Physical Oceanography Distributed Active Archive Center (PO.DAAC)

Global Optical-derived Lake Area (GOLA) Time Series Data Set - Water Area (MEaSUREs Project)

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User's Handbook
Version 2.0

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1. *Introduction*

The Global Optical Lake Area (GOLA) determination process estimates surface area of lakes and reservoirs from Terra/Aqua MODIS satellite optical imagery with a 500 m spatial resolution and an 8-day temporal resolution for the 2000-2016 period. The purpose of these area products is to provide satellite-derived lake surface area data in a form that is more recognizable to the observational community and as a way to get users accustomed to using satellite data for lake hydrology. GOLA provides data for 427 of the world's largest lakes and reservoirs (i.e., water bodies larger than roughly 1 km^2). Lake area was processed with limits established by an input vector polygon. To allow for maximum usability, all processing data is included (i.e., NetCDF files, vector polygons, etc).
As described in Khandelwal et al. (2017), we have evaluated the performance of the approach on a global set of reservoirs comparing temporal variations in the surface extent maps with changes in relative water level height from satellite altimetry observations. Furthermore, *in situ* observations and higher resolution Landsat-based reference maps for isolated time steps were used for comparison with the MODIS-estimated area for five case studies in Khandelwal et al. (2017).

2. Methodology

2.1 Lake Locations

In order to estimate the surface area of the target, a static spatial extent is required as one of the inputs. We defined the initial spatial extents of water bodies using the vector polygons available as part of the Global Reservoir and Dam database (GRanD; Lehner et al., 2011) and Global Lakes and Wetlands Database (GLWD; Lehner and Döll, 2004), with quality checks ensured by visual comparison with high resolution satellite imagery (i.e., Google Earth, ESRI World Map) and Global Surface Water Explorer (Pekel et al., 2016). Whenever we identified a mismatch (i.e., polygon spatial extent not overlapping properly with the satellite imagery due to inaccurate georeferencing), the polygon was edited to match the expected location. In case a lake was not available as part of either database, a polygon was drawn by hand using high resolution imagery from various sources (e.g., Google Earth, ESRI World Map). Once correctly identified, these locations were used to construct a mask for MODIS data extraction.

2.2 Data Extraction from MODIS Imagery

The mask was then used to extract all of the data from three MODIS products whose nominal footprint overlapped the polygon of the corresponding lake. Specifically, we used: (i) two multispectral reflectance data products from the MODIS instruments onboard NASA's Terra and Aqua satellites as an input to the water/land classification algorithm (Collection 5 MCD43A4 and MOD0911), and (ii) static water and land classification labels to train the classification model (MODIS MOD44W). All MODIS data used to create the GOLA records are publicly available via the U.S. Geological Survey (USGS) Land Processes Distributed Active Archive Center (LP DAAC; http://lpdaac.usgs.gov), and a more detailed description of the classification algorithm can be found in Khandelwal et al. (2017)*.

**It shall be noted that the surface water extent mask contains six flag values: missing data (0), water (1), land (2), and pixels removed from processing (3-5). Values 3-5 are intentionally repeated values of each other due to the classification.*

2.3 MODIS Reflectance Data

The primary reflectance product was the bidirectional reflectance distribution function (BRDF) adjusted MCD43A4 16-day composite product. The MCD43A4 product is generated by the USGS using data from both the Terra and Aqua satellites to assure that the combined data product is of the highest possible quality. However, by ignoring poor data quality pixels, the MCD43A4 product suffers from a high degree of missing values, especially before Aqua data became available in 2002. This can introduce a high degree of incompleteness in classification maps. To alleviate this issue, we also used the MOD09A1 eight-day composite product collected solely from the Terra satellite. Since the MOD09A1 product is generally less reliable than MCD43A4 as it is not BRDF-adjusted, we combined these two products to compensate for the primary limitations of each, in addition to noise and missing values (cfr. Khandelwal et al., 2017). We also used quality flags to filter out pixels with snow, ice, or clouds. For the MOD10A1 product, information about the data quality is available along with the multispectral values in the 16-bit quality assessment state flags, whereas the quality flags for the MCD43A4 product are available as a separate product (MCD43A2 BRDF/Albedo Quality Product).

2.4 MODIS Land/Water Mask

In order to distinguish between land and water bodies, we used static water extent masks derived from the MODIS MOD44W product (Carroll et al., 2009) to train the supervised classification models. This product, distributed publicly by the USGS, combines MODIS 250 m reflectance data with the SRTM Water Body Dataset from 60°N to 60°S, with reflectance data used solely poleward of 60°N. We aggregated the MOD44W product from 250 m to 500 m to match the resolution of the other MODIS products. In particular, if the 500 m pixel had all of its four pixels at 250 m labeled as water or land in the MOD44W product, then we considered the pixel as a water or land pixel. We excluded partial pixels from the training set pool.

2.5 Ice Cover Assessment

Though frozen lake areas are a part of the unprocessed MODIS data product, they do not appear in the time series.

3. Data Packaging and Variable Identification

3.1 Sample Surface Area Data (NetCDF format)

Format: netcdf4
Title = '[*continent*]_[*name*]_WaterAreaV2_[*id*].nc'
Example: 'South_America_AguaVermelha_WaterAreaV2_448.nc'

3.2 Variables

variable	dimension	datatype	units	long_name
lat	yc, xc	float	degrees north	latitude

lon	xc, yc	float	degrees east	longitude
surface_water_extent_mask	xc, yc, time	float		land_classification_flag
surface_water_extent	time	float	m^2	surface_water_extent_time_series

3.3 Dimensions

dimension	axis	datatype	units	long_name
yc	Y	double	degrees north	longitude
xc	X	double	degrees east	latitude
time	T	double	days since 1900-01-01T00:00:00	time

