Assessing the added value of SWOT lake observations to enhance Canadian hydrological forecasting : Data assimilation accounting for latency, revisit time and error

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INTRODUCTION & OBJECTIVES

The Canadian landscape is dotted with hundreds of thousands of unmonitored lakes, for which there are no observations available. The Surface Water and Ocean Topography (SWOT) mission will provide global-scale observations of water levels in lakes, which can help improve Canadian hydrological forecasting, especially the routing component, by assimilating the observed water levels.

Nevertheless, several critical considerations need thorough examination to gauge the true potential and consequences of integrating SWOT data into a forecasting system. These considerations include data latency, revisit time, as well as observational error associated with SWOT data.

The objective of our work is to analyze the impact of these different elements on the performance and sensitivity of the GEM-Hydro model developed at ECCC (Gaborit et al., 2017). Our findings will provide crucial insights into harnessing SWOT data for better hydrological predictions in Canada, helping to address the longstanding challenges posed by unmonitored lakes and data scarcity.

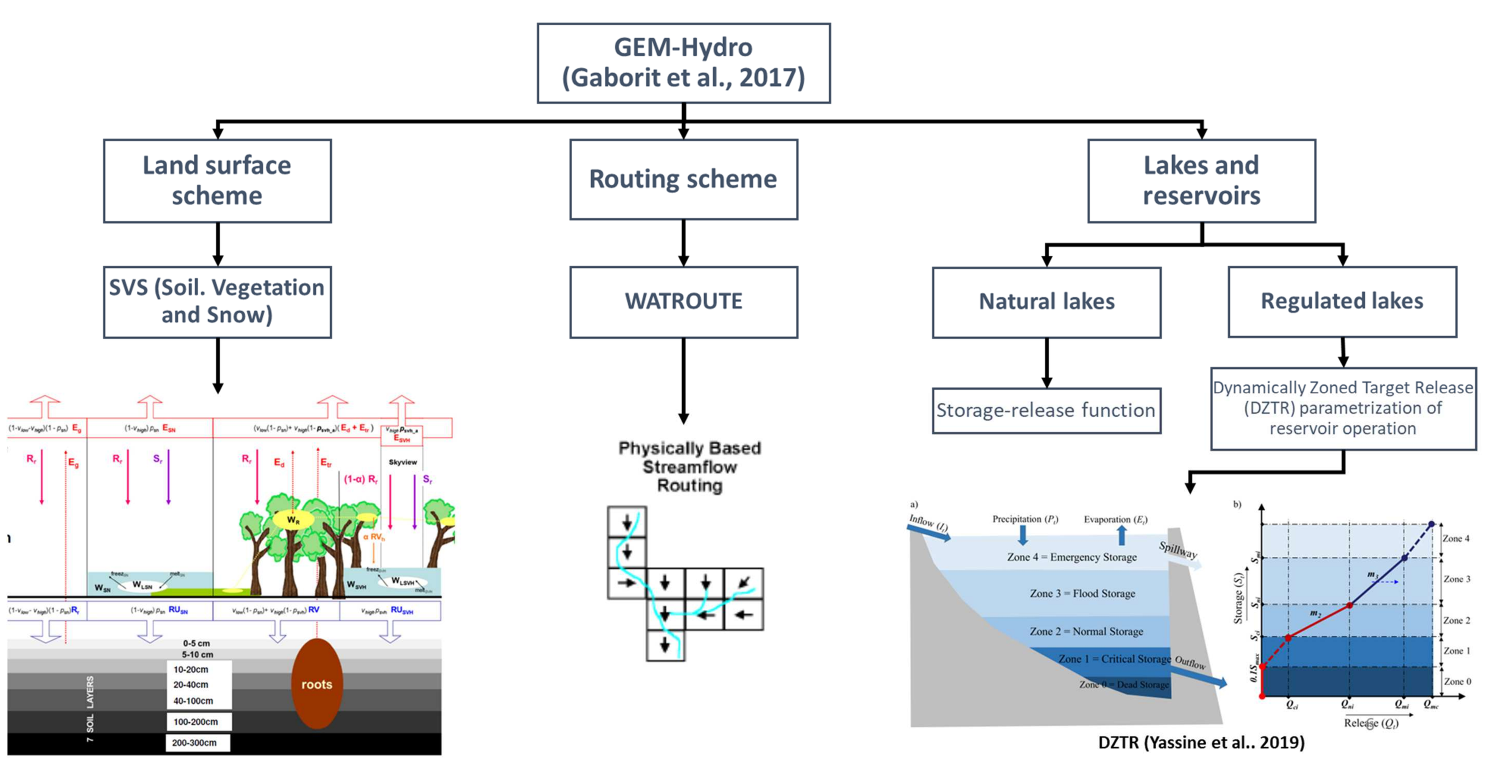
METHODOLOGY

To achieve this objective, we implemented a methodology that involved the use of the GEM-Hydro hydrologic model in two distinct watersheds: the Lake of the Woods watershed - LotW (~70000Km^2), characterized by primarily regulated flow regimes and relatively large modeled lakes, and the Petawawa watershed - PTW (~4000km^2), featuring a natural flow regime with smaller modeled lakes. Our analyses were conducted following a schedule closely aligned with the planned SWOT satellite observations over the lakes.

