HIMALA: Climate Impacts on Glaciers, Snow, and Hydrology in the Himalayan Region

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ICIMOD

Glaciers are the largest reservoir of freshwater on Earth, supporting one third of the world's population. The Himalaya possess one of the largest resources of snow and ice, which act as a freshwater reservoir for more than 1.3 billion people. This article describes a new project called HIMALA, which focuses on utilizing satellite-based products for better understanding of hydrological processes of the river basins of the region. With support from the US Agency for International Development (USAID), the International Centre for Integrated Mountain Development (ICIMOD), together with its partners and member countries, has been working on the application of satellite-based rainfall estimates for flood prediction. The US National Aeronautics and Space Administration (NASA) partners are working with ICIMOD to incorporate snowmelt and glacier melt into a widely used hydrological model. Thus, through improved modeling of the contribution of snow and ice meltwater to river flow in the region, the HIMALA project will improve the ability of ICIMOD and its partners to understand the impact of weather and climate on floods, droughts, and other water- and climate-induced natural hazards in the Himalayan region in Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan.

The need for monitoring glaciers

Glaciers are the largest reservoir of freshwater on Earth, supporting one third of the world's population. The Himalaya possess one of the largest resources of snow and ice, which act as a freshwater reservoir for more than 1.3 billion people. Monitoring of glaciers is important to assess the overall health of this reservoir (Kulkarni et al 2007; Immerzeel et al 2010). Glaciers and snowfields also form potential hazards in the Himalaya, and in similarly glacierized regions of the world. Water resources will be affected by climate change as well as population growth, changing economic activity, land-use change, rapid urbanization, and inefficient water use. National governments have limited capacity to determine and accurately predict possible impacts to water resources due to scarcity of hydrometeorological data, limited technical capacity, and the transboundary nature of many major river systems. These factors have also led to recent controversies surrounding the fate of Himalayan glacier melt (Schiermeier 2010), which highlight the need for further glaciological and hydrological research in this region.

Collaboration among NASA, USAID, and ICIMOD

HIMALA is a project funded by the US National Aeronautics and Space Administration (NASA) Applied Sciences Program and the US Agency for International Development (USAID) in collaboration with the International Centre for Integrated Mountain Development (ICIMOD). NASA's Applied Sciences Program promotes and funds activities that enable innovative uses of NASA Earth science data products in organizations' policy, business, and management decisions. This includes applying NASA research results to support improvements in disaster management, drinking water quality and availability, climate adaptation and mitigation strategies, ecological forecasting, and food security issues.

