Geophysical Research Abstracts, Vol. 9, 09542, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-09542

Ice flow velocity fields in the Gregoriev ice cap (Tien-Shan,Central Asia): Comparison the results of the 3D ice flow and the 2D ice stream modeling

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The Gregoriev ice cap is one of flat-top glaciers located on the south slop of Terskey Ala Tau at elevations from about 4100 m up to 4650 m (the summit). Its length from the summit along the flowline is about 3.7 km and the width in transverse direction is about 3 km. The average ice thickness is about 100 m and ice temperature decreases from -1^0C at 4100 m to -3^0C at 4600 m.

Ice flow velocity fields were obtained by the 3D ice flow model (HHVF model) and the 2D ice stream model (HHF model). The models are so-called higher-order ice sheet models and include diagnostic equations: mass conservation and stress equilibrium equations. The mechanical equilibrium equations in the 3D ice flow model are rewritten in terms of stress deviator components and represent the integro-differential system in terms of ice flow velocity components. The diagnostic system in the 2D ice stream model have been obtained by depth integration of the mechanical equilibrium equations taking into account additional assumptions about horizontal velocity depth independence and zero vertical velocity in a shallow ice layer.

The finite-difference method was applied for the diagnostic system solution in both 3D and 2D models. It's established what for high ice surface slopes and/or high bedrock surface oscillations the solution instability appears in the 2D flowline (HVF model) and 3D ice flow finite-difference models (ISMIP-HOM experiments). The stability can be achieved by extending of the diagnostic equations to the boundary points taking into account the boundary conditions. Numerical simulations have shown that such approach also leads to the solution stability in the 2D ice stream finite-difference model.

So, such approach expands the area of the finite-difference method applications.

The deviation between depth averaged horizontal flowline velocities in the 2D flowline model and 3D ice flow model increases with ice surface slopes growing in transverse direction. It's about 50% in the area of high ice surface slops close to the Gregoriev ice cap summit. The ice flow velocity achieves the maximum value (about 8 m/a) at the lateral slope of the Gregoriev ice cap.

The average deviation between depth averaged horizontal velocity in the 3D ice flow model and the ice stream velocity is about 20%.