CO-SEISMIC DISPLACEMENT OF 24-MARCH-2011 M_W=6.8 MONG HPAYAK (TAR LAY) EARTHQUAKE, MYANMAR

Itthi Trisirisatayawong[1], Andy Hooper[2], Anuphao Aobpaet[3]

[1] Department of Survey Engineering, Chulalongkorn University, Bangkok, Thailand. Itthi.t@eng.chula.ac.th
[2] Department of Remote Sensing, Delft University of Technology, Netherlands. a.j.hooper@tudelft.nl
[3] Geo-Informatics and Space Technology Development, Bangkok, Thailand.anuphao@eoc.gistda.or.th

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ABSTRACT

The 2011 M_w=6.8 Mong Hpayak earthquake occurred on the western segment of the Nam Ma fault, one of many left-lateral faults in the borderregion of Myanmar, Laos and Thailand. SAR images are probably the only available geodetic data for studying the co-seismic motion of this earthquake. Two-pass DInSAR processing of both ascending and descending ALOS PALSAR images reveals surface displacement pattern of nearly pure strike-slip fault. These InSAR results are modelled as elastic repsonse to slip on a planar fault and then downsampled for the inversion to solve for fault parameters. The co-seismic displacements predicted by the resulted fault model agrees well with InSAR observations. We then calculate the distribution of Coulomb stress change in nearby active faults and it is revealed that sections of nearby faults in northern Thailand have increasing stress. This information would help re-evaluate the likelihood of future earthquake in this fault zone.

1. INTRODUCTION

The M_w=6.8 Nam Ma earthquake (described as Myanmar earthquake in USGS catalogue and also referred to as Mong Hpayak or Tar Lay earthquake in the media report) occurred on the evening of 24 March 2011 in the border region of Myanmar, Thailand and Laos, known as the Golden Triangle (Fig. 1). It is the strongest seismic event on SE Asia peninsular since the December 2004 M_w=9.2 Sumatra Andaman earthquake. The tremor could be felt as far as Hanoi, Vietnam and also by people living in highrise building in Bangkok.

The Nam Ma fault on which the earthquake occurred is one of the many near parallel left-lateral faults trending SE-NW between the Sagaing fault in central Myanmar and the Red River fault in northern Vietnam. About 60 km south of the Nam Ma fault lies another left-lateral active fault in northern Thailand called the Mae Chan fault. In May 2007 a M_w=6.1 earthquake occurred in Laos at a location that is likely to be an eastern segment of the Mae Chan fault. Study on the estimation of ground motion of this earthquake is in [1] (the study incorrectly label this earthquake as Nam Ma). The two earthquakes are only 104 km apart, and what seems to be a cluster in space and time poses the question of whether the Mong Hpayak earthquake could have been triggered by the 2007 event in Laos.

In general, the geometry of active faults in the Golden Triangle region of northern Thailand is poorly documented. Co-seismic displacement from geodetic measurements, either from GPS or InSAR can be used to derive such information. To the best of our knowledge there is no CGPS (Continuous GPS Station) in the region, with the closest CGPS to the epicenter being in Chiengmai, which is too distant to record a deformation signal. As such, SAR satellites are probably the only instruments that can provide geodetic data for the study of co-seismic motion. Unfortunately no SAR image was acquired before the Laos earthquake, and therefore it is impossible to perform InSAR analysis on co-seismic motion of the Laos earthquake.

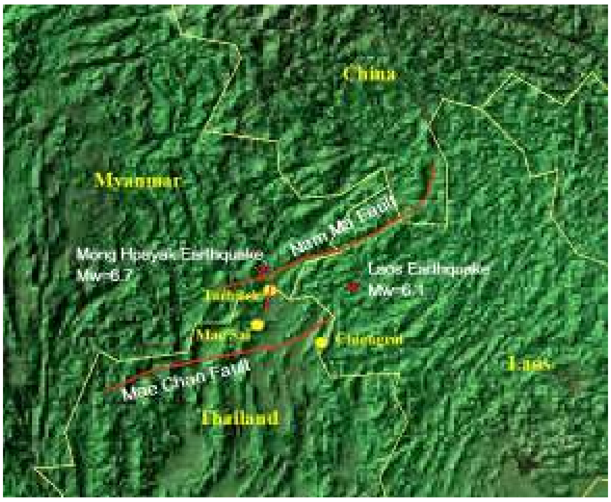

Figure 1. Location map of Nam Ma and Mae Chan fault. Surface traces of the Nam Ma fault and a small unnamed fault are approximated from a figure in http://www.earthobservatory.sg/media/news-and-features/295-myanmar-earthquake-of-march-24th-magnitude-68.html. Earthquake epicenters (red stars) are from USGS reports.

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Situation is different for the 2011 Mong Hpayak earthquake. There exists pre-earthquake ALOS L-Band SAR images in the catalogue and this coupled with rapid tasking for post-earthquake image acquisition open up an opportunity to determine the co-seismic deformation field resulting from the earthquake. Details of these data and DInSAR processing are provided in Section 2 and 3 respectively. Section 4 and 5 describe the determination of fault geometry, which is subsequently used in the computation of Coulomb stress change as explained in Section 6. Section 7 concludes the paper.

