Supplement of

An ensemble of 48 physically perturbed model estimates of 1/8° terrestrial water budget over the conterminous United States, 1980–2015

Hui Zheng et al.

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Table S1. The 25 AmeriFlux sites over CONUS used in this study, including site ID, site names, locations, landcover types recorded at the site, data start year, and data end year for the annual ET cycle and interannual ET anomaly.

Site ID	Site Name	Longitude	Latitude	Data Start	Data End	Data DOI	Data Citation	Acknowledgment	Landcover Type
US-Ho1	Howland Forest (main tower)	-68.74	45.20	1995	2020	10.17190/AMF/1246061	(Hollinger, 2016)	-	Evergreen Forests
US-Me2	Metolius mature ponderosa pine	-121.56	44.45	2002	2021	10.17190/AMF/1246076	(Law, 2016)	The MetoliusAmeriFlux research was supported by the Office of Science (BER), U.S. Department of Energy, Grant No. DE-FG02-06ER64318).	
US-NR1	Niwot Ridge Forest (LTER NWT1)	-105.55	40.03	1998	2021	10.17190/AMF/1246088	(Blanken et al., 2016)	Funding for the AmeriFlux core site US-NR1 data was provided by the U.S. Department of Energy’s Office of Science.	
US-Wrc	Wind River Crane Site	-121.95	45.82	1998	2015	10.17190/AMF/1246114	(Wharton, 2016)	-	
US-GLE	GLEES	-106.24	41.37	1999	2020	10.17190/AMF/1246056	(Massman, 2016)	-	
US-CMW	Charleston Mesquite Woodland	-110.18	31.67	2000	2019	10.17190/AMF/1660339	(Scott, 2020)	-	Deciduous Forests

US-Ha1	Harvard Forest EMS Tower (HFR1)	-72.17	42.54	1991	2020	10.17190/AMF/1246059	(Munger, 2016)	Operation of the US-Ha1 site is supported by the AmeriFlux Management Project with funding by the U.S. Department of Energy's Office of Science under Contract No. DE-AC02-05CH11231, and additionally is a part of the Harvard Forest LTER site supported by the National Science Foundation (DEB-1832210).	
US-MMS	Morgan Monroe State Forest	-86.41	39.32	1999	2021	10.17190/AMF/1246080	(Novick and Phillips, 2016)	AmeriFlux Management Project	
US-WCr	Willow Creek	-90.08	45.81	1998	2020	10.17190/AMF/1246111	(Desai, 2016c)	-	
US-PFa	Park Falls/WLEF	-90.27	45.95	1995	2020	10.17190/AMF/1246090	(Desai, 2016a)	-	Mixed Forests Shrublands
US-NC1	NC_Clearcut	-76.71	35.81	2005	2012	10.17190/AMF/1246082	(Noormets, 2016)	-	
US-Ced	Cedar Bridge	-74.38	39.84	2005	2014	10.17190/AMF/1246043	(Clark, 2016)	-	
US-FR3	Freeman Ranch- Woodland	-97.99	29.94	2004	2012	10.17190/AMF/1246055	(Heilman, 2016)	-	

US-KS2	Kennedy Space Center (scrub oak)	-80.67	28.61	1999	2006	10.17190/AMF/1246070	(Drake and Hinkle, 2016)	-	
US-SO2	Sky Oaks- Old Stand	-116.62	33.37	1997	2006	10.17190/AMF/1246097	(Oechel, 2016)	-	
US-SRM	Santa Rita Mesquite	-110.87	31.82	2003	2021	10.17190/AMF/1246104	(Scott, 2016a)	Funding for the AmeriFlux core site was provided by the U.S. Department of Energy's Office of Science and the USDA.	Savannas
US-Ton	Tonzi Ranch	-120.97	38.43	2001	2020	10.17190/AMF/1245971	(Ma et al., 2016a)	This research was supported by the US Department of Energy Terrestrial Carbon Program, grant No. DE-FG03-00ER63013 and DE-SC0005130. This research was supported in part by the Office of Science (BER), U.S. Department of Energy, Grant No. DE-FG02-03ER63638.	
US-IB2	Fermi National Accelerator Laboratory- Batavia (Prairie site)	-88.24	41.84	2004	2018	10.17190/AFM/1246066	(Matamala, 2016)	-	Grasslands
US-Kon	Konza Prairie LTER (KNZ)	-96.56	39.08	2004	2019	10.17190/AMF/1246068	(Brunsell, 2016)	-	
US-Var	Vaira Ranch- Ione	-120.95	38.41	2000	2020	10.17190/AMF/1245984	(Ma et al., 2016b)	This research was supported in part by the Office of Science (BER), U.S. Department of	

