
by Laurie J. Schmidt

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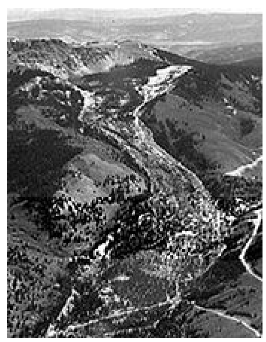
Title graphic: Slope failure near McClure Pass, Colorado, destroys a two-lane highway and leaves a car stranded in the debris. (Image courtesy of the USGS)

Summer of 2001 was a season of devastating landslides. During June and July, landslides and floods throughout China's southern provinces left thousands dead or homeless. At least 35 people died in a landslide west of Kathmandu, Nepal, and intense rain triggered severe flooding and landslides in 20 counties in West Virginia. In August, a landslide caused Ecuador's Sote oil pipeline to break, spilling some 1,000 barrels of crude oil and halting oil transport for a week.

Mass wasting, the downward gravitation of rock, debris, and dirt, continually sculpts Earth's landscapes. Research indicates that on most slopes, a certain amount of downhill movement is occurring constantly, although it may often be imperceptible.



The Slumgullion landslide in Hinsdale County, Colorado, probably dammed Lake Fork between 800 and 900 years ago. Based on photogeologic analysis, it appears to be the only landslide in the area with continuously moving material. (Image courtesy of the *USGS Slumgullion Field Trip*.)

Landslides — sudden, short-lived geomorphic events that involve the rapid-to-slow descent of soil or rock in sloping terrains — occur worldwide, often in conjunction with natural hazards like earthquakes, floods, or volcanic eruptions. Landslides can also be caused by excessive precipitation or human activities, such as deforestation or development, that disturb natural slope stability.

On average, landslides in the United States cause $1 to $2 billion in property damage and more than 25 fatalities per year. Posing threats to settlements and structures, landslides often result in catastrophic damage to highways, railways, waterways, and pipelines. According to the U.S. Transportation Research Board, annual costs for the repair of minor slope failures by state departments of transportation exceed $100 million.

For more information, visit the Alaska SAR Facility DAAC and the EROS Data Center DAAC (now named the Land Processes DAAC). (A new browser window will open.)

In a landslide triggered by the 1994 Northridge, California, earthquake, this house crumbled near Golden, Colorado. (Image courtesy of the USGS Open-file Report 95-213. A new browser window will open.)

To determine where protective measures are necessary, scientists produce landslide inventory and risk assessment maps for many areas in the United States and Canada. But because landslides do not display a clear relationship between magnitude and frequency, as do earthquakes and floods, landslide studies are challenging to scientists. "It is very difficult to represent landslide hazards in quantitative terms over large areas," said Vernon Singhroy, Senior Research Scientist at the Canada Centre for Remote Sensing.

Although aerial photography has been used extensively to produce landslide inventory maps, air photos are not readily available in all areas. Scientists increasingly rely on global satellite data to help assess the risk for potential landslides.

The Thematic Mapper (TM), an Earth observing instrument aboard NASA's Landsat 4 and 5 satellites, measures solar radiation reflected or emitted by the Earth's surface, providing high-resolution images of the Earth's surface. Its large-area mapping capabilities make it a useful tool for land cover mapping and assessment. But the TM's spatial resolution is generally considered too coarse to accurately identify landslide features — unless the data are merged with higher resolution radar images.

Synthetic aperture radar (SAR) instruments transmit radar signals and then measure how strongly the signals are scattered back. Because SAR produces its own radar signal which can penetrate cloud cover, the sensor generates images with greater detail at a higher spatial resolution, and making it especially useful for mapping the geomorphology of landslides.

"SAR images provide information on the terrain roughness and texture, while TM images provide an infrared reflection of the object," said Singhroy.

