Status Report on Volcano Pilot Project

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WG Disasters #6
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Overview

- Motivation and objectives
- Data usage
- New results
- Capacity building
- Sustainability
Pilot Team

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WHY?

- Over 300,000 people have been killed by volcanoes since the 1600s.
- Hundreds of millions live within 20 km of an active volcano today.
- In 2010, the Eyjafjallajökull eruption brought losses of $200m/day, and 100,000 cancelled flights.
WHAT IS MISSING?

- Large monitoring gaps exist at many hazardous volcanoes around the world
- Current EO data collection is not usually coordinated for volcano monitoring
- Need systematic observations before, during, and after volcanic events
Objective A – Regional Demonstration
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.

Objective B – Geohazard Supersites and Natural Laboratories
Multi-disciplinary, multi-platform monitoring of a few volcanoes that represent a diverse cross section of eruptive activity and unrest.

Objective C – Significant Global Event
Specific studies in case of a major eruption with significant regional or global impact, 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.
Objective B: Supersites

• Work continues on approved volcano Supersites:
  – Hawaiʻi
  – Iceland
  – Italy
  – Ecuador
  – New Zealand

• Critical for hazards assessment and mitigation efforts and highly valued by local agencies

• Volcano supersites provide opportunities for scientific innovation due to the availability of high spatial and temporal resolution datasets
Objective B: Hawaiʻi
Objective B: Hawaiʻi

Inflation of Mauna Loa volcano, Hawaiʻi

Cosmo-SkyMed

August 22, 2014 – August 27, 2016
InSAR shows ~1.5 cm LOS decrease from April to August 2015, correlating with GPS
Objective C: Large event

- Proposal has been submitted to ensure rapid access to data if a large volcanic event occurs
- Fogo eruption serves as a demonstration
Objective A: Regional demonstration

- Demonstrate how EO data can be used to cost-effectively monitor all 315 volcanoes in the region that erupted in the last 10,000 years
- Identify volcanoes that may became active in the near future
- Track new and ongoing eruptive activity

Why Latin America?
- Diversity of environments
- Abundant volcanic activity
- Benefits to local users
- 64% of volcanoes in the region have no ground monitoring of any type
<table>
<thead>
<tr>
<th>Topic/region</th>
<th>Value Added Partner</th>
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<tbody>
<tr>
<td>Northern Andes and Lesser Antilles SAR</td>
<td>University of Bristol</td>
</tr>
<tr>
<td>Southern and Austral Andes SAR</td>
<td>Cornell University</td>
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<tr>
<td>Galápagos SAR</td>
<td>IREA/CNR</td>
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<tr>
<td>Mexico SAR</td>
<td>University of Miami</td>
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<tr>
<td>Central America SAR</td>
<td>Pennsylvania State University</td>
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<tr>
<td>Detection of ash plumes and thermal anomalies</td>
<td>NOAA</td>
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<tr>
<td>Development and testing of EO-based methodology for improved monitoring of surface deformation</td>
<td>All</td>
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<tr>
<td>Capacity-building and training activities in countries that do not currently have access to abundant EO data and/or the ability to process and interpret such data</td>
<td>All</td>
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<tr>
<td>Collect feedback from users</td>
<td>All</td>
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</tbody>
</table>
**SAR Data Usage**

<table>
<thead>
<tr>
<th>Mission</th>
<th>Ordered / Allocated</th>
<th>Noteworthy results</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADARSAT-2</td>
<td>243 / 270</td>
<td>Córdon Caulle, Pacaya</td>
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<tr>
<td>COSMO-SkyMed</td>
<td>491 / 600</td>
<td>Fernandina, Wolf</td>
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<tr>
<td>TSX</td>
<td>164 / 400</td>
<td>Chiles–Cerro Negro</td>
</tr>
<tr>
<td>ALOS-2</td>
<td>98 / 200</td>
<td>Arc-wide studies</td>
</tr>
<tr>
<td>TDX (CoSSC exp.)</td>
<td>22/150</td>
<td>Montserrat</td>
</tr>
</tbody>
</table>

*Sentinel-1A data have not been included, since those data are distributed at no cost and with no restrictions.*
Volcanic Cloud Alert Report

DATE: 2016-08-01
TIME: 07:30:20
Production Date and Time: 2016-08-01 14:34:22 UTC
PRIMARY INSTRUMENT: NPP VIIRS