For both watersheds the hydrological model is forced with CaPA precipitation and using direct insertion mode to replace simulated streamflow by the observed one where available. The simulation period is of 10 years for the LotW basin (2010-2019) and 5 years for the Petawawa basin (2015-2019) and the data used for water level assimilation are derived from control station. The assimilation process entailed adjusting the initial lake water levels within the model, accounting for a specified range of data latency and revisit time intervals. This approach allowed us to comprehensively assess the sensitivity of the model simulations to various selected parameters.

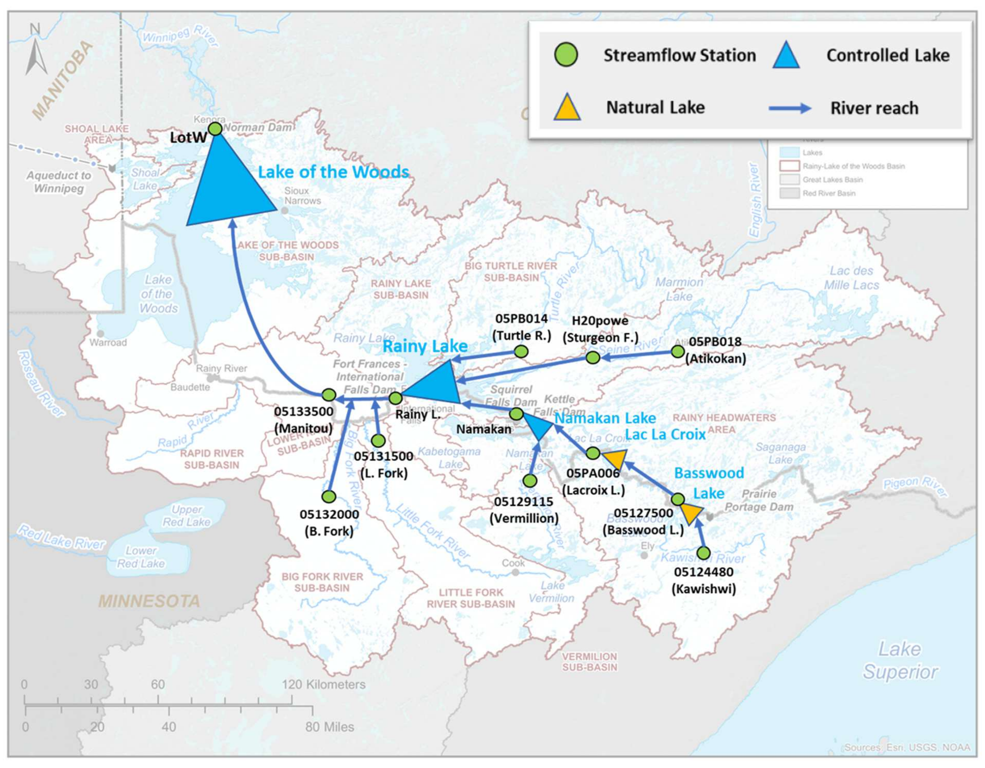
By using these two contrasting watershed scenarios, our methodology aimed to provide a comprehensive evaluation of the impact of SWOT data assimilation on hydrological simulations, considering the differences in lake size and flow regimes. Additionally, the "synchronization" of our analysis with the SWOT satellite's observation schedule ensured that our findings would be relevant to the practical application of SWOT data when it becomes available. This comprehensive approach enabled us to assess the potential benefits and limitations of SWOT data assimilation in improving hydrological forecasting in both regulated and natural flow regimes with lakes of varying sizes.

