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Cold climates, complex hydrology: can a land surface model accurately simulate deep percolation?

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1 Additional Simulation Results

This section presents a comparison of soil moisture and percolation simulations with and without the soil freezing module activated in the SVS land surface model. To highlight the potential influence of the soil freezing module, the analysis focuses on the months where soil freezing is likely to occur (November to April). Figures S1 and S2 show the daily averaged soil moisture and percolation volumes, respectively, for three periods: November 2019 to April 2020, November 2020 to April 2021, and November 2021 to April 2022.

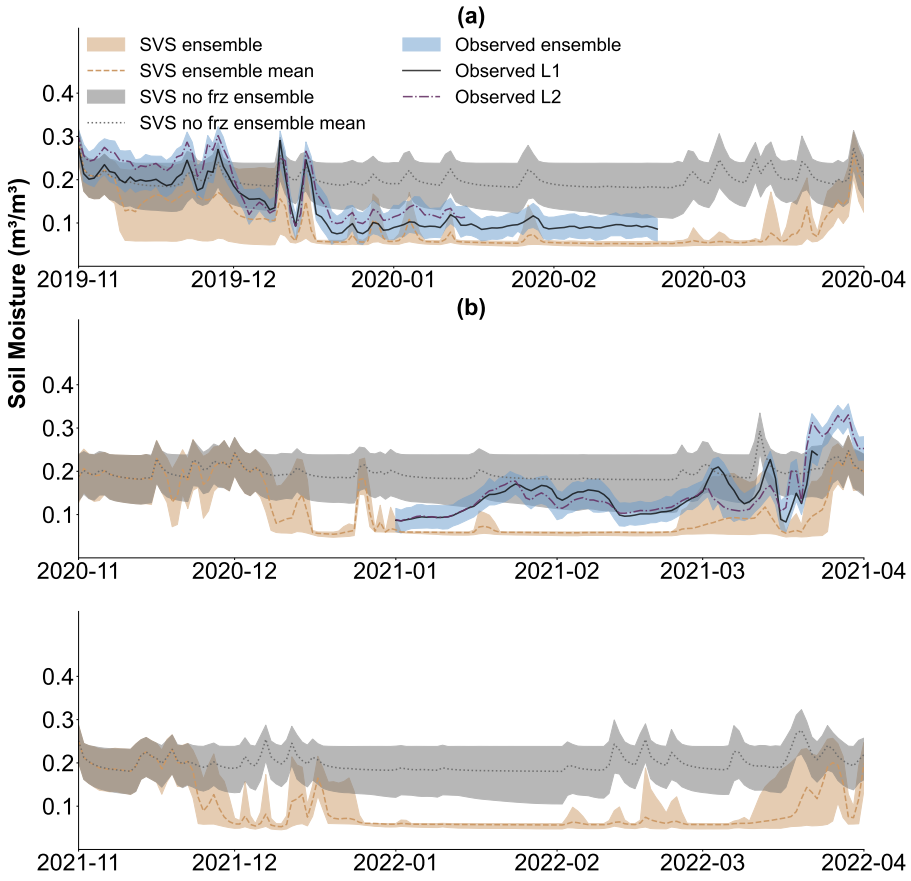

Figure S1. Daily averaged soil moisture ($m^3\ m^{-3}$) simulated with and without the soil freezing module in the SVS model. (a) November 2019 to April 2020. (b) November 2020 to April 2021. (c) November 2021 to April 2022 (no observations available for this period). The lines represent the ensemble means of the SVS model with soil freezing (gold brown), without soil freezing ("no frz", grey), and observations from lysimeters L1 (black) and L2 (purple). The shaded areas represent the 95% confidence intervals of the corresponding SVS ensembles.