3.4 Global Attributes

Attribute	Comment	Example
title	Title for the data in the file	Global Lake/Reservoir Surface Water Area Extent Time Series Data for Lake Agua Vermelha
summary	Summary or abstract for the data in the file	The Global Lake/Reservoir Surface Water Extent Mask Time Series are derived from MODIS. The purpose of this dataset is to provide surface water dynamics for several hundred lakes and reservoirs throughout the globe, with a base temporal resolution of 8 days and a spatial resolution of 500 meters. With the exception of periods of low-quality input data, these time series will extend across the lifespan of the MODIS multispectral reflectance products, from roughly 2000-2016. These time series will allow us to satisfy the project goal to produce ESDRs of suitable quality to support long-term trend analysis and global water dynamics models for the longest length possible (in most cases, about 20 years, the length of the altimetry record) of key measures of surface water storages and fluxes. This product should be accessible and of direct use to both water managers and the scientific community worldwide, and will allow for improved assessment and modeling of human impact on the global water cycle.
keywords	A comma separated list of keywords	TERRESTRIAL HYDROSPHERE, SURFACE WATER PROCESSES/MEASUREMENTS, LAKES/RESERVOIRS, MODIS, MEaSUREs
conventions	A comma separated list of conventions	CF-1.7
UUID	Unique identifier for data set	12c562cc-a333-11e9-bca8-a93c32dfccb5
DOI	Digital object identifier	10.5067/UCLRS-AREV2
history	An audit trail for modifications to the original data	Continuing efforts have been made to improve the quality of surface area estimations from previous versions including: new buffer extraction method to automatically detect the extent of individual lakes and reservoirs, improved temporal consistency in the algorithm, automatic detection of time steps with a high proportion of incorrectly classified or missing values, and an improved and expanded training set.

source	The method of production of the original data	MEaSUREs UCLA toolbox 2018
processing_level	Description of the processing or quality control level of the data	L3
comment	Useful additional information	Surface area estimates were calculated by using classified MODIS imagery through the study period. Lake shapefiles are primarily obtained from GranD, secondly GLWD1, thirdly Global Surface Water Explorer, and finally digitized by hand for a few waterbodies.
standard_name_vocabulary	CF standard name vocabulary	CF Standard Name Table v27
product_version	Version identifier of the data file or product as assigned by the data creator.	Version 2.0
date_created	Creation date of this version of the data (netCDF)	2019-01-11T01:52:00 AM
creator_name	Name of the person (or creator type) principally responsible for creating this data	MEaSUREs Team (Lettenmaier D., Noujdina N., Tortini R., Yeo S.)
creator_email	Email address of the person (or creator type) principally responsible for creating this data	dlettenm@ucla.edu (Lettenmaier D.), nnoujdina@ucla.edu (Noujdina N.), rtortini@ucla.edu (Tortini R.), samyeo@ucla.edu (Yeo S.)
creator_type	Specifies type of creator	Group
institution	Name of the institution primarily responsible for originating this data	University of California Los Angeles, Department of Geography
creator_institution	The institution of the creator	Land Surface Hydrology Research Group, UCLA
creator_url	The URL of the of the entity principally responsible for creating this data.	http://hydro.ucla.edu
program	The overarching program(s) of which the dataset is a part.	NASA Earth Science Data Systems (ESDS)
publisher_name	The name of the entity responsible for publishing the data file or product to users.	PO.DAAC (Physical Oceanography Distributed Active Archive Center
publisher_email	The email address of the entity responsible for publishing the data file or product to users.	podaac@podaac.jpl.nasa.gov
publisher_url	The URL of the entity responsible for publishing the data file or product to user.	podaac.jpl.nasa.gov
publisher_type	Specifies type of publisher	Institution
publisher_institution	The institution that presented the data file or equivalent product to users.	PO.DAAC
project		MEaSUREs

geospatial_lat_min	Describes a simple lower latitude limit	-20.2186955829839
geospatial_lat_max	Describes a simple upper latitude limit	-19.656195845917
geospatial_lon_min	Describes a simple lower longitude limit	-50.3662515859588
geospatial_lon_max	Describes a simple upper longitude limit	-49.1362437634452
geospatial_lat_units	Units for the latitude axis	degrees_north
geospatial_lon_units	Units for the longitude axis	degrees_east
geospatial_lon_resolution	Information about the targeted spacing of points in latitude	500 meters
geospatial_lat_resolution	Information about the targeted spacing of points in latitude	500 meters
time_coverage_start	Describes the time of the first data point in the data set	2000-02-18T00:00:00
time_coverage_end	Describes the time of the last data point in the data set	2016-10-15T00:00:00
time_coverage_resolution	Describes the targeted time period between each value in the data set	8 days
keywords_vocabulary	Identifies the controlled keyword vocabulary used to specify the values within the attribute "keywords"	Global Change Master Directory (GCMD)
platform	Name of the platform(s) that supported the sensor data used to create this data set or product	TERRA/AQUA
platform_vocabulary	Controlled vocabulary for the names used in the "platform" attribute	NASA/GCMD Platform Keywords. Version 8.6
instrument	Name of the contributing instrument(s) or sensor(s) used to create this data set or product	MODIS
instrument_vocabulary	Controlled vocabulary for the names used in the "instrument" attribute	NASA/GCMD Instrument Keywords. Version 8.6
cdm_data_type	The data type	Grid
references	Published or web-based references that describe the data or methods used to produce it	Khandelwal et al. (2017). An approach for global monitoring of surface water extent variations using MODIS data. Remote Sensing of Environment, 202, 113-128

4. References

Carroll, M.L., J.R. Townshend, C.M. DiMiceli, P. Noojipady, and R.A. Sohlberg (2009). A New Global Raster Water Mask at 250 m Resolution. International Journal of Digital Earth, 2, 291-308.

Hall, D. K., G.A. Riggs, and V.V. Salomonson (2006). MODIS/Terra Snow Cover Daily L3 Global 500m Grid. Version 5. Boulder, Colorado USA: NASA National Snow and Ice Data Center Distributed Active Archive Center.

Khandelwal, A., A. Karpatne, M. Marlier, J. Kim, D.P. Lettenmaier, V. Kumar (2017). An approach for global monitoring of surface water extent variations in reservoirs using MODIS data. Remote Sensing of Environment, 202, 113-128.

Lehner, B., and P. Döll (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology, 296(1-4), 1-22.

Lehner, B., C. Reidy Liermann, C. Revenga, C. Vörösmarty, B. Fekete, P. Crouzet, P. Döll, M. Endejan, K. Frenken, J. Magome, C. Nilsson, J. Robertson, R. Rödel, N. Sindorf, and D. Wisser (2011). High- resolution mapping of the world's reservoirs and dams for sustainable river-flow management. Frontiers in Ecology and the Environment, 9(9), 494-502.