								Energy, Grant No. DE-FG02-03ER63638.	
US-Wkg	Walnut Gulch Kendall Grasslands	-109.94	31.74	2004	2021	10.17190/AMF/1246112	(Scott, 2016b)	Funding for the AmeriFlux core site was provided by the U.S. Department of Energy's Office of Science and the USDA.	
US-ARM	ARM Southern Great Plains site- Lamont	-97.49	36.61	2003	2021	10.17190/AMF/1246027	(Biraud et al., 2016)	This research was supported by the Office of Biological and Environmental Research of the US Department of Energy under contract No. DE-AC02-05CH11231 as part of the Atmospheric Radiation Measurement Program (ARM).	Croplands
US-Ne1	Mead - irrigated continuous maize site	-96.48	41.17	2001	2020	10.17190/AMF/1246084	(Suyker, 2016a)	-	
US-Ne2	Mead - irrigated maize-soybean rotation site	-96.47	41.16	2001	2020	10.17190/AMF/1246085	(Suyker, 2016b)	-	
US-Ne3	Mead - rainfed maize-soybean rotation site	-96.44	41.18	2001	2020	10.17190/AMF/1246086	(Suyker, 2016c)	-	

Table S2. Correlation coefficient (R) between different ET products (FLUXCOM, GLEAM, CR-based ET) and ET observations from 25 AmeriFlux sites and for annual ET cycle and interannual ET anomaly.

Site ID	Annual ET Cycle			Interannual ET Anomaly		
	FLUXCOM	GLEAM	CR-based	FLUXCOM	GLEAM	CR-based
US-Ho1	0.99	0.96	0.99	0.18	0.00	0.11
US-Me2	0.90	0.91	0.97	0.17	0.67	0.42
US-NR1	0.96	0.94	0.95	0.11	0.32	0.01
US-Wrc	0.98	0.67	0.95	0.05	-0.02	-0.11
US-GLE	0.77	0.67	0.75	0.20	-0.09	0.07
US-CMW	0.85	0.75	0.87	0.32	0.47	0.39
US-Ha1	1.00	0.96	0.99	0.34	0.15	0.00
US-MMS	0.99	0.97	0.98	0.34	0.36	0.35
US-WCr	0.99	0.93	0.98	0.38	0.24	0.30
US-PFa	0.99	0.97	1.00	0.30	0.27	0.33
US-NC1	0.99	0.98	0.99	0.43	0.37	0.31
US-Ced	0.99	0.95	0.98	0.11	0.39	0.41
US-FR3	0.97	0.95	0.98	0.86	0.87	0.85
US-KS2	0.96	0.92	0.85	0.06	0.25	0.13
US-SO2	0.94	0.61	0.91	0.68	0.48	0.34
US-SRM	0.97	0.96	0.98	0.65	0.78	0.69
US-Ton	0.91	0.99	0.90	0.71	0.82	0.62
US-IB2	0.99	0.98	0.99	0.36	0.46	0.25
US-Kon	0.99	0.97	0.97	0.36	0.53	0.06
US-Var	0.55	0.81	0.54	0.67	0.65	0.56
US-Wkg	0.98	0.98	0.99	0.41	0.70	0.50
US-ARM	0.87	0.88	0.91	0.33	0.29	0.44
US-Ne1	1.00	0.95	0.94	0.05	0.25	-0.11
US-Ne2	1.00	0.94	0.92	-0.03	0.13	-0.10
US-Ne3	1.00	0.94	0.93	0.31	0.29	0.17
Median	0.98	0.95	0.97	0.33	0.36	0.31
Average	0.94	0.90	0.93	0.33	0.39	0.28
Frequency of being the best	16/25	2/25	10/25	9/25	13/25	3/25

Table S3. As in Figure S2, but for Taylor skill score (TSS).

