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Assessing the factors governing the ability to predict late-spring flooding in cold-region mountain basins

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1. Maps of sand and clay fractions.

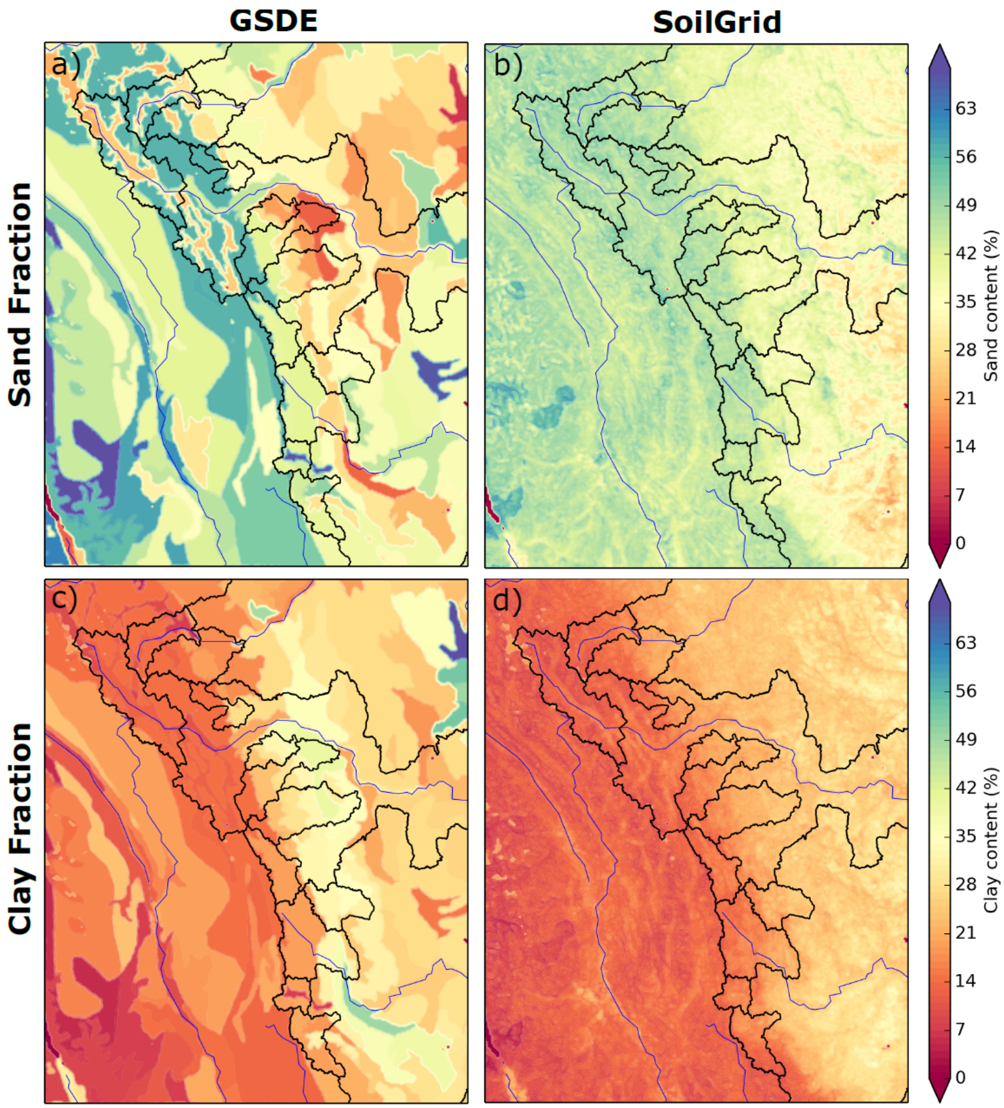

Figure S1: Soil texture (top 50-cm) over the region of interest in this study: fraction of sand from (a) GSDE and (b) SoilGrid and fraction of clay from (c) GSDE and (d) SoilGrid. The catchments of interest in this study are shown in black.

