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Changing hydrology of the Aral Sea: Results from satellite altimetry, GRACE satellite gravimetry and hydrological modeling

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Water is an indispensable good for human life. The most accessible form for human consumption is storage in surface reservoirs and lakes. This paper addresses the Aral Sea that has been shrinking significantly over the last decades due to water overexploitation in this region. In our study we analyse the observations of satellite altimetry and satellite gravimetry in order to quantify the changes of water level and water mass. The results are compared with hydrological simulations performed with the global WaterGAP Hydrological Model (WGHM). The Aral Sea was one of the biggest lakes worldwide until the 1960s, but reckless exploitation and diversion of the primary tributaries Amu Darya and Syr Darya for agricultural purposes led to an irreversible change in the ecosystem of the region (UNEP 2003).

The lack of a ground-based observation network for comprehensive assessment of water storage change in that region was a constraint for the quantification of this disaster over a long period. Nowadays, modern methods of satellite remote sensing allow for the observation of the environmental changes.

Satellite altimetry enables the determination of the lake surface and thus the advancing desiccation. In our study we apply multi-mission altimetry data from TOPEX/Poseidon, Jason 1 and 2, and Envisat from 1992 until 2010 with a temporal resolution of a few days in order to estimate the lake level change. The results show that the Eastern Aral basin which in 1992 was the largest sub-part of the Aral Sea suffered the most rapid and significant decline in water level, culminating in almost drying-out in 2009.

The substantial loss of water mass in the region of the Aral Sea also leads to variations of the gravity field which can be identified in the observations of the GRACE satellite gravity field mission. Being in orbit since 2002, GRACE provides a unique data source for the quantification of spatio-temporal variations of the continental water storage. In our study we apply different algorithms based on global and regional mathematical base functions in order to analyse the observations of GRACE with respect to water mass changes in the region.

Finally the variations of water level and water storage for the Aral Sea estimated from space observations are compared with the output of the WGHM global hydrology model. WGHM has a spatial resolution of 0.5 degree and a computation time step of one day. The model is driven by climate data on precipitation, air temperature and radiation from different data sources. The contribution will be concluded by a discussion of the concordance of the results, existing deficits in data analysis and modeling, and prospects for improvements.