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Development of an integrated hydrological modeling framework in mountainous areas including rainfall and snowfall quantification derived from data Integration

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Summary

United Nations Water concluded that water is the core of sustainable development and its three dimensions (society, economy, and the environment). In most Asian countries, mountains bring fresh water to millions. Over mountainous regions, the precipitation mainly falls as snowfall in winter, causing a natural delay in river discharges by preserving winter precipitation to sustain streamflows during the summer. Hence, accurate estimation and prediction of discharge during all seasons are imperative to support optimal water resource planning and management. For sustainable development, there is increased focus on integrated water resource policies, which are unachievable without precise quantification of the available water resources.

One of the key gaps in knowledge regarding mountain regions is the interplay of precipitation and temperature with changing altitudes. An effort is made to propose a conceptual framework to bridge this gap and overcome the lack of observational data and large uncertainties due to the interplay of temperature and precipitation. This study integrates the merits of observational data with distributed atmospheric reanalysis and/or atmospheric model data to maximize their utilization in establishing a simplified,

operational, and integrated approach. Due to significant biases, data from atmospheric reanalysis and/or atmospheric models are not frequently used to simulate the hydrological response specifically in a basin scale. However, through the integration of dynamical equations and model physics, these models have robust potential in developing 3-D distribution/profiles. Following the proposed framework, 2-D spatial distributions of precipitation and 3-D spatial distributions of temperature in the form of vertical profile of temperature (VPT) are achieved through integration of in-situ data with radar\reanalysis or atmospheric model products. The water and energy budget-based distributed hydrological model with snow (WEB-DHM-S) is used to simulate the discharge and spatial distribution of snow cover using temperature reproduced from VPT and corrected precipitation with the logical calibration approach.

This framework was applied to the Oi River Basin of Japan due to policy implications regarding the maximization of hydropower generation and minimization of flood damages to downstream properties by improving dam operations. Precise estimation and prediction of discharge information are crucial for practitioners engaged in policy, planning, and operational roles for catchment management. The calibration and validation outcomes based on quantitative and spatial evaluation by pixel-by-pixel analysis were promising. The application of this study has robust potential toward developing countries like Pakistan suffering from frequent water-related disasters such as floods and droughts. It is because of the fact that recent current practices for water resource management are apparently becoming incompatible with growing demands of the agriculture, energy, and industrial sectors and in coping with water-related disasters under climate change. The glacier and snowmelt water from the northern mountain ranges of Pakistan are a prime source for sustaining river flows. It is therefore essential to incorporate accurate rainfall and snowfall quantification and distribution by integrating data optimize the available water resources. Through application of such integrated data analysis, a system can efficiently help policy and decision makers to effectively overcome the major water-related issues in the fields of irrigation and hydropower, and other industries associated with water.