2. Adjustment of Manning's roughness parameters.

In this study, parameters for the routing scheme WATROUTE were derived using the standard procedures implemented in the operational hydrological system of ECCC (Durnford et al., 2018). In particular, two Manning's roughness parameters are used for flood plain flow, n_f, and channel flow, n_c, based on values derived from the literature (Chow, 1959). n_f varies spatially with vegetation type (0.035 for low vegetation and 0.075 for high vegetation) and seasonally to represent temporal changes in vegetation. For channel flow, the value of n_c is affected by the roughness of the channel surface on the bottom and sides as well as the roughness of the underside of the ice cover overlying the river when ice is present. It varies with drainage area between 0.03 and 0.05 to represent the overall decrease of Manning coefficient from the headwaters to the river mouth (Decharme et al. 2010). These variations are effective at large scale and over our region of interest, n_c is almost constant, equals to 0.044.

Preliminary hydrological simulations with GEM-Hydro using the default Manning's parameters and all combinations of initial snow conditions and atmospheric forcing showed a delay in simulated peak flow for most of the 12 hydrometric stations considered in this study. This suggests that uncertainties in modelling of river routing with WATROUTE potentially affects the simulations. In particular, erosion and changes in river channels were reported for many rivers impacted by the June 2013 flood (Pomeroy et al., 2016b) and a shift from sub-surface to overland flow was noted (Pomeroy et al., 2016a; Fang and Pomeroy, 2016), suggesting that the default routing parameters used in WATROUTE may not be suitable for this extreme event. Therefore, additional routing experiments were made using the *1.0km_SND_GSS*, *1.0km_OPL_GSD* *2.5km_SND_GSD* and *2.5km_OPL_GSD* simulations that benefited from the most accurate precipitation forcing. The Manning's coefficients over the GEM-Hydro simulation domain were adjusted using constant multiplication factors (ranging from 0.4 to 1.1) and the timing and amplitude of the simulated peak flow compared to discharge observations. Figure S1 shows the distributions of models errors for the different multiplication factors. As mentioned before, the default configuration of GEM-Hydro was associated on average with a delay of simulated peak flow and an underestimation of peak flow amplitude. As expected, decreasing the Manning's coefficients led to increasing peak flow amplitude and earlier peak flow time, improving the overall model performances. The best performances were obtained for the multiplication factor equals to 0.8 that was used in the hydrological simulations presented in this study. The size of the box plot on Fig. S1 shows that simple, spatially uniform adjustment of Manning's coefficients is not sufficient to capture the peak flow timing and magnitudes observed at various hydrometric stations. This is likely due to the substantial spatial and temporal variability in runoff, storage and channel processes (Fang and Pomeroy, 2016) and that such a hydraulic calibration is necessarily combined with other sources of uncertainties in the timing and magnitude of intense precipitation and snowmelt in the land surface scheme, and in the other hydraulic parameters of the routine scheme such as channel width and geometry.

