Assessing drought propagation from snow to groundwater under changing climate: application of SWAT-MODFLOW model in North Saskatchewan Watershed in western Canada

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In snow dominated regions such Canadian watersheds, snow storage is often contemplated as a principal water resource to both surface water and groundwater systems. Snow accumulation and groundwater resources are connected through soil-plant-water systems and within the hydrologic cycle. Various processes such as precipitation type (snow or rain), temperature, vegetation growth, evapotranspiration rates, runoff, and infiltration can define the extent of groundwater recharge and discharge, their rates, and their spatiotemporal dynamics. Snow accumulation, on the other hand, can be affected by changes in hydrological and meteorological factors. It can fall below the long-term average, causing snow accumulation deficiencies and snow droughts. Snow drought can also occur due to high-temperature-induced early snowmelt. Studies have shown that the increasing impacts of climate change will likely amplify hydrologic processes such as changes in snow, rain, melt and runoff, infiltration, and groundwater recharge, and as a result the feedback mechanisms between groundwater and surface water across time and space. Such changes can lead to consequent changes in how droughts propagate from snow to groundwater. Therefore, assessing spatiotemporal changes in drought propagation patterns from snow to groundwater and the mechanisms driving these changes becomes increasingly crucial, especially in mid-to-high latitude regions.

In this study we calibrated a process-based hydrologic model (i.e., SWAT) and a groundwater model (i.e., MODFLOW) of the North Saskatchewan River Basin, Alberta, Canada, using streamflow data and hydraulic head data for the period between 1980-2013. The coupled surface water-groundwater (SW-GW) model was applied to simulate snow accumulation/melt, and groundwater heads. Climate predictions from an ensemble of five Global Climate Models under two extreme projected socioeconomic conditions(i.e., SSP 126 and SSP 585) of the CMIP6 were implemented to project SW-GW changes for the 2040-2073 period. Due to projected changes in snowmelt infiltration, the interaction mechanisms between snow drought and groundwater drought are constrained in this study. The results of this study will determine how drought propagation will be regulated by eco-hydrological and climatic parameters under various climate change scenarios. The variation of snow and groundwater drought under different hydro-climatic, ecological, and geologic regions including mountains, foothills, and plains will be examined and the feedback mechanisms between snow and groundwater drought will be determined across a range of spatiotemporal scales.