

**Large Scale Evaluation of Relationships between Hydrological Signatures and Processes**

H. McMillan<sup>1</sup>, S. J. Gnann<sup>2</sup>, and R. Araki<sup>1</sup>

<sup>1</sup>Department of Geography, San Diego State University, San Diego, CA, USA

<sup>2</sup>Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany

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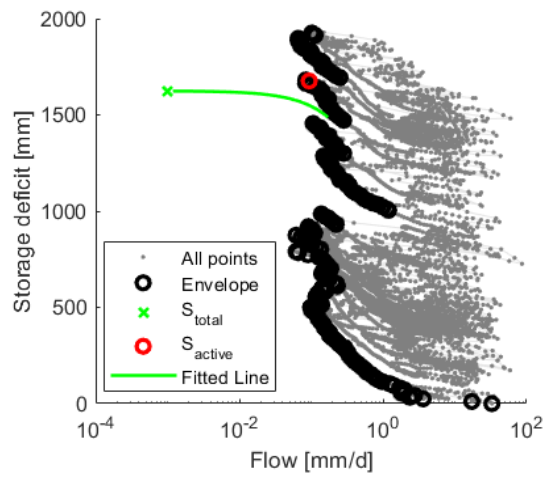
Tables S1 to S6

**Introduction**

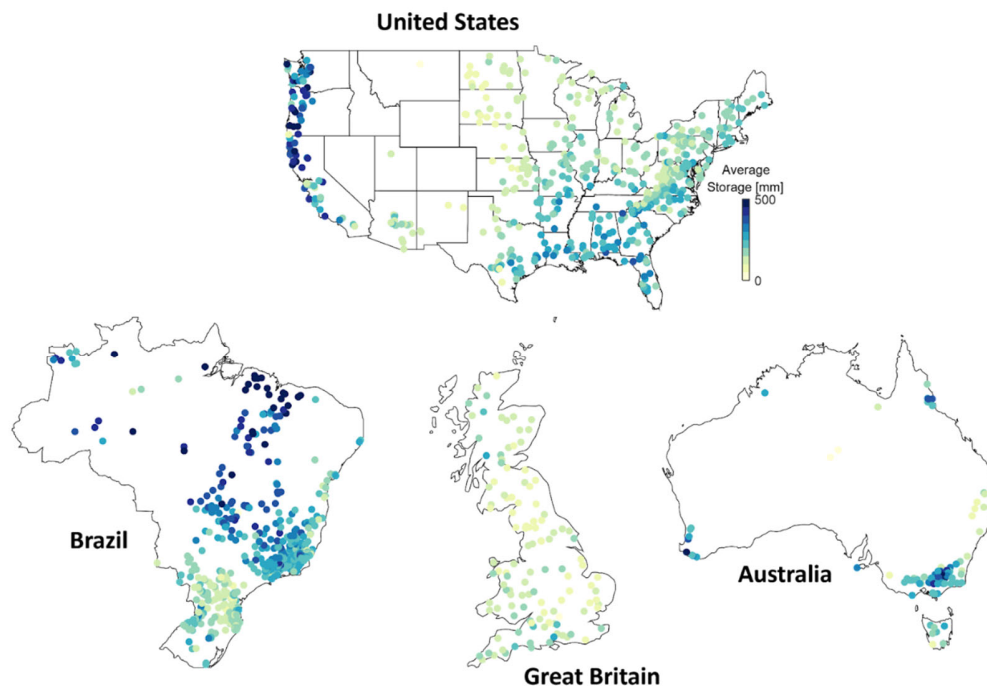
This supporting information contains Figures and Tables that were not included in the main manuscript. Figures and Tables present either additional information or full results of the analysis.

Figure S1 illustrates the uncertainties in calculating StorageFraction signatures. Figures S2 to S9 present maps of eight selected signatures (AverageStorage, EventRR, RecessionParameters\_b, BaseflowRecessionK, IE\_effect, SE\_effect, IE\_thresh, and SE\_thresh). Figures S10 and S11 present relationships between signatures and aridity.