Site ID	Annual ET Cycle			Interannual ET Anomaly		
	FLUXCOM	GLEAM	CR-based	FLUXCOM	GLEAM	CR-based
US-Ho1	0.99	0.94	0.92	0.15	0.50	0.38
US-Me2	0.93	0.93	0.84	0.04	0.58	0.49
US-NR1	0.98	0.64	0.75	0.16	0.66	0.51
US-Wrc	0.83	0.82	0.66	0.04	0.47	0.24
US-GLE	0.74	0.44	0.63	0.10	0.25	0.32
US-CMW	0.15	0.40	0.54	0.47	0.70	0.66
US-Ha1	0.95	0.94	0.82	0.15	0.41	0.24
US-MMS	0.98	0.97	0.88	0.34	0.65	0.67
US-WCr	0.99	0.95	0.94	0.19	0.35	0.27
US-PFa	0.92	0.86	0.79	0.50	0.63	0.63
US-NC1	0.57	0.68	0.82	0.01	0.05	0.04
US-Ced	0.93	0.98	0.95	0.03	0.28	0.27
US-FR3	0.72	0.95	0.76	0.64	0.92	0.74
US-KS2	0.97	0.64	0.81	0.06	0.46	0.39
US-SO2	0.89	0.65	0.96	0.30	0.63	0.28
US-SRM	0.76	0.98	0.99	0.70	0.87	0.81
US-Ton	0.95	0.95	0.94	0.68	0.91	0.72
US-IB2	0.91	0.93	0.98	0.14	0.45	0.38
US-Kon	1.00	0.96	0.98	0.35	0.35	0.47
US-Var	0.77	0.86	0.76	0.69	0.82	0.73
US-Wkg	0.85	0.98	0.92	0.59	0.80	0.74
US-ARM	0.86	0.76	0.75	0.58	0.55	0.67
US-Ne1	1.00	0.91	0.97	0.35	0.37	0.41
US-Ne2	1.00	0.94	0.95	0.31	0.32	0.40
US-Ne3	0.99	0.96	0.93	0.52	0.47	0.57
Median	0.93	0.93	0.88	0.31	0.50	0.47
Average	0.86	0.84	0.85	0.32	0.54	0.48
Frequency of being the best	16/25	5/25	6/25	0/25	18/25	8/25

Table S4. As in Figure S2, but for RMSE (mm month^{-1}).

Site ID	Annual ET Cycle			Interannual ET Anomaly		
	FLUXCOM	GLEAM	CR-based	FLUXCOM	GLEAM	CR-based
US-Ho1	0.24	0.92	0.43	0.28	0.40	0.31
US-Me2	0.43	0.39	0.50	0.37	0.28	0.34
US-NR1	0.61	0.67	0.75	0.24	0.27	0.34
US-Wrc	0.51	1.78	0.60	0.42	0.66	0.47
US-GLE	0.78	0.94	1.10	0.39	0.45	0.43
US-CMW	1.74	1.58	1.54	0.36	0.35	0.37
US-Ha1	0.35	0.89	0.67	0.40	0.45	0.45
US-MMS	0.50	0.71	0.90	0.22	0.24	0.25
US-WCr	0.32	0.76	0.57	0.33	0.35	0.34
US-PFa	0.56	0.92	0.82	0.22	0.25	0.23
US-NC1	2.52	2.21	2.12	1.21	1.20	1.21
US-Ced	0.42	0.52	0.41	0.55	0.51	0.51
US-FR3	0.57	0.28	0.45	0.46	0.38	0.44
US-KS2	0.27	1.22	0.74	0.46	0.46	0.49
US-SO2	0.22	0.52	0.62	0.48	0.53	0.55
US-SRM	0.34	0.22	0.32	0.26	0.21	0.25
US-Ton	0.40	0.24	0.39	0.25	0.22	0.27
US-IB2	0.52	0.53	0.32	0.31	0.29	0.33
US-Kon	0.19	0.42	0.37	0.37	0.34	0.47
US-Var	0.89	0.64	0.89	0.24	0.29	0.28
US-Wkg	0.21	0.15	0.22	0.30	0.23	0.30
US-ARM	0.54	0.70	0.69	0.53	0.54	0.50
US-Ne1	0.20	0.69	0.62	0.40	0.36	0.48
US-Ne2	0.16	0.56	0.65	0.43	0.40	0.49
US-Ne3	0.26	0.47	0.65	0.31	0.31	0.37
Median	0.42	0.67	0.62	0.37	0.35	0.37
Average	0.55	0.76	0.69	0.39	0.40	0.42
Frequency of being the best	16/25	6/25	3/25	14/25	14/25	1/25