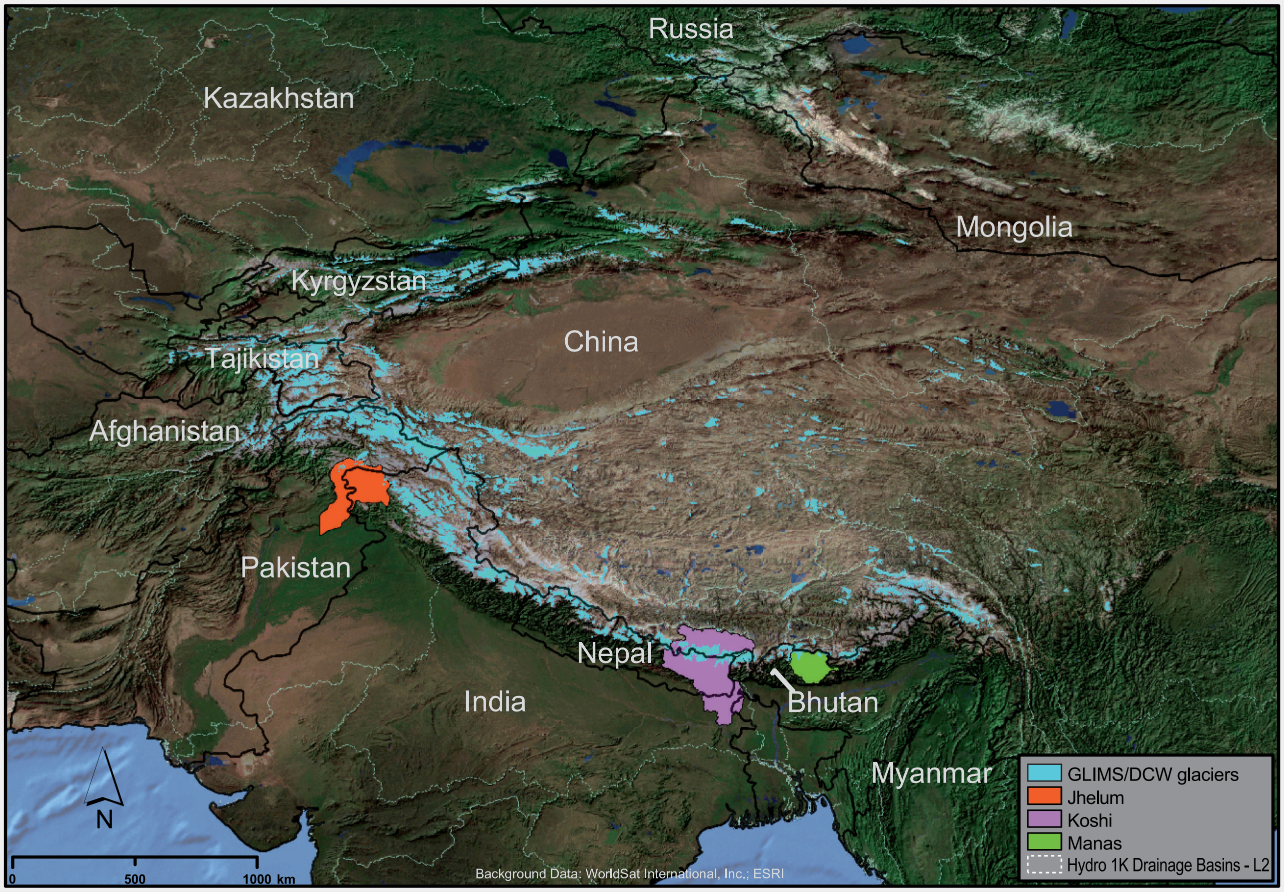
The HIMALA project focuses on utilizing satellite-based products to improve our knowledge of hydrological processes of local river basins. With USAID support, ICIMOD and its partners have been working on the application of satellite-based rainfall estimates for flood prediction. Through this work, the need to incorporate the snow and glacier component into the model has been discovered. HIMALA aims to address this gap by developing a system that will improve our understanding of the impact of weather and climate on floods, droughts, and other water- and climate-induced natural hazards in the Himalayan region, an area that is home to over 200 million inhabitants in Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan (Figure 1).

Our multi-organizational, multidisciplinary team leverages the extensive resources and expertise of NASA, the US Geological Survey (USGS), USAID, and ICIMOD. Among our main goals, we aim to:

1. introduce the use of NASA Earth Science products and models to ICIMOD and its member countries through collaboration with USAID and USGS;
2. enhance the decision-making capacity of ICIMOD and its member countries for management of water resources (floods, agricultural water) in the short- (snow, rainfall) and the long-term (glaciers); and
3. provide projections of climate change impacts on water resources through 2100 using the IPCC (Intergovernmental Panel on Climate Change) models.

To accomplish these goals, we focus on creating an end-to-end sub-

FIGURE 1 Region where the HIMALA research project will operate. Three specific river basins were selected for implementing the model first: Koshi, Manas, and Jehlum. These sub-basins are part of transboundary rivers that flow through more than 1 country. (Map by Joseph Nigro)



basin prototype hydrological model that includes both snow and glacier meltwater contributions to local river networks (Figure 2). We are developing new user interfaces so that models will be easy to learn and can be used to monitor streamflow in other basins in the region. Model implementation in any Himalayan region basin by ICIMOD, its member countries, and other scientists will be focused on improving our understanding of the contribution of snow and ice to hydrology in the region. NASA and USAID will provide training and data inputs for the member country experts as needed. In partnership with ICIMOD, the sub-basin prototype hydrological model will be replicated for several key basins before the end of the project.

Hydrological modeling for HIMALA

Snow and glacier meltwater and outflow in the study region will be estimated using a spatially distributed version of the Utah Energy Balance (UEB) snow accumulation and ablation model (Tarboton 1994; Tarboton et al 1995). The Utah Energy Balance (UEB) model will be run over nonglaciated surfaces and will produce daily snow–water equivalent (SWE) maps for the Himalayan region, which will be used to estimate total snow–water per sub-basin for early warning of floods. Similar SWE maps for the Afghanistan region by the USGS for the US Famine Early Warning Systems Network (earlywarning.usgs.gov) have been providing critical insights into impending drought conditions—and possible crop failure—in the region, or potential flooding hazards due to snowmelt.