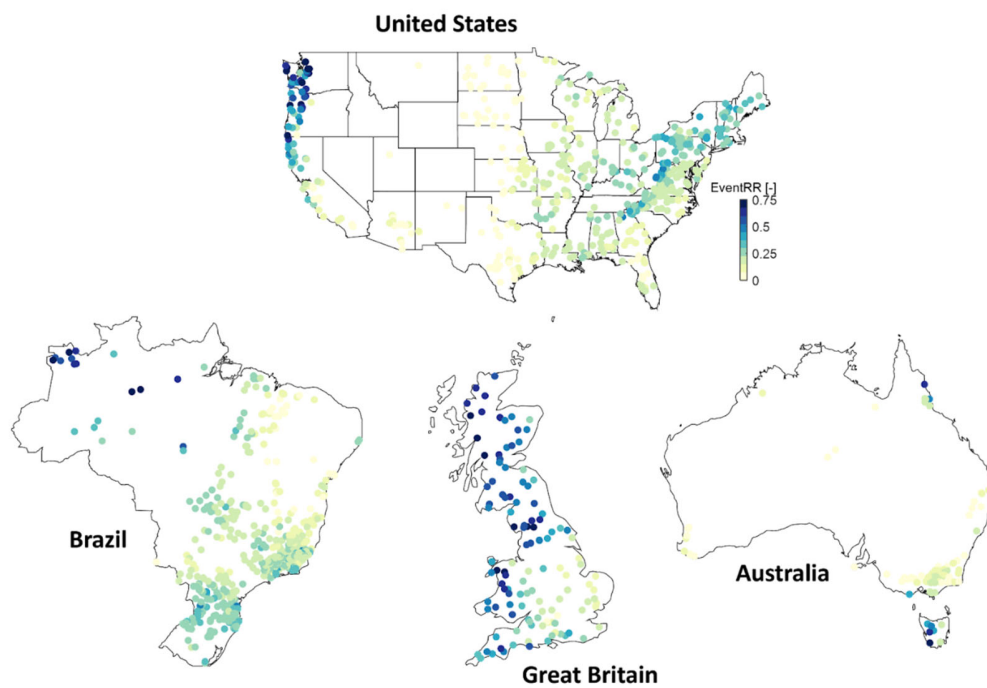
Tables S1 and S2 provide additional information on signature selection and calculation methods. Tables S3 and S4 show signature distributions converted to percentiles. Tables S5 and S6 show rank correlations of signature values and aridity by country.



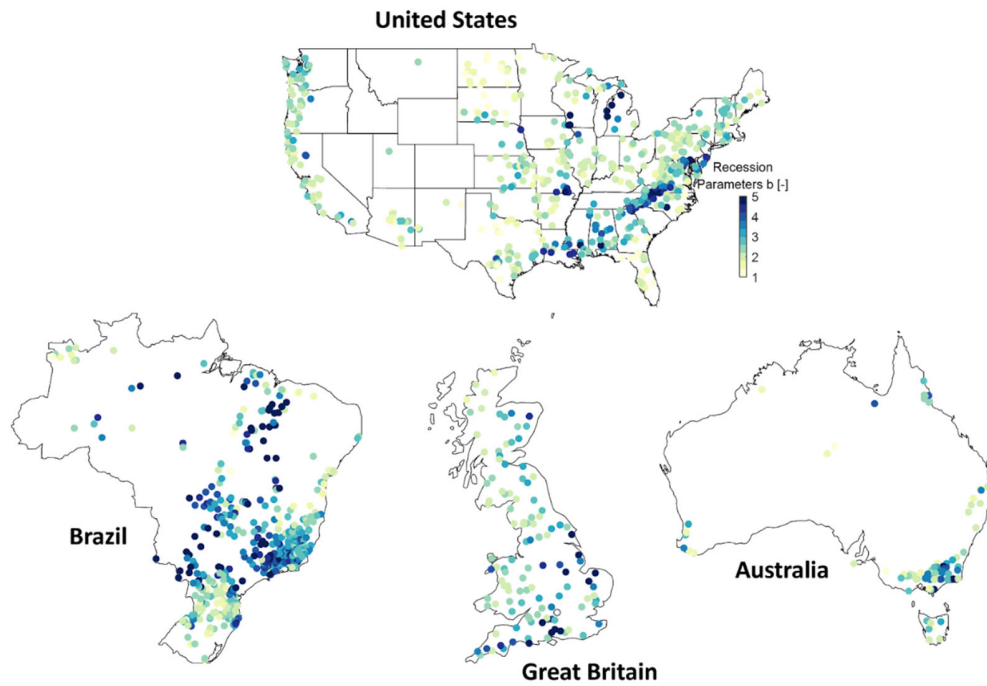
**Figure S1.** Plot showing StorageFraction signature calculation.