Possible Volcanic Ash Cloud

Basic Information
- Volcanic Region(s): Mexico and Central America
- Country/Countries: Guatemala
- Volcanic Subregion(s): Guatemala
- VAAC Region(s) of Nearby Volcanoes: Washington
- Mean Object Date/Time: 2016-08-01 07:30:20 UTC
- Radiative Center (Lat, Lon): 14.760 °, -91.550 °

Nearby Volcanoes (meeting alert criteria):
- Santa Maria (0.00 km)
- Santo Tomas (9.40 km)
- Amealonga (10.50 km)
- Toliman (42.20 km)
- Atitlan (43.90 km)

Maximum Height [AMSL]: 7.60 km; 24934 ft
90th Percentile Height [AMSL]: 6.20 km; 20341 ft
Mean Tropopause Height [AMSL]: 16.50 km; 54134 ft

Show More ▲

Results: Santiaguito
Results: Chiles – Cerro Negro

- **Mw 5.6**

A series of graphs showing seismic activity over time, with specific dates marked. The graphs indicate significant seismic activity in the North, East, and Up directions.
Results: Chiles – Cerro Negro

Ground deformation – is it magma or “just” the earthquake?
Results: Masaya (2012 explosions)

Subsidence (3 Apr-28 Apr)

Uplift (11 Mar-3 Apr)

Uplift (28 Apr-17 Jul)

Cumulative displacement (cm)

Month (2012)

Jan Feb Mar Apr May Jun Jul Aug

b) Uplift (11 Mar-3 Apr)

c) Subsidence (3 Apr-28 Apr)

d) Uplift (28 Apr-17 Jul)

(data from Cosmo-SkyMed)
Results: Masaya (2015–2016)

November 4, 2015 – May 14, 2016
Sentinel-1a, ascending track

Modeled source depth: 1.5 km
Results: Pacaya

Complex deformation of Pacaya, Guatemala, revealed by RADARSAT-2
Modeling of InSAR reveals the magmatic plumbing system at Pacaya
Results: Popocatepetl

Radarsat-2 displacement time-series

Next steps:
- combine with TSX in collaboration with Thomas Walter, GFZ
- use GPS zenith delays to assess troposphere
- explore TSX over Colima
OVDAS installed 3 continuous GPS stations in response to interferograms showing inflation of Cordón Cauillé
Results: Fernandina

Deformation of Fernandina volcano, Galápagos, in space and time
Results: Request from Peru

On August 31, 2016, OVS (Peru) sent a request to Matt Pritchard for thermal satellite imagery and InSAR covering fumaroles on the flank of Sabancaya volcano.
Results: ALOS2 broad-scale InSAR

Results: ALOS2 broad-scale InSAR

Villarica, Chile

The volcano is capped by a glacier. Even 1-2-day interferograms (X- and L-band) are not very coherent, implying that InSAR will not be useful for studying shallow magma dynamics.
Results: Lessons learned

Villarica, Chile

Deformation may not be centered on the volcano. This means that extremely high resolution SAR scenes (like TSX Spotlight) of a volcano’s summit might “miss” volcano-wide deformation.
Results: Lessons learned

- 43 examples of deformation > 5 km from volcano associated with unrest
- Eight observations of distal deformation associated with volcanic eruptions
- Ten distal deformation signals associated with major earthquakes, ~25 have an unclear relationship with eruptive centres
Results: Lessons learned

• Is there an ability to exploit the massive archive of CSK data (hundreds of scenes, in some cases) available over some volcanoes?
  • Villarica
  • Santiaguito
  • Masaya
  • Tungaraha

• What are the spatial-temporal characteristics of deformation?
• How frequently are acquisitions needed?
Results: Publications


• STREVA workshop in Pasto, Colombia: “Interpreting and modelling volcano InSAR” (will involve scientists from Colombia and Ecuador) – September, 2016

• Cities on Volcanoes 9 workshop in Puerto Varas, Chile: “Interferometric Synthetic Aperture Radar (InSAR) Processing” – November 2016

• IAVCEI workshop in Portland, OR, USA: “Volcano remote sensing” – August 2017
What elements of the pilot have proven to be successful, especially with regard to user interest and involvement? Are there specific elements that will be "missed" if stopped now? Which ones and why?

