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Using a Regional Climate Model for the Simulation of Hydrologic Processes in the High Himalayan Wangchu Watershed

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Since the late 70ies of the previous century, computer aided modelling of physical processes has developed to a substantial scientific tool that is widely applied in the most diverse scientific branches. For the scientific fields of hydrology and climatology, the mapping of the multiple exchange fluxes of mass and energy between landsurface and atmosphere is of special interest, since the mass and energy balance at the landsurface is defining the lower border conditions of the atmospheric climate models on one hand, while it is determining the upper boundary of the landsurface models on the other. If well developed and thoroughly tested, both, regional climate models and landsurface models can be reliable instruments to assist with the investigation of multiple environmental variables. This study focuses on an application of the hydrological landsurface model PROMET (Process of Radiation Mass and Energy Transfer Model), which is being developed at the Ludwig-Maximilians Universität (LMU) in Munich at the Chair of Geography and Remote Sensing. PROMET is successfully applied in central Europe to the Upper Danube watershed as part of the BMB+F funded cooperative project GLOWA-Danube. Supporting the idea of twinning the Upper Danube with the Brahmaputra, which is a basic issue of the EU funded cooperative project 'Brahmatwinn - Twinning European and South Asian River Basins to enhance capacity and implement adaptive management approaches', PROMET was applied to the quantitative analysis of the landsurface water balance of the Wangchu watershed located in Bhutan, Asia without adjusting the model parameterisation. The Wangchu represents a small sized subcatchment of the Brahmaputra river system. The catchment covers a large part of the West of the Kingdom of Bhutan. It comprises high mountain regions of the Himalaya in the North, characterized by cold temperatures and low precipitation rates, temperate forested hills and evergreen deciduous forests featuring a humid monsoon climate in the more southern regions.

Hydrological investigations in the Himalaya are predominantly limited by the low density of the meteorological measuring network. Nonetheless, the high mountain regions are considered to be sensitive indicators for the assessment of climate change effects and therefore the interest in studying the possible changes in those environments is high.

In cooperation with the Institute for Atmospheric and Environmental Sciences (IAU) of the Goethe Universität Frankfurt (GUF), the Climate Local Model (CLM) was applied to provide meteorological input data for the landsurface model PROMET. To sensibly bridge the gap between the geometric resolutions of both models (CLM = 50 x 50 km, PROMET = 1 x 1 km), mass and energy conservative downscaling techniques were applied. Based on the meteorological data provided by the regional climate model, the major components of the landsurface water balance were calculated and analyzed for a 30 year time series from 1971 to the year 2000.

Due to the scarcely available station data, the validation of the results proved difficult. The relatively small size of the catchment, compared to the spatial resolution of the regional climate model, of about 4.6 x 10^3 km^2, led to high deviations of modelled and measured precipitation rates, which also affected the accuracy of the absolute discharge rates that were modelled for five different gauges of the Wangchu subcatchment. Nonetheless, the average seasonal dynamic of the discharge rates was well reproduced by the model compared to the measured data. Apart from the scaling issues, also problems of parameterisation contributed to the deviations. The applied model system was lacking detailed information on the distribution of different soil types within the catchment and had to resort to the relatively coarse global soil map provided by the FAO. The landcover map, being derived from remote sensing information provided by Brahmatwinn project partners, can be considered to be adequately detailed and accurate, while the parameters that are characterizing the hydrological properties of the different landcover categories were not adapted to the environment of the Southern Himalaya for this first approach.

The results of this study indicate that an application of regional climate models for hydrological applications in high mountain watersheds is promising. The seasonal dynamics of the landsurface water balance can be simulated using modelled meteorological data with a satisfying accuracy. The derivation of absolute values again is accompanied by greater insecurities. Nonetheless, climate change effects that manifest in a shift of seasonal patterns could well be mapped by a combined model system that is using regional climate model data. The further development and refinement of all model systems that can be combined to investigate the effect of climate change in mountainous regions can therefore be considered to be a sensible and promising task for the future.