Heterogeneous data sets from different Earth observation satellites are applied for the estimation of water storage variations in continental hydrology. A specific focus of the study is put on the analysis of signals in the regime of surface water (rivers and lakes) that are related to long-term environmental changes and extreme weather situations, e.g. flood and drought. In particular the study aims at the combined analysis of geometrical and gravimetrical space observation systems for an improved understanding of dynamical processes in the global water cycle. Most global Earth observation systems deliver integral signals that are influenced by a multitude of different processes. The dedicated satellite gravity field mission GRACE, for example, has demonstrated its capability for the observation of water mass variations in continental hydrology. However, from GRACE observations alone the contributions of particular hydrological storage compartments (e.g. surface water, ground water, soil moisture or snow) cannot be quantified. The combination of various sensors with different sensitivity for individual effects can be beneficial for the separation of such integral signals into individual contributors and consequently lead to a deeper insight into dynamic processes and their interactions.

The key issue of the thesis is the development of a multi-sensor approach for the quantification and advanced analysis of storage variations in the hydrological compartment of surface water. Temporal changes of the surface extent and height
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of large water bodies can be computed from optical/radar remote sensing data and multi-mission satellite altimetry. Water volume changes can be obtained from a geometrical intersection of observed water extents and levels with a digital elevation model as well as from satellite-based estimates of mass variations observed by GRACE. As major test case for the combined analysis of the heterogeneous observation systems the region of the Aral Sea has been chosen that is characterised by ongoing large-scale hydrological changes since several decades. The thesis will provide a comprehensive analysis of the consistency of heterogeneous data sets and a conclusion with respect to their applicability in the frame of advanced studies of hydrological processes.

A generally good agreement between observed mass variations from GRACE and lake water volume variations has been found (Fig 1). GRACE features a much more pronounced inter-annual signal, but the long-term characteristics of gravimetric and geometrical data are very similar. Hence, water storage in the Aral Sea turned out to be a strong contributor to the long-term mass change observed by GRACE. However there are also significant contributions from other mass signals in the area surrounding the lake. The comparison of geometrically based volume estimates with GRACE mass changes provides a promising means to analyse and separate the GRACE signals and – in turn – to estimate mass change signals in other hydrological compartments such as ground water. The combination of multi-satellite data proved to be effective in a comprehensive analysis of the hydrological condition of a region which otherwise is very poorly monitored by in-situ observations. Future work will comprise the analysis of the residual GRACE signal with respect to its consistency with soil moisture, snow and ground-water changes from observations and hydrological models.

Fig. 1: Left: Volume change in [km³/year] of the Aral Sea resulting from GRACE and the geometrical approach; Right: Respective composite seasonal cycles of lake water storage.

References

Stand: 17.02.2017