Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2018-509-RC3, 2018

Hydrology and Earth System Sciences Discussions

Open Access

HESSD

Interactive comment

Interactive comment on "Impact of glacier loss on annual basin water yields" *by* Evan Carnahan et al.

Anonymous Referee #3

Received and published: 6 November 2018

This manuscript addresses the "peak water" concept associated with glacier response to climatic warming. As reviewed in the introduction to the manuscript, this concept was described in two review articles and has been studied empirically in a number of site-specific studies. Although the empirical studies generally confirmed the conceptual model in broad terms, two fundamental questions arise from this body of literature: (1) what is the time scale over which the "peak water" cycle progresses, and (2) does the trajectory ultimately lead to reduced runoff.

To address these questions, the authors combined a numerical model of glacier dynamics with a parameterized model of vegetation succession and its influence on runoff. They applied the model to glaciers within simplified valley geometries for scenarios representing various combinations of bed slope, vegetation type, and rates of vegetation development for two different climate types and two different climate change scenarios.

Printer-friendly version

Discussion paper

The simulations confirmed that basin runoff ultimately decreases relative to pre-warming conditions. For scenarios without vegetation development, this decrease results from the surface lowering associated with glacier thinning and retreat, and the subsequent reduction in precipitation. Development of vegetation results in greater reductions in basin runoff. The magnitude of and time to “peak water” were greatest for continental glaciers with shallow bed slopes and lowest for steep maritime glaciers.

Overall, this is an interesting and relevant study. However, the conclusions, at least in qualitative terms, could have been deduced fairly directly from the underlying assumptions and basic knowledge of glacier dynamics. I believe that some further analysis and more detailed consideration of vegetation dynamics and ecohydrology would strengthen the contribution of this work. Some specific comments follow.

1. There are additional processes by which annual runoff would decline in a warming climate that are not accounted for in the model. First, as pointed out by another reviewer, recent literature suggests that a shift from snow to rain results in decreased runoff even with no change in the amount of precipitation. Second, increasing air temperatures would be expected to increase evapotranspiration, subject to soil moisture availability. A third reason that one would expect glacier retreat ultimately to reduce basin runoff is that evaporation/condensation from snow or ice is typically low and often dominated by condensation, whereas an unglaciated surface would lose water by evaporation.

2. The scenarios represent glacier retreat followed by vegetation succession. However, retreat can also result in formation of lakes, which can accelerate glacier retreat and would ultimately provide an additional mechanism for reduced basin runoff via evaporation (Moyer et al., 2016). While it is likely not feasible to incorporate lakes into the model, this point should be acknowledged.

3. The model does not accommodate the development of a supra-glacial debris layer, which can reduce meltwater generation and the rate of glacier retreat. See Frans et al.

Printer-friendly version

Discussion paper

(2016). This point should at least be addressed as a discussion point if not incorporated into the model.

4. The analysis focuses on annual runoff, and the authors appropriately acknowledge the importance of considering seasonal runoff variations, particularly in late summer. This discussion could be extended by commenting on the relative magnitude of glacier contributions to seasonal and annual runoff (e.g., as a fraction of total runoff). Good references to draw upon are Frans et al. (2016) and Naz et al. (2014), both of which analyzed effects of glacier retreat on seasonal runoff.

5. The climate scenarios do not include decadal fluctuations, which can complicate peak water cycles – e.g., by generating transient periods of glacier advance, at least early in the warming phase. See, for example, Figure 4 in Clarke et al. (2015) and Figures 8 and 9 in Frans et al. (2016). Also, the magnitude of glacier runoff varies interannually, being greater in warm/dry years than in cool/wet years. See, for example, Naz et al. (2014). This compensating effect is an important aspect of glacier contributions to basin runoff that is not captured in the model.

6. The model scenarios are rather abstract, and I would encourage the authors to make a more structured effort to "map" the model scenarios into the real world. The authors should consider how they might synthesize their model results with results from the literature to develop a more nuanced conceptual model than those proposed by Jansson et al. (2003) and Moore et al. (2009).

7. Related to the preceding comment, the analysis does not consider the covariation of vegetation succession, climatic regime and elevation, or their influences on runoff generation. The authors cite only two papers to support the range of runoff ratios and three papers to support the parameterized model of landscape evolution. The authors should review a broader selection of papers to provide a better framing of their vegetation scenarios. A selection from the last five years includes Wietrzyk et al. (2018), Fickert et al. (2017), Whelan and Bach (2017), Eichel et al. (2015), Klaar et al.

(2015), Cowie et al. (2014) and Mizuno and Fujita (2014).

References

Clarke et al. (2015). Projected deglaciation of western Canada in the twenty-first century. Nature Geoscience 8: 372–377.

Cowie et al. (2014). Effects of glacial retreat on proglacial streams and riparian zones in the Coast and North Cascade Mountains. Earth Surface Processes and Landforms 39: 351–365, DOI: 10.1002/esp.3453.

Eichel et al. (2015). Conditions for feedbacks between geomorphic and vegetation dynamics on lateral moraine slopes: a biogeomorphic feedback window. Earth Surface Processes and Landforms 41: 406-419. DOI: 10.1002/esp.3859.

Fickert et al. (2017). Klebelsberg revisited: did primary succession of plants in glacier forelands a century ago differ from today? Alpine Biology 127: 17-29. DOI: 10.1007/s00035-016-0179-1

Frans et al. (2016). Implications of decadal to century scale glacio-hydrological change for water resources of the Hood River basin, OR, USA. Hydrological Processes 30: 4314-4329. DOI: 10.1002/hyp.10872

Klaar et al. (2015). Vegetation succession in deglaciated landscapes: implications for sediment and landscape stability. Earth Surface Processes and Landforms 40: 1088-1100. DOI: 10.1002/esp.3691

Mizuno and Fugita. (2014). Vegetation succession on Mt. Kenya in relation to glacial fluctuation and global warming. Journal of Vegetation Science 25: 559-570. DOI: 10.1111/jvs.12081

Moyer et al. (2016). Streamflow response to the rapid retreat of a lake-calving glacier. Hydrological Processes 30: 3650-3665. DOI: 10.1002/hyp.10890

Naz et al. (2014). Modeling the effect of glacier recession on streamflow response using a coupled glacio-hydrological model. Hydrology and Earth System Sciences 18: 787–802

Whelan and Bach. (2017). Retreating glaciers, incipient soils, emerging forests: 100 years of landscape change on Mount Baker, Washington, USA. Annals of the American Association of Geographers 107: 336-349. DOI: 10.1080/24694452.2016.1235480

Wietrzyk et al. (2018). The relationships between soil chemical properties and vegetation succession in the aspect of changes of distance from the glacier forehead and time elapsed after glacier retreat in the Irenebreen foreland (NW Svalbard). Plant and Soil 428: 195-211

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-509, 2018.