

Table S1: Spatial and temporal evaluation statistics (bias, RMSE, and R^2 , with relative bias and rRMSE in parentheses) for uncalibrated ELM-simulated runoff (Q_r), latent heat flux (LH), gross primary productivity (GPP), land surface temperature (LST), and near-surface soil moisture against their respective benchmark datasets. Spatial statistics are computed across grid cells for temporally-averaged fields, whereas temporal statistics are computed across the monthly time series of spatially-averaged values.

32emVariable	35emBenchmark	Spatial statistics			Temporal statistics		
		Bias (Relative bias)	RMSE (rRMSE)	R^2	Bias (Relative bias)	RMSE (rRMSE)	R^2
Q_r [mm yr $^{-1}$] LH [W m $^{-2}$] 310emGPP [$\mu\text{CO}_2\text{m}^{-2}\text{s}^{-1}$]	GRFR	-15.5 (-6.4%)	147.6 (60.8%)	0.92	-23.5 (-9.7%)	101.2 (41.7%)	0.55
	MODIS	+5.7 (+15.3%)	10.7 (28.8%)	0.89	+6.0 (+16.0%)	13.0 (34.9%)	0.96
	MOD17A2H	+0.45 (+21.0%)	1.04 (48.1%)	0.86	+0.27 (+12.5%)	0.61 (28.2%)	0.97
	FLUXCOM-X	+0.11 (+4.7%)	0.65 (26.6%)	0.92	-0.01 (-0.5%)	0.74 (30.5%)	0.93
	Zhang2019	-0.27 (-9.4%)	0.85 (30.2%)	0.89	-0.28 (-10.4%)	0.73 (26.9%)	0.93
LST [K]	MODIS	-0.76 (-0.27%)	1.89 (0.66%)	0.96	-0.76 (-0.27%)	0.97 (0.34%)	1.00
Near-surface SM	Zheng2023	+0.04 (+17.3%)	0.06 (26.9%)	0.83	+0.03 (+10.5%)	0.03 (11.8%)	0.99
35emSWE [m]	SNODAS	-6.0e-3 (-45.62%)	2.9e-2 (237.08%)	0.77	-5.0e-3 (-45.76%)	8.0e-3 (64.35%)	0.96
	UA	-6.0e-3 (-47.01%)	2.6e-2 (208.70%)	0.83	-6.0e-3 (-47.01%)	8.0e-3 (68.23%)	0.97
	SNOTEL	-0.12 (-55.46%)	0.21 (115.28%)	0.42	-	-	-
27emSnow Depth [m]	SNODAS	-0.021 (-44.13%)	0.085 (177.07%)	0.82	-0.021 (-44.77%)	0.030 (63.28%)	0.96
	UA	-0.016 (-37.15%)	0.069 (163.46%)	0.86	-0.016 (-37.15%)	0.024 (56.58%)	0.95

