# Hydrological responses in a boreal forest basin to climate and land cover changes

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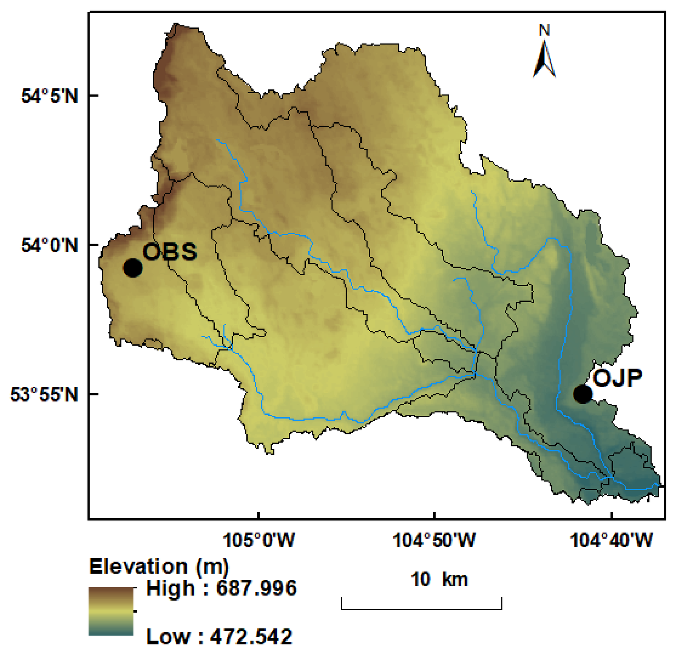
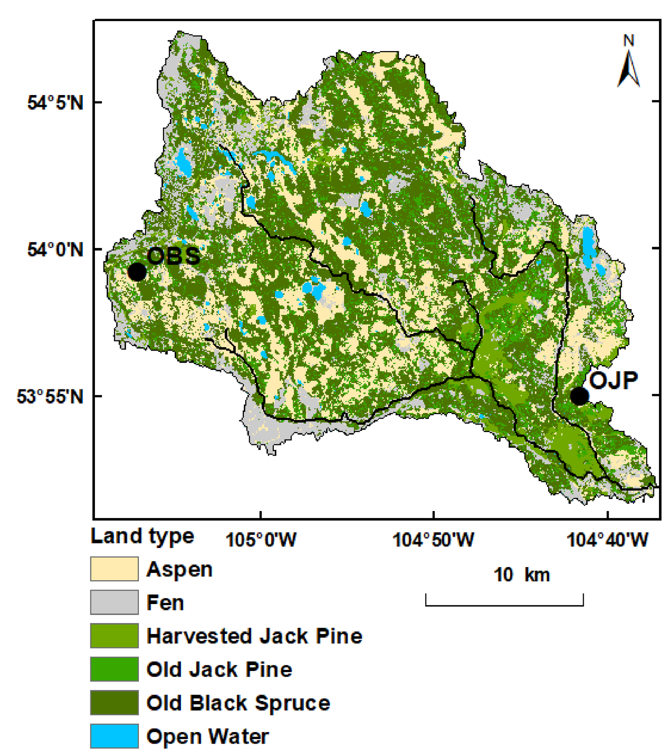
## Motivation

- Modeling the sensitivity of hydrological processes to the changes of precipitation and temperature, as well as the change of forest type, could improve the understanding of the dynamics of boreal forest hydrological behaviours under changing climates.

## Methodology

- The Cold Regions Hydrological Model (CRHM) was used to simulate snow interception and sublimation, sub-canopy energy balance snowmelt, infiltration, evapotranspiration and runoff processes over and through frozen and unfrozen ground in the boreal forest of Whitegull Creek Basin, Saskatchewan.
- The semi-distributed CRHM was set up based on six HRUs: Fen (15.8% ), Old black spruce (OBS 42.2%), Aspen (ASP, 22.8%), Old jack pine (OJP 11.1%), Harvested jack pine (HJP 5.4%) and Channel/open water (2.7%).

