Colorado Lakes and Reservoirs: Capturing water storage changes using the SWOT satellite

Alex Marquez[1], Toby Minear[2]

[1]RECCS Program, [2]CIRES, University of Colorado Boulder

Introduction

Accurate monitoring of inland surface water bodies is essential for effective water resource management, particularly in semi-arid regions like Colorado, where seasonal variability in precipitation and snowmelt, along with increasing climate pressures, create ongoing challenges for water availability and planning. The National Aeronautics and Space Administration (NASA) launched the Surface Water and Ocean Topography (SWOT) satellite to provide global, high-resolution measurements of water surface elevation and area, offering a powerful new tool for monitoring lakes, reservoirs, and rivers from space.

This project explores the potential of SWOT to improve surface water monitoring across Colorado by comparing satellite observations with available ground-based measurements. By analyzing time series data from the SWOT Prior Lake Database and combining it with geospatial datasets such as reservoir boundaries and water division maps, we aim to assess SWOT's reliability and identify where remote sensing can enhance traditional hydrologic monitoring methods.

Materials

SWOT Satellite Data – Utilized both the Prior Lake product, which provides static lake boundaries and reference surface areas, and the reach-level time series data accessed through NASA's Hydrocron API, containing water surface elevation (WSE) and surface area measurements over multiple satellite passes.

USGS National Water Information System (NWIS) – Daily reservoir elevation data used for ground-truth comparison and validation of SWOT-derived water surface elevations.

Colorado Division of Water Resources (DWR) – Provided shapefiles defining water division boundaries used to spatially categorize lakes and reservoirs for regional analysis.

Python (v3.10) and Scientific Libraries – Employed libraries such as pandas and geopandas for data manipulation and spatial analysis; matplotlib for plotting; requests and dataretrieval to download and manage data; and numpy for numerical computations.

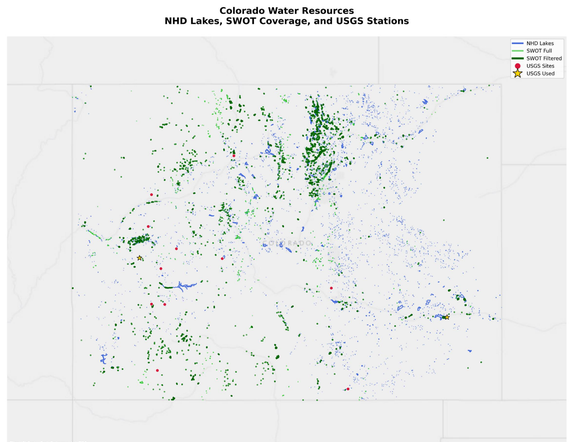
Methodology

1. Site Identification and Mapping:
We began by mapping Colorado's reservoirs using USGS station locations, SWOT lake coverage, and the National Hydrography Dataset (NHD). This spatial analysis was used to identify reservoirs with overlapping SWOT and USGS data and to contextualize each site within Colorado's Division of Water Resources (DWR) boundaries.

2. Time Series Extraction and Comparison:
For reservoirs with both SWOT and USGS data (e.g., Fruit Growers, Lake Maloya, John Martin), we extracted time series of water surface elevation (WSE). SWOT reach-level observations were accessed via the Hydrocron API, and USGS records were pulled from NWIS. Data were filtered by site and date, interpolated where needed, and plotted to compare elevation trends over time.

3. Regional Volume Estimation:
Using the static surface area provided in the SWOT Prior Lake database and observed changes in WSE, we approximated changes in reservoir storage. These estimates were aggregated by DWR division to evaluate regional trends in water availability. This required spatially joining SWOT lake locations with DWR boundaries and computing total and average storage change for each division.

4. Tool Development:
Custom Python scripts were developed to automate data filtering, WSE comparison, and storage calculation. These tools enable reproducible workflows for applying SWOT data to reservoir monitoring statewide.



Colorado Map Figure displaying locations of various datasets used in methods. Datasets include, National Hydrology Dataset (NHD), United States Geological Survey (USGS) reservoir stations, and Surface Water and Ocean Topography (SWOT) satellite fly over locations.

Results

WSE Comparison:
SWOT and USGS time series for selected reservoirs showed generally consistent trends in water surface elevation, especially during major seasonal changes. However, offsets were present, likely due to vertical datum differences and measurement timing. In reservoirs without USGS gauges, SWOT still revealed meaningful elevation patterns.

