Supplemental material for “Towards coordinated regional multi-satellite InSAR volcano observations: Results from the Latin America pilot project” by Pritchard et al.

Questionnaire completed by volcano observatories

1. Name of your organization and brief statement of mandate. Who are your stakeholders/who do you provide information to?

2. What satellite data were provided to you as part of the CEOS volcano pilot project? How was the data used? (For example, images used in staff meetings, discussions of volcano alert levels, strategies for deploying ground sensors used in making figures for internal or external distribution, etc.)? If you passed the data or insights gleaned from the data onto others -- whom did you pass on the information, what information did you pass on, and what did they do with the information? Specifically, what difference did satellite data make? Did it cause you to do anything different?

3. Were the data useful? If so, please describe in a few lines what level of products was most useful: (For example, raw data, interferograms, google earth files, a written summary of the significance of the data, etc.). If not, how could we improve on the use of satellite data for your needs? For example, by sending data in a more timely manner or in a different format.

4. Looking to the future, would your organization like to increase the use satellite of observations and what do you think is needed to make that happen? For instance, do you need access to data? Training in interpreting SAR, InSAR, visible, IR, etc. datasets? (What kind -- short courses, extended visits of a few weeks to months or a full MS or PhD degree?) Computing resources and/or training for data processing and analysis methods?
Table S1: Table of 319 Holocene active volcanoes (include restless Pleistocene volcanoes) from the GVP that were the focus of satellite SAR observations. 63 volcanoes were classified as “Active” because they were restless – defined here as having eruptions during LAPP (28 volcanoes), seismic swarms (9) or other satellite detected unrest (54) since 1990. (Attached Excel file)
Figure S1: Compilation of ALOS-2 interferograms from ScanSAR (a, c-f) and stripmap (b) beams that span before, during and after the VEI 4 April 2015 Calbuco volcano eruptions. The black and grey arrows are the satellite heading and line-of-sight. Interferograms were processed with the ISCE and GMTSAR softwares with the 1 and 3 arcsec SRTM for stripmap and ScanSAR respectively. Ionospheric signals [i.e., Gomba et al., 2017] were mitigated with quadratic ramps. The pre-eruptive interferogram (a) does not show ground deformation, while the co-eruptive pairs (b-c) show ground subsidence shifted from the eruptive vent (signals in the black box) as predicted by the ascending (c) and descending geometries (b), in agreement with Sentinel-1A time series and individual interferograms [Delgado et al., 2017]. On the other hand, none of the post-eruptive interferograms (d-f) show unambiguous evidence of ground deformation. The only geodetic instrument in the volcano is a tiltmeter 4 km W of the summit (red square) whose north component recorded ~80 µrads interpreted as ground deformation during December 2015 - June 2016. However, this is not consistent with InSAR and as the tiltmeter records are partially correlated with the temperature we conclude that there is no unambiguous post-eruptive ground deformation.
Figure S2: Sentinel-1 ascending (a) and descending (b) interferograms at Sabancaya and Ambato volcanoes (blue and red triangles) that show inflation from a deep source ongoing as of April 2017. Interferograms were processed with the ISCE software with the 1 arcsec SRTM. Phase delays were mitigated with the same method as for the previous data sets. The red square is the TerraSAR-X swath and the black square shows potential aseismic slip due to a shallow fault, in agreement with previous work [Jay et al., 2015]. Preliminary analysis shows that the spatial footprint of the deformation signal is similar to a previous inflation event between at least 1992 and 1997 [Pritchard and Simons, 2004]. We did not detect inflation with TerraSAR-X interferograms between January and October 2015.
Figure S3: Mean velocity from TerraSAR-X (a) and deformation time series from the location of the red circle (b) at Ubinas volcano that span a period of unrest. Interferograms were processed with the ROI_PAC software and with the 1 arcsec SRTM. We used the same atmospheric correction and time series approach as for Peteroa. Legend as in the previous figures. The time series does not show unambiguous evidence of ground deformation.
S4: TerraSAR-X interferogram at Guallatiri volcano. The interferogram was processed with the ISCE software and with the 1 arcsec SRTM. The black dots are the OVDAS tiltmeters that recorded deformation between May 27 - June 01 2015 but as the interferogram does not show unambiguous evidence of ground deformation it’s likely that the tiltmeters are recording thermal variations rather than actual ground deformation.
Figure S5: Rate maps of mean velocities from ALOS-1 (a) and ENVISAT (b) data at Peteroa volcano (red triangle). Yellow triangles are holocene volcanoes. The black and grey arrows are the satellite heading and line-of-sight. The number in the white box is the look angle. The volcano underwent a period of unrest including several small eruptions between July 2010 and July 2011 [Aguilera et al., 2016]. Interferograms were processed with the ROI_PAC software and with the 3 arcsec SRTM. Topography correlated phase delays were estimated for ENVISAT only with a linear function that relates topography and phase and jointly inverted with a quadratic ramp. For ENVISAT we only processed the non-winter imagery that covers the period of unrest (January - June 2011) and as this data set is small we decided to calculate the mean velocity from a stack rather than from a time series as we did for ALOS. The January 2011 ENVISAT image was not included because interferograms calculated with that image show a signal interpreted as ionosphere. Neither of the rate maps show unambiguous evidence of ground deformation that might be related to the eruptions. The subsidence signal observed S of Peteroa in the ALOS rate map has been previously analyzed and was likely triggered by the M_w 8.8 2010 Maule earthquake [Pritchard et al., 2013].
Figure S6: 12-day Sentinel-1 interferograms over southern Chile that have low coherence in areas of rugged topography.