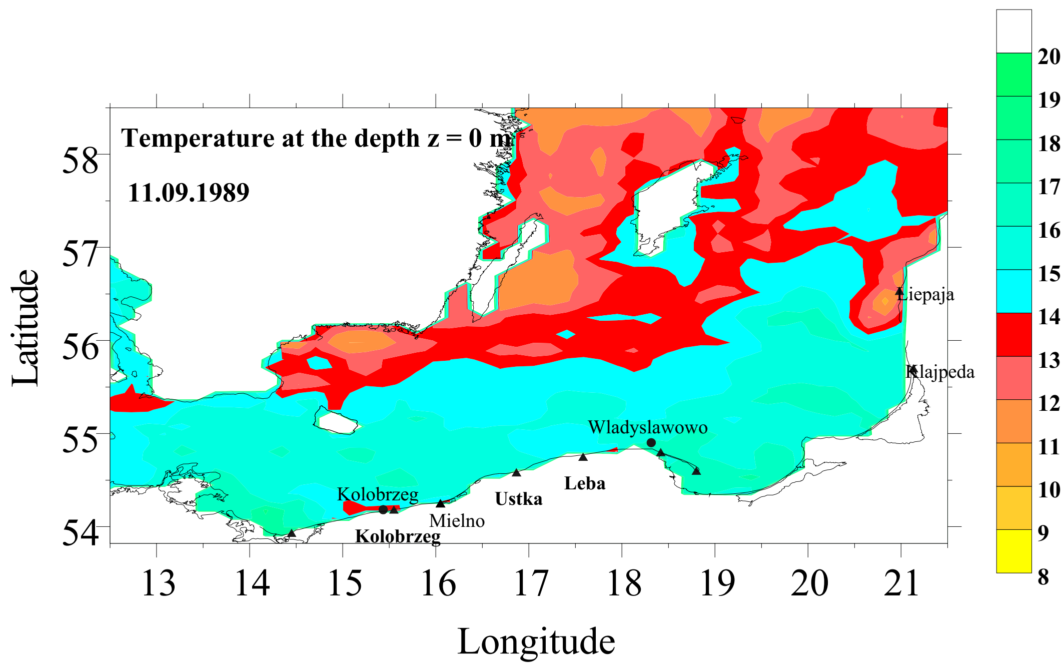

Fig. 4 continued c. - results on 11.09.1989 at 12:00

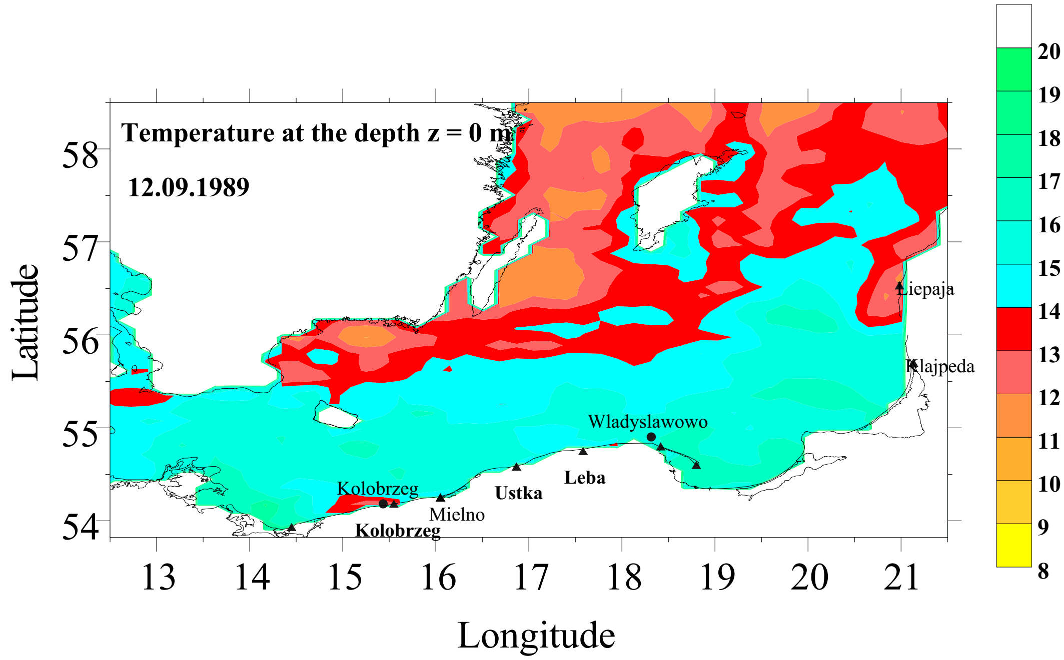

Fig. 4 continued d. - results on 12.09.1989 at 12:00

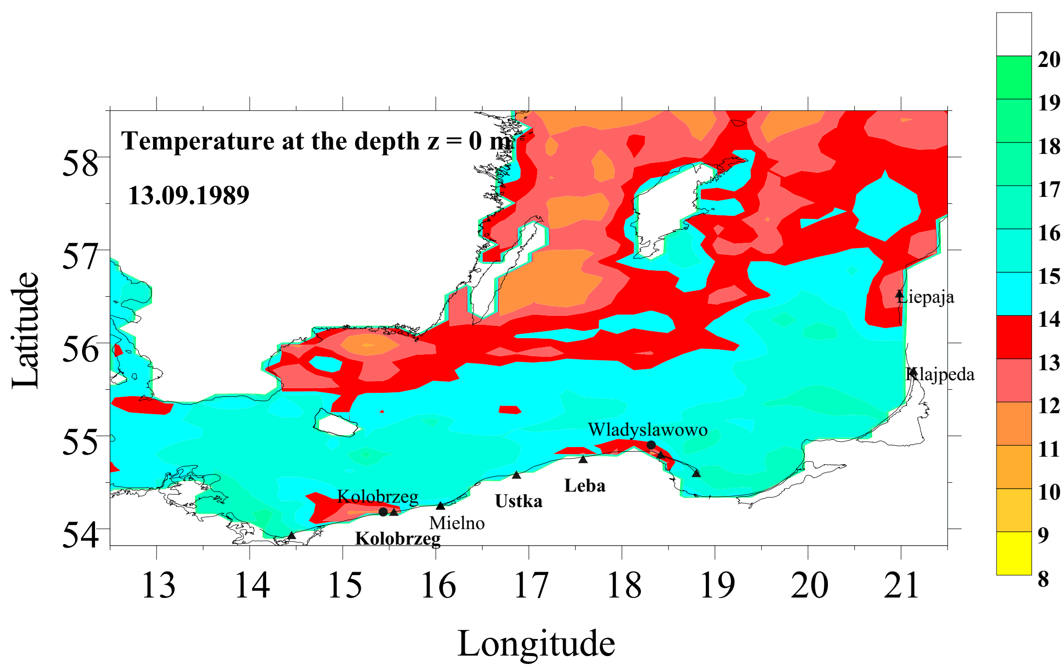

