Biennial report for Permanent Supersite

Ecuadorian Volcanoes Supersite

Proposal documents	
Acceptance letter(s)	
Previous reviews	*n.a.*
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Science teams

Team 1	*Anieri Morales, Univ. of Miami, Fl-USA* *Falk Amelung, Univ. of Miami, Fl-USA*	*amorales@rsmas.miami.edu* *famelung@rsmas.miami.edu*
Team 2	*Susanne K Ebmeier, Univ. of Leeds, UK*	*s.k.ebmeirer@leeds.ac.uk*
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Team 4	*Paul Lundgren, JPL-NASA- CA-USA*	*Paul.R.Lundgren@jpl.nasa.gov*

Science team issues

Graduate students Anieri Morales, and until-recently post-doc Susanne Ebmeier have worked on and published using the Supersite data. Soon more publications are forthcoming. The team leader, Patricia Mothes is seeking a graduate student to work on certain InSAR topics. Co-leader Falk Amelung is starting a project on-going low level deformation within the caldera of Pichincha volcano, just 12 km W of Quito, Ecuador´s capital.

In situ data

Type of data	Data provider	How to access	Type of access
Data of 24 GPS stations available on UNAVCO website	*IGEPN……*	***http://www.unavco.org/***	*Freely available*
Catálogo Sísmico IGEPN de 2012 hasta Agosto de 2016 **Open data request**	……	***www.igepn.edu.ec***	***Request on front of web page***

Real-time Seismic spectrograms, helicorder & infrasound plots; **Data from 19 BB seismic stations available on IRIS site.** **All seismic locations and maps of events w/ 3 mag. or greater** **Processed Recent GPS Plots** **Lengthy analytic reports with plots on volcanic activity, per volcano** **Live webcam footage on 5 volcanoes**	

In situ data issues

When data is requested it is generally given. We seek one-to-one collaborations and want to form a relationship with data users of the IGEPN´s large data base and work on science projects together.

Our web site has a wealth of real-time monitoring data freely available, which forms the basis of inquiry for interested earth scientists. We are working to a more open data base, but the development is on-going. We have worked with UNAVCO to get data from 24 CGPS stations uploaded. This task has been very difficult because we are not using their system called "DataWorks" which facilitates such processes. Our many collaborations include scientists from IRD, JICA, Leeds, neighboring Colombia and Peru, Penn State, Fairbanks, Florence, USGS, North Carolina, Bristol and Miami, among others.

Satellite data

Type of data	Data provider	How to access	Type of access
COSMO-SkyMed	*ASI*		*Via SuperSite coordinator P. Mothes, interested scientists must read and initialize* *all pages of ASI´s license agreement for CSK data* *Coverage: Cotopaxi and Tungurahua volcano*
TerraSAR-X	*DLR*		*Freely available from DLR after ordering* *Coverage: Pichincha and Tungurahua voclanoes* http://webservices.unavco.org/brokered/ssara/gui?collectionName=Geohazard.Supersite.TerraSAR-X_SSC&intersectsWith=POLYGON((-79.2 1.4,-77.7 1.4,-77.7 -3.4,-79.2 -3.32,-79.2 1.4))&output=map
Sentinel 1	*ESA*		*All volcanoes: Readily available from the ASF or ESA.*
RADARSAT-2	*CSA*	*.ACP format via Adq. Plan. Tool; NEODF*	*Written request to P. Mothes or F. Amelung*

account info

A top priority is to develop an optimal observation strategy for all potentially hazardous volcanoes in Ecuador, as a function of the vegetation type, sensor wavelength and repeat time. This requires the analysis of 0.5-year time series from each sensor for each volcano. As the first 2 years of the Supersite were characterized by the response to volcanic crises at Chiles and Cotopaxi volcanoes, and because of quota and ordering limitations described below, this task has not been completed. The following gives the status, and the next steps.

1. Cotopaxi: CSK, TSX Spotlight and Sentinel-1 all work very well. For this volcano everything is in place.

2. Chiles-Cerro Negro: Initial work using TSX and CSK was successful. However, X-band need to supplemented with another sensor because of potential temporal gaps. We need to test Rsat-2 and ALOS-2. Sentinel-1 worked very well.

3. Pichincha: Preliminary data suggest that TSX stripmap works but additional data are required because of temporal gaps. We need to test whether Rsat-2, Sentinel-1 and ALOS-2 can fill these gaps.

4. *Tungurahua:* Preliminary data show that it is not well-suited for CSK and TSX. Alos-1 worked well. We need to test Rsat-2, ALOS-2 and Sentinel-1. Our current expectation is to use Rsat-2 but it is unclear whether the volcano is covered using a well-suited mode.

5. *Cayambe:* We plan to test whether this volcano can be monitored by Sentinel-1. It would be preferred to use Rsat-2 but the quota does not allow this.

6. *Reventador and Sangay:* Lower priority.

Satellite data issues

We highly appreciate the SAR data provides by CEOS.

We take this opportunity to suggest improvements. In the absence of InSAR expertise at IGEPN, data used to be ordered by graduate students at Bristol and Miami. As those students have moved on, no recent data have been ordered. It would be a tremendous help if the burden of data ordering could be removed from the Supersite team, which is the only component in the data analysis chain that requires human interaction. We are currently investigating whether Unavco could assume this responsibility. Our current priority is to understand the value of Sentinel-1a, b for this Supersites, because data are available online.

Details:

CSK: The bottleneck is that spreadsheets need to be emailed to ASI. Once the order is received, the data are automatically ingested into the Unavco system. It would be helpful if data ordering could be automated. We appreciate that ASI takes care of data acquisition and we don't need to worry about whether data exist. *Request to ASI:* Implement automated data ordering.

