

Supplementary material

Evaluating precipitation products for hydrologic modeling over a large river basin in the Midwestern United States – the Wabash River Watershed

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Table S1. Data source and description for SWAT modeling.

Data type	Description	Source
DEM	US Geological Survey (USGS) National Elevation Dataset (NED)	https://lta.cr.usgs.gov/NED
Land use	National Land Cover Database 2011 (NLCD 2011)	https://www.mrlc.gov/
Soil	State Soil Geographic Data Base	The ArcSWAT built-in soil database
Climate	Daily temperature Daily solar radiation, relative humidity and wind speed	https://www1.ncdc.noaa.gov/pub/data/ghcn/daily/ Weather Generator Data: WGEN_US_COOP_1960_2010

Table S2. Four USGS streamflow gauge stations located in midstream and downstream of the main stream and major tributaries.

ID	Station	Catchment area (km ²)	Latitude	Longitude	Website
Station 1	Wabash River at Terre Haute	3.15×10^4	39°27'57"N	87°25'11"W	https://waterdata.usgs.gov/in/nwis/uv?site_no=03341500
Station 2	White River (IN) at Old US Highway 41 located at Hazleton	3.07×10^4	38°29'23"N	87°33'00"W	https://waterdata.usgs.gov/nwis/inventory/?site_no=03374100
Station 3	Wabash River at Mount Carmel	7.39×10^4	38°23'54"N	87°45'23"W	https://waterdata.usgs.gov/nwis/inventory/?site_no=03377500
Station 4	Little Wabash River at Carmel, IL	0.83×10^4	38°30'39"N	87°17'22"W	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=03381500

Table S3. Calibration (2003–2009) and validation (2010–2013) performance metrics for daily runoff at the four monitoring points of SWAT-GHCN-0.25. NS: Nash-Sutcliffe efficiency.

ID	Calibration					Validation		
	R^2	NS	PBIAS	P factor	R factor	R^2	NS	PBIAS
Station 1	0.78	0.76	-4.90	0.84	1.26	0.81	0.78	-6.64
Station 2	0.80	0.76	-4.00	0.75	1.02	0.85	0.82	-8.58
Station 3	0.72	0.71	-3.00	0.81	1.25	0.79	0.77	-6.63
Station 4	0.84	0.79	-23.00	0.51	1.27	0.81	0.76	-30.73

Table S4. Calibration (2003–2009) and validation (2010–2013) performance metrics for daily runoff at the four monitoring points of SWAT-GHCN-0.385.

ID	Calibration					Validation		
	R^2	NS	PBIAS	P factor	R factor	R^2	NS	PBIAS
Station 1	0.78	0.75	-4.10	0.83	1.25	0.82	0.79	-6.41
Station 2	0.80	0.76	-3.60	0.77	1.03	0.85	0.82	-7.85
Station 3	0.72	0.71	-2.60	0.80	1.24	0.79	0.78	-6.01
Station 4	0.83	0.78	-17.90	0.53	1.27	0.81	0.77	-24.10

Table S5. Performance of TRMM 3B42 and CFSR as input of SWAT with the optimized parameter set derived from SWAT-GHCN-0.25. PBIAS: percent bias.

ID	TRMM 3B42						CFSR					
	Calibration			Validation			Calibration			Validation		
	(2003–2009)			(2010–2013)			(2003–2009)			(2010–2013)		
	R^2	NS	PBIAS	R^2	NS	PBIAS	R^2	NS	PBIAS	R^2	NS	PBIAS
Station 1	0.66	0.51	-20.63	0.69	0.68	-2.41	0.50	0.10	-42.71	0.51	0.12	-37.47
Station 2	0.66	0.61	-4.92	0.63	0.62	-0.44	0.43	0.31	-17.82	0.58	0.40	-36.59
Station 3	0.53	0.34	-9.44	0.46	0.36	-1.18	0.44	0.18	-26.28	0.45	0.13	-35.81
Station 4	0.48	0.29	-22.06	0.53	0.51	4.19	0.58	0.46	-29.46	0.57	0.34	-36.68

Table S6. Final ranges and calibrated values of SWAT-3B42 and SWAT-CFSR parameters.

