TOWARDS COORDINATED REGIONAL MULTI-SATELLITE INSAR VOLCANO OBSERVATIONS: RESULTS FROM THE CEOS PILOT PROJECT ON LATIN AMERICA

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INTRODUCTION

The Committee on Earth Observation Satellites (CEOS) has developed a 4-year pilot project (2013-2017) to demonstrate how satellite observations can be used to monitor large numbers of volcanoes cost-effectively, particularly in areas with scarce instrumentation and/or difficult access. The pilot aims to improve disaster risk management (DRM) by working directly with the volcano observatories that are governmentally responsible for volcano monitoring as well as with the international space agencies (ESA, CSA, ASI, DLR, JAXA, NASA, CNES) that collect and distribute data.

Latin America, encompassing ~319 volcanoes spanning from central Mexico in the north to Chile in the south and including the Caribbean and Galapagos, was chosen as a test area because:

- the volcanoes span a range of eruption types, ages and environments;
- volcanic activity is abundant and eruptions have a strong impact on both local populations and air traffic;
- at the national level, there are well-established volcano observatories that are well-placed to incorporate satellite observations into existing systems for forecasting eruptive activity and setting alert levels based on ground-based data.

Here we highlight several case studies where CEOS data have successfully been used by volcano observatories to monitor volcanoes and respond to crises.