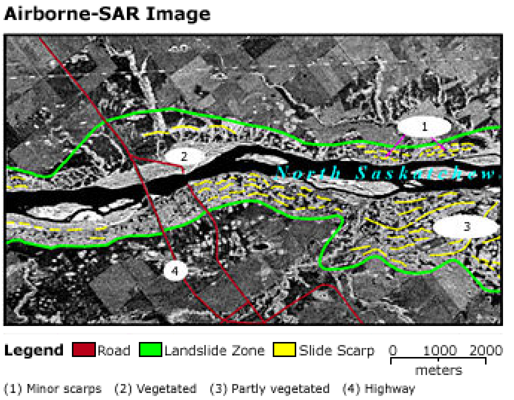
By combining two images from different instruments, Singhroy and colleagues found they could produce a third image containing topographic details essential to producing high-quality landslide maps. The process, known as image fusion, combines radar terrain information with Landsat spectral land cover images. "Fused images are now used frequently in geologic mapping and geohazard assessment, such as landslide mapping," said Singhroy.

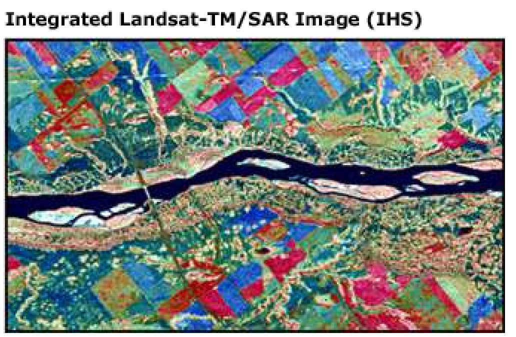
The researchers are also experimenting with another technique, known as radar interferometry, to produce slope maps that will aid in slope stability studies in mountainous terrains prone to landslides. SAR interferometry (INSAR) operates on the premise that if the backscattered signal differs between two images of the same object, taken at two different times, then the object has moved or changed. INSAR imagery is used to monitor landslide motion and produce detailed contour maps, which help characterize hazardous areas.

"SAR interferometry is a useful tool for detecting and monitoring mass movement and, therefore, contributes to the assessment and mitigation of landslide hazards," said Singhroy. "Major geomorphic features, such as slides, ridges, and faults, are well-defined and easily interpreted in InSAR images. These features provide clues that help us map potential slide areas."

Radarsat-1, an advanced Earth observation satellite launched by the Canadian Space Agency in 1995, produces InSAR images for landslide assessment. Other radar systems, such as the European Remote Sensing Satellite (ERS) 1 and 2 and NASA's Shuttle Radar Topography Mission (SRTM), also have potential for geohazard assessment.

Singhroy, along with colleagues K. Mattar and L. Gray, used InSAR and high-resolution SAR images to map the geomorphic features of landslide areas in the Fraser Valley, located in British Columbia, Canada. Landslides in the Fraser Valley, which links the resource-rich prairie provinces with metropolitan Vancouver, have caused serious damage to major transportation links. In 1997, landslides caused the derailment of the Canadian National Railway, resulting in two deaths and $20 million in damage. To date, 35 landslides, ranging in size from 1 million to 500 million cubic meters, have been identified in the Fraser Valley.




These two images show a landslide area along the North Saskatchewan River, Saskatchewan, Canada: High-resolution SAR image (top), and combined Landsat-TM/SAR image (bottom). (Images courtesy of Vernon Singhroy, CCRS)

Singhroy said that, although the role of Earth observation data in producing landslide maps is still in its infancy, developing new remote sensing techniques to identify landslides and debris flows will assist in the current national landslide inventory and hazard mapping in mountainous terrains.

"The integration of SAR and TM images, along with SAR interferometric techniques, are extremely useful in characterizing landslides and will supplement the air photo methods currently being used," said Singhroy in an article published in *Advances in Space Research*.

According to Singhroy, fused data images create image perspectives that can help civil defense workers know where potentially hazardous areas are. "In the case of volcanoes, they help us map dangerous terrains and potential lava paths," he said.

The 1985 volcanic eruption of Nevado del Ruiz in the Columbian Andes Mountains proved just how invaluable accurate hazard maps are in identifying at-risk communities. When the volcano erupted, glacier melt spawned massive mudflows that buried 20,000 people in the town of Armero overnight. "The hazard zone was actually much larger than the risk maps had indicated," said Singhroy. (See Life on the Brink for information about population centers on or near volcanoes.)

"Image fusion and perspective views will help us mitigate these risks. We need to learn how to live in hazardous areas and use these tools to minimize damage," he said.

**References**

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