EGU2020-10055, updated on 28 Jan 2021
https://doi.org/10.5194/egusphere-egu2020-10055
EGU General Assembly 2020

Water cycle changes in the headwater regions of the Yangtze River and Yellow River basins during the past three decades

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Yangtze River and Yellow River are the two most important rivers in China. Long-term observation shows that runoff ratio (i.e., runoff/precipitation, denoted as RR) in the headwater of both Yangtze River (HYZR) and Yellow River (HYER) has experienced significant decrease and then increase trend (referred as V-change) during the period 1980-2015. Over the whole period, RR of the HYER shows significant decreasing trend (-0.02/10a, $p < 0.05$), while it is not significant for the HYZR. Changes in RR in both HYZR and HYER pose great challenge on runoff predication and water management in the downstream. However, driven mechanisms underlying the V-change of RR are still unclear. Here, based on ground-based and remote sensing datasets, both terrestrial and atmospheric water budgets are investigated to understand the evolution of RR in the headwater regions of Yangtze River and Yellow River. Terrestrial water budgets are for evaporation estimation and water cycle analysis. Atmospheric water budgets are used to calibrate the estimated evaporation. Results show that TWS-REC agrees well with observed total water storage (TWS-GRACE) in both HYZR ($r = 0.94$, NSE = 0.83) and HYER ($r = 0.93$, NSE = 0.83) over the period of 2003-2012. Estimated evaporation from both terrestrial water balance and atmospheric water balance method also agree well with each other in the HYZR ($r = 0.89$, NSE = 0.80) and in the HYER ($r = 0.88$, NSE = 0.79) over the period of 2000-2015. It suggests that reconstructed TWS and estimated evaporation are reliable for analyzing long-term water cycle in the study areas. Both the ratio of the estimated evaporation to precipitation (ER) in two basin increase first and then decreased during the study period. The correlation coefficients between ER and RR in the HYZR and HYER are -0.63 and -0.79, respectively, presenting that RR variability could be mainly caused by the evolution ER. Meanwhile it also indicates the nonignored role of total water storage (TWS) changes in RR variability in the two basin. TWS-REC in both regions have experienced significant increasing with rate of 26 mm/10a (HYZR, $p < 0.05$) and 17mm/10a (HYER, $p < 0.05$), later of which is the main reason of downward trend of RR in HYER. Further analysis indicates that changes in ER are resulted from comprehensive effects of precipitation variability (26.4mm/10a, $p < 0.05$ in HYZR and 3.5mm/10a $p > 0.1$ in HYER) and of dramatic climate warming (0.6□/10a, $p < 0.05$ in HYZR and 0.5□/10a, $p < 0.05$ in HYER). TWS changes in both basin are positively related with dramatic temperature rising and significant vegetation greening. It means that annual fluctuation of precipitation-runoff process (i.e., V-change RR) has affected negatively by climate warming and vegetation greening in the HYZR and HYER. These findings can advance our understanding of the runoff ratio evolution and water

cycle in the headwater of Yangtze River and Yellow River and it is also important for ecological conservation strategy and downstream water resources management.