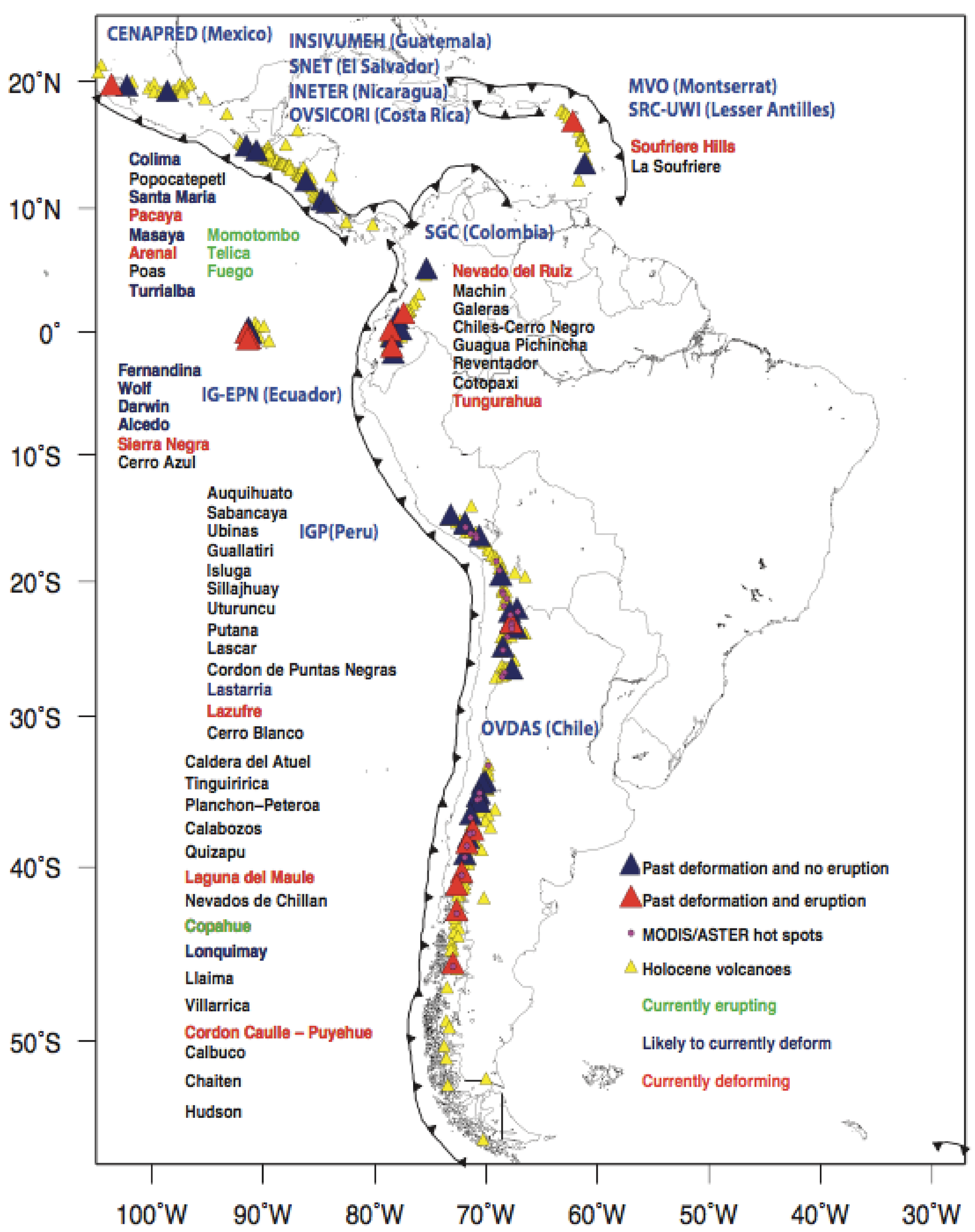

Fig.1 Summary of ~319 Latin American Holocene volcanoes from (Global Volcanism Program,2017) (yellow triangles) along with about 50 volcanoes with ground deformation shown as red and blue triangles for ongoing and past deformation, eruptions (green labels), and satellite-detected thermal anomalies as purple circles.

Villarica, Chile. The most hazardous volcano in the Southern Andes, with more than 50 historical eruptions and a semi permanent basaltic-andesitic lava lake. Erupted with a small Strombolian eruption On March 3rd 2015.

InSAR helped in the recognition of a source of uplift, that was off-center with respect to the volcano's summit and not well-covered by ground-based monitoring.

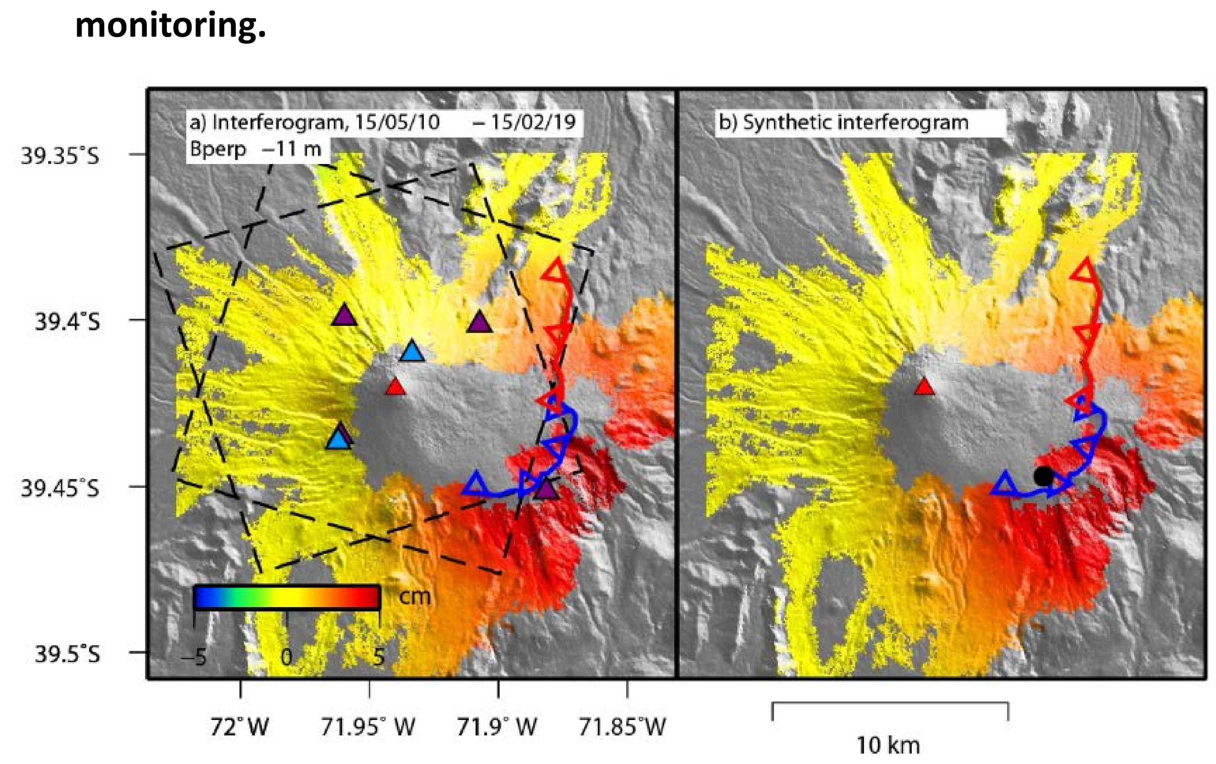

Fig.4 CSK (a) and synthetic interferograms (b) predicted by an inflating source (blackdot in b) SW of the volcano summit in mid April –May 2015. This result combined with GPS data increased the alert during May 2015.

