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Supplement of

Coherence of Global Hydroclimate Classification Systems

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Introduction

This supporting information contains expanded information on climate classification systems formation through three figures and four tables. The figures support the final number of zones chosen in the compared climate classification systems, while the first two tables outline the logic for choosing the framework behind the multivariate Water-Energy Clustering (WEC) climate classification system. Additionally, this information also includes mean hydroclimate coherence (mean annual evapotranspiration, ET, precipitation, P, locally-generated runoff, Q, phase difference, $\Delta\theta$, and potential evapotranspiration, PET,) as well as complexity (zone area distribution and patchiness of zones) for groups of WEC and Köppen-Geiger (KPG) zones. Lastly, P and PET clustering centers for the WEC system are shown.

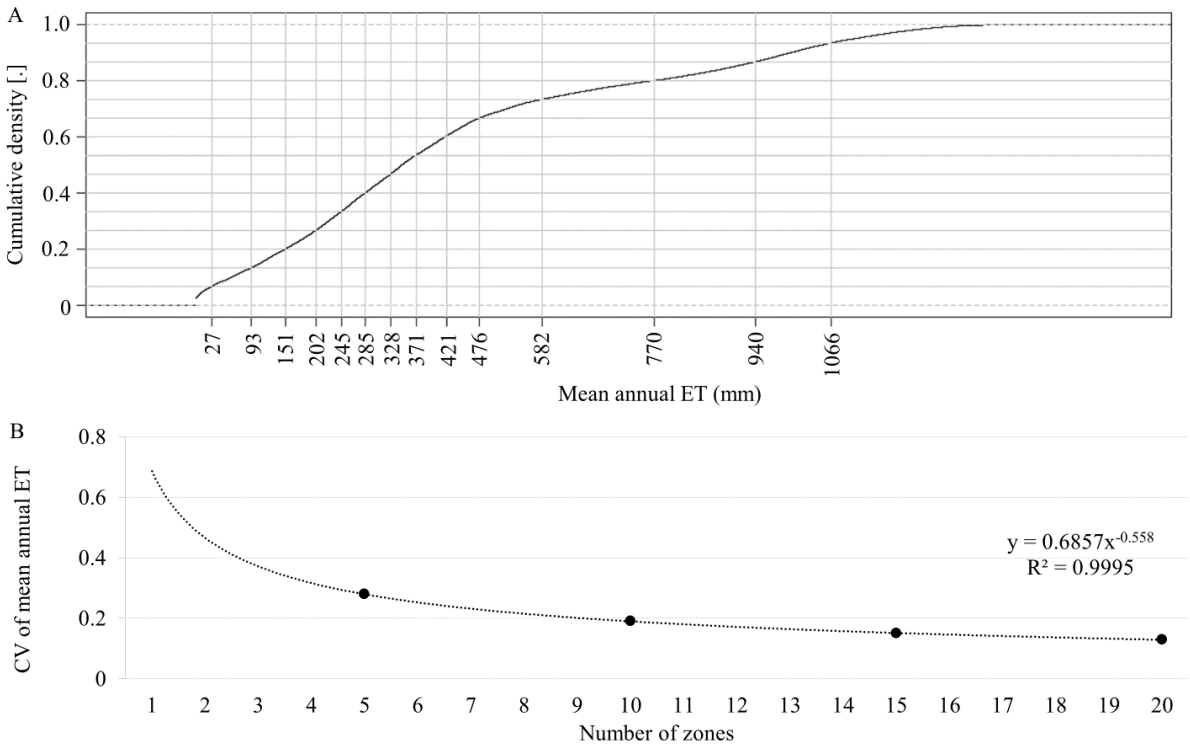

Figure S1. Method for determining zone boundaries for ET Area-optimizing classification system, ETA. (A) Cumulative distribution of global mean annual ET (mm) divided into 15 zones that result in an approximately equal number of pixels in each zone. (B) CV of mean annual ET as a function of number of zones.

