Integrating reservoirs into SWOT's global surface water storage and discharge monitoring

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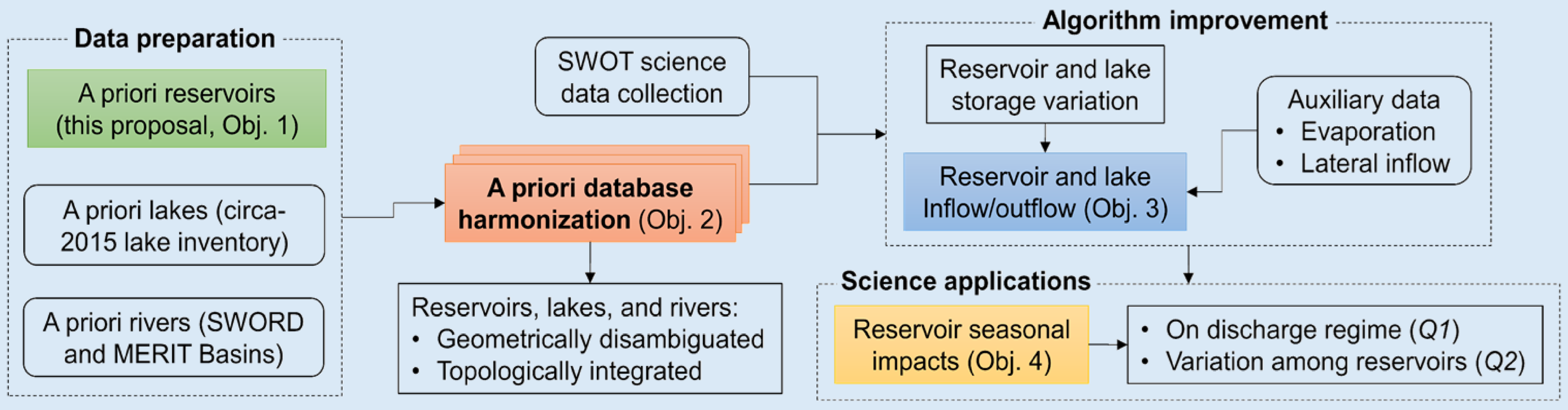
Background

- Reservoirs, typically manmade water impoundments on river channels, have unique significance to bridging lake science and river science.
- Integrating reservoirs to SWOT's water storage and discharge monitoring requires data "infrastructure" such as:
  - I. A comprehensive global reservoir database, including prior attributes and metadata that are critical to sufficing SWOT's accuracy and consistency requirements for reservoir storage monitoring.
  - II. Harmonized a priori river and lake databases with reliable connectivity and drainage topology among them
- In addition to the data infrastructure, a new algorithm is needed to improve the estimate of discharge at the lake-river interface, which is critical to assessing human water managements but has not been fully characterized by the existing discharge algorithm.