Table S5. The performances of the Noah-MP and the NLDAS ensemble means in simulating the annual cycle and interannual cycle of terrestrial water storage anomaly (TWSA, $\boldsymbol{W}'$).

RFC	Annual cycle		Interannual anomaly	
	Noah-MP EM	NLDAS EM	Noah-MP EM	NLDAS EM
NE	0.93	0.98	0.57	0.68
MA	0.74	0.98	0.65	0.83
OH	0.96	0.96	0.80	0.86
LM	0.96	0.90	0.88	0.77
SE	0.95	0.70	0.94	0.91
NC	0.98	0.91	0.93	0.90
NW	0.86	0.98	0.94	0.94
AB	0.76	0.47	0.77	0.79
MB	0.91	0.75	0.65	0.61
WG	0.91	0.65	0.78	0.84
CN	0.85	0.93	0.90	0.81
CB	0.97	0.94	0.77	0.69

Table S6. The performances of the Noah-MP and the NLDAS ensemble means in simulating the annual cycle and interannual cycle of soil moisture at 0–0.1 m, 0.1–0.4 m, 0.4–1.0 m, and 0.1–2.0 m ($w_{soil,i}$).

RFC	Depth 0–0.1 m									
	Annual cycle					Interannual anomaly				
	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic
NC	0.89	0.87	0.53	0.12	0.90	0.40	0.31	0.42	0.13	0.57
NW	0.84	0.87	0.75	0.45	0.87	0.61	0.61	0.60	0.50	0.82
AB	0.85	0.94	0.92	0.10	0.91	0.80	0.90	0.87	0.71	0.58
WG	0.88	0.71	0.79	0.21	0.88	0.75	0.64	0.72	0.34	0.82
CB	0.72	0.78	0.48	0.42	0.78	0.63	0.71	0.68	0.49	0.82
RFC	Depth 0.1–0.4 m									
	Annual cycle					Interannual anomaly				
	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic
NC	0.95	0.54	0.79	0.18	0.91	0.40	0.67	0.57	0.33	0.75
AB	0.96	0.76	0.84	0.25	0.98	0.61	0.85	0.89	0.86	0.67
WG	0.80	0.37	0.35	0.39	0.54	0.80	0.68	0.67	0.65	0.77
CB	0.69	0.91	0.81	0.86	0.87	0.75	0.87	0.83	0.85	0.83
RFC	Depth 0.4–1.0 m									
	Annual cycle					Interannual anomaly				
	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic
AB	0.81	0.94	0.85	0.75	0.94	0.80	0.66	0.76	0.42	0.74
WG	0.92	0.81	0.95	0.77	0.09	0.70	0.80	0.78	0.66	0.46
RFC	Depth 1.0–2.0 m									
	Annual cycle					Interannual anomaly				
	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic	Noah-MP EM	NLDAS EM	Noah	VIC	Mosaic
AB	0.70	0.72	0.71	-	0.70	0.63	0.55	0.60	-	0.48

Table S7. The performances of the Noah-MP and the NLDAS ensemble means in simulating the annual cycle and interannual cycle of snow water equivalent (SWE, $\boldsymbol{W_{snow}}$).