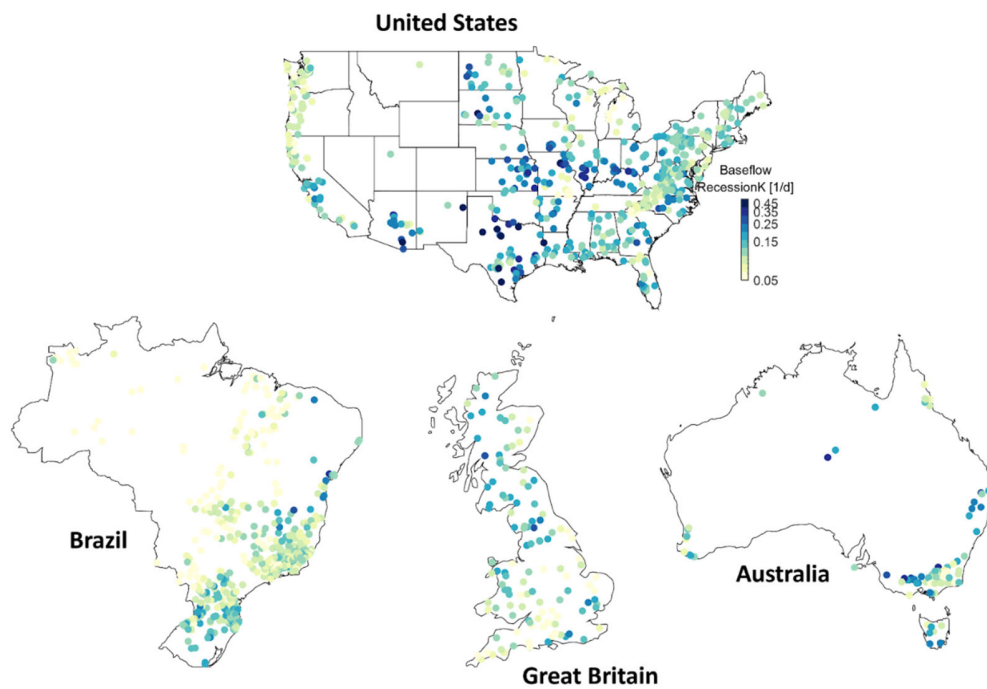
**Figure S2.** Maps of AverageStorage. Note that the maps of the countries are not to the same scale.



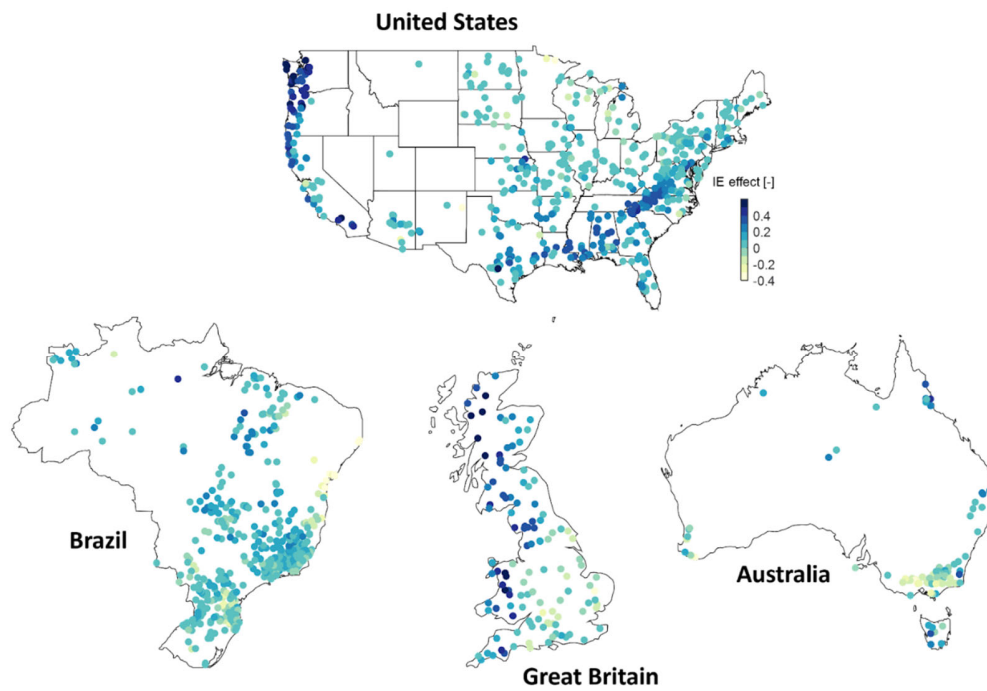
**Figure S3.** Maps of EventRR. Note that the maps of the countries are not to the same scale.