- InSAR results, both crisis and non-crisis
- Information about ash plumes
- On-site training (Colombia, Ecuador, Peru, Chile, etc.)
- All these elements would be “missed” because they provide both indications of potentially active volcanoes and situational awareness during eruptions
Are there elements of the pilot that are likely to be supported (possibly financially) from outside CEOS and the pilot going forward beyond 2017? If yes, what organizations might be willing to contribute to a sustainability plan?

- A number of database projects (including the Powell Center) will continue beyond 2017
- Outreach will continue via efforts like STREVA
- USGS (Volcano Disaster Assistance Program) is a logical partner in sustainability
In considering successes that should go forward, do these involve a transition from research to operations? Are there data issues involved?

- Operational effort MUST involve dedicated scientific personnel to coordinate work (FTE)
- Data availability (mostly SAR, but also some thermal/optical) must be assured
Do you consider that data for the sustainable elements should come from CEOS, or from commercial providers, or some mix?

- Data must come from a mix, but can be coordinated and supported by CEOS
Who are the key partners for achieving sustainability?

- Academic institutions (can provide training as well as data processing/interpretation)
- Operational institutions (e.g., USGS, NOAA)
- Space Agencies
- CEOS
Who are the main clients and users of the sustainable services?

- Volcano Observatories
- VAACs
- Academic Institutions
- Operational Institutions (e.g., USGS, NOAA)
What if any is the role for CEOS in the sustainable service?

- Facilitating access to satellite data for use in hazards assessment/mitigation and disaster response (beyond the International Charter)
What are the largest threats to sustainability, and what are the consequences of not achieving a sustainable service as proposed?

Threats

• Data availability
• Need trained scientists to work on data, communicate with VOs, interface with space agencies

Consequences

• Business as usual (VOs don’t get needed insights)
Does sustainability imply a simple continuation, or does it involve scaling something developed in the pilot to a global level, or other larger level? What is involved? Can you provide a description/vision of this larger system and what it entails from a cost perspective (using elements from the pilot as a the starting point for costing)?

- Many possibilities, from regional to global, depending on the level of support
Tier 0 [Pre-pilot]

- No coordinated global volcano observing strategy
- Limited, ad hoc data availability from commercial satellites (ALOS2, CSK, DLR, RSAT2)
Sustainability: Paths forward

Tier 1a [no cost, just data]: continued regional activities
- Quotas of satellite data from commercial satellites (write proposals, manage quotas, write reports)
- Coordinated approach—teams of academics work with VOs
- Best effort response to crises

Tier 1b [no cost, just data]: continued global activities
- Larger quotas from commercial satellites (write proposals, manage quotas, write reports)
- Coordinated approach—teams of academics for each region work directly with VOs
- *Best effort response to crises
Tier 2a [some new funds]: expanded regional activities
• Quotas of satellite data available from commercial satellites
• Partial FTE to support project management: proposals, quotas, reports, telecons, communicate with space agencies and VOs
• Coordinated approach—teams of academics work with VOs
• Best effort response to crises

Tier 2b [no cost, just data]: expanded global activities
• Larger quotas from commercial satellites
• Partial FTE (larger fraction than with option a) to support project management: proposals, quotas, reports, telecons, communicate with space agencies and VOs
• Coordinated approach—teams of academics for each region work directly with VOs
• Best effort response to crises
Tier 3 [new funds]: scalable to regional or global

- Large quotas of satellite data available from commercial satellites
- One or more FTE's:
  - Project management by a scientifically trained person: write proposals, manage quotas, write reports, communicate with space agencies and VOs, participate in telecons
  - Routine, near real time data processing—interpretation and processing strategy needs continuous scientific input (not just an advisory board); who will do the work, who has the oversight, and how this will be funded needs to be worked out
- Coordinated approach—teams of academics work directly with supported FTES and with VOs
- Routine response to all crises (but how to decide what constitutes a crisis?)
• Prepare a Journal of Applied Volcanology article describing the results of our work, focusing on the value to end users

• Develop broader space-based EO strategy using insights from pilot

• Powell Center (2017–2019)
  – 15–20 volcano remote sensing experts
  – Global in scope
  – USGS sponsored
  – Use existing databases to understand the best satellite indicators of potential eruptions
  – Provide feedback to space agencies
Thank you