Part III: Hydrological changes

"Climate change" is often a synonym for "climate warming." However, according to *Schär & Frei*, the intrinsic link between the energy and hydrological cycle of the climate system justifies the equation with "climate moistening." In terms of energy, the moistening is more relevant than the warming. The authors assume that orographic precipitation could increase in mid and high latitudes at a similar rate as the atmospheric moisture content. The frequency and intensity of extreme events could even be more important as they may even increase independent of a decrease in mean precipitation amounts, which is especially well known in arid and semi-arid regions.

Diaz discusses the network of mountain observatories in the western US that are documenting the temperature increase since the last century. In stark contrast, information on the temperature change above 2000 m is scarce, as the present observatories cover only less than 10% of the territory. However, changes in the alpine cryosphere do not only signal large scale climate change, but - being directly coupled with the run-off regime - also represent important decision-making tools for managers and policy makers. The author proposes an adequate monitoring of critical and environmental variables in the mountains of the western US as a part of a global change mountain network.

Investigation of the spatial variability of snow cover and evaporation in relation to temperature, precipitation and rate of drainage in altitudes between 1500 and 2000 m in the Swiss Alps is the topic of *Menzel & Lang* showing astonishing differences between Eastern and Western, Northern and Southern Alps. Based on IPCC scenarios, a drastic reduction of the snow cover could be possible in the next 50 to 100 years with all its consequences for the hydrological regime.

Runoff sub-components under different environmental conditions, discussed by *Becker,* show the difficulties and uncertainties in the understanding of hydrological processes in heterogeneous mountain areas. The different response time between the runoff generating event and the corresponding increase in surface flow, interflow and baseflow may show that our knowledge about these complex processes in mountain catchments is still very limited. For two investigated hillslope/spring systems in the

Southern Black Forest Mountains, Germany, *Uhlenbrook et al.* demonstrate that the processes and hydrological responses in mountainous landscapes can be very diverse, even on relatively similar systems. The spatial heterogeneity appears to be related to highly variable soil structure overlain by land use and vegetation patterns, which will have a significant influence on the future recharge of springs and the discharge and composition of runoff components and their hydrochemical composition. Consequently, multi-disciplinary approaches are required to decode the complex hillslope system with its non-linear processes and numerous feedback mechanisms. In the same sense, *Kirnbauer et al.* identify space-time patterns of runoff generation in the Austrian Alps in a small, well equipped catchment. If typical and well defined runoff events, identified in a small to very small experimental catchment, are also applicable to medium-size catchments, remain an open question: Different threshold conditions in a complex system may create different runoff conditions.

Analyzing their results from the Spanish Pyrenees, including paleodata about climate variability and land use and land cover changes with a special focus on deforestation, *Garcia-Ruiz et al.* consider three scales: Small experimental plots to understand the impact of different land use types on runoff and erosion; small experimental catchments to get the information about discharge and sediment transport; the basin or large scale study including the growth of the Ebro delta since the Roman time. This integrative and comparative analysis of different scales can lead to a more precise interpretation of changes and to a better differentiation of natural and human driving forces.

McGlynn's article investigates the role of the riparian zones in steep mountain watersheds in very different catchments from New Zealand to the US. Riparian zones are narrow in the headwaters and can increase in lower areas to a valley bottom and even to a flood plain. The author discusses different scales and the problem of modeling complex mountain watersheds, as it is done also in the contribution of *Gurtz et al.* about the use of hydrological models for the simulation of climate change impacts on mountain hydrology in different catchments of the Swiss Alps. Interesting is the statement, that the interflow is more or less the most important runoff component in mountain regions, when the necessary storage capacity with adequate soil and slope conditions are existing.

Effects of climate variability and change on mountain water resources in the western US, discussed by *Leung,* threaten the urbanised and industrialised region with its export oriented and irrigated agriculture. The variations of ENSO play an important role for the precipitation regime and for the precipitation anomalies in the different mountain areas. Warmer temperatures effects are expressed mainly in the reduction of snowpack along the coastal mountains. In contrast, in the Rocky Mountains, snowpack change is governed by temperature and precipitation changes, so that the reduction in this continental climate is limited. High-resolution modelling will be important in future research programs, but higher spatial resolution improves the simulation of temperature and snow, but does not necessarily improve the simulation of precipitation.