Supplementary Material to paper 'Using evapotranspiration signatures to assess evapotranspiration realism in rainfall-runoff models'

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This supporting information contains:

- Section S1: Evaluating the reliability of remotely sensed vs. flux tower AET data
- Section S2: Optimised objective functions
- Section S3: AET signatures for a more representative subset of sites
- Section S4: Split sample testing independent objective function values, and AET signature results

Section S1: Evaluating the reliability of remotely sensed vs. flux tower AET data

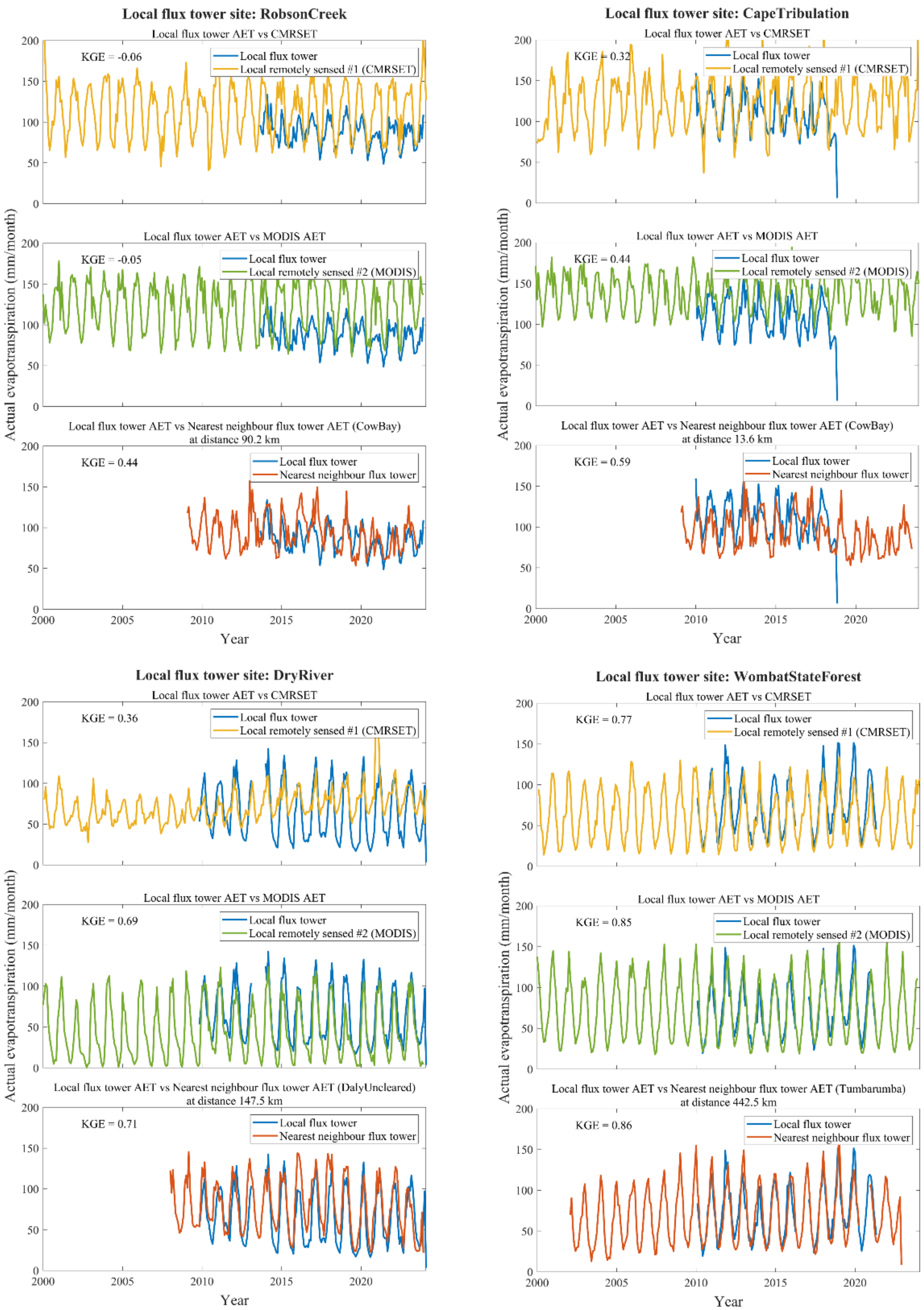
The quality of remotely sensed information extracted at the site in question was compared with the quality of information from "nearest neighbour" flux tower sites that are 10s to 100s of kilometers away. The results show that the distant flux tower information is often superior to the remotely sensed at-site information, and exceptions to this have clear underlying reasons (see Table S1). Although we acknowledge issues about the representativeness of flux towers (given differences in footprint and spatial separation), this analysis indicates that the flux tower information is still the best source of information. This is particularly the case when you consider that the separation between the flux tower and the catchment in our paper is typically much smaller than the distance between the pairs of flux towers that are tested here. Thus, if the comparison flux towers still provide a better (or at least comparable) result despite this distance, it is very likely that the adopted flux tower information is superior to the remotely sensed alternative for the selected catchments.

Table S1: Comparison of the quality of remotely sensed information at the target flux tower with the quality of information at the comparison flux tower.

