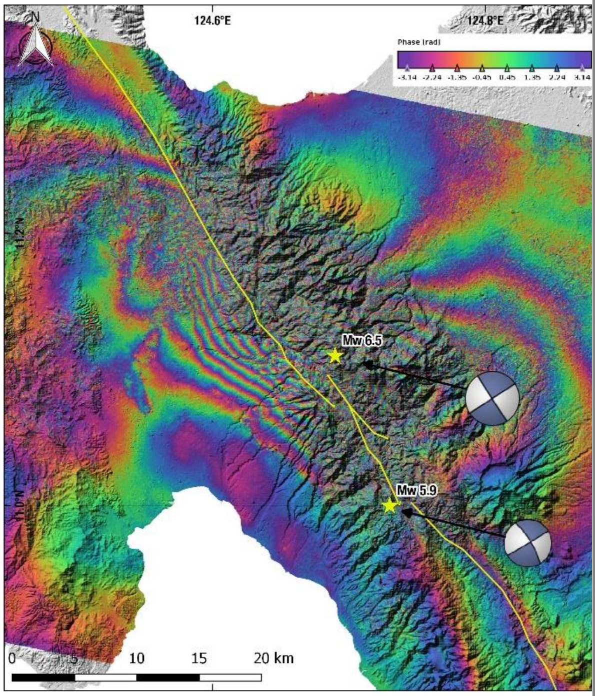
A preliminary report on the Jul. 6, 2017 M=6.5 Philippines earthquake

July 12

2017



Sotirios Valkaniotis, Michael Foumelis and Athanassios Ganas

A preliminary report on the Jul. 6, 2017 M=6.5 Philippines earthquake

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Abstract

Philippines is considered as among the most active tectonic areas in the Asia – Pacific region. The July 6 2017, 08:03:57 UTC earthquake (M6.5, USGS – followed by a M5.9 aftershock on July 10) occurred on an on-shore strike-slip fault which is part of the central Leyte fault zone of Philippines. The rupture kinematics was left-lateral as it was determined by the USGS moment tensor inversion and surface breaks while the hypocentre depth was at 6.5 km. The epicentre was located at 11.11°N, 124.69°E, 15 km northeast of Ormoc City (Leyte, Philippines) according to PHIVOLCS, the Philippine Institute of Volcanology and Seismology. The epicentre is clearly associated with a mapped, NW-SE-striking fault, very well expressed in the region's morphology and marked on satellite images and aerial photos. Due to shallow depth of the earthquake and considering its M6.5 magnitude (USGS) significant ground deformation is expected. We investigated the surface earthquake effects by means of SAR interferometry using the ESA Sentinel satellites. Regarding InSAR processing we used data from Copernicus Sentinel-1 satellite constellation and ESA's SNAP open source toolbox. Data were downloaded from the Sentinel Open Access Hub. We processed a pair of Sentinel-1 IW SLC images from descending track 61 covering the pre- (01/07/2017) and post- (07/07/2017) Leyte 2017 seismic event period. The differential interferogram provides an estimation of the relative motion of the earth surface in the direction viewing of the satellite (LOS). We obtained a maximum LOS displacement of +28.3 cm (towards) and a minimum LOS displacement of -12.1 cm (away). We note these are preliminary results, as no precise orbits are yet available. A 21-km long seismic fault is inferred from the Sentinel-1 fringe pattern.

Date of report

This report was released to EMSC-CSEM on July 12, 2017, 5:40 pm Greek time.

1. Tectonic setting

Philippines is considered as among the most active tectonic areas in Asia – Pacific. A prominent tectonic feature is the Philippine Fault Zone (PFZ; Besana and Ando, 2005; Fig. 1), a series of left-lateral fault segments spanning several hundred kilometres through the Philippine archipelago. The July 6 2017 M6.5 event also occurred on a major, strike-slip fault with left-lateral kinematics. The epicentre was located 11.11°N, 124.69°E, 15 km northeast of Ormoc City (Leyte, Philippines) according to PHIVOLCS[1].