2. DATA

Both ascending and descending ALOS PALSAR SLC (single look complex) images with precision orbit and standard attitude data spanning the period of mid-February and early April 2011 were requested through Sentinel Asia. Acquisition details and perpendicular baselines are given in Tab. 1.

Table 1. Acquisition details and perpendicular baselines of ALOS PALSAR images.

Path	Pre-quake date	Post-quake date	Perp. Baseline (m)
Asc.	16 Feb 2011	3 Apr 2011	48.7
Desc.	14 Feb 2011	1 Apr 2011	436.2

3. DInSAR PROCESSING

We use GAMMA software to generate multi-looked interferograms (4 and 6 multilook in range and azimuth direction respectively) of both ascending and descending image pairs by 2-pass DInSAR technique. Band filtering is applied in both range and azimuth. Although the study area is vegetated and situated in tropical zone, the coherence is very good. This could be attributed to the fact that the SAR imaging period is in the dry season and also to the long wavelength of L-band PALSAR. The topographic phases are simulated from 3-sec SRTM DEM and removed from the interferogram. The diffrential interferograms of both paths are presented in Fig. 2. The phases are then unwrapped by a minimum cost-flow algorithm using Delauney triangulation.

As the time separation from the earthquake to image acquisition date are only 8 and 10 days for descending and ascending path, we assume any postseismic deformation will be relatively small and interpret the deormation as co-seismic motion only. The interferograms are geocoded into UTM (zone 47) coordinate system. For later stage modelling, the look vector data in terms of azimuth and incidence of each position to the satellite are generated.

4. FIRST APPROXIMATION OF NAM MA FAULT PARAMETERS

As information describing geometric characteristic of Nam Ma fault is not available, the estimates of some of the parameters i.e. position, strike, length and slip are initially derived from the ascending-path geocoded interferogram. The dip angle and width are estimated close to vertical, assuming that the fault's dip is similar to that of Mae Chan's fault as reported in [2]. We then use these estimates to generate co-seismic ground surface displacement by Okada's formula [3].

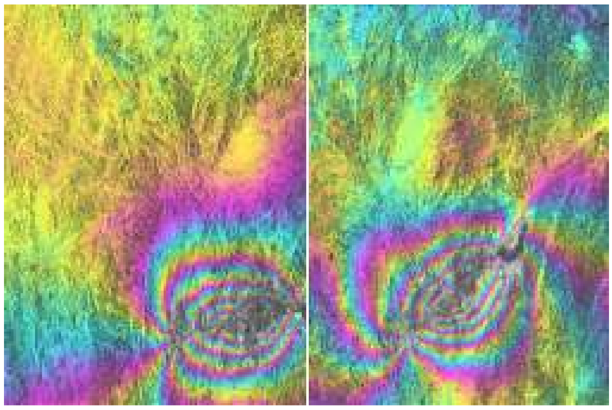

Figure 2. Interferogram from ascending (left) and descending SAR image pair.

The co-seismic displacement field are then mapped into radar line-of-sight direction, assuming a fixed heading and incidence angle over the entire image for both ascending and descending path. Comparisons with displacements obtained from InSAR are made and parameters are re-estimated until the displacement pattern generated from Okada's formula closely resemble InSAR result. The parameters are then used as initial values in the inverson analysis.

5. INVERSION ANALYSIS

We model the fault plane as a rectangular patch and calculate the Greens functions for its slips. To reduce the number of points in the inversion analysis we downsampled both interferograms by an adaptive quad-tree subsampling described in [4]. We then estimate covariance from the non-deformin region and apply a Markov chain Monte Carlo algorithm to find the posterior probability distribution of the slip. In order to restrict the range of solutions to distributions of slip that are physically reasonable, we apply an additional smoothing constraint; we assume that the probability distribution of the Laplacian of the slip is Gaussian, and simultaneously solve for the variance of this distribution.

The resulted model characterize the Nam Ma fault as near vertical, almost pure strike-slip. The slip is 2.5 m, and the computed moment magnitude from the model is M_w=6.75 which is close to the seismic estimate. The model with maximum *a posteriori* probability is used to generate modelled co-seismic motion in the radar line-of-sight and the differences are computed. These are shown in Fig. 3.

