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The roughness of englacial R-channels determined by a combined laboratory and numerical study

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In 1972, Röthlisberger presented a theoretical study describing water flow through pressurised en- and subglacial channels. The existence of these so-called R-channels has been confirmed through field observations. To our knowledge, however, no physical experiment has ever been conducted to actually measure the properties of such englacial channelised water flow in the laboratory. Here we present such a laboratory study, combined with a one-to-one numerical analysis.

First, we highlight the key features of our novel laboratory experiment, such as the 1.6m long R-channel and the realistically high Reynolds numbers (up to 70'000) at which we run the experiment. Then we present results of the channel geometry evolution and the hydraulic Darcy-Weisbach roughness f. Even though ice is a very smooth material, the measured roughness of our R-channels is very high (f in the range 0.02 to 0.15). Such high channel roughness has also been inferred in studies fitting R-channel models to field experiments. We find that the high roughness is due to the formation of scallops/ripple during channel evolution.

In parallel to the laboratory experiment, we conducted numerical simulations using a virtual setup corresponding one-to-one to the laboratory setup. This was achieved by producing an imprint of the R-channel at the end of the experiment, 3D-scanning this imprint and using this geometry to perform large eddy simulations solving the Navier-Stokes equation (OpenFOAM framework).The roughness calculated in the numerical experiments agrees well with the measurements and allow us to estimate and tighten the experimental errors.

In conclusion, R-channels are expected to have a very high hydraulic roughness with the exact f value depending on the amount of scalloping.