remote sensing

MDPI

Supplementary Materials for

Decadal Lake Volume Changes (2003–2020) and Driving Forces at a Global Scale

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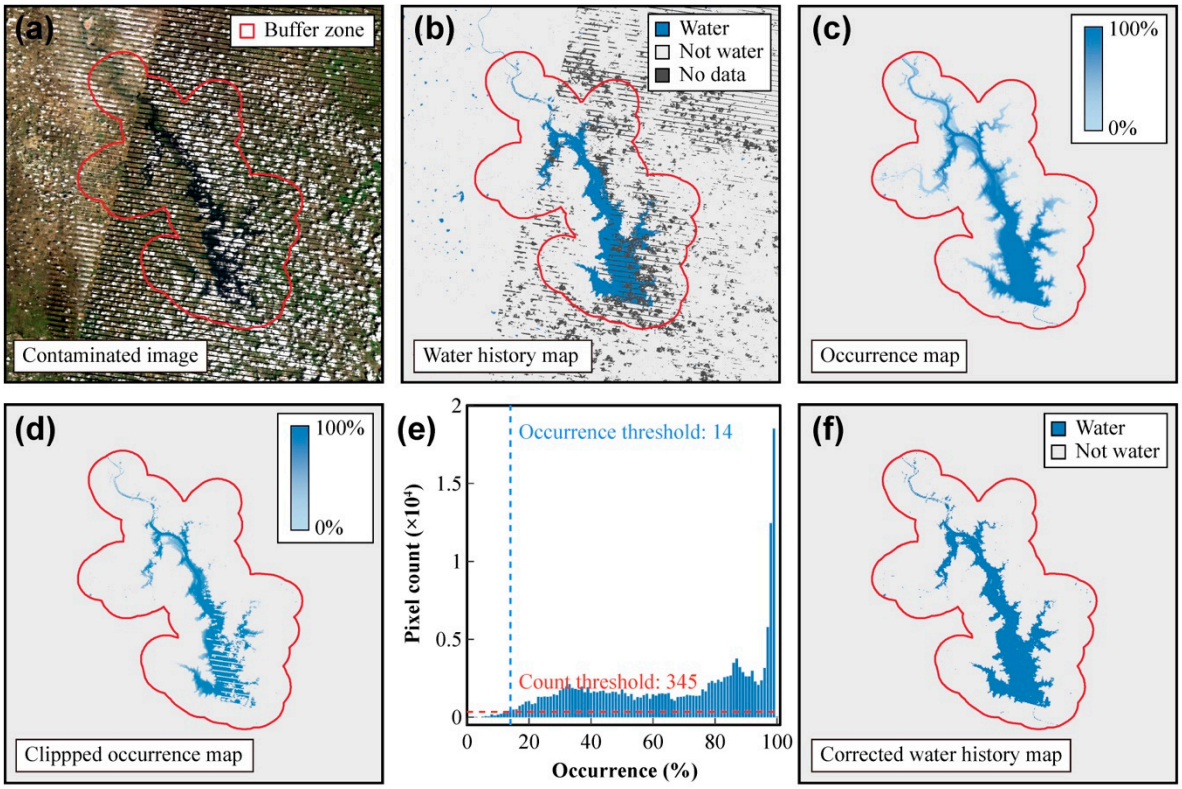

Figure S1. Correction of the GSW water history maps. The Falcon International Reservoir (26.76° N, 99.26° W) is used as an example here. (a) A low-quality Landsat image of the Falcon International Reservoir acquired in September of 2004; (b) the corresponding water history map of (a) extracted from the GSW database; (c) the water occurrence map of the Falcon Reservoir extracted from the GSW database; (d) the water occurrence map obtained by clipping (c) using (b) as a mask; (e) the histogram of the occurrence values in map (d), binned into 100 bars that were ordered from low to high occurrence; (f) the final, corrected water history map. In (a-c, d, and f), the buffered region was denoted by the red curve. In (e), a count threshold was calculated as 0.17 * averaged *y*-values (pixel counts) of the 100 bars. An occurrence threshold was then defined as the first occurrence whose *y*-value (pixel count) is greater than the count threshold [38]. This occurrence threshold was then used to binarize the water history map shown in (c): pixels in (c) with an occurrence value larger than this occurrence threshold was deemed as the final water bodies (f).

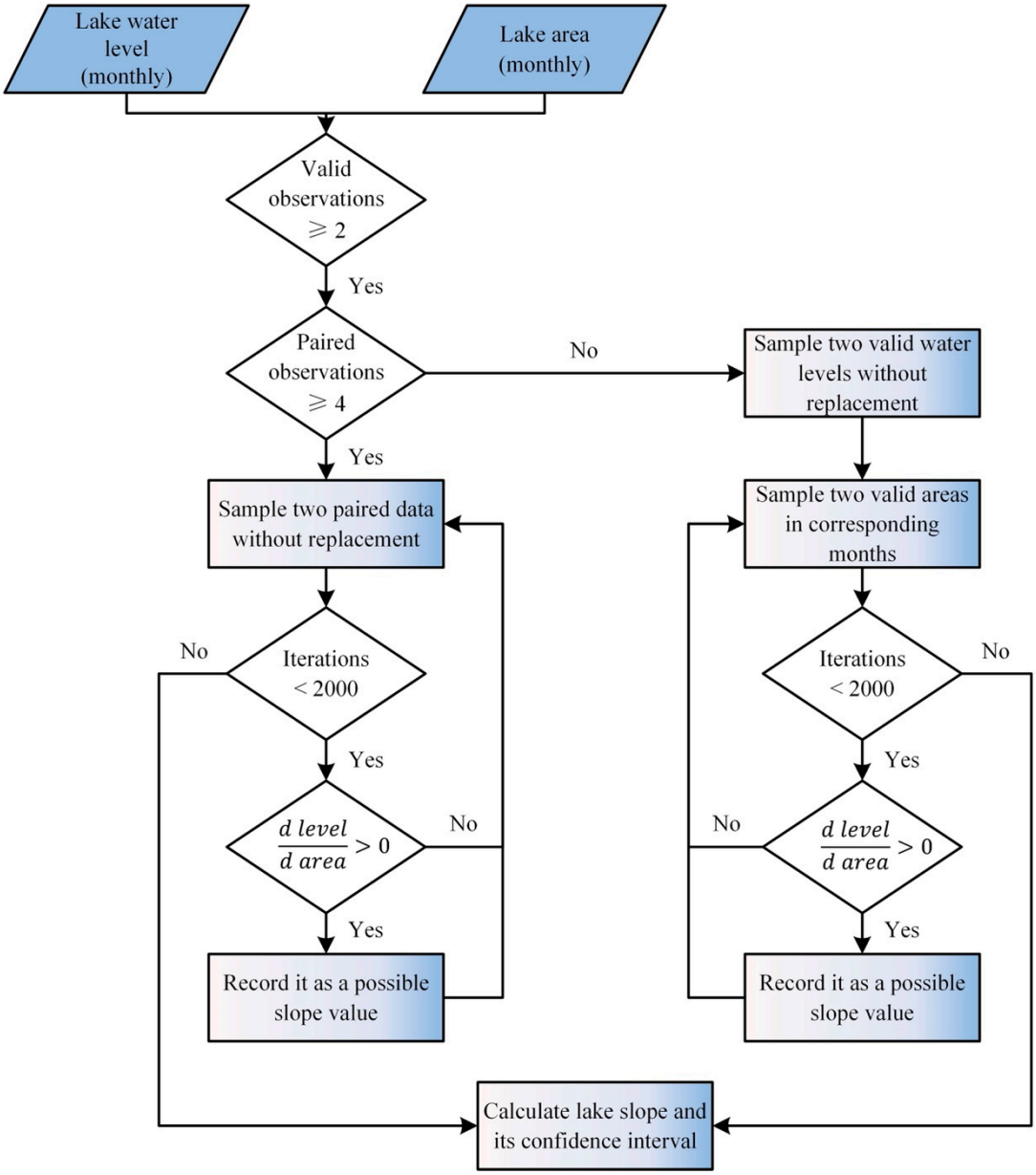

Figure S2. Sampling-based method for calculating the regression slope between lake area and lake water levels.

