Supplemental material

Use of satellite remote sensing to validate reservoir operations in global hydrological models: a case study from the CONUS

Kedar Otta[1], Hannes Müller Schmied[2,3], Simon N. Gosling[4], Naota Hanasaki[1,5]

[1]National Institute for Environmental Studies, Tsukuba, 305-8506, Japan

[2]Institute of Physical Geography, Goethe University Frankfurt, 60438 Frankfurt am Main, Germany

[3]Senckenberg Leibniz Biodiversity and Climate Research Centre (SBiK-F), 60325 Frankfurt am Main, Germany

[4]School of Geography, University of Nottingham, Nottingham NG7 2RD, United Kingdom

[5]The University of Tokyo, Tokyo, 113-0033, Japan

Correspondence to: Naota Hanasaki (hanasaki@nies.go.jp)

Supplementary Figures

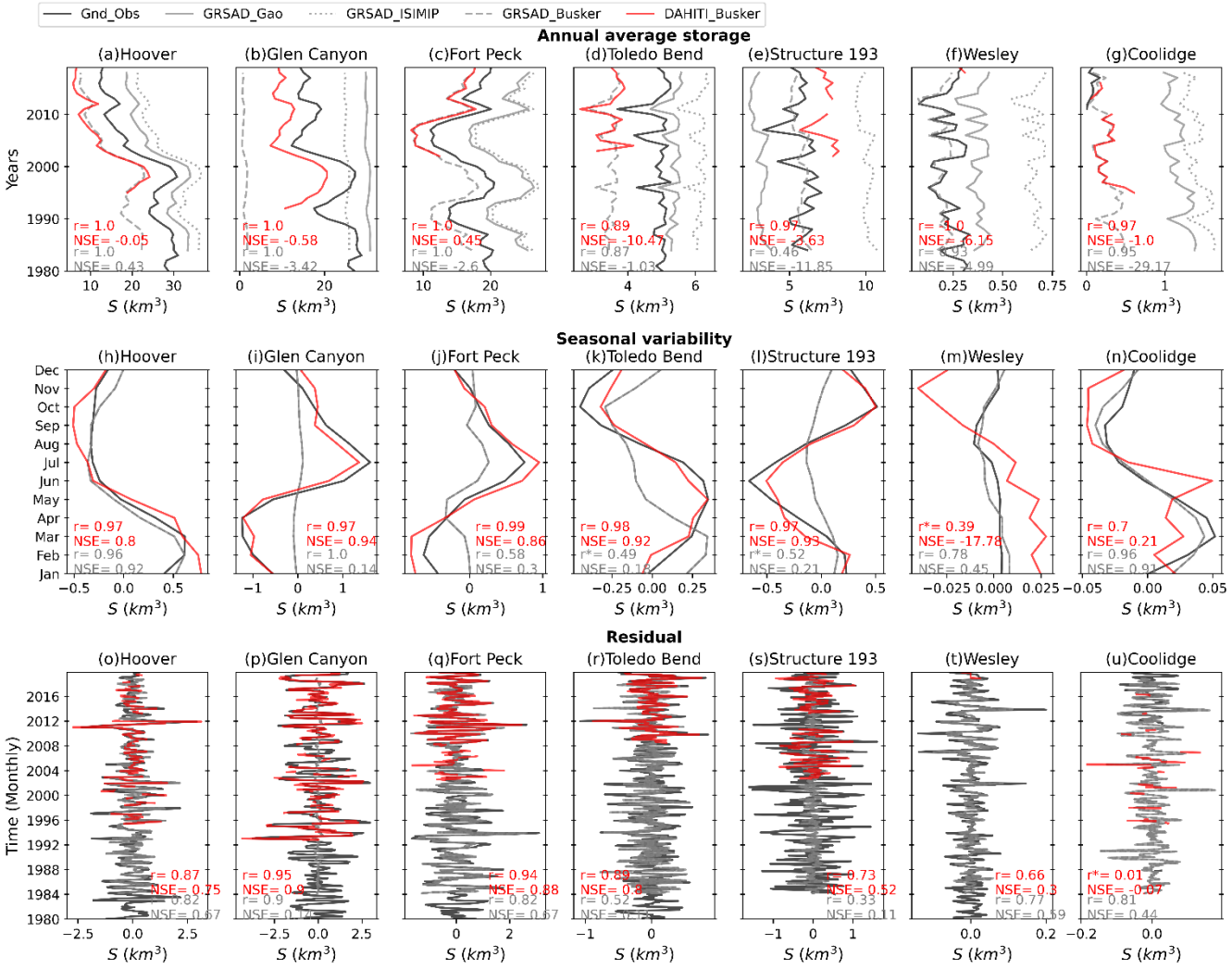

Figure S1: Decomposed reservoir storage components from satellite and ground observation. Annual mean storage (a-g), seasonal variability (h-n), and residuals (o-u) from satellite-derived data for raw storage compared with ground observations. Corresponding correlation coefficients (r) and NSE values are shown in the figure. r* indicates insignificant correlation (p > 0.05).