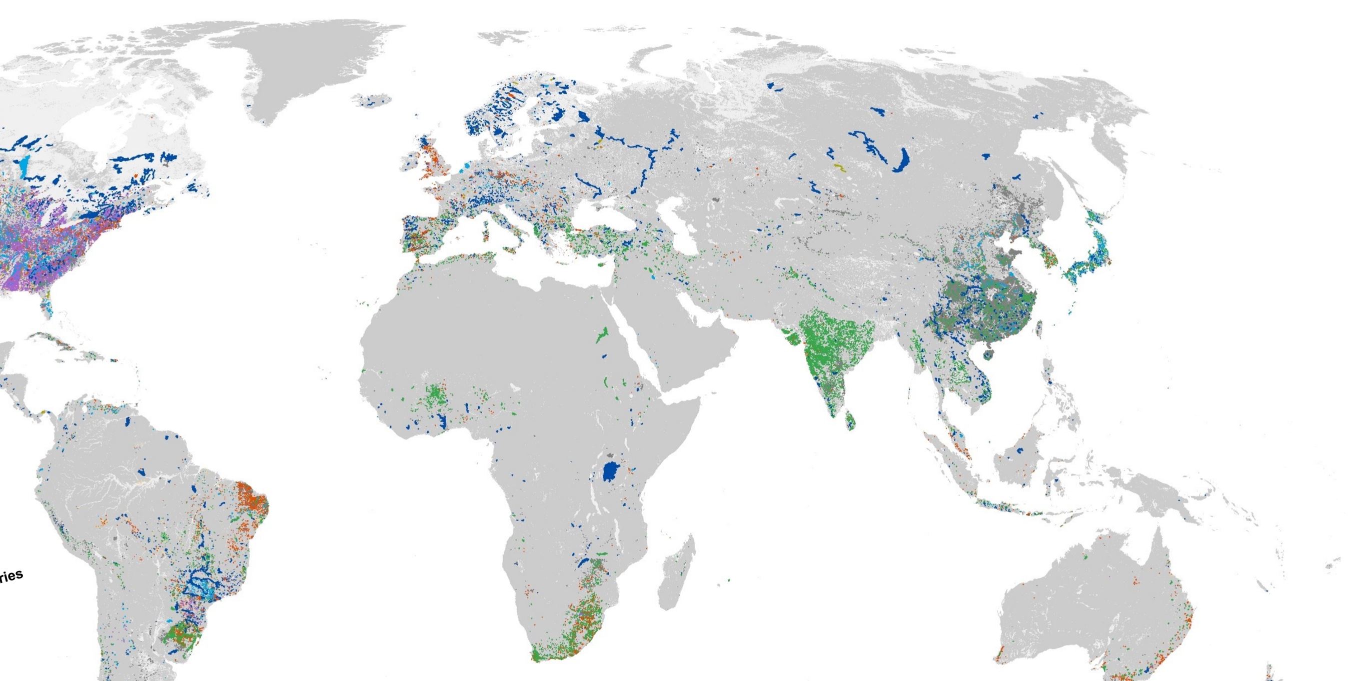
Objectives

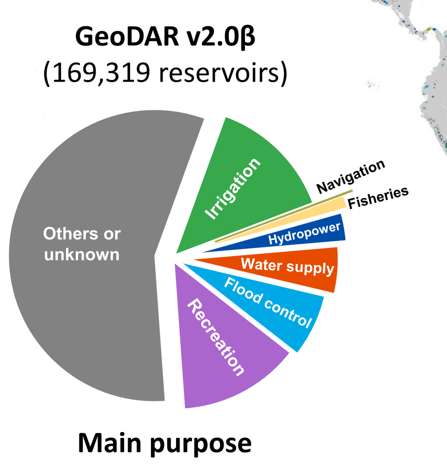
- Objective 1: Establish an a priori global reservoir database.
- Objective 2: Harmonize a priori reservoir, lake, and river databases.
- Objective 3: Improve discharge estimations at the lake-river interface.
- Objective 4: Understand reservoir impacts on seasonal storage-discharge interactions.

Methods



Obj. 1. Prior reservoir dataset





- v1.1 (*Wang et al., 2022, doi:10.5194/essd-14-1869-2022*): 21,515 reservoirs
- **Update here: v2.0β: 169,319 reservoirs with prior attributes, and registered to PLD**

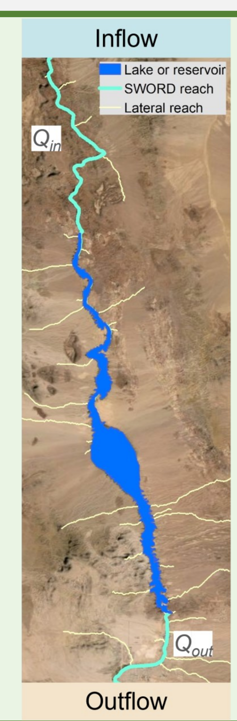
Figure 1: Georeferenced global Dams And Reservoirs GeoDAR database (v2.0 beta).

