Comparison and calibration of a temperature-index based coupled glacier mass balance dynamic evolution model and applications in regional melt projections

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Projection of the changes in the dynamics of glacier accumulation, ablation, and melt runoff is crucial for the management and planning of downstream water use and aquatic ecosystems. The temperature-index models (TIMs) and energy-balanced approaches (EBMs) are widely used to predict glacier changes. In most studies, the TIMs and EBMs are applied with limited or no calibration of model parameters for regional estimates of glacier changes. Hence, they do not account for the spatially variable glacier characteristics for individual glaciers or a group of glaciers at a regional scale. On the other hand, the scarcity of high-resolution measured data at the scale of individual glaciers poses a significant challenge for predicting glacier changes at a regional scale.

This research compared the performance and predicted the uncertainty of a coupled glacier mass balance dynamic evolution model (CGMBDEM) using two TIMs for application in regional studies. The Classical Temperature Index Model (CTIM) and the Pellicciotti Temperature Index Model (PTIM) were examined using the best available data from Athabasca Glacier in Western Canada. The CTIM calculates melt using degree-day factors and a threshold temperature, whereas the PTIM incorporates melt due to radiative forcing. The CGMBDEM was calibrated, and an uncertainty prediction was made based on the optimized range of physical and meteorological parameters via Latin Hypercube Sampling and 95 Percent Prediction Uncertainty (95PPU). Calibration and uncertainty assessment results indicate that the CGMBDEM simulations using the CTIM tend to have a statistically better (bR^2=0.726, p-factor=0.77, r-factor=1.04) performance than those using the PTIM (bR^2=0.551, p-factor=0.31, r-factor=1.02). This demonstrates the sensitivity of model performance to TIM choice and associated parameters. We concluded that the 95PPU based on optimized parameter ranges in our CTIM-based CGMBDEM can be useful in modelling regional changes in glacier melt runoff, mass-balance, and evolution while balancing errors due to the issue of parameter transferability. The results can inform downstream water users and managers for their future planning of resource development and ecosystem health.