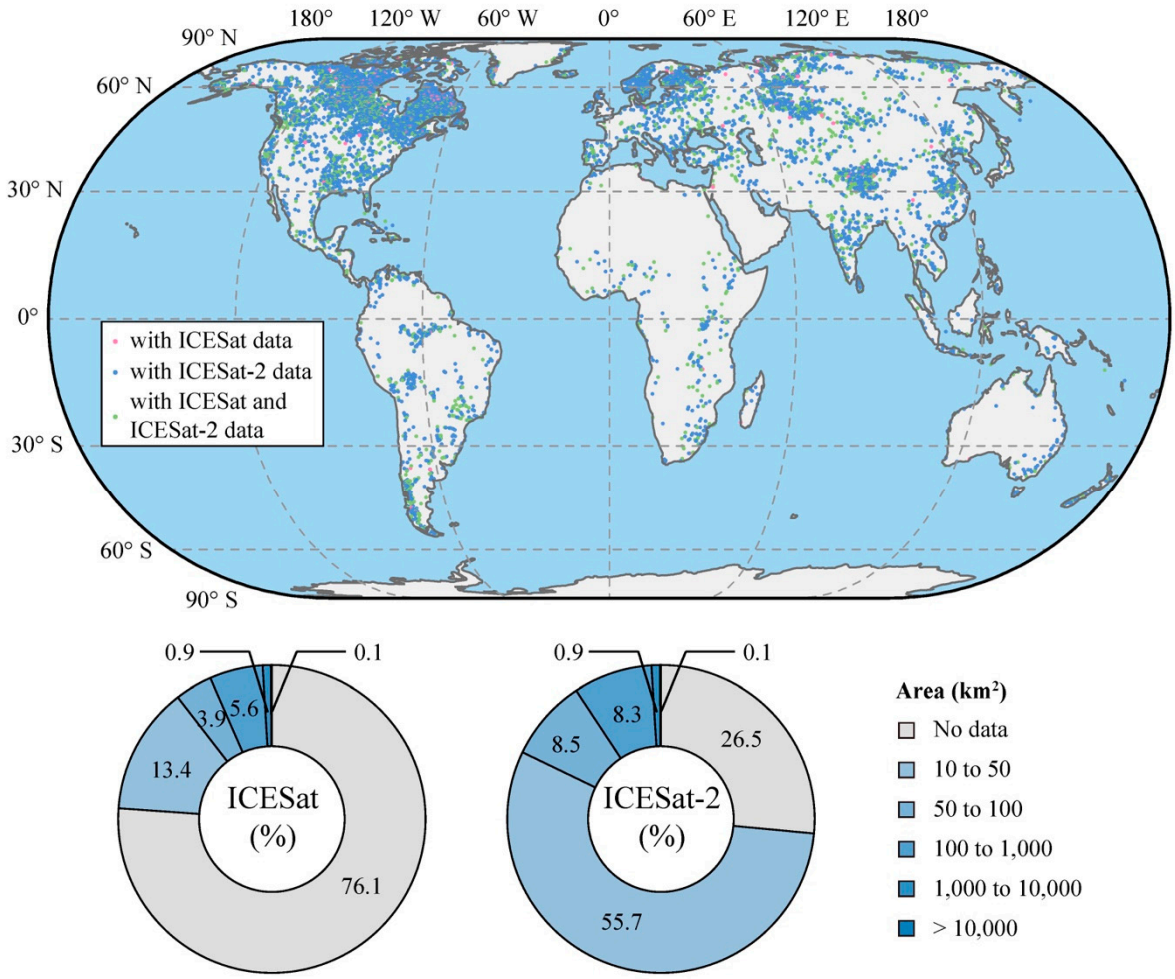

Figure S3. Spatial pattern and size distribution of the lakes with ICESat, ICESat-2, or both observations.

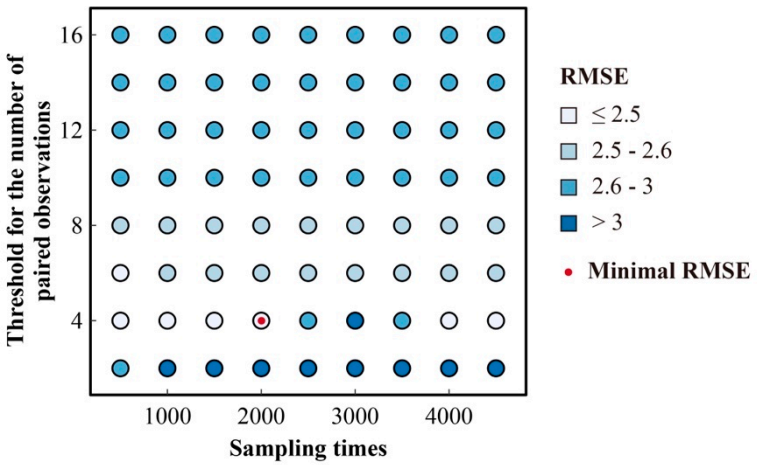

Figure S4. Comparison of in situ and area-derived water levels calculated by different parameters. The root mean square error (RMSE) reaches to the minimum when the threshold for the number of paired observations is set to 4 and the sampling times set to 2000.