The UEB model will also be run using the same dynamic parameters over glaciated surfaces. Glacier outlines and glacier characterization parameters will determine the relative contribution by snow over the glacier and glacier melt to streamflow. The output will focus on long-term changes in ice mass over both the accumulation and deposition zones. By running the UEB over both glaciated and nonglaciated surfaces, we will be able to understand the impact of increasing temperatures and changing snow/rain proportions on streamflow.

Gridded flow from the cryosphere from the UEB model will be incorporated into the USGS

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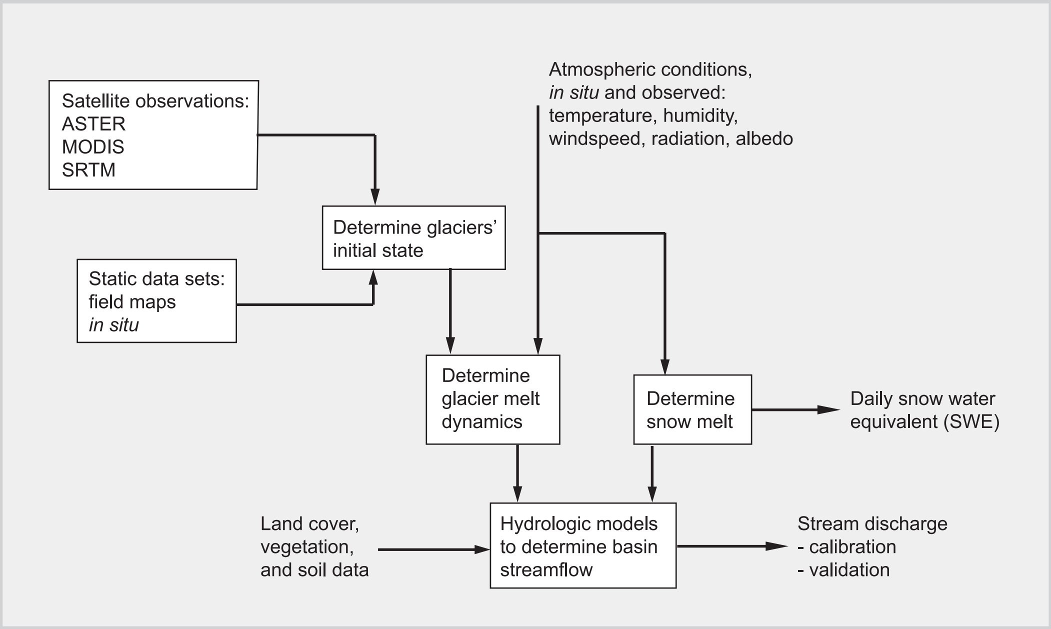
FIGURE 2 Generalized process diagram for the HIMALA project.



Geospatial Stream Flow Model (GeoSFM) (Artan et al 2007; Asante et al 2007), and it can be used with any streamflow model. ICIMOD has several years of experience with the GeoSFM, demonstrating the utility of hydrological models in the region (Shrestha et al 2008). Digital elevation model topography, land cover, and soil information are used to derive and parameterize the sub-basins. The hydrological model is then forced by daily estimates of precipitation and evapotranspiration to predict daily discharge at any point in the catchment and is then validated using hydrological station information.

Validating the usability of the model will focus on clear linkage between the model and required data sets, inputs, and simple user interfaces for calibration, and the simplicity of using the model in different sub-basins. The model will be tested in the pilot basins and will later be scaled up to other basins in the Himalayan region.

Climate data from the IPCC AR4 model scenarios will be incorporated into the analysis to estimate the time at which the majority of glaciers in the region may melt and snow is no longer a significant contributor to river flow. The HIMALA project will determine the rate of change and estimate the overall increase or decrease of water resources through time. Scenarios will be developed that estimate the impact of both increases and decreases in precipitation according to the current state of glaciers and observed temperature trends. These will enable long-term estimates of the impact of precipitation dynamics on long-term river flow in the region.

Conclusion

The HIMALA project focuses on providing research and investigative tools that will foster an improved understanding of climate change on hydrological resources in the Hindu Kush–Himalaya region. As was stated in a recent panel on the changing climate in the region, there is a crucial role for regional organizations like ICIMOD in raising awareness, promoting research, and filling in data and knowledge gaps (Manandhar and Rasul 2010). This project will enhance international and regional collaboration and provide ICIMOD and its member countries with the modeling tools and methods needed to assess the quantitative impact of a changing climate on disasters, water resources, ecology, and food security.

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