ICIMOD

FOR MOUNTAINS AND PEOPLE

Predicting Floods in the Himalayan Region

using satellite rainfall estimates and models

INFORMATION SHEET #5/09

Early warning of floods is essential for helping to save lives, property, and livelihoods from the adverse impacts of flooding. In order to provide early warning, however, it is necessary to know how much rain is falling where and when, and how much of it will flow downstream. In the Hindu Kush-Himalayan region, monsoon rains in the mountains swell rivers and threaten hundreds of millions of people downstream with massive floods, but there is little rainfall information available. Recent advances in estimating rainfall from satellite observations, and using models to predict the flow of water in rivers, offer a chance to overcome some of these problems and help people to know when floods are coming. This information sheet describes some of the first experiments using these methods on a regional scale to predict floods in the downstream areas of the Indus, Ganges, and Brahmaputra river basins.

The Hindu Kush-Himalayan region is the source of ten major rivers that provide freshwater to some 1.3 billion people – a fifth of the world's population – living downstream. Some of this water comes from melting of the vast stores of ice and snow accumulated in the high mountains, and some from storage in natural lakes, wetlands, forestlands, soil, and underground. But during the intense monsoon season, most of the water comes directly from rainfall – and all too often heavy rainfall in the mountains, outstripping the storage capacity of soil and water bodies, leads to flooding downstream. Every year vast numbers of people are affected by these floods, losing homes and livelihoods; fields, crops, and livestock; roads, bridges, electricity lines and local infrastructure. Climate change is leading to an increase in the number and intensity of floods, and expansion of settlements in flood plain areas is increasing the risk of disaster. Flood impacts can be reduced to some extent through early warning that gives people time to move themselves and their property to higher ground, and protect what is left behind. But early warning means knowing how much rain has fallen and where, and how this will contribute to downstream flows.

Rainfall estimates and rainfall-runoff modelling

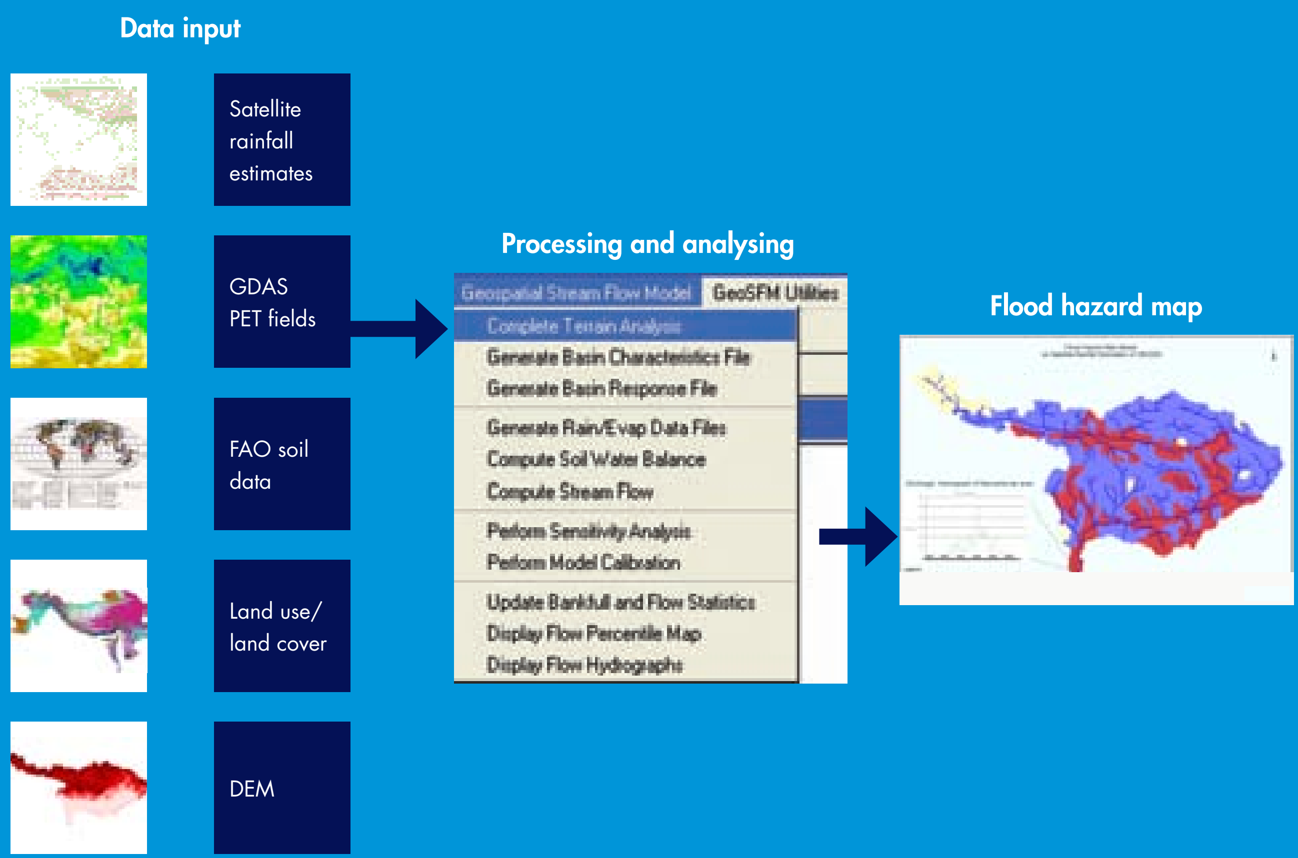
Rainfall can be measured directly, but in areas where rainfall varies over short distances and time, measuring stations have to be closely spaced for the information to be useful, and it must also be immediately available. In the poorly accessible and sparsely populated mountains of the Himalayas, there are not enough observing stations to enable accurate rainfall interpolation over a larger area. Thus scientists are focusing on estimating rainfall from information gathered from satellite observations. These methods are being adapted and tested for the Himalayan region.

