Satellite Imagery for Volcanic Hazards Mitigation

R. T. Helz
U.S. Geological Survey, M.S. 926A, Reston, VA 20192
G. A. Ellrod
National Oceanic and Atmospheric Administration, Camp Springs, MD 20746
G. Wadge
University of Reading, Reading RG6 6AL UK

As world population and urbanization increase, volcanoes pose an ever greater hazard to life, property, and infrastructure in volcanically active regions. The rise in air traffic world-wide increases the risk of encounters between airborne ash and aircraft, even at great distances from the source. The Committee on Earth Observation Satellites (CEOS), an international association of civilian space agencies, seeks to foster cooperation to increase the usefulness and accessibility of satellite imagery. In February 1997, CEOS initiated the Disaster Management Support Project to assess the present and potential use of satellite-derived information for the mitigation of several hazards, including volcanic hazards.

The final report of the CEOS Volcanic Hazards Working Group [1] reviews current use of satellite data for mitigation of volcanic hazards. The best-developed application is the use of infrared (IR) channels to detect and track volcanic ash clouds [2], which is now a basic tool of the global system of Volcanic Ash Advisory Centers (VAACs) and Meteorological Watch Offices (MWOs) that relay information on ash clouds to airports and pilots. Rapidly developing applications for observing volcanic activity close to the source include IR monitoring of hot spots and lava flows, and using interferometric synthetic aperture radar (InSAR) to detect deformation and other topographic changes preceding and caused by volcanic eruptions.

The report specifies the minimum spectral channels needed for effective remote sensing of volcanic hazards, together with recommendations for threshold and optimum spatial and temporal resolutions. Spectral bands used in detection of volcanic ash and surface-based hazards are, besides the visible (0.5-1.0 microns), a range of IR bands, especially those centered near 1.6, 3.9, 7.3, 8.5, 11 and 12 microns. Dual ultraviolet (UV, 0.3 - 0.4 micron) channels, although limited to daytime use, are valuable for assessment of ash and sulfur dioxide (SO_2) plume extent and total mass.

The report notes that the meteorological satellites, with a pixel size of 1 to a few km square, are generally well-adapted to monitoring volcanic ash and aerosol plumes, even though they have not been designed for that purpose. Although somewhat low in spatial resolution, the frequency with which images are taken (every 15-30 minutes) is sufficient to allow effective tracking of volcanic plumes. The main limitations of the current systems are: (1) blocking of volcanic plumes by clouds at higher levels, (2) interference from ice or water vapor [2,3], (2) reduced capability at night, and (3) limited ability to detect small-scale events. Impending loss of the 12 micron band on some new geostationary satellites represents a step backward, as that particular band is essential to identify silicates in aerosols. The recommendation of the report is to expand the number of bands on geostationary and other meteorological satellites, not decrease them.

Review of the use of satellite imagery for assessment of the onset of eruptions and monitoring of proximal hazards shows that current satellite systems are in general less well adapted to these applications. One application (using meteorological satellites to detect a thermal signal, in order to identify volcanic activity in real time) is fairly well-developed [4]. However, given that volcanic eruptions can be very short, and that the heat sources associated with them are often 10's or 100's of meters in size (though very hot), there are intrinsic problems with the meteorological satellite imagery, both in timeliness and spatial resolution: There are typically gaps of 4-6 hours between passes for polar orbiting satellites, and pixel size is 4 km and higher on geostationary satellites. This application has been further complicated by high false alarm rates (from other heat sources or from reflection) and by the presence of clouds. Once an eruption has begun, the spatial resolutions of some low earth orbit systems are sufficient for tracking the activity, but temporal resolution (once every 16 days for Landsat and similar satellites), problems with cloud cover, lack of rapid access to imagery, and cost remain important barriers to effective use of such imagery by the volcanological community.

Some of the most promising applications of satellite imagery to volcanic hazards assessment and mitigation are in the areas of (1) monitoring deformation [5], (2) documenting substantial changes in topography at volcanoes (such as emplacement of lava or pyroclastic flows [6], or major slope failure), and (3) in generating high-quality topographic data for volcanoes. These applications depend on the availability of SAR imagery, and of stereo imagery. Current systems include ERS-2, the new ENVISAT, and (for topography and stereo) the ASTER sensor on the TERRA satellite. Existing C-band SAR imagery has been successfully used for all of these applications, with two notable limitations: it is not possible (with present or projected capabilities) to monitor a growing dome, or other part of a volcano, where the surface itself is not simply deforming but is continually changing. And the C-band SAR shows complete decorrelation in all but sparsely vegetated areas. There is an urgent need for L-band radar to expand InSAR applications in vegetated areas, which include most volcanoes in the tropics . The single most important and widespread contribution that space-based imagery could make to improved volcanic hazards mitigation, however, would be the generation of higher-resolution topographic maps and digital elevation models for all of the world's active volcanoes, with priority given to those in populated areas.

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