Evaluation of Snowmelt Estimation Techniques for Enhanced Peak Flow Prediction Using MAC-HBV

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Introduction

Amongst other applications, models estimating snowmelt are widely applied in flood forecasting, operational forecasting, numerical weather prediction and climate modelling[1]. Current study focuses on peak flows that are caused by a combination of sudden snowmelt and heavy rains during spring and can also lead to floods. Therefore, accurate predictions of spring snowmelt are critical to water resource managers and flood forecasters.

Previous studies reveal high uncertainty in spring peak flow predictions and thus suggest a need for robust snowmelt estimation technique to improve the simulations.

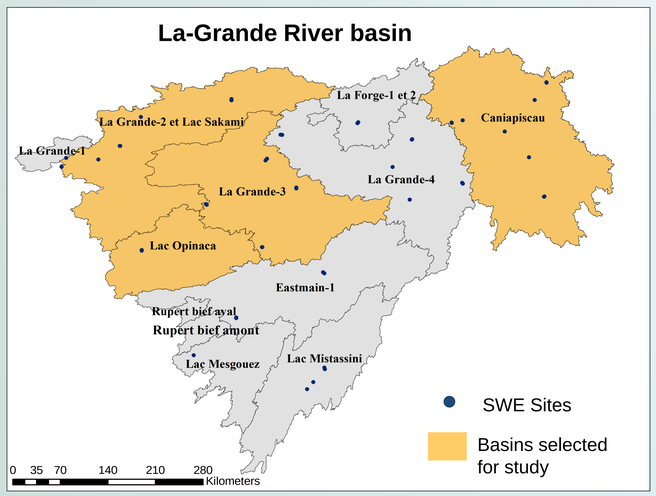
Objectives

- To identify robust snowmelt estimation technique by replacing current snowmelt component in MAC-HBV
- Adapt SNOW-17 and evaluate the performance of simple degree-day based snowmelt routine and SNOW-17 within MAC-HBV hydrological model
- Analyze the selected snowmelt methods for spring peak flow prediction

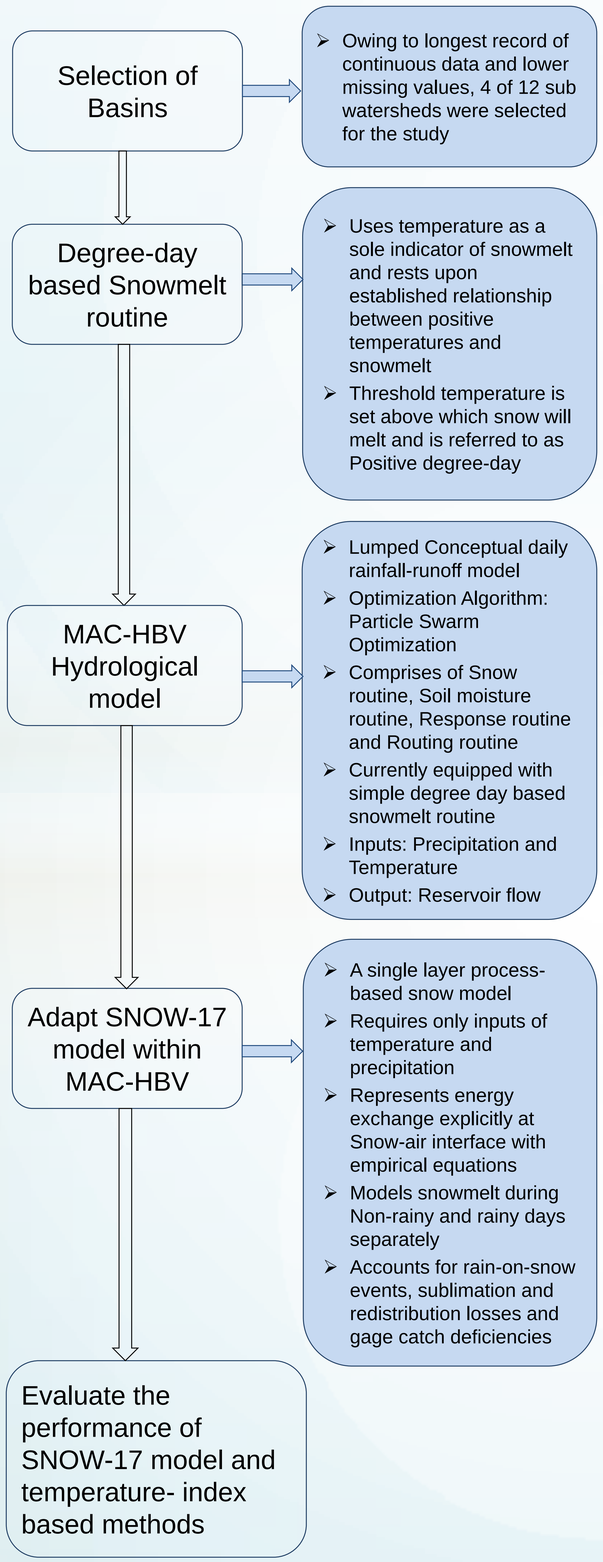
Study Area and Data

- Present study uses 1970-2005 (36 years) data at La-Grande River Basin(LGRB) located in North-Central Quebec
- Total drainage area is about 209,000 km^2 and ranges in elevation from ~6m to ~1139m
- LGRB is mainly covered by forests(97%) and water(3%) [2]