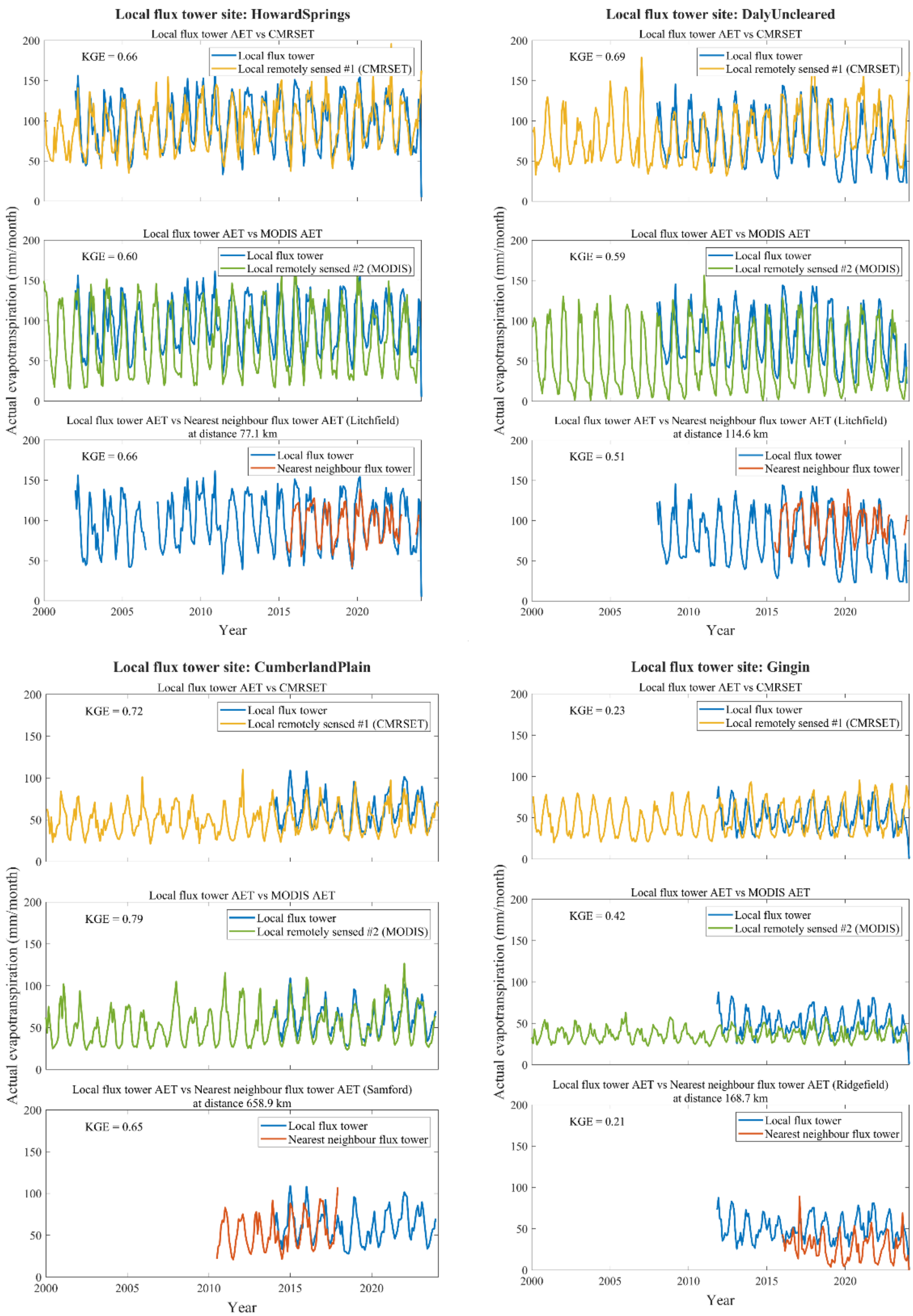
Legend for Table S1:

- [green] Comparison flux tower is the best representative of the target flux tower than remotely sensed AET at the target site
- [yellow] Comparison flux tower is not the best option, but the score is broadly comparable with KGEs of remotely sensed AET at the target site
- [red] The lowest KGE score is observed for the comparison flux tower, but reasons are apparent (see "comment").

Target flux tower	Comparison “nearest neighbour” flux tower	Distance between target and comparison flux tower (km)	Comparison (KGE) for target flux AET versus…			Results	Comment
			Remotely sensed dataset # 1 (CMRSET)	Remotely sensed dataset #2 (MODIS)	Comparison “nearest neighbour” flux tower		
Robson Creek	Cow Bay	90.2	-0.06	-0.05	0.44	Comparison flux tower AET is the best option over remotely sensed AET at the target site	
Cape Trib-ulation	Cow Bay	13.6	0.32	0.44	0.59		
Dry River	Daly Uncleared	147.5	0.36	0.69	0.71		
Wombat State Forest	Tumba-rumba	442.5	0.77	0.85	0.86		Surprising result, given comparison and target sites are 400 km distant.
Howard Springs	Litchfield	77.1	0.66	0.6	0.66	Comparison flux tower gives a score that is broadly comparable with the scores for remotely sensed AET.	Remarkable result (equal scores) given Howard Springs is wetter than Litchfield.
Daly Uncleared	Litchfield	114.6	0.69	0.59	0.51		Litchfield is considerably wetter than the Daly uncleared site, yet the scores are broadly comparable.
Cumber-land Plain	Samford	658.9	0.72	0.79	0.65		Surprising result, given comparison and target sites are more than 600 km distant.
Gingin	Ridgefield	168.7	0.23	0.42	0.21	Lowest KGE score is observed for comparison flux tower.	The difference is easily explained as Gingin is located very close to the coast, whereas Ridgefield is >150 km from the coast. No such situation arises in the submitted manuscript, except perhaps for Samford (to a small degree)
Sturt Plain	Dry River	213	0.63	0.45	0.31		The two flux towers have different climate conditions, for example by Koppen-Geiger class, see below. No differences of this magnitude occur in the submitted manuscript. • Sturt Plain – Arid steppe hot • Dry River – Tropical savanna



Local flux tower site: RobsonCreek
Local flux tower AET vs CMRSET
KGE = -0.06
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = -0.05
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (CowBay)
at distance 90.2 km
KGE = 0.44
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: CapeTribulation
Local flux tower AET vs CMRSET
KGE = 0.32
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.44
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (CowBay)
at distance 13.6 km
KGE = 0.59
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: DryRiver
Local flux tower AET vs CMRSET
KGE = 0.36
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.69
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (DalyUncleared)
at distance 147.5 km
KGE = 0.71
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: WombatStateForest
Local flux tower AET vs CMRSET
KGE = 0.77
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.85
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (Tumbarumba)
at distance 442.5 km
KGE = 0.86
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year


Local flux tower site: HowardSprings
Local flux tower AET vs CMRSET
KGE = 0.66
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.60
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (Litchfield) at distance 77.1 km
KGE = 0.66
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: DalyUncleared
Local flux tower AET vs CMRSET
KGE = 0.69
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.59
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (Litchfield) at distance 114.6 km
KGE = 0.51
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: CumberlandPlain
Local flux tower AET vs CMRSET
KGE = 0.72
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.79
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (Samford) at distance 658.9 km
KGE = 0.65
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year
Local flux tower site: Gingin
Local flux tower AET vs CMRSET
KGE = 0.23
Local flux tower
Local remotely sensed #1 (CMRSET)
Local flux tower AET vs MODIS AET
KGE = 0.42
Local flux tower
Local remotely sensed #2 (MODIS)
Local flux tower AET vs Nearest neighbour flux tower AET (Ridgefield) at distance 168.7 km
KGE = 0.21
Local flux tower
Nearest neighbour flux tower
Actual evapotranspiration (mm/month)
Year