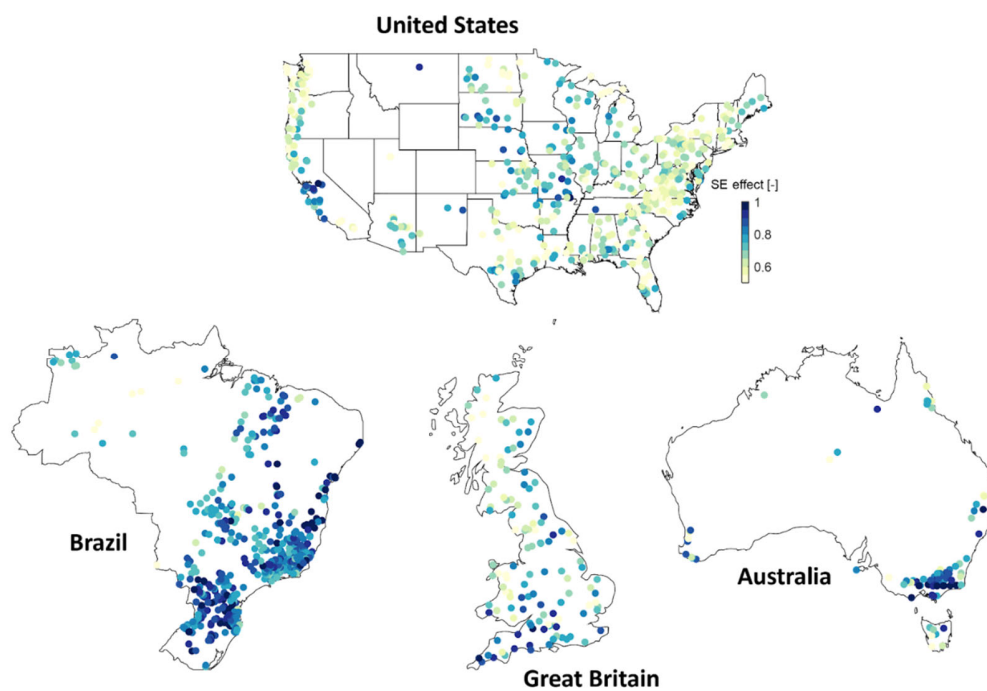
**Figure S4.** Maps of RecessionParameters\_b. Note that the maps of the countries are not to the same scale.



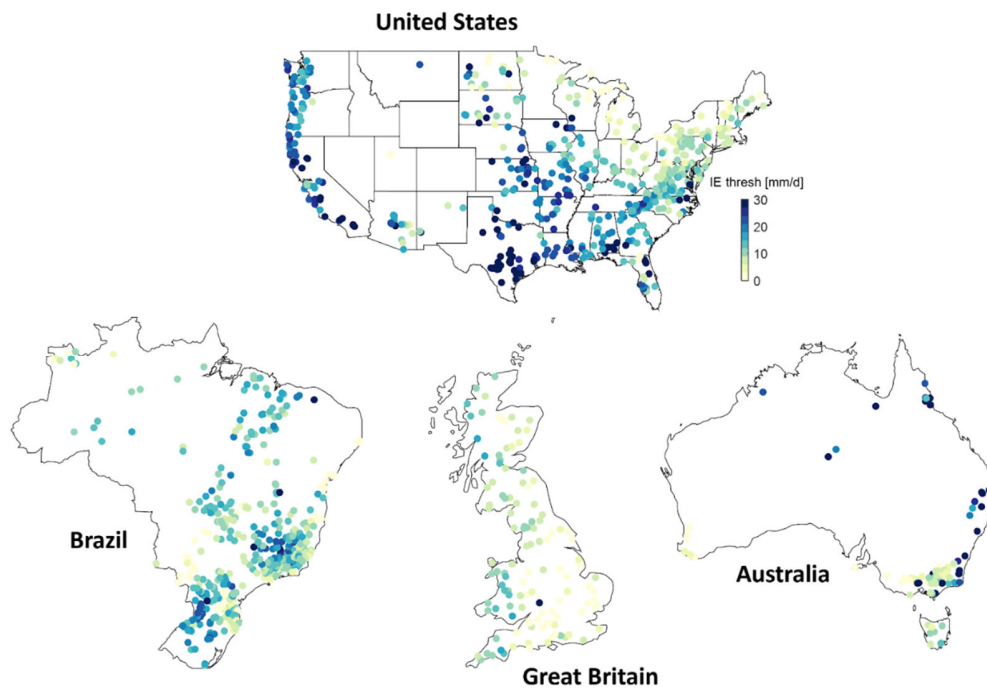
**Figure S5.** Maps of BaseflowRecessionK. Note that the maps of the countries are not to the same scale.