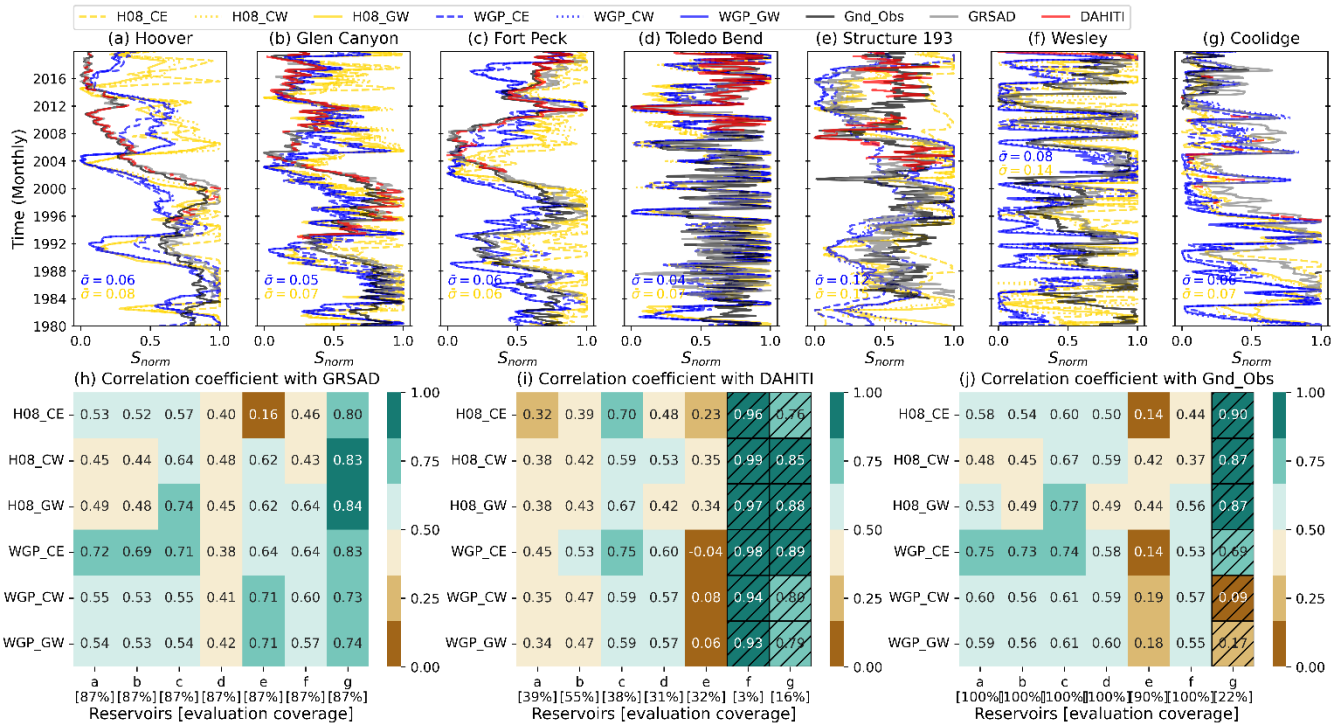

Figure S2: Validation of simulated monthly normalized reservoir storage. (a)-(g) Model simulations compared with satellite data and ground truth for monthly normalized reservoir storage. (h)-(g) Average correlation coefficient with three evaluation datasets: GRSAD, DAHITI, and ground observation, respectively, for each of the reservoirs (a)-(g). The color indicates the magnitude of the correlation. Values in square brackets indicate percentage temporal coverage from 01/1980 to 12/2019 of reservoir storage for each reservoir's evaluation data. Reservoirs with hatched marks had < 30% coverage and were not included in subsequent analyses.

