Geophysical Research Abstracts
Vol. 14, EGU2012-2111, 2012
EGU General Assembly 2012

A physically-based model for the energy and mass fluxes across the ice/debris/snow/atmosphere continuum, with potential for year-round simulations of the mass balance of debris-covered glaciers

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Debris-covered glaciers respond differently than white glaciers to atmospheric forcing, due to the presence of debris at the surface during the ablation season and at the snow/ice interface during the accumulation season. At the surface, they induce conflicting effects on the underlying ice through a reduced albedo, dominant for thin debris covers, and increased thermal shielding, dominant for thicker debris covers. Understanding the response of debris-covers glaciers to a variety of meteorological conditions in a physically sound manner is essential to quantify meltwater discharge and to predict their response to climate change. To tackle this issue, we developed the Crocus-DEB model as an adaptation of the Crocus snowpack model, to simulate the energy and mass balance of debris-covered glaciers, including periods where debris are covered by snow. Crocus-DEB was evaluated with data gathered during a field experiment at Col de Porte, France with very good results in terms of conductive heat flux both at the surface and at the debris/ice interface, with and without snow at the surface. The model was also driven by meteorological data from the Changri Nup glacier in Nepal, Himalaya. The relationships between the model parameters, meteorological conditions, and the critical debris thickness are explored and discussed.