SELECTED CASE STUDIES

Chile – Cerro Negro. Stratovolcanoes in the Ecuador - Colombia border with no historical eruptions. Earthquake swarm between September and October 2014 ended with a Mw 5.6 earthquake on October 20 2014. cGPS recorded inflation with a source 10 km S of the volcanoes.

InSAR data confirmed lack of magmatic deformation, complemented ground stations for modeling and helped the volcano observatory determine the appropriate state of alert.

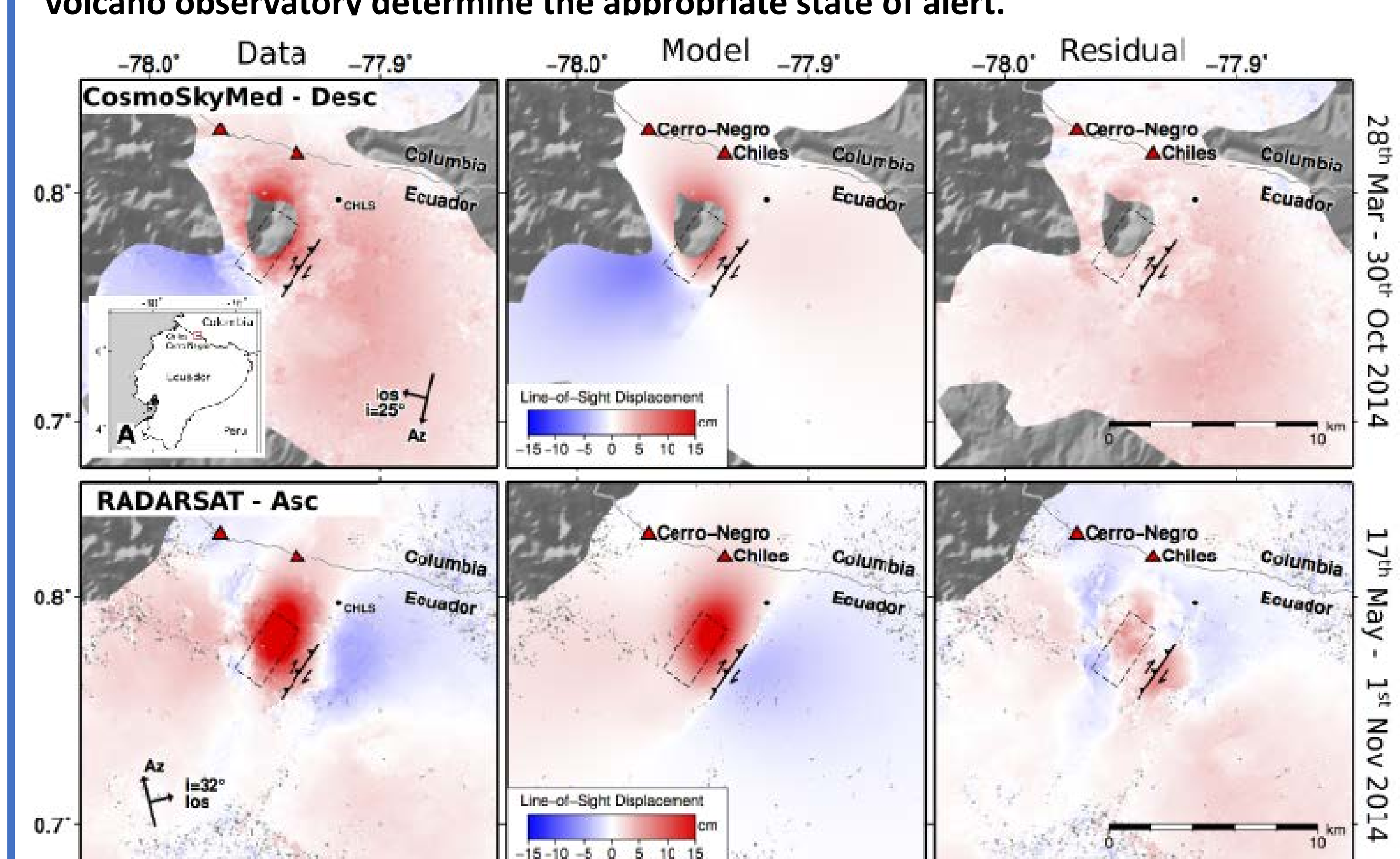

Fig.2 Observed deformation (left), modeled deformation (middle), and residual deformation (data minus model; right) based on InSAR data spanning the M5.6 earthquake near Chiles and Cerro Negro volcanoes, acquired by COSMO-SkyMed (top) and RADARSAT-2 (bottom). All deformation in the images can be explained by the earthquake, suggesting that any magma accumulation or transport associated with the episode of unrest was small or otherwise not detectable.

