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Enhancing runoff-infiltration partitioning in the SVS land surface model improves streamflow simulations under frozen soil conditions

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S1: Land-use and soil-texture analysis of the $\alpha_{no\text{-}imp}$ calibration

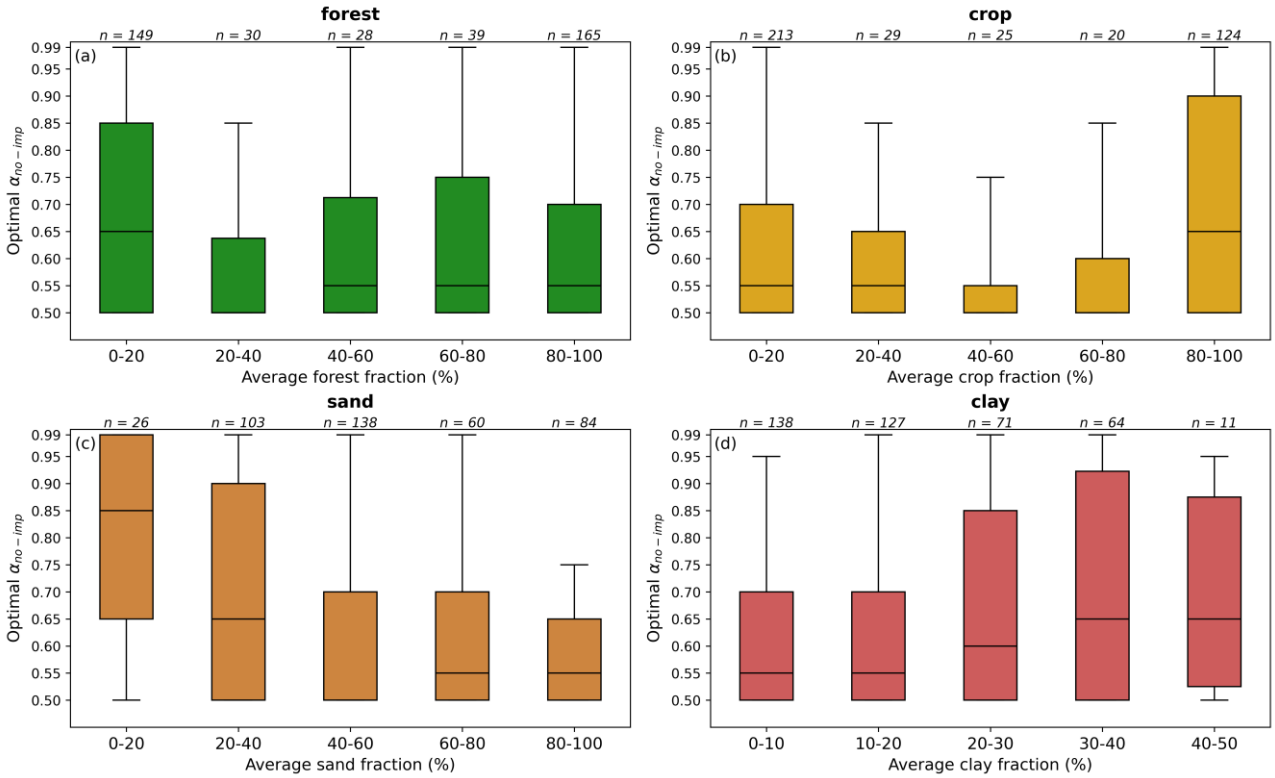

Figure S1: Boxplots of the optimal $\alpha_{no\text{-}imp}$ value in relation to the average forest (a), crop (b), sand (c) and clay (d) fractions. Simulations were performed using values of $\alpha_{no\text{-}imp}$ from 0.5 to 0.99 with increments of 0.05 on the Great-Lakes and Saint-Lawrence domain from 1 September 2016 to 31 August 2018. Details on boxplot representation are given in the legend of Fig. 4 of the main manuscript. The number of catchments for each surface cover fraction bin (*n*) is indicated on top of the boxes.