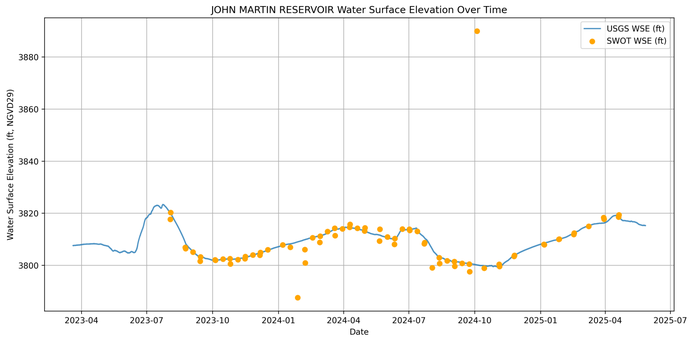
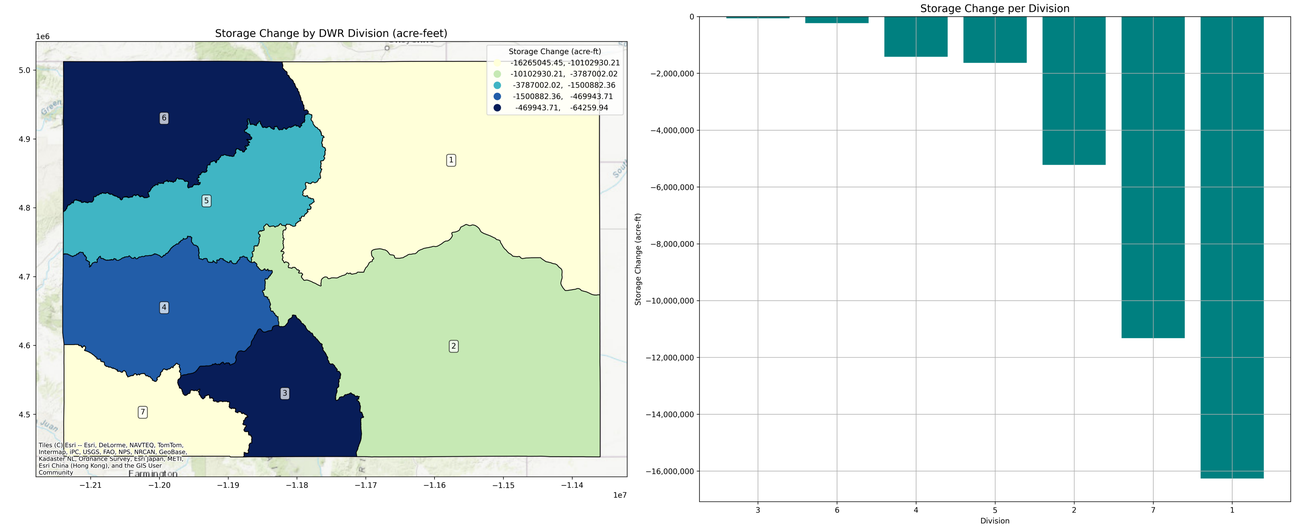


Figure validating SWOT water surface elevation (WSE) data points to USGS ground station continuous timeseries at John Martin Reservoir

Storage Change by Region:
Using static surface area from the Prior Lake product and WSE changes, we estimated volume fluctuations across Colorado's water divisions. The results showed substantial total storage change in Divisions 1, 2, and 5, with Division 1 accounting for nearly half of the statewide loss over the study period. Variability across divisions highlights the need for regional water monitoring.



Two-panel figure analyzing Colorado reservoir/lake storage changes from SWOT satellite data, including a map of changes by water division and a graph of storage change per division.

Conclusion

SWOT satellite data align reasonably well with USGS reservoir measurements, indicating its promise as a tool for large-scale hydrologic monitoring. Limitations such as vertical datum differences and inconsistent surface area estimates highlight areas for improvement. Future work will focus on improving the Hydrocron code to enhance data extraction, processing, and accessibility. By refining this tool, it can become a reliable resource for researchers and water managers to efficiently analyze SWOT data across multiple reservoirs. This study lays groundwork for leveraging satellite and ground-based observations together, advancing water resource monitoring and management capabilities.

Acknowledgements

This research was conducted through the RECCS (Research Experience for Community College Students) program, hosted by the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder and funded by the National Science Foundation (NSF) under grant number 'EAR 1757930'. I would like to thank my mentor Dr. Toby Minear for his guidance and support throughout this project. I also thank the RECCS staff and faculty for providing a supportive and engaging research experience, and the NASA PO.DAAC team for making SWOT data available via the Hydrocron API.