Cordón Caulle, Chile. Fissural rhyodactitic volcano. InSAR data were used to calculate post-eruptive uplift of up to 0.8 m between March 2012 and May 2015. The volcano does not have ground geodetic instrumentation and the permanent seismic stations did not detect abnormal seismicity during the unrest period, so the uplift would not have been detected without satellite data.

InSAR results motivated the responsible volcano observatory, El Observatorio Volcanológico de Los Andes del Sur, to install continuous GPS stations on the volcano to better monitor the deformation.

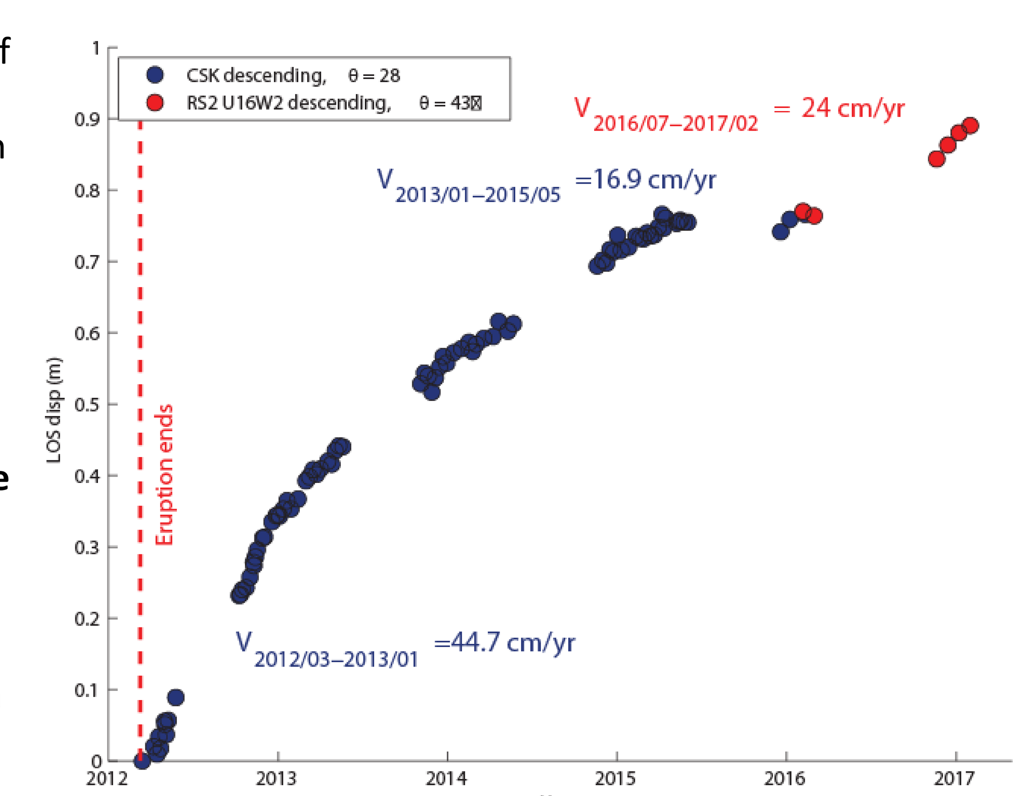

Fig.3 Time series of LOS displacements from near the location of maximum observed deformation for COSMO-SkyMed (blue dots) and RADARSAT-2 (red dots) interferograms. Velocities for various time periods are given by blue and red text.

Reventador, Ecuador. Horseshoe-shaped caldera which had a large VEI 4 eruption in 2002 with little warning. Topographic change associated with ongoing eruption.

InSAR data were critical to measuring flow thickness and hence effusion rates.