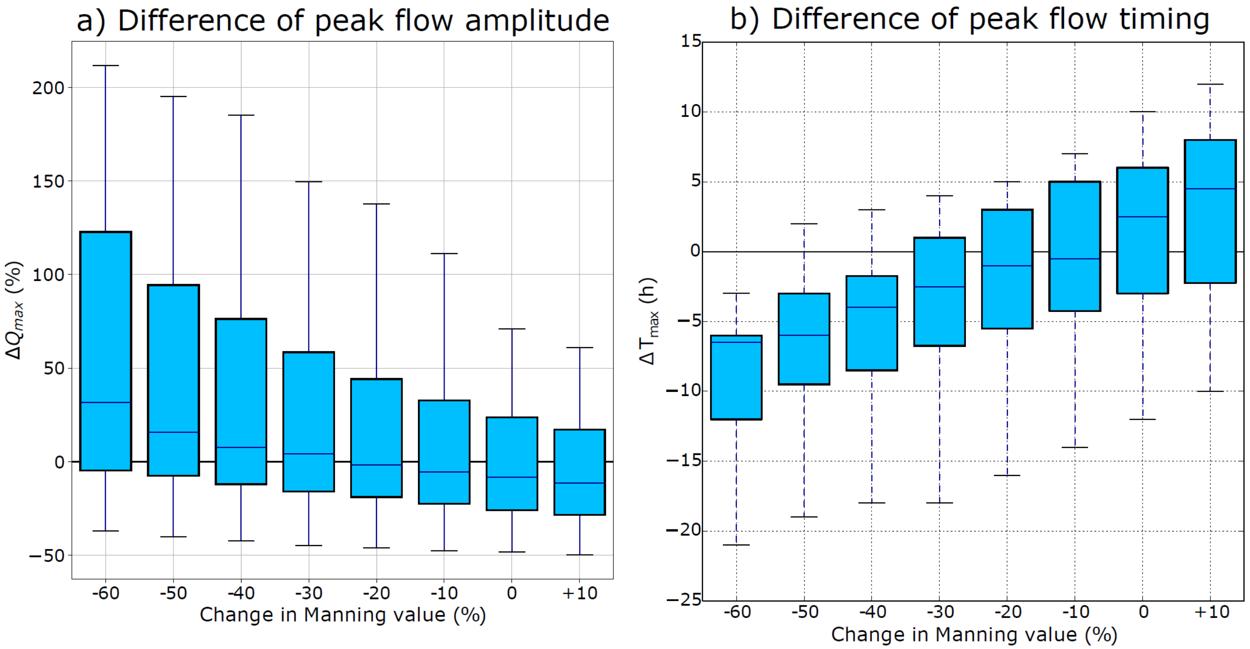

Figure S2: Distribution of model errors at 12 hydrometric stations for 4 GEM-Hydro simulations in terms of peak (a) amplitude and (b) timing for different correction factors applied to the default Manning coefficients.

