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Hydrologic responses to climatic changes and irrigation expansion within the Aral Sea basin

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Quantitative understanding of the Aral Sea's water budget and its dynamics is not straightforward because the magnitude of groundwater discharge into the sea is very uncertain. From a catchment-scale water balance perspective, groundwater recharge may be approximately estimated by closing the water balance equation and treating the groundwater term as a fitting parameter. However, then the predicted groundwater flow can be considerably affected by the estimated evapotranspiration, which is also uncertain due to measurement difficulties. Furthermore, in the specific case of the Aral Sea, evapotranspiration and groundwater recharge may have changed considerably in the past decades, due to the enormous expansion of irrigation in the region. We here aim at quantifying changes in total discharge into the Aral Sea by using GIS-based, basin scale hydrological modeling. Aral Sea catchments are delineated based on elevation data. This allows us to quantify unmonitored discharges as well as Amu Darya and Syr Darya river runoff. Then we investigate how the hydrological system has responded to the observed climatic changes and anthropogenic activities, through scenario analyses. From observed temperature and precipitation data, we reproduce representative hydrological conditions in the beginning of the last century, before the intensive irrigation started, and in the end of the last century, after a considerable Aral Sea shrinkage. The impact of anthropogenic activities is considered by adding an irrigation unit to the model. Our model results reveal physically different characteristics between Amu Darya and Syr Darya catchments, and comparisons of model scenarios show considerably increased evapotranspiration within the basin, suggesting that most of the irrigation water does not add to groundwater flows.