Historical Observed Climate data from Hydro-Quebec:
Precipitation, Tmax and Tmin data: 1970-2005
SWE data: On every 15th from Jan-Apr in 1970-2005
Observed flow data varies based upon sub-basin



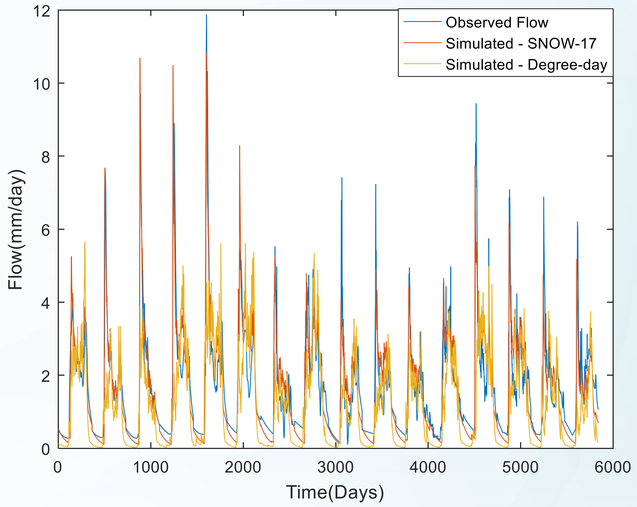
Methods



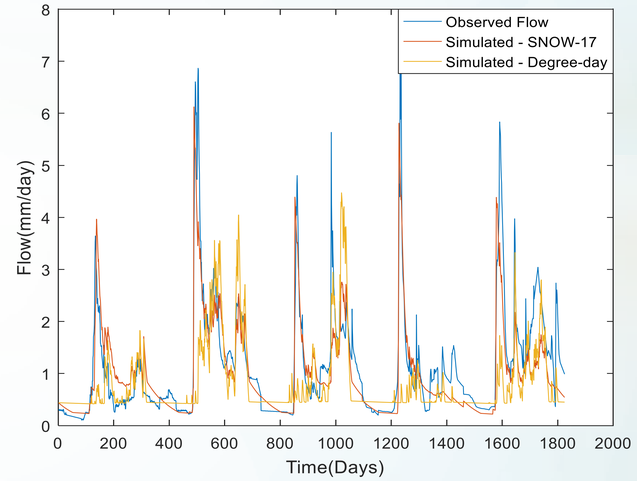
Results

Validation Performance Results

a) Caniapiscau



b) La_Grande_2



Model Performance Statistics: Even Years Calibration

Snowmelt Routine	SNOW-17 model within MAC-HBV		Degree Day Snowmelt Routine	
Basin name	NSE	VE	NSE	VE
Caniapiscau	0.8008	0.0305	0.2945	0.2983
La_Grande_3	0.7529	0.0266	0.4009	0.1865
La_Grande_2_et_Lac_Sakami	0.7208	0.0476	0.4228	0.2069
Lac_Opinaca	0.6514	0.1191	0.1853	0.2650

Model Performance Statistics: Odd Years Validation

Snowmelt Routine	SNOW-17 model within MAC-HBV		Degree Day Snowmelt Routine	
Basin name	NSE	VE	NSE	VE
Caniapiscau	0.7949	0.0221	0.1789	0.3044
La_Grande_3	0.4166	0.1626	-0.0152	0.3103
La_Grande_2_et_Lac_Sakami	0.7226	0.1636	0.0041	0.3070
Lac_Opinaca	0.6211	0.1815	0.0906	0.3155

Discussion

The performance evaluation of current MAC-HBV model consisting of degree-day based snowmelt routine indicated that acceptable NSE values were obtained during calibration period(i.e., Even years) while for the validation period(i.e., Odd years), model failed to predict observed flow correctly for all the 4 sub-basins considered in the study. For SNOW-17 model adapted within MAC-HBV, the model performed better during both calibration and validation periods. SNOW-17 model performance could be better owing to consideration of gage-catch deficiencies and rain-snow partitioning while modeling snow accumulation and melt. Further improvements might be achieved by using high temporal resolution(hourly data) or by adapting other snowmelt estimation techniques such as radiation energy methods.

The mean absolute error calculation for the peak flows reveals that SNOW-17 model within MAC-HBV capture peak flows better for Lac-Opinaca, Caniapiscau and La-Grande-2 sub-basins than simple degree-day method. While, for La-Grande -3 sub-watershed both snowmelt estimation techniques poorly simulates peak flows and at times overestimates peak flows. This performance evaluation indicates that there is still a need to identify robust snowmelt estimation technique that can better predict amount and time of peak flow.

Future work

To improve the results and identify robust snowmelt estimation technique, we are planning to do the following:

- Changing the calibration and validation periods for the selected snowmelt routines
- Adapting different snowmelt estimation techniques such as Radiation energy based algorithm
- Use of higher temporal resolution data (Hourly data)
- Employ chosen snowmelt estimation techniques within different hydrological model to test its robustness

References

[1] Essery, R., Morin, S., Lejeune, Y., Ménard, C.B., 2013. A comparison of 1701 snow models using observations from an alpine site. Adv. Water Resour. 55, 131-148.
[2] Coulibaly P, Keum J, 2016. Snow Network Design and Evaluation for La Grande River Basin, Hydro-Quebec, Canada (Project No. 016-0223-24134). McMaster University.

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