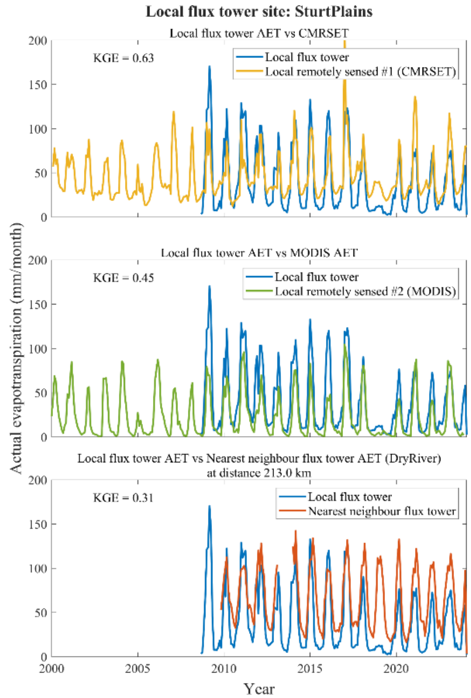


Figure S1: Comparison of local flux tower AET, at site remotely sensed AET, and nearest neighbour flux tower AET.

Section S2: Optimised objective functions

Table S2: Optimised objective function values of the model calibrated to discharge only.

Ozflux tower site	Nearest catchment ID	Optimised values of the objective function (OF) $OF_Q = \frac{1}{2}\left(KGE_Q + KGE_{Q^{0.2}}\right) - 5\lvert\ln(B+1)\rvert^{2.5}$				
		SIMHYD	IHACRES	VIC	SACRAMENTO	GR4J
Sturt Plains	G9030124	0.72	0.78	0.48	0.75	0.65
Ridgefield	614224	0.82	0.88	0.76	0.83	0.92
Gingin	617003	0.76	0.80	0.83	0.80	0.84
Dry River	G8140011	0.68	0.82	0.36	0.80	0.54
Daly Uncleared	G8140063	0.62	0.90	0.69	0.84	0.78
Cumberland Plains	212260	0.65	0.81	0.66	0.75	0.83

Samford	143107A	0.74	0.84	0.67	0.79	0.70
Wombat State Forest	407221	0.83	0.81	0.86	0.86	0.83
Howard Springs	G8150018	0.83	0.89	0.78	0.91	0.85
Litchfield	G8150180	0.74	0.95	0.73	0.92	0.95
Robson Creek	111007A	0.84	0.83	0.69	0.92	0.87
Tumbarumba	410061	0.79	0.83	0.76	0.84	0.82
Cow Bay	108002A	0.78	0.82	0.74	0.86	0.84
Cape Tribulation	108003A	0.81	0.82	0.64	0.85	0.88

Table S3: Optimised objective function values of models calibrated to discharge and flux tower AET.

Ozflux tower site	Nearest catchment ID	Optimised values of the objective function (OF) $OF_{Q+AET} = \frac{1}{2}(OF_Q + OF_{AET})$ where, $OF_Q = \frac{1}{2}\left(KGE_Q + KGE_{Q^{0.2}}\right) - 5\|\ln(B+1)\|^{2.5}$ $OF_{AET} = \frac{1}{2}(KGE_{AET^{0.5},NoMean,Daily} + KGE_{AET^{0.5},NoMean,Monthly})$				
		SIMHYD	IHACRES	VIC	SACRAMENTO	GR4J
Sturt Plains	G9030124	0.64	0.40	0.70	0.80	0.64
Ridgefield	614224	0.72	0.65	0.70	0.69	0.78
Gingin	617003	0.64	0.60	0.74	0.70	0.71
Dry River	G8140011	0.57	0.35	0.65	0.79	0.49
Daly Uncleared	G8140063	0.68	0.78	0.72	0.73	0.77
Cumberland Plains	212260	0.64	0.68	0.65	0.66	0.68
Samford	143107A	0.50	0.82	0.70	0.73	0.56
Wombat State Forest	407221	0.70	0.79	0.82	0.79	0.78
Howard Springs	G8150018	0.69	0.75	0.73	0.71	0.63
Litchfield	G8150180	0.63	0.76	0.69	0.61	0.62
Robson Creek	111007A	0.67	0.70	0.61	0.49	0.72
Tumbarumba	410061	0.66	0.77	0.77	0.78	0.82
Cow Bay	108002A	0.60	0.66	0.63	0.68	0.69

Cape Tribulation	108003A	0.55	0.69	0.33	0.53	0.70

Section S3: AET signatures for a more representative subset of sites

The purpose of this section is to compare AET signatures derived from simulated AET and flux tower AET for a subset of sites. This subset was selected based on the proximity of flux towers (either very close to or within the catchments) and similarity in dominant land cover between the catchments and flux tower locations. Out of 14 sites, 9 met these criteria and the corresponding results are presented in Figure S3 to S10. Overall, the subset figures do not show any substantial change from the results obtained using all 14 sites.

