Using Satellite Data to Investigate the 12 May 2008 Sichuan Earthquake, China

PAGES 138-139

The *M* 8.0 earthquake that struck Sichuan Province in southwestern China on 12 May 2008 was the most devastating earthquake in that country in the past 5 decades. At least 69,000 deaths have been confirmed and more than 374,000 people were injured, according to China's Ministry of Civil Affairs. Overall, more than 45.5 million people in 10 provinces and regions in China were affected by the earthquake. Landslides and rockfalls damaged or destroyed several mountain roads and railways and buried buildings in the Beichuan-Wenchuan area of Sichuan Province, cutting off access to the region for several days (Figures 1a and 1b). Landslides also dammed several rivers, and the resultant creation of 36 barrier lakes (dangerous earthquake lakes) threatened about 700,000 people downstream.

The use of remotely sensed data in natural hazards mapping as a source of input data for hazard assessment has grown more popular in recent years [*Strozzi et al.*, 2005; *Tronin*, 2006]. Some satellite data (including data from FORMOSAT 2; the Constellation of Small Satellites for the Mediterranean Basin Observation (COSMO-SkyMed); the phased array type L-band synthetic aperture radar on board Japan's Advanced Land Observing Satellite (PALSAR/ALOS); IKONOS; and other sources) were used in the Sichuan earthquake zone to provide information to Chinese authorities, which affected the rescue and recovery efforts. This brief report presents an overview of the use of satellite images in investigating ground changes in the area directly affected by the earthquake.

Satellite Monitoring of Existing Hazards

Satellite images acquired before and after earthquakes can be used to record deformations and associated landscape features that take place during such incidents [*Tronin*, 2006]. FORMOSAT 2 is an optical Earth observation satellite operated by Taiwan's space organization (NSPO, http://www.nspo.org.tw/2008e/), which has a high resolution (spatial resolution of 2 meters) and a daily revisit capability. Among the first FORMOSAT 2 images of the Sichuan earthquake that were released, Figures 1c and 1d show Beichuan County, one of the areas in Sichuan Province that was most affected by the earthquake. Figure 1d reveals the abundant landslides (shown in brown) and clusters of houses (shown in white) along the Jianjiang River that were destroyed by the quake. A road along the river also was severely damaged. The earthquake caused numerous landslides on mountains in Beichuan County and formed barrier lakes that posed a serious threat to downstream regions. Two or more optical satellite images also can be used to assess the barrier lake risk in the area affected by the earthquake (Figures 1e and 1f).

However, optical satellite measurements are limited by cloudy and rainy conditions. Synthetic aperture radar (SAR) images can overcome such limitations and operate well in all weather conditions. Updated SAR images can be overlaid on previously obtained optical satellite images, allowing the National Disaster Reduction Center of China (NDRCC; under China's Ministry of Civil Affairs) to assess damage around buildings or bridges.

Under the International Charter on Space and Major Disasters, some SAR images of the quake area were sent to Chinese authorities as soon as the images were acquired from the satellite. These SAR images were analyzed along with some images obtained by the NDRCC. By comparing the SAR image from the COSMO-SkyMed satellite (acquired on 13 May 2008) with high-resolution optical IKONOS images obtained in 2007, the NDRCC found many collapsed buildings in the city of Dujiangyan (Figures 1g and 1h).

Interferometric synthetic aperture radar (InSAR) systems provide another means for obtaining images of areas affected by natural hazards. InSAR systems exploit the phase differences of the radar wave returning signals between two SAR images acquired over an identical scene. The phase differences are then calculated and converted into height information, which can clearly indicate surface deformation related to earthquakes [*Tronin*, 2006]. InSAR has attracted much attention from researchers involved with landslide monitoring and hazard assessment associated with the earthquakes [*Stramondo et al.*, 2008].