S2: Spatial performance and catchment characteristics for the noFr and Fr experiments

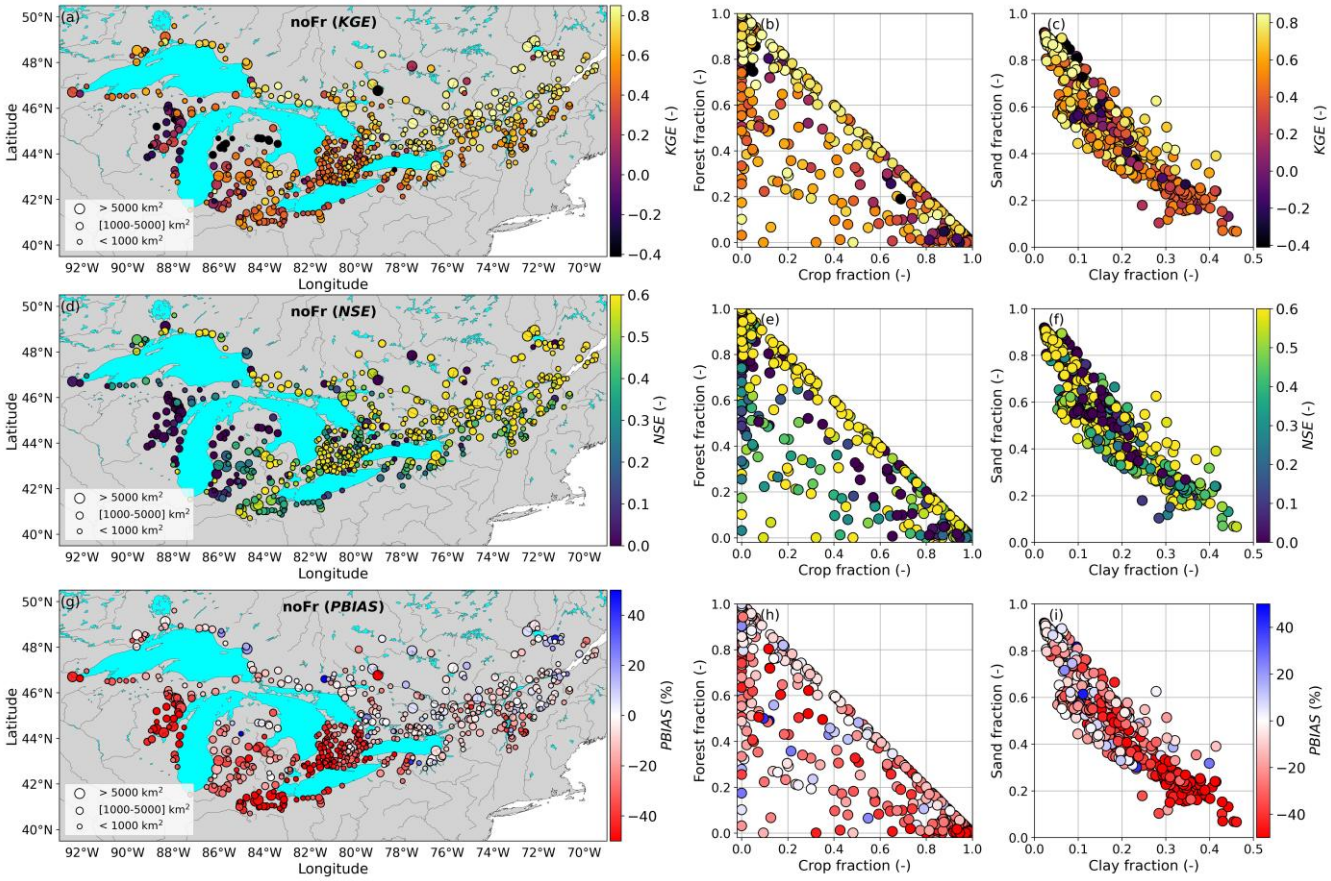

Figure S2: Spatial performance and catchment characteristics for the noFr experiment (2016–2021). Left panels (a, d, g) show the Great Lakes and St. Lawrence domain with KGE, NSE, and PBIAS at each station. Right panels (b, c, e, f, h, i) show corresponding forest-crop and sand-clay fractions categorized by performance scores. In (a) to (f), a good performance of the model is represented by yellow shades. In (g) to (i), underestimation of streamflow is shown by red colors while an overestimation is shown by blue colors with pale red and blue dots show a low absolute bias.