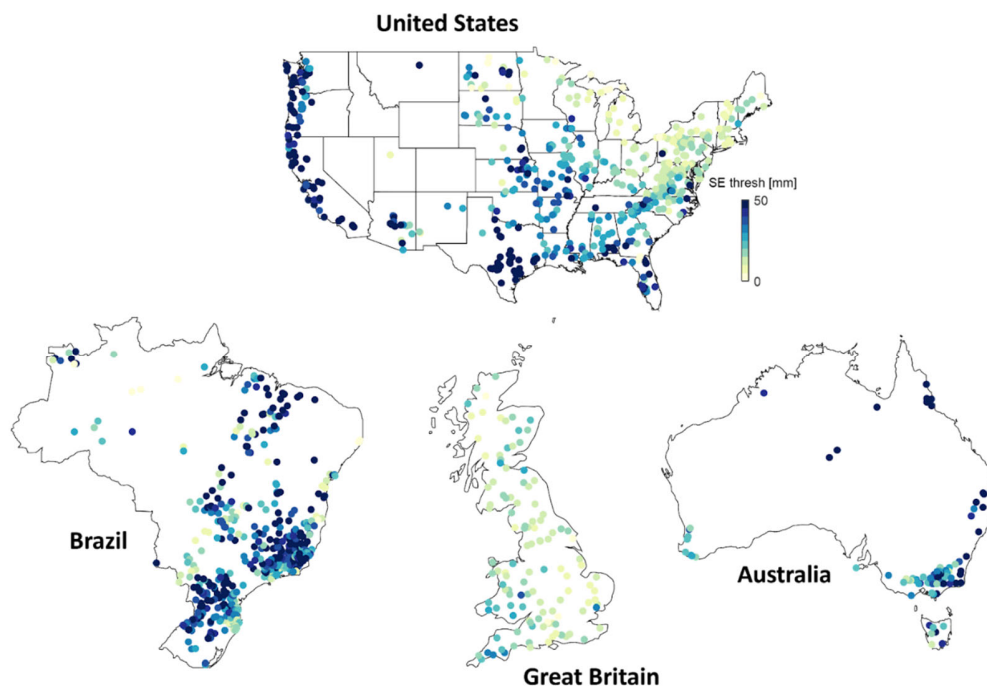
**Figure S6.** Maps of IE\_effect. Note that the maps of the countries are not to the same scale.