Pekel J.F., A. Cottam, N. Gorelick and A.S. Belward (2016). High-resolution mapping of global surface water and its long-term changes. doi:10.1038/nature20584.

Appendix I: Coverage

Africa (n = 49)

Lake ID	Name	Lat	Lon	Area Min (m²)	Area Max (m²)
535	Selingue	11.748	-7.9478	77491876	457438193
546	Kossou	8.2146	-5.2729	280559229	577003220
1471	Buyo	6.9313	-6.8271	102821630	533427456
393	Volta	8.9271	0.4069	4261409197	7872831136
542	Tiga	11.5521	8.7416	58387231	177522940
1439	Shiroro	10.2438	7.162	103894925	409998568
417	Kainji	11.2813	4.8456	628736023	1616596447
67	Fitri	13.0521	17.7309	100031064	833091330
66	Iro	10.2521	19.5686	105397538	127936726
1499	Lagdo	9.1396	14.1736	336799871	722327320
553	Mai-Ndombe	-1.4562	18.7205	443056044	2328405478
554	Tumba	-0.5145	18.2694	651060553	787368977
60	Qarun	29.6188	30.9456	225391883	267894352
331	Nasser	24.0563	33.6861	3336443842	5570614047
416	Mweru	-8.3979	29.2152	4947673815	5051139422
69	Kivu	-1.5062	29.4497	2294704026	2429939155
4	Edward	-0.002	29.9895	2210557723	2261861208
564	Mweru Wantipa	-8.3479	30.3064	1051399468	1470843029
73	Upemba	-8.427	26.6438	427815259	695709611
74	Kisale	-8.0687	26.6702	215517572	340663731
315	Tanganyika	-3.2562	30.977	32585441139	32854194127
1432	Cyohoha-sud	-2.252	30.2545	21465894	53879393
1547	Itezhi Tezhi	-15.2937	26.097	171512490	373291890
394	Kariba	-16.3812	29.0999	4470487000	5348871366
11	Bangweulu	-10.777	30.1165	1848857416	2983329892
414	Cahora Bassa	-15.4229	32.7652	1793260751	2876859060

580	Vaaldam	-26.727	28.5339	103465607	356548493
1431	Sterkfontein	-28.3062	29.1217	53450075	77921194
574	Massinger Barragen	-23.7437	32.2028	14811467	140816262
76	Sibayi	-27.1895	32.7688	30696228	63109727
1437	Jebel Aulia	15.323	32.8705	134805812	1023493807
403	Er Rosieres	11.8855	34.815	11591583	634102497
543	Yardi	10.3521	40.6427	54308711	136308424
402	Tana	12.3855	37.7429	2982685915	3395689708
93	Turkana	4.7355	36.8737	7203739232	7818737084
405	Albert	2.4271	31.5219	5400604170	5542279068
398	Kyoga	2.0063	33.5809	2494980813	2802372409
97	Abaya	6.7021	38.1544	1081237060	1177404264
99	Shala	7.6188	38.7314	280773888	305459666
88	Nakuwa	1.3813	33.5867	66758929	88010164
314	Owen Falls	0.573	34.9496	66474505996	67001279025
339	George (1)	0.1688	30.3896	238271419	281203206
82	Rukwa	-7.3104	32.9448	5361321585	5986837724
85	Eyasi	-3.2687	35.4263	238486078	1253393527
91	Naivasha	-0.6062	36.5082	89727435	141674898
87	Ihema	-1.7187	30.9076	65041658	92088684
317	Malawi	-9.4104	34.8037	29414070019	29552954351
79	Chilwa	-14.877	35.9487	911871160	1477926774
81	Chiuta	-14.2645	36.0338	68905518	313831364

Asia (n = 143)

Lake ID	Name	Lat	Lon	Area Min (m2)	Area Max (m2)
1342	Taymyr	75.2354	111.4141	3925038644	4629119954
110	Tuz	39.0521	33.8049	1407733302	1688292531
107	Beysehir	38.0604	31.987	621866938	747227756
525	Keban Baraji	39.2563	40.0483	427171283	627018752
1450	Karakaya	38.8896	39.6052	176449645	341522367
1454	Ust Khantaika	68.5646	92.049	2003841167	2335489223

787	Kureiskaya	67.3354	91.1811	352684632	589453438
828	Khantayskoye	68.6063	93.4763	801536467	961028056
609	Mingechaurskoye	41.1313	47.4831	418370266	604264905
260	Sevan	40.7104	46.0824	1234074223	1308560874
275	Kara-Bogaz-Gol	42.2979	56.1662	20192322130	20623357273
1597	Batman Baraji	38.3479	41.4218	6225109	68476201
1438	Ataturk	38.2771	39.4971	645264762	906504687
526	Dukan	36.2771	45.2786	77706535	266177081
527	Bahrat Assad	36.8729	39.1707	646338056	865934148
1457	Qadisiyah	34.4938	42.6808	108617422	485343854
269	Buhayrat ath Tharthar	34.6313	44.2503	1606507477	2151311856
388	Razazza	33.1979	44.289	258878677	1377681051
115	Urmia (1)	37.9063	46.4105	1734444203	4087106141
112	Van	39.0813	43.8457	3558615840	3704583917
387	Habbaniyah	33.4563	43.7812	108402763	397977667
111	Ercek	38.8188	43.8494	105826855	122140935
1534	Mosul	37.0646	43.3163	165072722	367925416
3849	Jabbul (1)	36.1771	37.7308	81999714	179884188
3949	Jabhul (3)	35.9979	37.9488	71910744	129439338
1829	Urmia (2)	38.3479	45.9058	1694946958	2248337695
3871	Jabhul (2)	36.1729	37.8991	181386801	295585355
2319	Adhaim	34.8604	44.8201	1502613	93591296
2328	Hammar (1)	31.0354	47.4436	0	1216257531
434	Vilyui	63.6146	117.9894	1726716481	2287620281
1378	Novosibirskoye	54.9313	83.9157	1002457231	1240728650
232	Chany	55.1521	78.9981	1286451003	1685501965
238	Zhalauly	53.0688	74.8271	124502183	233119604
1442	Aral (3)	46.8896	62.1853	2814822627	3871803228
610	Sarykamyshskoye	42.4521	58.6535	3782075793	4086247505
277	Aral (2)	46.1354	61.7252	5386651339	11409122447
803	Aral (4)	46.4729	60.4491	381878247	765688425
424	Aydar Kol	41.1979	68.4689	3237056754	3776923978