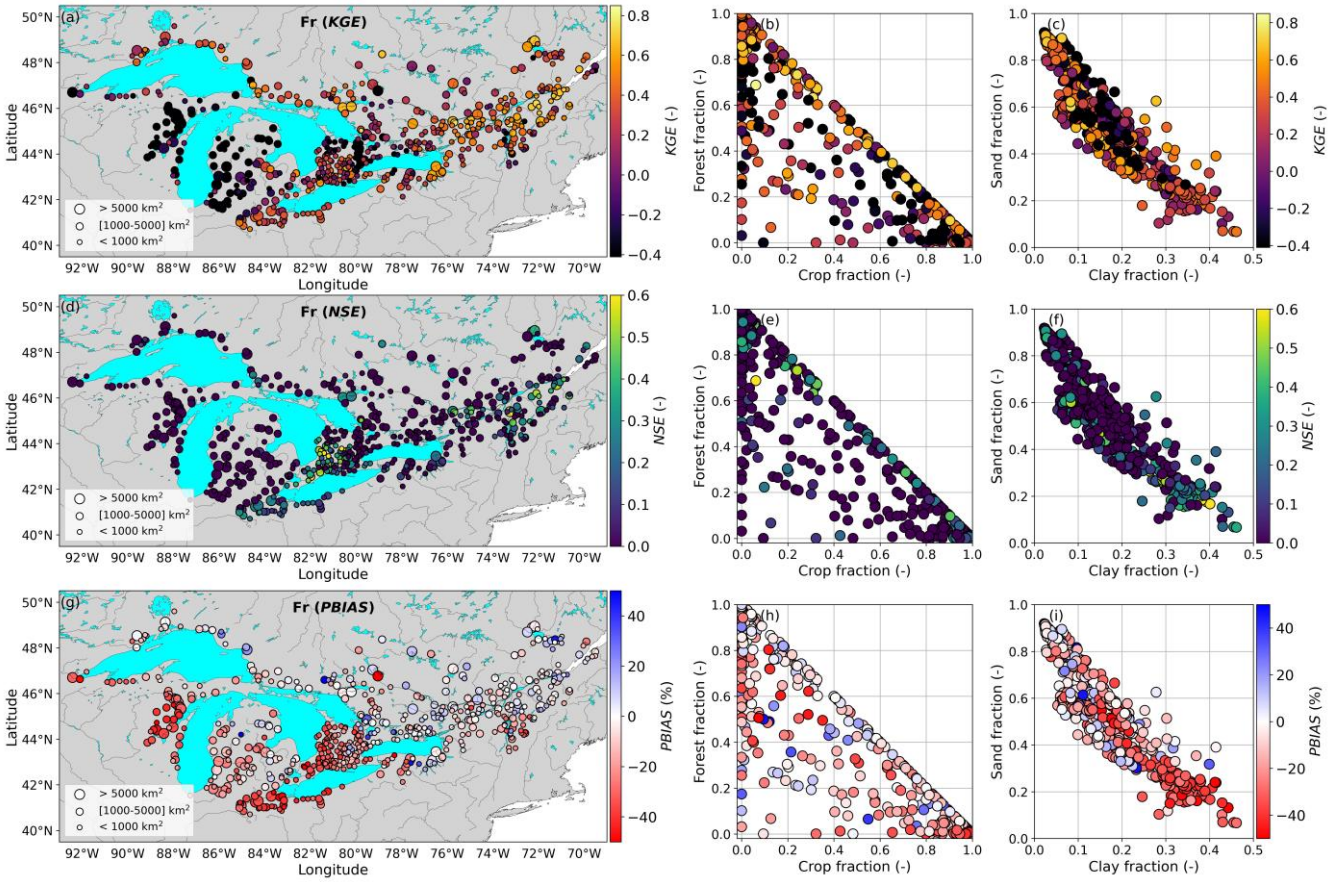

Figure S3: Same as Figure S2 but for the Fr experiment.

S3: Near-surface meteorological variable evaluation of the Fr experiment

	period/ variable	Full period 2016-09-01 to 2021-08-31	Winter 11/01 to 02/28	Spring 03/01 to 06/30	Summer 07/01 to 10/31
Δ*BIAS* (°C)	*TD*	**0.024**	**0.012**	**0.033**	0.005
	TT	**0.029**	**0.055**	**0.027**	0.006
Δ*RMSE* (°C)	*TD*	**0.011**	0.006	**0.018**	0.002
	TT	**0.013**	**0.018**	**0.016**	0
Δ*STD* (°C)	*TD*	0.003	0.005	0.004	0
	TT	0.008	0.008	0.008	0.002

Table S1: Differences of the bias (*BIAS*), root mean square error (*RMSE*) and standard deviation of the error (*STD*) for the 2 m dew point temperature (*TD*) and the 2 m air temperature (*TT*) between the default soil freezing experiment (Fr) and the experiment without soil freezing (noFr). The performances are evaluated over the full period (from 1 September 2016 to 31 August 2021) and seasonally with winter period spanning from 1 November to 28 February, spring period from 1 March to 30 June and summer period from 1 July to 31 October. Positive values greater than 0.01°C are shown in bold and represent an improvement of the Fr experiment compared to noFr.

