DOCTORAL THESIS

How the regional water cycle responds to recent climate change in northwest aridzone of China ?

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Abstract

Climate change has posed significant challenges for the world's sustainable development, and the water cycle is highly dependent on the climate system. In particular, the arid zone fragile ecosystems in northwest China are highly vulnerable to the sophisticated hydrological variations. While ground-based measurements are less capable for large scale hydrological modelling, remote sensing techniques offer enhanced and effective alternatives for various hydrological states/fluxes. With the advancement of the Gravity Recovery and Climate Experiment (GRACE) satellites, the Terrestrial Water Storage (TWS), an integrative measurement of regional hydro-climatic environment, can now be measured as well for examining the overall hydrological response to recent climate change.

TWS is an essential element of the water cycle and a key state variable for land surface-atmosphere interaction. Investigating the TWS change is important for understanding the response of the water cycle to climate change. In this study, the intra-annual and inter-annual spatio-temporal change pattern of TWS in Xinjiang Uyghur Autonomous Region of China during 2003-2015 are characterized from Gravity Recovery and Climate Experiment (GRACE) Tellus data products. Sub-regional re-analysis reveals that the increasing/decreasing rate in sub-regions, namely, Altay Mountains (ATM), Junggar Basin (JGB), Tianshan

Mountains (TSM), Tarim Basin (TRB) and Kunlun Mountains (KLM), are -3.41mm, -5.82mm, -6.76mm, -2.59mm and +3.05mm per year in unit of equivalent water height (EWH), respectively. The results suggest that TWS variation presents certain spatio-temporal patterns with spatial heterogeneity. The uncertainties from different GRACE products are also assessed.

In conjunction with gridded meteorological data products and land surface model simulations of hydrological variables, the heterogeneous mechanisms of seasonal TWS change are analyzed. The correlation relationship among various hydrologic states/fluxes variables (e.g. snow water, soil water, snow amount) and climatic variables (e.g. temperature and precipitation) with GRACE-derived TWS variation in different sub-regions are investigated. The findings appear to indicate that 1) temperature month-over-month change and temperature anomaly with 4-month time lag, rather than precipitation, are more capable to explain the intra-annual TWS variation; 2) In most part of the study area, the TWS intra-annual change can be primarily attributed to the snow accumulation in winter and melt in spring.

On the other hand, the glacier mass variation, which is particularly sensitive to recent climate change, could be a substantial contributor to inter-annual TWS change. The elevation trends over glaciers are estimated based on ICESat altimetry measurements. Correlation analysis results suggest that, during 2003-2009, the inter-annual TWS loss in Tianshan Mountains (TSM) was tightly associated with glacier mass variation induced by temperature change, particularly

in summer. In contrast, TWS gain in Kunlun Mountains (KLM) can be attributed to glacier mass increase.

By utilizing remote sensing observation techniques/products, this study has characterized the spatio-temporal change pattern of TWS in northwest arid zone of China, as well as the underlying mechanism. It suggests that TWS is an effective indicator of regional climate change. This study contributes to a better understanding of the hydrologic and climatic processes in arid zone water cycle, and could be beneficial for regional water resources management and climate change adaptation effort.

Keywords: Water cycle, Terrestrial Water Storage (TWS), Gravity Recovery and Climate Experiment (GRACE), Climate change, Remote sensing, Arid zone

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