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| **Pilot Name:** Volcano |
| **August 2016** | **PI or PoC:**Mike Poland and Simona Zoffoli | **Collaborating organisations:**USGS, ASI, CNR/IREA, University of Bristol, Cornell University, University of Miami, Pennsylvania State University, NOAA, Open University, University of Iceland, INGV |
| **Achievements:** * Processed numerous interferograms for the volcano Supersites, particularly in Hawai‘i spanning the May 2015 summit intrusion at Kīlauea Volcano
* Characterized deformation and ash emissions associated with the April 2015 eruption of Calbuco volcano, Chile
* Supported local scientists in their response to ongoing unrest at Cotopaxi volcano, Ecuador
* Characterized inflation of Fernandina volcano, Galapagos
* Detected and modeled deformation at Cerro Negro / Chiles volcanoes on the Ecuador-Columbia border
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| **Activities**: * We tested the utility of ALOS2 data for regional monitoring. Making interferograms using the wide-swath mode was mostly successful, but requires tweaking before we can order on a large scale.
* We responded to eruptive activity in Latin America, including at Calbuco (Chile) and Cotopaxi (Ecuador). Products have been distributed to local end users (especially volcano observatories and ash advisory centers), where they have aided in constraining such variables as erupted volumes and ash emissions.
* We have tracked unrest at several volcanoes in Latin America, including Chiles-Cerro Negro (on the Columbia-Ecuador border), where thousands of earthquakes suggest a reawakening of the system and may have triggered a nearby tectonic earthquake, and at Cordon Caulle (Chile), which is inflating following it’s 2011–2012 eruption. These insights have been provided to local scientists and managers, who have used them to inform their decisions about what is likely to occur at the volcanoes and how they should respond.
* We continue to support the volcano Supersites. In Hawai‘i, these data were instrumental in mapping deformation associated with a small intrusion at Kīlauea’s summit – the first such event in that area in over 30 years. Following the formation of the Ecuador supersite (for Cotopaxi and Tungurahua volcanoes), we are working with the space agencies to arrange data acquisition and distribution.
* We completed a data proposal to CEOS for Objective C of the project – monitoring a major eruptive event in a populated area. When we identify such an event, we should be prepared to order data immediately to track not just eruptive activity, but also pre- and post-eruptive changes.
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| **Data accessed this Q** (#images /satellite)ALOS2: 5COSMO-SkyMed: 213TerraSAR-X: 16RADARSAT-2: 39Numbers of images are only reported for Objective A, since C has not started and B has a different system for tracking orders. | **Total data accessed to date** (#images /satellite)ALOS2: 5COSMO-SkyMed: 313TerraSAR-X: 26RADARSAT-2: 139Pleiades: 3Note that we do not include Sentinel-1a data in these tallies, even though we make sue of them as part of the pilot, because those data are distributed at no cost and with no restrictions. |
| **Products:** (delivered this quarter)Interferograms, amplitude imagery, and other products derived from SAR dataAsh and thermal anomaly maps | **User** (by product)SERNAGEOMIN, Chile; Observatorio San Calixto, Bolivia; Instituto Geofísico del Perú; Instituto Geofísico de la Universidad Nacional de San Agustín, Peru; Instituto Geofísico, Escuela Politécnica Nacional, Ecuador; Servicio Geológico ColmbianoBuenos Aires Volcanic Ash Advisory Center; Argentinian government | **User or practitioner endorsement/opinion/outcomes**Data are being used by various government agencies to ascertain whether unrest at a volcano is related to magma ascent (which may inform installation of ground-based equipment and monitoring levels) and how eruptive activity is impacting the region (including location and hazard of ash plumes). The pilot has received numerous informal enthusiastic expressions of thanks and confirmation of the importance of these datasets from local volcano observatories, VAACS, and other government agencies, but during times of crisis there is little time to formulate a formal endorsement and provide feedback. Regarding the Supersites, major initiatives (MED-SUV and FUTUREVOLC) depend upon the data for scientific purposes, and in Hawaii Supersite data have been specifically identified as a critical resource by the Hawaiian Volcano Observatory for hazards monitoring and mitigation.  |
| **List any publications directly stemming from pilot work**Work related to Objective A has appeared in multiple on-line stories and newsletters:<http://comet.nerc.ac.uk/latest-earthquakes-and-eruptions/satellite-observations-of-the-ongoing-april-2015-eruption-of-volcan-calbuco-chile/><http://www.nerc.ac.uk/research/funded/programmes/resilience/bulletin-mar2015/>In addition, two articles were recently published that are relevant to Objective A, although they were initiated prior to the availability of pilot data:Muller, C., del Potro, R., Biggs, J., Gottsmann, J., Ebmeier, S. K., Guillaume, S., Cattin, P.-H., and Van der Laat, R. (2015). Integrated velocity field from ground and satellite geodetic techniques: application to Arenal volcano. Geophysical Journal International, 200(2), 863–879, doi:10.1093/gji/ggu444.Jay, J. A., Delgado, F. J., Torres, J. L., Pritchard, M. E., Macedo, O., and Aguilar, V. (2015). Deformation and seismicity near Sabancaya volcano, southern Peru, from 2002 to 2015. Geophysical Research Letters, 42(8), 2780–2788, doi:10.1002/2015GL063589.A presentation relevant to Objective C—a test response to a volcanic crisis in Fogo—was made at IGARSS 2015 (a paper on the topic is in preparation):Ferrucci, F., Hirn, B., Faria, B., and Zoffoli, S. (2015). Multi-payload multi-platform simultaneous tactical monitoring of major effusive eruptions in 2014. IGARSS 2015, Milan, Italy. Several presentations that make use of Pilot data will be made at the Fall American Geophysical Union meeting in December 2015, and a manuscript for the Journal of Applied Volcanology is in preparation (submission planned for 2016). |
