ICIMOD

FOR MOUNTAINS AND PEOPLE

HIMALA: Climate Impacts on Snow, Glaciers, and Hydrology in the Hindu Kush Himalayas

The Hindu Kush Himalayan (HKH) region, sometimes called the 'Third Pole', is one of the largest sources of snow and ice outside the polar regions. Over 1.3 billion people living in the region and the downstream plains depend on the melt waters from the HKH mountains to meet their needs for drinking, irrigation, hydropower, navigation, and other uses. Snow and glacial melts contribute to the flow downstream and are of particular importance in the low-flow season.

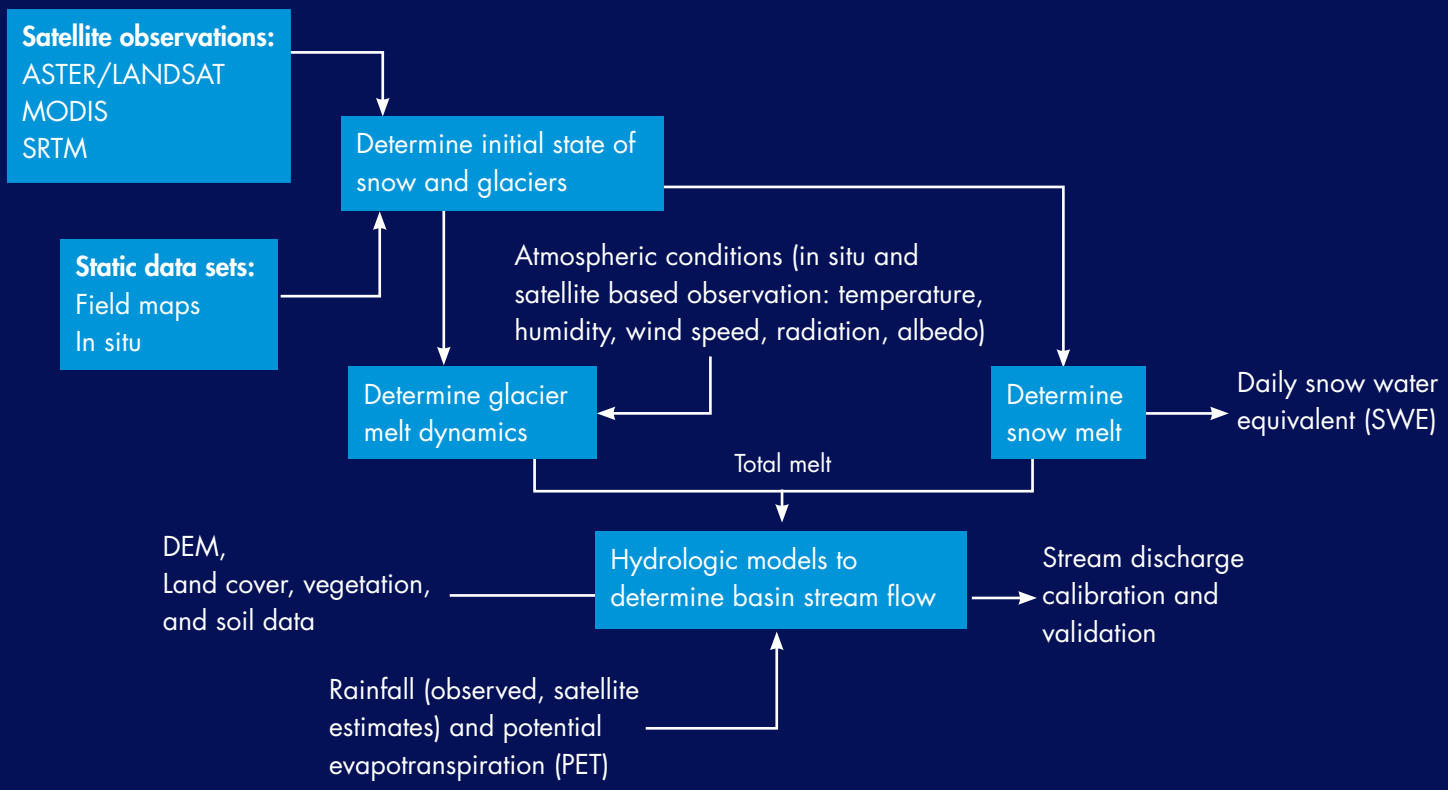
Climate change, population growth, infrastructure development, land use change, rapid urbanization, and inefficient water use are all having an impact on water resources in the HKH. Of all the drivers affecting the hydrological regime in the region, climate change is of particular concern, as the warming trend in the region is significantly higher than the global average. The most visible impact of climate change in the region is the rapid retreat of glaciers, which affects water availability in the major river basins of the HKH with serious implications for the lives and livelihoods of millions of people. To improve understanding of the contribution of snow and glacier melt to total runoff in river basins, the HIMALA project is developing a modelling tool, HIMALA-BASINS, which integrates snow and ice melt with streamflow. This new tool will enable proper water resource management and the development of appropriate strategies for adaptation to climate change.