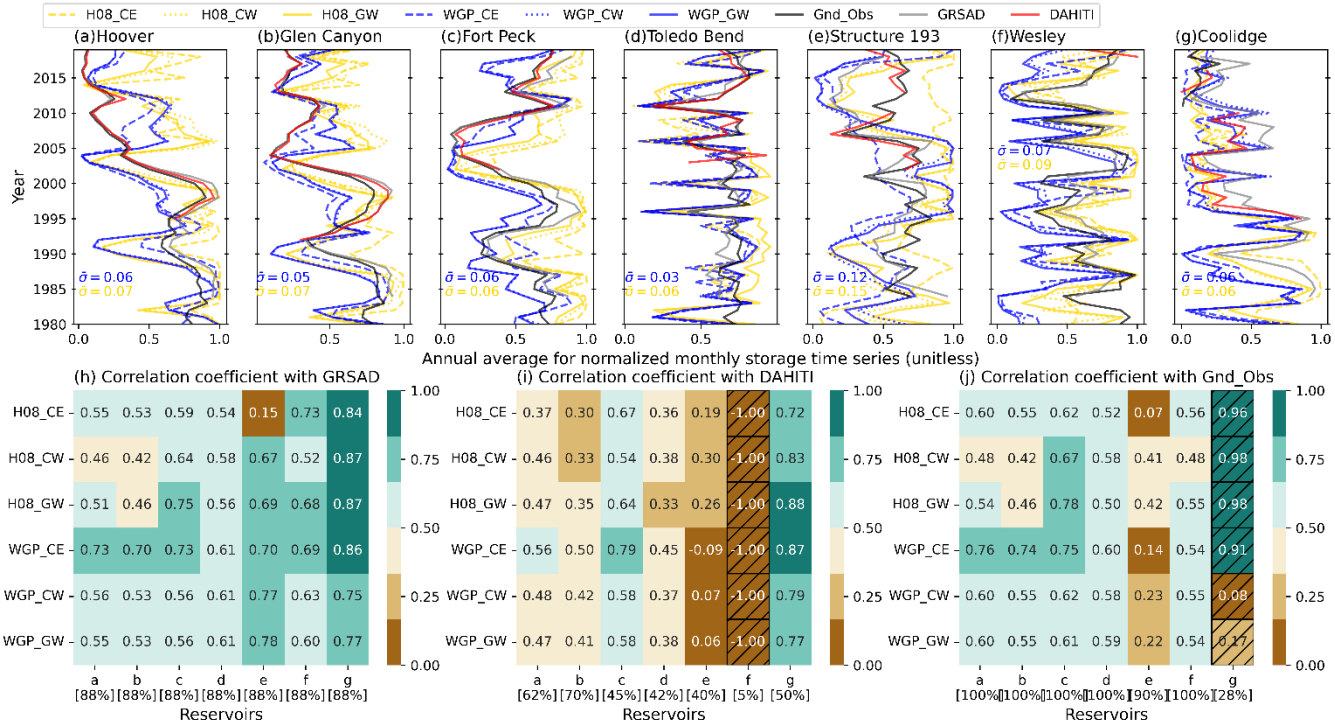

Figure S3: Same as Figure S2, but for annual average normalized reservoir storage.