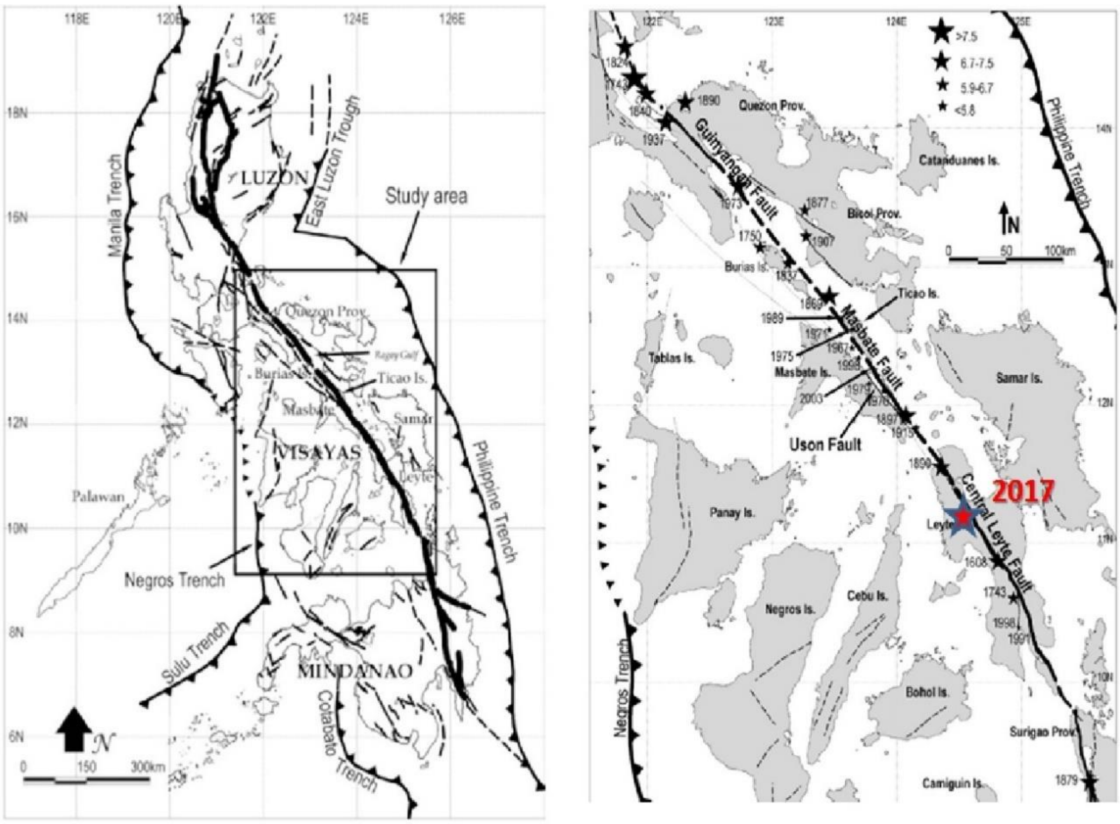

Figure 1. Left) Map showing the extent of the PFZ (bold solid line) transecting the Philippine archipelago. Also shown are the major tectonic features of the region. Solid hachured lines are trenches while dashed lines are other active faults in adjoining islands. The rectangular area defines the area shown in right. Right) Map showing the historical earthquakes along the central portion of the PFZ (modified from PHIVOLCS, 2000). Star indicates the epicentre of the July 2017 event. The 2017 earthquake occurred on the central Leyte Fault. The historical seismicity is from Besana & Ando (2005). Note that July 6 earthquake filled a seismic gap between 1608 & 1899 events.

[1] http://www.phivolcs.dost.gov.ph/html/update_SOEPD/2017_Earthquake_Information/July/2017_0706_0803_B5F.html

2. Satellite data

We investigated the surface earthquake effects by means of SAR interferometry using the **ESA Sentinel** satellites (C-band; one fringe corresponds to half wavelength or 28 mm). Regarding InSAR processing we used ESA's **SNAP** open source toolbox. Data were downloaded from the Sentinel Open Access Hub. We processed a pair of Sentinel-1 IW SLC images from descending track 61 covering the pre- (01/07/2017) and post- (07/07/2017) Leyte 2017 seismic event period. Details of the interferometric pair used in this study are reported in Table 1.