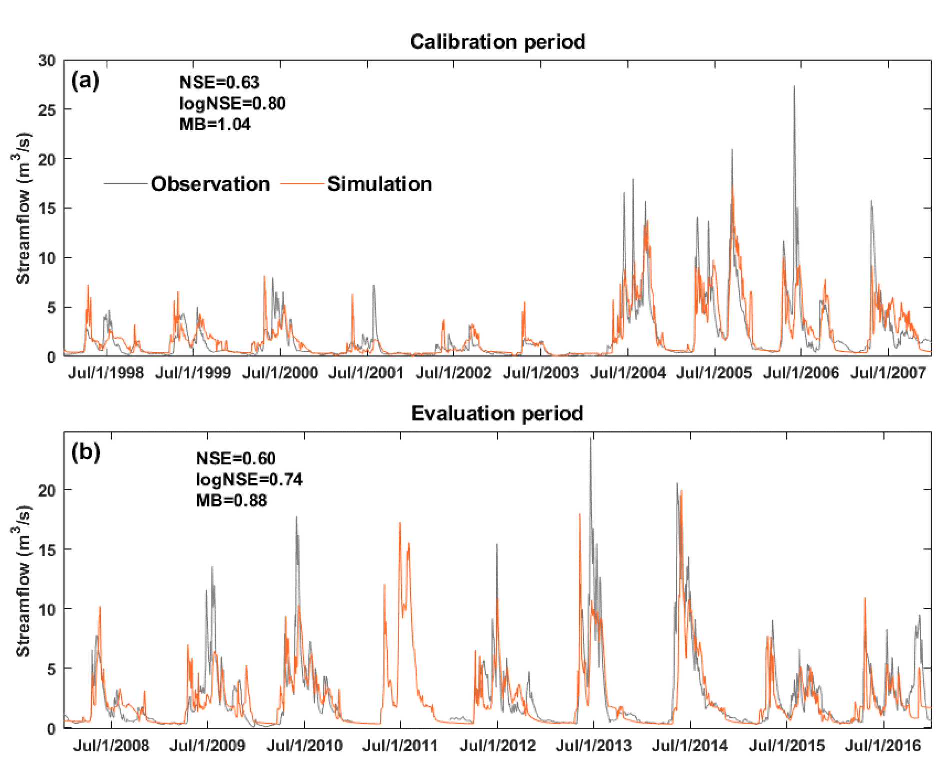


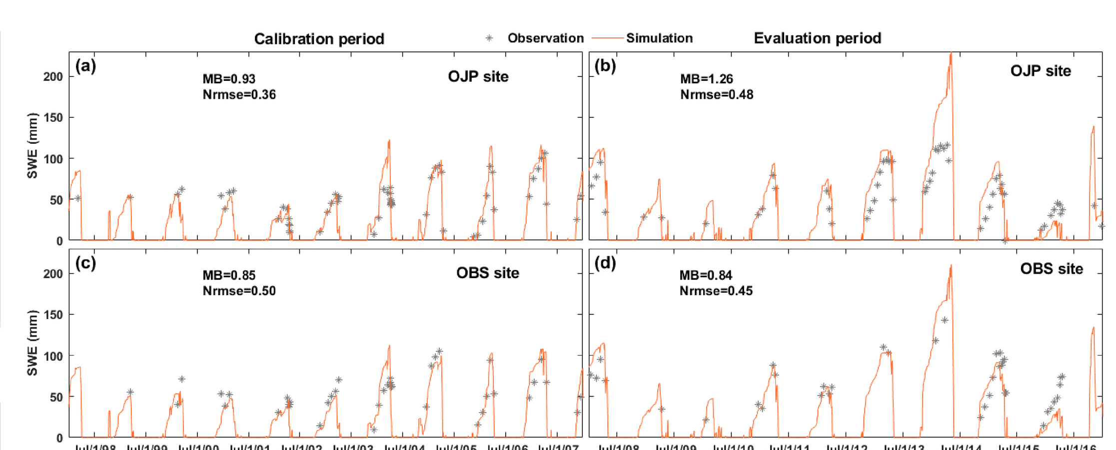



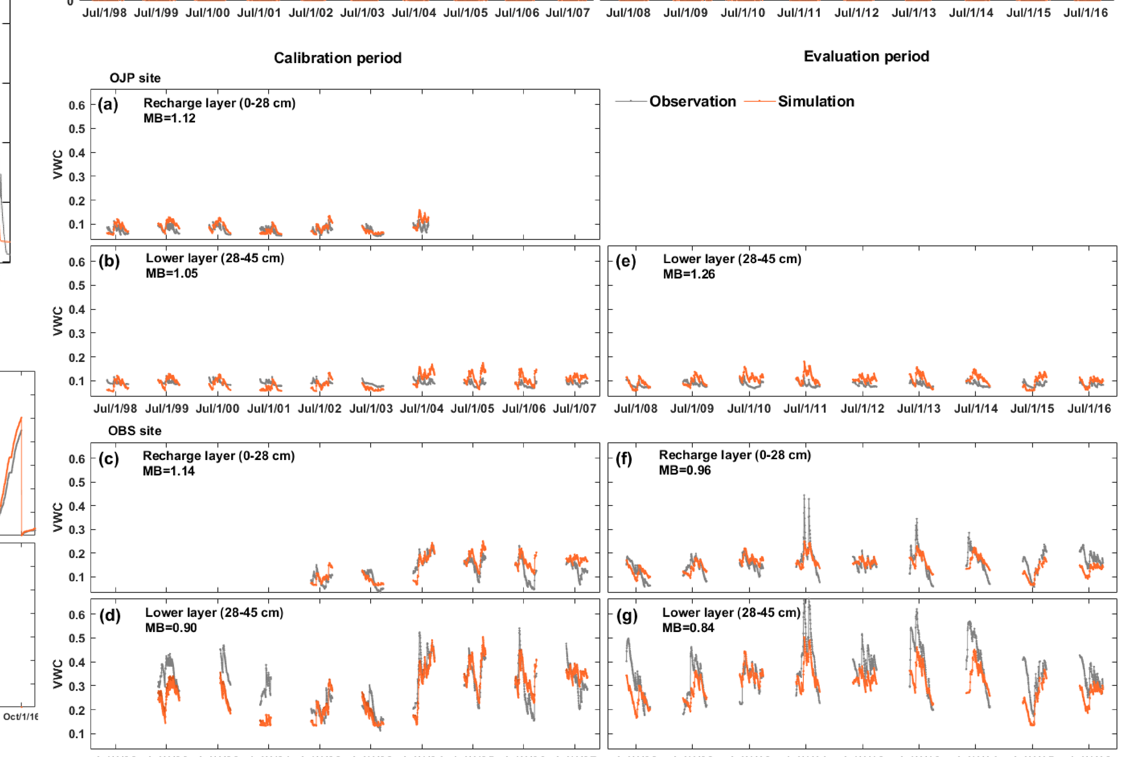

### Climate and land cover change scenarios:

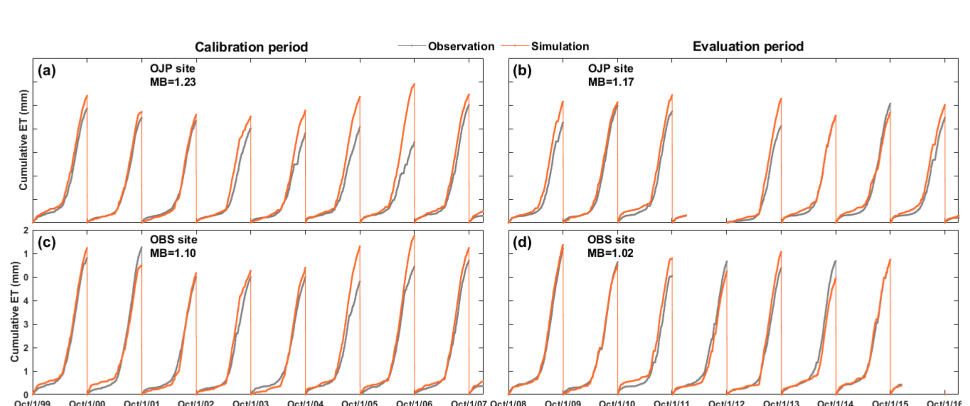
- Temperature change scenarios were set up by linear increments in