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Latin America Volcano Monitoring With ALOS

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Deformation of the Earth's surface at volcanoes provides clues to the myriad processes occurring below and above the surface, and might provide warning of an imminent eruption. Unfortunately, experience has shown that different volcanoes have different behaviors before eruptions, such that a history of precursory activity and eruption should be established for each individual volcano. As of 1997, surface deformation had been observed at only 44 different volcanoes using ground-based methods (e.g., traditional surveying, tiltmeters, or Global Positioning System) out of the more than 1,500 potentially active volcanoes around the world [Dvorak and Dzurisin, 1997]. In the last decade or so, observations of deformation at volcanoes have more than doubled to about 110, due largely to the use of satellite-based Interferometric Synthetic Aperture Radar (InSAR).

One limitation of these InSAR studies has been the difficulty in applying the available C-band radar data (wavelength of 5.6 cm) to vegetated volcanoes like the 300 Holocene volcanoes in Latin America [including Mexico, Central America, the Caribbean, and the Northern, Central, Southern, and Austral Andes (see Figure 1)]. L-band radar data (wavelength of 23.6 cm) from the Japanese Advanced Land Observing

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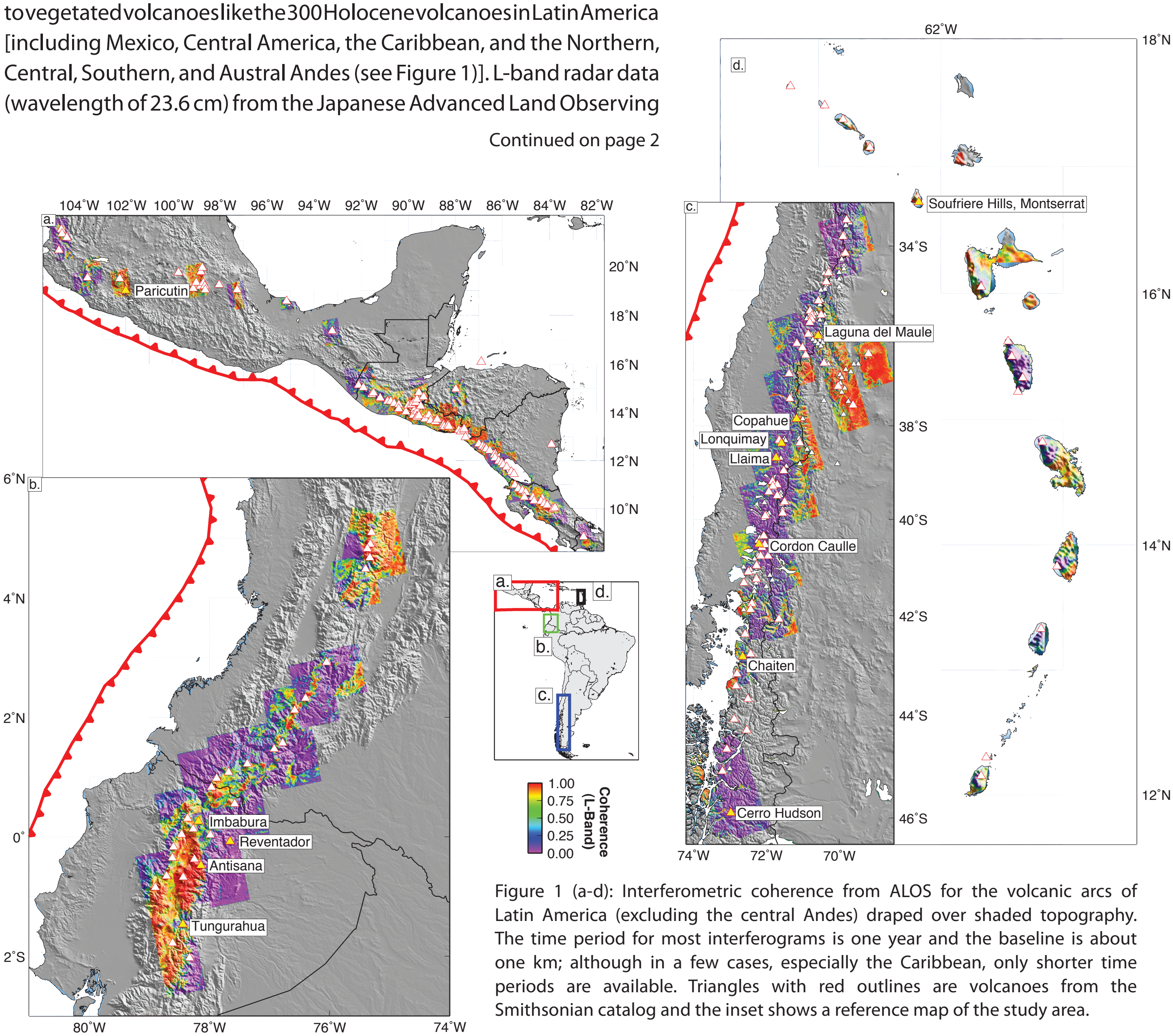

Figure 1 (a-d): Interferometric coherence from ALOS for the volcanic arcs of Latin America (excluding the central Andes) draped over shaded topography. The time period for most interferograms is one year and the baseline is about one km; although in a few cases, especially the Caribbean, only shorter time periods are available. Triangles with red outlines are volcanoes from the Smithsonian catalog and the inset shows a reference map of the study area.

