Geophysical Research Abstracts
Vol. 19, EGU2017-9128, 2017
EGU General Assembly 2017
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Application of the satellite system of the earth's gravity field measurement (GRACE) for the evaluation of water balance in large Russian river catchments

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Space-based Earth observing systems provided a substantially large amount of information to the scientific community in recent decades. Cumulative effects of redistribution of masses in the Earth system can be seen in the changes of the gravity field of the Earth. Gravity Recovery and Climate Experiment (GRACE) satellites, launched 17.03.2002 from Plesetsk, provide a set of monthly Earth's gravity field observations. GRACE data is very useful for hydrological and climatological studies, especially over large territory, not completely covered by the meteorological and hydrological networks, like Russia. Possible application of the satellite gravity survey data obtained under the GRACE for solving various hydrological problems is discussed. The GRACE-based monthly gravity field data are transformed into the maps of water level equivalent and averaged for the catchments of the largest rivers of Russia. The temporal variability of the parameter is analyzed. Possible application of the GRACE data for the evaluation of particular components of water balance within the largest river basins of the European part of Russia is discussed. After averaging over 15 large Russian rivers basins annual component shows amplitude increase since 2009. Trend component grows until 2009 and then reaches a plateau. It is mostly dominated by Siberian rivers. Map for the trend show gravity field increase in Siberia, at Back Sea and decrease over Caspian Sea since 2003.

GRACE satellite gravimetry data can be used for estimating terrestrial water storage (TWS) in a river basin scale. Terrestrial water storage (TWS) is the integrated sum of all basin storages (surface water bodies, soil and ground aquifer, snowpack and glaciers) and the ability to estimate TWS dynamics is useful for understanding the basin's water cycle, its interconnection with the local climate, physics of predictability of extreme hydrological events. Despite the importance of the TWS estimates, reliable ground-based monitoring data of all TWS components are scarce or absent at all. Since observations are not sufficient to monitor TWS, hydrological models are considered as a comprehensive tool to simulate TWS components at a basin scale. However accuracy of the model-derived TWS is influenced by the uncertainty of the model structure and parameters, reliability of input data, etc. To improve the TWS-estimates, it is reasonable to combine the simulated TWS with independent observations provided by the GRACE gravity data.

Ninety-seven monthly TWS retrieval from GRACE data (from April 2002 to December 2009) was examined and compared with TWS-estimates obtained by the ECOMAG hydrological model simulations. The case study was carried out for the Northern Dvina River basin. Quantitative analyze between the hydrological model and GRACE-based TWS showed that latter is in good consistency with the simulation results on both seasonal and inter-annual time scales. Overall, the results highlight the benefit of assimilating GRACE data for hydrological applications, particularly in data-sparse regions, while also providing insight on future refinements of the methodology of GRACE-data application in watershed hydrology.

The study is financially supported by the Russian Foundation for Basic Research (Proj.№ 16-35-60080; 16-05-00753) and the Russian Science Foundation (Grant No. 14-17-00155).