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# Numerical modelling of rapidly-rising glacier outburst floods

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Glacier outburst floods, or *jökulhlaups*, from subglacial geothermal areas, marginal lakes and subglacial volcanic eruptions are common in Iceland and they pose a substantial hazard to settled areas as well as to roads, communication lines and other infrastructure near glaciers. Jökulhlaups have attracted increasing attention in recent years in many glacier areas because of an increased frequency due to the formation of terminus and marginal lakes in connection with global warming and the associated glacier downwasting. Jökulhlaups can be categorized into two groups, slowly and rapidly rising, with marked differences in the flood hydrographs. Slowly-rising jökulhlaups are traditionally explained by the theory of Nye (1976) through a conduit-melt–discharge feedback mechanism. The initial subglacial propagation and the development of the flood hydrograph of rapidly-rising jökulhlaups is, on the other hand, not quantitatively understood. We present observations of glacier outburst floods from W-Vatnajökull in Iceland that may be interpreted in terms of a conceptual theory for such floods as a pressure wave in the basal hydraulic system that propagates downglacier and creates the initial flood path by lifting the glacier from its sole. This theory is being implemented as a numerical model for rapidly-rising jökulhlaups in the Elmer/Ice Open-Source Finite-Element Software. The model describes the subglacial propagation of the jökulhlaup front using visco-elastic plate dynamics for the overlying glacier ice combined with a turbulent sheet model for the subglacial water flood. The evolution of the subglacial flooded area is simulated numerically through the solution of a contact problem that represents the lifting of the ice from the underlying glacier bed where the subglacial water pressure exceeds the normal stress in the ice at the sole of the glacier. We hence can identify 4 crucial components of the model: 1) A visco-elastic ice-deformation model, 2) a two-dimensional pressurized water-sheet model based on Manning's law for turbulent friction in water flow, 3) the solution of a contact problem induced by hydraulic jacking of the glacier, and 4) the consistent (in terms of the spatial stress distribution) solution of the fluid–structure interaction between the ice and the water-sheet. We present and discuss these different aspects in terms of their numerical implementation in Elmer/Ice. The aim of the model is to explain the speed of propagation of the subglacial flood front at the beginning of the flood as well as the time-dependent flood hydrograph after the flood bursts out from under the glacier at the ice margin.