Table1. Characteristics of the interferometric pair used to study the 2017 Leyte earthquake.

Satellite	Track	Master	Slave	Perpendicular baseline (m)	Incident Angle (°)
Sentinel-1	61	S1A 01/07/2017	S1B 07/07/2017	9.6	36.8 (average)

The interferogram was flattened and topographic phase compensated for based on a reference SRTM DTM (~90m). In order to reduce the effects of phase noise adaptive filtering (Goldstein & Werner 1998) was applied, in addition to multilooking operation using a factor of 10:2 (azimuth: range) obtaining approximately a square pixel interferogram. Phase unwrapping was successfully performed using SHAPHU and final results were terrain corrected at 40m spatial resolution.

The differential interferogram provides an estimation of the relative motion of the Earth surface in the direction viewing of the satellite (LOS; Fig. 2). The interferogram is of good quality and contains the phase difference produced by the July 6, 2017 event. Areas characterized by low coherence, the noisy areas in the images, can be attributed to temporal decorrelation mainly due to the vegetation cover. The deformation field, visualized by a number of fringes forming two lobes on either side of the fault, occurs in the central part of the island where the M6.5 epicenter is located. We obtained a maximum LOS displacement of +28.3 cm (towards) and a minimum LOS displacement of -12.1 cm (away). We note these are preliminary results, as no precise orbits are yet available.