1577	Karkheh	32.7104	48.3536	1287954	133088540
2329	Hammar (2)	31.5188	47.5896	0	1158299618
2314	Dez	32.8563	48.8496	14596808	70837449
433	Ust Ilim	58.0813	107.0634	1713407627	2087558152
425	Krasnoyarskoye	56.0229	96.9641	1585041583	2696116236
459	Sayano Shushenskaya	52.9271	96.0847	183962708	1743674537
1947	Boguchany	59.0813	106.0961	631526590	1987312429
218	Uvs	50.7646	94.5408	3606914101	3705871871
583	Bratskoye	56.4688	115.7805	4211608324	5904838011
612	Toktogulskoye	41.9354	73.4278	166360675	334867940
460	Chardarinskoye	41.3313	68.9973	217234843	895986399
479	Kayrakkum	40.5021	70.636	249648343	614353875
615	Zaysan	49.8354	88.5516	4151289163	5040835793
431	Kapchagayskoye	44.0271	78.7104	1118802374	1377466392
278	Balkhash	46.9188	79.861	17184735778	20211212116
338	Issyk-kul	42.8479	78.7598	6194198256	6278344559
233	Alakol	46.5604	83.4951	2948555144	3163214080
209	Ulungar	47.5063	88.1771	876023118	946216590
234	Sasykkol	46.7896	81.7687	768264332	1204665949
575	Markakol	48.9188	86.3953	432967074	502087251
1830	Nurek	38.9146	70.1375	48942237	160135566
625	Tarbela	34.6896	73.5711	109905375	311684775
316	Baikal	55.9479	117.3288	32110830232	34914490594
413	Hovs Gol	51.6938	103.097	2773393453	3445275922
217	Hyargas	49.4229	94.5116	1404728077	1585041583
216	Har us Nuur	48.4604	93.5105	960169421	1120734305
347	Bosten	42.3104	88.2201	891049243	1873543193
411	Har Nuur	48.3354	94.2275	616500464	713096985
372	Dorgon	47.9688	94.3594	331862715	399909598
2313	Thein	32.6396	76.0937	8801016	72554720
628	Beas	32.1896	76.5719	77706535	245355164
643	Bhakra	31.6604	77.1801	59675184	148973302

4034	Tehri	30.7021	78.9614	0	54738029
141	La-ang	30.9271	81.5995	265962422	1045174359
121	Pangong	34.0646	79.4068	554464032	760965928
175	Gozha	35.1688	81.4897	451857060	1057409919
181	Memar	34.4104	82.8498	290433540	638610335
176	Bangdag	35.0813	81.9063	91659366	251150955
180	Aru	34.1938	82.8479	317051248	620364325
178	Gyeze Caka	34.0938	81.2506	121926276	258449359
182	Heishi Beihu	35.7021	83.0728	142104216	741861283
177	Orba	34.6854	81.3708	131156610	662652135
179	Lumajangdong	34.2063	82.1347	286998997	497579414
140	Ma-pang yung-tso	30.8688	81.8556	405061412	549741535
958	Vallabhsagar	21.598	74.2393	152407845	525270416
519	Gandhi Sagar	24.7813	75.973	71696085	672955764
353	Zeyaskoye	54.8396	130.9002	1862166270	2269588930
226	Barun-Torey	50.3146	116.735	245784482	1577743179
385	Hulun	49.4729	119.4808	1768574973	2372839878
163	Na-Mu	31.0146	91.3248	2008134346	2313164694
158	Se-lin	32.0938	89.7462	1807213582	2449258459
152	Cha-jih nan-mu-tso	31.1646	86.3075	1079305130	1182126760
155	Tang-je yung-tso	31.4521	87.2356	835237920	918740246
202	Har (1)	38.4979	98.2928	539008588	786939659
205	Ayakkum	37.7188	90.4286	642474195	1083168991
146	Ta-jo	31.2938	84.5629	479333404	533642115
156	Ang-tzu	31.2313	87.6402	406134707	551244148
170	Dorsoidong	33.6271	90.3755	460014100	540296542
185	Dagze	31.8854	88.4336	337229188	396475055
199	Dabsan	37.1563	95.7846	264459809	1682067422
191	Xijir Ulan	35.3854	90.7847	319412497	580867081
189	Dogai Coring	34.7563	89.5702	413862429	546521651
166	Dogen	31.8979	91.5179	149831937	180957483
201	Qinghai	37.3146	101.8117	4100629654	4427340554

285	Ngoring	35.1646	98.4172	561333118	713740962
645	Govind Ballabah Pant	24.2855	83.2114	242564598	480621358
1723	Bansagar	24.3355	81.4927	0	529563595
365	Yang-Cho-Yung	29.2688	91.4951	561333118	666301337
135	Pu-mo-tso	28.7063	90.7993	331004079	368140075
2311	Farakka	25.5729	88.5934	138240355	1806998923
959	Ujjani	18.4646	75.4398	88224823	277983322
963	Nagarjuna Sagar	16.748	79.5296	124072865	295156037
496	Tungabhadra	15.3771	76.5248	15026126	381234270
1500	Srisailam	16.423	79.1174	429318	564767661
1712	Almatti	16.698	76.1505	2575907	453359673
587	Chukchagirskoye	52.1979	137.6264	351611337	385956767
1978	Longyangxia	36.2813	101.3157	175161692	422019468
1567	Sanmenxia	35.7479	112.7177	0	293868083
2280	Thaphanseik	23.6688	95.7887	0	441982749
646	Indawngy	25.3438	96.6544	96167203	121067640
1005	Senanayake Samudra	7.348	81.6475	2575907	65685634
1533	Fengman	43.8688	129.1821	69334836	428029918
1958	Baishan	42.8563	128.3285	0	107973445
224	Khanka	45.4271	134.6891	4273859415	5803733652
2282	Xiaolangdi	35.2146	112.8699	2146589	286569680
343	Sanhezha	33.7188	119.7066	1090896713	1841773671
632	Han Shui	32.9188	112.0609	260810607	565840955
2315	Geheyan	30.5521	111.4257	0	82858349
1619	Three Gorges	31.2188	111.5656	0	821714407
449	Gaoyou	33.1896	120.5118	720610048	1135331112
1986	Ertan	27.4521	102.4508	6439768	82429031
1568	Wuqiangxi	28.8604	111.3293	0	147256030
4033	Zhexi	28.4146	112.1269	0	100245723
970	Nam Ngum	18.8771	103.1851	363632238	459584782
969	Sirikit	18.2688	100.9616	123214229	261454584
968	Bhumphol K. K. Nam	18.098	99.5302	78350512	299019898
972	Lam Pao	17.0563	103.8661	22753847	277983322