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Satellite (ALOS), archived at the Alaska Satellite Facility (ASF), are more successful at imaging the deformation of Latin American volcanoes.

The data from ALOS is used to make preliminary surveys of the volcanoes of Central America, the Caribbean, and the Northern and Southern Andes with data that spans 2006-2008. Not included, are the more arid Central Andes as previous C-band studies have already revealed eight areas of volcanic deformation. While the survey is spatially comprehensive, it is quite possible that some deformation was missed that is small in magnitude or spatial scale or temporally aliased. Because data acquisitions are infrequent, data quantity and quality are not uniform across all volcanoes. Nonetheless, the new observations reveal volcanic deformation in 11 different areas. Several of these areas were thought to be dormant by the science community, demonstrating the current incompleteness of global-volcano monitoring and the potential for ALOS data to reveal unsuspected activity.

In the Northern Andes, data quality, or for these purposes coherence of the InSAR signal, seems to be highest at high elevations where there is no snow and less vegetation (Figure 1b). A 46-day repeat provides coherent interferograms in the vegetated lowlands when the spatial baseline is small and/or when spatial averaging is applied. For longer time spans, the lower elevation regions become decorrelated. In the Southern Andes, it is necessary to avoid austral winter. Even considering summer only, coherence is the lowest in the foothills on the western side of Cordillera (Figure 1c) which receives the most precipitation and has the most vegetation. In the Caribbean (Figure 1d), the coherence is the lowest of any region studied and the short time-period interferograms with small baselines are essential. Vegetation and terrain cause the most problems, with the inland areas of most of the islands becoming decorrelated the fastest. In the Northern Andes, Central America, and the Caribbean, the L-band coherence results are clearly superior to previous C-band results from these areas (e.g., Zebker, et al., 2000). On the other hand, L-band is more sensitive to ionospheric effects than C-band and such effects are observed in a few percent of scenes from the Northern, Central, and Southern Andes.

With good control of the orbital baseline (<250 m), the conclusion is that at L-band, sufficient coherence is maintained for volcanic applications in vegetated areas at 46 days, most of the time. Sufficient coherence for interferograms will not be possible all of the time, as shown by incoherent L-band interferograms made by InSAR systems on aircraft and on the space shuttle with baselines spanning one to 7 days. The incoherence in the interferograms has been associated with weather systems. Furthermore, 46-day interferograms do not work in most snow or ice areas (e.g., the volcanoes of the Southern and Austral Andes during austral winter). A significant fraction of volcanoes around the world have snow cover for at least part of the year. A shorter repeat time for future InSAR systems [like the National Aeronautics and Space Administration's (NASA) proposed Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) InSAR mission] will maximize the chance that there will not be a precipitation, wind, or melting event that might diminish coherence.

References:

Dvorak, J. J., and D. Dzurisin (1997), Volcano geodesy: The Search for Magma Reservoirs and the Formation of Eruptive Vents, Rev. Geophys., 35, 343-384.

Zebker, H. A., F. Amelung, and S. Jonsson (2000), Remote Sensing of Volcano Surface and Internal Processes Using Radar Interferometry, in Remote Sensing of Active Volcanism, Geophys. Monogr. Ser., Vol. 116, edited by P. J. Mouginis-Mark, J. A. Crisp, and J. H. Fink, pp. 179-205, AGU, Washington, D.C.

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Quad Polarization PALSAR Radar, Radar Texture, and Optical Data for Land-Cover Classification

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Faculty and students within the Department of Geography at George Mason University in Fairfax, Virginia, have conducted research with radar and the integration of radar and optical data for improved land-cover mapping for many years. Much of that work has been possible by acquiring RADARSAT-1, and more recently ALOS Phased Array L-band SAR (PALSAR), data from ASF.

The basic research included two related activities: 1) examining methods to improve digital classification of land cover by extraction of radar-derived data layers, and 2) comparing radar and optical data results with the option of integrating them to assess multisensory classification accuracy. These were important as most of the spaceborne systems were single wavelength and single polarization, thus greatly limiting digital-classification strategies.

The primary method to extract radar-derived values was by using various texture measures. Variance, mean Euclidean distance, kurtosis, and skewness were often evaluated at different window sizes ranging from 5x5 to 13x13. Very frequently, texture measures provide improved classification accuracies sometimes for individual classes and often for overall accuracies over the original radar. Merging texture and original radar measurements generally results in better accuracies. Other spatial methods that have been examined include the comparison of despeckle techniques with different window sizes, despeckling at a small window size, then extracting texture at a larger window size, and post-classification filtering.