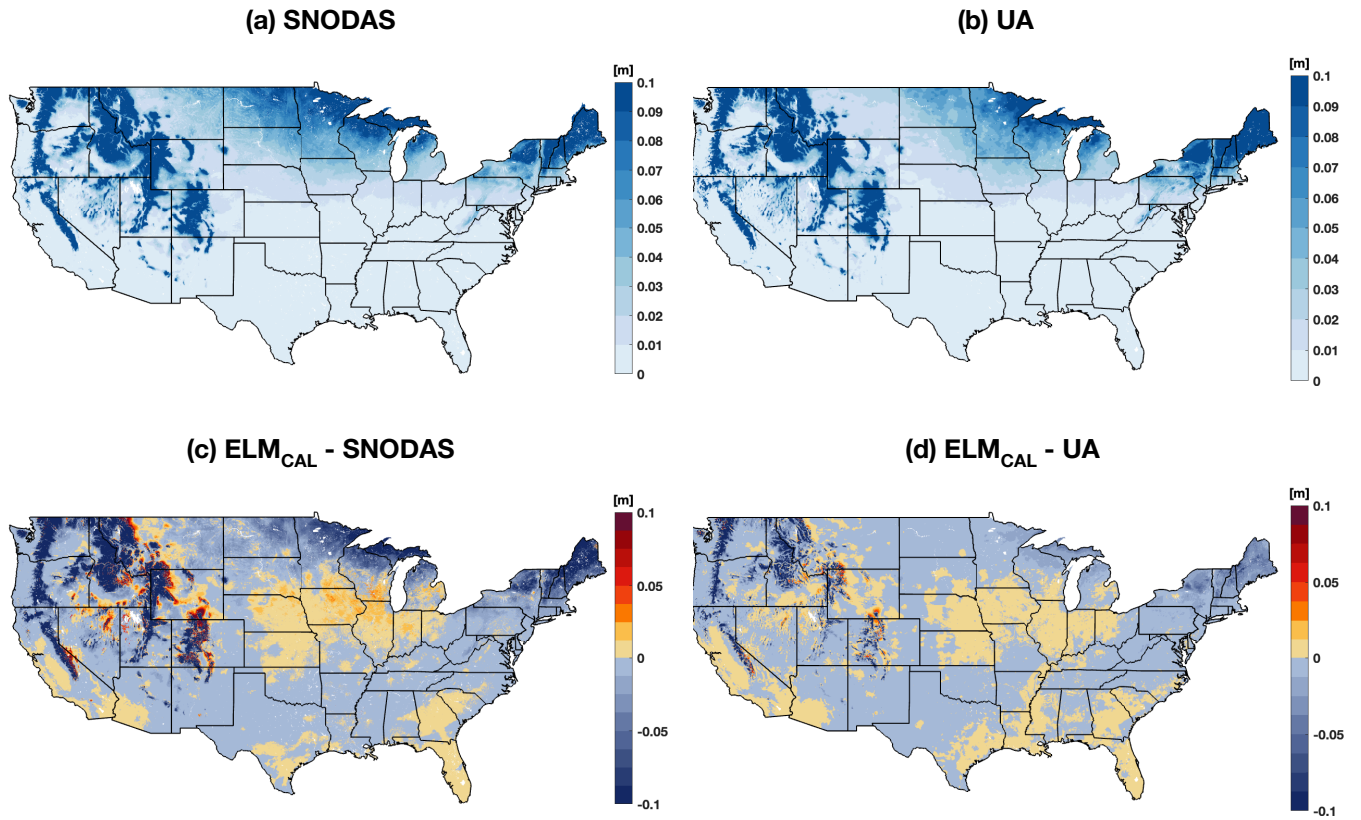


Figure S1: Temporally-averaged snow depth benchmark of (a) SNODAS at 1 km and (b) UA at 4 km. (c) Temporally-averaged bias between ELM-simulated SWE and SNODAS. (d) Temporally-averaged bias between ELM-simulated SWE and UA.