Fig. 4 continued e. results: on 13.09.1989 at 12:00

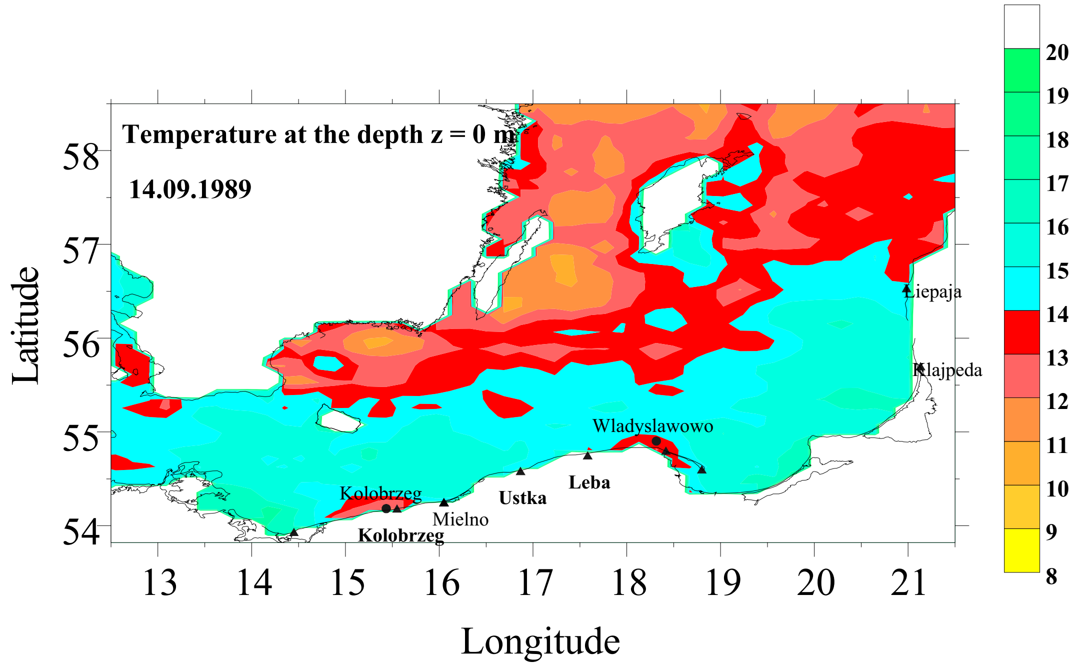

Fig. 4 continued f. results: on 14.09.1989 at 12:00

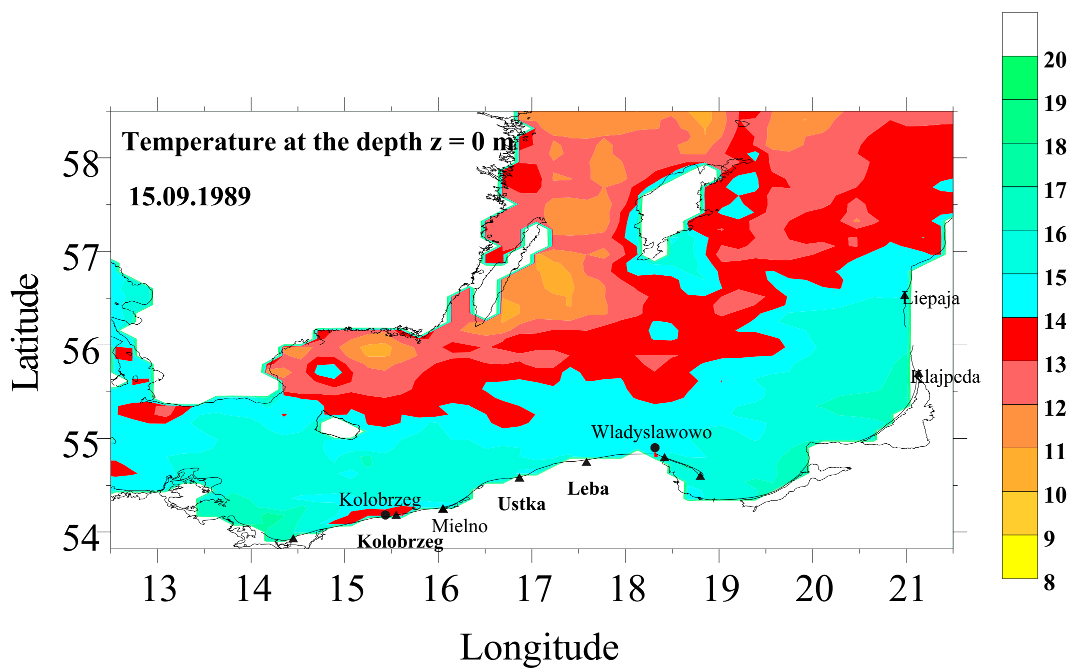

Fig. 4 continued g. results: on 15.09.1989 at 12:00

