CEOS Volcano Pilot Overview

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<tr><td>Volcano Pilot
April 2014- end 2017
Theme area: Volcanoes</td><td rowspan="2">Lead:
Michael Poland, USGS mpoland@usgs.gov
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Contributing projects:
Geohazards Supersites and Natural Laboratories
CSA Volcano Watch
NOAA Volcanic Cloud Monitoring
Global Volcano Model
STREVA
Other relevant projects: EVOSS</td></tr>
<tr><td>Geographic areas of focus:
A. The Latin American volcanic arc (Mexico through southern Chile, including the Antilles and Galapagos) for regional monitoring

B. Volcano supersites of the GSNL

C. Site of major volcanic event 2014-2017</td></tr>
<tr><td>Partners:
CEOS partners:
USGS, ASI, CSA, ESA, NOAA, JAXA, NASA, DLR, CNES

Other partners:
University of Bristol (UK), Cornell University (US), University of Iceland, British Geological Survey, Italian National Research Council / Istituto per il Rilevamento Elettromagnetico dell'Ambiente (IREA –CNR), Italian Civil Protection Department, the Open University (UK), VAACs (Buenos Aires and Washington), volcano observatories (several with confirmed interest in Latin America), VDAP, Civil Protection agencies.

Research Consortia:
IAVCEI, STREVA (University of Bristol), Global Volcano Model (BGS), WOVO, VHUB, COMET+(University of Leeds), ALVO</td><td>Pilot objectives:
This pilot represents a stepping-stone towards the long-term goals of the Santorini Report on satellite EO and geohazards with respect to volcanic activity, namely: 1) global background observations at all Holocene volcanoes; 2) weekly observations at restless volcanoes; 3) daily observations at erupting volcanoes; 4) development of novel measurements; 5) 20-year sustainability; and 6) capacity-building. Specifically, the pilot aims to:
A. Demonstrate the feasibility of integrated, systematic and sustained monitoring of Holocene volcanoes using space-based EO;
B. Demonstrate applicability and superior timeliness of space-based EO products to the operational community (such as volcano observatories and VAACs) for better understanding volcanic activity and reducing impact and risk from eruptions;
C. Build the capacity for use of EO data in volcanic observatories in Latin America as a showcase for global capacity development opportunities.

CEOS objectives:
Improve coordination of satellite data acquisition over volcanoes, demonstrate efficiency of EO-based monitoring methodologies as a complement to in-situ measurements, and support and continue the GSNL initiative

User communities:
The CEOS Volcano Pilot develops monitoring products and operational satellite monitoring protocols to be used by volcanic observatories and VAACs, as well as civil protection agencies, in order to enable systematic monitoring of volcanic unrest.</td></tr>
<tr><td colspan="2">Description:
The pilot consists of three components: a regional study to demonstrate the feasibility of global volcanic monitoring, focused on Latin America; detailed studies of a few frequently active volcanic systems (namely the Hawai‘i and Iceland volcano Supersites); and a third component to address a major volcanic event anywhere in the world if such an eruption takes place during the course of the pilot. The pilot will</td></tr>
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showcase how a wide range of sensors can produce valuable information for use by volcano observatories, Civil Protection agencies, and other organizations responsible for volcano hazard mitigation and response.

Regional Demonstration

CEOS aims to demonstrate the feasibility of global volcano monitoring of Holocene volcanoes by undertaking regional monitoring of volcanic arcs in Latin America, stretching from Mexico to southern Chile, and including the Lesser Antilles, using satellite EO data to track deformation as well as gas, ash, and thermal emissions. Emissions are targeted over the entire region by utilizing existing tools—for example, data processing and display interfaces developed by NOAA, interfaces developed through the EVOSS project, and those developed by other agencies—and adding new data sources made available by contributing space agencies. Deformation and surface change will be examined using different types of data across the region, including:

- L-band SAR data from Central America, the Lesser Antilles, and the Northern, Central, and Southern Andes
- C-band SAR data from the Central and Southern Andes
- X-band SAR data for a few individual volcanoes that are persistently active or restless (e.g., Galeras, Tungurahua) to assess how shorter repeat times may counter the decreased coherence that is associated with shorter wavelength SAR data
- Landsat-8, SPOT-5, and Sentinel-2 HR data (Visible-NIR-SWIR) to assess surface changes at volcanoes showing unrest
- SPOT-5 and Sentinel-2 (NIR-SWIR) day and nighttime acquisitions for computing and mapping High-Temperature thermal anomalies at erupting volcanoes
- Landsat-8 (TIR) and ALI (EO-1) nighttime acquisitions with strategic revisit, to assess thermal anomalies
- Pleiades VHR data to assess ground deformation (volume changes, dome growth) at selected volcanoes
- A wide range of publicly available NASA, NOAA and ESA data and products to detect, assess and track volcanic ash plumes
- VIIRS and MODIS data and products to detect, assess and monitor surface, high-temperature thermal anomalies at moderate spatial and temporal resolution
- GOES-East, GOES-West data and products – where appropriate – to detect, assess and monitor surface, High-Temperature thermal anomalies at very-high temporal resolution