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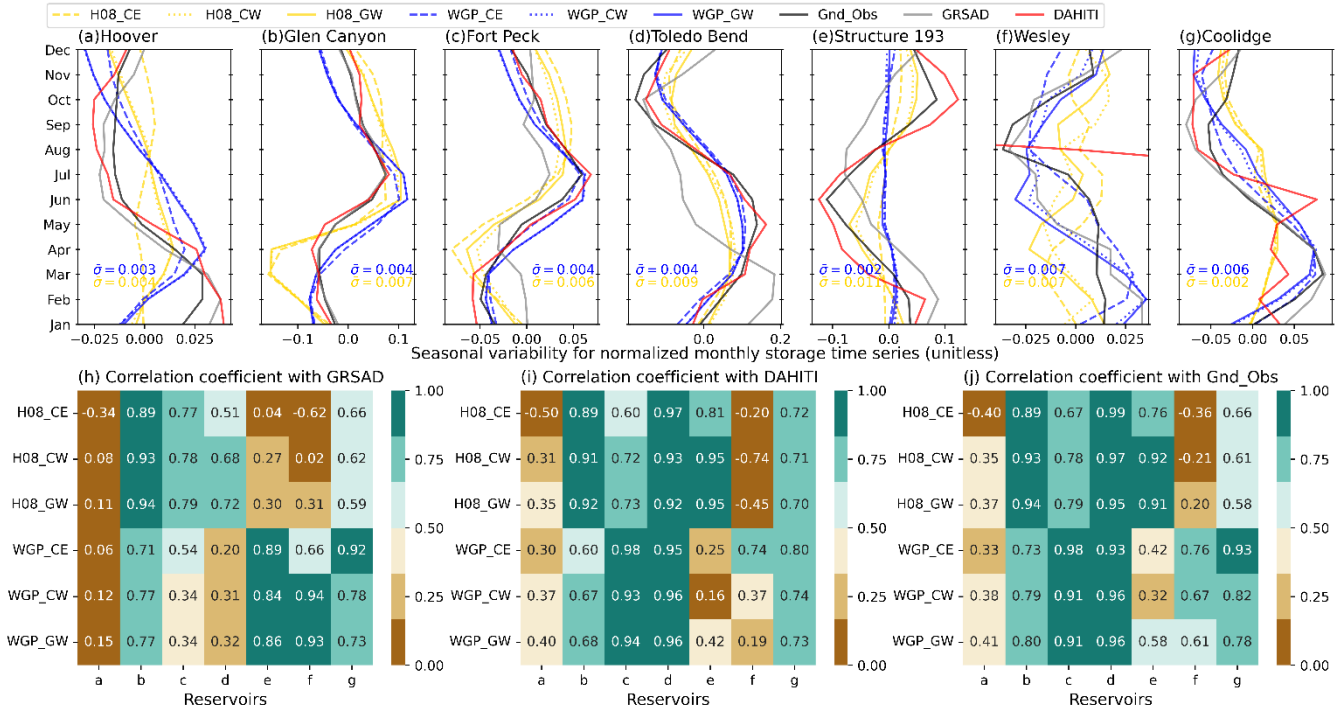
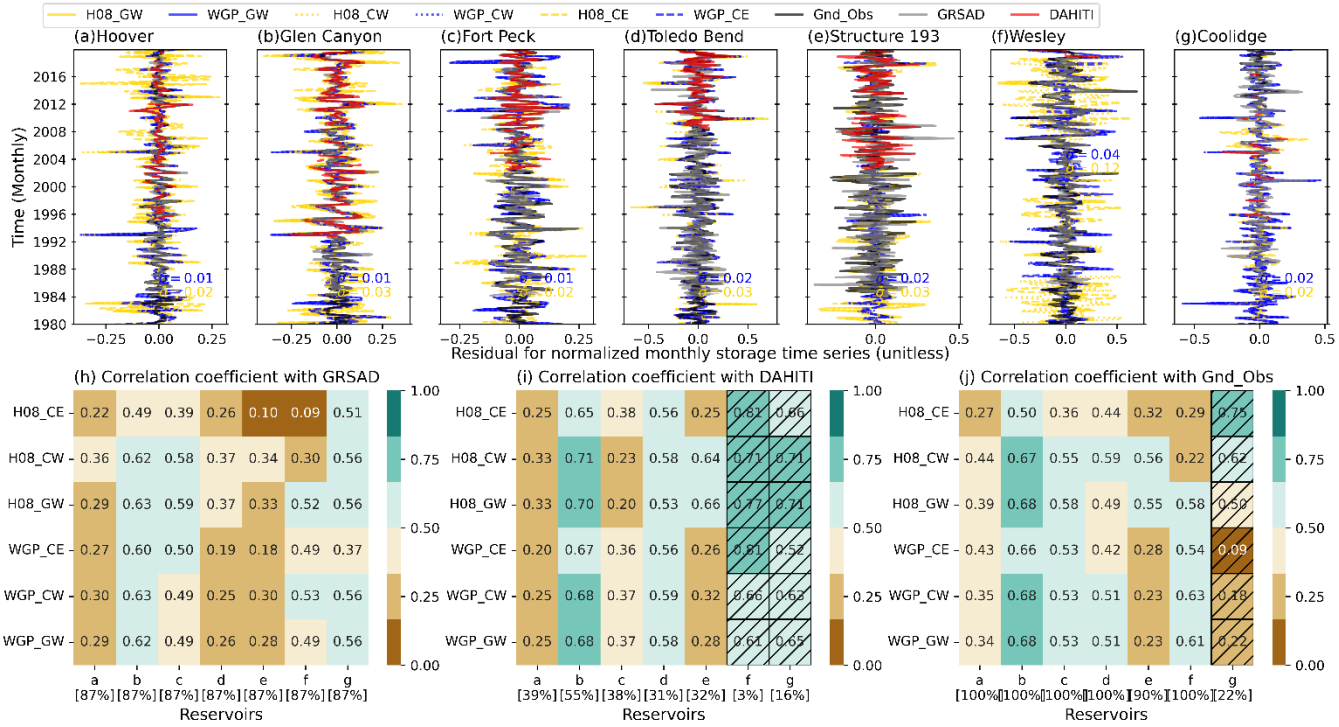