TSX: Both, the image acquisition and data production need to be requested using the DLR EOweb system (using an older computer system). Data are disseminated via the DLR Supersites server. A risk is that the ordering of acquisitions may be forgotten and no data exist. In addition, the DLR Supersites system is not fully compatible with the SSARA system, making the download of imagery difficult (details: (1) some metadata on the DLR server and visible in SSARA are not associated with any imagery because some zip files contain multiple data sets. (2) need of cookie and its limited validity). *Request to DLR:* (1) work with Unavco to resolve SSARA compatibility issues.

Rsat-2: In our experience from Rsat-1, this sensor is best suited from all current sensors for volcano monitoring because it is C-band and has high-bandwidth modes. Our plan was to acquire for the relevant volcanoes test data in different modes in order to determine which mode works best. However, this has not been possible because of the low quota (50 scenes total) and complex data ordering procedure. Furthermore, it is unclear whether the relevant volcanoes are continuously covered using well-suited modes. Because of all these complexities, this sensor has not been used. *Request to CSA:* (1) cover all relevant volcanoes using Wide Ultra Fine mode every 24 days so that good data will be available for the next crises, (2) annual quota of 45 scenes so that 3 volcanoes can be covered.

Sentinel-1a,b: For this sensor all imagery is openly available and convenient to use. Currently we have mostly only 24-day coverage. There are no (or very few) Sentinel-1B imagery. Preliminary results indicate that 24 day repeat works for some volcanoes. 6-day coverage would work. *Request to ESA:* Cover all volcanoes with both Sentinel-1A,B every 12 days to obtain 6-day repeat.

Alos-2. This sensor would be very valuable for densely vegetated volcanoes but is not available from the Supersites. We are trying to use Alos-2 data from different data sources. *Request to JAXA:* Participate in GSNL and provide data.

Research results

In our Supersite proposal 3 objectives were listed: (1) volcano monitoring from space, (2) promote and facilitate fundamental research by the international scientific community, (3) access to satellite imagery in the event of disasters

Publications

Peer reviewed journal articles

Ebmeier SK, Elliott JR, Nocquet JM, Biggs J, Mothes P, Jarrín P, Yépez M, Aguaiza S, Lundgren P and Samsonov SV (2016). Shallow earthquake inhibits unrest near Chiles–Cerro Negro volcanoes, Ecuador–Colombian border. Earth and Planetary Science Letters, Volume 450, 15 September 2016, Pages 283–291.

Morales R A, Amelung F, Mothes P (2016). Volcano deformation survey over the Northern and Central Andes with ALOS InSAR time series. Geochemistry Geophysics Geosystems, June. DOI: 10.1002/2016GC006393.

Anieri M. Morales Rivera, Falk Amelung, Patricia Mothes, Sang-Hoon Hong, Jean-Mathieu Nocquet, and Paul Jarrin (In final revision-2017). Ground deformation before the 2015 eruptions of Cotopaxi volcano detected by InSAR. Submitted to Geophysical Research Letters.

Conference presentations/proceedings

-Amelung F., et al., 2017. InSAR monitoring of volcanoes in Ecuador, Japan, Hawaii and Mexico. IAVCEI General Assembly, Portland-USA, August, 2017

-Amelung, F., et al., 2017. Deformation monitoring for the Ecuadorian Volcano Geohazard Supersite. Fringe meeting in Helsinki, Finland, June 2017

-Morales A., 2016. Ground Deformation during the 2015-2016 Eruption of Cotopaxi Volcano from InSAR and GPS. Fall AGU, San Francisco-CA

-Anieri Marie Morales Rivera, Fabien Albino, Falk Amelung, Patricia M Gregg and Patricia A Mothes. (2015) Volcano Deformation Sources at Tungurahua Volcano from Finite Element Methods and Multidisciplinary Data Integration. AGU abstract, ID# 72627, San Francisco CA.

Research products

Type of product	Product provider	How to access	Type of access
(https://github.com/yunjunz/PySAR)	Heresh Fattahi and Yunjun Zhang		…
http://insarmaps.miami.edu	…	…	…

Research product issues

Dissemination and outreach

The direct access to the Ecuadorian Volcano Supersites is on the IGEPN´s website front. The IGEPN has tens of thousands of viewers, especially during a crisis. http://www.igepn.edu.ec/nosotros/the-ecuador-volcano-supersite

Funding

All ground-based monitoring of Cotopaxi, Tungurahua and Cerro Negro volcanoes has been carried out under the national budget of the Instituto Geofísico of the EPN-Quito.

Societal benefits

The Stakeholders are the population living around large, dangerous and active volcanoes such as Cotopaxi and Tungurahua. The best way to monitor for ground deformation over such large stratocones is via InSAR. When local scientists have this perspective they are able to communicate more effectively with the local officials and the public in general about potential volcanic hazards and the impacts. Nonetheless, both of these volcanoes and others also benefit from CGPS networks which provide ground truth.

Conclusive remarks and suggestions for improvement

I believe that the Ecuadorian Volcano Supersite has performed moderately well in its first two years. Fortunately we had mild eruptive activity and magma intrusions on such large stratocones as Cotopaxi, and a magma chamber-fault interaction near Cerro Negro volcano on the Ecuadorian-Colombian border. These experiences have been published and also presented orally at international scientific venues. Other volcanoes in Ecuador continue to merit close attention due to sharp jumps in seismicity or dike intrusions, such is the case of Cayambe and Cerro Azul in Galapagos, respectively. The seismic and CGPS networks on these volcanoes, operated by the IGEPN have served to demonstrate the state of unrest of the volcanoes.