perturbations of the reference observed temperature of up to +6 °C (Canada's Changing Climate Report 2019).
- Precipitation change scenarios were generated by multiplying the reference observed precipitation from 70% to 130% (Canada's Changing Climate Report 2019).
- The forest harvesting scenarios were designed by setting clear-cut of specific forest types in the hydrological model.

## Model performance for the simulation of multiple variables







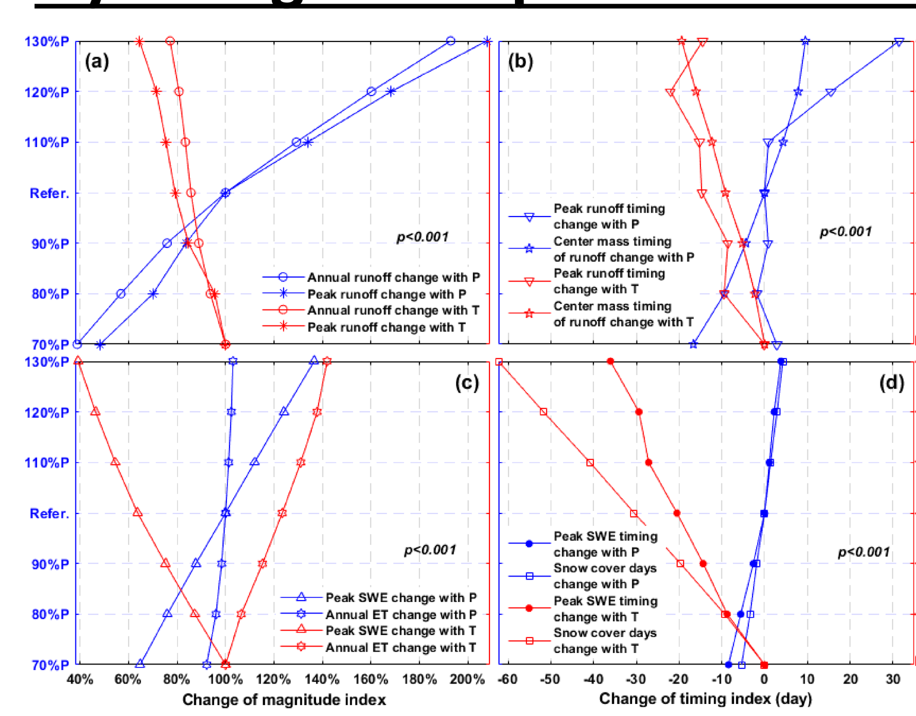
$$MB=\frac{\sum Sim}{\sum Obs} \quad Nrmse=\sqrt{\frac{\sum(sim^2-obs^2)}{n}}$$