3. Detailed evaluation of model performances.

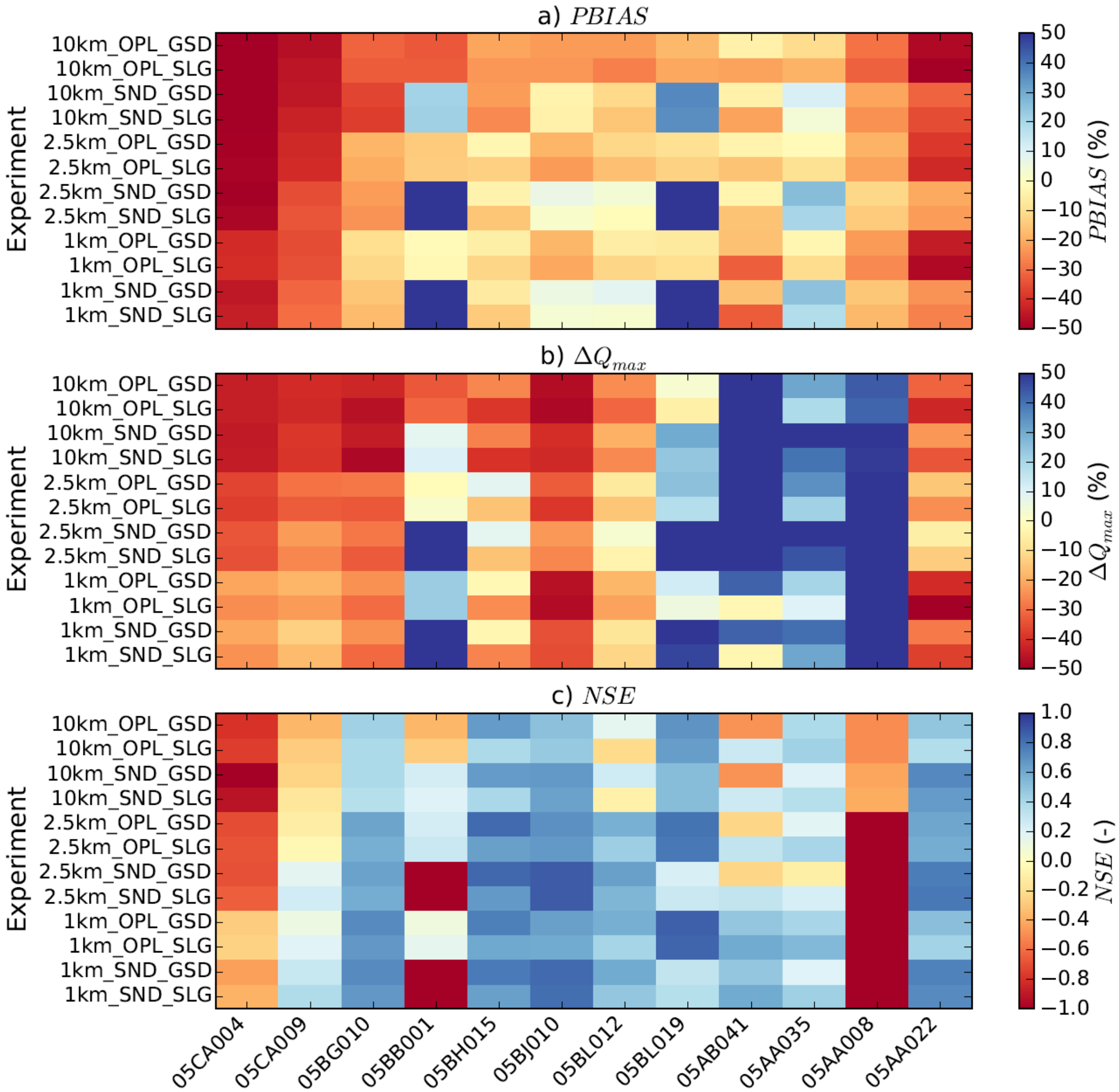

Figure S3: Overview of performances for the different GEM-Hydro experiments (Table 4 of the main manuscript) at all hydrometric stations considered in this study (Table 1 of the main manuscript). The definitions of the error metrics are given in Appendix A of the main manuscript.

4. Simulated streamflow prior to the flooding event

The insertion of SNODAS SWE near peak snow accumulation in configuration *SND* (see Sect. 2.3.3 in the main paper) affected the amount of snowmelt in the headwater basins prior to the flooding event. Figure S4 shows the example of simulated daily streamflow by GEM-Hydro in configurations *OPL* and *SND* for the hydrometric station located on the Bow River at Banff (station 05BB001).

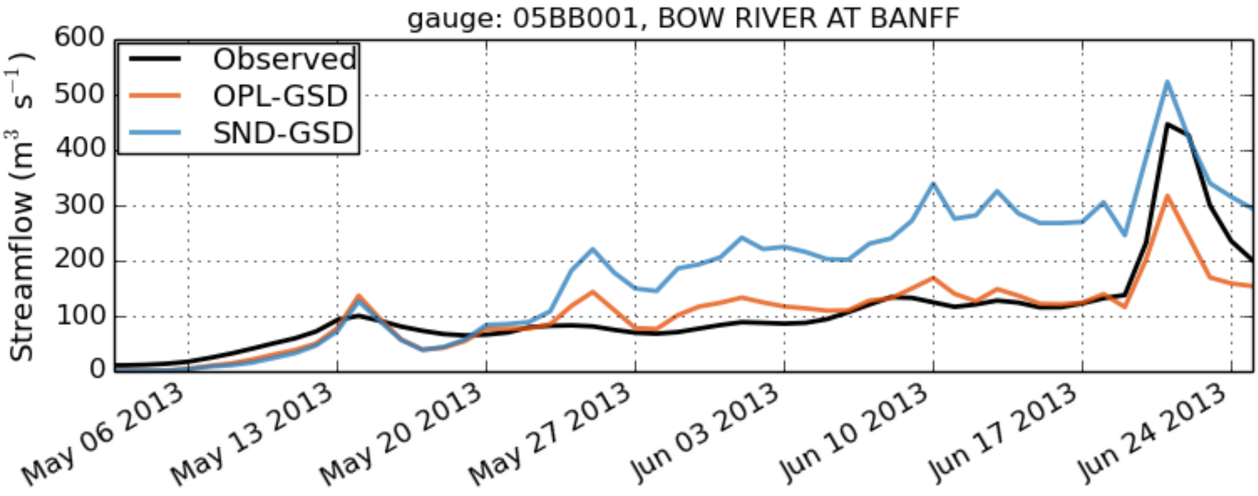

Figure S4: Comparison at the hydrometric station 05BB001 (Bow River at Banff) of observed daily streamflow with simulated daily values using two versions of GEM-Hydro: (i) OPL-GSD: the default version without the insertion of SNODAS SWE and (ii) SND-GSD: the configuration of GEM-Hydro with the insertion of SNODAD SWE on 1st May 2013. Results with the GSDE soil database are shown here. The atmospheric forcing consisted of the regional model combined with precipitation from the operational version of CaPA until 18 June 2013 and the atmospheric forcing at 10 km specifically generated for the event (see Sect. 2.3.3 for more details).

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