S4: Hydrographs of the Richelieu, Ottawa and Mistassini Rivers.

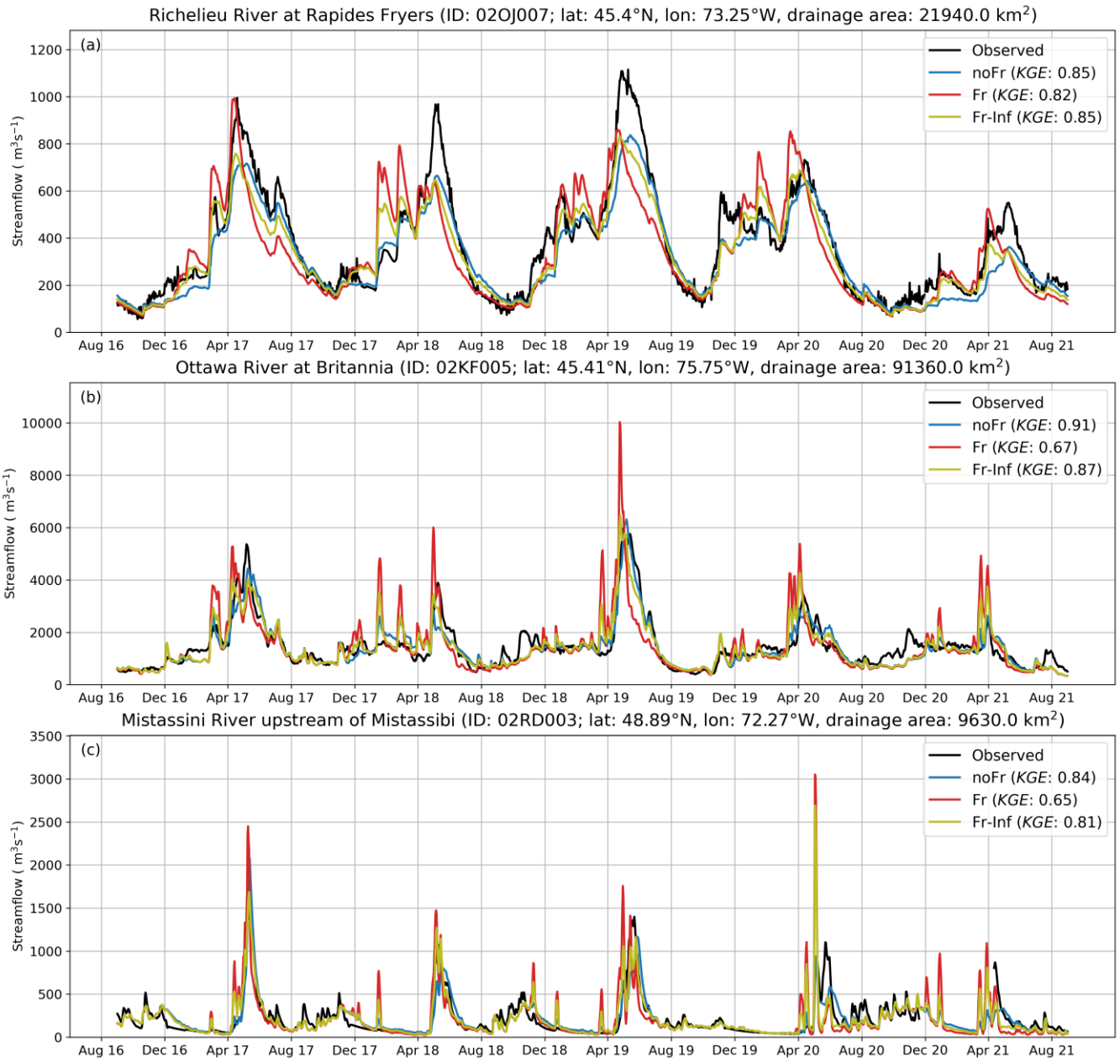

Figure S4: Observed and simulated streamflow of the Richelieu River (station ID: 02OJ007) (a), the Ottawa River (station ID: 02KF005) (b) and the Mistassini River (station ID: 02RD003) (c) for the 2016-2021 evaluation period. Simulations of the no freezing experiment (noFr) are in blue, the soil freezing experiment (Fr) in red and enhanced frozen soil infiltration (Fr-Inf) in yellow.