RFC	Annual cycle		Interannual anomaly	
	Noah-MP EM	NLDAS EM	Noah-MP EM	NLDAS EM
NE	0.95	0.69	0.75	0.84
MA	0.84	0.44	0.72	0.40
OH	0.66	0.29	0.64	0.30
LM	0.17	0.04	0.15	0.05
SE	0.11	0.04	0.19	0.05
NC	0.81	0.70	0.82	0.69
NW	0.87	0.55	0.85	0.55
AB	0.20	0.22	0.20	0.22
MB	0.75	0.73	0.56	0.55
WG	0.50	0.47	0.45	0.34
CN	0.72	0.46	0.85	0.52
CB	0.74	0.69	0.82	0.74

Table S8. The performances of the Noah-MP and the NLDAS ensemble means in simulating the annual cycle against FLUXNET evapotranspiration (ET, ***E***) and the interannual anomaly against GLEAM ET.

RFC	Annual cycle		Interannual anomaly	
	Noah-MP EM	NLDAS EM	Noah-MP EM	NLDAS EM
NE	0.99	0.97	0.87	0.69
MA	0.99	0.97	0.87	0.77
OH	0.97	1.00	0.80	0.84
LM	0.98	1.00	0.68	0.72
SE	0.96	0.99	0.72	0.59
NC	0.97	1.00	0.81	0.86
NW	0.99	1.00	0.90	0.85
AB	0.98	1.00	0.91	0.92
MB	0.95	0.99	0.90	0.94
WG	0.98	0.98	0.95	0.95
CN	0.91	0.96	0.93	0.89
CB	0.92	0.96	0.97	0.92

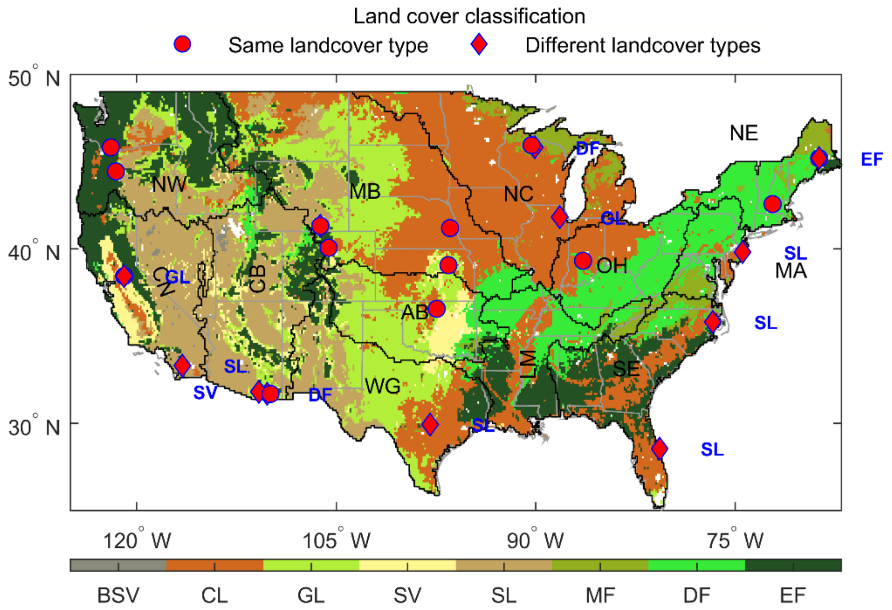

Figure S1. The twelve RFCs and land cover classifications over the CONUS. NE denotes Northeast, MA denotes Mid-Atlantic, OH denotes Ohio, LM denotes Lower Mississippi, SE denotes Southeast, NC denotes North Central, NW denotes Northwest, AB denotes Arkansas, MB denotes Missouri, WG denotes West Gulf, CN denotes California-Nevada, and CB denotes Colorado. Red circles and diamonds with blue edge indicate the location of the 25 AmeriFlux sites. The circle indicates that the dominant land cover type in the area is consistent with the AmeriFlux record; while the diamond indicates inconsistent, and the blue label next to the diamond indicates the land cover type recorded by AmeriFlux.