977	Srinagarind	15.1313	99.5448	256732087	383166201
1478	Thale Luang	7.8813	100.842	1043242429	1256398752
661	Tai (1)	31.6229	121.3739	2324112300	2643739455
652	Zhelin	29.4313	115.8485	188685205	316407272
1976	Dongjiang	26.0729	114.0452	75559945	163570109
653	Poyang	29.8313	117.8369	769337627	3727767082
319	Boeng Tonle Chhma	13.3396	105.1129	2077469182	6469605671
639	Kasumiga-ura	36.2438	141.1199	155627729	251794932

Europe (n = 35)

Lake ID	Name	Lat	Lon	Area Min (m²)	Area Max (m²)
430	Valdecanas	39.9729	-5.2441	24041801	67617565
356	Inarinjarvi	69.4438	29.3636	1063635028	1975291529
26	Vanern	59.4979	14.4437	5304007649	6924467956
268	Vattern	58.9646	15.351	1839627081	2151955833
508	Malaren	59.7604	18.5697	852195976	3823504967
340	Ijsselmeer	53.1604	5.8825	87151528	145324100
851	Konstanz	47.8979	9.9403	510888268	560689141
397	Saimmaa	62.7104	30.7667	3455150233	5835073856
22	Onega	62.9938	38.846	9692494936	11100657556
435	Vygozero	63.9604	36.4707	1166027340	1485869155
505	Paijanne	62.3229	26.8618	936986256	1710617061
953	Beloye	60.4063	38.6041	1165598022	1425764653
396	Ladoga	61.8646	34.5352	17274463213	21980645725
1000	Sheksna	59.9979	39.6015	221528022	358909741
956	IlMen	58.5396	32.2572	837169850	1539533889
520	Kiyevskoye	51.3021	31.1325	556181303	736280150
221	Peipus	59.0938	29.4022	3410071857	3643191461
223	Rybinskoye	59.3104	40.5369	3362202914	4701674675
955	Kubenskoye	59.9271	40.4898	344956910	539867224
1341	Gorky	58.1813	45.39	1050970151	1588690785
1451	Cheboksary	56.7521	48.3837	920886835	1436068282

1376	Kuybyshevskoye	56.2438	53.1985	4234576830	5789566162
1377	Volgograd	52.1646	48.5174	2381855554	3303815683
810	Kama	59.5271	59.9408	1427267265	3196056898
809	Votkinskoye	58.1854	57.259	951153745	1195220955
1618	Nizhne Kamskaya	56.9229	55.4761	869368691	1707182518
1462	Saratov Reservoir	53.5563	50.688	1422115451	2113102566
590	Krasnooskolskoye	49.6354	38.0317	57957913	114627872
503	Kremenshugskoye	49.8521	33.9044	1920124182	2127055397
1598	Dniepr	48.6896	35.8857	160779543	323491017
592	Tsimlyanskoye	48.7146	44.0182	1949532456	2447755847
873	Kakhovskoye	47.9521	35.7501	2054500676	2238248725
600	Tshchikskoye	45.2563	39.7791	208863145	403773459
502	Sivash	46.3729	35.6389	2086699517	2459132770
601	Kiziltashskiy	45.2646	37.4111	227753131	254156180

North America (n = 128)

Lake ID	Name	Lat	Lon	Area Min (m2)	Area Max (m2)
14	Eagle (2)	40.8104	-120.7403	6.93E+07	1.25E+08
665	Clear (2)	42.0063	-121.1274	3.43E+07	1.04E+08
461	Mead	36.7938	-114.2639	3.12E+08	5.94E+08
368	Salton Sea	33.6104	-115.9239	8.72E+08	1.01E+09
291	Mono	38.1604	-118.9907	2.02E+08	2.64E+08
312	Walker (2)	38.8979	-118.7818	1.12E+08	1.56E+08
701	Alvara Obregon	28.2188	-109.859	3.13E+07	1.71E+08
715	Chapala	20.4146	-102.6981	7.37E+08	1.13E+09
293	Adjuntas	24.148	-98.6972	7.34E+07	4.07E+08
716	Infiernillo	19.0021	-101.5087	9.85E+07	3.25E+08
717	Miguel Aleman	18.498	-96.4344	2.51E+08	4.30E+08
1469	Baird Inlet	61.0813	-163.9246	1187278575	1.44E+09
436	Becharof	58.1813	-156.821	1.14E+09	1.36E+09
680	Flaming Gorge	41.5563	-109.4224	8.82E+07	1.78E+08
19	Great Salt	41.8313	-112.5027	4.70E+09	6.53E+09