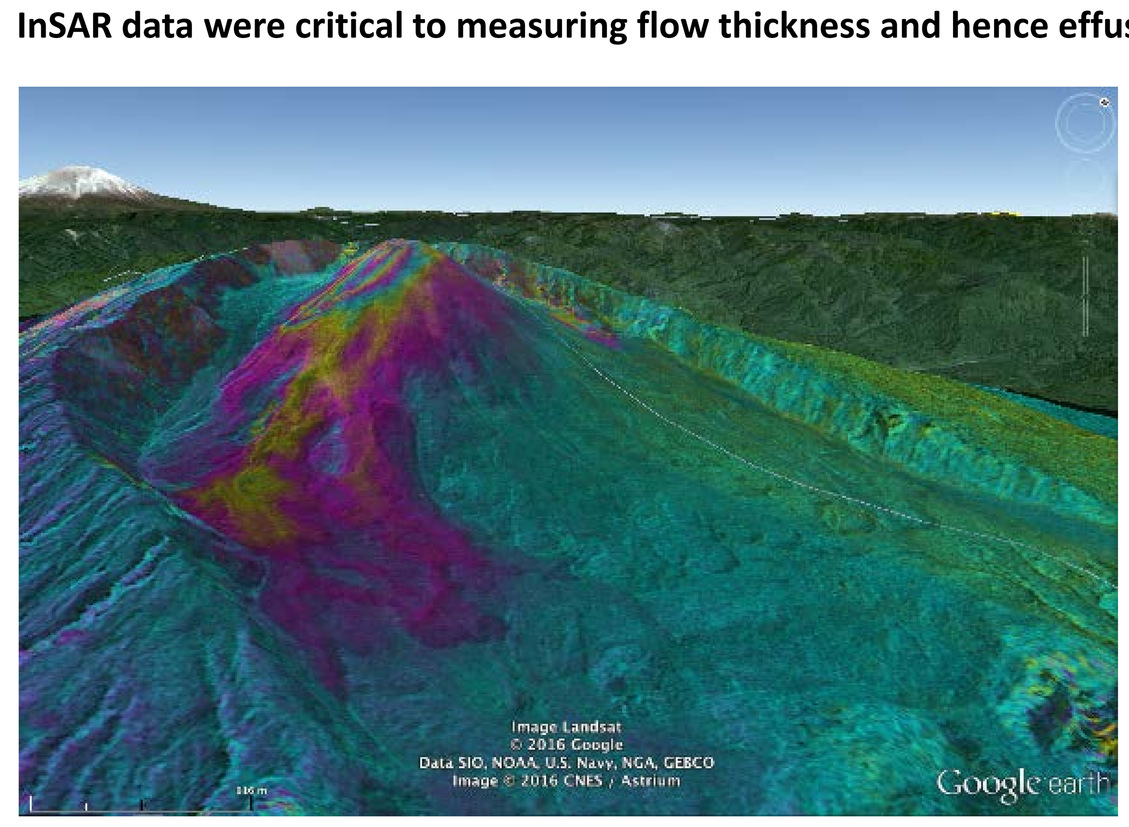

Fig.5 Topographic fringes from a TanDEM-X image pair showing thickness of new lava flows at Volcán Reventador, Ecuador. One complete color cycle corresponds to 25 m of new lava. Images like these supplement limited ground based measurements and allow volcano observatories to see how the rate of eruption is changing over time.

LESSON LEARNED

- A volcano monitoring system must involve multiple space agencies and satellite platforms to make the most of each satellite system, to get nearly daily coverage when needed and to have updated high resolution topographic maps
- Data quotas should be assigned for a) systematic background observations using the needed observing mode (spatial resolution, polarization, etc.), b) case studies requiring dense datasets and c) flexible response to unrest and eruption.
- A systematic background mission using ascending and descending passes should take into account both the level of activity at each volcano and the temporal and spatial baselines required to form coherent interferograms and observe deformation transients
- Acquisition plans need to be flexible to accommodate changes in activity, evolving methods and improved understanding of data types
- Near real-time data access is vital for decision making, requiring frequent overpasses, rapid tasking and short data latency
- Coordination between space agencies, scientists and volcano observatories is crucial in order to provide an operational response and avoid conflicting requests for satellite tasking or interpretations of satellite observations to observatories.

CEOS

REFERENCE

Pritchard, M.E., J. Biggs, C. Wauthier, E. Sansosti, D.W.D Arnold, F. Delgado, S.K. Ebmeier, S.T. Henderson, K. Stephens, C. Cooper, K. Wnuk, F. Amelung, V. Aguilar, P. Mothes, O. Macedo, L.E. Lara, M.P. Poland, and S. Zoffoli (in review). Towards coordinated regional multi-satellite InSAR volcano observations: Results from the Latin America pilot project. Journal of Applied Volcanology.