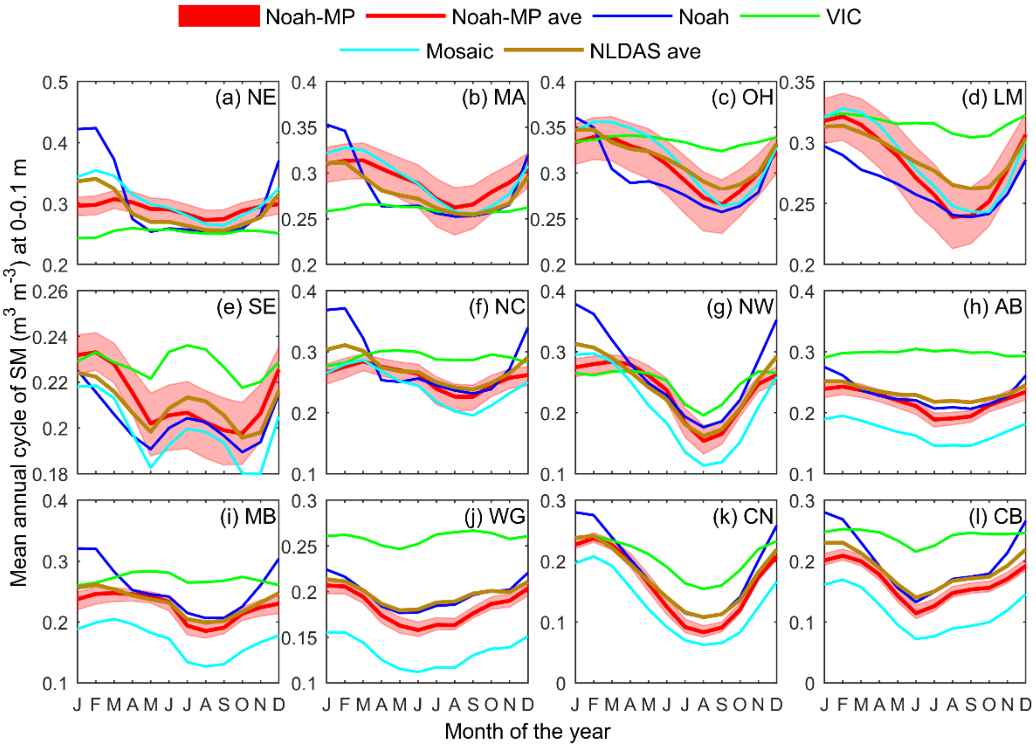

Figure S2. As in Figure 1, but for soil moisture at 0–0.1 m.

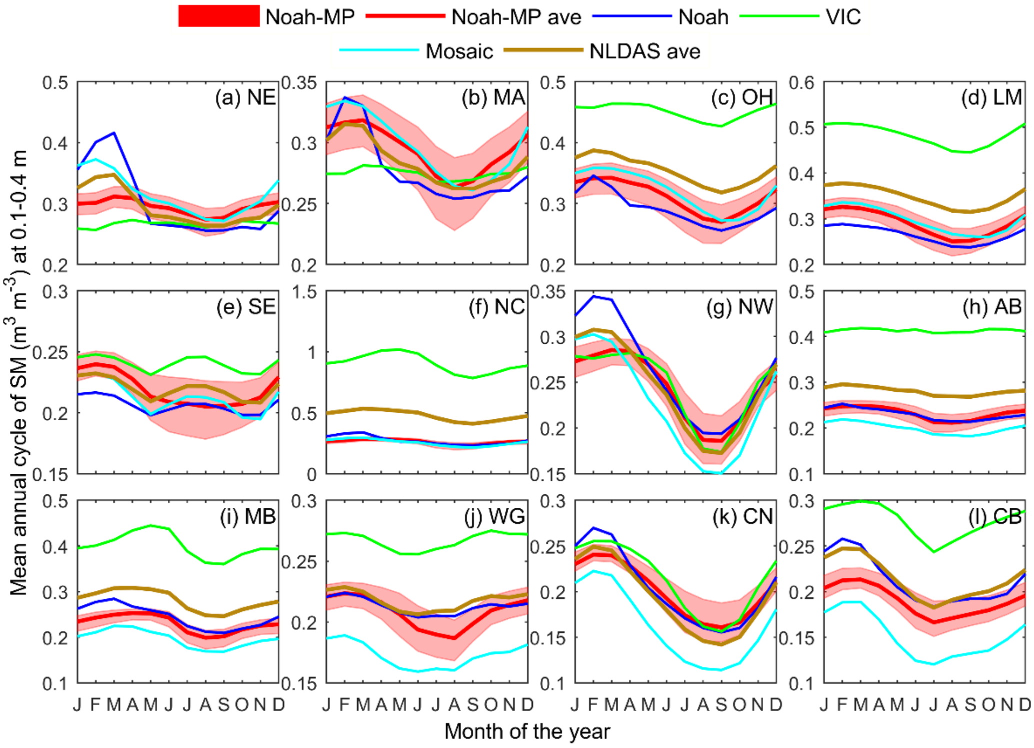

Figure S3. As in Figure 1, but for soil moisture at 0.1–0.4 m.

