Satellite methods for monitoring volcanic activity in the Andes Cordillera

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The central part of the Andes situated between southern Peru and Chile bears 50 active or potentially volcanoes, spread along a 1500 km-long arc. These volcanic structures mostly rise to between 4000 and 7000 m, are very remote with abrupt slopes and are often cloaked in snow. Few studies have been made on them as such conditions make field surveying extremely difficult.

A team of IRD researchers working in partnership with the University of Chile (Santiago) and the Observatoire de Physique du Globe of Clermont-Ferrand focused special attention on the Lastarria-Cordon del Azufre volcanic complex. With a surface area of 1600 km^2, it is situated in the central Andes Cordillera at the border between Argentina and Chile near Antofagasta.

Research projects on deformations of the earth crust, conducted in this region between 1992 and 2000 by a North American team, had led to the detection of a long wavelength signal over the area's topography, extracted from analysis of data collected by the European Space Agency (ESA) satellite ERS-1. This deformation would correspond to crustal inflation affecting the whole Lastarria-Cordon del Azufre complex. Although this volcano is not considered as active, as the last eruption dates back 9000 years, such inflation could express an underlying activity related to the dynamics of a functioning magma chamber.

IRD geophysicists continued such investigations on the deformations at work in the Lastarria-Cordon del Azufre complex in 2003, by using

radar interferometry. This measurement method is based on the superimposition of two satellite radar images of the same geographical area taken at different times. The resulting differential signal between the images, termed the interferogram, provides a way of detecting possible deformation of the earth crust. The value of the wavelength associated with it is proportional to the depth of the source of deformation, down in the lithosphere. For this study, the scientists made use of data acquired by ENVISAT, a satellite ESA launched in 2002. Its ASAR (Advanced Synthetic Aperture Radar) sensor enables it, like its predecessors ERS-l, ERS-2, to perform radar imagery in any weathers. This attribute proves particularly useful for surveillance of the mountainous regions of Latin America.

Between March 2003 and June 2005, ENVISAT recorded a time-series of eight images of the Lastarria-Cordon del Azufre volcanic complex. The IRD team used special software to process the images and obtained 28 interferograms. This data set led to measurement of inflation of about a centimetre affecting the crust over the whole of the area studied . As in the North American study, a long wavelength regional-scale signal was found, covering a surface area of about 45 km long by 35 km wide corresponding to the entire volcanic complex. A short wavelength signal not previously identified was also revealed, but unlike the first, it was located at the smaller scale of the Lastarria volcano only.

Two distinct hypotheses are envisaged to explain the emission of these two wavelengths. As the inflation measured at regional scale corresponds to a long wavelength signal, it has a fairly deep source, estimated by the geophysicists at between 7 and 15 km down. An inflation located at such a depth is highly likely to be generated by magmatic activity.

The source of the short wavelength signal, located at about 1000 m beneath the summit of the Lastarria volcano, is more uncertain, however. Indications nevertheless suggest a link with the circulation of

hydrothermal fluids.

Future forecasting of the possible evolution of the Lastarria-Cordon del Azufre volcanic complex requires the acquisition of field data to complement the satellite data obtained. GPS measurements especially will enable researchers to check if these inflation effects measured using satellite data effectively correspond to movements of the earth crust.

The hope is to obtain further information on changes of mass or density at depth using gravimetry, a geophysical method used for detecting the spatial and temporal variations of the gravity field. Thus, a modification of gravity combined with a displacement of the terrestrial crust could indicate a filling or an emptying of a magma chamber and therefore confirm an underlying volcanic activity. If this turned out to be true, the Lastatria-Cordon del Azufre volcanic complex would be the only area under the Andes where the formation of large magma reservoirs has been demonstrated. In the future, such observation methods could be applied to studying volcanic activity in many regions, like the Andean Cordillera, where access is difficult and thus make the surveillance of volcanic structures as effective as possible.

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