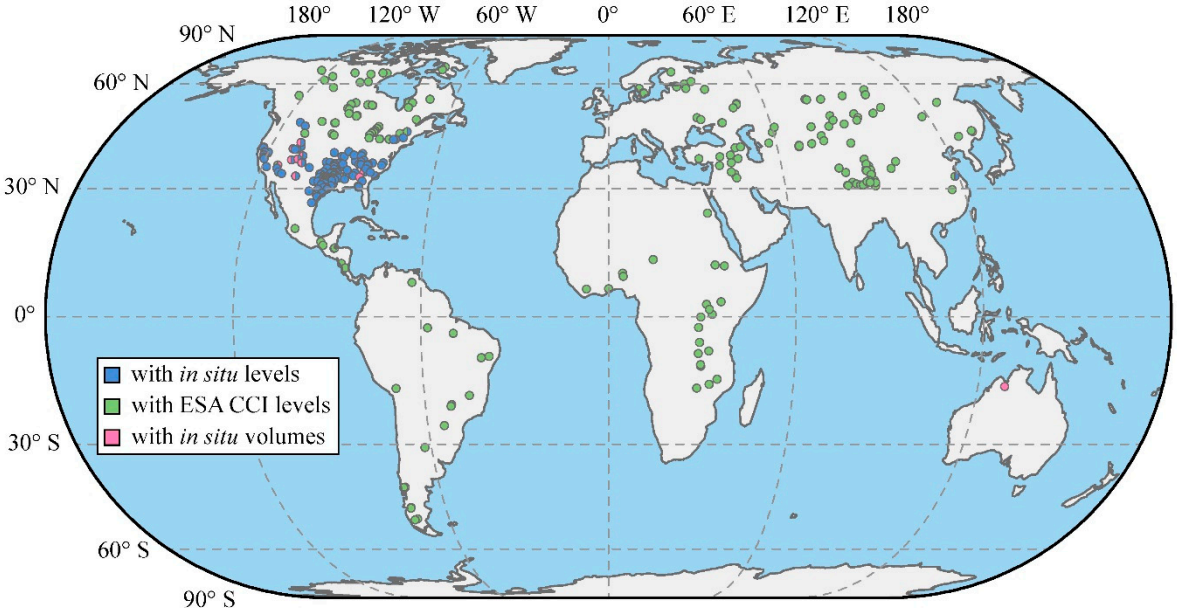

Figure S5. Spatial distribution of the lakes used for validating the results of the current study. Blue dots (or lakes) have in situ measurements of lake water level, green dots have ESA CCI water levels, and red dots have in situ measurements of lake volume.

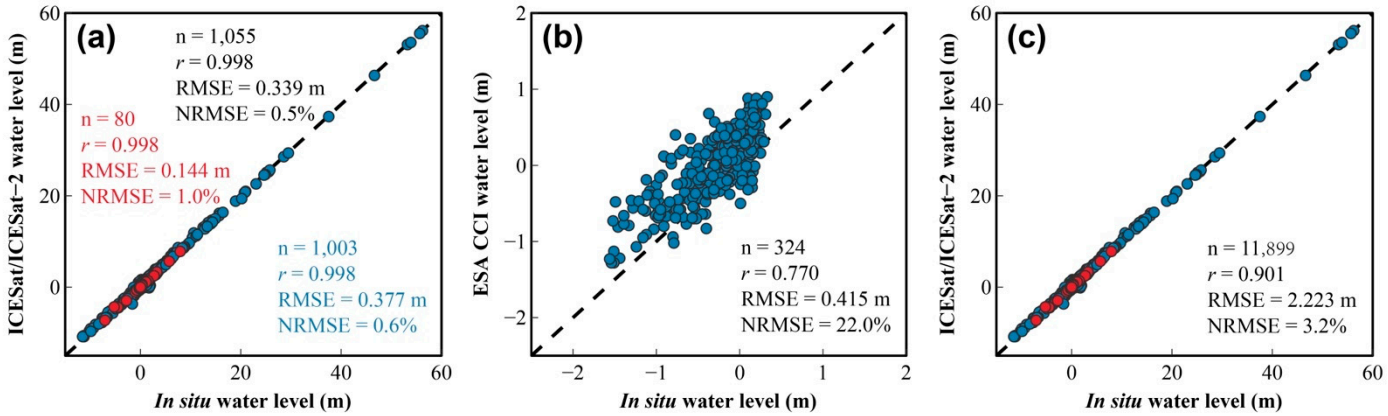

Figure S6. Validation of lake water levels. (a) Comparison between in situ water levels and lake water levels derived from ICESat/ICESat-2 data for the 132 lakes listed in Table S1. For spatial pattern of the 132 lakes, see Figure S5. In this panel, each dot represents a water level observation from a lake, with its value normalized by subtracting the first available water level of this lake during 2003-2020. The normalization was used because lakes differ greatly in altitude, and because the vertical datums of ICESat/ICESat-2 data (EGM2008 geoid) and in situ measurements (NAVD88 geoid for lakes in the United States, and Yellow Sea 1985 for lakes in China) are inconsistent. The overall accuracy of ICESat and ICESat-2 data was written in black. The accuracy of ICESat (ICESat-2) alone was written in red (blue); (b) Comparison between in situ water levels and water levels extracted from the ESA CCI database, for 250 lakes having both observations; (c) Comparison between in situ water levels and area-derived water levels by the sampling-based method.

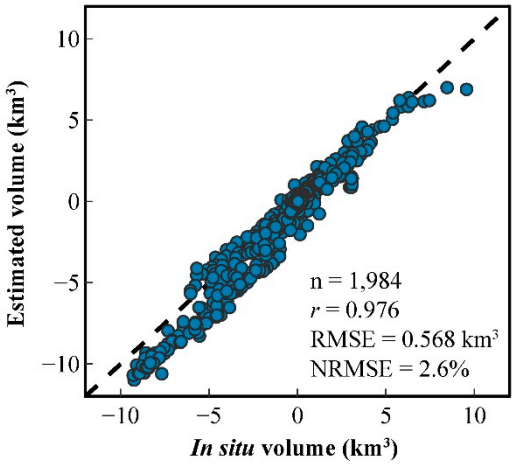

Figure S7. Accuracy assessment for the estimated lake volumes. Shown here is the overall accuracy of the estimated lake volumes compared with in situ volumes of the 14 lakes listed in Table S3. For spatial pattern of the 14 lakes, see Figure S5. Each dot represents a lake volume in a certain month, with its value normalized by subtracting the first volume available for this lake during 2003-2020. The normalization was used because lakes differ greatly in volume.

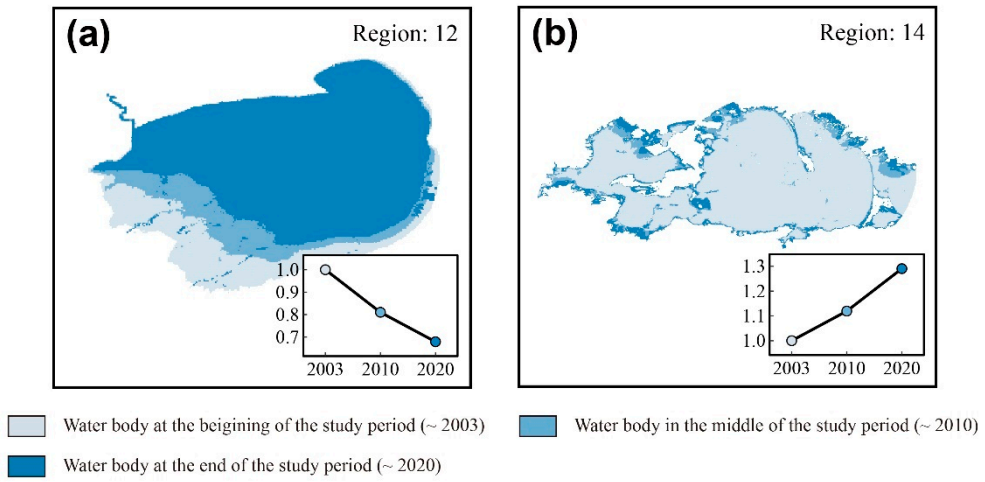

Figure S8. Shoreline changes for two lakes with drastic volume changes. (a) Airag Lake in region 12 (48.93° N, 93.36° E), and (b) Xijir Lake in region 14 (35.21° N, 90.33° E). The inset panels present the changes in relative area (lake area in 2003 equals to 1).