From 2006 to 2010, the project 'Application of Satellite Rainfall Estimates in the HKH Region' built the capacity of ICIMOD's regional partners to test and apply advanced technology for rainfall estimation and tested the use of a United States Geological Survey (USGS) hydrological model, the Geospatial Streamflow Model (GeoSFM), for timely flood prediction in pilot basins. The regional partners deemed it important to incorporate snow and ice into the hydrological model, as many of the basins in the HKH are snow and glacier fed. Accordingly, ICIMOD, in collaboration with its technical partners – the United States National Aeronautics and Space Administration (NASA) and USGS – has embarked on the four-year (2010–2013) HIMALA project, 'Climate Impacts on Snow, Glaciers and Hydrology in the Himalayan Region'. The project is funded by the United States Agency for International Development Office for US Foreign Disaster Assistance (USAID/OFDA) and NASA.

HIMALA project

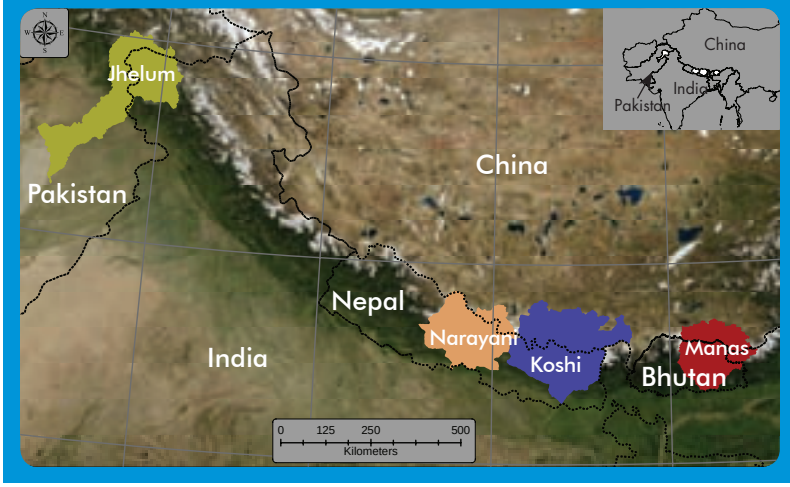
The HIMALA project is developing a prototype integrated hydrological model to assess water availability and improve understanding of the contribution of snow and glaciers to the flows of the rivers in the HKH (Figure 1).

Figure 1: **Modelling Framework of HIMALA project**



The project focuses on the use of satellite-based products to improve the knowledge of hydrological processes of river basins, with the objective of enhancing the decision making capacity of ICIMOD and its regional member countries for management of water resources in the short and long term. The hydrological model will also be used to explore the implications of the fourth Intergovernmental Panel for Climate Change (IPCC) Assessment Report scenarios for the water resources of the Himalayan region. The ultimate goal is to minimize the loss of lives and property via reduction in natural vulnerability in the Hindu Kush Himalayan region, in particular the Ganges, Brahmaputra, and Indus basins. The project includes testing of the model in the Langtang and Imja sub-basins and upscaling in the Jhelum, Koshi, Manas, and Narayani basins (Figure 2).

Figure 2: **HIMALA basins**



Glacier mapping and change detection

The first activity was glacier mapping and assessment, carried out using a semi-automatic methodology developed at ICIMOD based on recent LANDSAT satellite images and Shuttle Radar Topography Mission digital elevation models (SRTM DEMs). The glacier polygons derived from a Landsat7 ETM+ image from 2007 were used as a base map. To detect the changes in glacier area over four decades in three of the basins (Langtang and Imja in Nepal and Manas in Bhutan), the base map was overlaid with satellite images from 1980, 1990, 2000, and 2010. The glacier outlines were prepared for consecutive years.

The initial findings (Figure 3) showed that the glacier coverage in the Langtang basin declined from 171.76 to 129.29 km^2 between 1977 and 2009, with an overall loss of glacier area of 24.7% (Table). In the

Imja valley sub-basin of Dudh Koshi basin, 27% of glacier area was lost between 1979 and 2010. Significant decreases in glacier area are recorded below the elevation of 5,800 m a.s.l. Owing to glacier shrinkage, the snout elevations of Kimjung and Lirung glaciers shifted upward by 100 m and the snout of Yala glacier by 100 to 150 m.

Glacier delineations will also be conducted for the Jhelum, Koshi, and Narayani basins. The glacier outlines derived from different time series data will be compared and the changes in glacier areas and volumes estimated. Glacier outlines and parameters will help to determine the relative contribution of glacial melt to the runoff in the river basins.

