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Residual Tidal Circulation in the Keret Bay, White Sea

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Tidal sea level oscillations and currents can be described in a harmonic approximation. In this case, averaging over time of tidal oscillations should lead to almost zero result. But in reality, the due to nonlinear effects the residual tidal currents are appear. These currents form residual tidal circulation, which is inherent in the White Sea. The residual tidal circulation in real sea was investigated for the first time by V. V. Timonov (Timonov, 1960). He proposed the explanation of phenomena and introduced term «secondary tidal currents». Following investigations were carried out using numerical simulations because of the experimental difficulty to extract residual tidal currents from in situ current measurements.

We have investigated tides in Keret Bay for many years using complex approach, including analysis of in situ measurements (Smagin et. all, 2009; Ionov et. all, 2013; Ionov et. all, 2016), remote sensing (Krylov, 2014)., and results of numerical simulations (Ionov et. all, 2015). Model of Keret Bay with spatial step of 33 describes sea water dynamics quite well: the correlation coefficient between the modeled sea level and the measurements is up to 1, and the correlation coefficient between the simulated and observed currents equals to 0.9. The root-mean-square error (RMSE) is 2 times smaller than permissible error, both for sea level and currents (Ionov, et. all, 2015).

The analysis of measurements and model results shows that sea level oscillations occurs over all area synchronically. The parameters of the tidal ellipses of 16 constituents were calculated using the harmonic analysis. It was found that for a period of one month the maximal velocities of tidal currents (up to 80 cm/s) were observed in narrow and shallow parts of Podpakhta Strait. In the Keret Bay the maximal velocities of tidal currents exceed 30 cm/s at narrow places of Srednyaya Salma and Uzkaya Salma straits. Tidal currents have basically reverse character. Measurements show that tidal currents have reversing type, and significant impact of nonlinear shallow-water tidal harmonics. Semidiurnal tidal currents turn synchronously in the both straits. The phase differences between tidal sea level fluctuations and tidal currents correspond to standing semidiurnal tidal wave (Ionov, et. all, 2016). In case of Keret Strait, the inter-tidal zones areas and their temporal variabilities are calculated by numerical model.

With help of numerical simulations were found several interested features. There are three residual cyclonic gyres: in Podpakhta Strait, Lebyazya Bay and in the central part of the Keret Bay. There are residual currents with speed more than 5 cm/s in the north part of Lebyazya Bay and in the east part of Podpakhta Strait. In the Keret Bay residual currents is about 1-2 cm/s, in the north part raises up to 3 cm/s. It was shown that currents from Podpahta Bay should affect on the residual currents in Keret Strait. Special fieldwork was carried out to measure in situ currents speed at different depth in 2015-2016. Obtained results were very similar to numerical model simulations, especially for residual tidal circulation.

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