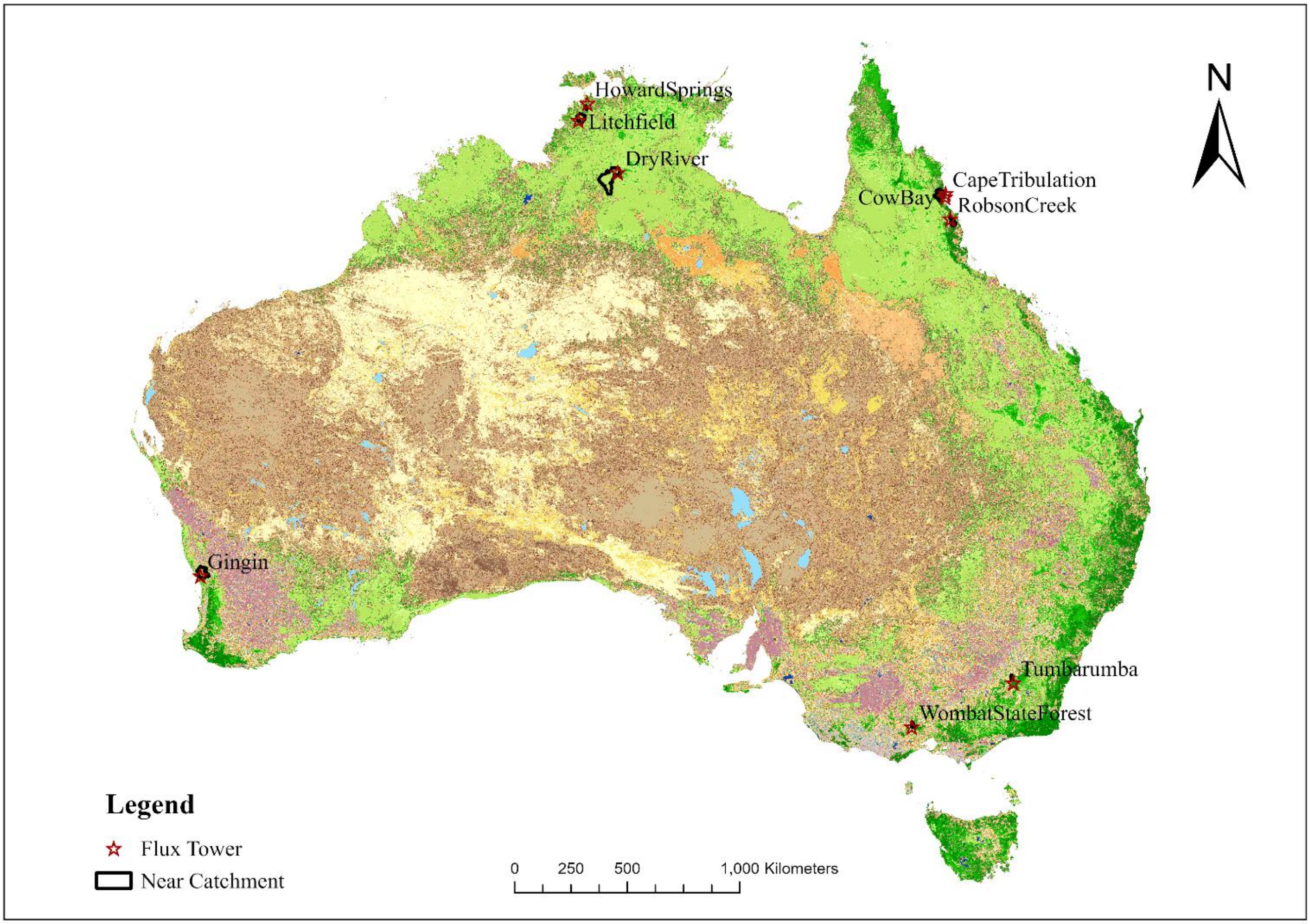


Figure S2: Map of the subset of paired catchments and flux towers.

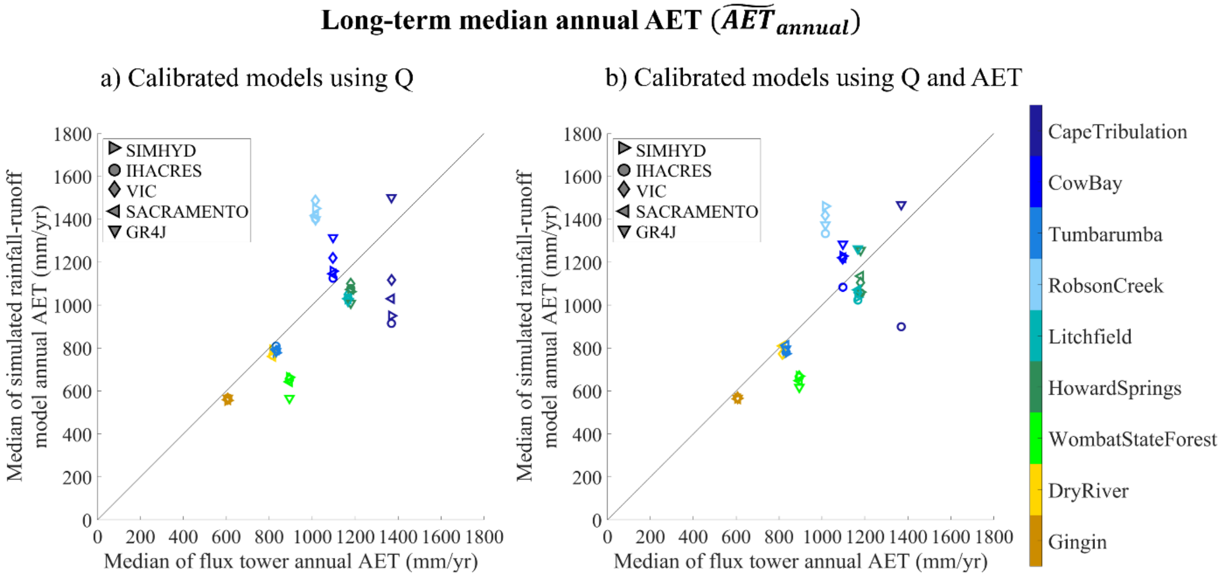


Figure S3: Comparison of long-term median annual AET ($\widetilde{AET}_{annual}$) between models a) calibrated using streamflow (Q) only, and b) calibrated using Q and flux tower AET, and flux towers.

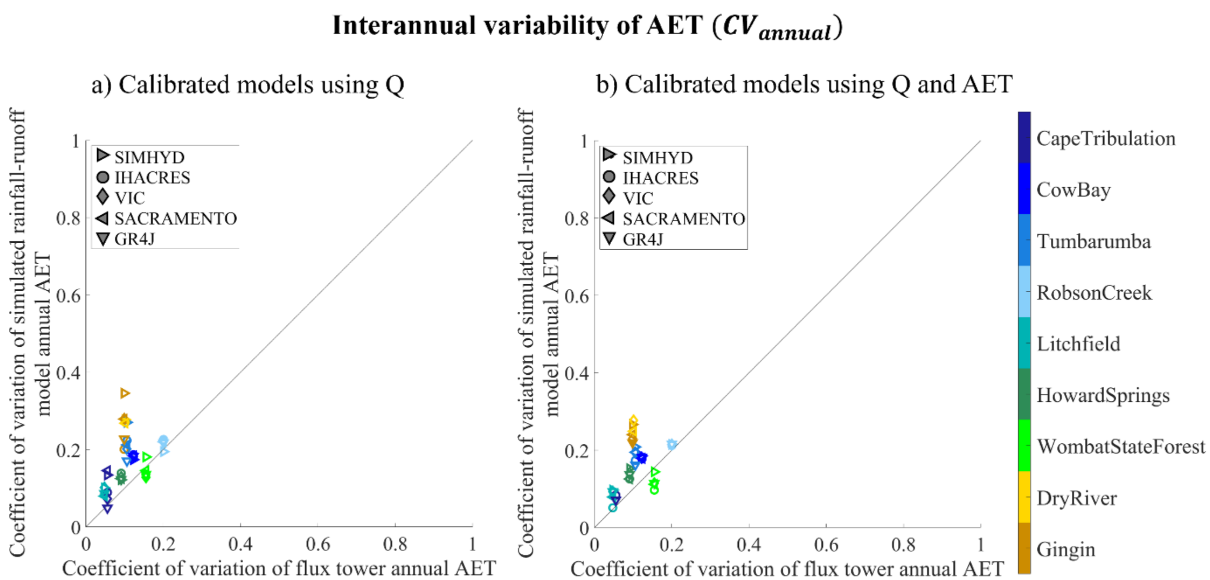


Figure S4: Comparison of interannual variability of AET (CV_{annual}) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