678	Bear (2)	42.2646	-111.3416	2.68E+08	3.22E+08
673	Dworshak	46.9646	-115.8297	7.30E+06	1.25E+08
462	Powell	37.9979	-110.3725	9.19E+07	3.40E+08
1261	Livingston	31.0688	-95.1956	2.65E+08	3.60E+08
1273	Denison	34.1688	-96.5364	2.10E+08	3.80E+08
453	Toledo Bend	32.0646	-93.9559	4.20E+08	6.49E+08
706	Falcon	27.0979	-99.2793	61607115	3.33E+08
351	Nicaragua	12.2021	-84.9974	7718062043	7.89E+09
350	Managua	12.5855	-86.1001	9.93E+08	1.13E+09
721	Izabal	15.8771	-88.7721	7.08E+08	7.35E+08
28	Peten Itza	17.098	-89.6563	9.53E+07	1.08E+08
720	Malpaso	17.3063	-93.1919	1.76E+08	2.69E+08
341	Angostura	16.4813	-92.2725	1.92E+08	5.38E+08
1516	Mica	52.8646	-119.2472	3.52E+08	1.09E+09
1995	Revelstoke	52.1479	-118.6563	7.99E+07	3.67E+08
258	Iliama	59.8896	-154.1816	2.60E+09	4.09E+09
1418	Hugh Keenleyside	51.1313	-118.283	4.18E+08	8.99E+08
1155	Williston	56.9938	-124.974	1.52E+09	3.73E+09
669	Libby	49.5521	-115.532	1.20E+08	3.82E+08
1905	Hungry Horse	48.4229	-113.9917	8.37E+07	2.04E+08
682	Fort Peck	48.1021	-106.4027	6.85E+08	1.05E+09
1493	Grand Coulee	48.8979	-118.0436	1.90E+08	3.78E+08
671	Flathead	48.1688	-114.2003	4.74E+08	5.38E+08
486	Yellowstone	44.6479	-110.3721	3.28E+08	4.02E+08
1465	Oahe	47.5729	-101.463	797243288	1508193684
1602	Harry Truman	38.4896	-93.5013	86292892	288286951
1604	Bagnell	38.4063	-92.7713	36062701	203282012
1279	Table Rock	36.8854	-93.5113	25115096	206072579
1278	Bull Shoals	36.7938	-92.7177	45078377	234836876
468	Eufaula	35.5896	-95.5452	269611624	493071576
1603	Blakely Mountain	34.7729	-93.2153	73198697	157345000
1495	Kentucky	37.0979	-88.2355	349894066	683688711

1297	Okeechobee	27.2813	-80.7041	1239226037	1524937081
1466	Selawik	66.7396	-160.6958	1217116167	1448518500
1168	Diefenbaker	51.3604	-106.9028	243852551	449925130
203	Winnipegosis	53.2688	-100.3346	5147306626	5670859770
42	Manitoba	51.8813	-99.1055	4819951748	5550436107
454	Lesser Slave	55.6563	-115.2274	1110216017	2084767586
484	Dore	55.0021	-107.4129	620578984	1070074796
1164	Montreal	54.6813	-105.7191	449710471	837384509
1161	Primrose	55.1104	-109.6926	423951399	519689284
12	Winnipeg	53.9521	-98.2684	24074858305	24477129151
252	Cedar	53.7229	-100.1052	2490902293	2913780397
1171	Deschambault	55.1021	-103.188	540081883	1542324455
266	Woods	49.9979	-94.6067	3426385936	4347058112
5	Lower Red	48.2896	-94.5815	1111718629	1169032565
506	St. Claire	42.7771	-82.6549	1143058834	1249100348
684	Sakakawea	48.2563	-102.1422	982064632	1504973800
480	Winnebago	44.2896	-88.3574	596966501	670594516
337	Superior	49.1021	-86.6697	81878001923	82717103704
336	Huron	46.6354	-81.6874	59230625543	60137988865
335	Michigan	46.1896	-85.1572	58013724035	58585790099
333	Erie	43.1854	-78.9427	25764868108	26231965952
1285	Dale Hollow	36.7521	-85.1944	21895211	103894925
1295	Gaston	36.6938	-77.886	28978956	79853124
1861	Norris	36.5313	-83.6075	8371699	100031064
1287	Hartwell	34.8729	-82.8461	93376637	227538472
1290	Murray (2)	34.2438	-81.2642	103894925	191046453
1289	Clark Hill	34.1063	-82.395	137167060	313402047
1291	Marion	33.7604	-80.2769	232904946	374579843
21	Windsor	21.1313	-73.4673	153051821	217449502
1009	Teshekpuk	70.8146	-153.9936	864216876	1138980314
412	Martre	63.6688	-118.1587	1783601099	2281395171
429	Kasba	60.7479	-102.3265	1280225894	1404728077

1081	Keller	64.1646	-121.7386	381234270	500155321
1025	Hardish	64.8646	-117.7189	285067067	472893636
442	Nueltin	61.0146	-98.7827	1711261038	2156034353
421	Great Bear	67.1229	-119.6073	30492301854	31829412367
420	Great Slave	63.4396	-111.1554	28249974609	33643065717
348	Athabasca	59.7021	-107.1739	7590125317	7898375549
236	Reindeer	58.2813	-101.2959	5590577328	7396073639
410	Southern Indian	57.7854	-98.283	3528134272	4596277137
423	Wollaston	59.0021	-103.0125	2210343064	2801513773
512	Ear Falls	50.7979	-91.5629	1000095983	1433277715
441	Claire	58.9521	-112.1942	1195435614	1558638534
470	Gods	54.9396	-93.8488	1040881181	1279581917
222	Nipigon	50.3729	-88.3621	4416178290	4828323447
1302	Champlain	45.1771	-73.1144	972619639	1195435614
9	Manitou	45.9479	-82.0406	94449932	111837306
1219	Abitibi	49.0438	-79.6647	987860423	1130823275
334	Ontario	44.5729	-75.7959	19152299585	19518293071
244	Dubawnt	63.7188	-100.9961	3360056325	3597683767
408	Baker	64.3979	-94.9828	1634627797	1952108364
409	Yathkyed	63.0604	-97.7403	1211320376	1313712688
440	Aberdeen	64.8229	-98.0559	996232122	1342691644
443	Napaktuluk	66.6396	-113.1058	963389305	1486942449
1031	Aylmer	64.4979	-108.5886	645694079	888687995
1111	Kamilukuak	62.6021	-101.8155	567558227	666086678
475	Tehek	65.1688	-95.4537	391323240	623584209
1115	Tebesjuak	64.0063	-98.9539	416223677	495432824
1042	McAlpine	66.8104	-102.9831	473108295	2698048166
498	Mallery	64.1979	-98.4127	406349366	450354448
1017	Colville	67.4271	-125.9525	428888554	521406555
1053	Schultz	65.0021	-97.3425	325422947	458726146
1016	Aubry	67.6854	-126.6984	365778827	506595089
1019	Maunoir	67.6646	-125.1281	320056474	519903943