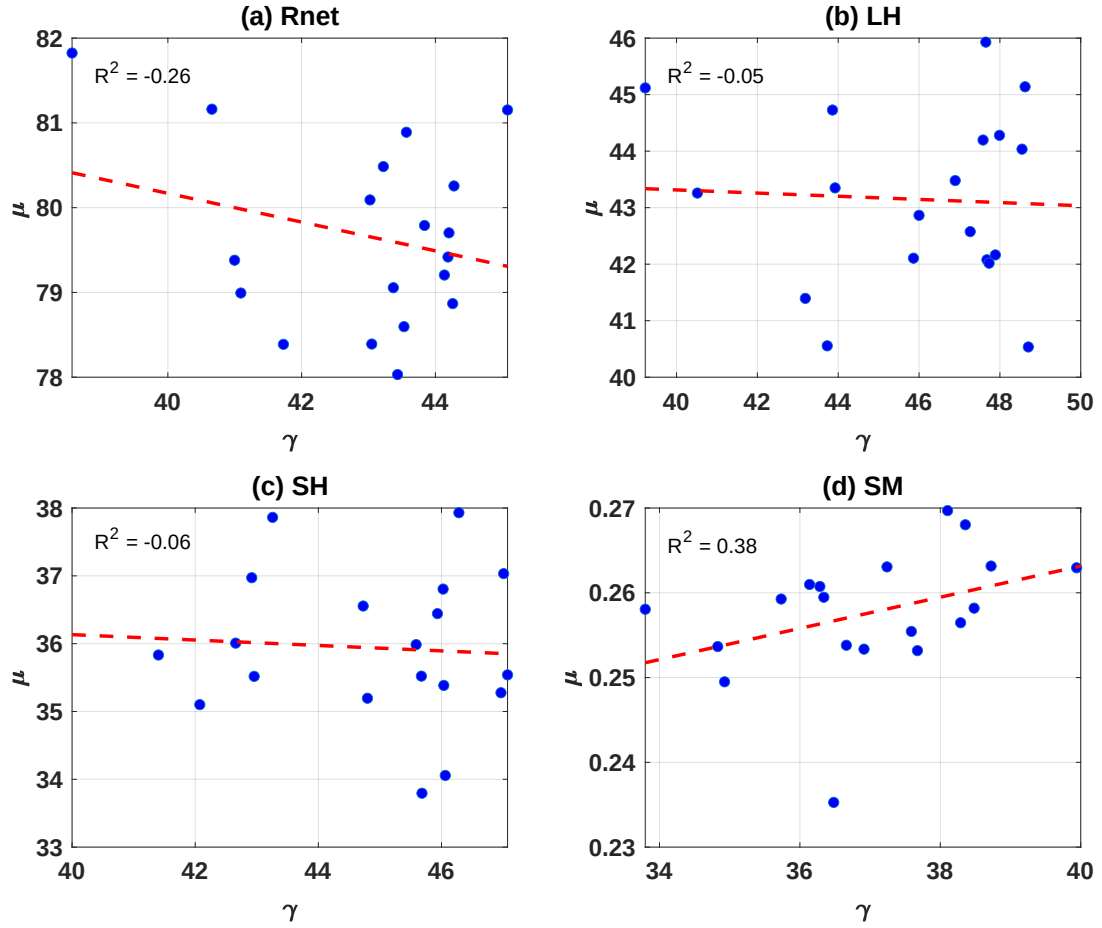


Figure S2: Scatter plot of information loss (γ) and domain-average value (μ) for the following four ELM-simulated variables: (a) net radiation (Rnet), (b) latent heat flux (LH), (c) sensible heat flux (SH), and (d) soil moisture (SM).

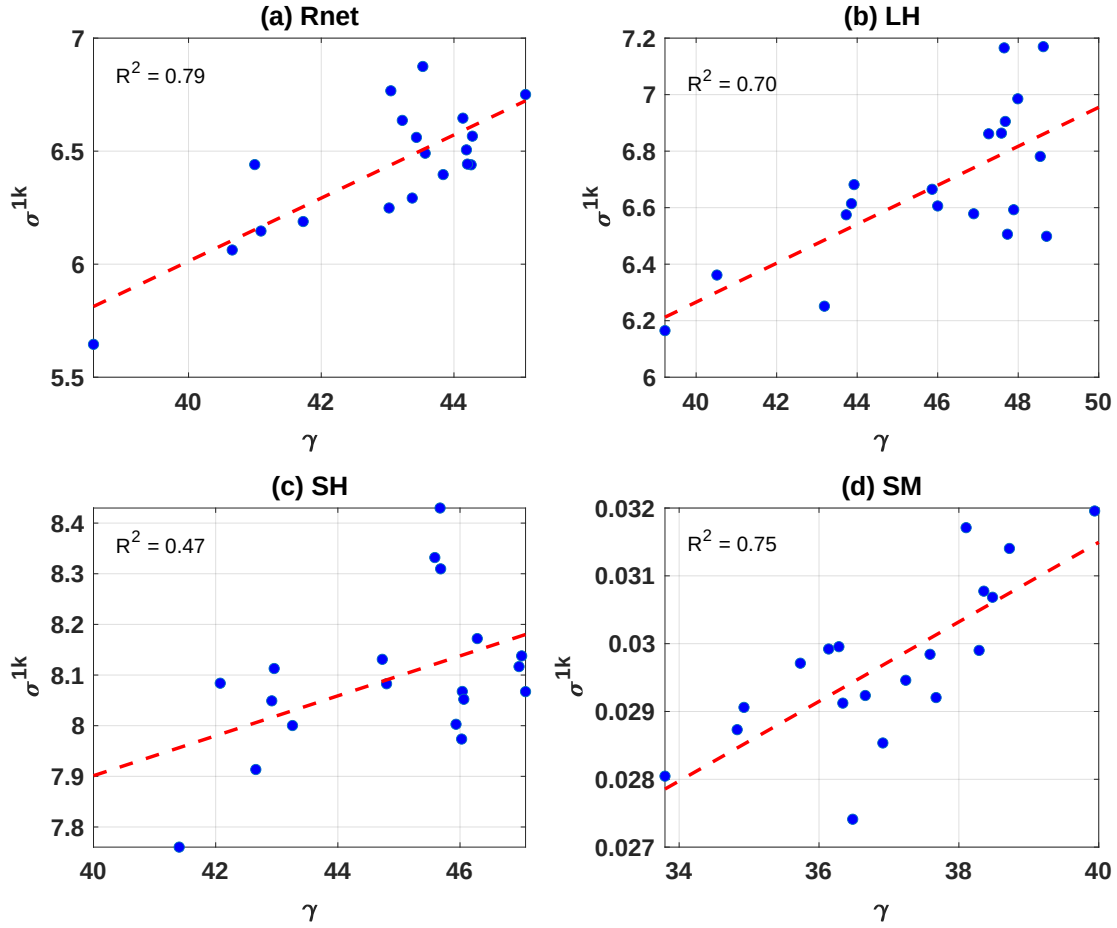


Figure S3: Scatter plot of information loss (γ) and domain standard deviation (σ) for the following four ELM-simulated variables: (a) net radiation (Rnet), (b) latent heat flux (LH), (c) sensible heat flux (SH), and (d) soil moisture (SM).