Only some of the rain that falls on the ground flows into the rivers. Rain can be absorbed into the soil, caught by vegetation, held in a lake or reservoir, or replenish underground stores. The proportion of rainfall in a catchment area that will contribute to river flow can be calculated using information about the soil, land cover and vegetation, evapotranspiration, slope, and other factors using a mathematical 'rainfall runoff model'. Models of this type are used to predict the amount of rainfall in a river basin that will become part of the river flow. Together with estimates of the rainfall, these models can be used to calculate the water flow at a particular time and place, and thus the potential for floods. There are many hydrological models available for predicting floods, varying in degrees of complexity and purpose. They range from simple combinations of parameters to models based on complex physical knowledge and theory. The techniques have developed rapidly since geographic information system (GIS) and remote sensing data have become readily available.

The Geospatial Stream Flow model

The Geospatial Streamflow Model (GeoSFM) was developed by the United States Geological Survey (USGS) to support flood hazard monitoring in parts of Africa where there was little data from hydro-meteorological stations. It is a catchment-scale (semi-distributed) hydrological model designed to run with widely available remotely-sensed datasets. The model uses satellite rainfall estimates, observed rainfall and estimates of potential evapotranspiration; together with geographical datasets describing the land surface – elevation, soil, land cover/vegetation – to forecast the likely flow of water in rivers on a daily basis. It is built in a modular way. The rainfall-runoff simulation component, has three main sub-modules for water balance, catchment routing, and distributed channel routing. A graphical user interface running within a GIS environment is used for preparing and inputting data and visualising the outputs.

GeoSFM Modelling



Many of the catchments in the Himalayan region have no rainfall or river flow measuring stations making it difficult to predict the occurrence of floods downstream. Even where stations exist, obtaining real-time data and information for flood forecasting is difficult. Sharing of real-time data and information across national borders remains a challenge in the region. Since the GeoSFM model uses satellite based rainfall estimates, other remotely sensed data and global datasets, it offers a way to predict the amount of water leaving different catchments (discharge) in the greater Himalayan region and provide a basis for predicting floods and giving early warning to downstream populations.

The ICIMOD project

ICIMOD and its partners have been working together since June 2006 in a project on 'Application of Satellite Rainfall Estimation in the Hindu Kush-Himalayan region' to strengthen regional cooperation in data and information exchange and to build the capacity of partner institutions in preparing and using satellite rainfall estimates. The overall goal is to minimise the loss of lives and livelihoods by reducing the vulnerability in the HKH region (riverine floods, flash floods, drought, climate change), in particular in the Indus, Ganges, and Brahmaputra basins. The accuracy of the satellite rainfall estimates (CPC-RFE2.0) have been assessed by validating at regional and national levels with technical support from US National Oceanic and Atmospheric Administration (NOAA) and the USGS. These satellite-based rainfall estimates are now being used in tests of the GeoSFM model to predict discharge in various basins in the region towards development of a basin-wide flood forecasting system.