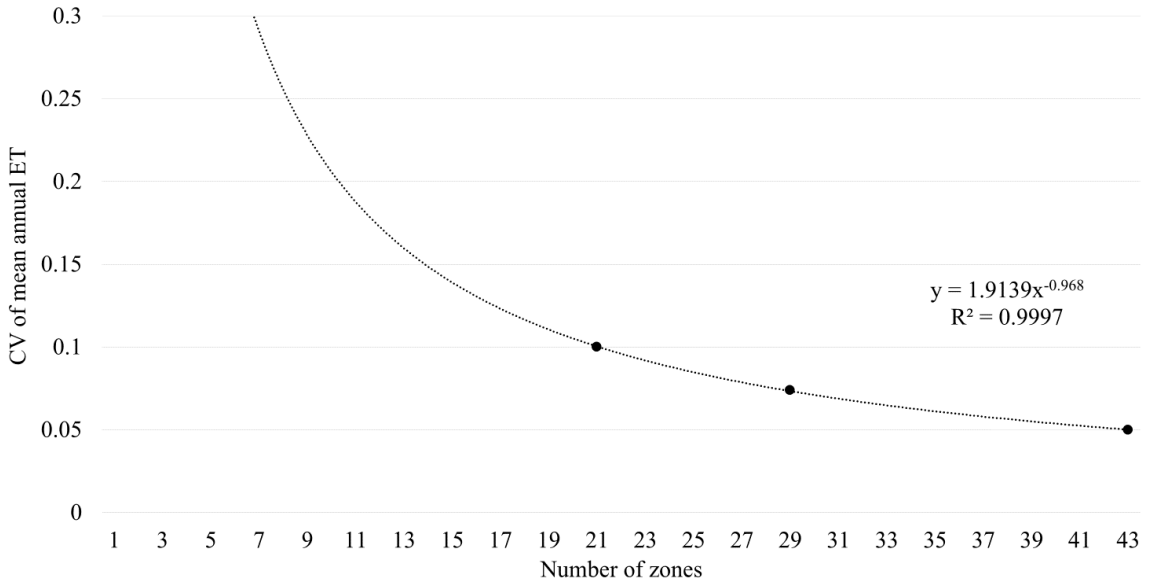

Figure S2. CV of ET as a function of number of zones for the ET Variability-optimizing classification system (ETV).