Latin America was chosen for the regional component because: 1) the volcanoes are situated in a diversity of environments (from rain forest to high-altitude desert), providing a good test of the capabilities of different types of satellite data in different settings, 2) volcanic activity is abundant, including persistent eruptive activity (e.g., Tungarahua, Arenal, Reventador, Villarica, Soufriere Hills) and deformation with no eruption (e.g., Lazufre), 3) explosive eruptions that disrupt air travel are likely to occur over the course of the three-year pilot, based on experience over the past decade (e.g., Cordon Caulle, Chaiten, Guagua Pinchincha, Popocatèpel), and 4) volcano observatories and monitoring agencies in Latin American countries will directly benefit from the additional resources that this pilot will make available. It is hoped that the regional study will demonstrate that EO data can help to identify volcanoes that may become active in the future (i.e., provide a forecasting ability) as well as track eruptive activity that may impact populations and infrastructure on the ground and in the air, ultimately leading to improved targeting for permanent EO-based observations and in-situ volcanic monitoring efforts.

Supersite activity

In addition to regional studies, we are conducting multi-disciplinary, multi-platform monitoring of a few volcanoes that represent a diverse cross section of eruptive activity and unrest. The exact sites will coincide with the volcanic supersites (Hawai'i and Iceland). The goal of the Supersite component is to establish the importance of EO data (including SAR, VHR, and visual/near/short-wave/thermal IR scenes) for both operational monitoring and for scientific investigation of eruptive processes and unrest. The Supersite locales offer the following benefits for demonstrating the value of EO monitoring

and research:

- Hawai'i: location of persistent eruptive activity at Kīlauea Volcano. Hawai'i is already a GSNL Supersite, and InSAR and thermal data are used for operational volcano monitoring by the USGS Hawaiian Volcano Observatory.
- Iceland: home to numerous deforming volcanoes and site of frequent eruptions. Ash emissions have demonstrated their potential to impact air travel in Europe. Also a GSNL Supersite.

Similar strategies for on-going monitoring are being developed for other volcano supersites: Italian volcanoes site, New Zealand volcanoes and Ecuador volcanoes candidate sites.

Significant Global Event

If, during the course of the pilot, there is a major eruption with significant regional or global impact, the volcano will be the object of specific study, and a range of pre-event (if possible), event, and post-event products will be developed by the partners. The 2010 "100-year" eruption of Merapi, Indonesia, provides an example of an event that would qualify for intensive study as part of the pilot because of the level of risk to a large population and the need for EO data by local agencies tasked with volcano monitoring and civil defense. Although the space charter may also be activated for such an important volcanic eruption (as it was for Merapi in 2010), the pilot will go beyond the space charter mission by providing data for a comprehensive analysis of all aspects of the eruption cycle, including local (e.g., mass flows on the volcanic slopes), regional (e.g., ash emissions that may be hazardous to aircrafts), and global (e.g., volatile and aerosol emissions that may influence climate) impacts.

CEOS contribution to pilot:

The main CEOS contribution is satellite data, which will be used by partners to demonstrate viability of volcanic risk reduction/mitigation and support to operational monitoring of volcanic eruptions and unrest. In some cases. CEOS agencies are providing value-added support and/or training to operational users and other partners.

Key pilot outputs/deliverables:

In the Latin American volcanic arc, the pilot provides access to derived products from optical satellite data that will allow for easy recognition of thermal, gas, and ash emissions. SAR data is analyzed to assess deformation of volcanoes across the region, providing insights on the types of data and repeat times best suited to monitoring volcanoes in different environments and supplying deformation information to operational users. The Latin American demonstration is a precursor demonstration to showcase how monitoring Holocene volcanoes would work on a global scale beyond 2017.

At the supersites, optical and SAR data will be combined to demonstrate the benefit of operational volcano monitoring during pre-, syn-, and post-eruption periods, with specific benefit to on-site volcano-monitoring agencies and general benefit to the scientific community attempting to better understand how volcanoes work. This component will directly support the GSNL initiative.

CEOS outputs/deliverables:

Collection of L, C and X-band data over Latin America and at certain specific volcanic sites outside this area; VHR data collects over select volcanoes.
Coordinated observation strategy 2014-2017 for pilot volcanoes, in coordination with the GSNL;
Draft plan for global observation strategy beyond 2017.

Key user communities:

Washington and Buenos Aires VAACs; Operational volcano-monitoring agencies in Latin American countries (Chile, Bolivia, Peru, Ecuador, Columbia, Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, and Mexico); Operational volcano monitoring agencies for Supersites (USGS, Iceland Meteorological Office, United Nations, etc.); Civil Protection agencies in Latin America and at Supersite locales; and volcano eruption response and capacity-building agencies (e.g., VDAP).