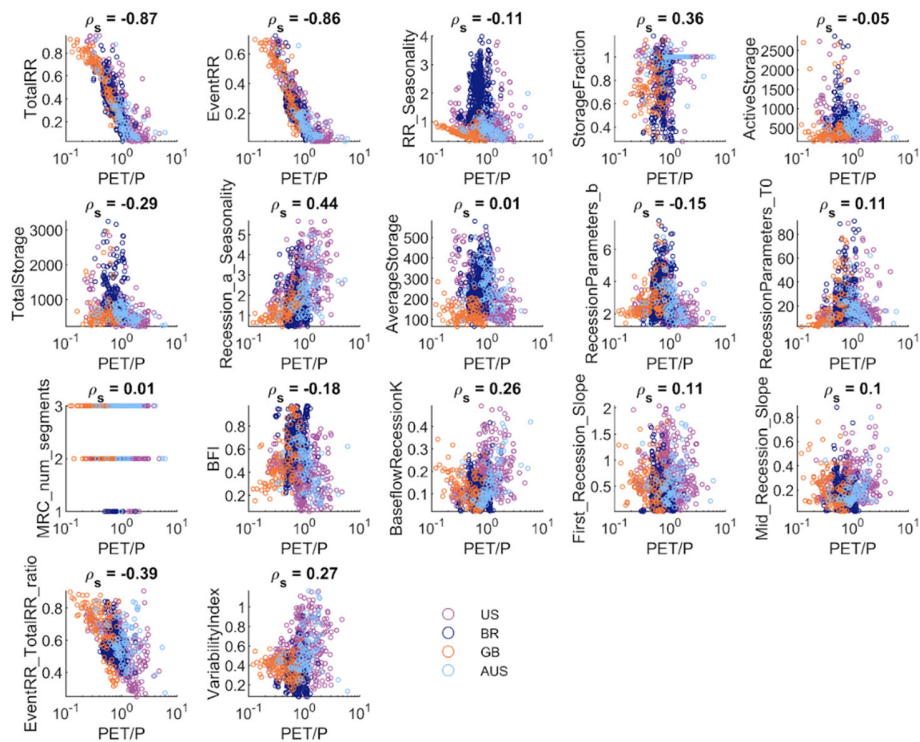
**Figure S7.** Maps of SE\_effect. Note that the maps of the countries are not to the same scale.



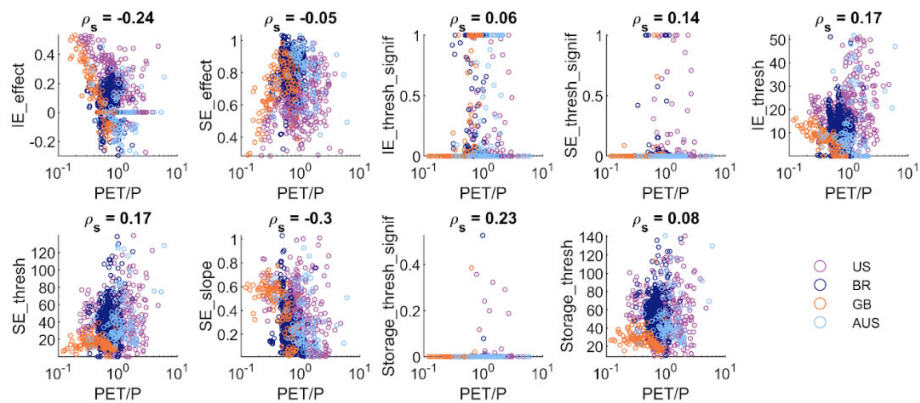
**Figure S8.** Maps of IE\_thresh. Note that the maps of the countries are not to the same scale.



**Figure S9.** Maps of SE\_thresh. Note that the maps of the countries are not to the same scale.



**Figure S10.** Relationship between groundwater signatures and aridity (PET/P).



**Figure S11.** Relationship between overland flow signatures and aridity (PET/P).

**Table S1.** Signatures that were removed from the analysis.

Signature	Reason
RecessionParameters_a	Units depend on RecessionParameters_b, RecessionParameters_T0 is used instead
Spearman's_rho	Superseded by Recession_a_Seasonality for variations in recessions
min_Qf_perc	Uninformative signature which mostly yields a value of 0

**Table S2.** Watershed-specific parameters and methods of estimation.

Workflow	Parameter	Description	Method of Estimation
OF	max_recessiondays	Max. length of recession after rainfall, to calculate event volume	Set to 5
GW	recession_length	minimum number of days of decreasing flow required to count as a recession	Set to 2
GW	start_water_year	Month when the water year starts	Set to 10 for US and Great Britain, 4 for Australia, 9 for Brazil
GW	eps	Allowed increase in flow during recession period	Set to median flow * 0.001 in most cases, checked visually that recessions were not being rejected due to diurnal cycles. Higher values (up to median flow * 0.17) needed for intermittent watersheds (Eel and Santa Catalina CZOs).
GW	n_start	Days after flow peak to start recession period	Set to 1