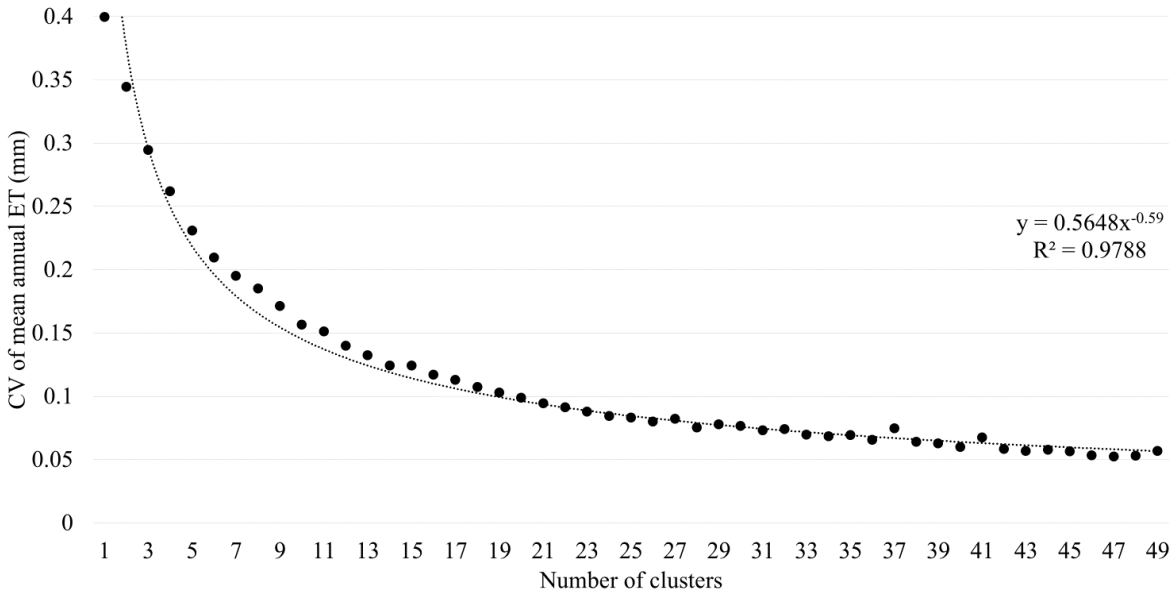

Figure S3. CV of ET as a function of number of clusters for the ET Clustering classification system (ETC).

The following framework describes the elimination thresholds for choosing the final multivariate clustering classification system. Since there are several systems that meet our conditions (Table S1), the schemes with fewer parameters were chosen, resulting in the ET,PET and P,PET systems to compare (Table S2).

Maximize Water Budget Coherence

$$Mean\ elimination\ threshold\ =\ KPG\ value(1.50)$$

1. Mean CV(ET) threshold ≤ 0.33 = 0.22(1.50)
2. Mean CV(P) threshold ≤ 0.53 = 0.35(1.50)
3. Mean CV(Q) threshold ≤ 1.31 = 0.87(1.50)

Minimize Zone Complexity

4. Number of zones ≤ 30 = # of KPG zones
5. Number of parameters ≤ 24 = # of KPG parameters
6. CV(# of pixels in each zone) ≤ 0.61 = 1.21(0.50)
7. Mean(# of patches) ≤ 68 = 45*1.50

Hierarchically, water budget coherence and number of zones were given highest priority. Therefore, the P,PET clustering system with 22 zones (denoted Water-Energy Clustering), was chosen for comparison against the other climate classification methods.

Table S1. Candidate multi-conditional clusters (marked as 1) and their corresponding number of zones, based on meeting above conditions.

nzones	ET,PET	ET,P	P,PET	ET,PET	ET,Q	ET,P,PET	ET,PET,Q	P,PET,Q	P,PET,Δθ	PET,Δθ
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	1	0	0	0	0
17	1	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	1	1	0	0	0
20	0	0	0	0	0	1	1	1	0	0
21	0	0	0	0	0	1	1	1	1	0
22	0	0	1	0	0	1	1	1	1	0
23	0	0	0	0	0	0	1	0	1	0
24	0	0	0	0	0	0	0	0	1	0
25	0	0	0	0	0	0	0	1	0	0
26	0	0	0	0	0	0	0	1	0	0
27	0	0	0	0	0	0	0	1	1	0
28	0	0	1	0	0	0	0	0	0	0
29	0	0	1	0	0	0	1	1	1	0

Table S2. Water budget coherence and zone complexity (mean±sd) of final candidate clustering schemes (ET,PET and P,PET) and corresponding potential number of zones.

	ET,PET					P,PET		
CV(ET)	0.37(0.30)	0.39(0.32)	0.39(0.33)	0.37(0.32)	0.36(0.32)	0.34(0.25)	0.35(0.28)	0.35(0.29)
CV(P)	0.51(0.21)	0.53(0.23)	0.53(0.23)	0.52(0.23)	0.50(0.23)	0.25(0.23)	0.25(0.24)	0.24(0.23)
CV(Q)	1.42(0.46)	1.48(0.61)	1.47(0.60)	1.42(0.57)	1.41(0.56)	0.90(0.74)	1.5(3.42)	1.36(2.93)
n.zones	14	15	16	17	18	22	28	29
n.parameters	2	2	2	2	2	2	2	2
CV(pixels)	0.53	0.57	0.43	0.51	0.49	0.56	0.57	0.59
n.patches	395(137)	386(136)	380(134)	370(133)	361(124)	360(147)	314(141)	309(140)