| **List objective milestones and state progress to date (%)**Objective A (regional monitoring of Latin American volcanic arcs)* Our primary goal is systematic arc-wide monitoring of volcanoes in Latin America. Thus far, we are tracking activity at a large number of volcanoes in a coordinated fashion, but these are mostly scattered between Mexico and Chile. Study of individual volcanoes is helping us to refine our overall strategy—for example, identifying which satellites or wavelengths are best for volcanoes in forested versus desert terrain. However, more work needs to be done on overall, regular reconnaissance, which currently relies upon ALOS2 data (see point below) and Sentinel due to their wide swath modes and the fact that they cover the entire region. We also require a large team to compete the task, given the substantial numbers of volcanoes across the region. The team is now in place, but the archive of available Sentinel and ALOS2 data is still relatively small—it will take at least another 6 months for sufficient acquisitions to be made. We anticipate that we are on pace to achieving overall monitoring of all volcanoes and focused analysis of restless/erupting sites in 2016. (60% complete)
* We are ordering ALOS2 data, but have not yet begun ordering on a large scale for regional deformation analysis owing to small bugs in data processing. (10% complete)
* We have added new partners to focus on Mexican and Central American volcanoes, so all of Latin America is now covered by expert scientists and the volcano pilot team is largely complete. (100% complete)
* Initial pilot evaluation, including feedback from end users, has been provided for use in World Conference on Disaster Risk Reduction presentation. (100% completed)
* We continue to examine individual volcanoes and volcanic regions for signs of deformation, thermal anomalies, and ash, reporting results as they become available to users at volcano observatories and ash advisory centers, and have covered roughly half of all volcanoes in the arc in one way or another. (50% complete)
* We will write a Journal of Applied Volcanology article describing the results of our work, and especially the value to end users, to be submitted in 2016. (0% complete)

Objective B (support volcano supersites)* We continue to support exploitation of Supersite data in Hawaii, Iceland, Italy, and now Ecuador, the last of which is a new volcano Supersite. (50% complete)

Objective C (response to major eruption)* Completed and submitted proposal for data in advance of a major eruption, preferably in SE Asia. (100% complete)
* Have not yet identified a volcano that is likely to have a significant impact in local population or infrastructure and that would be well suited for study as the Objective C target. (0% complete)
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| **Issues identified and risk management approach*** There continues to be poor coordination among users of some Supersite data (Hawai‘i, for example). This persistent issue will need to be addressed by the Supersites initiative team at some point in the future.
* Most products delivered continue to be derived from InSAR, although we are making more attempts to integrate InSAR and thermal datasets, and SAR amplitude imagery have been used to map changes at some erupting volcanoes (including Calbuco and Cotopaxi). Still, more effort needs to be targeted towards data integration.
* Obtaining helpful feedback is a challenge. Nearly all agencies we have talked with have responded by saying things like “yes, interferograms are valuable” but detailed feedback has not been provided in a formal way. This is not surprising given how busy most volcano monitoring agencies in Latin America are (data products are most useful during a crisis, which is also when end users have the least amount of time to provide feedback). However, we do know that the satellite data have been useful to the observatories as they assess the hazard from increased level of seismic and degassing activity (i.e., is the ground deformation caused by magma moving toward the surface?), plan installations of future sensors in new areas of unrest found by the satellite sensors, and determine the alert level for volcanoes (in particular by validating or not the limited ground-based deformation sensor networks). To further document this feedback, we are developing a questionnaire that will be distributed to volcano observatories in Latin America at more convenient times.
* Although the Pilot team has invested a tremendous amount of effort in tracking activity at Latin American volcanoes, we have not yet formally reached out to other groups working in the region. A goal for the coming period is to establish ties to those groups so that our and their results are more complimentary and provide a complete picture of volcanic activity from Mexico to Patagonia.
* Some satellites have something of a random acquisition style—the mode or resolution of acquisitions over a given area changes frequently, leading to a lack of consistency in results and a lack of understanding of what acquisitions might be scheduled next. To alleviate this, we hope to develop an acquisition strategy for different satellite types that might be used by the space agencies for tasking to provide the most useful data for volcano disaster risk reduction.
* We are sensitive to limited data quotas. Although the space agencies have been quite generous in providing SAR data especially, for some volcanoes (especially those in vegetated areas) dozens of images are needed to glean a useful deformation result because time series methods are required to mitigate against atmospheric artifacts and poor coherence. It is therefore quite easy to consume hundreds of images studying just a few volcanoes, especially when acquisitions are frequent (as with X-band sensors).
* Sustainability of the pilot beyond 2017 demands two mutually supporting resources: data and personnel. Senior scientists and their students are needed to do the actual work of studying volcanic unrest and eruption, while remote sensing imagery are needed to provide the data to be studied. These two resources are oddly symbiotic—one cannot exist without the other—and when both are working together, most other needs will fall into place. For example, having both scientists and high-level data will increase the odds of success for research proposals submitted to national and international science and development agencies. Even if proposals are not successful, data at no cost ensures that the work will be done, since obtaining results is the surest way to justify future funding. It is therefore our view that the primary hurdles for continuing the disaster risk reduction work of the pilot are the definition of teams to accomplish the work and the commitment from space agencies (and their partners) to provide relevant data. If the team approach is to be adopted, we encourage CEOS to require researchers and their groups to commit not only to research activities, but also to outreach and capacity building as a means of supporting the overall disaster risk reduction effort. The blueprint laid by the volcano pilot in this regard should provide a starting point to developing DRR teams, which will go a long way towards realizing the goals of the 2012 Santorini report.
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