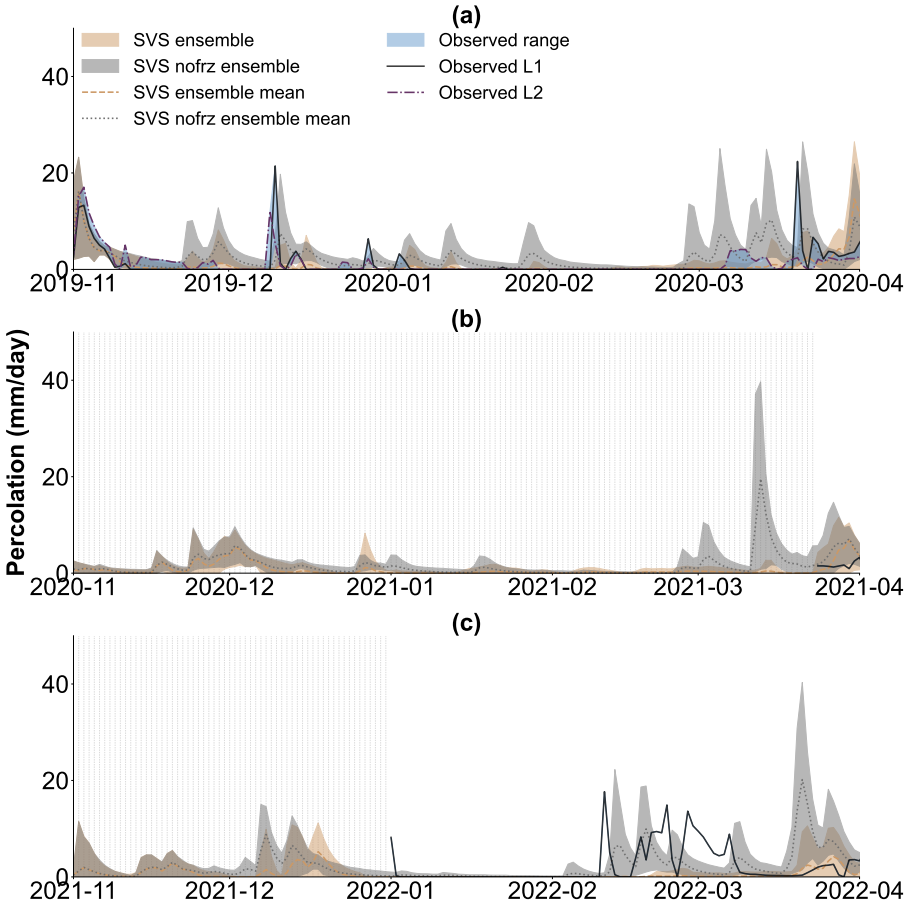

Figure S2. Daily averaged percolation (mm d^{-1}) simulated with and without the soil freezing module in the SVS model. (a) November 2019 to April 2020. (b) November 2020 to April 2021. (c) November 2021 to April 2022. The lines represent the ensemble means of the SVS model with soil freezing (gold brown), without soil freezing ("no frz", grey), and observations from lysimeters L1 (black) and L2 (purple). The shaded areas represent the 95% confidence intervals of the corresponding SVS ensembles.

2 Comparison of PTF-Estimated and Laboratory-Measured Soil Properties

This section presents a comparison of soil hydraulic properties estimated from laboratory measurements and estimated using pedotransfer functions (PTFs). Table S1 summarizes the descriptive statistics of the observed and PTF-predicted soil properties for topsoil and cover material.

Soil Type	Parameter	Observation				Model			PTF Reference
		N	Min	Max	Median	Ens-Min	Ens-Max	PTF Estimate	
Topsoil	Sand (%)	6	37.0	92.0	75.0				-
	Clay (%)	6	0.0	0.0	0.0				-
	K_{sat} (m·s^{-1})	58	1.0×10^{-6}	2.1×10^{-4}	1.4×10^{-5}	5.1×10^{-7}	5.0×10^{-6}	1.29×10^{-5}	Clapp and Hornberger (1978)
	ψ_{ae} (m)	4	0.24	0.51	0.39	0.05	0.45	0.08	Clapp and Hornberger (1978)
	b (-)	4	0.4	2.4	1.0	1.0	2.0	3.50	Clapp and Hornberger (1978)
	θ_{sat} (m^3·m^{-3})					0.39	0.44	0.39	Boone et al. (1999)
	θ_{fc} (m^3·m^{-3})					0.08	0.17	0.09	Boone et al. (1999)
	θ_{unf} (m^3·m^{-3})					0.06	0.10	0.03	Niu and Yang (2006)
Cover M.	Sand (%)	5	55.0	78.0	68.0				-
	Clay (%)	5	6.0	12.0	7.0				-
	K_{sat} (m·s^{-1})	64	2.0×10^{-6}	1.3×10^{-4}	1.8×10^{-5}	1.0×10^{-6}	5.0×10^{-6}	1.01×10^{-5}	
	ψ_{ae} (m)	7	0.32	0.40	0.35	0.6	0.8	0.10	
	b (-)	7	1.3	2.1	1.9	1.0	3.5	4.53	
	θ_{sat} (m^3·m^{-3})					0.35	0.37	0.40	
	θ_{fc} (m^3·m^{-3})					0.20	0.28	0.18	
	θ_{unf} (m^3·m^{-3})					0.03	0.05	0.06	

Table S1. Descriptive statistics of laboratory-estimated and PTF-predicted physical and hydraulic soil properties for topsoil and cover material. Observed parameters include percentages of sand and clay, saturated hydraulic conductivity (K_{sat}), air entry pressure (ψ_{ae}), and the b coefficient. 'N' represents the number of samples. 'Ens-Min' and 'Ens-Max' indicate parameter ranges for ensemble construction. 'PTF Estimate' represents the mean estimate from the pedotransfer function (PTF), and 'PTF Reference' indicates the source of the PTF.

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