A HYDROLOGICAL AND WATER TEMPERATURE MODELLING FRAMEWORK TO SIMULATE THE TIMING OF RIVER FREEZE-UP AND ICE-COVER BREAKUP IN LARGE-SCALE CATCHMENTS

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INTRODUCTION

- In mid- to high-latitude lakes and rivers, the formation and breakup of ice covers are important seasonal events.
- River freeze-up and ice-cover break-up events are controlled by stream water and air temperature. They influence the timing of ice melt, freeze onset and ice duration.
- Ice jamming after ice-cover break-up is one of the major trigger of floods in many cold region rivers.
- Hydraulic models equipped with energy balance algorithms have been successfully implemented at local scale to simulate ice formation and ice-break [1, 2].
- The spatial and temporal variability of the air temperature 0^oC isotherm has been studied to understand the timing of freeze-up and break-up events.

OBJECTIVE

Simulate the spatio-temporal variability of river freeze-up and ice-cover breakup events using simulated stream water temperature time series. A semi-Lagrangian water temperature model for advection-dominated river systems, RBM [3], is coupled with MESH, a semi-distributed hydrological model [4], to simulate stream water temperature in the Athabasca River basin (ARB).

CASE OF STUDY

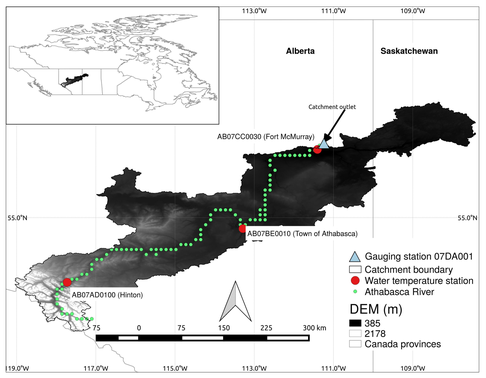

Figure 1: Geographical location of the Athabasca River basin (ARB). Streamflow and water temperature station locations, digital elevation model (DEM) and the Athabasca River model (green dots) are included.

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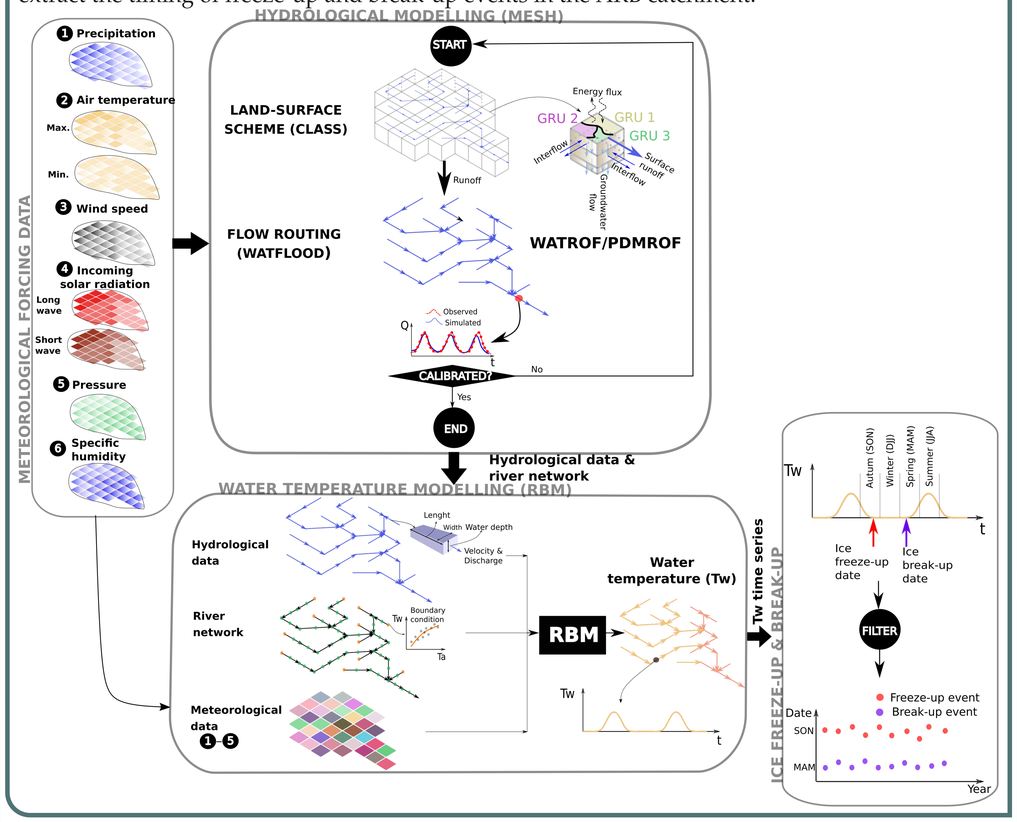
MODELLING APPROACH

RBM has been designed to use as stand-alone software or in conjunction with hydrological models such as VIC [5] and DHSVM to simulate nominal daily water temperatures in rivers basins. In this research, we coupled RBM with the MEC-Surface & Hydrology System (MESH) model [4] to first simulate hydrological processes and the stream temperature across the river reaches and then to extract the timing of freeze-up and break-up events in the ARB catchment.



CALIBRATION AND VALIDATION OF MESH

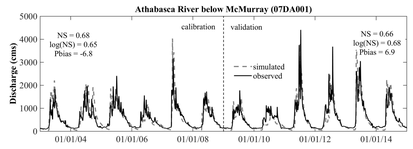


Figure 2: Observed and simulated streamflows at the gauging station "Athabasca River below McMurray" (07DA001) for the calibration and validation period. MESH performance statistics are included.