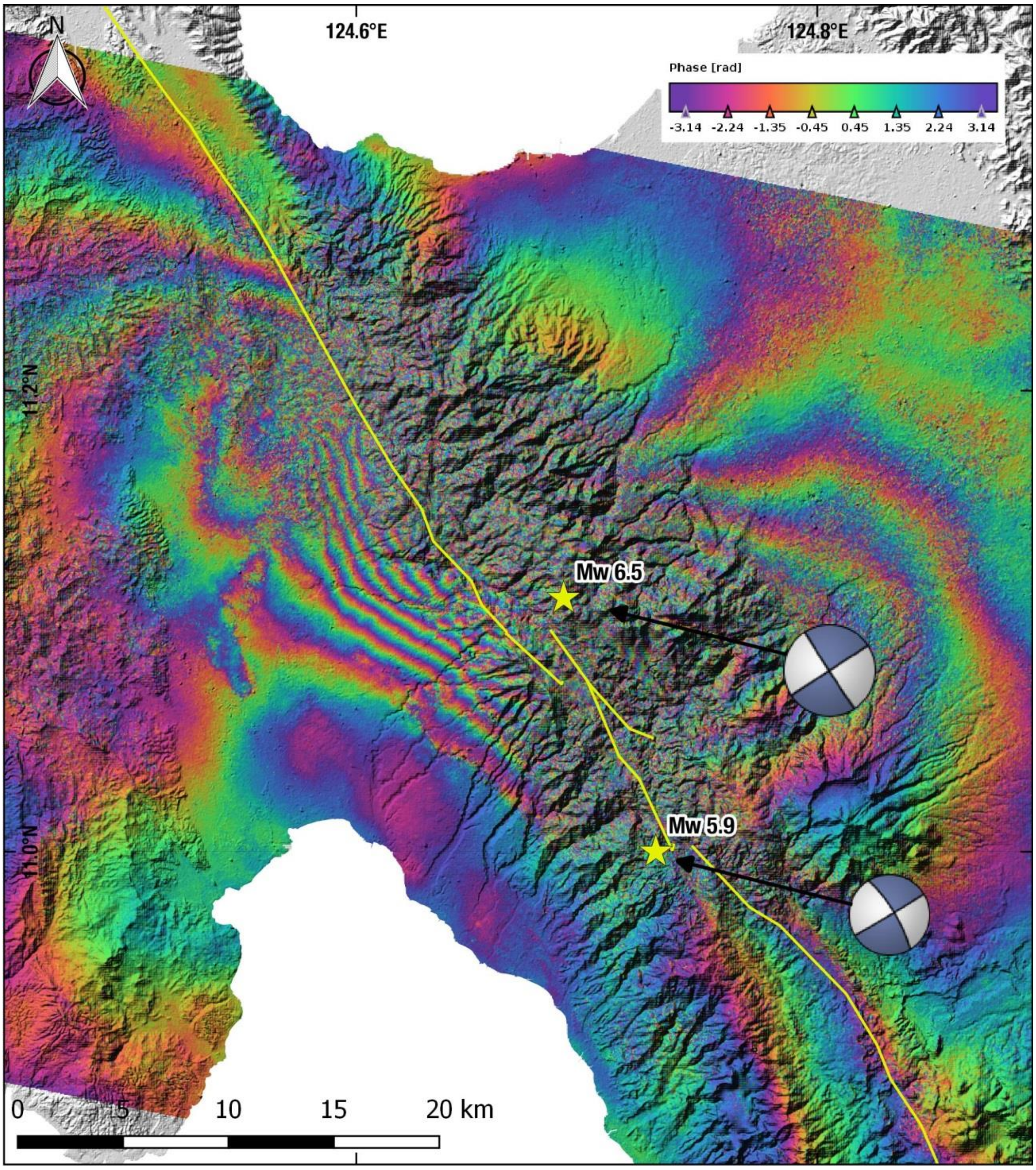

Figure 2. Sentinel 1 A wrapped interferogram descending orbit showing ground deformation caused by the July 6, 2017 Leyte M6.5 earthquake. Yellow lines are mapped fault traces.

3. Fault modeling

A preliminary modeling of the co-seismic displacements together with LOS displacements from SAR interferometry (Figure 3) gives the following preliminary parameters for the fault (Table 2) :

Table 2. Leyte 2017 earthquake fault parameters

Fault length	21 km
Fault width	12 km

Fault Dip angle	73° east
Azimuth	N328°E
Fault Slip	1.0 m
Centre of upper edge of the fault	677.6 km E 1233.7 km N (UTM51)

The seismic moment from this geodetic model is **7.56 × 10^{18}** N-m (the USGS seismic moment from radiated seismic waves is 7.056 × 10^{18} N-m or 7% less)