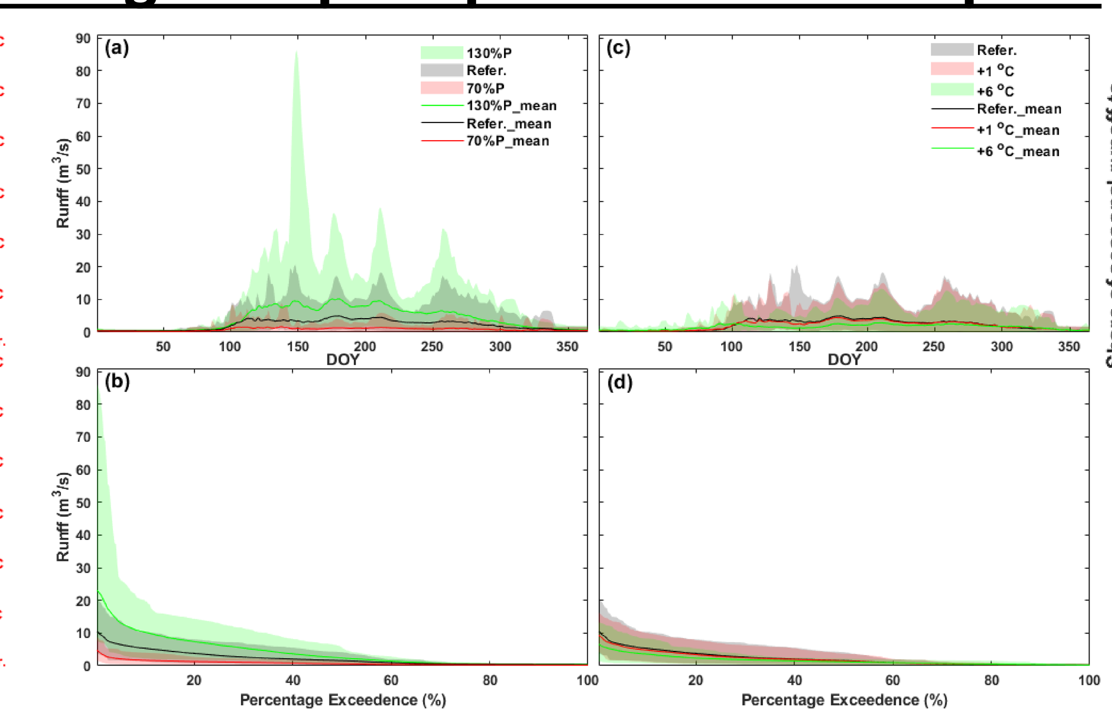
- CRHM generally produced good performance for the simulation of runoff, snow water equivalent (SWE), evapotranspiration (ET) and soil liquid volumetric water content (VWC).
- Model parameters describing snow processes, evapotranspiration, surface runoff generation and runoff routing were obtained from existing literatures and expert knowledge.
- Soil parameters, such as hydraulic conductivities and organic layer runoff factors, were slightly adjusted by the simulation of runoff in the calibration period;
- Calibration period is 1998-2006, and evaluation period is 2007-2016. Observed precipitation and temperature in the period of 1998-2016 were used as reference climate inputs.

