# Monitoring Water Levels in Canadian Lakes and Reservoirs using the Surface Water and Ocean Topography (SWOT) Mission

Logie, Gordon
Yee, Lauren
Nieuwenhuis, Greg

## Introduction

- With shifting precipitation patterns due to climate change, it is more important than ever to understand the inflows and outflows of the surface water bodies we rely on for growing food, recreation, and supporting a rich and diverse biosphere.
- The Surface Water and Ocean Topography (SWOT) mission, launched in December 2022, uses Ka-band radar interferometry to measure the elevation of oceans and larger surface water bodies.
- SWOT features a claimed minimum revisit interval of 21 days, with 90% global coverage.
- In Canada, the National Hydrological Service (NHS) monitors surface water using a network of water monitoring stations; however, many are seasonal or discontinued.
- SWOT data could potentially supplement and extend water monitoring capabilities in Canada, assuming the data is of sufficient accuracy, temporal resolution, and spatial coverage.

## Objectives

The goals of this research were to evaluate the SWOT water level data in the following ways:

- Assess accuracy through comparison with NHS station data.
- Evaluate the timeliness and spatial coverage of the data.
- Make note of any other issues with the data observed during the course of the analysis.

## Methods

**Study Area:**

- Due to time and processing constraints, we chose to limit our analysis to the province of Alberta.

**Software Utilized:**

- All data retrieval, processing, analysis, and plot visualization was performed using Python.
- Maps were created using QGIS.

**NHS Data Retrieval and Filtering:**

- NHS station data were downloaded as a SQLite database.
- Stations within the database were filtered as follows:
  - Within the province of Alberta; have water level data for both 2023 and 2024; are measuring lake/reservoirs (not rivers); measured water elevation values are within a similar range to the local terrain elevation (above sea level).
- Filtering resulted in a total of 13 stations (**Figure 1**).

**SWOT Data Retrieval:**

- SWOT data were downloaded using the NASA Earthaccess Python package.
- We used the SWOT Level 2 Lake Single-Pass Vector Data Product.
  - Water elevation provided as attributes attached to polygons approximating the shape of the lake.
  - Each polygon assigned a Lake ID from a database of known lakes, allowing specific lakes to be tracked and compared through time. Some lakes also feature a Lake Name attribute, though this was not always provided.
- The Alberta provincial bounds were used to spatially limit the query, along with a temporal range of Jan 1, 2023 to Dec 31, 2024.

**Data Combination and Analysis:**

- SWOT Lake IDs corresponding to the 13 selected stations were identified and used to filter the data.
- Overlapping measurement dates between SWOT and station were used to combine both into a single dataframe.
- Statistics and plots were generated from the combined dataset.

## Results

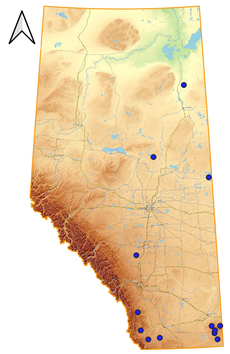



**Figure 1:** Selected Reservoir Locations after filtering.

**Table 1:** Statistics for absolute water level difference between SWOT and NHS station measurements.

| Statistic | Overall | 2023 | 2024 |
|---|---|---|---|
| Mean | 2.3 m | 3.19 m | 1.93 m |
| Median | 0.37 m | 0.39 m | 0.37 m |
| Min | 0.0 m | 0.0 m | 0.0 m |
| Max | 155.67 m | 86.96 m | 155.67 m |
| Std | 10.28 m | 11.43 m | 9.76 m |

**Table 2:** Statistics for absolute water level difference between SWOT and NHS station measurements broken down by reservoir.

| Statistic | Michel Reservoir | Bullshead Reservoir | Cressday Reservoir | Chain Lakes Reservoir | Cold Lake | Calling Lake | Glenniffer Reservoir | Waterton Reservoir | Mclelland Lake | St. Mary's Reservoir | Bare Creek Reservoir | Reesor Reservoir | Oldman Reservoir |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.08 m | 0.12 m | 0.12 m | 0.26 m | 0.46 m | 0.73 m | 0.79 m | 0.82 m | 1.12 m | 3.0 m | 3.27 m | 3.68 m | 10.56 m |
| Median | 0.06 m | 0.06 m | 0.04 m | 0.14 m | 0.22 m | 0.73 m | 0.13 m | 0.43 m | 0.43 m | 1.15 m | 3.28 m | 3.67 m | 0.34 m |
| Min | 0.0 m | 0.0 m | 0.0 m | 0.01 m | 0.05 m | 0.59 m | 0.01 m | 0.02 m | 0.01 m | 0.14 m | 2.67 m | 3.46 m | 0.0 m |
| Max | 0.37 m | 0.54 m | 1.48 m | 1.21 m | 11.04 m | 0.92 m | 14.61 m | 4.47 m | 41.17 m | 13.05 m | 3.7 m | 3.89 m | 155.67 m |
| Std | 0.09 m | 0.15 m | 0.25 m | 0.29 m | 1.36 m | 0.07 m | 2.21 m | 1.01 m | 4.68 m | 3.42 m | 0.16 m | 0.08 m | 28.59 m |

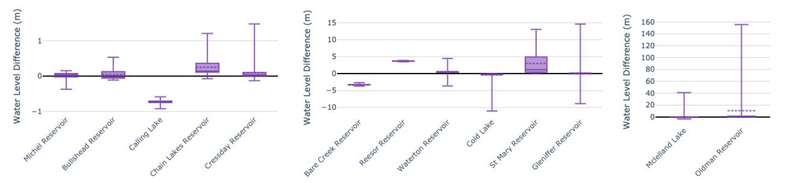



**Figure 2:** Box plots for water between SWOT and NHS station measurements. Please note the differing y-axis scales used to capture the wide intra-reservoir differences.

