

# **Earthquake Deformation Mapping caused by the Taal Volcano Eruption using InSAR**

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## **Abstract**

Synthetic-aperture radar (SAR) satellites utilize microwaves that are less affected by the atmosphere. The long wavelengths of microwaves allow us to measure changes on the Earth's surface such as ground surface deformations and displacement. The study utilized Sentinel-1B Single Look Complex (SLC) of the Taal Volcano area and its vicinity to determine the deformation caused by the January 12, 2020 volcanic eruption. The calculation of interferogram, coherence, and phase unwrapping using SNAPHU plugin to obtain the displacement of the area of interest, were conducted by utilizing multiple satellite imaging passes such as the prior (January 11, 2020) and after (January 23, 2020) volcanic eruption images. Results show that there is a displacement ranging from -0.305 meters to 0.523 meters gradient. Negative displacement represents the collapse or subsidence of the surface that is created after an eruption while positive displacement represents the increased height or uplift of the ground surface. Accordingly, higher (positive) values (west of Taal lake) indicate that the area was moved closer to the satellite for there was an uplift. It was found out that the general location of fissures was along the Pansipit river valley which is the major source of drainage of Taal Lake. This coincides with the generated earthquake deformation map in which deformation occurs along the Pansipit river and on the municipality of Lemery, Batangas. The utilization of the earthquake deformation map from Sentinel-1 images is a powerful tool in detecting areas where fissures could occur.

Keywords: displacement, earthquake deformation, interferometry, radar, SAR

## **1 INTRODUCTION**

Ground deformation is a common geological hazard that is caused by the Earth's material subsurface movement (Massonnet and Feigl, 1998). This is induced by natural or anthropogenic factors such as drought, underground water withdrawal, landslide, volcanic eruptions, and many more. Through the utilization of Interferometric Synthetic Aperture Radar (InSAR), one can easily monitor and measure topography, displacements, and deformation happening on the Earth's surface up to a millimeter precision (Pritchard, 2006). InSAR works by subtracting one radar image from another radar image and then measures the ground surface changes or displacement between the two images (Tripathy-Land, 2020). Accordingly, it also detects changes in the Earth's surface by recording the time when the reflected signal reached back to the satellite sensor. The phase of return of the microwave signal is dependent on the distance of the satellite to the ground. By then, the interferogram can be created by utilizing the phase

difference of the first pass and the second pass of the satellite in the same area (UNAVCO, 2019). This will result into color fringes or what we call as the interferometric phase.

The study utilized Sentinel-1B single look complex (SLC), interferometric wide (IW) swath images of the Taal Volcano area and its vicinity to determine the deformation caused by the January 12, 2020 volcanic eruption. Phase unwrapping and displacement calculation were conducted to obtain the absolute measurement of the deformation using SNAPHU plugin of the Sentinel Application Platform (SNAP) Desktop 7.0 software.

## 2 METHODOLOGY

Utilizing Single Look Complex (SLC), Interferometric Wide (IW) swath images of the Taal Volcano and its vicinity with sensing dates of January 11, 2020 (before the eruption) and January 23, 2020 (after the eruption) were downloaded from the Copernicus Open Access Scientific Hub website (<https://scihub.copernicus.eu/>) and were later examined with the use of the Sentinel Application Platform (SNAP) Desktop 7.0 software. The processing tools of the Sentinel-1 toolbox (S1TB) were utilized for interferogram formation, phase filtering, and geometric correction of the images. For the phase unwrapping algorithm for SAR interferometry, SNAPHU plugin was utilized. As such, Google Earth Pro and ArcGIS 10.5 were utilized for the presentation of outputs and generation of maps. The general workflow as seen in Figure 1 was then followed to come up with the interferogram and displacement that were used to map deformation following a volcanic eruption. The Intensity\_IW2\_VV bands of the two different dates were utilized in the study to determine the phase difference of these two SAR observations.

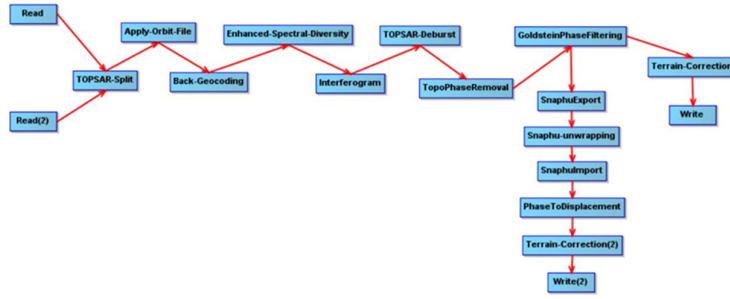


Figure 1. General workflow for the generation of earthquake deformation map

The relevant sub-swaths, and bursts of the ascending Sentinel-1B images were coregistered using back geocoding and enhanced spectral diversity techniques. After the two images were precisely coregistered, interferogram was created by cross-multiplying the master image from the complex conjugate slave image after coregistration. Coherence and wrapped phase bands were also created in this step. Debursting will then follow to remove the fringes for better image visualization. To show deformation patterns, differential interferometry through topographic phase removal were performed. The resulting images were then filtered for phase unwrapping to proceed. Phase unwrapping involves the usage of an external plugin called SNAPHU for the displacement calculation. Terrain correction was applied last to correct the image distortions for the output images of the wrapped phase, coherence, and the unwrapped phase's displacement.

### 3 RESULTS AND DISCUSSION

Interferogram formation (Figure 2) and coherence estimation (Figure 3) in relation to topography were involved in this part of the study.