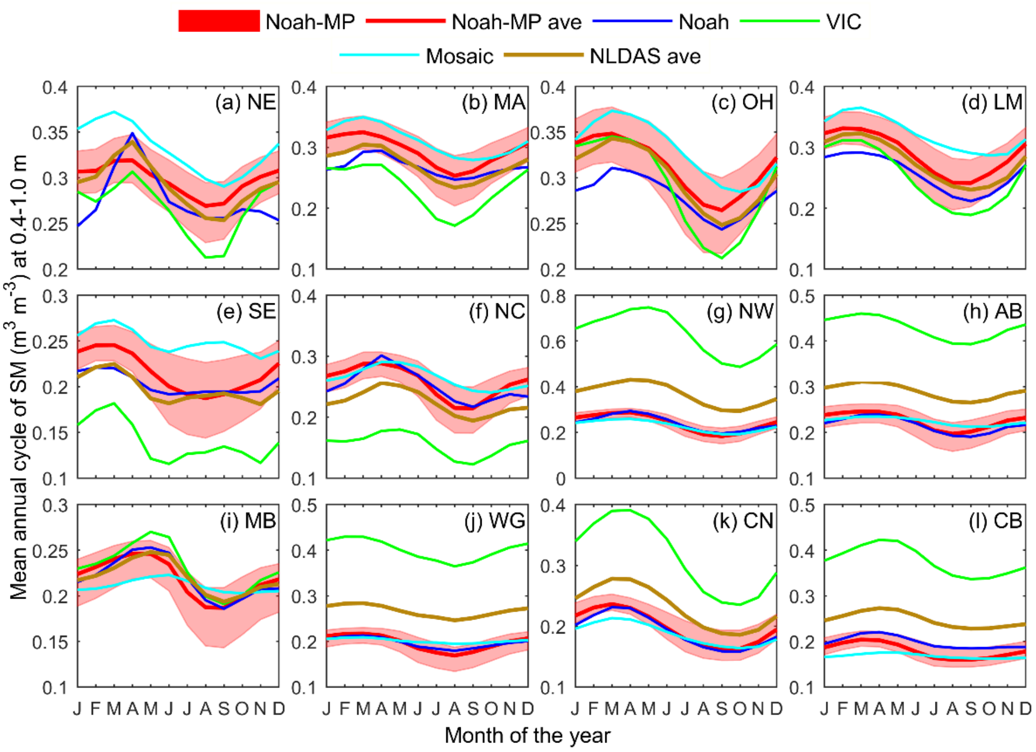

Figure S4. As in Figure 1, but for soil moisture at 0.4–1.0 m.

