Assimilation of Satellite Albedo to Improve Simulations of Glacier Hydrology during Wildfires and Heatwaves

André Bertoncini, Centre for Hydrology, University of Saskatchewan; John W. Pomeroy, Centre for Hydrology, University of Saskatchewan, Canmore

The increasing frequency and magnitude of wildfires and heatwaves have contributed to changes to the hydrology of snow and ice-dominated mountain headwater basins. The deposition of wildfire soot and prolonged above-seasonal temperatures can potentially darken snow and ice, decreasing albedo and consequently increasing melt. Most hydrological and land surface models rely on albedo relationships that are not able to capture the darkening of snow and ice by soot or heatwaves and the albedo refresh by summer snowfall. Thus, it may be beneficial to use satellite albedo estimates to improve model prediction. This research develops a framework for satellite albedo data assimilation into a physically based hydrological energy budget model to diagnose the effects of assimilation on prediction of streamflow in two highly glacierized basins, the Athabasca and Peyto glacier research basins. Sentinel-2 albedo data assimilation into the modular multi-physics Cold Regions Hydrological Model (CRHM) was performed using an Ensemble Kalman Filter method. Assimilation was done between July 2017 and September 2021 during spring and summer (May to September). A control run (CTRL) with a popular land surface model snow albedo routine and a constant glacier ice albedo of 0.3 was used as a reference. A data assimilation run (DA) was implemented using the same CTRL parameterization but with albedo assimilation. Both runs were forced by nearby off-ice station observations. DA and CTRL streamflow predictions were evaluated against daily observed streamflow in the melt seasons of 2018 (heavily wildfire-impacted), 2019 (lightly wildfire-impacted), 2020 (normal), and 2021 (heatwave and lightly wildfire-impacted). DA improved streamflow predictions in the heavily wildfire-impacted year of 2018 for both basins. DA in Peyto was beneficial for all years but 2021. Overall four-year streamflow prediction was enhanced by DA in Peyto but not in Athabasca. Improvements in streamflow prediction by DA were mainly caused by prolonged snowcover over glacier ice, followed by decreased ice albedo, resulting in reduced streamflow during spring and summer. In 2021, the prolonged snowcover acted to deteriorate streamflow prediction, since CTRL was already negatively biased. These findings reveal that satellite albedo data assimilation can increase the accuracy of streamflow predictions of glacierized basins under extreme wildfire conditions, but it was not beneficial during the heatwave year of 2021, where other factors led to model predictive errors. In normal or lightly wildfire-impacted years, the benefits of DA appear to be basin-specific.