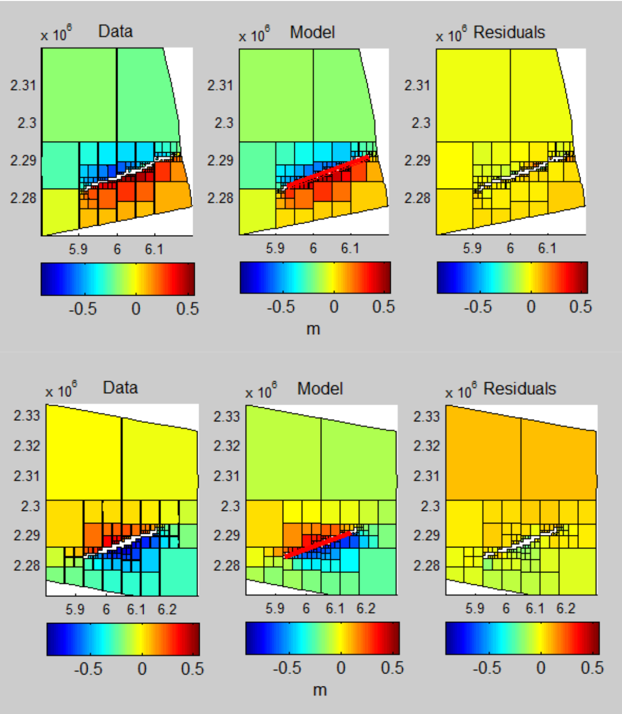

Figure 3. (above) Coseismic displacement in the line-of-sight of the ascending ALOS path from the downsampled interferogram (left), model (middle) and the residual between the two (right). The images in below row are from descending path.

The residuals in the ascending path show an overall good agreement between the model and InSAR observations. Certain locations near the fault exhibit errors significantly larger than others, however. The pattern is somewhat reversal in descending direction where overall the results are not as good but there are less observations in the rupture area that have large residuals. This indicates that single fault plane is too simple to properly model the deformation from this earthquake.

Despite this limitation, it is obvious from both ascending and descending residuals that the single-plane model is realistic enough for this intial study. Partitioning the fault into multiple patches and including stiffness that varyies with the depth would result in an improved model but this will be the subject of further research.

6. COULOMB STRESS CHANGE COMPUTATION

It has been widely accepted that an earthquake redistribute stress in the surrounding region. As a result, depending on their locations, orientations and geometries, nearby faults may be further loaded or relaxed and the likelihood of the next earthquakes changes.

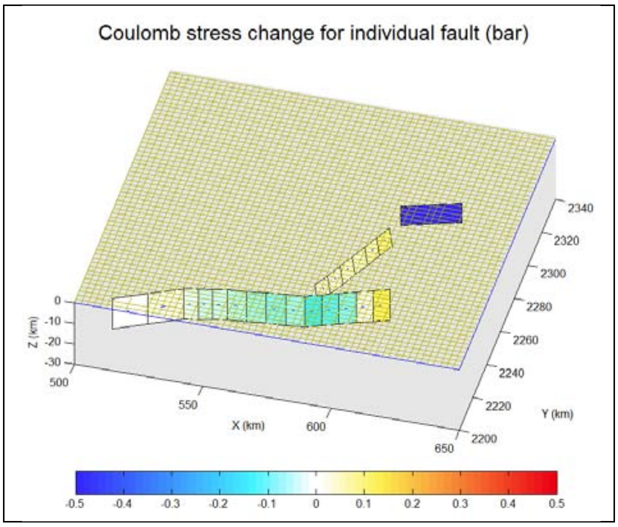

Figure 4.Coulomb stress change on segments of Mae Chan fault and a reverse fault.

The parameters of the ruptured segment of Nam Ma fault obtained from our inversion analysis are used in the computation of comlomb stress change. We use the USGS Coulomb program [5, 6] for this computation. The stress change is resolved on segments of Mae Chan fault (left-lateral) in northern Thailand and also on a reverse fault in between Nam Ma and Mae Chan.

As shown in Fig. 4, the middle segments of Mae Chan faults are in a stress shadow zone while failure on east and west ends are promoted by the increased stress. The whole unnamed north-south reverse fault passing through two border cities of Mae Sai in Thailand and Tachilek in Myanmar are in stress triggering zone. The greatest Coulomb stress imparted from Nam Ma earthquake is in the northern tip of this fault while the remaining of the faults the stress change are very low (<0.05 bar) and perhaps negligible.

We would like to note here that geometrical information of Mae Chan and the unnamed reverse faults in this study including the surface trace are roughly estimated from graphical secondary source. Because Coulomb stress changes depend on geometry and orientation of the fault planes, the results could differ from those shown in Fig. 4 if a more reliable set of fault parameters were used.

7. CONCLUSION

ALOS PALSAR images have proved to be valuable data to determine co-seismic surface displacement of the Nam Ma earthquake. The computed deformations from InSAR are used in the inversion analysis of fault parameters using simple fault plane model which subsequently be used to compute Coulomb stress changes in nearby faults. We found that most of the Mae Chan fault falls in a stress shadow and so Coulomb failure is inhibited. On the northern part of the reverse fault passing through Mae Sai and Tachilek, maximum Coulomb stress change increases by 0.15 bar. This indicates that the eastern and northern tip of these two faults may have higher probability of seismic risk.

We plan to improve on inverse modeling by using multiple patches and variable stiffness. Further, we also plan to acquire more accurate geometry and orientation of the fault systems in this region. This more realistic representation of the faults could lead to a better understanding of fault inter-relationship and ultimately the improvement on the sesimic risk assessment.

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