Testing of the GeoSFM model

The GeoSFM model has been set up for the Brahmaputra and the Bagmati basins to simulate flows at Bahadurabad in Bangladesh and Pandhera Dovan in Nepal to assess and verify its application for the greater Himalayan region. Rainfall estimates (RFE) were produced by the Climate Prediction Centre (NOAA/CPC) and verified using ground rain gauge stations at selected sites. The model parameters were estimated from FAO's Digital Soil Map of the World and the USGS Global Land Cover dataset.

In a first test, the model was used to predict the daily streamflow at Pandhera Dovan gauging station. The results were compared with the actual flows observed. The results from the model were close to the observed result when measured rainfall values were used, but estimates

Partners

Afghanistan: Water Resource Planning Unit; General Planning Department, Ministry of Energy and Water

Bangladesh: Bangladesh Water Development Board; Bangladesh Meteorological Department

Bhutan: Hydro-meteorological Services Division, Department of Energy, Ministry of Economic Affairs, Ministry of Agriculture

China: China Meteorological Administration; China Bureau of Hydrology; Tibet Meteorological Bureau; Bureau of Hydrology

India: National Centre for Medium Range Weather Forecasting; North-East Centre for Environmental Research and Development; Centre for Geo-Informatics Research and Training

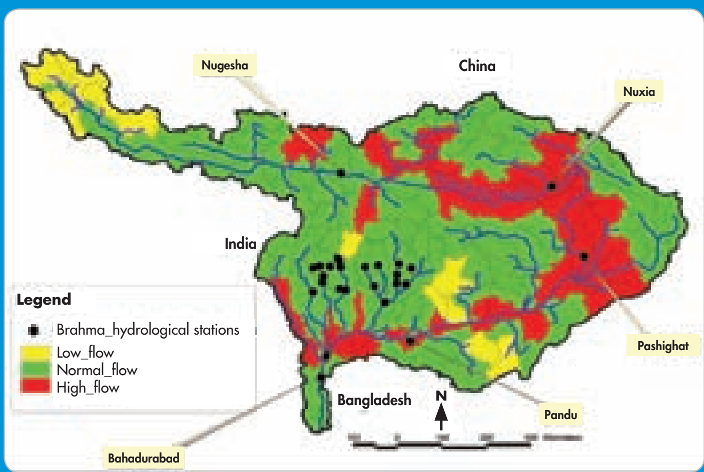
Nepal: Department of Hydrology and Meteorology; Department of Water Induced Prevention; Department of Meteorology, Tri-Chandra Campus; Central Department of Hydrology and Meteorology, Tribhuvan University

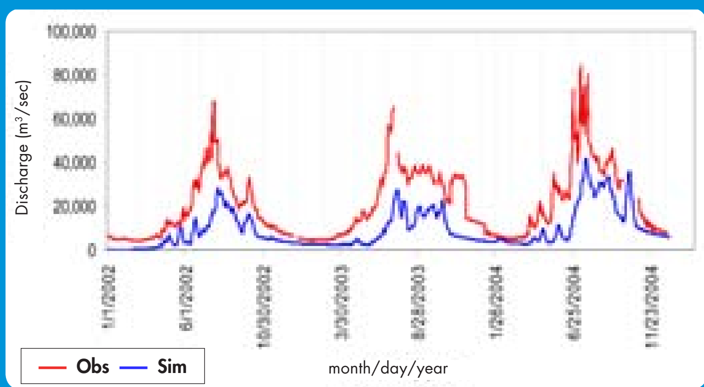
Pakistan: Flood Forecasting Division; Pakistan Meteorological Department

National Oceanic and Atmospheric Administration, US

United States Geological Survey

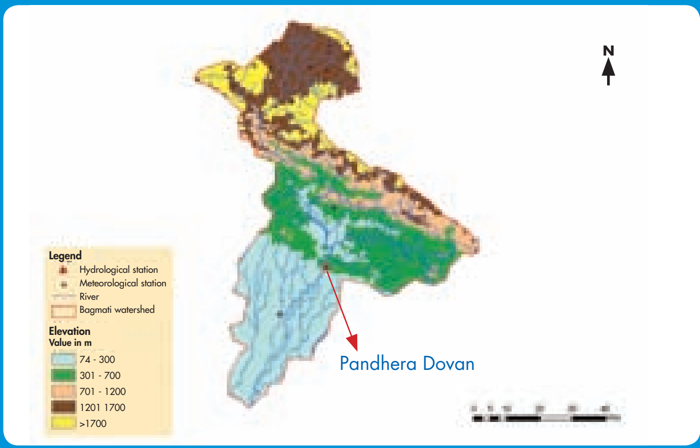
Regional level analysis – Brahmaputra Basin (China, India, Bhutan, Bangladesh)

