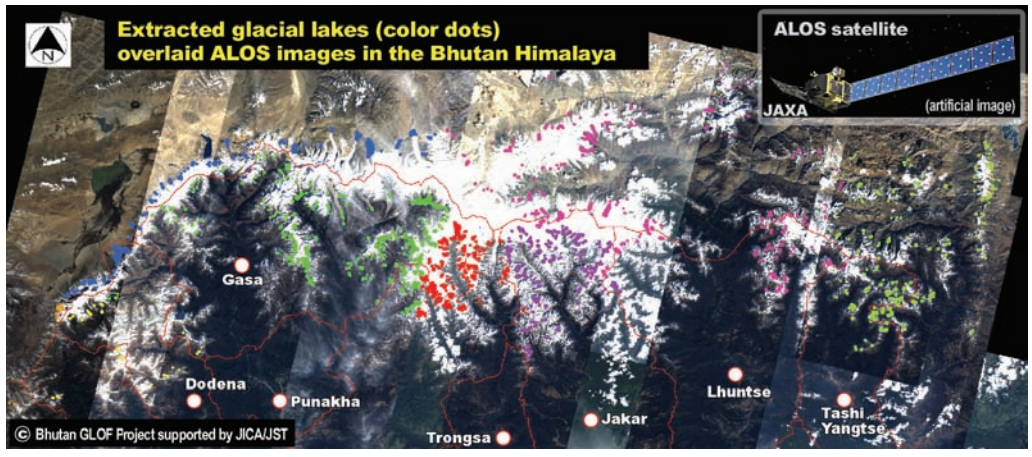
This is the second article of a 15-part series on the GLOF research and mitigation project between May 2009 and March 2012. The articles will highlight latest findings on glacier, glacial lakes condition and natural hazards in the Bhutan Himalayas. Experts from the department of geology and mines (DGM), Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST) are involved with the project.

Glacial lake inventory updated



One of the most important activities of the project was to come up with a new glacial lake inventory to understand its existing condition. In recent years, various types of satellite data are available. These data differ in terms of resolution, recurrence, number of spectral bands, functional capability and cost.

The accuracy of satellite data has also significantly improved. They are effective in monitoring surface conditions, including remote regions where most mountainous glaciers and glacial lakes are located. In addition, satellites make it possible to identify temporal changes and compare these changes to historical archived data.

The new glacial lake inventory for the Bhutan Himalayan region is being developed by utilizing two instruments (PRISM and AVNIR-2) onboard the Advanced Land Observing Satellite (ALOS, nicknamed 'Daichi'), which operated from January 2006 to April 2011 by the Japan Aerospace Exploration Agency (JAXA). The established procedure for conducting the inventory consists of image processing, lake extraction, and screening of extracted lakes to identify glacial lakes. The satellite remote sensing team

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of the project, which consisted of Japanese experts along with some Bhutanese counterparts worked together. The team trekked up to the glacial lakes in 2010 and 2011 to collect ground control points (GCPs) and measure the shapes of several glacial lakes. These measurements were necessary to maintain the quality of satellite data. The measured lake shorelines were used to validate the remote sensed glacial lake inventory. The final processed satellite images have 2.5 meters ground resolution. This value means that you may recognize the difference of a TATA track and Omni van at the front of your house using these images. These are the first digital maps with precise resolution and accuracy covering almost entire Bhutan. Of course, the result will also contribute for any other applications like disaster monitoring, land-cover changes, land management, water resources estimation as the base map.

The new inventory of glacial lakes in the Bhutan Himalayas is in its final stages of development. As of now approximately 900 glacial lakes have been extracted based on the parameters that the extracted glacial lake lays between the terminus of the mother glacier and youngest moraine ridge (Little Ice Age moraine). Lakes located within 2 km of the Little Ice Age moraine down valley are also included to take into account a possible flooding event with multiple lakes being involved and the minimum lake size was set at 0.01 square km considering the fact that small lakes contribute a less amount of GLOF risk. The final version of the inventory of entire Bhutan Himalayan region will be released in February, 2012 that can be viewed at http://www.eorc.jaxa.jp/ALOS/en/bhutan_gli/index.htm.

What is a glacial lake

In general, glacial lake in mountain glacier is classified as proglacial lake or supraglacial lake, depending on the location of the lake whether it is in front or surface of the glacier(see figure).

The proglacial lake is further classified as moraine-dammed or ice-dammed lake, according to the situation of the dam part either moraine or glacier ice. The latter case is rare in the Bhutan Himalaya. Supraglacial lakes initially appear in closed basins on the ice surface as small ponds and grow up to large supraglacial or moraine dammed lake through expansion and decay. A large supraglacial lake at the terminus of Thorthormi Glacier in Lunana was also expanded from supraglacial ponds since the 1960's. Appearance and disappearance of those lakes are controlled by the ice surface and sub-glacial topographies and change of the ice flow (mass balance). Most of the lakes located over approximately 3600 meters elevation in the Bhutan Himalaya, such as the lakes near Phajoding are of glacial origin. These lakes were mostly formed after the terminations of the Last Glacial Maximum (lowest temperature period in the last glacial age, about twenty thousand years ago), some climatic anomaly in recent several thousand years ago and termination of the Little Ice Age (low temperature period in the medieval, about 150 years ago).

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