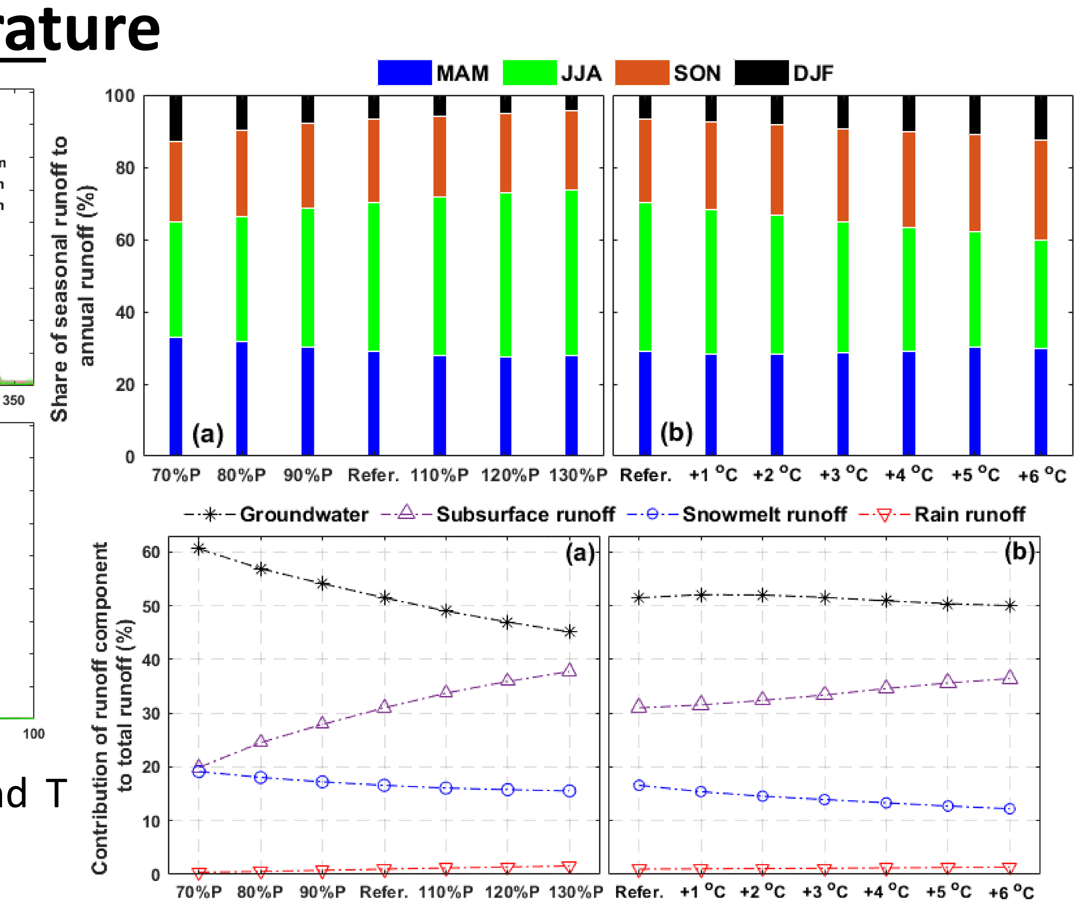
## Conclusions

- The hydrological processes in the boreal forest basin show larger sensitivity to climate changes, compared to the changes of land cover.
- The basin hydrological behaviours show mainly non-linear responses to linear changes of precipitation and temperature.
- The effects of warming on annual/seasonal runoff, runoff components and SWE can be partly compensated by increased precipitation but enhanced by decreased precipitation.