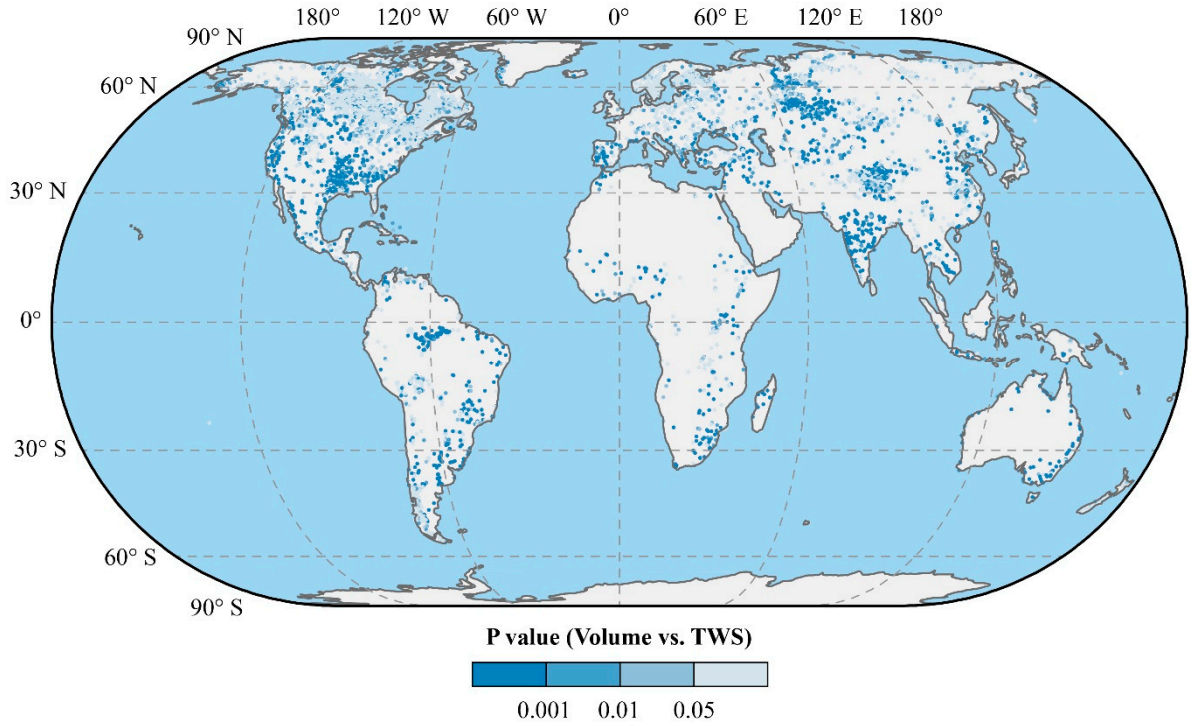

Figure S9. P values of the correlation coefficients between monthly lake volume and TWS.

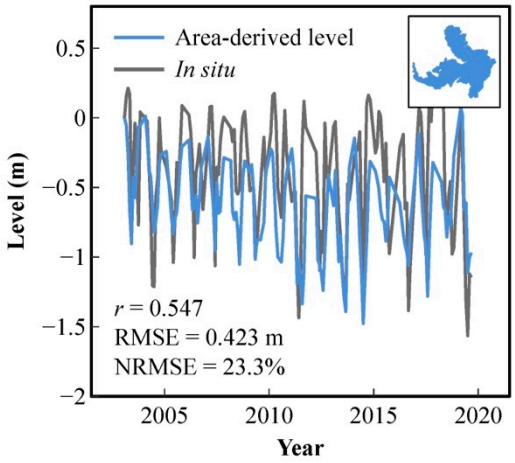

Figure S10. Area-derived water levels compared with in situ lake water levels for Lake Hongze in the lower Yangtze River Basin in China.

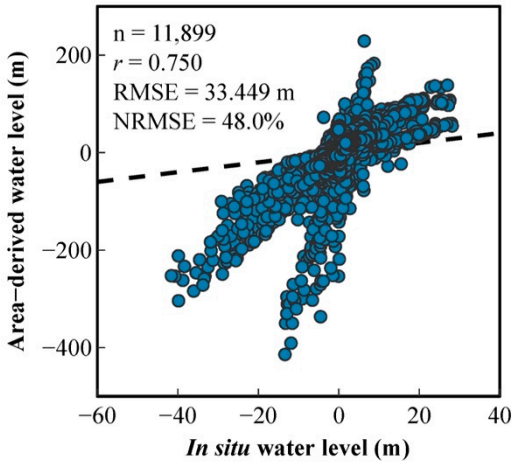

Figure S11. Validation of area-derived water levels for the 132 lakes described in Table S1. Here, lake water levels were derived from lake area using the topographic slopes (”Slope_100”) provided by Messager et al. [30], instead of using the ”Regression slope” between lake water levels and lake area as described in section 2.5 in the main text. ”Slope_100” was defined by Messager et al. [30] as the average topographic slope within a 100-meter buffer around the lake boundary, in unit of degree. We converted ‘Slope_100’ into ”Regression slope” (i.e., $\frac{d\ level}{d\ area}$, m^{-1}), as follows: $Regression\ slope = \left(sqrt\left(\frac{area+1}{\pi}\right) - sqrt\left(\frac{area}{\pi}\right)\right) * \tan\left(\frac{180*Slope\_100}{\pi}\right)$, where $area$ is the area of a lake provided by the HydroLAKES database (in unit of m^2). We assumed a circular shape of lake boundary for all lakes during the conversion. The dashed line corresponds to the line of identity ($y = x$).

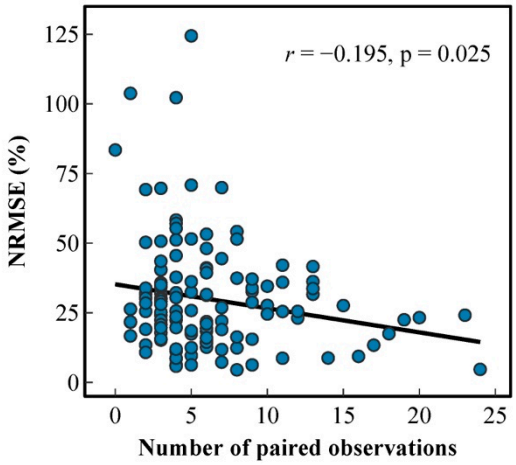

Figure S12. Relationship between the accuracy of the estimated lake water levels (NRMSE, %) and the number of paired observations between lake water level and lake area. Each dot represents one of the 132 lakes having in situ measurements of lake water level. The accuracy of the estimated lake water levels compared against in situ measurements was indicated by NRMSE, which is the normalized RMSE and is calculated as RMSE divided by the range of the in situ lake water levels.