Parameter	SWAT-3B42		SWAT-CFSR	
	Final range	Best estimation	Final range	Best Estimations
r_CN2.mgt	−0.16/0.16	0.05	−0.06/0.24	0.07
v_ALPHA_BF.gw	0.19/0.57	0.34	0.50/0.97	0.94
v_GW_DELAY.gw	148.36/385.14	157.95	159.13/353.00	171.83
r_GWQMN.gw	−0.48/0.38	−0.31	−0.72/0.43	0.30
v_ALPHA_BNK.rte	0.68/1.00	0.89	0.68/1.00	0.77
v_CH_N2.rte	0.02/0.11	0.05	0.011/0.15	0.10
v_CH_N1.sub	0.00/0.37	0.14	0.06/0.48	0.17
v_EPCO.hru	0.31/0.60	0.51	0.27/0.80	0.45
r_SLSUBBSN.hru	−0.06/0.58	0.22	−0.21/0.34	−0.02
v_ESCO.hru	0.60/1.00	0.69	0.22/0.68	0.36
v_GW_REVAP.gw	0.00/0.08	0.05	0.12/0.18	0.17
v_RCHRG_DP.gw	0.50/0.83	0.59	0.25/0.75	0.42
r_OV_N.hru	0.967/2.85	2.16	1.06/2.36	1.46
v_REVAPMN.gw	138.15/414.51	289.73	234.30/411.00	340.76
v_CH_K2.rte	152.96/384.33	184.08	30.13/222.15	73.24
r_SOL_K(1).sol	4.15/7.96	7.73	0.95/4.65	3.61
r_SOL_AWC(1).sol	5.34/9.00	6.38	5.66/9.00	8.39
v_SFTMP.bsn	−2.22/3.34	−0.13	−1.10/2.05	0.22
v_SMTMP.bsn	−2.32/3.05	−0.30	−3.45/−0.34	−2.32
r_SOL_BD(1).mgt	−0.12/0.36	0.29	−0.08/0.37	0.28

Table S7. Evaluation coefficients for the four stations of SWAT-3B42 in the calibration period and validation periods.

ID	Calibration (2003–2009)					Validation (2010–2013)		
	R^2	NS	PBIAS	P factor	R factor	R^2	NS	PBIAS
Station 1	0.71	0.68	−18.10	0.64	1.18	0.69	0.68	−2.41
Station 2	0.76	0.75	−0.90	0.62	0.86	0.79	0.74	4.76
Station 3	0.76	0.76	−4.60	0.67	1.06	0.76	0.73	4.63
Station 4	0.70	0.70	−7.00	0.44	1.14	0.73	0.65	17.01

Table S8. Evaluation coefficients for the four stations of SWAT-CFSR for the calibration and validation periods.

ID	Calibration (2003–2009)					Validation (2010–2013)		
	R^2	NS	PBIAS	P -factor	R -factor	R^2	NS	PBIAS
Station 1	0.51	0.49	−11.30	0.56	1.14	0.58	0.56	−13.37
Station 2	0.51	0.50	7.50	0.65	0.89	0.72	0.69	−11.71
Station 3	0.60	0.60	1.10	0.69	1.11	0.69	0.67	−11.67
Station 4	0.67	0.66	−8.00	0.43	1.04	0.71	0.70	−19.34

Table S9. List of p values of the optimized SWAT model using four different datasets (sorted by sum of individual sensitivity).

