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Spatial downscaling and correction of precipitation and temperature time series to high resolution hydrological response units in the Canadian Rocky Mountains

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Precipitation is the central driving force of most hydrological processes, and is also the most variable element of the hydrological cycle. As the precipitation to runoff ratio is non-linear, errors in precipitation estimations are amplified in streamflow simulations. Therefore, the accurate estimate of areal precipitation is essential for watershed models and relevant impacts studies. A procedure is presented to demonstrate the spatial distribution of daily precipitation and temperature estimates across the Rocky Mountains within the framework of the ACRU agro-hydrological modelling system (ACRU). ACRU (Schulze, 1995) is a physical-conceptual, semi-distributed hydrological modelling system designed to be responsive to changes in land use and climate. The model has been updated to include specific high-mountain and cold climate routines and is applied to simulate impacts of land cover and climate change on the hydrological behaviour of numerous Rocky Mountain watersheds in Alberta, Canada. Both air temperature and precipitation time series need to be downscaled to hydrological response units (HRUs), as they are the spatial modelling units for the model. The estimation of accurate daily air temperatures is critical for the separation of rain and snow.

The precipitation estimation procedure integrates a spatially distributed daily precipitation database for the period 1950 to 2010 at a scale of 10 by 10 km with a 1971-2000 climate normal database available at 2 by 2 km (PRISM). Resulting daily precipitation time series are further downscaled to the spatial resolution of hydrological response units, defined by 100 m elevation bands, land cover, and solar radiation, which have an average size of about 15 km2. As snow measurements are known to have a potential under-catch of up to 40%, further adjustment of snowfall may need to be increased using a procedure by Richter (1995). Finally, precipitation input to HRUs with slopes steeper than 10% need to be further corrected, because the true, sloped area, has a larger area than the planimetric area derived from a GIS. The omission of correcting for sloped areas would result in incorrect calculations of interception volumes, soil moisture storages, groundwater recharge rates, actual evapotranspiration volumes, and runoff coefficients.

Daily minimum and maximum air temperatures are estimated for each HRU by downscaling the 10km time series to the HRUs by (a) applying monthly mean lapse rates, estimated either from surrounding climate stations or from the PRISM climate normal dataset in combination with a digital elevation model, (b) adjusting further for aspect of the HRU based on monthly mean incoming solar radiation, and (c) adjusting for canopy cover using the monthly mean leaf area indices.

Precipitation estimates can be verified using independent snow water equivalent measurements derived from snow pillow or snow course observations, while temperature estimates are verified against either independent temperature measurements from climate stations, or from fire observation towers.