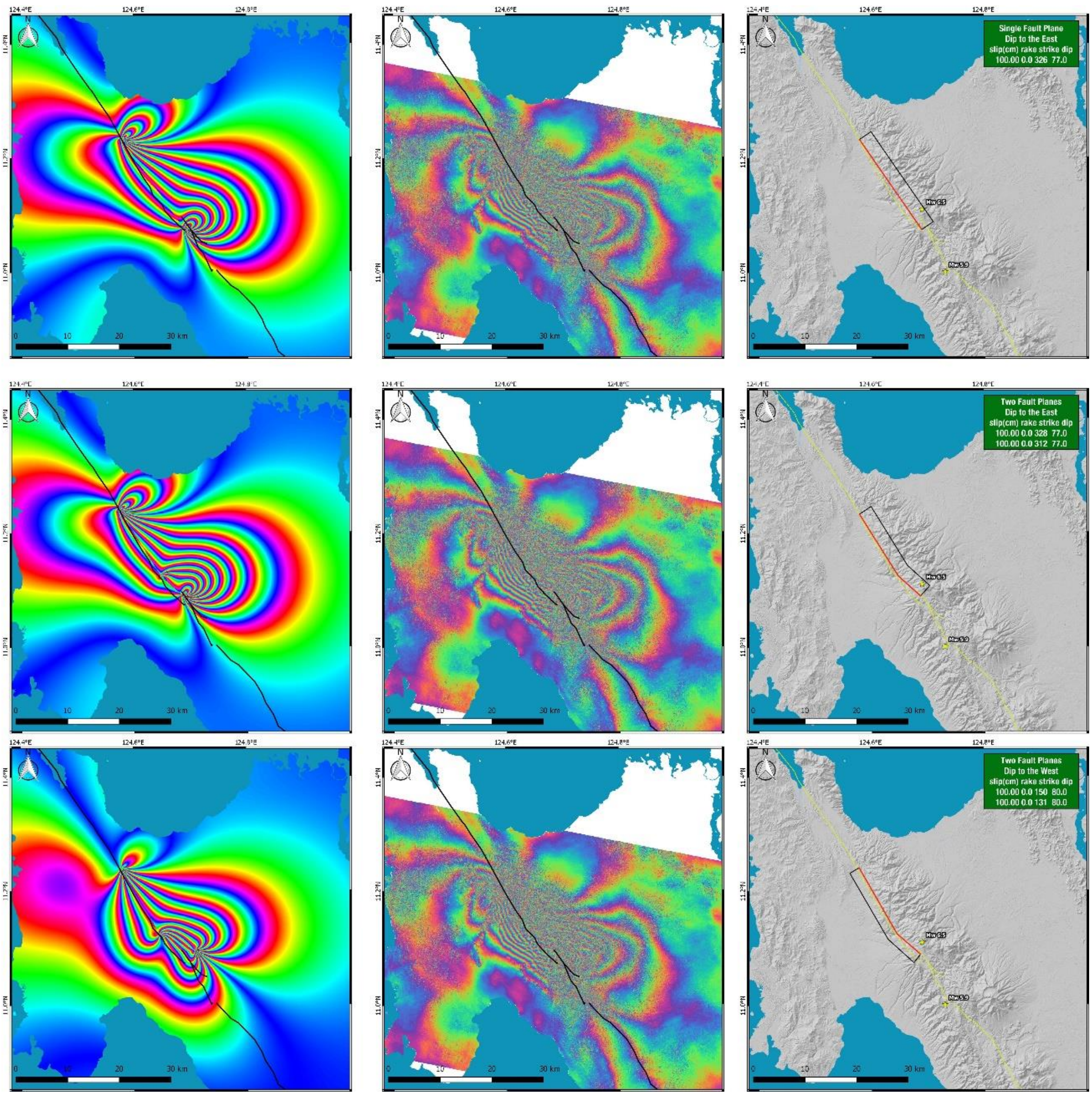

Figure 3. Fault models from forward inversion using one fault plane dipping east (top) two fault segments dipping east (middle) and two segments dipping west. Synthetic fringes were calculated by the code RNGCHN (Feigl & Dupre 1999).

Our forward modeling shows that the left-lateral rupture has a NW-NNW orientation and it follows a mapped fault trace for most its part. The rupture extent is estimated at 20-25 km while possible secondary ruptures at it southern termination cannot be excluded. Moreover, to the south the rupture extent is ambiguous due to interferogram loss of quality. It is possible that the July 10 event (Mw 5.9) possibly ruptured a southern extension of about 10 km length.

4. Geo-environmental Effects and surface ruptures

Surface ruptures were observed in the field and photographs were published by PHIVOLCS (Figure 4). The published surface breaks also indicate left-lateral displacements of the order of a few cm to decimetres.