Parameter	SWAT-GHCN-0.25	SWAT-GHCN-0.385	SWAT-3B42	SWAT-CFSR
r_CN2.mgt	0.00	0.00	0.00	0.00
v_ALPHA_BNK.rte	0.13	0.11	0.00	0.02
v_CH_N2.rte	0.10	0.11	0.00	0.11
v_RCHRG_DP.gw	0.21	0.21	0.04	0.01
v_ESCO.hru	0.14	0.20	0.00	0.22
v_CH_N1.sub	0.01	0.03	0.74	0.01
r_SOL_AWC(1).sol	0.08	0.09	0.31	0.40
r_SOL_K(1).sol	0.30	0.30	0.23	0.24
v_REVAPMN.gw	0.16	0.17	0.97	0.10
v_EPCO.hru	0.15	0.16	0.56	0.96
r_GWQMN.gw	0.54	0.46	0.45	0.40
r_SOL_BD(1).mgt	0.53	0.60	0.17	0.63
v_SFTMP.bsn	0.60	0.64	0.09	0.69
v_CH_K2.rte	0.54	0.65	0.00	0.84
v_GW_DELAY.gw	0.37	0.39	0.72	0.56
v_ALPHA_BF.gw	0.37	0.38	0.44	0.92
r_SLSUBBSN.hru	0.90	0.90	0.30	0.48
v_SMTMP.bsn	0.69	0.63	0.59	0.78
v_GW_REVAP.gw	0.93	0.92	0.29	0.98
r_OV_N.hru	0.82	0.81	0.99	0.55

Table S10. Performance of the CFSR temperature dataset as input of SWAT with the optimized parameter set derived from SWAT-GHCN-0.385.

ID	Calibration (2003–2009)			Validation (2010–2013)		
	R^2	NS	PBIAS	R^2	NS	PBIAS
Station 1	0.76	0.73	0.98	0.83	0.79	−1.16
Station 2	0.78	0.74	0.40	0.84	0.81	−4.08
Station 3	0.72	0.70	1.77	0.80	0.78	−1.97
Station 4	0.82	0.78	−12.05	0.80	0.77	−19.88

Table S11. Final ranges, best estimations and P values for SWAT calibration using Daymet rainfall and temperature inputs.

Parameters	Final range	Best estimation	P value
r_CN2.mgt	-0.12/0.19	0.07	0.00
v_ALPHA_BF.gw	0.25/0.76	0.45	0.85
v_GW_DELAY.gw	30.00/193.25	42.65	0.26
r_GWQMN.gw	-0.43/0.25	-0.41	0.31
v_ALPHA_BNK.rte	0.60/0.96	0.78	0.00
v_CH_N2.rte	0.02/0.15	0.07	0.07
v_CH_N1.sub	0.00/0.27	0.07	0.28
v_EPCO.hru	0.06/0.66	0.57	0.48
r_SLSUBBSN.hru	0.04/0.43	0.10	0.67
v_ESCO.hru	0.59/0.94	0.74	0.21
v_GW_REVAP.gw	0.02/0.10	0.03	0.11
v_RCHRG_DP.gw	0.59/0.86	0.86	0.36
r_OV_N.hru	-0.80/1.16	1.07	0.82
v_REVAPMN.gw	129.15/387.48	257.41	0.39
v_CH_K2.rte	0.00/182.00	25.03	0.02
r_SOL_K(1).sol	5.97/9.00	7.25	0.20
r_SOL_AWC(1).sol	0.44/5.15	4.81	0.70
v_SFTMP.bsn	-2.03/3.90	-1.29	0.96
v_SMTMP.bsn	-4.89/-0.87	-2.08	0.30
r_SOL_BD(1).mgt	-0.23/0.32	-0.03	0.64

Table S12. Calibration (2003–2009) and validation (2010–2013) performance metrics for daily runoff at the four monitoring points with Daymet rainfall and temperature as inputs.

ID	Calibration (2003–2009)					Validation (2010–2013)		
	R^2	NS	PBIAS	P factor	R factor	R^2	NS	PBIAS
Station 1	0.78	0.76	3.80	0.74	1.11	0.79	0.77	1.01
Station 2	0.79	0.76	3.70	0.69	0.91	0.84	0.80	4.45
Station 3	0.69	0.68	5.10	0.72	1.11	0.74	0.73	4.35
Station 4	0.81	0.79	-12.30	0.50	1.22	0.82	0.80	-12.80