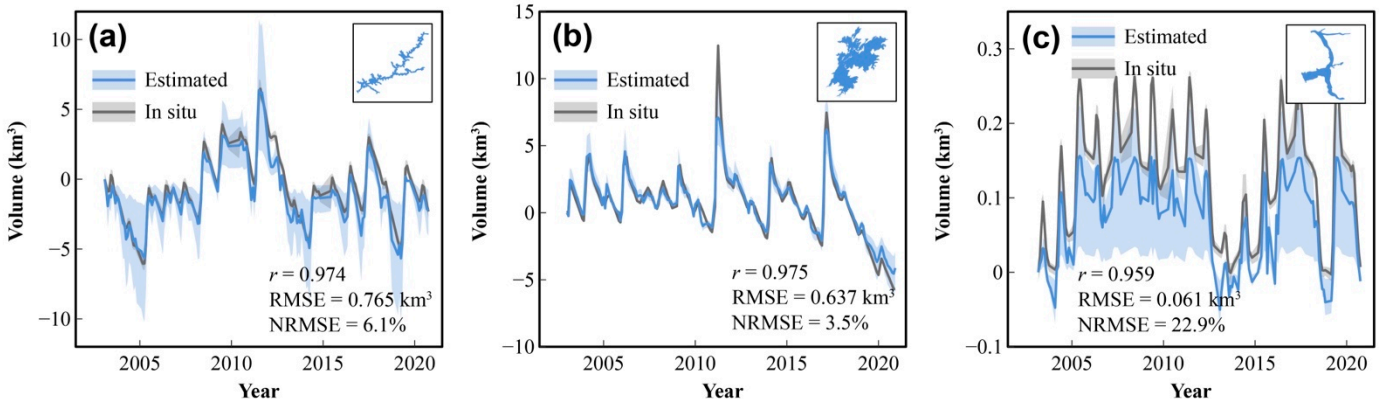

Figure S13. Time series of the estimated lake volumes compared to in situ lake volumes for three typical lakes. The three lakes are (a) Lake Powell (37.37° N, 110.73° W), (b) Lake Argyle (16.12° S, 128.74° E), and (c) McPhee Reservoir (37.58° N, 108.58° W). In each panel, the y values have been normalized by subtracting the first volume available for this lake during 2003-2020. The blue shadows denote the 90% confidence interval of the estimated volumes, and gray shadows denote the range of the daily in situ measurements within each month.

Table S1. Validation of ICESat/ICESat-2-derived lake water levels. 131 lakes with in situ measurements of lake water level were obtained from the U.S. Lakes website (http://www.uslakes.info/), and they have at least two paired in situ and ICESat/ICESat-2-derived water levels (such that a change in lake water level can be calculated and compared). In addition, in situ measurements of water level for Lake Hongze were obtained from a local hydrological station. The spatial distribution of these 132 lakes is shown in Figure S5. In the table below, "Pearson's *r*" means the Pearson correlation coefficient between the estimated and in situ time series of lake water level; "RMSE" is the root mean square error between estimated and in situ time series of lake water level; "NRMSE" is the normalized RMSE, and is calculated as RMSE divided by the range of the in situ lake water levels.

Lake ID	Lake name	Latitude (°)	Longitude (°)	Pearson's r	RMSE (km^3)	NRMSE (%)
64	Lake Champlain	45.05	-73.33	0.618	0.168	69.1
145	Lake Hongze	33.09	118.73	0.824	0.266	17.6
730	Flathead Lake	47.68	-114.23	0.956	0.709	27.3
743	Canyon Ferry Lake	46.65	-111.73	0.999	0.126	2.8
784	Flaming Gorge Reservoir	40.92	-109.42	0.996	0.077	3.6
786	Shasta Lake	40.72	-122.42	1.000	0.142	0.6
792	Lake Tahoe	39.16	-120.14	0.535	0.149	48.8
796	Harry S. Truman Reservoir	38.26	-93.41	0.954	0.186	15.2
797	Osage Lake	38.21	-92.63	0.964	0.105	7.7
799	Lake Powell	37.37	-110.73	0.997	0.635	4.0
800	Lake Barkley	37.02	-88.22	0.889	0.408	26.2
804	Table Rock Lake	36.60	-93.31	0.977	0.133	7.3
805	John H. Kerr Reservoir	36.60	-78.29	0.788	0.314	15.4
806	Grand Lake	36.47	-95.04	0.981	0.137	5.1
807	Oologah Lake	36.42	-95.68	0.991	0.081	6.9
811	Greers Ferry Lake	35.52	-91.99	0.992	0.631	14.1
814	Robert S. Kerr Reservoir	35.35	-94.78	0.601	0.203	31.7
822	Hartwell Lake	34.36	-82.82	0.889	0.539	60.9
823	Lake Sidney Lanier	34.16	-84.07	0.985	0.557	9.6
825	Lake Texoma	33.82	-96.57	0.936	0.294	29.2
826	Grenada Lake	33.81	-89.77	0.881	0.434	30.3
830	Lake Moultrie	33.24	-80.00	0.770	0.160	32.9
831	Elephant Butte Reservoir	33.16	-107.19	1.000	0.102	0.7
832	Lake Tawakoni	32.81	-95.91	0.898	0.129	16.3
835	Cedar Creek Reservoir	32.18	-96.07	0.835	0.099	25.0
836	Richland-Chambers Reservoir	31.95	-96.10	1.000	0.052	57.1
838	Toledo Bend Reservoir	31.17	-93.57	0.958	0.565	27.3
839	Sam Rayburn Reservoir	31.06	-94.11	0.981	0.159	6.1
841	Lake Livingston	30.63	-95.02	0.407	0.438	95.7
848	Amistad Reservoir	29.45	-101.05	0.999	0.519	3.5
855	Falcon Reservoir	26.56	-99.17	0.996	0.159	3.6
9074	Great Sacandaga Lake	43.32	-73.92	0.981	0.120	10.9
9096	Owasco Lake	42.90	-76.54	1.000	0.036	13.2
9097	Canandalgua Lake	42.87	-77.27	0.999	0.154	101.0
9132	Fontenelle Reservoir	42.03	-110.07	0.998	0.147	3.4
9172	Trinity Lake	40.80	-122.76	1.000	0.451	2.0
9180	Whiskeytown Lake	40.60	-122.54	0.998	0.104	3.4
9189	Starvation Reservoir	40.19	-110.44	-0.665	0.137	131.1
9194	Strawberry Reservoir	40.14	-111.03	0.998	0.111	8.0
9208	Lake Oroville	39.54	-121.48	1.000	0.191	0.3
9209	Mark Twain Lake	39.53	-91.65	0.988	0.143	6.3
9212	Stampede Reservoir	39.47	-120.11	1.000	0.201	2.4
9220	New Bullards Bar Reservoir	39.39	-121.14	0.997	0.935	8.1
9224	Tuttle Creek Lake	39.26	-96.59	0.997	0.750	9.8
9229	Monroe Lake	39.01	-86.50	0.993	0.113	7.0
9235	Folsom Lake	38.71	-121.16	0.999	0.398	2.5
9239	Carlyle Lake	38.62	-89.35	0.981	0.079	8.1
9244	Ruedi Reservoir	38.45	-107.33	1.000	0.139	1.0
9246	Patoka Lake	38.43	-86.71	0.937	0.604	33.0
9259	New Hogan Lake	38.15	-120.81	0.996	0.122	4.3