1. Results

Table S3. Hydroclimate coherence (CV of within-zone mean annual ET, P, Q, Δθ, and PET) and complexity (CV_z of pixel distribution across zones and number of, n, zone patches, and number of, n, zones) in established and proposed climate classification systems. For all coherence and complexity metrics, except for CV_z of pixels, mean(standard deviation) are shown. Significantly higher ($^{\uparrow}$) or lower ($^{\downarrow}$) values than KPG were determined based on K-S tests. Bold indicates the best overall system for each metric (more than one system had statistically similar results for some metrics). Shown here are poor performing systems, HDL and ETV, which are not compared to KPG in the main text.

	Established Systems		Proposed system
Metric	KPG	HDL	ETV
CV(ET)	0.27(0.21)	0.59(0.48)$^{\uparrow}$	**0.07(5.0E-3)$^{\downarrow}$**
CV(P)	0.38(0.20)	0.78(0.58)$^{\uparrow}$	1.21(0.66)$^{\uparrow}$
CV(Q)	0.88(0.30)	1.78(1.33)$^{\uparrow}$	1.85(0.51)$^{\uparrow}$
CV(Δθ)	0.24(0.18)	0.37(0.13)$^{\uparrow}$	0.44(0.10)$^{\uparrow}$
CV(PET)	0.20(0.13)	0.34(0.14)$^{\uparrow}$	0.58(0.18)$^{\uparrow}$
CV_z(zone areas)	1.21	0.97$^{\uparrow}$	1.26
n patches	46(36)	199(59)$^{\uparrow}$	113(46)$^{\uparrow}$
n zones	28	38$^{\uparrow}$	29$^{\uparrow}$

Table S4. Clustering P and PET centers for WEC zones and their associated groups, which are based on increasing zonal mean P/PET.

Zone	P (mm y^{-1})	PET (mm y^{-1})	Group
1	2445.19	1151.49	G1
2	1575.11	571.88	G2
3	1055.23	892.63	G5
4	210.17	250.62	G3
5	526.98	1873.07	G2
6	1534.58	1183.66	G4
7	340.96	418.04	G1
8	3144.31	1178.57	G1
9	639.37	1381.73	G1
10	1956.48	1176.52	G5
11	906.53	1643.58	G2
12	542.11	362.02	G2
13	332.30	819.78	G4
14	4477.14	1152.22	G1
15	605.95	595.15	G1
16	610.91	970.25	G3
17	132.41	2300.26	G4
18	1179.42	1343.33	G1
19	956.43	402.88	G5
20	126.47	1899.25	G4
21	216.80	1127.74	G5
22	245.02	1502.96	G4

Table S5. Mean hydroclimate coherence, CV of pixels, and mean number of patches in KPG and WEC groups.

KPG Group	mean CV(ET)	mean CV(P)	mean CV(Q)	mean CV(Δθ)	mean CV(PET)	CV of pixels	mean number of patches
Tropical	0.11	0.26	0.55	0.28	0.13	0.54	69
Arid	0.48	0.49	0.98	0.47	0.18	0.46	66
Temperate	0.21	0.38	0.79	0.24	0.21	0.77	45
Boreal	0.20	0.32	0.94	0.10	0.17	1.72	29
Polar	1.29	0.70	1.55	0.42	0.46	0.49	97
WEC Group	mean CV(ET)	mean CV(P)	mean CV(Q)	mean CV(Δθ)	mean CV(PET)	CV of pixels	mean number of patches
G1	0.29	0.11	0.39	0.31	0.21	0.84	72
G2	0.14	0.12	0.69	0.39	0.13	0.34	85
G3	0.41	0.29	0.91	0.45	0.21	0.07	39
G4	0.24	0.21	0.98	0.28	0.09	0.24	55
G5	0.71	0.68	1.20	0.48	0.06	0.09	26