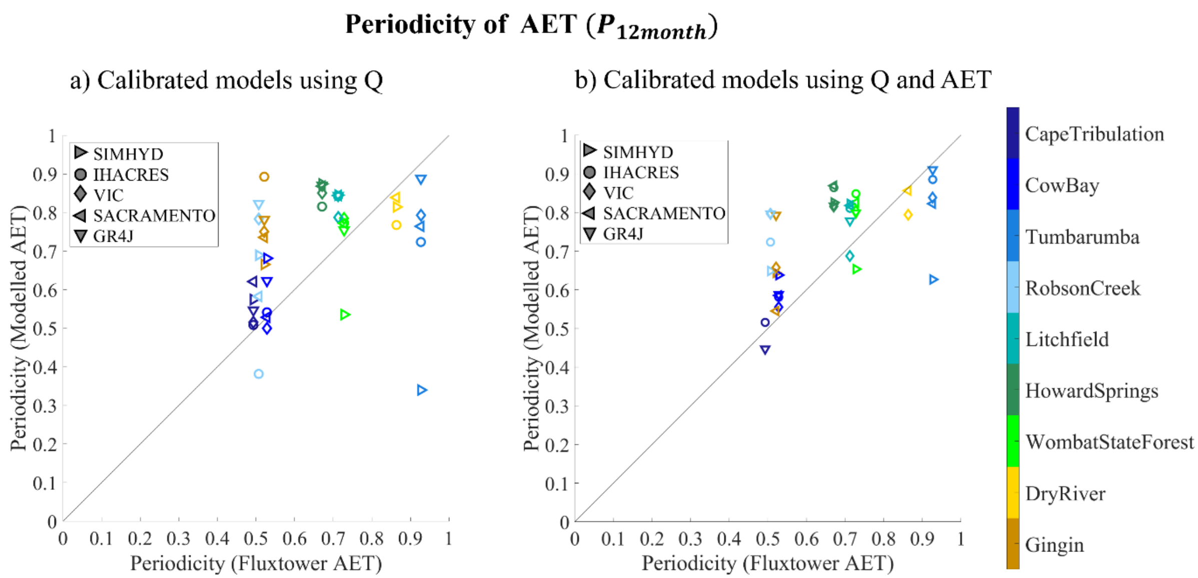


Figure S5: Comparison of periodicity of AET ($P_{12month}$) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

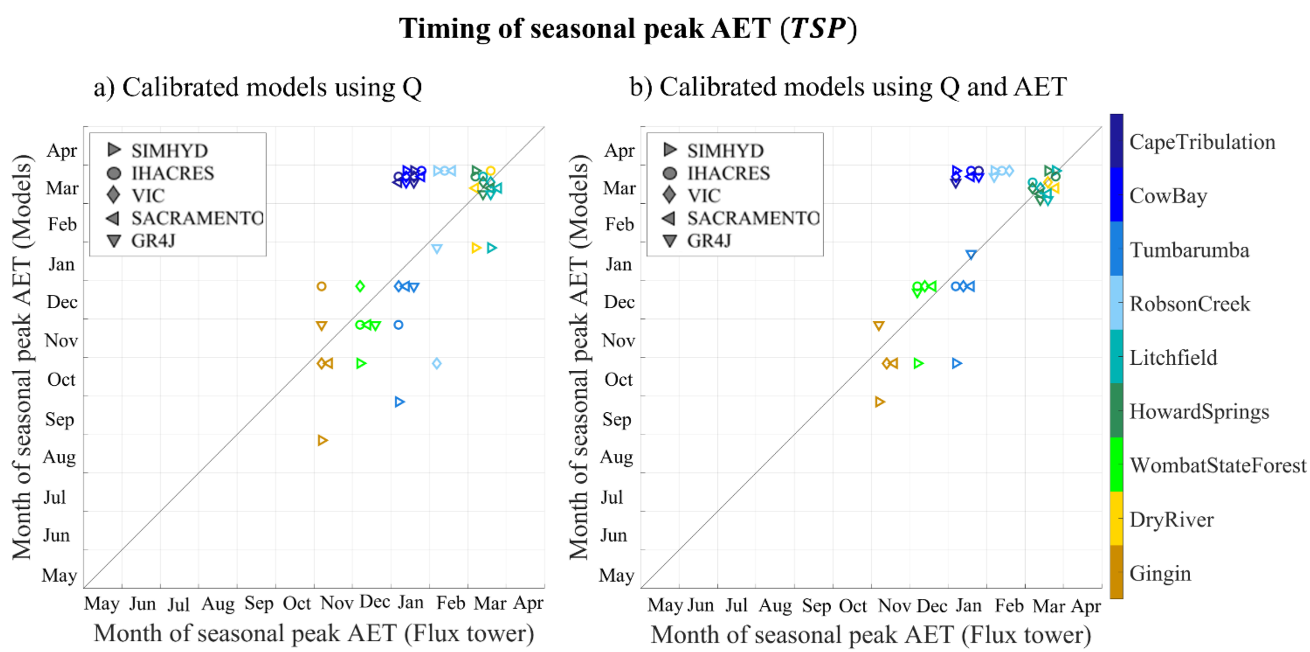


Figure S6: Comparison of timing of seasonal peak (TSP) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers (Note that this signature takes integer values only (i.e., either one calendar month or the next), leading to several points overlying the same plotting position; to make every point visible we subject each point to a jitter (i.e., a unique offset within the same grid cell)).