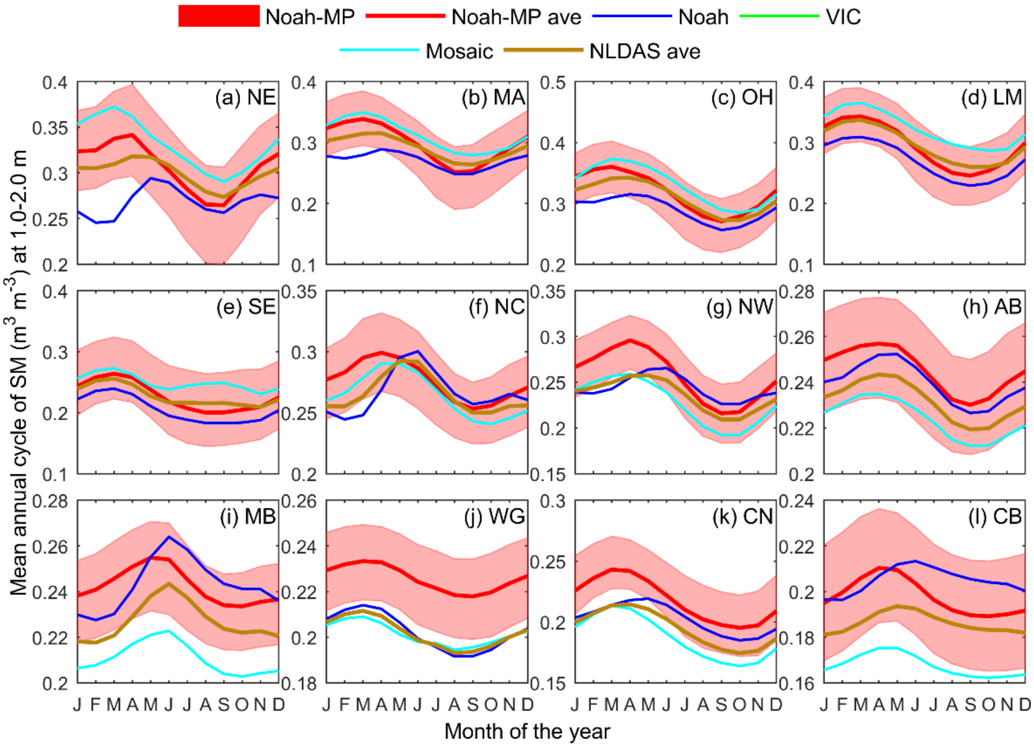

Figure S5. As in Figure 1, but for soil moisture at 1.0–2.0 m.

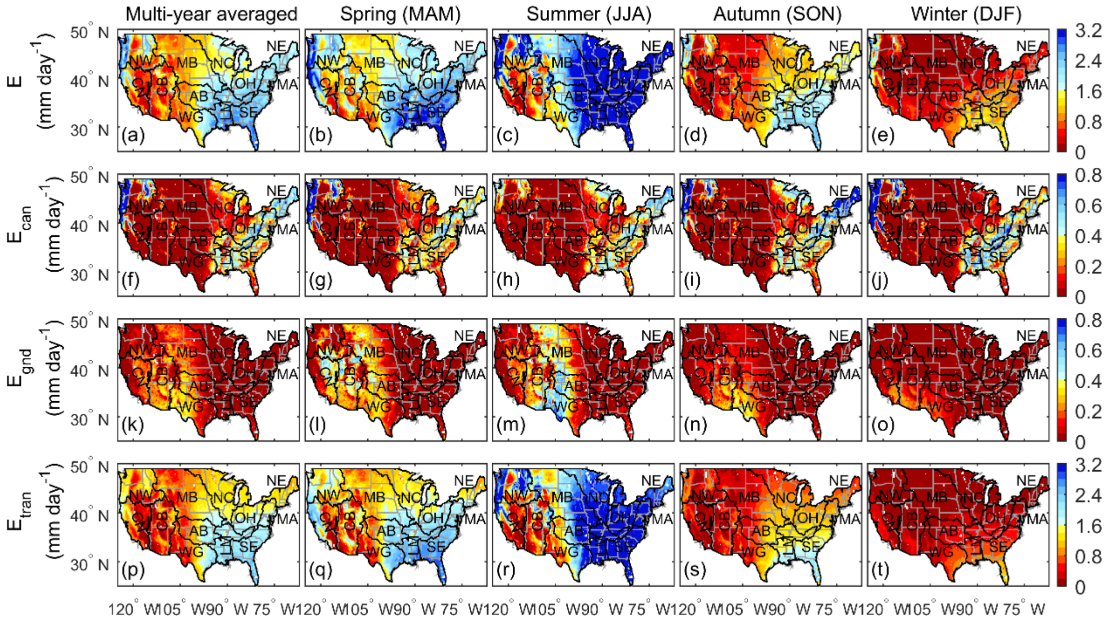

Figure S6. Spatial distribution of the multi-year averaged and seasonally averaged total evapotranspiration (E), canopy evaporation (E_{can}), ground evaporation (E_{gnd}), and transpiration (E_{tran}) from GLEAM.

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