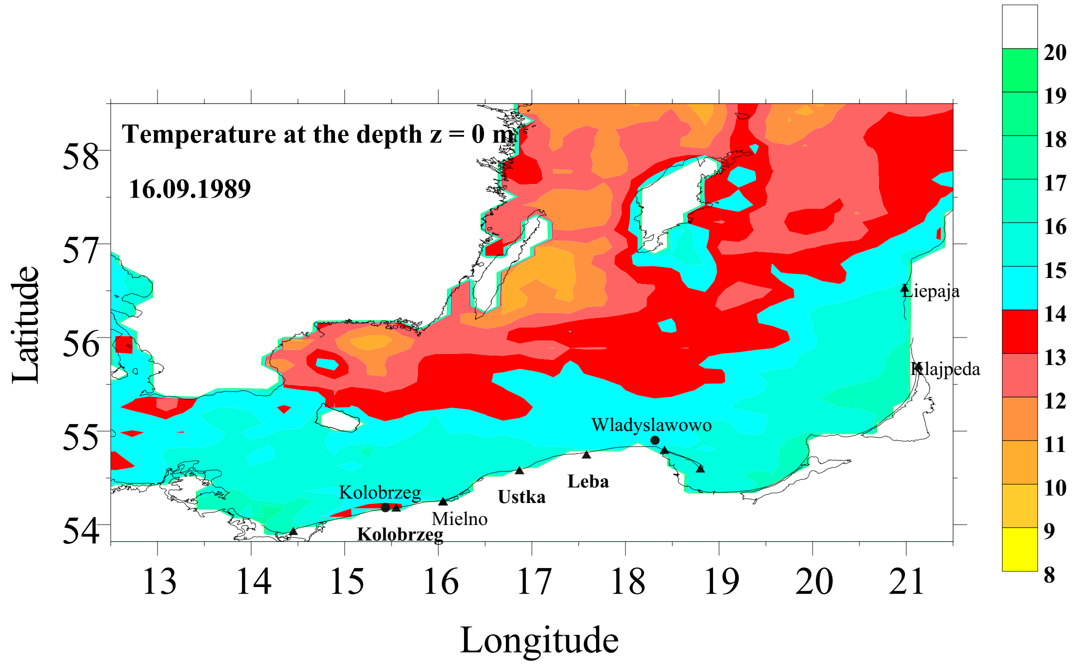

Fig. 4 continued h. results: on 16.09.1989 at 12:00

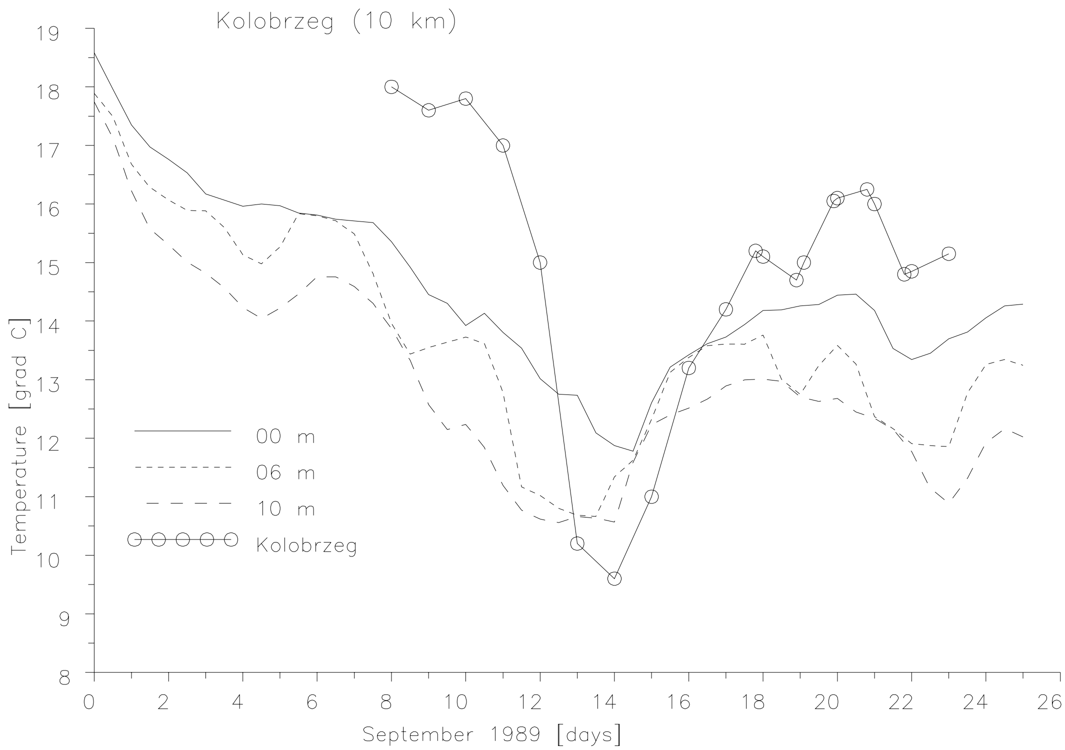

Fig. 5 Time evolution of sea temperature [^{o}C] at selected depth in the numerical grid point near Kołobrzeg calculated by the model (horizontal space steps of numerical grid ∼ 10 km). In figure the observed time evolution of sea surface layer temperature at station: Kołobrzeg taken from (Malicki and Miętus, 1994) was also depicted (cf. Fig. 1). Location of point - see Fig. 2.