Seasonal snow cover

To understand the spatial and temporal variation of snow cover and to validate the integrated hydrological model, daily snow cover and snow albedo maps for the Dudh Koshi, Langtang, and Manas basins have been prepared using 500 m Moderate Resolution Imaging Spectroradiometer (MODIS) snow data (from morning and afternoon satellite passes, i.e., MOD10A1 and MYD10A1) (Figure 4). Since daily products are contaminated with cloud pixels, an 8-day composite snow cover and albedo product was created using a moving 8-day approach, rescaled to 90 m spatial resolution and converted into GeoTiff format for assimilation into the model.

Decadal glacier changes in the Langtang sub-basin of Nepal

Year	Number	Glacier area		Elevation (m a.s.l.)	
		(km^2)	(%)	Highest	Lowest
1977	52	171.76	48.75	7,160	3,997
1988	74	154.33	43.80	7,184	4,007
2000	76	137.91	39.14	7,160	4,020
2009	76	129.29	36.70	7,160	4,112

Integrated hydrological model

The NASA partners are working with ICIMOD to incorporate snow and glacier melt, in gridded format, into a widely used hydrological model, the Utah Energy Balance (UEB) model. The new HIMALA-

Figure 3: **Glacier mapping of Langtang sub-basin from satellite images of 1977, 1988, 2000, and 2009**