S5: Score maps of simulated freezing depth for the Fr experiment

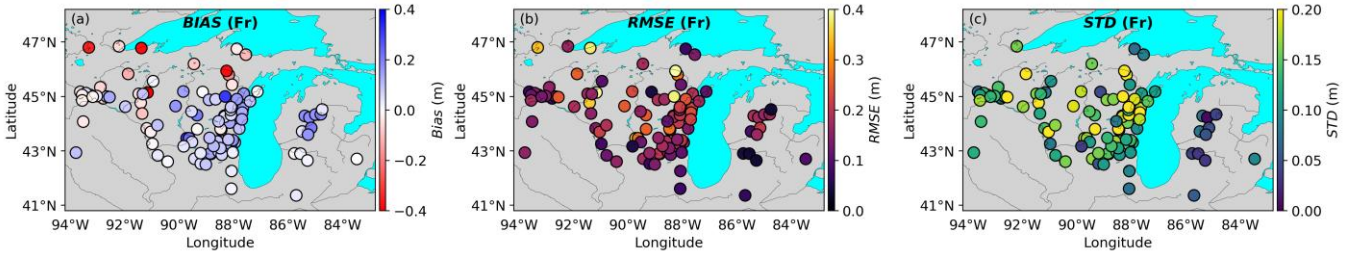

Figure S5: Freezing depth score maps of the *BIAS* (a), *RMSE* (b) and standard deviation *STD* (c) at each station over the 2016-2021 period for the Fr experiment for the region of Central U.S.