Key outcomes:

- identification of volcanoes that are in a state of unrest in Latin America and the Lesser Antilles
- demonstration of the feasibility of operational volcanic monitoring of Holocene volcanoes using EO
- comprehensive tracking of unrest and eruptive activity using satellite data in support of hazards mitigation activities
- validation of EO-based methodology for improved monitoring of surface deformation
- improved EO-based monitoring of key parameters for volcanoes that are about to erupt, are erupting, or have just erupted, especially in the developing world (where in-situ resources may be scarce)
- capacity-building in countries that do not currently have access to abundant EO data and/or the ability to process and interpret such data

Milestones and schedule:

2014: Begin studies at Supersite volcanoes. Begin collection of data over Latin America data and development of derived products. Establish ties with users and work with them to define procedures for delivering products.

2015: Provide derived products to appropriate users in Latin America (e.g., VAAC, Observatories) and agencies working on Supersite volcanoes. Collect feedback from users about the data and derived products, and use the feedback to refine monitoring strategies. Provide initial evaluation of pilot results to the World Conference on Disaster Risk Reduction.

2016 and 2017: Receive reports from Latin American users on derived products and adjust as needed. Evaluate results from Supersite studies. Develop broader space-based EO strategy using insights from pilot in a formal report.

EO data requirements:

The volcano thematic team has developed a detailed set of EO data requirements, including the designation of specific polygons of interest and identification of specific satellite data types and satellites that may provide support to the pilot. These requirements will be considered by CEOS and addressed in the Acquisition Plan that implements the Observation Strategy.

Main contribution by partner:

USGS: support to volcano observatories in Latin America through VDAP; conduct Supersite studies in Hawai‘i and process regional data from the Galapagos

ASI: access to COSMO-Skymed data on selected volcanoes

Italian Civil Protection Department: methodologies and practices for EO-based operational volcanic monitoring ; support (training, capacity development)

CSA: access to Volcano Watch data archive; possible modification of Volcano Watch data acquisition plan to support pilot objectives, and provision of Radarsat-2 data over Central and Southern Andes and at Supersites; processing of some data from the Volcano Watch archive.

ESA: Sentinel-1 data collects over areas of interest; access to exploitation platform (seismic pilot) and integration of volcanic studies into data repository; scientific animation for volcanic community, along the same lines as that described by the seismic pilot.

The Open University: The Open University: post-processing and interpretation of electro-optical satellite data for tracking thermal emissions and volcanic aerosols at Latin American and Supersite volcanoes, contribution to capacity building by distant learning technologies

CNES: Optical data (SPOT, Pleiades) to support HR detection and mapping of erupted products and dome deformation studies.

University of Bristol: contribution of effort of doctoral student to perform analysis of SAR data over Latin America, and capacity building in Latin American through STREVA

Cornell University: contribution of effort of doctoral student to perform analysis of SAR data over Latin America

NOAA: satellite-based information on airborne volcanic clouds as well as thermal and gas emissions, from volcanoes in Latin America and that are the subject of Supersite studies, along with real-time access to GOES-West and GOES–East crude data – and future ABI's – for the high temporal resolution thermal monitoring of the geographic area of focus.

EVOSS: real-time quantitative thermal and SO2 monitoring over the whole of Europe, of Africa, the Middle-East, the Lesser Antilles, the Atlantic and the northwestern Indian Ocean (includes any erupting volcano in this region of focus under 65° latitude). EVOSS' stretching to all erupting/severely unresting volcanoes in Latin America and on the Hawai'i Supersite is feasible under ad-hoc data provision agreements

BGS: contribution through Supersite studies in Iceland, Post-doctoral effort in the Futurevolc project and contributions to EVOSS

Global Volcano Model network (GVM): will work alongside the CEOS initiative, as GVM produces a section on volcanoes for the UNISDR 2015 Global Assessment Report (GAR15) and we will continue to work alongside CEOS in response to global post-2015 developments

Latin American volcanic observatories: use of EO-generated products, validation with in-situ data, use of prototype products and provision of feedback

IREA – CNR: contribution of staff member time to analyze SAR data over Galapagos as part of Latin American volcano project

Capacity building:
The CEOS pilot will work with designated developing-world volcano observatories and VAACs to identify EO-based methodologies that complement existing monitoring efforts and provide a more robust monitoring capacity. Where possible, EO-based methodologies and practices will be transferred with training to ensure sustainability. STREVA will be an important venue for this work. The Open University will outline and test the porting on volcano-related capacity building its 40-year know-how

Outreach activities:
Training in the use and interpretation of EO data will be provided to volcanologists in the developing world (Latin America in particular) through research consortia (e.g., STREVA) and VDAP. Results will be highlighted at research conferences (e.g., AGU, EGU) and workshops (especially those organized by CEOS agencies).

Suggested evaluation criteria:
- Identification of new areas of unrest through regional InSAR monitoring
- Uptake by Latin American volcano monitoring agencies of EO-based methodologies for tracking deformation, as well as gas, thermal, and ash emissions
- Utilization of EO data for operational monitoring by volcano observatories at Supersite targets
- Interest expressed by volcano community to broaden approaches adopted in pilot (especially regional monitoring and new methodologies for EO-based monitoring) through representative bodies such as IAVCEI, WOVO or GVM

CEOS Pilot Volcano Team:
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