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2.1 Modelling Global Climate Change

Present global climate modelling state-of-the-art and results have been published by the 4th Assessment Reports of the IPCC (IPCC 2007a, b, c). They compile the results from 21 different atmosphere–ocean global circulation models (AOGCM) for the IPCC scenario A1B (IPCC 2000), evaluated as multimodel datasets (MMD-A1B) in the Program for Climate Model Diagnosis and Intercomparison (PCMDI). According to the 4th IPCC report the temperature projections based on the MMD-A1B models indicate a significant warming over the 21st century. Temperature rise greater than the global mean is projected for South Asia (3.3 °C) and East Asia (3.3 °C), and is significantly higher than the global mean in the continental interior of Asia, for example, 3.7 °C in central Asia, 3.8 °C in Tibet, and 4.3 °C in northern Asia.

2.2 Hydrological Impacts of Climate Change

Glacier retreat and permafrost thaw in high mountains, for example, the Alps, Himalaya, and the Quinghai-Tibetan Plateau, have presently

reached an extent and speed that is without historical precedence (Frauenfelder et al. 2009; Karma et al. 2003; Lang et al. 2011; Paul et al. 2004; Ren et al. 2004; Subba 2001). This is likely to have substantial impacts on the hydrological dynamics, resulting in a greater variability in precipitation and stream flows, and increasing the intensity of extreme events comprising water quantity and quality. Declining dry season discharge in rivers of such kind is expected to have major impacts on their ecological ecosystem services (ESS) and unforeseen socioeconomic consequences for rural and urban development (Kääb et al. 2005; Morrison and Gleick 2004). Changing discharge regimes of rivers fed by melting glaciers, snowfields, and permafrost, impact the design and implementation of sustainable integrated land and water resources management (ILWRM) both in the urban and rural domain and is likely to change vulnerabilities of sensitive management systems with respect to floods and erosion (Hutton et al. 2011; Nepal 2012; Nepal et al. 2013; Prasch et al. 2011).

Considering the geographic distribution of glaciers in alpine mountains, the global dimension of this phenomenon becomes obvious (IUCN 2003; Querner 2002), and today diminishing glacier resources have become an international affair as rivers such as the upper Danube and upper Brahmaputra provide the downstream countries with essential water resources to sustain food production, socioeconomic development, and the environment.

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2.3 Applied Geoinformatics in Hydrological Modelling and Integrated Land and Water Resources Management (ILWRM)

Geoinformatics is applied in various ways in hydrological water balance modelling ranging from integrating remote sensing and geographic information system (GIS) (Flügel 2011a; Flügel et al. 2000; Helmschrot and Flügel 2002) to sophisticated data management and software developments for process based, distributed river basin models (Fink et al. 2007; Kralisch et al. 2003, 2005a, 2007, 2009; Krause 2002; Mauser and Bach 2009). The latter either apply raster cells as distributed model entities (Mauser and Ludwig 2002) or hydrological response units (HRU) delineated by means of GIS analysis (Flügel 1995, 1996; Krause et al. 2006) and based on a thorough hydrological system analysis (Flügel 2000). Both techniques use topological models derived from GIS modelling (Pfennig et al. 2009) and respective landscape analysis (Wolf et al. 2009). Object oriented modelling has improved increasingly in recent years to develop process modules (Krause 2002; Krause and Flügel 2005) for model design in model framework systems (MFS). Examples are the Jena Adaptable Modelling System (JAMS) (Kralisch et al. 2005b, 2007; Kralisch and Krause 2007) and the Object Modelling System (OMS) developed by the United States Geological Survey (USGS) (David et al. 2013). The benefit of distributed hydrological river basin models for climate change impact analysis has been demonstrated by various modelling studies (Fink et al. 2007; Helmschrot 2006a, b; Krause and Hanisch 2009; Mauser and Bach 2009).

Applied Geoinformatics for ILWRM concerns the spatial assessment and analysis of landscape systems integrating their natural environment (NE) and its human dimension (HD) and applies innovative software and hardware technologies to provide the detailed information required to adapt toward sustainable ILWRM (Flügel 2009, 2011a; Kralisch et al. 2012). The potential of applied geoinformatics in ILWRM can be described with respect to the BRAHMATWINN project as follows:

1. Model results obtained from the different AOGCM deliver information for model grids cells that are by far too large for applied integrated water resources management (IWRM) and landscape management. They have to be downscaled by means of models and methods developed by means of geoinformatics (Dobler et al. 2011).
2. Changing land use and land cover (LULC), that is, by deforestation or retreating glaciers happens on a meso-scale level in remote areas with no or limited access. Remote sensing combined with GIS are geoinformatics technologies that provide the means for a multi-scale comprehensive LULC classification and process oriented analysis. This in turn will allow the delineation of process based landscape model entities for water and solute transport modelling (Lang et al. 2011).
3. Efficient and sustainable IWRM depends on hydrological measurements of high quality from a sufficient dense hydrometric infrastructure. In alpine mountain massifs and particularly in the Himalaya, there is a considerable lack of both of these IWRM prerequisites. Geoinformatics provides the means, that is, geostatistic and process based modelling tools to regionalize the required input data (Prasch et al. 2011).
4. Adapting IWRM to changing environment conditions, that is, to ongoing climate change requires appropriate model tools that are able to represent the hydrological processes which control the river basin water balance and its water and solute transport dynamics. These models apply model entities derived by geoinformatics, that is, from the response units (RU) landscape model (Flügel 1995, 1996; Flügel and Märker 2003) and attribute the latter by means of remote sensing and GIS analysis.
5. Applied in “what-if?” scenario analysis these modelling tools permit predictions of changing water balances, discharge regimes and water resources regeneration, and support IWRM decision making by means of an IWRMS (Flügel and Busch 2011).

As sustainable ILWRM applies a holistic systems approach (Flügel 2000) that accounts for scale related system process dynamics, integrated geoinformatics toolsets are required that offer methods and technologies for multiscale system assessment, modelling, and analysis. The integrated land management system (ILMS) applied in the BRAHMATWINN project provided appropriate software components to carry out such integrated river basin analysis (Kralisch et al. 2012; Zander et al. 2012).

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