Subject title:

Impact of temperate glaciers melting on aquifer dynamics in the case of eastern Iceland

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Scientific context

Since the early 21st century, glaciers worldwide have with few exceptions, been shrinking at unprecedented rates due to climate change [Zemp et al., 2016]. The mechanisms of glaciers and their evolution under climate change are well studied [Aðalgeirsdóttir et al., 2011], as the associated effects on surface hydrology (both subglacial flow and down-ice flow). Meltwater runoff is initially expected to rise until a "peak water" and then steadily decrease and disappear with the glacier. However, there is a big lack of knowledge when it comes to the groundwater component [Vincent et al., 2019], that is pointed out by the scientific community [Hood et al., 2006]. It is due to the fact that for a long time, the geological formations in glacierised valleys were thought to be too impermeable to enable any water infiltration and hence to form any aquifers [Williams et al., 2015]. Based on field measurements, it was recently demonstrated that pro-, sub-and peri-glacial aquifers do exist and are fairly ubiquitous in glacierised catchments [Hayashi, 2020], both in sedimentary formations [Vincent et al., 2021] and in the bedrock [Cochand et al., 2019]. But these aquifers are poorly known [Vincent at al., 2019]. There exist only a few studies on shallow aquifers, showing high recharge of aquifers by glacial meltwater [Miller et al., 2021], and a strong connection between rivers and aquifers [Ó Dochartaigh et al., 2019] and between lakes and aquifers [Hood et al., 2006]. This knowledge gap penalizes studies on glacier melting impacts. Groundwater flows are indeed not simulated in glacier systems modelling studies, which leads to inaccurate results - only the subglacial flow, strictly flowing between the ice and the ground, is considered [Kaser et al., 2010]. Studying aquifer dynamics in glacierised catchments will enable to achieve a complete understanding of the water cycle in those areas, bringing new fundamental knowledge both in glaciology and hydrogeology fields. The general objective of the project is to understand the role of aquifers in the dynamics of water fluxes contributed to basal surface flow and to the ocean, and to study its future evolution following glacier melting under climate change.

Problems addressed

The problem addressed by this PhD project is to understand and quantify the role of peri-, sub- and pro-glacial aquifers in the spatio-temporal distribution of water fluxes contributed to the surface flux and exported to the oceanic domain; and the current and future impact of the upcoming big amounts of melting water on their hydrodynamic regime.

To tackle this problem, the case study site of South-East Vatnajökull, Iceland is chosen. These glaciers are well studied from a glaciological point of view [Aðalgeirsdóttir et al., 2011, Hannesdóttir, et al., 2015], enabling a lot of data and expertise sharing with glaciologists (team from UoI involved in this project). The approach adopted is to couple glacio-hydrological numerical modelling with hydrogeological one, based on extensive field data acquisition. The hydrodynamic behaviour of the sub-glacial aquifers is the hardest to model, as they are inaccessible to direct measurement, and the variations in time and space of water inputs is dictated by the highly variable and complex sub-glacial hydrology dynamics (in relation to glacier melting variations), not the classical surface hydroclimatic dynamics. Therefore, the coupling method will enable to model the sub-glacial dynamics using the outputs of the glacio-hydrological model as inputs for the hydrogeological one. Sensitivity tests performed with the new model built will also guide new data acquisition and new field observations.

Methodology

The pilot site is composed of four temperate outlet glaciers of the Vatnajökull icecap. Field observations and analysis of hydro-climatology and glaciology data enabled to establish a conceptual model of the studied catchments: the system is multi-layered, with thin sedimentary aquifers (tills and sands) lying over a thick fractured basaltic aquifer. Based on a rigorous field data acquisition a regional hydrogeological numerical model is being built, using ModelMuse interface for Modflow.

Expected results and perspectives

The scientific perspective is: (i) To obtain an operational understanding of aquifer systems not or little known in the glacial domain, (ii) To predict their hydrodynamic response to climate change, (iii) to develop a new coupled glaciohydrological/hydrogeological modelling method, that could be next applied to other temperate glacierised catchments, e.g.: the Hindu Kush Himalayan region, the Alps, Andes, and Rocky Mountain.

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