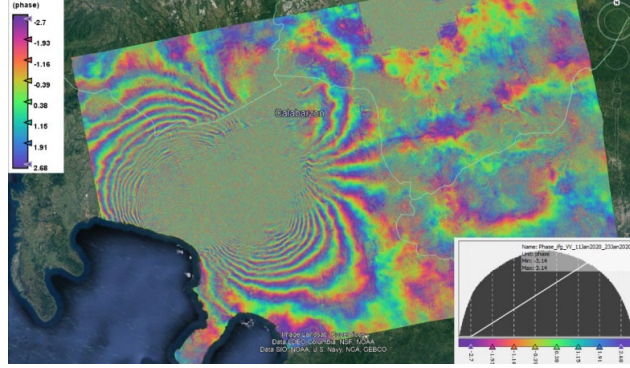


Figure 2. Wrapped phase interferogram of the area of interest

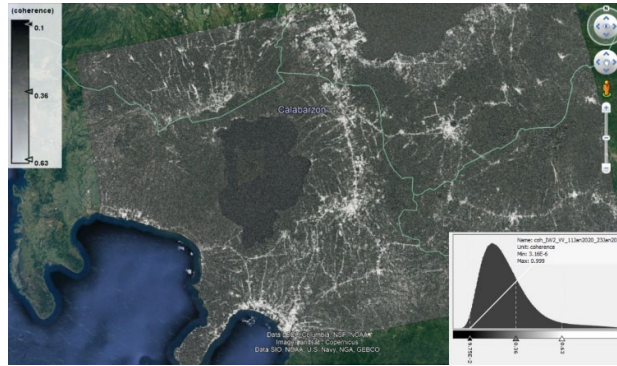


Figure 3. Coherence image of the area of interest

The fringes of the wrapped phase interferogram consists of a color cycle ranging from  $-\pi$  to  $+\pi$  ( $-3.14$  to  $+3.14$ ). This was determined by detecting the distance between the satellite and the ground targets. Fringes indicates some increment of displacement that corresponds to deformation. The denser the fringes are, the greater its deformation. As we saw in the image, dense fringes are surrounding the Taal Lake. A study by Tripathy-Land (2020) indicated that each fringe of the Sentinel-1 image depicts approximately 2.8 centimeters of movement and scientists count these fringes to calculate the displacement that happened in an area.

Coherence images is also one of the outputs of the conducted interferometry and serves as an indicator for the quality of the phase images that were created. Coherence also tells how pixels from the master and slave images are related. In Figure 3, the output of coherence is a gradient from black to white. Areas with low coherence (darker) have no clear fringes in the interferogram while areas with high coherence (brighter) are those that have no clear fringes in the

interferogram. Low coherence is a result of volume scattering of the target objects which include forests and mountainous areas. Values closer to one represent mostly of the built-up areas. As such, lower values are those that have the greatest interferometric phase noise while values closer to 1 have lesser phase noise (Braun and Veci, 2015).

The earthquake deformation map, as seen on Figure 4 was a result of phase unwrapping and displacement calculation. Here, the fringes that initially appear to follow the contour are not clearly visible since the topographic phase was removed during the process.

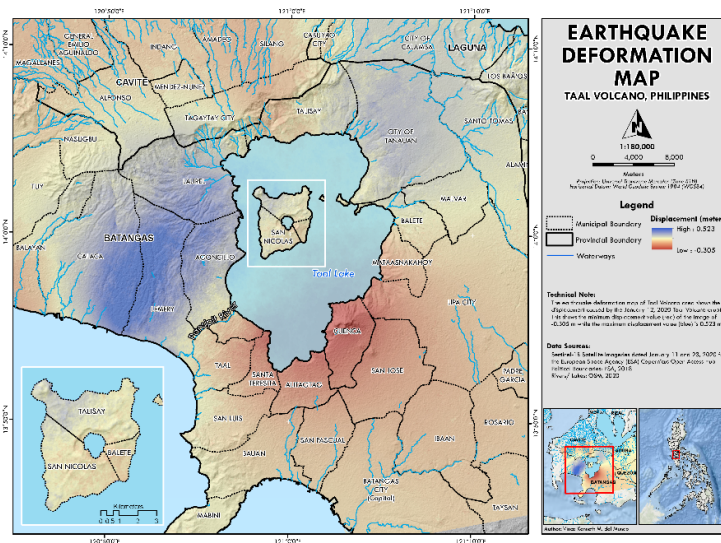


Figure 4. Earthquake deformation map of Taal Volcano and its vicinity

The displacement ranging from -0.305 meters (red) to 0.523 meters (blue) gradient is presented on the map. Negative displacement represents the collapse or subsidence of the surface that is created after an eruption while positive displacement represents the increased height or uplift of the ground surface. Since the satellite image was captured in its ascending pass, it is evident on the image that the southeast part Taal Lake (occupying by the municipalities of Taal, Santa Teresita, Alitagtag, and Cuenca in Batangas) has negative displacement values indicating that these areas are moved away from the satellite and are subsiding the most. Accordingly, higher (positive) values (west of Taal lake) indicate that the area was moved closer to the satellite for there was an uplift. It was found out that the general location of fissures was along the Pansipit river valley which is the major source of drainage of Taal Lake. This coincides with the generated earthquake deformation map in which deformation occurs along the Pansipit river and on the municipality of Lemery, Batangas.

Both InSAR and DInSAR are considered powerful tools in measuring topography, elevation, displacement, and deformation with high spatial sampling and high accuracy without even going to the actual place itself. The images that have been created can be used by scientists for proper planning of areas in which earthquakes and ground shaking events occurred following a volcanic eruption.

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