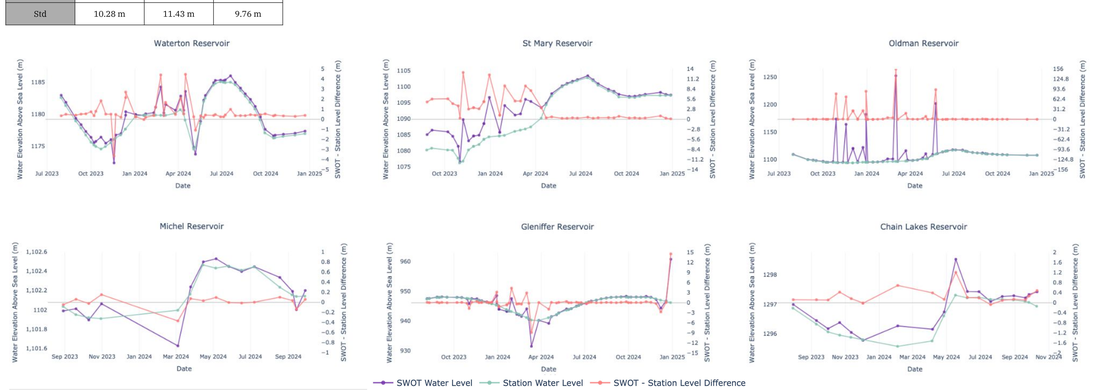



**Figure 3:** Time series plots comparing SWOT and NHS water level measurements for a subset of reservoirs. Please note the x and y-axes differ between plots.

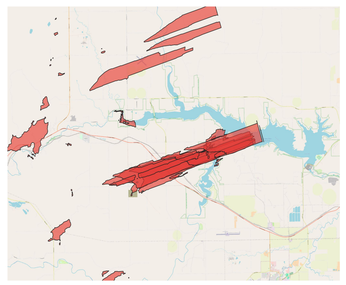


**Figure 4:** Bad measurements over the Oldman Reservoir.

**Table 3:** SWOT data availability statistics. Note these numbers were calculated prior to filtering to the 13 study reservoir locations.

| | |
|---|---|
| Total polygon count | 1,564,619 |
| Number of unique Lake IDs | 36,269 |
| Number of Named Lakes | 1410 |
| Number of polygons per Lake ID - average | 43.14 |
| Number of polygons per Lake ID - minimum | 1 |
| Number of polygons per Lake ID - maximum | 196 |
| Number of polygons per Lake ID - standard deviation | 26.47 |
| Days between measurements - average | 18.21 |
| Days between measurements - minimum | 0 |
| Days between measurements - maximum | 628 |
| Days between measurements - standard deviation | 25.16 |

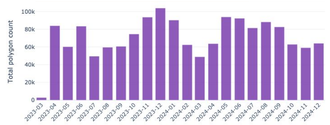



**Figure 5:** Total count for SWOT polygons broken down by year and month.

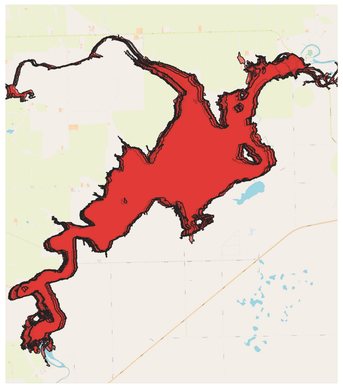


**Figure 6:** Spatial misalignment between polygons over St. Mary Reservoir.

## Discussion

**Accuracy**

- The overall average deviation between the water stations and SWOT measurements was 2.3 meters. The average deviation was higher in 2023 than 2024 (**Table 1**).
- The median deviations were much lower than the average (0.37 m overall), due to the influence of large outliers (**Table 1, Figure 2**).
- The Michel Reservoir had the highest overall agreement between the SWOT data and NHS station; the Oldman Reservoir had the worst overall agreement, due primarily to some very large outliers (**Table 2; Figures 2 & 3**).
- Looking closer at the Oldman Reservoir, it was found that the large outlier measurements had very inaccurate geometries which did not align well with the reservoir (**Figure 4**).

**Spatial and Temporal Coverage**

- There were over 1.5 million lake polygons retrieved over Alberta between 2023 and 2024 (**Table 3**).
- In total there were 36,269 unique Lake IDs in the dataset, but only 1410 had a populated Lake Name attribute.
- The mean number of measurements per lake was 43, with an average interval of 18 days between measurements; however this was quite variable, with some lakes having as few as a single measurement or as many as 196, and a maximum of 628 days between them.
- The earliest data availability was March 2023, but only a small amount; data availability increased significantly in April 2023 (**Figure 5**).
- The amount of data available varied between months, but there wasn't a clear seasonal pattern to this variation.

**Data Issues**

- Some inaccurate geometry, particularly associated with poor accuracy measurements (**Figure 4**).
- Alignment between polygons over the same lake can shift around (**Figure 6**).
- The data is only available in shapefile format, which may limit its usability for some users.

## Conclusions & Future Work

- The SWOT water level data is generally of high accuracy, with the exception of some troubling outliers; however, these could be easily filtered out.
- The interval between measurements was in line with the claimed 21 days, but highly variable depending on the lake. As such, SWOT data is unlikely to serve as a replacement for terrestrial monitoring sensors, but could be a useful supplement.
- Further investigation is warranted for some of the large measurement errors, such as those associated with the Oldman Reservoir.
- We would like to expand this analysis outside of Alberta, ideally covering the entirety of Canada.
- We plan to develop an interactive online application to ingest SWOT data, visualize it, and track changes in water levels over time.
- We plan to investigate the other SWOT data products, such as their river vector product, and their raster format products.