Lake ID	Lake name	Latitude (°)	Longitude (°)	Pearson's r	RMSE (km^3)	NRMSE (%)
9272	Don Pedro Reservoir	37.70	-120.42	1.000	0.311	6.7
9277	McPhee Reservoir	37.58	-108.57	1.000	0.122	1.5
9284	Green River Lake	37.25	-85.34	1.000	0.024	11.2
9295	Barren River Lake	36.89	-86.12	1.000	0.080	12.5
9299	Great Salt Plains Lake	36.75	-98.14	0.740	0.081	24.3
9300	Kaw Lake	36.70	-96.93	0.960	0.247	12.3
9301	Heron Reservoir	36.67	-106.70	0.997	0.316	2.6
9304	El Vado Lake	36.59	-106.73	1.000	0.402	2.0
9306	South Holston Lake	36.52	-82.09	1.000	0.281	24.9
9313	Beaver Lake	36.42	-93.85	0.998	0.101	3.1
9319	Lake Hudson	36.30	-95.16	0.936	0.046	21.5
9322	Norfork Lake	36.25	-92.24	0.999	0.063	1.4
9326	Cherokee Lake	36.16	-83.50	0.999	0.468	6.8
9327	J. Percy Priest Lake	36.16	-86.62	0.964	0.116	11.9
9330	Center Hill Lake	36.10	-85.83	0.998	0.071	2.8
9332	Douglas Lake	35.96	-83.53	1.000	0.111	1.5
9333	Falls Lake	35.95	-78.58	0.985	0.242	9.8
9335	Fort Gibson Lake	35.87	-95.23	0.844	0.313	29.3
9345	Isabella Lake	35.65	-118.48	1.000	0.176	2.5
9348	Tenkiller Lake	35.60	-95.04	0.999	0.120	3.9
9355	Ute Reservoir	35.35	-103.45	0.983	0.299	23.4
9358	Lake Thunderbird	35.22	-97.22	0.618	0.114	62.6
9360	Lake Mohave	35.20	-114.57	0.964	0.115	8.8
9367	Chatuge Lake	35.02	-83.79	1.000	0.131	53.8
9371	Wister Lake	34.94	-94.72	0.999	0.216	15.8
9378	Arkabutla Lake	34.76	-90.12	0.995	0.164	5.2
9396	Waurika Lake	34.24	-98.06	0.992	0.103	16.2
9397	Alamo Lake	34.24	-113.60	0.986	0.125	9.1
9398	Degray Lake	34.22	-93.11	0.996	0.149	3.8
9401	Lake Greenwood	34.17	-81.91	0.913	0.160	25.0
9405	Lake Greeson	34.15	-93.72	1.000	0.110	15.7
9406	Broken Bow Lake	34.15	-94.68	0.998	0.163	14.9
9411	Hugo Lake	34.01	-95.38	0.562	0.097	35.5
9412	Lewis Smith Lake	33.94	-87.11	0.998	0.163	4.2
9414	Pat Mayse Lake	33.85	-95.56	0.977	0.152	13.1
9415	Lake Pleasant	33.85	-112.27	1.000	0.125	1.3
9419	Lake Kemp	33.75	-99.15	0.991	0.123	13.9
9420	Millwood Lake	33.69	-93.97	0.643	0.273	64.0
9424	Lake Kickapoo	33.66	-98.78	0.911	0.159	15.8
9434	Texarkana Lake	33.31	-94.16	0.996	0.104	5.2
9436	Lake Tuscaloosa	33.27	-87.51	1.000	0.173	47.2
9438	Lake Bridgeport	33.22	-97.83	0.672	0.100	41.1
9443	Lewisville Lake	33.07	-96.97	0.941	0.078	15.0
9446	Lavon Lake	33.03	-96.47	0.988	0.144	8.1
9450	Grapevine Lake	32.97	-97.06	0.999	0.046	2.0
9454	Eagle Mountain Lake	32.87	-97.50	0.999	0.056	9.2
9455	Possum Kingdom Lake	32.87	-98.43	0.936	0.522	71.3
9456	Hubbard Creek Lake	32.83	-98.96	0.545	0.040	43.5
9457	Lake Fork	32.81	-95.53	0.954	0.073	11.9
9460	Lake Ray Hubbard	32.80	-96.50	0.966	0.073	20.0
9462	Lake O' the Pines	32.75	-94.51	0.996	0.064	2.9
9463	Lake Claiborne	32.74	-92.91	0.367	0.194	58.0
9464	Bayou Darbonne Reservoir	32.71	-92.34	0.815	0.142	26.0
9465	Caddo Lake	32.71	-93.92	0.947	0.101	15.8
9467	Benbrook Lake	32.65	-97.46	0.972	0.228	8.2
9468	Joe Pool Lake	32.64	-96.99	0.880	0.257	49.5
9473	Cross Lake	32.51	-93.80	0.867	0.088	41.2

Lake ID	Lake name	Latitude (°)	Longitude (°)	Pearson's r	RMSE (km^3)	NRMSE (%)
9475	Ross R. Barnett Reservoir	32.40	-90.06	0.906	0.158	28.8
9477	Lake Granbury	32.38	-97.69	0.324	0.081	38.1
9478	Lake Bistineau	32.32	-93.42	0.144	0.122	200.4
9481	Martin Lake	32.27	-94.54	0.949	0.076	24.8
9482	Bardwell Lake	32.25	-96.65	0.980	0.370	15.4
9484	Lake Palestine	32.15	-95.47	1.000	0.171	19.4
9486	Lake Murvaul	32.04	-94.42	0.742	0.171	43.0
9487	Navarro Mills Lake	31.95	-96.70	1.000	0.082	12.9
9490	E. V. Spence Reservoir	31.90	-100.52	0.968	0.057	15.6
9492	Lake Whitney	31.87	-97.37	0.995	0.086	4.0
9493	Lake Blackshear	31.85	-83.94	-0.758	0.078	256.5
9495	Lake Brownwood	31.84	-99.00	0.990	0.039	6.0
9496	Lake Waco	31.58	-97.20	0.922	0.172	21.6
9504	Lake Limestone	31.33	-96.33	0.936	0.138	20.5
9508	Stillhouse Hollow Lake	31.02	-97.53	0.992	0.085	4.9
9513	Steinhagen Reservoir	30.80	-94.17	-0.411	0.084	137.2
9516	Lake Seminole	30.71	-84.87	0.595	0.158	36.9
9525	Lake Talquin	30.39	-84.65	0.401	0.035	57.9
9526	Lake Conroe	30.36	-95.56	0.896	0.149	37.7
9528	Somerville Lake	30.31	-96.52	0.985	0.212	10.2
9540	Lake Houston	29.92	-95.13	0.902	0.108	27.2
9542	Canyon Lake	29.87	-98.20	0.988	0.040	11.9
9594	Lake Texana	28.89	-96.57	0.719	0.119	97.8
9605	Choke Canyon Lake	28.48	-98.25	0.967	0.172	13.5
9615	Lake Corpus Christi	28.05	-97.87	0.990	0.109	8.3

Table S2. Validation of area-derived water levels for the 132 lakes described in Table S1. The notations are the same as those described in the legend to Table S1.

