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Satellite Monitoring of Pakistan's Rockslide-Dammed Lake Gojal

On 4 January 2010, a rockslide 1200 meters long, 350 meters wide, and 125 meters high dammed the Hunza River in Attabad, northern Pakistan, and formed Lake Gojal. The initial mass movement of rock killed 20 people and submerged several villages and 22 kilometers of the strategic Karakoram Highway linking Pakistan and China. Tens of thousands of people were displaced or cut off from overland connection with the rest of the country.

On 29 May, the lake overflow began to pour through a spillway excavated by Pakistani authorities. On approximately 20 July, the lake attained a maximum depth of 119 meters and a torrent at least 9 meters deep issued over the spillway, according to Pakistan's National Disaster Management Authority (NDMA). To date, the natural dam is holding and eroding slowly. However, the threat of a catastrophic outburst flood remains.

The filling of the lake has been monitored by using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Advanced Land Imager (ALI) satellite imagery to map the extent of the lake and ASTER and space shuttle digital terrain data to assess lake volume and fill history (Figure 1). Field data, adding to data from orbiting sensors, were obtained by coauthor Jean Schneider; NDMA; the Pamir Times, a community news blog; and Focus Humanitarian Assistance (FOCUS)–Pakistan. Glaciers, snowmelt, and rainfall runoff are all important in providing water inflow to the lake at various times throughout the year. Because of the key contribution of melting glaciers during the summer, NASA-funded Global Land Ice Measurements from Space (GLIMS) data are aiding with lake monitoring.

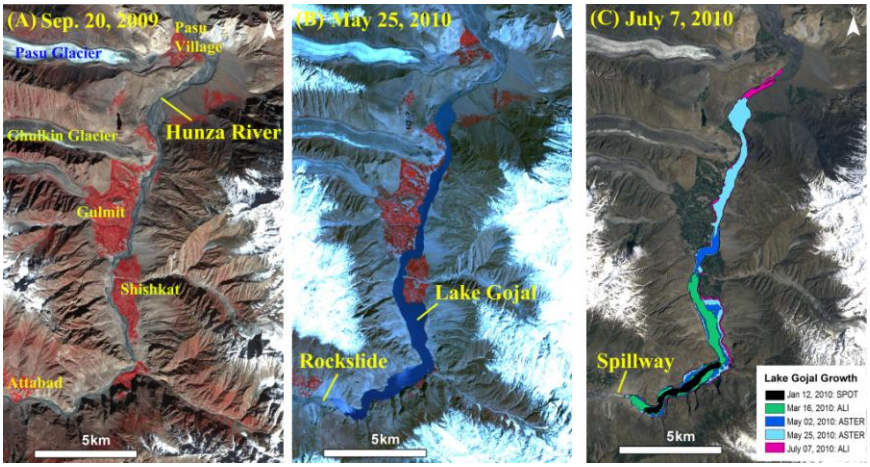

Fig. 1. Lake Gojal. (a) Prelandslide Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) false- color image mosaic of the Hunza Valley. Red indicates vegetation (mainly agricultural fields) and also includes villages. (b) ASTER false-color image 4 days before the overflow. Note the extensive late spring snowfields and glaciers feeding Lake Gojal. (c) Advanced Land Imager (ALI) near–true color base image, 7 July 2010, showing the growth of Lake Gojal based on Satellite Pour l'Observation de la Terre (SPOT), ALI, and ASTER imagery. The colors used to designate the lake mark the growing extent of the lake in the chronological sequence indicated by the legend.

At its maximum size, on approximately 20 July, the lake was about 22 kilometers long and 12 square kilometers, and it contained 585±40 million cubic meters of water (for comparison, this is about 200 times the volume of the new stadium for the Dallas Cowboys football team in Texas). Satellite images showed a slight retreat of the shoreline by late August compared with its peak several weeks before. Slight further retreat is expected until winter.

Satellite-derived lake volumes, which were 3–5 times higher than those indicated in media reports just prior to the overflow, improved disaster management planning and predictions of possible outburst floods. As early as 14 April, satellite and field-based data were used to project an overflow date range of 28 May to 2 June, bracketing the actual overflow date.

The dam's slow erosional incision has been surprising. Rather than resulting in a common mode of natural dam failure and outburst flooding upon overtopping, the initial rockslide has become a new geologic feature, which could prove transient and catastrophic or could last for centuries. The dam's nonfailure requires an assessment of whether the system will continue slow downcutting and produce a quasi-stable lake and controlled natural drainage, or whether there is significant potential for future catastrophic failure.

Satellite and field monitoring up to 9 October showed the spillway continuing to erode, so far not alarmingly, with the high monsoon flow now having decreased sharply as autumn set in. With the monsoon now ended for this year and glacier melting decreasing, inflow is plummeting and the threat of outburst from Lake Gojal is diminished until next June.

However the Hunza situation is resolved, satellite monitoring can assist managers in such rockslide dam emergencies. Similar rockslide events have occurred previously in the region and will occur again, according to geographers Jack Shroder and Michael Bishop of the University of Nebraska at Omaha and Ken Hewitt of Wilfrid Laurier University, Waterloo, Ontario, Canada.

As adverse as this current event has been, other such events could be worse with different timing, location, or volume. The formation and unresolved future of Lake Gojal, continued rockfalls in the Hunza region, and this past summer's unrelated monsoon-driven flooding in the Indus basin underscore the subcontinent's need for field, remote sensing, and model-based assessments of the disaster potential related to landslides, glacier surges, catastrophic monsoonal precipitation, glacier and landslide dam lake outbursts, and unseasonal snowpack melting. These natural hazards are tied to Pakistan-India transboundary issues of water resources, urban planning, food security, hydropower, climate change, and environmental conservation.

—Jeffrey S. Kargel and Gregory Leonard, University of Arizona, Tucson; E-mail: kargel@hwr.arizona.edu; Robert E. Crippen, Jet Propulsion Laboratory, California Institute of Technology, Pasadena; Keith B. Delaney and Stephen G. Evans, University of Waterloo, Waterloo, Ontario, Canada; and Jean Schneider, Universität für Bodenkultur Wien (BOKU University Vienna), Vienna, Austria