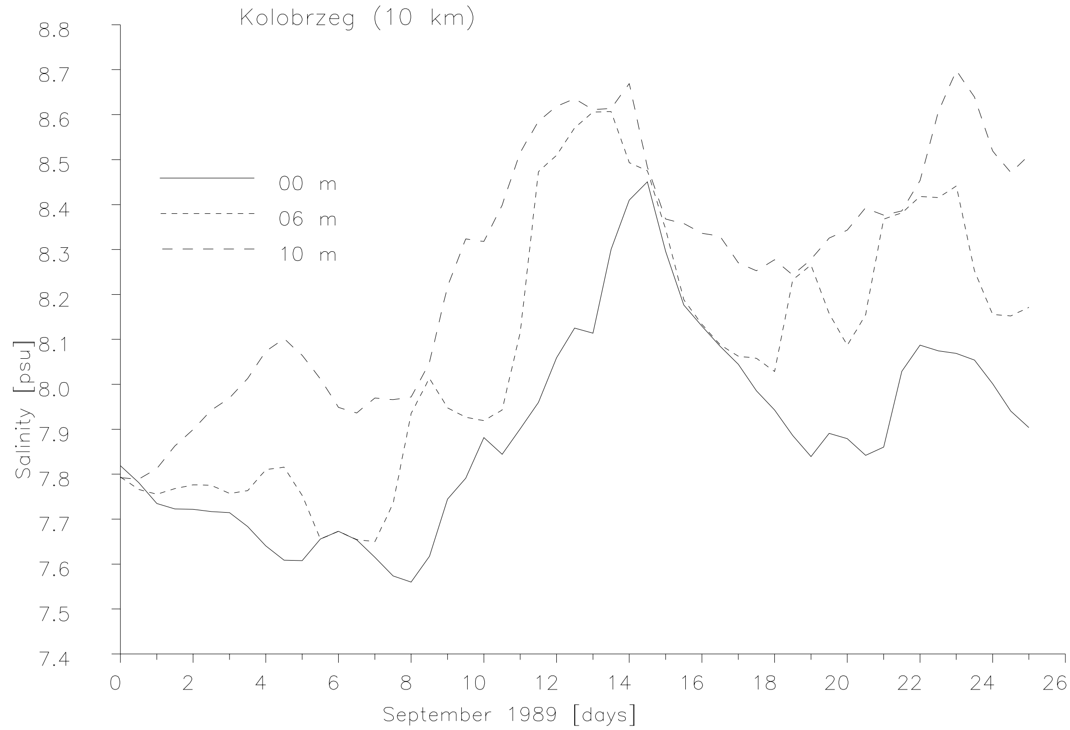

Fig. 6 Time evolution of sea water salinity [psu] at selected depth in the numerical grid point near Kołobrzeg calculated by the model (horizontal space steps of numerical grid $\sim$ 10 km). Location of point - see Fig. 2.