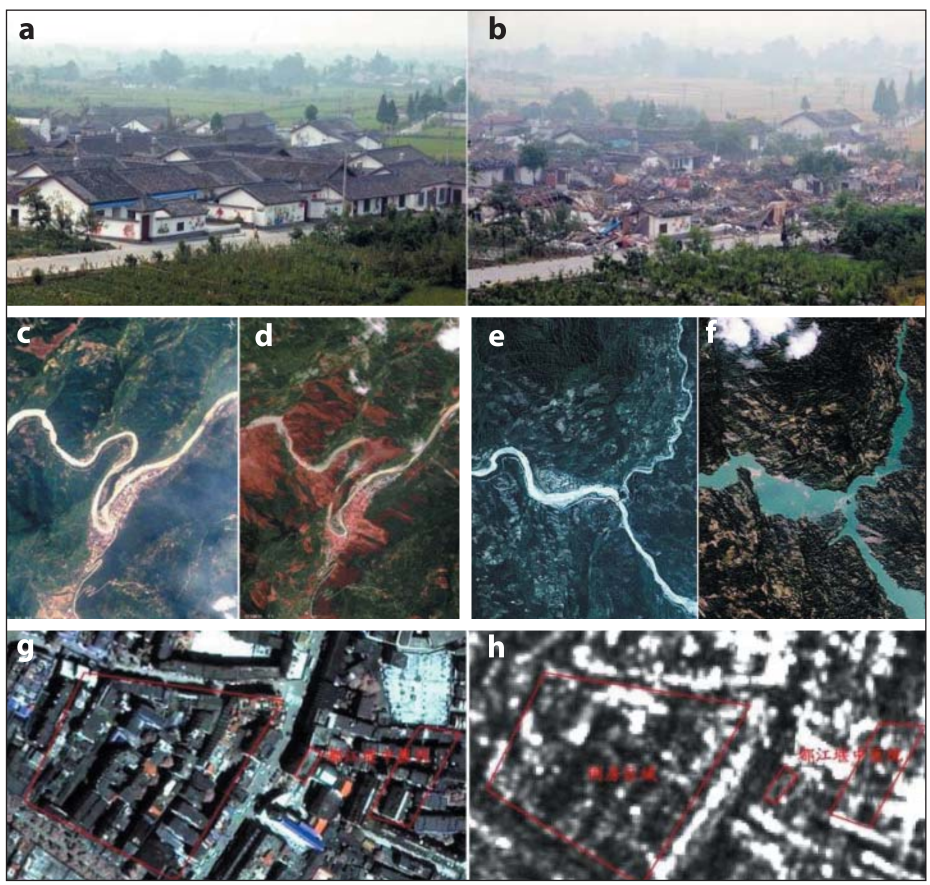

Fig. 1. Photographs and satellite images acquired before and after the 12 May 2008 Sichuan earthquake were used for hazard assessment. The first image pair shows Penghua Village in Mianzhu (a) on 11 August 2006 and (b) on 16 May 2008 (photographs from Xinhua Press). Next, FORMOSAT 2 satellite images show the town of Qushan, Beichuan County, taken (c) 14 May 2006 and (d) 14 May 2008. Brown areas in Figure 1d show the forest areas devastated by the earthquake (image from Taiwan's space organization (NSPO)). Another image pair shows (e) the Jianjiang River before the earthquake on 14 May 2006 (image from NSPO) and (f) the same swath from FORMOSAT 2 acquired on 22 May 2008 (10 days after the earthquake), showing the Tangjiashan Barrier Lake, created by blockage from earthquake-induced landslides. The final image pair shows (g) a high-resolution IKONOS image (1-meter resolution) of the city of Dujiangyan before the earthquake (from National Disaster Reduction Center of China), compared with (h) a synthetic aperture radar image (3-meter resolution) taken of the same swath on 13 May 2008 by Italy's Constellation of Small Satellites for the Mediterranean Basin Observation (COSMO-SkyMed). Bright spots in Figure 1h represent light scattering from many collapsed buildings.

The lower-frequency L-band SAR can penetrate deeper into vegetation cover, overcoming several limitations of conventional C-band SAR applications in landslide studies. The L-band SAR is therefore much less sensitive to temporal decorrelation induced by vegetation changes, and it is more suitable for monitoring slope deformations [*Strozzi et al.*, 2005]. Some L-band SAR images (such as PALSAR/ALOS) were used to monitor ground surface deformation across the earthquake-affected areas. According to analysis by Linlin Ge, a scientist at University of New South Wales, Australia, the ground displacement was more than 120 centimeters in Wenchuan County.