## Hydrological responses to the changes of precipitation and temperature

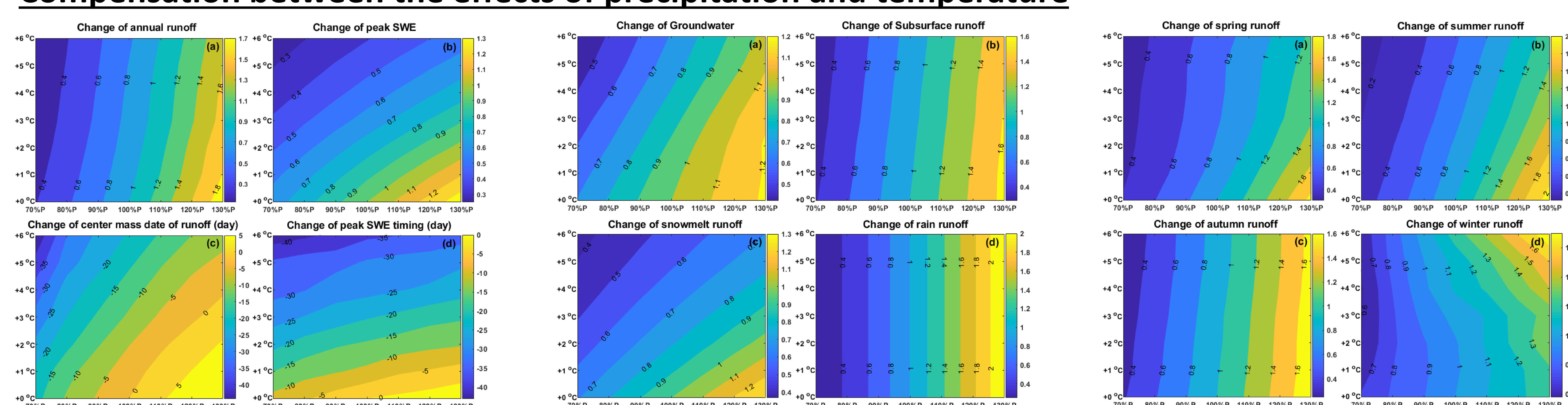






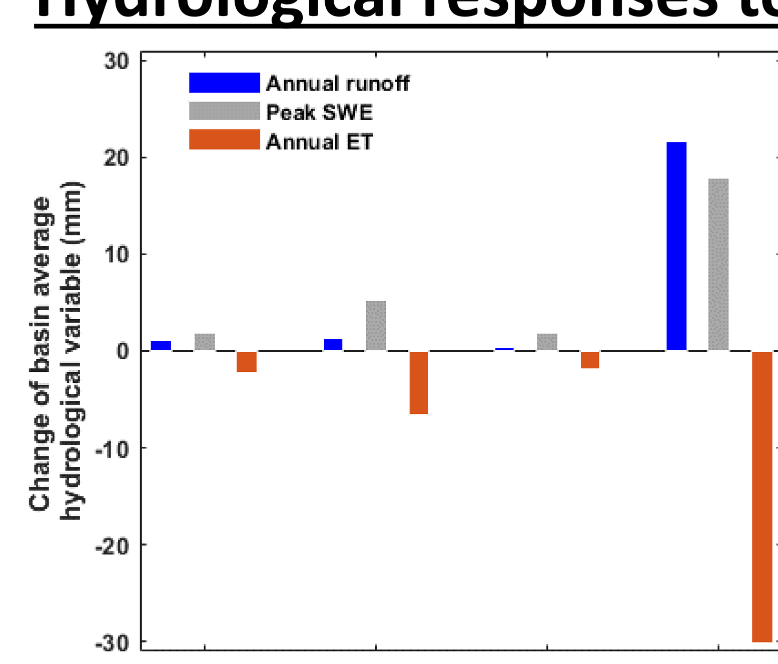

- Changes of magnitude indices were estimated by the ratio between the simulations produced by P and T change scenarios and the simulations forced by reference P and T;
- Changes of timing indices were estimated by the difference between the simulations produced by P and T change scenarios and the simulations forced by reference P and T.