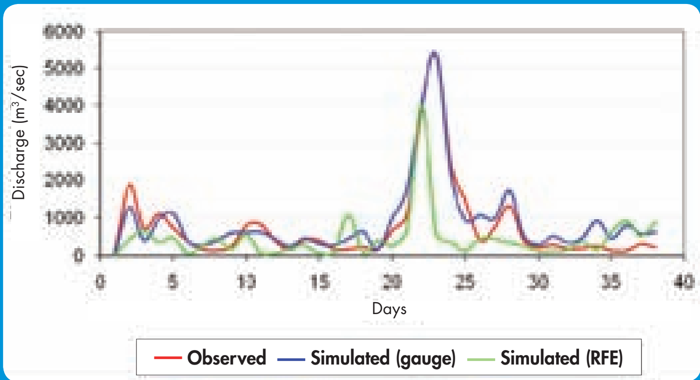




Simulated and observed flow of the Brahmaputra River at Bahadurabad, Bangladesh

National level analysis – Bagmati Basin (Nepal)





Comparison of observed and simulated daily flows at Pandhera Dovan

were less than observed values when satellite-based rainfall estimates were used as shown in the figure. Three years of daily satellite based rainfall estimates were then used to simulate the flows of the Brahmaputra at Bahadurabad in Bangladesh. The model captured the trend of the observed discharge very well, although again the magnitude of the flow was less than observed values.

In a further test, two years of daily discharge data (2002, 2003) was used to calibrate the model for flows from the Bagmati basin at Pandhera Dovan, and data from a third year (2004) was then used to validate the model by comparing the model results with the actual discharge. The predicted peak flows were still low compared to the observed flows. In other words, the model is promising, but it does not yet produce results that are close enough to the observed values to be useful for operational flood forecasting. The main problem seems to be that the satellite rainfall estimation method still significantly underestimates actual rainfall.

The way forward

It is likely that the loss of life and livelihoods from floods will rise in the coming years as a result of the increase in population, encroachment of urban development into traditional flood plain areas, and changes in rainfall patterns. It is extremely difficult to operate traditional flood forecasting models in the Himalayan region as the ground-based hydro-meteorological network is very limited, and often what limited data there is, is not easily shared in a timely way across the international borders. Using estimates of rainfall derived from satellite observations and mathematical models offers a way to predict floods in a timely fashion, even when there are only limited ground-based observation data available.

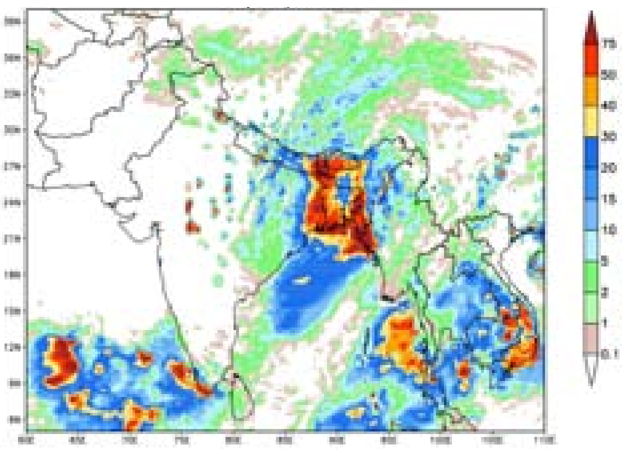
The GeoSFM predicts flows accurately when gauge observed rainfall are used, which indicates that the model itself can be used for flood forecasting when good quality rainfall data is available. However, the flows are underestimated when satellite-based rainfall estimates are used. Present work is focused on improving the satellite based rainfall estimates and developing higher resolution data that describes more exactly where and how much the rain is falling. At the same time the model parameters themselves are being fine tuned as the model is calibrated and validated for application to operational flood forecasting.

Further reading

Shrestha, M S; Bajracharya, S R; Mool, P (2008) *Satellite rainfall estimation in the Hindu Kush-Himalayan region*. Kathmandu: ICIMOD

Satellite rainfall estimation in the Hindu Kush-Himalayan region – Validation. ICIMOD Information Sheet 2008

NOAA/CPC precipitation estimate (mm): based on GPI, SSM/I, AMSUB & GTS (05/25/2009)



CPC RFE Version 2.0 - Expanded ASIA

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Photo: Chandra Shekhar Karki

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