Figure S4: Same as Figure S2, but for simulated monthly seasonal variability of normalized reservoir storage.



35 **Figure S5: Same as Figure S2, but for the residuals of normalized reservoir storage ($e_{norm,y,m}$).**

Supplementary Tables

Table S1: The longitude (Lon) and latitude (Lat) of reservoirs in the GRanD dataset and 0.5°×0.5° grids recommended by ISIMIP, used by H08 and WaterGAP.

	GRanD		ISIMIP		H08		WaterGAP	
Dam name	**Lon**	**Lat**	**Lon**	**Lat**	**Lon**	**Lat**	**Lon**	**Lat**
Hoover	-114.74	36.02	-114.75	36.25	-114.75	36.25	-114.75	36.25
Glen Canyon	-111.49	36.94	-111.25	37.25	-110.75	37.25	-111.25	37.25
Fort Peck	-106.41	48.00	-106.25	47.75	-106.25	48.25	-106.25	47.75
Toledo Bend	-93.57	31.17	-93.75	31.25	-93.75	31.25	-93.75	31.25
Structure 193	-81.10	26.94	-81.25	26.75	-81.25	26.75	-81.25	26.75
Wesley E. Seale	-97.87	28.05	-97.75	28.25	-97.75	28.25	-97.75	28.25
Coolidge	-110.52	33.18	-110.25	33.25	-110.75	33.25	-110.25	33.25

Table S2: Storage capacity (Sc, in MCM) in the ISIMIP and the GRBD datasets, and A-h relationship parameters (a and b) from GRBD.

Dam name	**ISIMIP Sc**	**GRBD Sc**	**a**	**b**
Hoover	36,700.00	34,069.08	0.136	288.760
Glen Canyon	25,070.00	30,000.70	0.141	1047.200
Fort Peck	23,560.00	22,773.70	0.044	643.317
Toledo Bend	6,287.70	5,522.29	0.020	39.455
Structure 193	10,510.00	3,546.48	0.006	-5.575
Wesley E. Seale	655.00	370.04	0.104	20.256
Coolidge	1,323.50	1,079.30	1.387	719.805

Table S3: The starting and ending dates of ground observation as in the ResOpsUS dataset.

Dam name	**Time series start**	**Time series end**
Hoover	1934-04-01	2021-01-28
Glen Canyon	1963-03-11	2021-01-27
Fort Peck	1938-01-02	2002-06-20
Toledo Bend	1966-10-02	2020-12-31
Structure 193	1984-01-01	2021-01-31
Wesley E. Seale	1948-09-01	2020-12-31
Coolidge	1980-01-01	2020-12-31

Table S4: The correlation coefficient (r), its corresponding p-value, and NSE for validation of reservoir storage from satellite data (GRSAD and DAHITI) compared against the ground truth (ResOpsUS) for monthly storage Sm,y. This table corresponds to Figure 3. For all correlations, the p-value was approximately 0.

Metrics	Dams	GRSAD_Gao	GRSAD_ISIMIP	GRSAD_Busker	DAHITI_Busker
r	**Hoover**	1.00	1.00	1.00	1.00
	Glen Canyon	0.99	0.99	0.99	1.00
	Fort Peck	0.98	0.98	0.98	1.00
	Toledo Bend	0.63	0.63	0.63	0.98
	Structure 193	0.42	0.42	0.42	0.93
	Wesley	0.89	0.89	0.89	0.99
	Coolidge	0.89	0.89	0.89	0.94
NSE	**Hoover**	0.43	-0.32	0.05	-0.18
	Glen Canyon	-3.18	-0.68	-12.37	-0.60
	Fort Peck	-2.37	-3.36	0.23	0.45
	Toledo Bend	-0.33	-5.26	-7.75	-4.56
	Structure 193	-6.83	-16.51	0.17	-1.7
	Wesley	-3.50	-32.85	0.57	0.75
	Coolidge	-81.99	-129.38	0.58	-0.37

Table S5: Same as Table S4, but for the normalized monthly storage (Snorm,y,m). This table corresponds to Figure 3. For all correlations, the p-value was approximately 0.