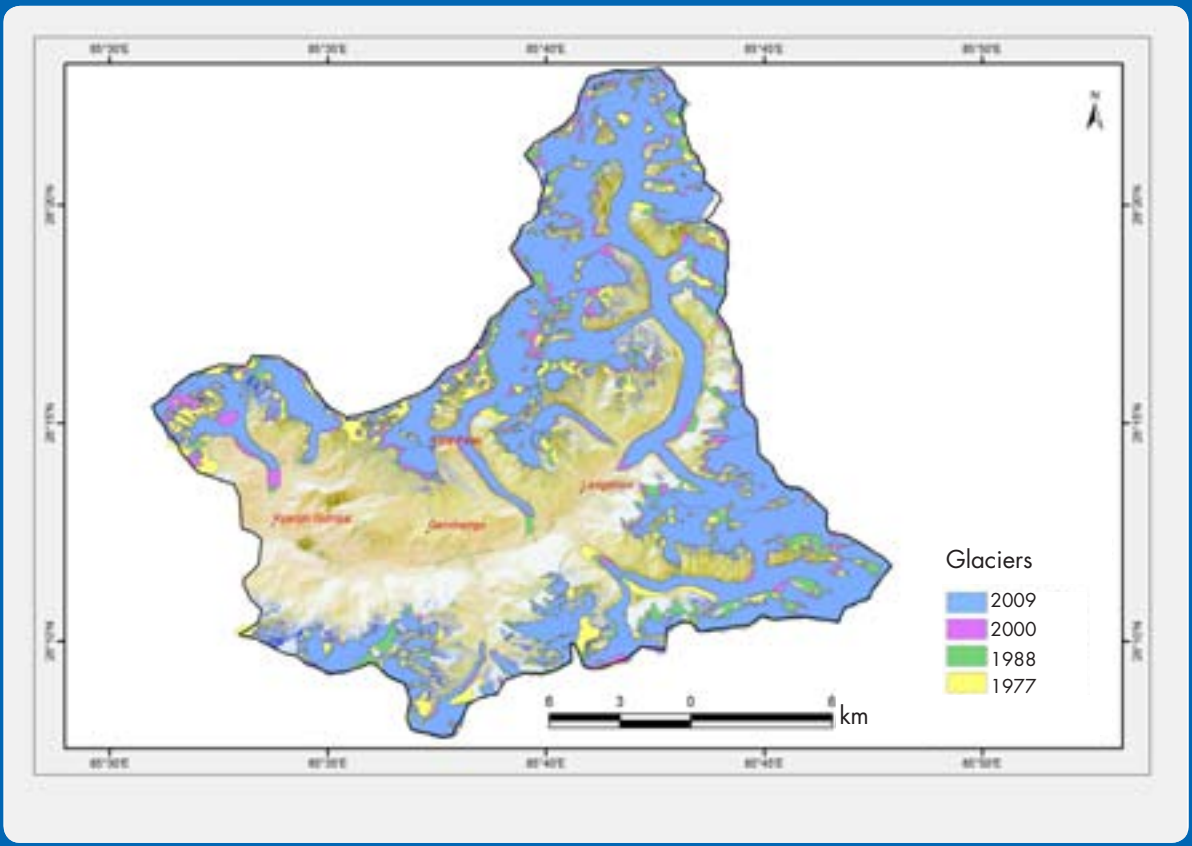
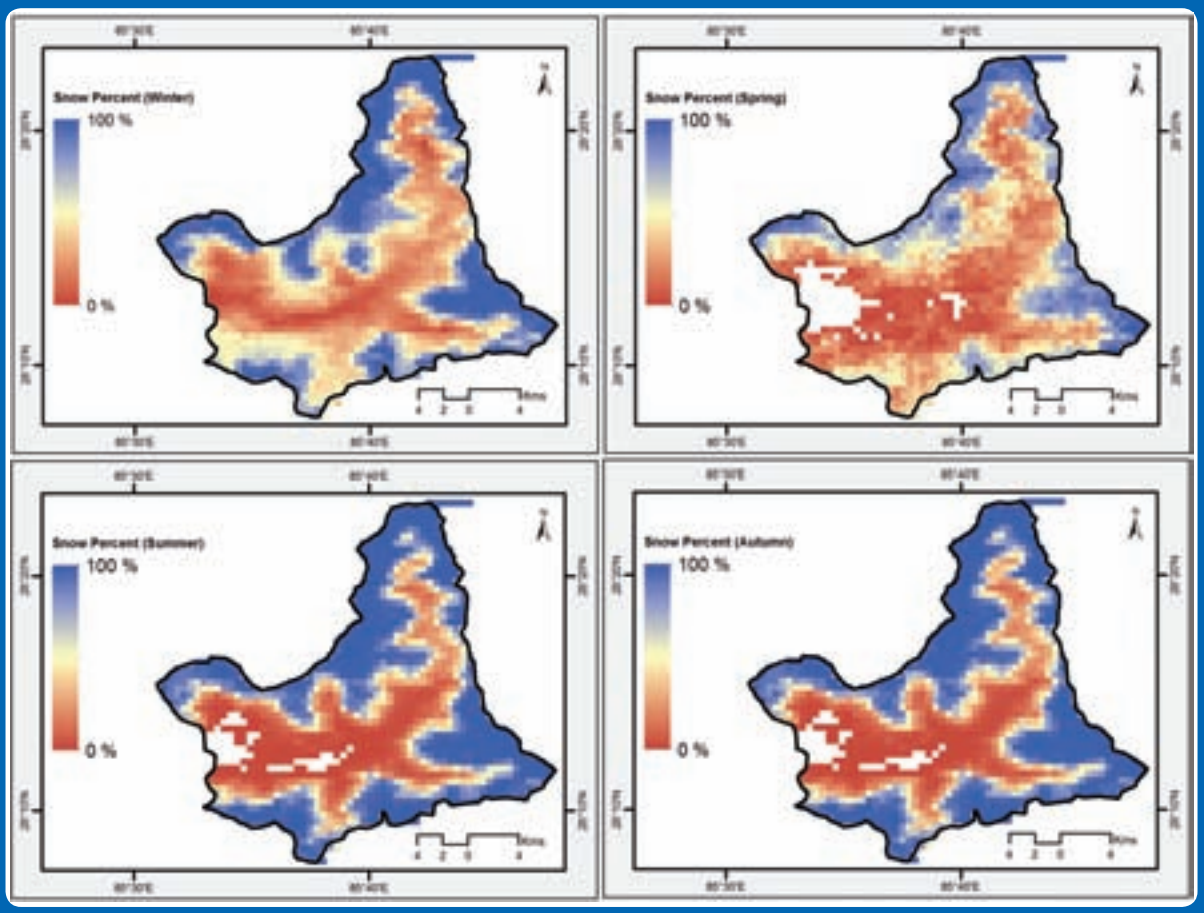


Figure 4: **Seasonal snow cover in the Langtang sub-basin during 2011**



BASINs modelling tool, with a simple graphical user interface using Mapwindow open-source GIS software, makes it easy to learn to use the model, to input data, and to monitor streamflow in other basins of the region. After the prototype is tested and evaluated, it will be upscaled and extended to other basins in the HKH region.

Various climate scenarios will be applied to obtain the impact on flow availability over the long term. The partners in the region will be trained to use the integrated hydrological model to assess the contribution of snow and glacial melt to runoff for improved water resources assessment and management.

Implementing partners in the region

Bangladesh	Bangladesh Water Development Board Bangladesh Meteorological Department
Bhutan	Department of Hydro-Meteorological Services, Bhutan
China	China Meteorological Administration Bureau of Hydrology, China Tibet Meteorological Bureau Tibet Bureau of Hydrology
India	National Centre for Medium Range Weather Forecasting Aaranyak
Nepal	Department of Hydrology and Meteorology, Nepal Department of Meteorology, Tri-Chandra Campus, Tribhuvan University Central Department of Hydrology and Meteorology, Tribhuvan University
Pakistan	Flood Forecasting Division, Pakistan Meteorological Department

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