Obj. 3 LakeFlow algorithm

See details in the poster of Riggs et al. on Thursday.

- LakeFlow (*Riggs et al., 2023, doi:10.1029/2023GL103924*) has been developed for estimating the flow law parameters of the inflow and outflow reaches surrounding a lake or reservoir via mass conservation.
- The algorithm was tested on three sample lake systems, with promising performance (median NSE = 0.88).
- LakeFlow is potentially applicable for 17,823 lakes and 50,099 reaches.

$$\delta V = n_{in}^{-1}(A_{0\,in} + \delta A_{in})^{5/3} W_{in}^{-2/3} S_{in}^{1/2} - n_{out}^{-1}(A_{0\,out} + \delta A_{out})^{5/3} W_{out}^{-2/3} S_{out}^{1/2} + \varepsilon$$



Obj. 2. Prior lake and river harmonization

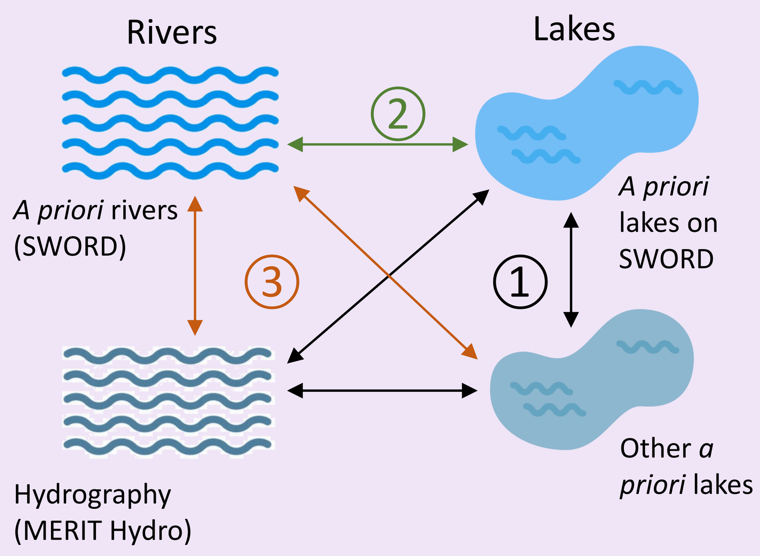


Figure 2: Concept for SWOT a priori lake-river harmonization.

Conceptual framework

Step ①: Completed

- Build drainage topology and catchments for *a priori* lakes (PLD-TopoCat)

Step ②: Automated; QC in progress

- Configure topology and connectivity between SWORD reaches and on-SWORD *a priori* lakes

Step ③: Automated; QC in progress

- Rectify SWORD reaches to PLD-TopoCat

Step 1: Developing the PLD-TopoCat

Figure 3: Lake boundaries and configured drainage in PLD-TopoCat (*Sikder et al., 2023, doi: 10.5194/essd-15-3483-2023*). (a) Global map of lake drainage types. (b) Definitions of lake drainage types. (c) Global lake composition by drainage types. (d) Distribution of the upstream lake abundance.

The constructed a priori lake topology and catchment (TopoCat) data includes:

- **Five components:**
  - **Lake boundaries**
  - **Lake outlets**
  - **Unit catchments**
  - **Connecting river reaches**
  - **Inter-lake reaches**
  - **Lake-network basins**
- **Attributes depicting drainage topology**