Figure 3 shows daily time series and scatter plots of observed and simulated stream water temperatures at the station a) AB07AD0100 (Hinton), b) AB07BE0100 (Town of Athabasca) and c) AB07CC0030 (Fort McMurray). RBM performance statistics are included.

VALIDATION OF RBM

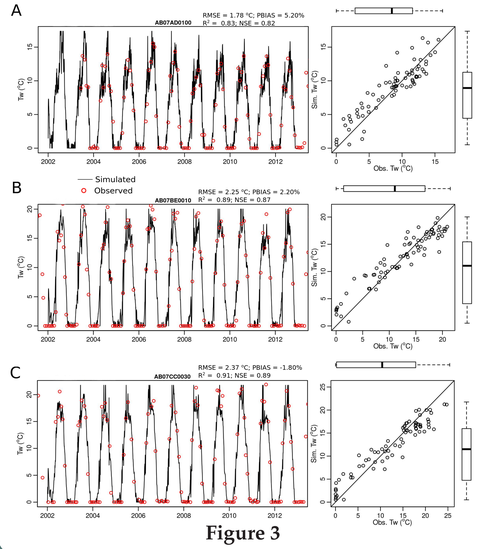


Figure 3

STREAM TEMPERATURE SIMULATIONS

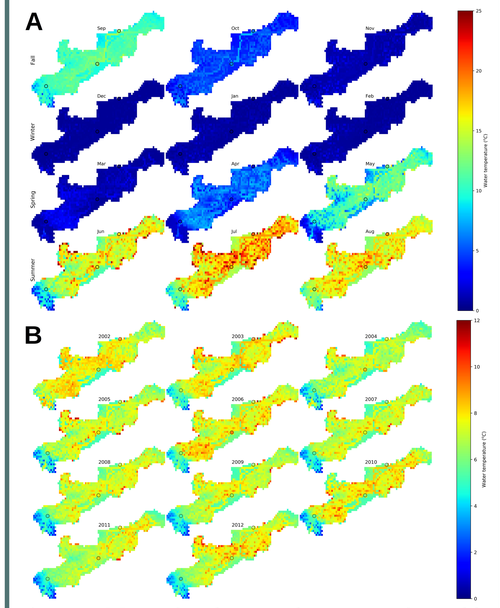


Figure 4: Maps of multi-annual averages of monthly simulated water temperature (°C) in the ARB. The dots indicate observed water temperature at the station locations.

VALIDATION OF FREEZE-UP AND BREAK-UP TIMING

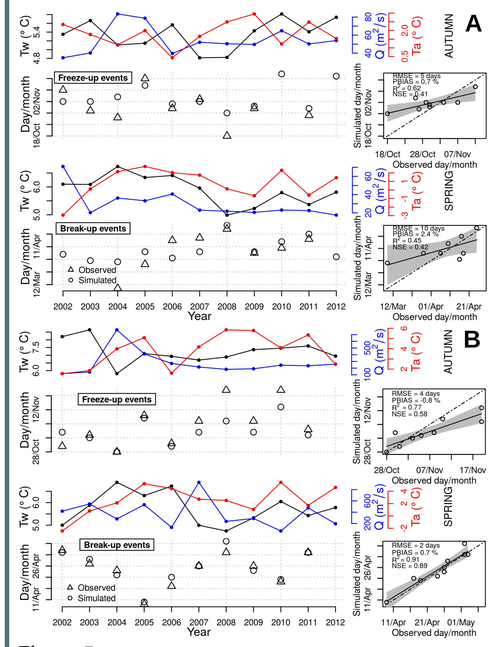


Figure 5: Time series of freeeze-up and break-up dates, and scatter plots of observed and simulated freeze-up and break-up dates at a) AB07AD0100 (Hinton) and b) AB07CC0030 (Fort McMurray). Autumn and spring time series of averaged water temperature (Tw), air temperature (Ta) and streamflow (Q) are included for each station. Performance statistics and linear fitting curves are included in the scatter plots.

SIMULATION OF FREEZE-UP AND BREAK-UP TIMING

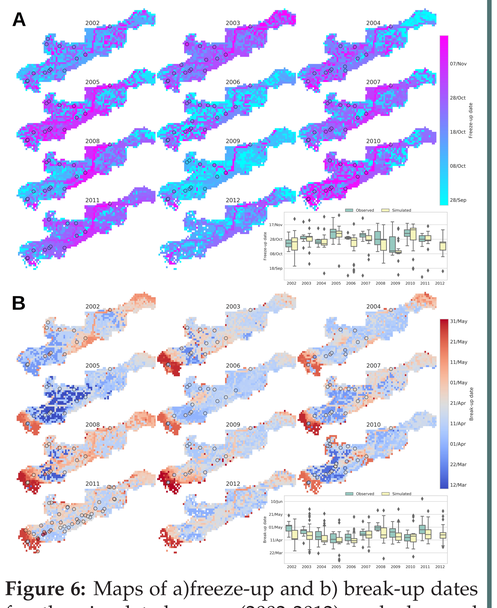


Figure 6: Maps of a)freeze-up and b) break-up dates for the simulated years (2002-2012) and observed freeze-up dates at Water Survey Canada gauge stations (see overlaying dots). The inset shows boxplots based on observed and simulated freeze-up and break-up dates for each simulated year. Empty pixels in the maps represent non estimated freeze-up dates.

CONCLUSIONS

- In the main tributaries of the ARB, freeze-up timing spans from the last week of September to the second week of November and progressively becomes earlier non-linearly from the headwater reaches to the catchment outlet.
- Break-up timing spans from the second week of March to the last week of May and occurs first at headwater reaches and lastly at the intermediate and outlet reaches.
- Freeze-up and break-up dates are correlated with meteorological and hydrological forcings and spatially controlled by these variables .

REFERENCES

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