SWAT-GHCN-0.25 and SWAT-GHCN-0.385 obtained identical optimized parameter sets after calibration with three iterations and 1000 LH samples for each iteration. To investigate if the SUFI-2 framework could identify different optimal parameter sets under the circumstance that two rainfall inputs are very close, the three-iteration calibrated SWAT-GHCN-0.25 and SWAT-GHCN-0.38 were further subjected to another two iterations with 2000 LH sample for each iteration. The final ranges and best estimations are listed in [Table S14](#) and the indicators used for measuring the performance of model outputs are listed in [Table S14](#). As shown in [Table S13](#), SWAT-GHCN-0.25 and SWAT-GHCN-0.385 identified the same optimal parameter space, but the optimal parameter sets differ from each other slightly. More iterations led to

better performance of simulations in fitting observations (Table S14); however, at the expense of model uncertainty. Overall, even though GHCN-D 0.25 and GHCN-D 0.385 are very close in representing the patterns of precipitation, SUFI-2 can still obtain the global optimized parameter sets when the parameter spaces are small enough. The results also illustrate the fact that the inverse model has a tendency to ill-posedness, which means that different parameter sets may lead to similar model outputs.

Table S13. Final ranges and best estimations of SWAT-GHCN-0.25 and SWAT-GHCN-0.385 after two additional iterations calibration.

Parameter	SWAT-GHCN-0.25		SWAT-GHCN-0.385	
	Final range	Best estimation	Final range	Best estimation
r_CN2.mgt	0.0065/0.1063	0.0115	0.0065/0.1063	0.0322
v_ALPHA_BF.gw	0.31/0.61	0.55	0.31/0.61	0.53
v_GW_DELAY.gw	27.37/132.71	32.25	27.37/132.71	35.04
r_GWQMN.gw	−0.65/−0.39	−0.64	−0.65/−0.39	−0.58
v_ALPHA_BNK.rte	0.86/0.96	0.89	0.86/0.96	0.87
v_CH_N2.rte	0.032/0.069	0.066	0.032/0.069	0.066
v_CH_N1.sub	0.000/0.133	0.075	0.000/0.133	0.031
v_EPCO.hru	0.13/0.23	0.19	0.13/0.23	0.15
r_SLSUBBSN.hru	0.09/0.35	0.11	0.09/0.35	0.15
v_ESCO.hru	0.49/0.61	0.53	0.49/0.61	0.58
v_GW_REVAP.gw	0.0200/0.0529	0.0242	0.0200/0.0529	0.0420
v_RCHRG_DP.gw	0.01/0.27	0.02	0.01/0.27	0.09
r_OV_N.hru	1.58/2.53	2.10	1.58/2.53	1.96
v_REVAPMN.gw	82.42/152.58	109.20	82.42/152.58	107.73
v_CH_K2.rte	96.36/289.10	151.24	96.36/289.10	185.93
r_SOL_K(1).sol	7.11/9.00	8.12	7.11/9.00	7.88
r_SOL_AWC(1).sol	−0.60/0.53	−0.07	−0.60/0.53	0.15
v_SFTMP.bsn	−2.78/−0.32	−2.38	−2.78/−0.32	−1.71
v_SMTMP.bsn	2.14/4.00	2.74	2.14/4.00	2.97
r_SOL_BD(1).mgt	0.28/0.45	0.33	0.28/0.45	0.32

Table S14. Performance metrics of SWAT-GHCN-0.25 and SWAT-GHCN-0.385 after two additional iterations.

ID	SWAT-GHCN-0.25						SWAT-GHCN-0.385					
	Calibration (2003–2009)			Validation (2010–2013)			Calibration (2003–2009)			Validation (2010–2013)		
	R^2	NS	PBIAS	R^2	NS	PBIAS	R^2	NS	PBIAS	R^2	NS	PBIAS
Station 1	0.79	0.78	0.28	0.80	0.79	−5.21	0.79	0.78	0.24	0.81	0.81	−1.90
Station 2	0.83	0.81	−1.33	0.88	0.86	−9.62	0.83	0.81	−1.41	0.89	0.88	−3.07
Station 3	0.82	0.81	1.49	0.88	0.87	−5.84	0.81	0.81	1.04	0.87	0.86	−0.67
Station 4	0.86	0.85	−7.25	0.87	0.85	−18.95	0.85	0.84	−1.23	0.85	0.84	−4.67