**Table S3.** 1st, 25th, 50th, 75th, and 99th percentiles of groundwater signatures.

Signature	1st	25th	50th	75th	99th
TotalRR [-]	0.03	0.26	0.37	0.49	0.95
EventRR [-]	0.01	0.14	0.21	0.28	0.72
RR_Seasonality [-]	0.30	0.62	0.96	1.74	4.02
StorageFraction [-]	0.28	0.72	0.91	1.00	1.18
ActiveStorage [mm]	154	347	474	643	2881
TotalStorage [mm]	218	409	568	836	3267
Recession_a_Seasonality [-]	0.44	1.10	1.60	2.46	5.68
AverageStorage [mm]	64	149	207	278	582
RecessionParameters_b [-]	1.20	2.02	2.52	3.46	7.77
RecessionParameters_T0 [d]	2.65	9.54	14.47	22.13	91.31
MRC_num_segments [-]	1.00	2.00	3.00	3.00	3.00
BFI [-]	0.06	0.38	0.53	0.70	0.98
BaseflowRecessionK [1/d]	0.02	0.08	0.11	0.17	0.49
First_Recession_Slope [1/d]	0.01	0.24	0.46	0.77	2.04
Mid_Recession_Slope [1/d]	0.02	0.12	0.17	0.24	0.90
EventRR_TotalRR_ratio [-]	0.25	0.50	0.55	0.64	0.91
VariabilityIndex [-]	0.08	0.25	0.35	0.51	1.17

**Table S4.** 1st, 25th, 50th, 75th, and 99th percentiles of overland flow signatures.

Signature	1st	25th	50th	75th	99th
IE_effect [-]	-0.30	0.00	0.07	0.18	0.53
SE_effect [-]	0.28	0.62	0.74	0.84	1.03
IE_thresh_signif [-]	0.00	0.00	0.00	0.00	1.00
SE_thresh_signif [-]	0.00	0.00	0.00	0.00	1.00
IE_thresh [mm/d]	0	8	12	18	52
SE_thresh [mm]	0	16	29	45	140
SE_slope [mm/mm]	0.01	0.14	0.26	0.44	1.03
Storage_thresh_signif [-]	0.00	0.00	0.00	0.00	0.53
Storage_thresh [mm]	9	30	44	60	142

**Table S5.** Rank correlation between groundwater signatures and aridity (PET/P) by country.

Signature	US	GB	AUS	BR	Total
TotalRR [-]	-0.89	-0.90	-0.82	-0.78	-0.87
EventRR [-]	-0.90	-0.92	-0.83	-0.77	-0.86
RR_Seasonality [-]	0.03	-0.48	-0.33	0.48	-0.11
StorageFraction [-]	0.22	0.26	0.27	0.13	0.36
ActiveStorage [mm]	-0.23	0.16	-0.43	0.23	-0.05
TotalStorage [mm]	-0.32	0.11	-0.46	-0.13	-0.29
Recession_a_Seasonality [-]	0.36	0.67	0.41	0.25	0.44
AverageStorage [mm]	-0.38	-0.17	-0.48	0.38	0.01
RecessionParameters_b [-]	-0.24	0.47	-0.45	0.22	-0.15
RecessionParameters_T0 [d]	0.11	0.77	-0.28	0.36	0.11
MRC_num_segments [-]	-0.06	-0.34	0.11	-0.09	0.01
BFI [-]	-0.25	0.54	-0.56	0.29	-0.18
BaseflowRecessionK [1/d]	0.38	-0.40	0.62	-0.18	0.26
First_Recession_Slope [1/d]	-0.05	-0.27	0.29	-0.22	0.11
Mid_Recession_Slope [1/d]	0.16	-0.30	0.44	-0.29	0.10
EventRR_TotalRR_ratio [-]	-0.59	-0.65	-0.06	-0.20	-0.39
VariabilityIndex [-]	0.26	-0.27	0.39	-0.18	0.27

**Table S6.** Rank correlation between overland flow signatures and aridity (PET/P) by country.

Signature	US	GB	AUS	BR	Total
IE_effect [-]	-0.34	-0.92	-0.18	0.03	-0.24
SE_effect [-]	0.25	0.40	-0.25	0.04	-0.05
IE_thresh_signif [-]	0.24	0.87	0.12	0.17	0.06
SE_thresh_signif [-]	0.06	0.57	0.35	0.15	0.14
IE_thresh [mm/d]	0.24	-0.79	-0.02	-0.12	0.17
SE_thresh [mm]	0.26	-0.26	0.05	0.11	0.17
SE_slope [mm/mm]	-0.32	-0.73	-0.29	-0.54	-0.30
Storage_thresh_signif [-]	0.19	0.61	0.50	0.12	0.23
Storage_thresh [mm]	0.17	-0.51	-0.01	0.09	0.08