Earthquake Hazard Assessment Using Multisensor Satellite Images

In summary, satellite images have been used for evaluating natural hazards such as the 12 May 2008 Sichuan earthquake. High-resolution optical satellite images can yield direct visual interpretations for disaster assessment. However, the limited availability of optical sensing data due to cloud cover makes it impossible to monitor natural hazards in all weather conditions. SAR data are, however, more likely to be available in the immediate aftermath of an event due to the all-weather capabilities of the radar sensor. Differential InSAR can be used for tectonic deformation analysis of ground movements due to earthquakes. If satellite remote sensing data are used more effectively, they may be able to reduce unnecessary suffering during damaging environmental events. For example, in future applications it would be of benefit to make more extensive use of combining optical and SAR images and of image fusion techniques.

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MEETINGS

Mineral Dust and Climate

Working Group on Dust and Climate Joint INQUA/QUEST Workshop; Villefranche-sur-Mer, France, 19–22 October 2008

PAGE 139

Mineral aerosol (referred to here as "dust") is an active climate and paleoclimate system component that may significantly influence the radiative properties of the atmosphere, as well as ocean and atmospheric carbon dioxide (CO_2) concentrations, through processes such as iron fertilization. The integrative, cross-cutting examination of the role and significance of dust provides the rationale for the Dust Indicators and Records of Terrestrial and Marine Paleoenvironments (DIRTMAP) working group sponsored by the International Union of Quaternary Research and the Natural Environment Research Council's Quantifying and Understanding the Earth System (QUEST) program. The working group aims to initiate coordinated progress to improve the representation of dust properties in dust cycle models, with particular focus on dust mineralogy, such as the concentrations of iron oxides and oxyhydroxides as either nanoparticles or mineral coatings, and particle size distribution. These two sets of factors are potentially significant in assessing the effects of dust on both radiative forcing and biogeochemical cycling. The working group also aims to improve model simulation of dust source regions, the episodic nature of dust emissions, and amounts of dust deposition over the continents.

A recent DIRTMAP workshop brought together 15 scientists from around the world, including representatives of the modern data and paleodata communities, dust cycle modelers, and specialists in the modern biogeochemical aspects of dust. Initial presentations provided an overview of the state-of-the-art research spectrum, including modeling, database, and dust source and emission studies.

Workshop presentations discussed new modeling and laboratory experiments to assess the significance of dust properties for both radiative forcing and biogeochemical cycling. The working group believes that enhanced data synthesis (including fluxes, mineralogy, and particle size) would help these efforts and can be accomplished through direct interaction with the modeling community.

The DIRTMAP working group agreed to produce an updated version of the DIRTMAP database. The updated database, DIRTMAP3, will incorporate (1) new records and age models that have become available since 2001; (2) longer records, and particularly high-resolution records, targeting specific time windows (e.g., within the last glacial stage; the ~1400-year periods of rapid North Atlantic warming and slow cooling, known as Dansgaard/Oeschger cycles; and the last interglacial stage, known as marine isotope stage 5e); (3) metadata to allow objective quality control; (4) additional data fields for information on particle size distribution, mineralogy, and isotopes, each relevant to locating dust sources, understanding radiative forcing, and investigating the availability of iron to phytoplankton; and (5) enhanced characterization of the eolian component of new and existing records (including development of new proxies, such as thorium-232 and magnetic properties). These updates will be coordinated with work led by DIRTMAP1 creator Karen Kohfeld (Simon Fraser University, Burnaby, British Columbia, Canada) to incorporate information on marine productivity and improved techniques for estimation of sedimentation rates (for example, using thorium-230 normalization techniques to remove sediment focusing effects).

Workshop participants discussed possible modes of operation of the DIRTMAP3 database and agreed that a geospatially referenced access database would be the preferred option. Discussions are ongoing, but working group participants are exploring the option of having the enhanced database hosted at the World Data Center, Boulder, Colo., to ensure dedicated resources for database setup and management as well as maximized scientific access.

The working group also agreed to promote enhanced liaisons between the dust data, iron fertilization, and modern dust modeling communities, to ensure the most effective communication and interaction between the various areas of the dust research community, both modern and paleo-focused.

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