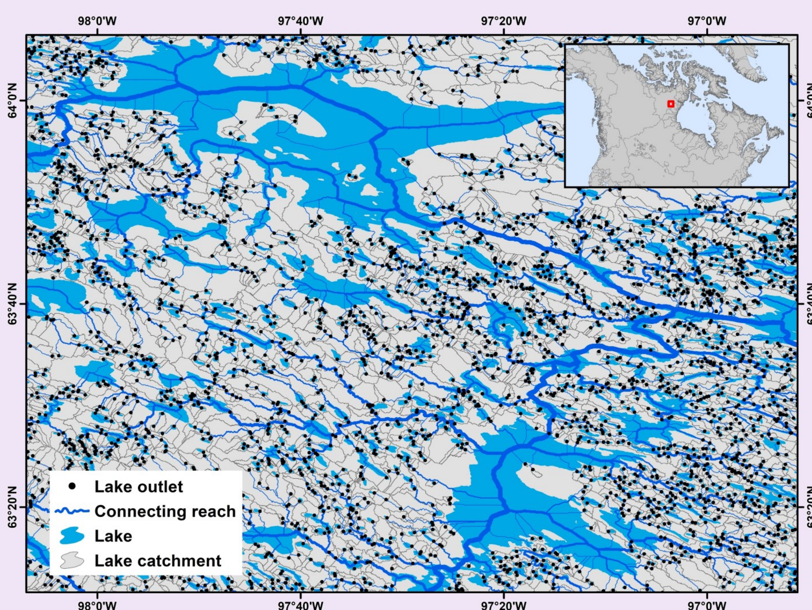
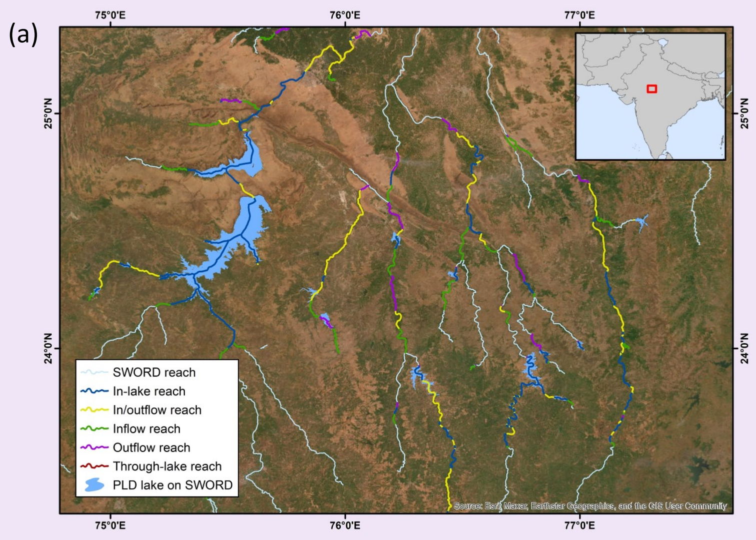


Figure 4: An example of the derived lake topology in the Canadian Shield. Here, Reach width representing drainage order.

Step 2: Configuring topology between SWORD and PLD



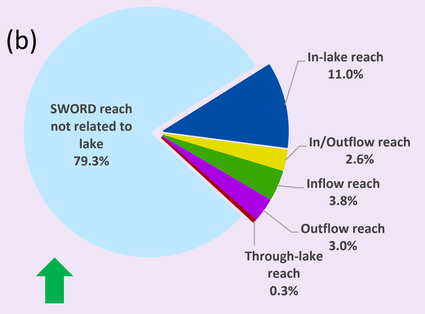


Figure 5: (a) An example of the configured SWORD-PLD topology. (b) The global frequency (in %) of different types of configured SWORD reaches according to their relationship to PLD.

Configuring drainage topology between PLD lakes and SWORD river network

- **PLD lakes:** Total 17,823 lakes out of ~6 million PLD lakes are located on the SWORD network.
- **SWORD reach level:** The drainage relation of 50,099 SWORD reaches (20.7% of the total) with PLD lakes have been configured.
- **SWORD node level:** Total 19,647 and 17,777 SWORD nodes have been identified as lake inlet and outlet, respectively.

