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Diffusion one-dimensional model of methane fluxes at the Black Sea shelf

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Introduction. As it is known, previous investigations of methane cycling in the Black Sea have shown that this cycle predominantly driven by methane microbial production into the bottom sediments under favourable reducing conditions and microbial oxidation in the water column. So, both microbial oxidation and emission to the atmosphere represents the major sinks of methane. Moreover, in the Black Sea predominantly at the margin of NW shelf numerous methane gas seeps were discovered. Obviously that the bubbles methane streams will provide additional methane incoming in the water column by dissolution of gas bubbles and additional atmospheric evasion.

Modern estimations of the methane flux to the atmosphere bases on the Fick's law. The equation of this law includes so-called transfer velocity as parameter which can be calculated from wind speed, water temperature and salinity data using empirical formulae. Unfortunately, results of calculations according to transfer velocity models can differ approximately twice. Besides, at the gas seeps sites, methane concentration in the near-surface atmosphere will be caused both emissions of dissolved methane and gas bubbles, which reach a sea surface.

The present work is an attempt to get the answers to two questions. What time is necessary for an establishment of observed (stationary) vertical distribution of methane in the water column in case of sources-sinks variability? What methane flux to the atmosphere should supported of observed methane vertical distribution at the gas seeps sites in possible range of sources-sinks variability?

Description of the model. To modelling of methane fluxes we used unsteady-state diffusive one-dimensional equation which described of methane concentration profile in the water column with spatially-variables (distributed) source (dissolution of bubbles methane) and sink (methane oxidation) and with vertical turbulent mixing coefficient

which depended only to spatial variable. Boundary conditions at the sea bottom and at the sea surface have been determined as flux of methane to the atmosphere and as flux of methane from the sea bottom to the water column (difference between methane production and methane oxidation into the bottom sediments). Balance of the dissolved methane in the water column also has been controlled. Numerical solution of the diffusive equation carried out by algorithm with stable and conservative difference scheme.

Sources of data. Per previous years the methane cycling at the NW Black Sea has been investigated during of the EU funded EROS project (1995-1997). Published data of this project (fluxes of the dissolved methane from the sea bottom to the water column, methane oxidation profiles in the water column, fluxes of the dissolved methane to the atmosphere, profiles of dissolved methane in the water column) were used to evolution of the presented model.

The profile of methane emission to the water column from the gas bubbles stream was calculated by bubbles model based on the Fick's first law of diffusion.

In the summer the Black Sea hydrological structure of water column consists of thin surface mixed layer situated at the depths approximately 0-20 m, the seasonal thermocline with significant density gradients caused in temperature situated at the depths approximately 20-40 m and the halocline (permanent pycnocline) with significant density gradients caused in salinity situated at the depths 50-150 m. Such sharp stratification inhibits vertical water mixing and is the main reason of the anoxic conditions below 100-150 m. It is widely accepted that the intensity of turbulent mixing in the stratified layer is closely related to the density gradient. In the surface mixed layer turbulent mixing is closely related to the wind velocity. The profiles of vertical turbulent mixing coefficients were calculated from CTD-data for density-stratified layer and from wind velocity data for surface mixed layer. CTD and wind data were collected in the summer during cruises of R/V "Professor Vodianitskiy" which carried out in the framework of EU funded project CRIMEA in 2003 and 2004 in the open parts of the NW Black Sea shelf.

Keywords: the Black Sea, methane fluxes, mathematical modelling.