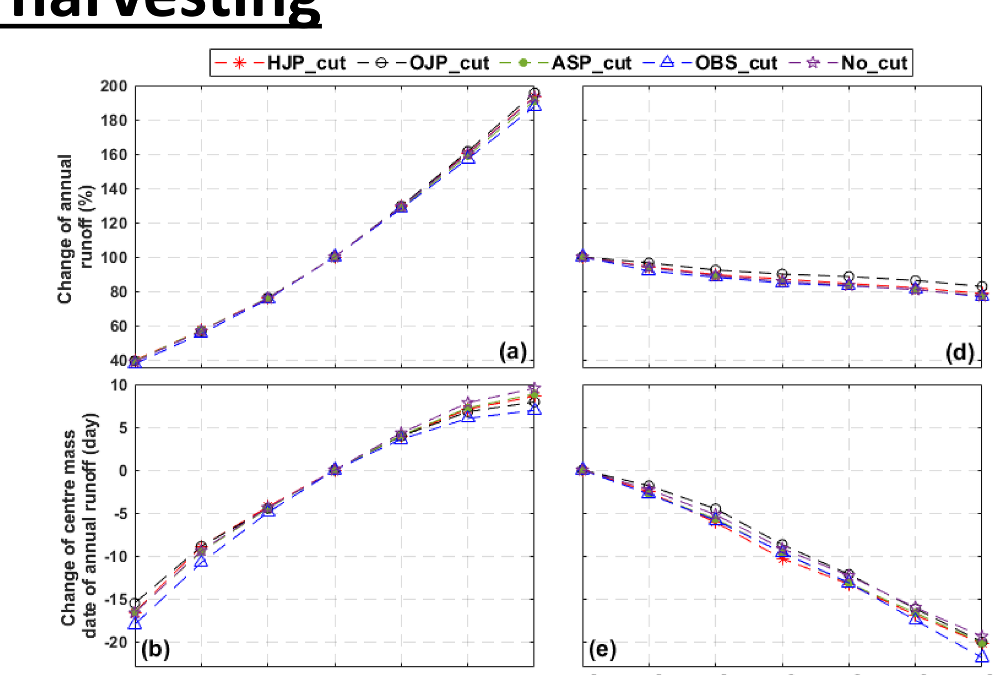
## Compensation between the effects of precipitation and temperature

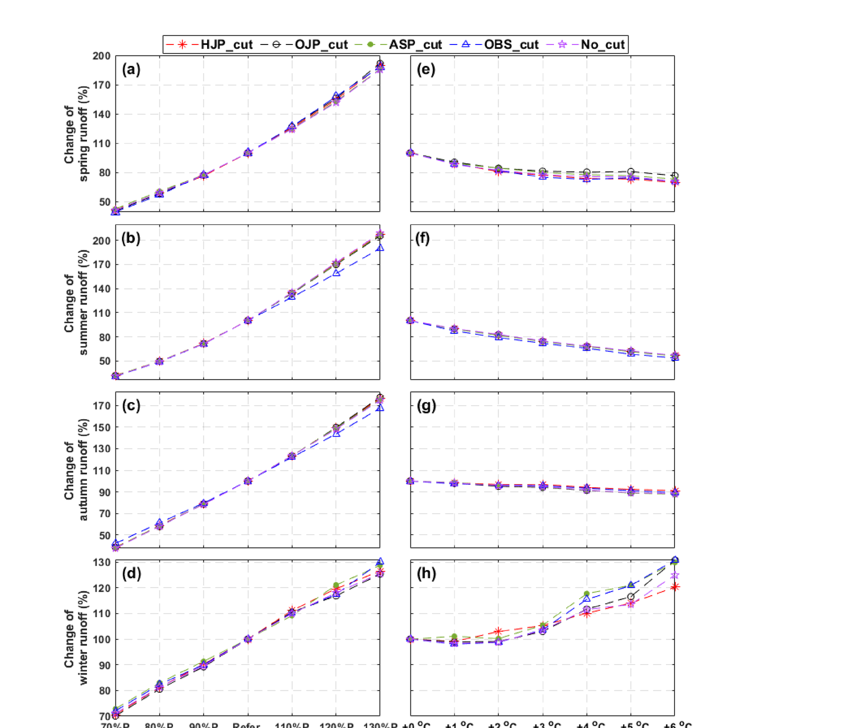



- The contours with a value of 1 on the annual runoff, runoff components, seasonal runoff and peak SWE change subplots indicate the effects of warming were compensated by the effects of increased precipitation;
- The contours with a value of 0 on the timing subplots indicate the effects of warming were compensated by the effects of increased precipitation.

## Hydrological responses to forest harvesting



- Changes of basin average hydrological variables caused by forest harvesting were estimated based on reference P and T inputs;
- The response of annual and seasonal runoff to climate changes under forest harvesting were investigated using a leave-one-out approach, in which the forest types were clear-cut to run the model using climate scenarios separately.