Lake ID	Lake name	Latitude (°)	Longitude (°)	Number of pairs	Pearson's r	RMSE (m)	NRMSE (%)
64	Lake Champlain	45.05	-73.33	6	0.952	0.318	31.3
145	Lake Hongze	33.09	118.73	20	0.547	0.423	23.3
730	Flathead Lake	47.68	-114.23	10	0.393	0.758	34.5
743	Canyon Ferry Lake	46.65	-111.73	5	0.652	1.261	25.8
784	Flaming Gorge Reservoir	40.92	-109.42	17	0.935	0.438	13.4
786	Shasta Lake	40.72	-122.42	9	0.974	2.873	6.3
792	Lake Tahoe	39.16	-120.14	7	0.828	0.561	26.9
796	Harry S. Truman Reservoir	38.26	-93.41	6	0.869	0.918	14.0
797	Osage Lake	38.21	-92.63	8	-0.061	0.747	54.2
799	Lake Powell	37.37	-110.73	16	0.966	2.072	9.4
800	Lake Barkley	37.02	-88.22	13	-0.091	0.684	41.6
804	Table Rock Lake	36.60	-93.31	13	0.448	2.264	36.2
805	John H. Kerr Reservoir	36.60	-78.29	7	0.470	2.395	69.9
806	Grand Lake	36.47	-95.04	11	0.094	1.260	42.1
807	Oologah Lake	36.42	-95.68	8	0.680	0.667	12.4
811	Greers Ferry Lake	35.52	-91.99	11	0.558	1.578	25.5
814	Robert S. Kerr Reservoir	35.35	-94.78	13	0.303	0.190	31.6
822	Hartwell Lake	34.36	-82.82	12	0.739	1.138	23.1
823	Lake Sidney Lanier	34.16	-84.07	15	0.629	1.627	27.6
825	Lake Texoma	33.82	-96.57	18	0.782	1.430	17.5
826	Grenada Lake	33.81	-89.77	4	0.897	1.048	11.2
830	Lake Moultrie	33.24	-80.00	5	-0.033	0.121	17.8
831	Elephant Butte Reservoir	33.16	-107.19	3	0.964	5.389	31.9
832	Lake Tawakoni	32.81	-95.91	6	0.954	0.709	18.4
835	Cedar Creek Reservoir	32.18	-96.07	12	0.887	0.496	25.5
836	Richland-Chambers Reservoir	31.95	-96.10	2	0.877	1.048	31.8
838	Toledo Bend Reservoir	31.17	-93.57	23	0.837	0.827	24.1
839	Sam Rayburn Reservoir	31.06	-94.11	19	0.859	1.127	22.5
841	Lake Livingston	30.63	-95.02	11	0.659	0.516	36.0
848	Amistad Reservoir	29.45	-101.05	24	0.990	0.761	4.7
855	Falcon Reservoir	26.56	-99.17	14	0.978	1.098	8.8
9074	Great Sacandaga Lake	43.32	-73.92	3	0.918	0.838	24.1
9096	Owasco Lake	42.90	-76.54	3	-0.342	0.205	40.4
9097	Canandalgua Lake	42.87	-77.27	4	-0.481	0.363	102.2
9132	Fontenelle Reservoir	42.03	-110.07	3	0.701	1.438	15.2
9172	Trinity Lake	40.80	-122.76	8	0.988	2.193	4.5
9180	Whiskeytown Lake	40.60	-122.54	2	0.507	2.337	69.2
9189	Starvation Reservoir	40.19	-110.44	2	0.890	0.972	13.4
9194	Strawberry Reservoir	40.14	-111.03	3	0.847	1.969	35.8
9208	Lake Oroville	39.54	-121.48	7	0.979	5.037	7.3
9209	Mark Twain Lake	39.53	-91.65	6	0.604	1.145	19.4
9212	Stampede Reservoir	39.47	-120.11	2	0.969	3.098	10.8
9220	New Bullards Bar Reservoir	39.39	-121.14	5	0.941	4.232	9.6
9224	Tuttle Creek Lake	39.26	-96.59	6	0.640	3.564	21.8
9229	Monroe Lake	39.01	-86.50	4	0.397	1.035	25.7
9235	Folsom Lake	38.71	-121.16	6	0.971	4.215	15.8
9239	Carlyle Lake	38.62	-89.35	9	0.494	0.933	32.7
9244	Ruedi Reservoir	38.45	-107.33	6	0.936	3.414	14.7
9246	Patoka Lake	38.43	-86.71	5	0.263	2.039	51.5
9259	New Hogan Lake	38.15	-120.81	4	0.962	2.143	8.5
9272	Don Pedro Reservoir	37.70	-120.42	4	0.981	2.644	6.3
9277	McPhee Reservoir	37.58	-108.57	4	0.959	4.189	22.4
9284	Green River Lake	37.25	-85.34	3	0.106	1.941	34.3
9295	Barren River Lake	36.89	-86.12	2	0.638	4.528	33.8
9299	Great Salt Plains Lake	36.75	-98.14	3	0.838	0.058	15.4

Lake ID	Lake name	Latitude (°)	Longitude (°)	Number of pairs	Pearson's r	RMSE (m)	NRMSE (%)
9300	Kaw Lake	36.70	-96.93	6	0.791	0.836	12.7
9301	Heron Reservoir	36.67	-106.70	5	0.984	1.512	6.3
9304	El Vado Lake	36.59	-106.73	3	0.965	5.246	17.9
9306	South Holston Lake	36.52	-82.09	3	0.072	2.348	35.0
9313	Beaver Lake	36.42	-93.85	3	0.606	2.344	40.5
9319	Lake Hudson	36.30	-95.16	1	0.430	0.558	16.7
9322	Norfork Lake	36.25	-92.24	3	0.767	3.111	29.9
9326	Cherokee Lake	36.16	-83.50	4	0.598	5.696	58.3
9327	J. Percy Priest Lake	36.16	-86.62	4	0.421	1.118	51.2
9330	Center Hill Lake	36.10	-85.83	3	-0.099	3.654	50.7
9332	Douglas Lake	35.96	-83.53	7	0.798	2.870	22.0
9333	Falls Lake	35.95	-78.58	6	0.416	0.867	41.2
9335	Fort Gibson Lake	35.87	-95.23	5	0.609	2.115	32.4
9345	Isabella Lake	35.65	-118.48	4	0.990	1.093	5.8
9348	Tenkiller Lake	35.60	-95.04	6	0.526	2.048	21.5
9355	Ute Reservoir	35.35	-103.45	5	0.900	0.744	36.2
9358	Lake Thunderbird	35.22	-97.22	4	0.282	0.679	57.1
9360	Lake Mohave	35.20	-114.57	8	0.619	1.030	37.4
9367	Chatuge Lake	35.02	-83.79	2	0.096	0.874	30.3
9371	Wister Lake	34.94	-94.72	3	0.566	1.170	20.8
9378	Arkabutla Lake	34.76	-90.12	3	0.801	2.418	30.2
9396	Waurika Lake	34.24	-98.06	1	0.520	0.259	21.6
9397	Alamo Lake	34.24	-113.60	4	0.976	2.912	19.7
9398	Degray Lake	34.22	-93.11	9	0.531	1.210	28.7
9401	Lake Greenwood	34.17	-81.91	5	0.185	1.578	124.4
9405	Lake Greeson	34.15	-93.72	1	0.473	0.974	21.8
9406	Broken Bow Lake	34.15	-94.68	2	0.428	1.621	25.5
9411	Hugo Lake	34.01	-95.38	7	0.727	0.916	11.8
9412	Lewis Smith Lake	33.94	-87.11	2	0.062	1.409	28.5
9414	Pat Mayse Lake	33.85	-95.56	6	0.782	0.746	21.8
9415	Lake Pleasant	33.85	-112.27	4	0.984	1.293	8.7
9419	Lake Kemp	33.75	-99.15	4	0.837	1.065	45.5
9420	Millwood Lake	33.69	-93.97	3	0.656	0.597	25.2
9424	Lake Kickapoo	33.66	-98.78	3	0.755	0.329	22.4
9434	Texarkana Lake	33.31	-94.16	13	0.507	2.550	33.7
9436	Lake Tuscaloosa	33.27	-87.51	1	0.132	0.710	103.8
9438	Lake Bridgeport	33.22	-97.83	5	0.986	5.364	70.8
9443	Lewisville Lake	33.07	-96.97	9	0.916	0.739	15.5
9446	Lavon Lake	33.03	-96.47	4	0.910	0.733	12.0
9450	Grapevine Lake	32.97	-97.06	5	0.900	1.536	17.4
9454	Eagle Mountain Lake	32.87	-97.50	6	0.954	0.482	14.5
9455	Possum Kingdom Lake	32.87	-98.43	11	0.967	0.377	8.7
9456	Hubbard Creek Lake	32.83	-98.96	3	0.977	6.485	69.7
9457	Lake Fork	32.81	-95.53	6	0.771	0.888	40.8
9460	Lake Ray Hubbard	32.80	-96.50	4	0.876	0.900	32.2
9462	Lake O' the Pines	32.75	-94.51	6	0.727	2.098	48.1
9463	Lake Claiborne	32.74	-92.91	4	0.355	1.336	55.3
9464	Bayou Darbonne Reservoir	32.71	-92.34	3	0.447	0.393	20.7
9465	Caddo Lake	32.71	-93.92	8	0.580	0.619	51.5
9467	Benbrook Lake	32.65	-97.46	4	0.804	1.255	23.6
9468	Joe Pool Lake	32.64	-96.99	8	0.625	0.464	16.3
9473	Cross Lake	32.51	-93.80	3	0.380	0.292	29.9
9475	Ross R. Barnett Reservoir	32.40	-90.06	3	0.225	0.203	43.5
9477	Lake Granbury	32.38	-97.69	9	0.941	1.033	33.8
9478	Lake Bistineau	32.32	-93.42	2	0.560	1.368	50.3
9481	Martin Lake	32.27	-94.54	4	0.710	0.978	30.5
9482	Bardwell Lake	32.25	-96.65	6	0.776	0.954	21.0