The classification results from radar and radar-derived values were compared to those from registered optical [Landsat Thematic Mapper (TM), SPOT, ASTER] data using the same classification and accuracy assessment methods. Different methods to integrate the radar, radar-derived values, and optical data were examined to evaluate multisensor classification accuracies. These methods included relative weighting of bands from the respective sensors and use of principle components analysis.

Recently, the Department has used quad-pol PALSAR data provided by ASF for studies in Bangladesh (Figure 2a), Sudan, Kenya (Figure 2b), California, and Washington, D.C. The PALSAR data were obtained at a 12.5-m spatial resolution and ASF remote-sensing software, MapReady, was used for pre-processing the imagery.

The recent, more-widely available, quad-polarization radar, such as PALSAR, increases the usefulness for feature delineation and allows for comparison of the various polarizations. For example, for four land covers in the Kenya scene, the VV polarization provided an overall accuracy of 85 percent versus 62 to 71 percent for the other three bands.

The use of radar texture on PALSAR images was often a useful procedure for increasing the capability to distinguish among the different land covers.

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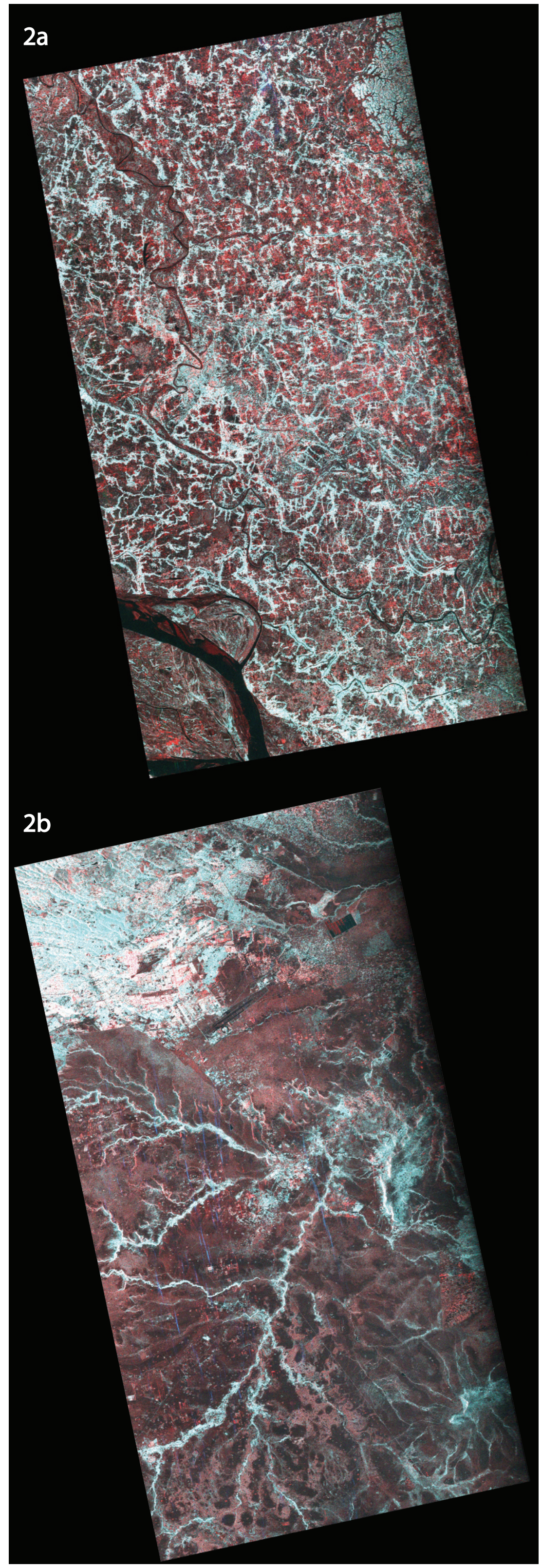

Figure 2a: PALSAR image (65 km by 35 km) for Bangladesh, acquired 14 March 2003. 2b: PALSAR image (65 km by 35 km) for Nairobi, Kenya, acquired 12 May 2007. Polarization for both images is HH, HV and VH; RGB.

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Generally, the Variance measure was best among those examined and the appropriate window size will vary by location. In Bangladesh, using a Variance 7x7 window, the producer's capability to classify agriculture increased from 71-percent accuracy using four original bands to 90 percent using a combination of radar and texture. In Kenya, the producer's accuracy for urban increased from 64 percent in the original radar to 87 percent using texture.

The question of whether classification accuracies can be increased by fusing multisensor data has been an important issue in the remote-sensing community. For these sites, the fusing of PALSAR with optical imagery, yielded better classification accuracies as opposed to taking either data set individually. In Bangladesh, the overall accuracy for radar was 91 percent and increased to 98 percent with a merge of Landsat TM and radar texture. In Kenya, the original radar had an overall accuracy increase from 77 percent with radar to 86 percent with Landsat TM and radar texture.

The wider availability of multiple-polarization spaceborne radar has made available to the geospatial industry a great wealth of data. There is good evidence in these studies that radar-derived measures and the merger of radar and optical data can be useful strategies in classifying land cover in diverse regions around the world.

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