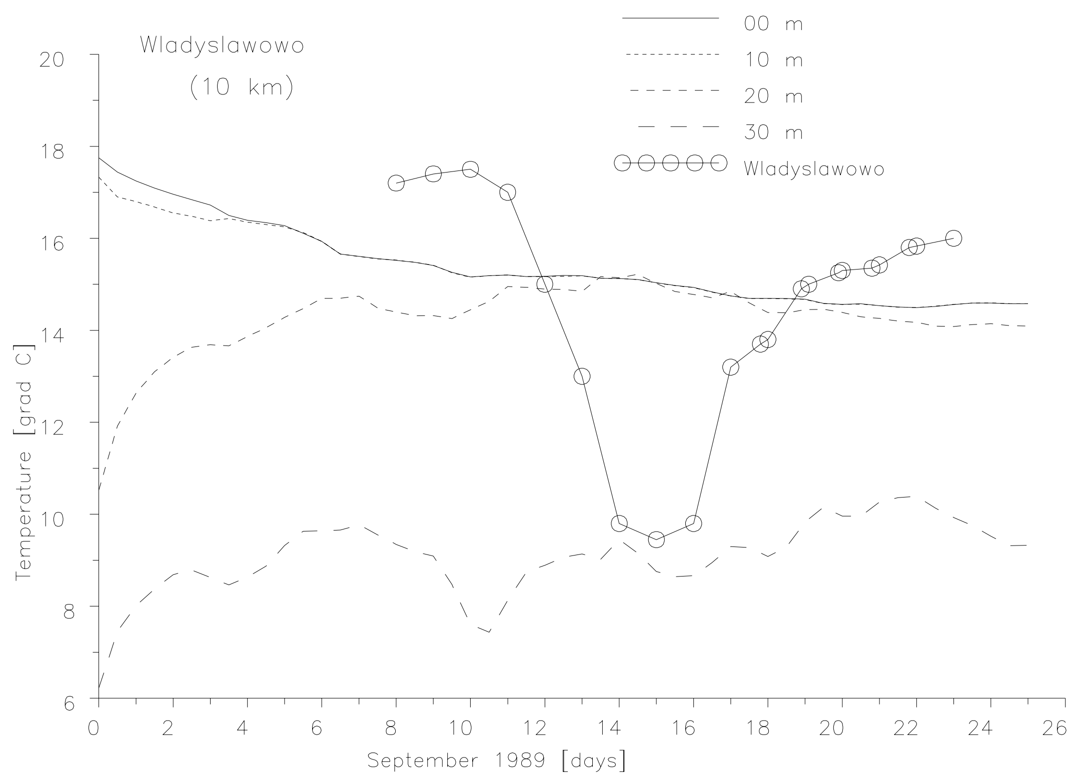

Fig. 7 Time evolution of sea temperature [^{o}C] at selected depth in the numerical grid point near Władysławowo calculated by the model (horizontal space steps of numerical grid $\sim$ 10 km). In figure the observed

time evolution of sea surface layer temperature at station: Kołobrzeg taken from (Malicki and Miętus, 1994) was also depicted (cf. Fig. 1). Location of point - see Fig. 2.

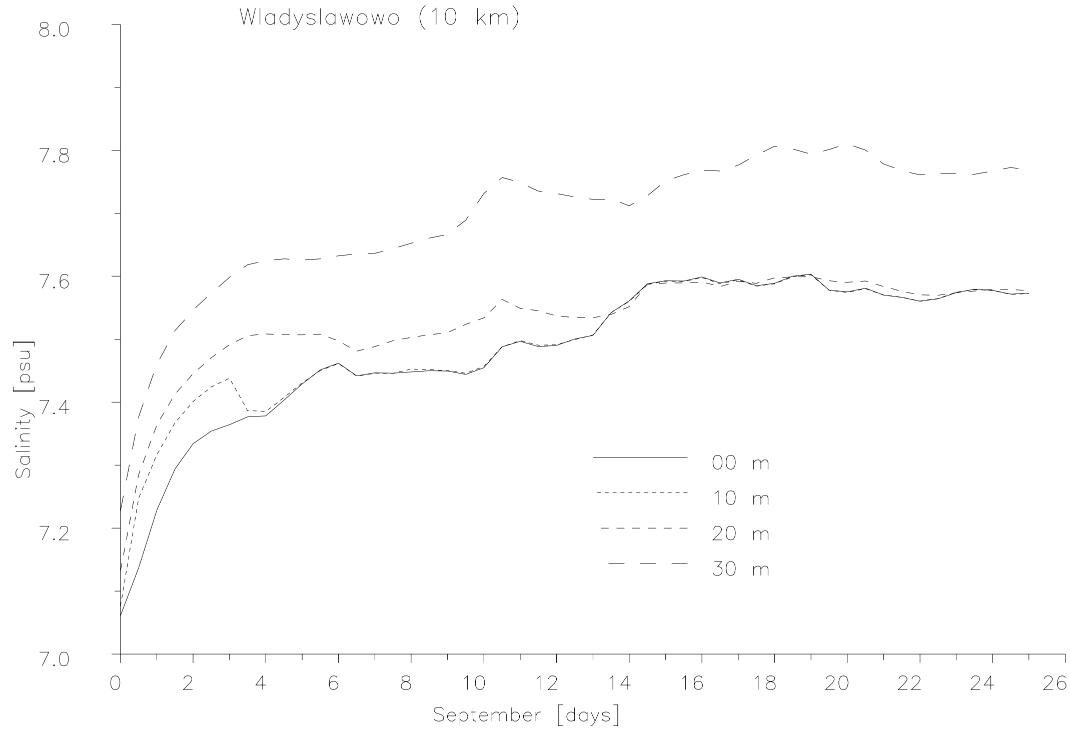

Fig. 8 Time evolution of sea water salinity [psu] at selected depth in the numerical grid point near Władysławowo calculated by the model (horizontal space steps of numerical grid ∼ 10 km). Location of point - see Fig. 2.

FINAL REMARKS

The results of simulation are in good agreement with the observed time evolution of the sea surface temperature only in the case of the station Kołobrzeg. At the station Władyslawowo, situated near the Hel Penisula, which is absent on model grid with horizontal space steps of numerical grid ~ 10 km the discrepances between the model and observed data are very large. In model results the strong fall of temperature is absent. The results of calculations with model version with horizontal space steps of numerical grid ~ 5 km gave more resonable results for this station. These will be ready to depict in short time.

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