Lake ID	Lake name	Latitude (°)	Longitude (°)	Number of pairs	Pearson's r	RMSE (m)	NRMSE (%)
9484	Lake Palestine	32.15	-95.47	2	0.572	0.406	19.1
9486	Lake Murvaul	32.04	-94.42	1	0.553	0.385	26.3
9487	Navarro Mills Lake	31.95	-96.70	3	0.672	0.534	15.6
9490	E. V. Spence Reservoir	31.90	-100.52	3	0.935	3.620	29.1
9492	Lake Whitney	31.87	-97.37	5	0.903	0.885	12.5
9493	Lake Blackshear	31.85	-83.94	3	-0.194	0.172	19.6
9495	Lake Brownwood	31.84	-99.00	10	0.972	1.345	27.7
9496	Lake Waco	31.58	-97.20	5	0.618	0.957	18.5
9504	Lake Limestone	31.33	-96.33	6	0.378	0.732	53.2
9508	Stillhouse Hollow Lake	31.02	-97.53	10	0.256	1.485	24.6
9513	Steinhagen Reservoir	30.80	-94.17	0	-0.115	0.316	83.5
9516	Lake Seminole	30.71	-84.87	9	0.285	0.269	37.1
9525	Lake Talquin	30.39	-84.65	4	0.067	0.077	23.6
9526	Lake Conroe	30.36	-95.56	7	0.577	0.868	44.5
9528	Somerville Lake	30.31	-96.52	6	0.831	1.138	16.0
9540	Lake Houston	29.92	-95.13	4	0.192	0.754	37.8
9542	Canyon Lake	29.87	-98.20	3	0.931	1.142	28.1
9594	Lake Texana	28.89	-96.57	6	0.553	0.559	31.6
9605	Choke Canyon Lake	28.48	-98.25	6	0.936	2.757	39.4
9615	Lake Corpus Christi	28.05	-97.87	7	0.948	0.988	19.0

Table S3. Validation of the estimated lake volumes. In situ measurements of lake volume of 14 lakes were used to assess the accuracy of the lake volumes estimated by the current study. Specifically, daily measurements of volume for El Vado Lake, Utah Lake, Lake Powell, Blue Mesa Reservoir, Elephant Butte Reservoir, Flaming Gorge Reservoir, Fontenelle Reservoir, Heron Reservoir, and McPhee Reservoir were obtained from the USBR (United States Bureau of Reclamation) website (https://www.usbr.gov/rsvrWater/HistoricalApp.html). Daily measurements of volume for West Point Lake, Lake Mead, Lake Seminole, and Lake Sidney Lanier were sourced from the USGS (United States Geological Survey) website (https://waterdata.usgs.gov/nwis/). Monthly measurements of volume for Lake Argyle were obtained from the Water Corporation website (https://www.watercorporation.com.au/). Spatial distribution of the 14 lakes is shown in Figure S5. In the table below, "Number of pairs" indicates the number of paired observations between lake water level and lake area; "Pearson's *r*" signifies the Pearson correlation coefficient between estimated and in situ time series of lake volume; "RMSE" is the root mean square error between estimated and in situ time series of lake volume; "NRMSE" is the normalized RMSE, and is calculated as RMSE divided by the range of in situ lake volumes; "Proportion" signifies the proportion of the in situ volumes falling into the 90% confidence interval of the estimated volume.

Lake ID	Lake name	Latitude (°)	Longitude (°)	Number of pairs	Pearson's r	RMSE (km^3)	NRMSE (%)	Proportion (%)
784	Flaming Gorge Reservoir	40.92	-109.42	17	0.963	0.220	18.3	78.4
788	Utah Lake	40.36	-111.89	11	0.907	0.126	12.9	100.0
799	Lake Powell	37.37	-110.73	16	0.974	0.765	6.1	91.8
809	Lake Mead	36.02	-114.74	32	0.982	1.772	18.9	84.8
823	Lake Sidney Lanier	34.16	-84.07	15	0.659	0.186	19.4	70.0
831	Elephant Butte Reservoir	33.16	-107.19	3	0.967	0.292	37.5	52.1
1632	Lake Argyle	-16.12	128.74	33	0.975	0.637	3.5	68.6
9132	Fontenelle Reservoir	42.03	-110.07	3	0.738	0.039	15.1	99.0
9244	Blue Mesa Reservoir	38.45	-107.33	6	0.935	0.080	11.4	94.4
9277	McPhee Reservoir	37.58	-108.57	4	0.959	0.061	22.9	55.6
9301	Heron Reservoir	36.67	-106.70	5	0.984	0.021	6.2	94.8
9304	El Vado Lake	36.59	-106.73	3	0.974	0.030	14.0	98.0
9452	West Point Lake	32.92	-85.19	1	0.497	0.124	34.4	69.8
9516	Lake Seminole	30.71	-84.87	9	0.449	0.014	29.9	97.8