Metric	Dam	GRSAD_Gao	GRSAD_ISIMIP	GRSAD_Busker	DAHITI_Busker
r	**Hoover**	1.00	1.00	1.00	1.00
	Glen Canyon	0.99	0.99	0.99	1.00
	Fort Peck	0.98	0.98	0.98	1.00
	Toledo Bend	0.63	0.63	0.63	0.98
	Structure 193	0.42	0.42	0.42	0.93
	Wesley	0.89	0.89	0.89	0.99
	Coolidge	0.89	0.89	0.89	0.94
NSE	**Hoover**	0.94	0.94	0.94	0.98
	Glen Canyon	0.93	0.93	0.93	0.95
	Fort Peck	0.83	0.83	0.83	0.98
	Toledo Bend	0.24	0.24	0.24	0.96
	Structure 193	-1.27	-1.27	-1.27	0.63
	Wesley	0.73	0.73	0.73	-7.78
	Coolidge	0.20	0.20	0.20	0.89

Table S6: The correlation coefficient (r), its corresponding p-value, and NSE for validation of reservoir storage from satellite data (GRSAD and DAHITI) compared against the ground truth (ResOpsUS) for decomposed normalized storage. This table corresponds to Figure 4.

Metric	Dam	Annual average storage		Seasonal variability		Residual	
		GRSAD	DAHITI	GRSAD	DAHITI	GRSAD	DAHITI
r	Hoover	1.00	1.00	0.96	0.97	0.82	0.87
	Glen Canyon	1.00	1.00	1.00	0.97	0.90	0.95
	Fort Peck	1.00	1.00	0.58	0.99	0.82	0.94
	Toledo Bend	0.87	0.89	0.49	0.98	0.52	0.89
	Structure 193	0.46	0.97	0.52	0.97	0.33	0.73
	Wesley	0.93	-1.00	0.78	0.39	0.77	0.66
	Coolidge	0.95	0.97	0.96	0.70	0.81	0.01
p-value	Hoover	0.00	0.00	0.00	0.00	0.00	0.00
	Glen Canyon	0.00	0.00	0.00	0.00	0.00	0.00
	Fort Peck	0.00	0.00	0.05	0.00	0.00	0.00
	Toledo Bend	0.00	0.00	0.11	0.00	0.00	0.00
	Structure 193	0.01	0.00	0.09	0.00	0.00	0.00
	Wesley	0.00	0.00	0.00	0.21	0.00	0.01
	Coolidge	0.00	0.01	0.00	0.01	0.00	0.99
NSE	Hoover	0.95	0.98	0.82	0.71	0.64	0.73
	Glen Canyon	0.94	0.95	0.99	0.92	0.73	0.85
	Fort Peck	0.85	0.98	0.33	0.92	0.62	0.89
	Toledo Bend	0.71	0.72	-0.01	0.96	-0.24	0.79
	Structure 193	-2.00	0.72	0.10	0.76	-0.34	0.34
	Wesley	0.79	-41.80	0.27	-288.88	0.60	0.14
	Coolidge	0.69	0.30	0.82	0.26	0.09	-0.06

Table S7: Mean model variability with input forcings ($\bar{\sigma}$). This table corresponds to Figure 4-8 (a-g) in the main article.

	Monthly storage		Annual average storage		Seasonal variability		Residuals	
	WGP	**H08**	**WGP**	**H08**	**WGP**	**H08**	**WGP**	**H08**
Hoover	0.06	0.08	0.06	0.07	0.003	0.004	0.01	0.02
Glen Canyon	0.05	0.07	0.05	0.07	0.004	0.007	0.01	0.03
Fort Peck	0.06	0.06	0.06	0.06	0.004	0.006	0.01	0.02
Toledo Bend	0.04	0.07	0.03	0.06	0.004	0.009	0.02	0.03
Structure 193	0.12	0.15	0.12	0.15	0.002	0.011	0.02	0.03
Wesley	0.08	0.14	0.07	0.09	0.007	0.007	0.04	0.12
Coolidge	0.06	0.07	0.06	0.06	0.006	0.002	0.02	0.02