Step 3: Harmonizing SWORD with PLD-TopoCat

A SWORD mirror network has been generated using MERIT Hydro to harmonize SWOT-visible lakes with inter-lake reaches.

- Total 19,0651 SWORD mirror reaches have been generated for SWORD reaches that are at least 2km in length.
- These mirror reaches are 2,286,330 km long (i.e., aligned with MERIT Hydro), about 5% larger than the original SWORD reaches

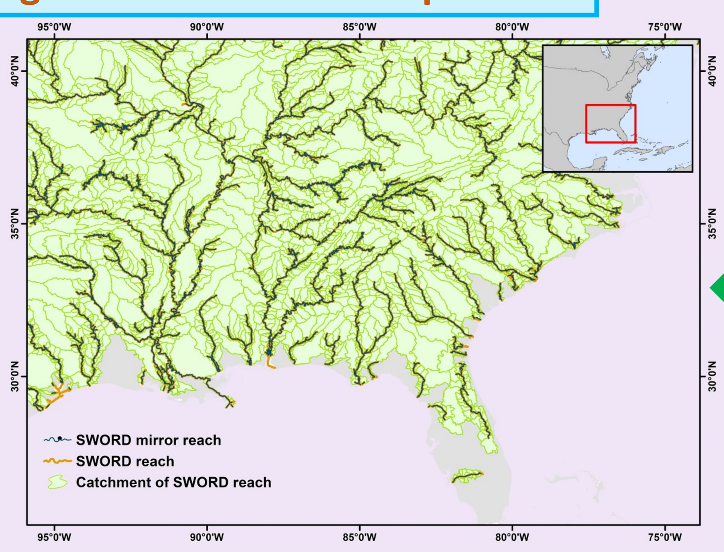


Figure 6: An example of SWORD mirror reaches (i.e., MERIT Hydro aligned) in part of the southeastern US.

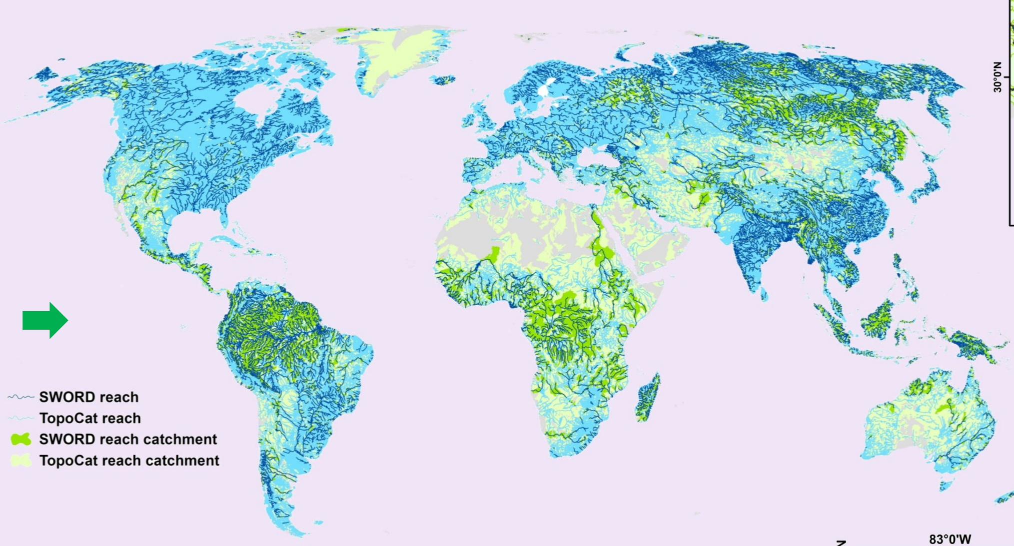


Figure 7: The harmonized SWORD mirror and PLD-TopoCat inter-lake global network and their associated catchments.