Conceptual model and core components of the hydrological forecasting system

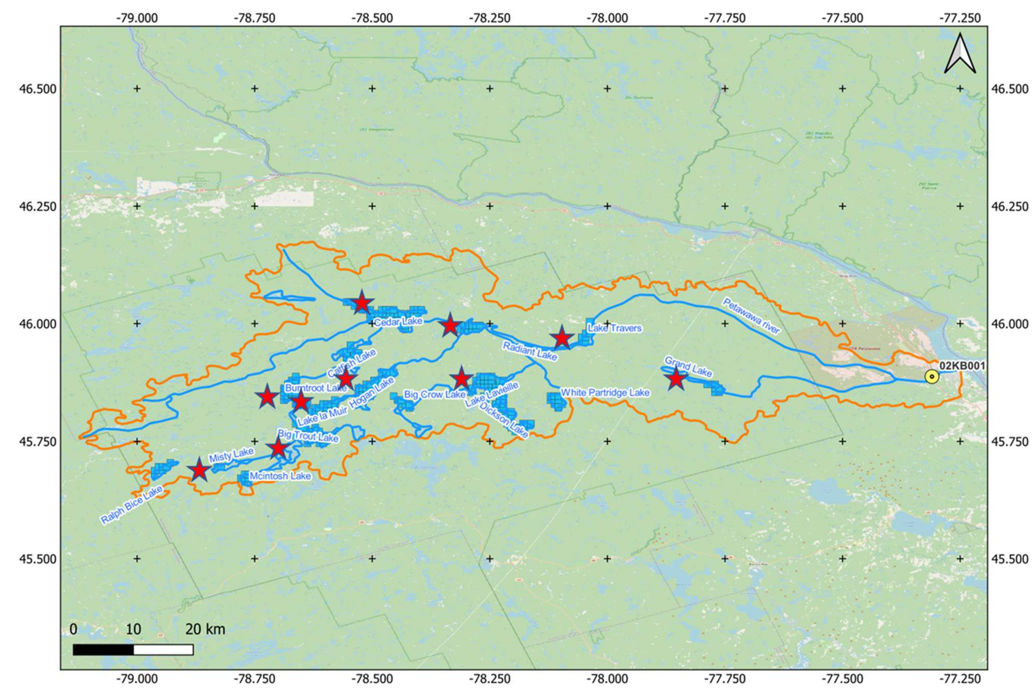


STUDY AREA

Lake of the Woods basin – Regulated flow system (~70 000 Km^2)



Petawawa basin – Natural flow system (~4 000 Km^2)