1118	Ford	63.7396	-97.1247	229470403	316192613
1112	Nowleye	62.5229	-101.1024	230329038	277768663
1121	Carey	62.3938	-102.9771	186109297	279271276
310	Mistassini	51.4771	-72.85	2093783261	2530614196
1240	Grande (1)	54.3396	-75.8997	2499917968	3348464742
1241	La Grande (3)	54.0896	-73.7722	1976794141	2804304339
1238	Low	52.9188	-75.9915	736709468	1056765942
2032	Laforge (1)	54.6354	-71.9946	757316726	1173325744
1490	La Grande (4)	54.2813	-72.7732	647840669	928829216
504	Manicouagan	52.1771	-68.5824	1607580771	2242112586
1247	Caniapiscau	54.9979	-69.0915	2697833507	3823719626
509	St. Jean	48.9729	-72.0422	1032938800	1081022402
1468	Sherman Bassin	68.1271	-97.7222	1270566242	1646863357
264	Amadjuak	65.5104	-71.7234	3048800868	3341595656
254	Smallwood	54.7729	-63.6503	4366377417	5541849750
118	Nettiling	67.1146	-70.5805	5225871796	7174974935

South America (n = 64)

Lake ID	Name	Lat	Lon	Area Min (m^2)	Area Max (m^2)
1617	La Vueltosa	8.0271	-71.2039	0	94235273
726	De Betania	2.7938	-75.3417	31125546	69549495
432	Guri	7.9438	-62.4598	1797553930	3726049811
777	Coari	-3.9145	-63.0451	212727006	974766228
780	Piorini	-3.2687	-62.9212	9015675	388318015
776	Amana	-2.2687	-64.29	64397681	136523083
779	Aiapua	-4.277	-61.9664	2361248	235910171
783	Taciula	-4.3604	-60.3852	15455443	175805669
2309	Represa de Samuel	-8.652	-62.8886	41643834	452930355
1778	Balbina	-0.9354	-59.185	917237633	1837695151
318	Titicaca	-15.1604	-68.11	7516926620	8554373257
51	Poopo	-18.1145	-66.3752	1230854339	3351899285

773	Brokopondo	5.0896	-54.7053	820426453	1410094550
1669	Cupari	-2.127	-54.6148	2882869510	3208721775
1670	Xingu	-1.552	-51.5127	1298042586	1370597306
1765	Furo Santa Maria	-1.5354	-49.1031	1222267981	1405801372
1589	Iguazu	-24.9104	-54.6395	290218881	460872736
1824	Yacyreta	-25.3437	-54.096	1381115594	1822025049
732	Rinihue	-39.6895	-71.8336	79423806	148329325
344	Chiquita	-30.0229	-61.5959	3308752839	6980493939
745	Lianquihui	-40.877	-72.0707	829442129	896630376
346	Nahuel Huapi	-40.6145	-70.5628	524626440	1071577408
748	Ranco	-40.0395	-71.82	402700164	498652708
744	Todos los Santos	-40.9687	-71.7789	169365900	326066924
37	Buenos Aires	-46.2062	-70.5709	1883202845	2992774885
785	Tucurui	-3.6395	-49.0803	836525873	2161615485
345	Sobradino	-8.8937	-40.645	1225273207	3898850254
1546	Itaparica	-8.4395	-38.0685	716960846	1236650130
1460	Serra da Mesa	-13.6895	-47.8961	380590293	1217330826
463	Repressa Tres Marias	-18.1104	-44.621	382307565	997090758
1422	Itumbiara	-17.9062	-47.7571	249219025	686264618
1419	Emborcacao	-18.1062	-47.3642	141030921	450783766
1479	Sao Simao	-18.2645	-49.3466	415365041	655139073
1621	Represa Nova Ponte	-18.9645	-46.7788	100675041	393899148
448	Agua Vermelha	-19.6562	-48.915	350323384	567558227
793	Repressa de Jupia	-18.9395	-50.0008	839960416	1281513848
1554	Mascarenhas de Moraes	-20.1437	-46.0879	93161978	251150955
1486	Marimbondo	-20.002	-48.0949	237627442	478904086
1548	Tres Irmaos	-20.5187	-49.9147	434255027	627877388
1420	Represa de Furnas	-20.4229	-44.9839	555537326	1158299618
1523	Jupia	-20.302	-51.0929	395831078	468600457
1779	Nova Avanhandava	-20.8979	-49.5625	185894639	241920621
798	Promissao	-21.0229	-48.6576	398621644	502301910
1680	Porto Primavera	-20.7104	-51.4475	1433492374	2205405908
794	Iepe	-22.4937	-50.2636	292365471	574212654

795	Chavantes	-22.9979	-49.0643	266606398	399050962
796	Barra Bonita	-23.0687	-48.361	270470259	396904373
501	Itaipu	-23.9479	-53.5266	964462599	1340545055
1551	Salto Caxias	-25.3104	-52.8182	29622933	132444563
2284	Salto Santiago	-25.452	-51.8789	60963138	219381433
2316	Segredo	-25.7062	-51.4527	9015675	72340061
1553	Foz do Areia	-25.8395	-51.0384	30910887	113983895
53	Mangueira	-32.702	-52.3352	777280007	899850260
808	Rincon-Bonete	-32.3187	-55.2483	560903800	1056765942
510	San Martin	-48.2853	-70.8418	1224414571	3054811318
754	Viedma	-49.3103	-71.2179	1272712831	2496054107
439	Colhue Huapi	-45.1729	-67.8664	25329754	885253452
43	Cardiel	-48.7228	-70.6159	364705532	656427026
741	Musters	-45.1395	-68.5178	436616276	545019038
44	Strobel	-48.3145	-70.7695	101962995	168292606
753	Argentino	-49.8853	-71.2413	1558423875	3607558078
1393	Poco da Cruz	-8.2854	-37.4977	0	44219741
802	Juparana	-19.0854	-39.9259	53879393	75130628
749	Fagnano	-54.4145	-66.9018	581725716	1623465533