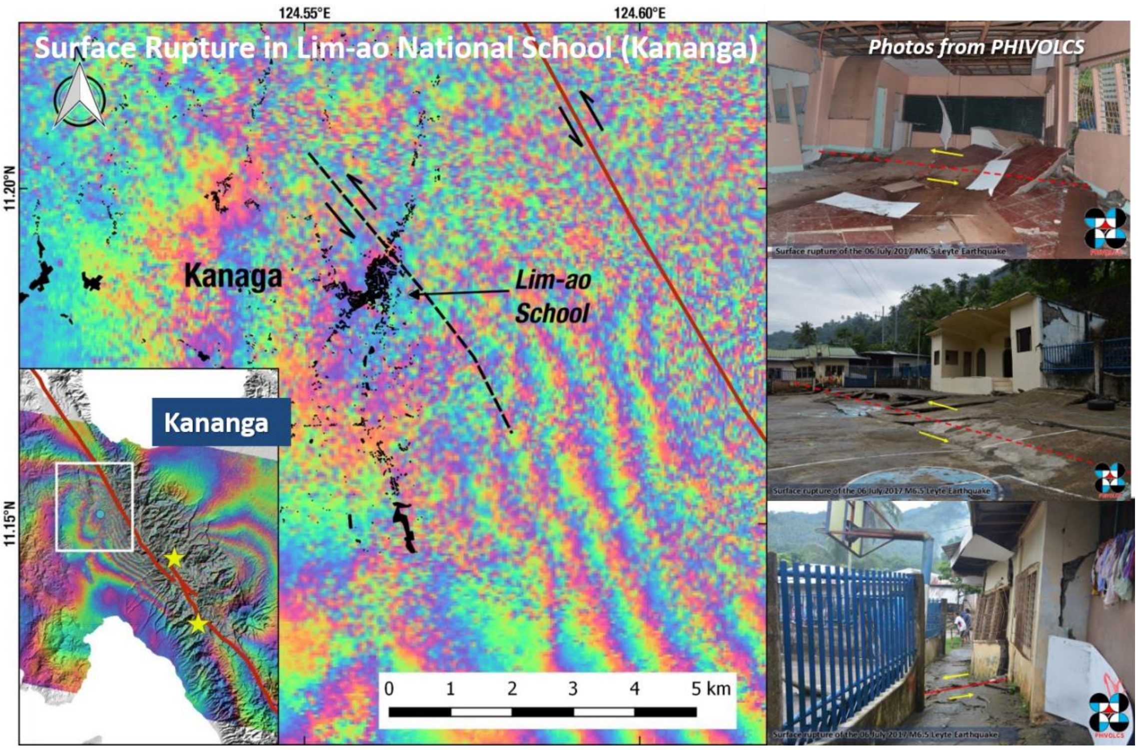

Figure 4. Location of the Kananga School where left-lateral surface ruptures were reported. The location of Kananga is about 3 km to the west of the mapped fault trace, indicating that rupture on secondary faults occurred within the main fault zone.

The intensity of the shaking reached **0.3 g** according to the USGS shake map (Figure 5 left) while the region is heavily susceptible to landslides (Fig. 5 right). Accelerations up to 0.1 g may have occurred at distances up to 30 km from the epicentre.

Due to cloud cover and satellite acquisition schedule, up to this date (July 12) there is no available optical image for Leyte island from Landsat 7/8 and Sentinel-2A/B. Sentinel-1 radar images penetrate the cloud cover and was possible to determine a number of sites of possible mass movements. Several landslides were mapped in Sentinel-1 false colour composites (Fig. 6). The area that was widely affected by these phenomena is the one close to the July 6 epicentre (Figure 6). This zone is characterized as highly susceptible (Figure 5) to slope failures probably due to the combination of geomorphological parameters (high elevation and steep slope) together with the highly fracture rock mass due to tectonic activity, resembling the Lefkada 2015 case (Papathanassiou et al. 2017).

