SATELLITE ALTIMETRY OF GORKY AND RYBINSK WATER RESERVOIRS ON THE VOLGA RIVER

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ABSTRACT

Gorky (1591 km^2) and Rybinsk (4580 km^2) water reservoirs on the Volga River in Russia were formed by Gorky (today Nizhny Novgorod) and Rybinsk Hydroelectric Stations dams. Gorky Reservoir is a long (430 km) and narrow (max 16 km) water body located right after the dam of Rybinsk downstream of the Volga River. Both play a very important role in water resources, hydroelectric power production, river transport, ecological state and local climate of the Tver, Vologda, Yaroslavl, Kostroma, Ivanovo, and Nizhny Novgorod Districts. Average depth of Rybinsk Reservoir is of 5.6 m (max. 28 m) and that of Gorky Reservoir – 3.6 m (max. 22 m), thus a permanent control of their depths is of great importance for many reasons.

Standard altimetry data processing (or Ocean-1 retracking algorithm) developed for the open ocean conditions can be inapplicable for the case of inland water bodies, especially for narrow elongated lakes, artificial water reservoirs and rivers, where the distance between shores is less than 5-10 km. These conditions are typical, for example, for the majority of reservoirs on the Volga River. Under these conditions only a few altimetry telemetric impulses fits the validity criteria, which cause a significant loss of data. Besides, errors in the water level retrieved from the altimetry measurements are enormous, as it was demonstrated on the basis of comparison of *in-situ* measurements at hydro-gauging stations for the water level of Gorky and Rybinsk Reservoirs on the Volga River and all available along track 10Hz TOPEX/Poseidon altimetry data and 20Hz Jason altimetry data over the reservoirs areas.

The problem of minimization of the errors was solved by retracking procedure. For justification of the optimal retracking algorithm the average impulse response of the statistically inhomogeneous surface were calculated theoretically based on the works of Brown (1977) and Barrick and Lipa (1985) for the model of the terrain in the

vicinity of Gorky and Rybinsk Reservoirs. The model represents the main typical features of the waveform examples (e.g., high peaks or irregular complex shape). The modeled waveforms are in good agreement with the Jason-1,2 waveforms for the same area. Data analysis showed, that for Gorky Reservoir an average significant wave height (SWH) was less than 0.3 m (corresponding to the width of the leading edge less than 1 telemetric gate). Since the meaningful value for monitoring of water level in inland waters is variations of the water level from the averaged, the retracking algorithm based on the detection of the beginning of the leading edge is preferable under these conditions.

The same methodology was applied for Rybinsk Reservoir. Two algorithms of waveform re-tracking valid for the coastal zone typical for Rybinsk Reservoir were suggested, including the threshold and improved threshold algorithms. These algorithms provided a refinement of the tracking point and estimating water level by solving the optimization problem. Application of the algorithms increases significantly the number of valid data and the accuracy of the water level retrieving from the altimetry in the coastal zones.

Comparison of Jason-1 and Jason-2 altimetry data with *in-situ* measurements at hydro-gauging stations for the water level of Gorky and Rybinsk Reservoirs shows that retracking significantly increases the number of data involved in the monitoring and significantly rises accuracy of altimetry measurements. General principles of retracking algorithms for complex area (land, coastal zone, inland waters, etc), based on the calculation of the waveform taking into account statistical inhomogeneity of the reflecting surface adjusted to a certain geographic region, are discussed.

Satellite monitoring of water reservoirs and lakes is of great importance for water resources management in the countries located in arid zones especially now when significant changes in regional climate are observed.

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