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Extension of the Representative Elementary Watershed approach for cold regions: constitutive relationships and an application

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Abstract. The Representative Elementary Watershed (REW) approach proposed by Reggiani et al. (1998, 1999) represents an attempt to develop a scale adaptable modeling framework for the hydrological research community. Tian et al. (2006) extended the original REW theory for cold regions through explicit treatment of energy balance equations to incorporate associated cold regions processes, such as snow and glacier melting/accumulation, and soil freezing/thawing. However, constitutive relationships for the cold regions processes needed to complete these new balance equations have been left unspecified in this derivation. In this paper we propose a set of closure schemes for cold regions processes within the extended framework. An energy balance method is proposed to close the balance equations of melting/accumulation processes as well as the widely-used and conceptual degree-day method, whereas the closure schemes for soil freezing and thawing are based on the maximum unfrozen-water content model. The proposed closure schemes are coupled to the previously derived balance equations and implemented within the Thermodynamic Watershed Hydrological Model (THModel, Tian, 2006) and then applied to the headwaters of the Urumqi River in Western China. The results of the 5-year calibration and 3-year validation analyses show that THModel can indeed simulate runoff processes in this glacier and snow-dominated catchment reasonably well, which shows the prospects of the REW approach and the developed closure schemes for cold regions processes.

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