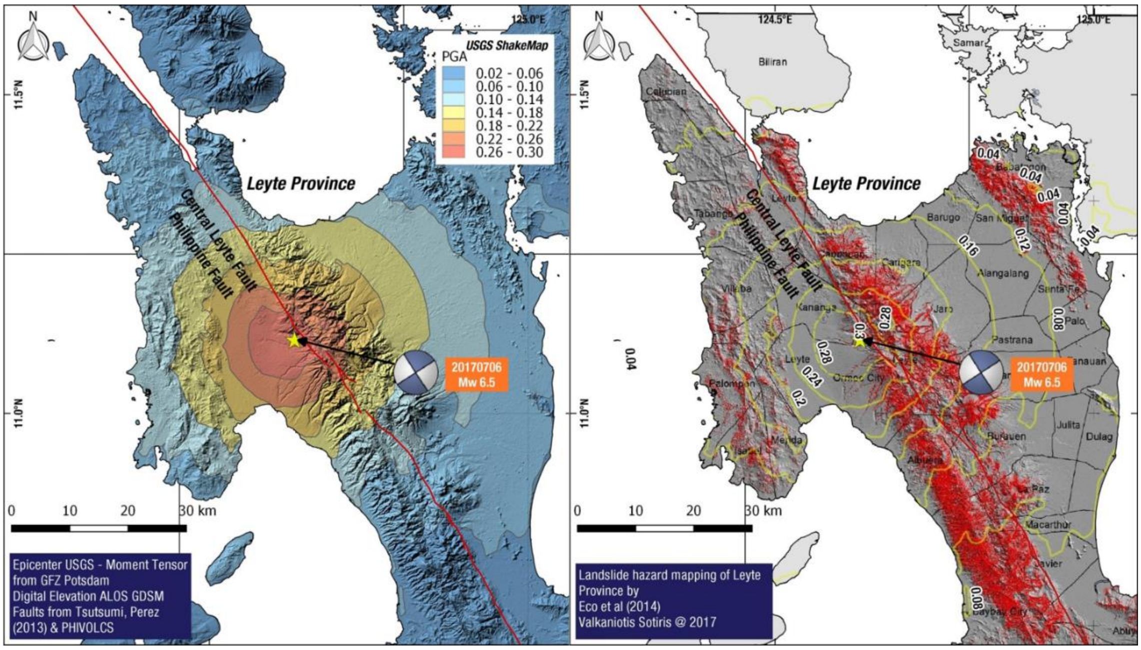

Figure 5. Strong Ground Motion and estimated Landslide Susceptibility for the Mw 6.5 earthquake: PGA map (left) and landslide susceptibility (Eco et al., 2014; right).

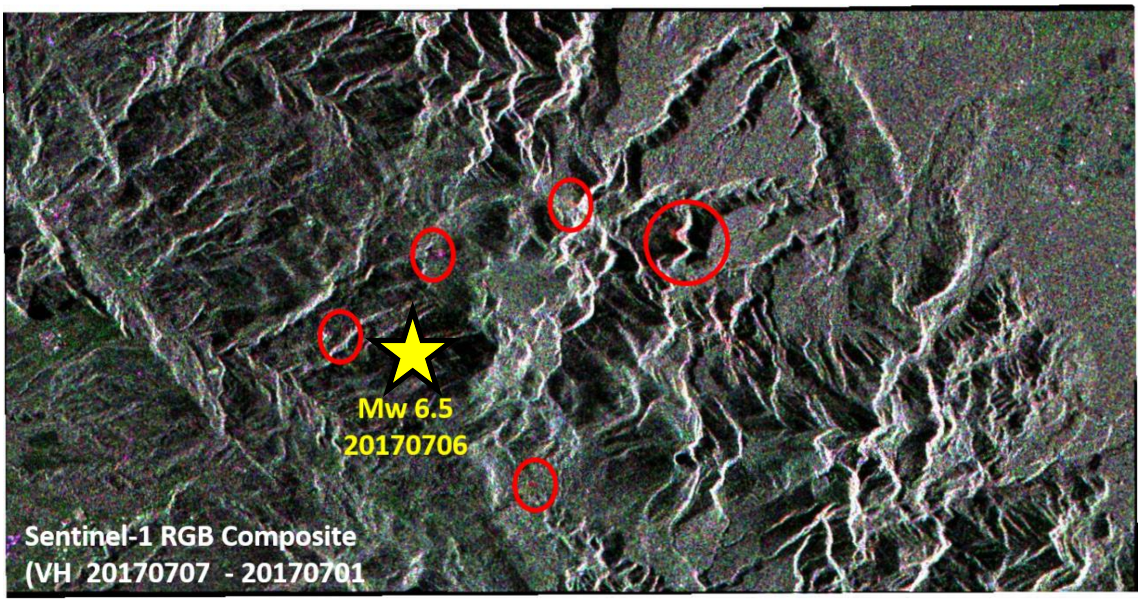

Figure 6. Sentinel-1 RGB composite showing locations of seismically-triggered landslides. R: S1 VH-20170707 (post event) G: S1 VH-20170701 and B: S1 VH-20170701

5. Acknowledgments

We thank ESA for satellite acquisition imagery.

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