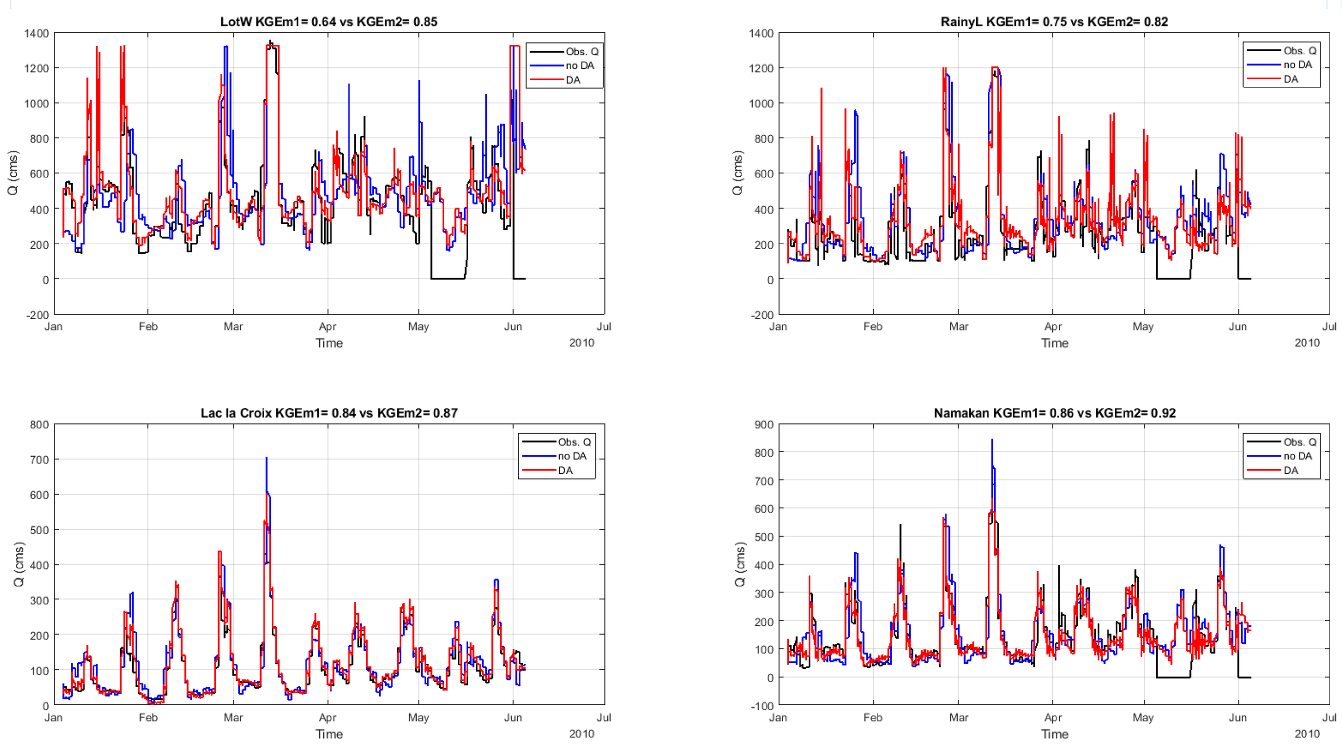


PRELIMINARY RESULTS

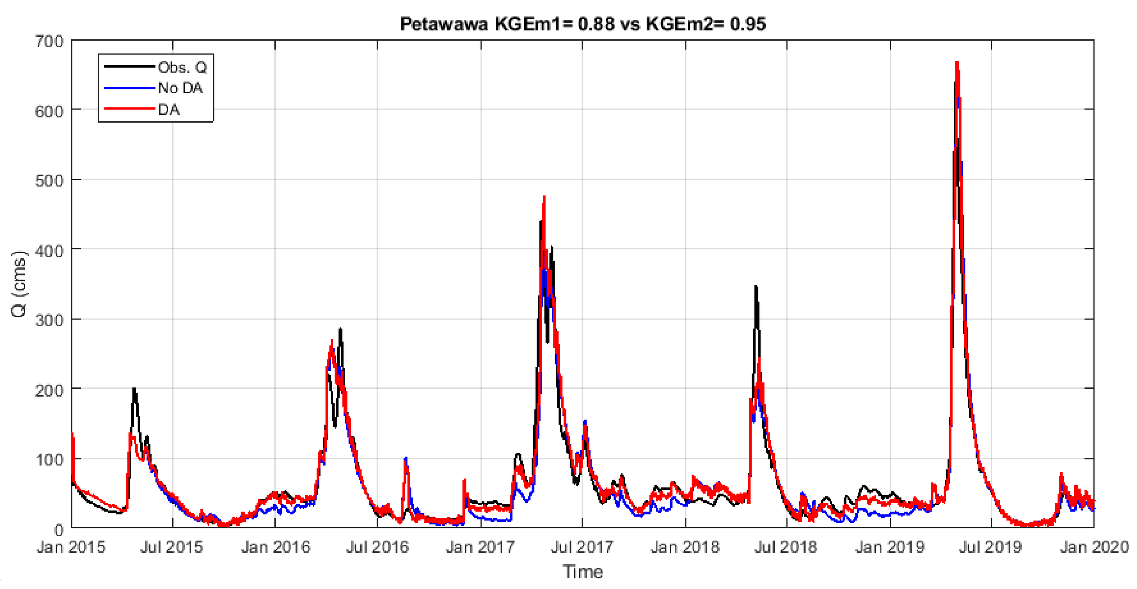
Simulated streamflow - Data assimilation (DA) vs no DA