Monthly variability of AET ($CV_{monthly}$)

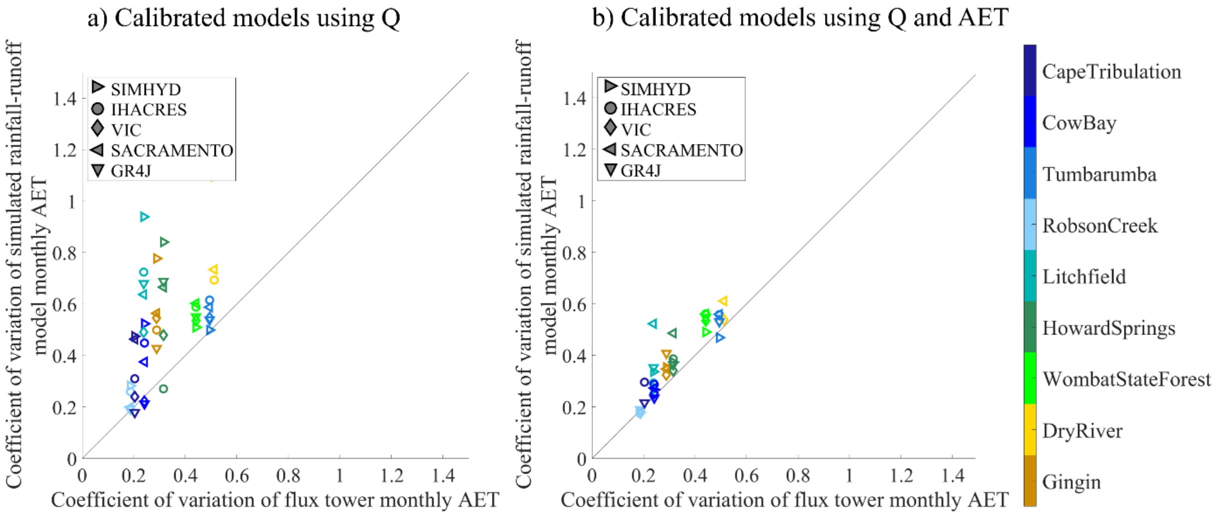


Figure S7: Comparison of monthly variability of AET ($CV_{monthly}$) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

Water Stress (WS)

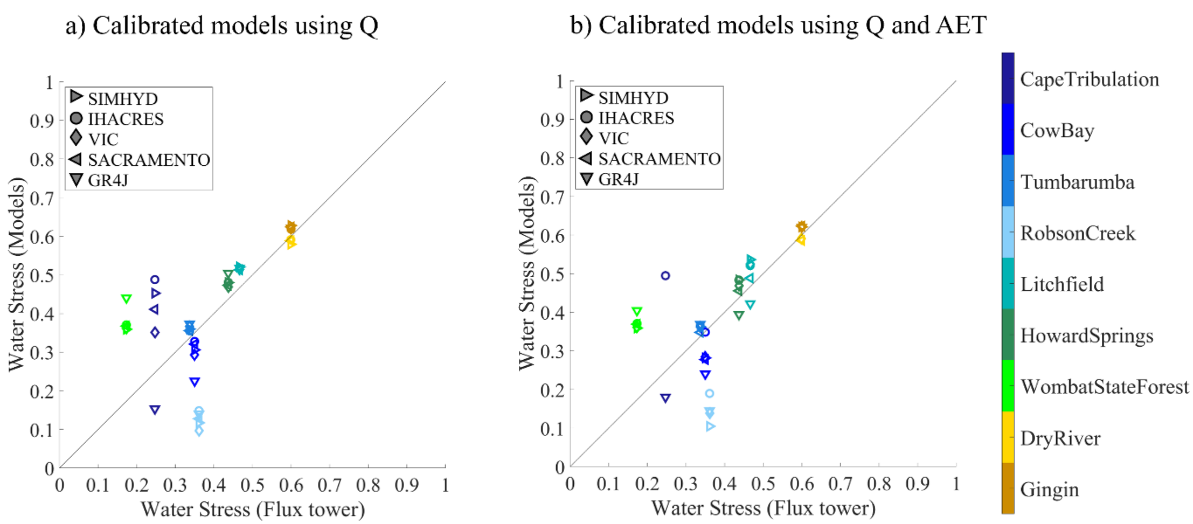


Figure S8: Comparison of water stress (WS) estimated between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

AET asynchronicity to PET (*AAP*)

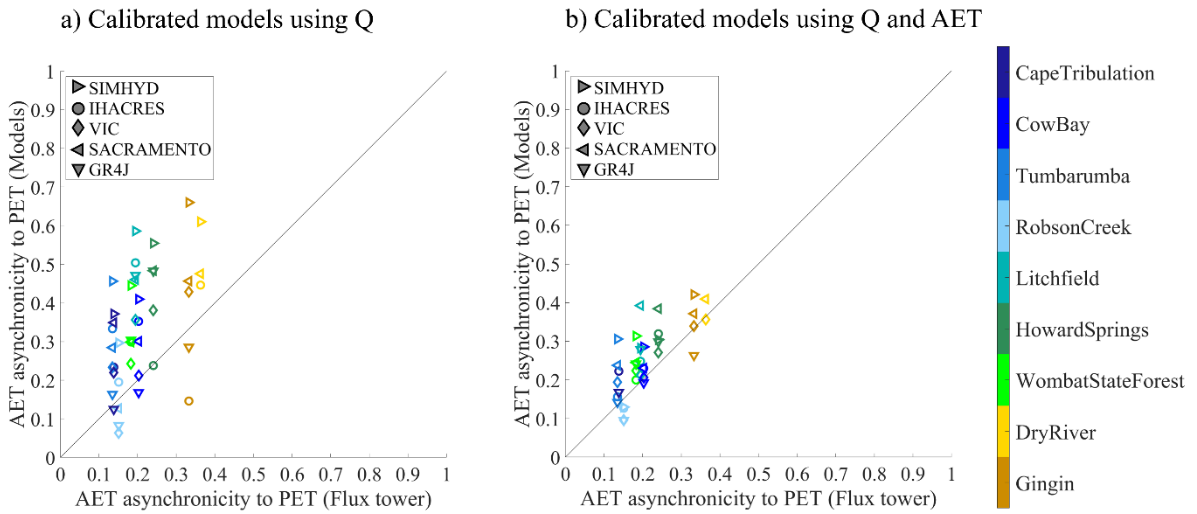


Figure S9: Comparison of AET asynchronicity to PET (AAP) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

AET responsiveness to a rainfall event (*R*)

