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Driving processes of long-term large scale groundwater recharge in cold and humid climates

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Large scale and long-term estimates of groundwater recharge (GWR) are strategic for assessing the relative impacts of climate change and land cover (LC) change on groundwater resources. This is especially true in cold and humid climates where global change has a high disrupting potential. Therefore, this work aims to determine the driving processes of long-term and large-scale GWR in cold and humid climates. Using a parsimonious model, GWR was simulated in the cold and humid region of southern Quebec, Canada (35 800 km^2) over the past decades (1961-2017) and for potential future conditions (12 scenarios, 1951-2100). Constant and time-variant LC were used, with a monthly time step and a 500 m x 500 m spatial resolution. The datasets and model are open source. The simulated past and future results showed the importance of seasonality for GWR and the key role of annual temperature in the spatial distribution of GWR rates. They highlighted the high responsiveness of the cold and humid region hydrology to long-term interannual climate variability and the importance of simulating the snow and freezing processes when estimating GWR in these climates. In the future, warmer temperatures during the cold months (less precipitation as snow, earlier snowpack melting) led to more liquid water available when the vegetation was dormant, leading to higher GWR. Warmer temperatures during the rest of the year extended the growing period and increased plant water uptake, directly decreasing the water available for GWR. The direction of the annual changes in GWR thus depended on whether the increase during the cold months could offset the decrease during the rest of the year. The sensitivity of GWR to climate change increased with the increase in LC change intensity. The spatial distribution of LC changes was identified as another driver of GWR change as afforestation took place on agricultural areas, located on the flattest and clayey areas, thus reducing the GWR rates for forested area over time. This work called for a more systematic inclusion of LC changes in long-term groundwater resource simulation and proposes a computationally-affordable methodology to tackle it.