S6: Performance of the AG23 configuration

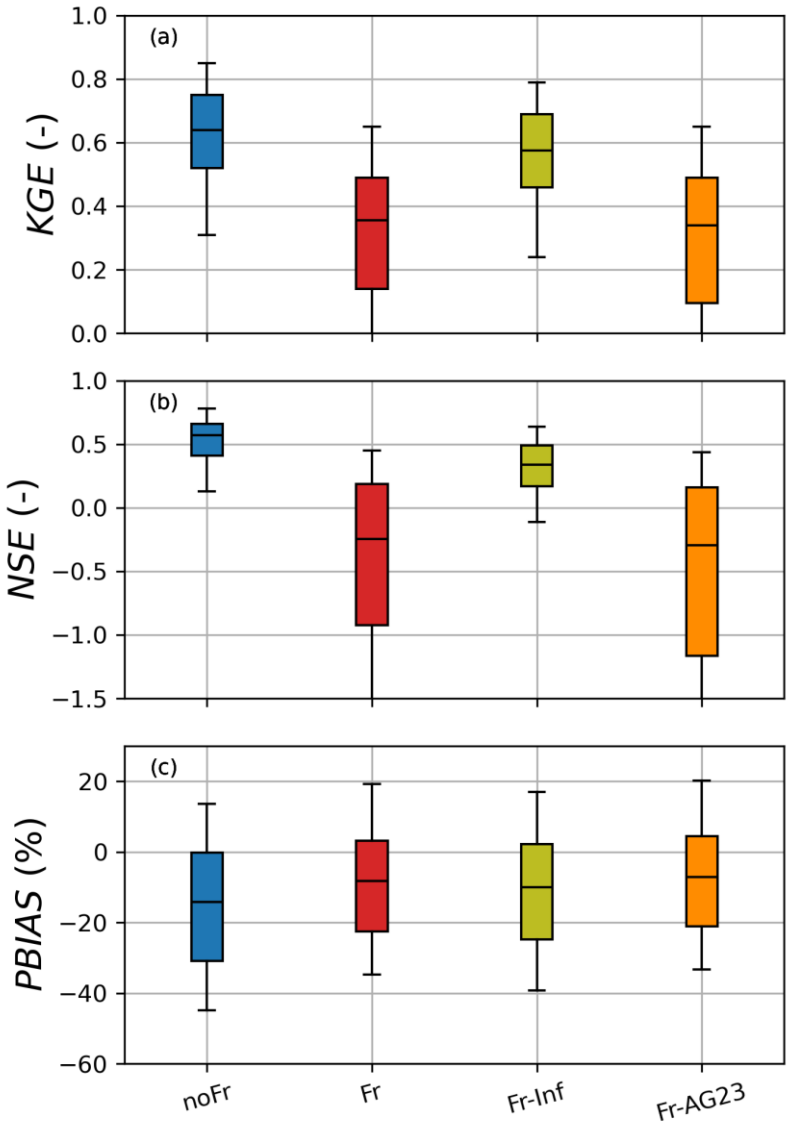

Figure S6: Boxplots of streamflow performances (KGE (a), NSE (b) and PBIAS (c)) for the three main configurations (noFr, Fr, Fr-Inf) and the AG23 configuration in the Great-Lakes and Saint-Lawrence domain for the 2016-2021 evaluation period. Details on boxplot representation are given in the legend of Fig. 4 of the manuscript. The target value for the KGE and NSE is 1.0 while the target value for the PBIAS is 0.0.

S7: Performance of the intermediate enhanced frozen soil infiltration configurations

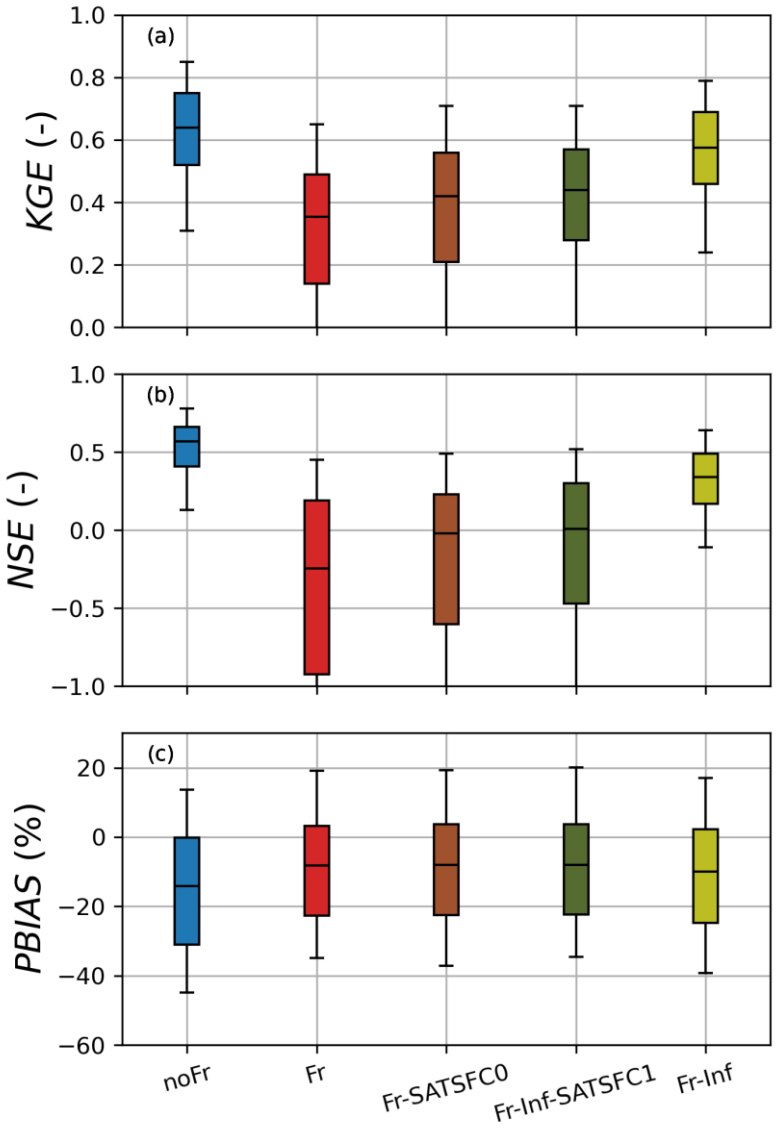

Figure S7: Boxplots of streamflow performances (KGE (a), NSE (b) and PBIAS (c)) for the three main configurations (noFr, Fr, Fr-Inf) and the two intermediate configurations (Fr-SATSFC0 and Fr-Inf-SATSFC1) in the Great-Lakes and Saint-Lawrence domain for the 2016-2021 evaluation period. Details on boxplot representation are given in the legend of Fig. 4 of the manuscript. The target value for the KGE and NSE is 1.0 while the target value for the PBIAS is 0.0.