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Numerical simulation of glacial-valley cross-section evolution

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Introduction

The U-shaped valley is one of the most well-known products of alpine glaciation, yet relatively little is known about how ice flow and glacial erosion interact in the development of this characteristic form. The present study focuses on the investigation of the influence of the lateral shear stress component on the formation of a U-shaped valley. Moreover, in the attempt to compare the model results with data from measured valleys, the model was run in order to constrain the value of the sliding coefficient in the sliding law.

Research methodology

A numerical flow model of a glacier in a transverse section has been developed and coupled with an erosion model. The core of the cross-section development model is the calculation of the flow pattern of a glacier in an initial preglacial V-shaped valley with a numerical flow model. The basal speed u_b is calculated with a power law of the shear stress acting on the bed τ_b, and the glacial erosion is considered to be a linear function of u_b^2. The developed two-dimensional model was compared with a simple shear model, and the different results were used to highlight the glacier stress conditions favorable to the formation of U-shaped valleys.

Results

The comparison between the two-dimensional model and the simple model shows the importance of the lateral drag from the side walls for the modeling of glacial erosion in a valley-cross section. While the simple model, which does not compute the lateral drag, fails to produce a glacial valley, the two-dimensional model simulates the proper pattern (central minimum in the basal sliding velocity at the valley center due to the increase of the drag) for the development of the U-shaped form. Comparison with field data shows that computed profiles with shape coefficients (*b*) similar to those obtained in measured valleys can be obtained with glacier sliding velocities greater than 3-4 m a^{-1} within 50 ka years. However, the model indicates significantly higher values for the form ratio (*FR*) than the measured valleys, and consequently the profile computed by the model can only develop by deepening without widening as opposed to the widening without deepening trend observed in the measured valleys.