Oceania and Pacific (n = 10)

Lake ID	Name	Lat	Lon	Area Min (m^2)	Area Max (m^2)
320	Eyre	-27.7479	137.4355	0	7924993257
762	Hume	-35.8437	147.3695	17816692	159062272
1470	Eildon	-36.927	145.8876	18889986	113983895
1440	Alexandrina	-35.227	139.2733	747657074	962959987
330	Frome	-30.1395	139.9471	0	2440672102
755	Argyle	-15.9895	129.0357	687337913	1381544912
763	Eucumbene	-35.8604	148.5726	34130771	107329468
1413	George (4)	-34.9145	149.3558	0	132015246
511	Taupo	-38.577	175.8906	582369693	625086822

998	Murray (1)	-6.602	141.6202	127078090	468600457

Appendix II: Classification Notes and Errors Documentation

Lake ID	Lake Name	Error Type	Notes
121	Pangong	Classification	Includes surrounding water
1440	Alexandrina	Classification	Pixels removed from processing bleed into waterbody
344	Chiquita	Classification	Buffer needs to be expanded
340	Ijsselmeer	Classification	Pixels removed from processing cover majority of waterbody
1478	Thale Luang	Classification	Ocean not fully masked
110	Tuz	Classification	Buffer needs to be expanded
2327	Aral (1)	Deleted	Waterbody removed from Version 2
270	Caspian	Deleted	Waterbody removed from Version 2
68	Chad	Deleted	Waterbody removed from Version 2
320	Eyre	Deleted	Waterbody removed from Version 2
415	Kafue	Deleted	Waterbody removed from Version 2
1286	Wolf Creek	Deleted	Waterbody removed from Version 2
332	Torrens	Deleted	Waterbody removed from Version 2
406	Kwania	Deleted	Merged with Kyoga (ID 398)
135	Pu-mo-tso	Other waterbody in classification	Includes additional water body to the East
803	Aral (4)	Other waterbody in classification	Includes North West part of Aral (1) (ID 2327)
180	Aru	Other waterbody in classification	Includes South East part of Memar (ID 181)
424	Aydar Kol	Other waterbody in classification	Includes Southern part of Chardarinskoye (ID 460)
1451	Cheboksary	Other waterbody in classification	Includes Southern part of Gorky (ID 1341)
777	Coari	Other waterbody in classification	Includes part of the Amazon River
1669	Cupari	Other waterbody in classification	Includes part of the Amazon River
170	Dorsoidong	Other waterbody in classification	Includes Western part of Chibzhang Co Lake
449	Gaoyou	Other waterbody in classification	Includes South East part of Sanhzeha (ID 343)
411	Har Nuur	Other waterbody in classification	Includes North West branch of Dorgon (ID 372)
385	Hulun	Other waterbody in classification	Includes adjacent wetland
1546	Itaparica	Other waterbody in classification	Includes Eastern part of Sobradino (ID 345)
3849	Jabbul (1)	Other waterbody in classification	Includes Western part of Jabbul (2) (ID 3871)
3871	Jabhul (2)	Other waterbody in classification	Includes Jabbul (1) (ID 3849) and Jabbul (3) (ID 3949)
3949	Jabhul (3)	Other waterbody in classification	Includes Southern part of Jabbul (2) (ID 3871)

1523	Jupia	Other waterbody in classification	Includes Southern part of Represa de Jupia (ID 793) and Western part of Tres Irmaos (ID 1548)
873	Kakhovskoye	Other waterbody in classification	Includes Southern part of Dniepr (ID 1598)
275	Kara-Bogaz-Gol	Other waterbody in classification	Includes Eastern edge of the Caspian Sea
503	Kremenshugskoye	Other waterbody in classification	Includes part of Dniepr river after hydro electric plant on Northern end
181	Memar	Other waterbody in classification	Includes Northern part of Aru (ID 180)
1618	Nizhne Kamskaya	Other waterbody in classification	Includes Southern part of Votkinskoye (ID 809)
1779	Nova Avanhandava	Other waterbody in classification	Includes Western part of Promissao (ID 798)
1680	Porto Primavera	Other waterbody in classification	Includes Sourthern part of Jupia (ID 1523)
793	Represa de Jupia	Other waterbody in classification	Includes Southern part of Sao Simao (ID 1479), Northern part of Jupia (ID 1523)
1466	Selawik	Other waterbody in classification	Includes additional water body to the East and West
502	Sivash	Other waterbody in classification	Includes the Western Edge of the Sea of Azov
1548	Tres Irmaos	Other waterbody in classification	Includes North West part of Nova Avanhandava (ID 1779)
1829	Urmia (2)	Other waterbody in classification	Includes Northern part of Urmia (1) (ID 115)
433	Ust Ilim	Other waterbody in classification	Includes North West part of Bratskoye (ID 583)
1377	Volgograd	Other waterbody in classification	Includes South West part of the Saratov Reservoir (ID 1462)
809	Votkinskoye	Other waterbody in classification	Includes Southern part of Kama (ID 810)

Appendix III: Acronyms

BRDF: Bidirectional Reflectance Distribution Function
CF: Climate and Forecast
ESDR: Earth System Data Records
ESDS: Earth Science Data System
ESRI: Environmental Systems Research Institute
G-REALM: Global Reservoir and Lake Monitor
GCMD: Global Change Master Directory
GLWD: Global Lakes and Wetlands Database
GOLA: Global Optical-derived Lake Area
GranD: Global Reservoir and Dam Database
L2: Level 2 - processing level for Time Series Data Set for Water Height (Altimetry)
L3: Level 3 - processing level for Time Series Data Set for Water Area (Surface Area)
L4: Level 4 - processing level for Time Series Data Set for Storage (Hypsometry)
LP DAAC: Land Processes Distributed Active Archive Center
MEaSUREs: Making Earth Science Data Records for Use in Research Environments
MODIS: Moderate Resolution Imaging Spectroradiometer
NASA: National Aeronautics and Space Administration
NetCDF: Network Common Data Form

PO.DAAC: Physical Oceanography Distributed Active Archive Center
SRTM: Shuttle Radar Topography Mission
UCLA: University of California, Los Angeles
USGS: United States Geological Survey