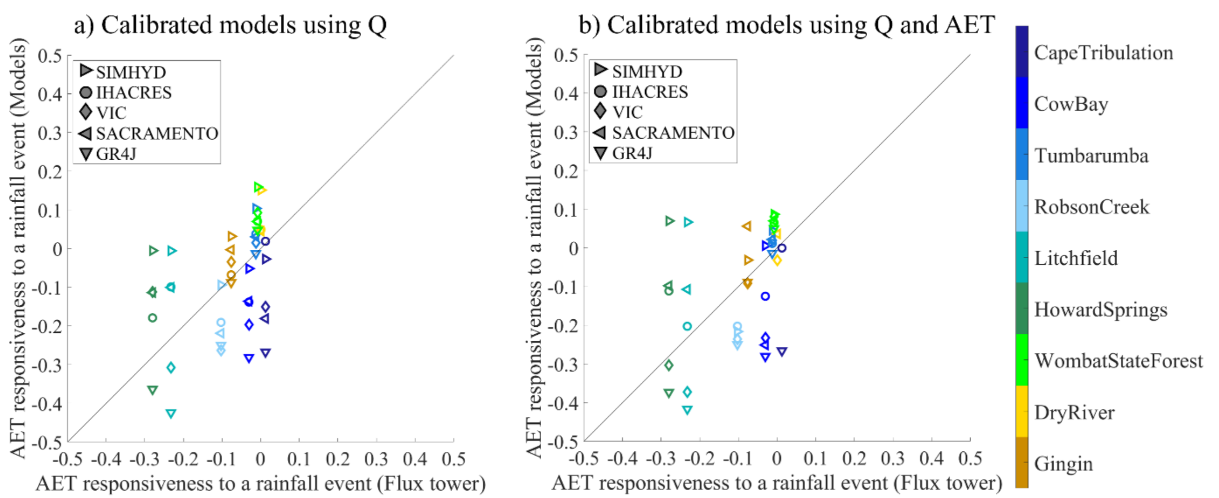


Figure S10: Comparison of index of AET responsiveness to a rainfall event (R) between models a) calibrated using Q only, and b) calibrated using Q and flux tower AET, and flux towers.

Section S4: Split sample testing independent objective function values, and AET signature results

As mentioned in the manuscript, two separate calibrations and evaluations were conducted using split sampling data, and the independent figures for objective function values and signature results are shown below.

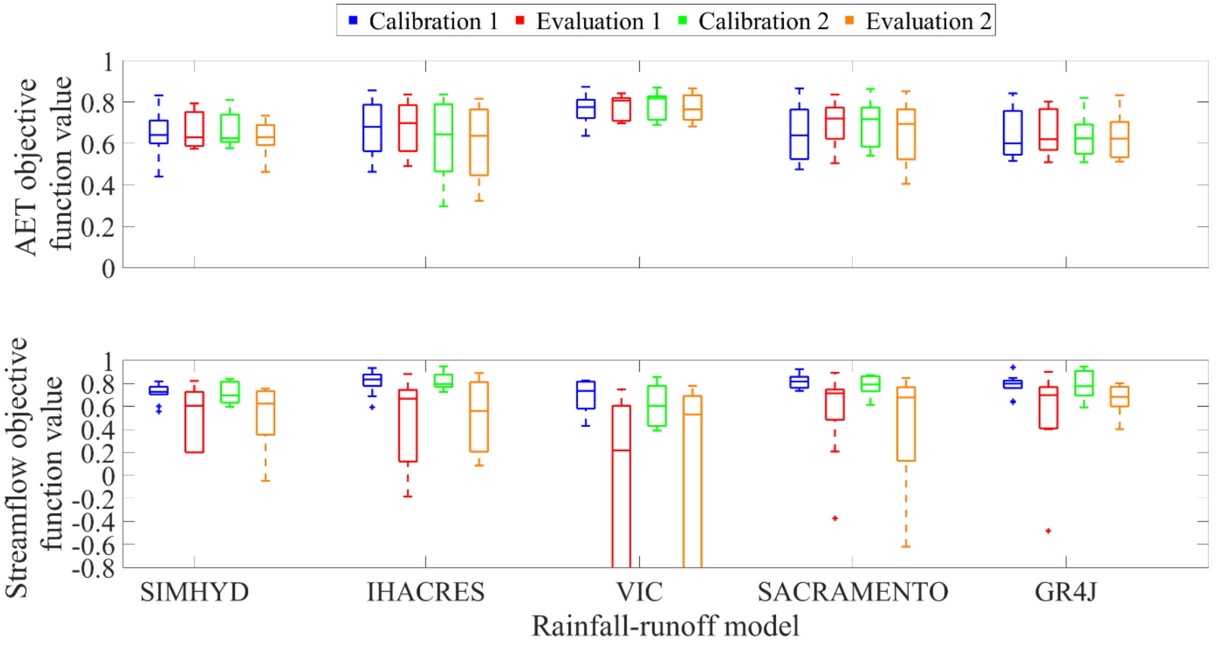


Figure S11: Distribution of objective function values for streamflow and AET during the calibration and evaluation periods in models used for AET signature calculations.

