Master thesis proposal: Peak water using the Open Global Glacier Model

Erik Holmgren
Advisor: Fabien Maussion

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1 Motivation

Mass loss from glaciers has increased during the second half of the 20th century (Vaughan et al., 2013) and is prediced, in all current climate projections, to continue throughout the 21st century (IPCC, 2014). The magnitude of the end of century glacial mass loss varies greatly depending on the region and climate scenario – Huss and Hock (2015) found a global glacier volume decrease between 25% (RCP2.6) and 48% (RCP8.5) and regional losses between 20 and 90%.

Glaciers play an important role as storage magasins, delaying up to 79% of the total precipitation falling on the glacier surface (Aral Basin) as meltwater runoff later in the season. The benefits of this seasonal delay is particularly important in regions with a warm and dry ablation season (Kaser et al., 2010). One of these areas is the Indus basin where, during the pre-monsoon season, up to 60% of the total irrigation volume comes from either snow or glacier melt – resulting in an 11% increase of the total crop production (Biemans et al., 2019). The Indus basin is also an example of large river basins which under the present climate experiences water scarcity – threatening the food security for millions of people (Kummu et al., 2014) in an area where large amounts of the freshwater resource is shared across state borders where the risk for amred conflict is high (Pritchard, 2019; Schleussner et al., 2016). The populated areas on the dry, western, slopes of the Andes are other examples of regions depending on glacier meltwater for potable water and power generation. Vergara et al. (2007) estimate the cost of mitigation and adaption to retreating glaciers in the Andes from US$300 million up to US$ 1.5 billion.

2 State of the art – Glacial hydrology

In alpine catchments snow accumulation and snow melt are the main contributors to runoff generation, while the influence of precipitation is small, during the months between June and October (Zappa et al., 2003).

The main factors controlling the discharge hydrograph are the topographical structure, the seasonal air temperature gradient, and the seasonal distribution of precipitation (Zappa et al., 2003).

Runoff peaks later in the summer – when the melt line has crept further up and thus exposing more of the catchment area to melt (Zappa et al., 2003).

Kaser et al. (2010) estimated the societal importance of glacier melt water under the assumption that the glaciers were in equilibrium with the local climate – any runoff from glacier net mass loss was not included in their analysis. Bliss et al. (2014) showed that glacier net mass loss is an important part of the total glacier runoff, indicating that the societal importance of glacier melt water might be higher than the estimates from Kaser et al. (2010).

The ratio between the summer runoff and total runoff of a glacier rises strongly with the glaciated area (Jansson et al., 2003).

3 Peak water using the OGGM

State of the art peak water estimations (Huss & Hock, 2018; Rounce et al., 2020) have relied on parametrizing the re-distribution of mass throughout the glacier with so called mass re-distribution curves developed by Huss et al. (2010). The parameterization by Huss et al. (2010) is a clear step up in performance compared to previous ice flow parametrizations but still relies on known glacier measurements for calibration. The flow of non-measured glaciers is estimated from known glaciers of the same size.

Employing the Open Global Glacier Model (OGGM, Maussion et al., 2019) for peak water calculations would be the first time a physical ice flow model is applied globally to calculate glacier runoff. It would be a step towards mitigating the problem of over parametrization present in the current global glacier models used for hydrological analysis. A new set of runoff estimates, based on a different modelling framework, will also broaden the scientific background about the subject. The OGGM uses the same mass balance scheme, a degree day model, as for example PyGEM (used by Rounce et al., 2020). Thus, any differences in the annual mass balance should stem from the different implementations of ice dynamics – possibly leading to slightly different area/length estimations and thus a different runoff.

In its current state OGGM does not save any hydrological outputs (not true any more...) so before any runoff calculations can be made this has to be added to the model and tested. The common approach is to use a fixed gauge – a hypothetical measuring station at the terminus of the glacier, measuring all water leaving the initially glaciated area. This implies calculating the runoff, Q, from glacial melt α, and liquid precipitation p_{liquid}:

$$Q = p_{liquid} + \alpha - R, \tag{1}$$

where R is the refreezing of melt water within the glacier. The runoff from snow melt and liquid precipitation is calculated from the initially glaciated area and is, as the glaciated area shrinks, divided into two part: on glacier and off glacier runoff.

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