Latency = 3days & revisit time = 6 days

Lake of the Woods basin

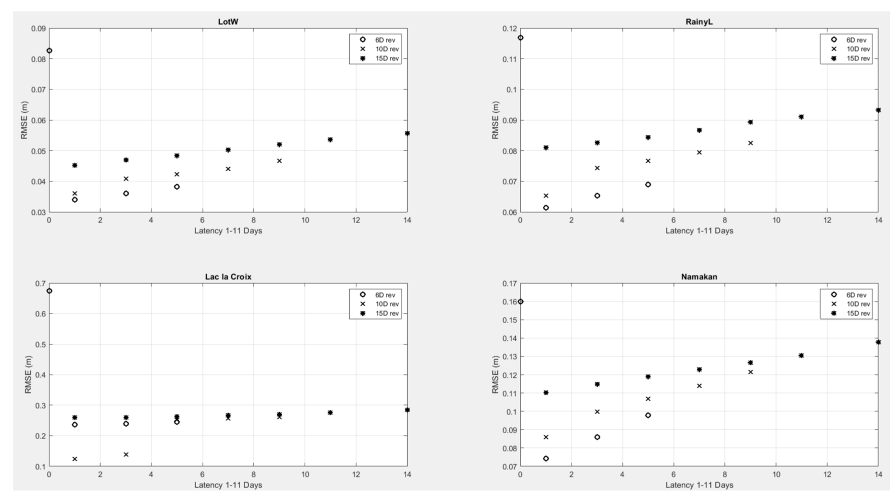


Petawawa basin

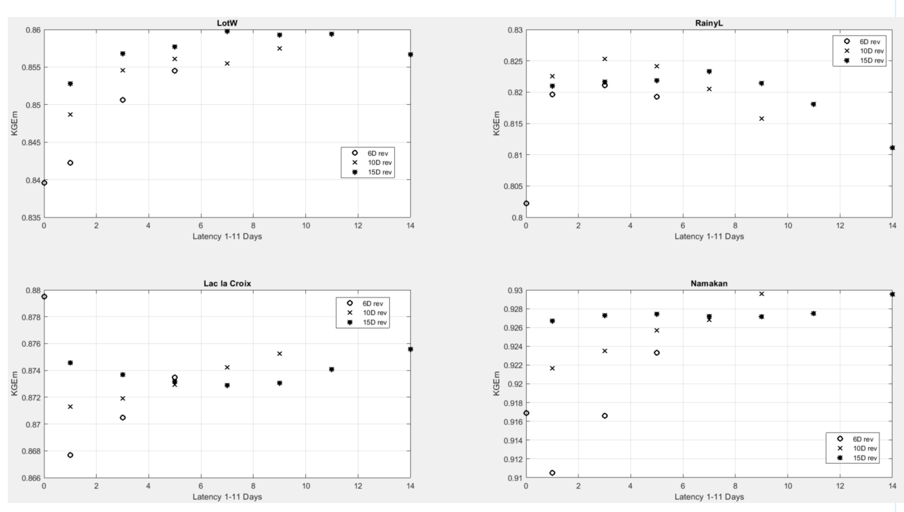


Sensitivity to latency and revisit time for the LotW watershed

Water Level



Discharge



PRELIMINARY CONCLUSIONS

- **Overall Improvement**: Water level assimilation do not only improve the performance of simulated water levels for all the lakes but most importantly improves downstream streamflow.
- **Lake of the Woods**: In the case of regulated lakes, the improvement in simulated water levels by assimilation translates into an improvement in simulated downstream streamflow, with better scores. The only case where simulated streamflow deteriorates slightly is for the only natural lake (Lacroix) simulated in the system.
- **Petawawa**: Some smaller lakes exhibited less sensitivity to data assimilation, resulting in more limited improvements in performance. It's important to note that the impact of SWOT data can vary depending on the characteristics of the lakes, highlighting the need for targeted analysis and considerations for smaller water bodies.
- **Latency Effect**: The effect of data latency on our simulations was found to be minimal, with negligible influence on the results. This implies that, in practice, the time lag between data acquisition and assimilation may not significantly affect the quality of hydrological predictions.
- **Revisit Time**: The choice of revisit time intervals had a more substantial impact, particularly in the Lake of the Woods region.

References

Gaborit, É., Fortin, V., Xu, X., Seglenieks, F., Tolson, B., Fry, L.M., Hunter, T., Anctil, F., and Gronewold, A.D. 2017. A Hydrological Prediction System Based on the SVS Land-Surface Scheme: efficient calibration of GEM-Hydro for streamflow simulation over the Lake Ontario basin. *Hydrology and Earth System Sciences,* 21(9):4825-4839. https://doi.org/10.5194/hess-21-4825-2017

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