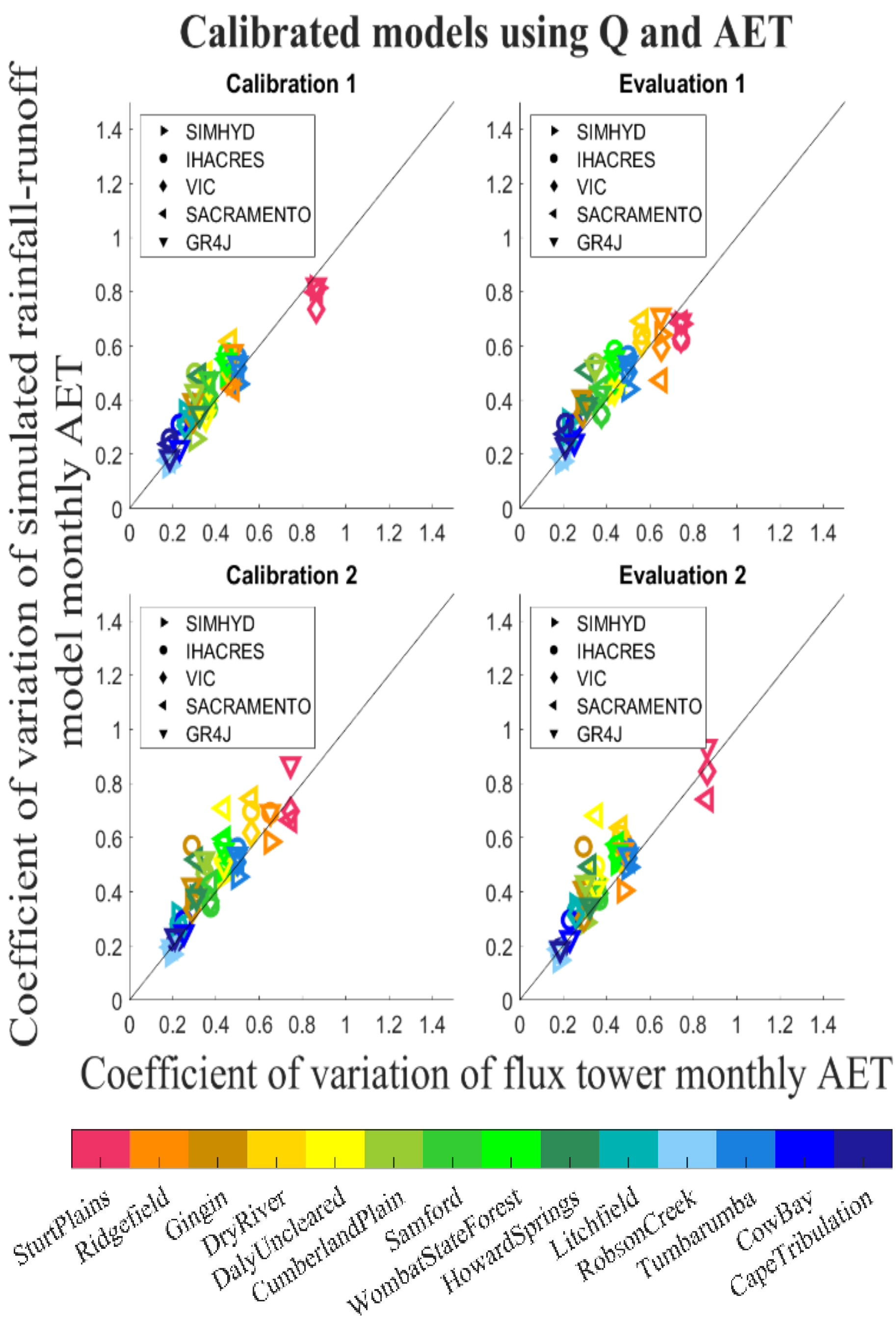


Figure S12: Coefficient of variation (CV) of monthly simulated AET vs CV of monthly flux tower AET over calibration and independent evaluation periods.

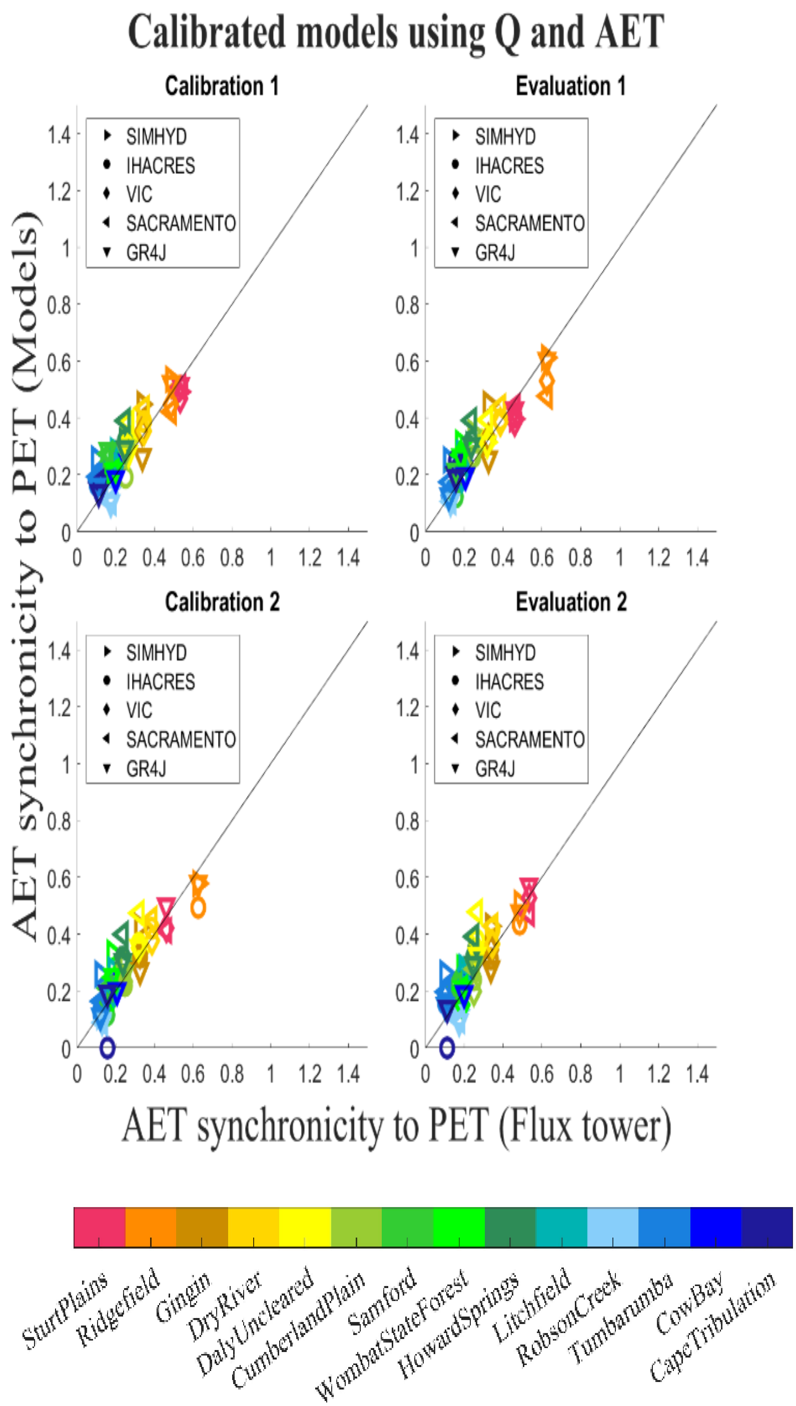


Figure S13: AET aysnchroncity to PET (AAP) calculated using simulated monthly AET vs AAP calculated using monthly flux tower over the calibration and independent evaluation periods.