SWORD mirror network has been merged with the PLD-TopoCat inter-lake network to integrate the SWORD off-network lakes in it.

- The harmonized network contains 2,286,330 km and 17,189,231 km of reaches from SWORD and TopoCat, respectively.
- Catchments of these reaches cover about 121,934,987 km², which is ~90% of the global land surface except the Antarctic.

In the final step all the necessary attributes generated from step-1 and step-2 have been joined with the merged network.

- The SWORD off-network PLD lake drainage topology from step-1
- The SWORD on-network PLD lake drainage topology from step-2.

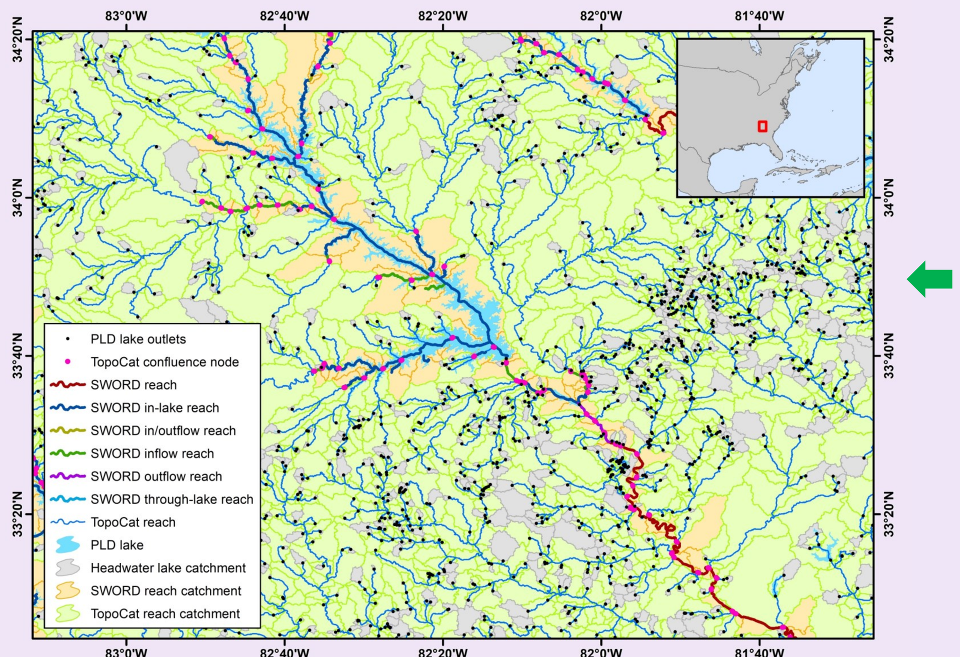


Figure 8: An example of harmonized SWORD-PLD data products.

References. (1) Wang, J., Walter, B.A., Yao, F., Song, C., Ding, M., Maroof, A.S., Zhu, J., Fan, C., McAlister, J.M., Sikder, S., Sheng, Y., Allen, G.H., Crétaux, J.-F., and Wada Y., 2022. **GeoDAR**: Georeferenced global dams and reservoirs dataset for bridging attributes and geolocations. Earth System Science Data, 14, 1869-1899, doi:10.5194/essd-14-1869-2022. (2) Sikder, M.S., Wang, J., Allen, G.H., Sheng, Y., Yamazaki, D., Song, C., Ding, M., Crétaux, J.-F., and Pavelsky, T.M., 2023. **Lake-TopoCat**: A global lake drainage topology and catchment dataset. Earth System Science Data, 15, 3483-3511, doi:10.5194/essd-15-3483-2023. (3) Riggs, R.M., Allen, G.H., Brinkerhoff, C.B., Sikder, M.S., and Wang, J., 2023. Turning lakes into river gauges using the **LakeFlow** algorithm. Geophysical Research Letters, 50(10), e2023GL103924, doi:10.1029/2023GL103924.

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