2009 EARTHQUAKES IN SUMATRA: THE USE OF L-BAND INTERFEROMETRY IN A SAR-HOSTILE ENVIRONMENT

Emmanuel Christophe, Aik Song Chia, Tiangang Yin, Leong Keong Kwoh

Centre for Remote Imaging, Sensing and Processing , National University of Singapore

1. INTRODUCTION

On September 30^{th}, 2009, a major earthquake of magnitude 7.6 occurred near the west coast of Sumatra close to the city of Padang. On October 1^{st} a significant aftershock (magnitude 6.6) occurred 270 km away. The casualties are estimated at 1200. This earthquake comes at a time when the seismic activity in the region is particularly high [1]. The purpose of this paper is to show the contribution L-band interferometry can have in such an event both from the damage assessment perspective and to enable a better understanding of the underlying geological phenomena.

The use of interferometry to assess earthquake displacement has been demonstrated a long time ago [2, 3] but mostly used in dry areas. Interferometry processing is a topic well explored [4] for more than a decade. However, its sensitivity to the image condition: baseline, loss of coherence, slopes, atmosphere. . . makes it difficult to use the same process for all images.

The region around the Sumatra earthquake is particularly hostile to interferometry: most of the area is covered by dense vegetation, the area is mountainous with steep slopes and the water content of the atmosphere is high. Furthermore, access to this region is difficult which makes spaceborne interferometry more suitable than airborne.

As there are currently no tandem missions for spaceborne interferometry, the temporal baselines are usually important: about 30-50 days depending on the orbit cycle. With such long temporal baselines, the loss of coherence is important for the shorter wavelengths (X and C bands). L-band is more promising as the coherence usually remains sufficiently high even in heavily forested areas.

2. PALSAR DATA

The Palsar sensor onboard the Alos satellite provides regular images from the Southeast Asia region. As shown on Fig. 1, several scenes cover the region of interest. However, the descending orbits are not sufficiently represented in the archives to enable successful interferometry. Only images on ascending orbits are captured more frequently. On path 447, right over the city of Padang, a temporal baseline of 46 days is available. On the neighbouring track, only 92 days baseline is available, reducing the coherence and the quality of the interferogram. On Siberut island (west of Padang), a temporal baseline of 46 days is available.

3. LANDSLIDE DETECTION

One of the important consequences of the earthquake is the major landslides that occurred in the area. These landslides are easy to see on optical images from SPOT5. However, several constraints make it difficult to rely only on optical images to detect landslide. First, the area is particularly cloudy and getting a cloud free image can take weeks. As shown on Fig. 2, the cloud fraction over the west coast of Sumatra is around 0.85-0.90. Secondly, landslides are mostly identified as patches of bare soil in the middle of the forest which are easy to spot but it is harder to tell whether or not it is really a landslide and if it was caused by the earthquake or if it was there before , see Fig. 3(a). To make the difference, a recent image before the event is required which makes the perfect scenario even more unlikely because of the clouds.

On the other hand, SAR systems are able to acquire the image independently of the weather. However, it is difficult to recognize a landslide from the SAR data directly. One important by-product of the interferometry processing is the availability of a coherence map which indicates the change in the scattering properties of each pixel. Between two consecutive orbits (46 days), the coherence usually remains high even for vegetated areas (in L-band). For example, many of the vegetated areas in Fig. 3(b) have a coherence above 0.8 (in yellow). In contrast, the part where the landslide occurred has a coherence below 0.2 (in blue).

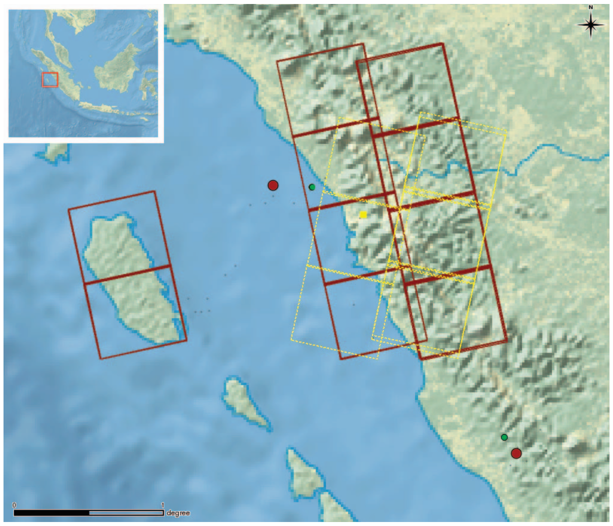


Fig. 1. Location of the earthquakes in Sep-Oct 2009 (red and green dots), and corresponding Palsar scene locations. Unfortunately, the descending orbit scenes (dotted yellow) do not have any recent image before the earthquakes. Only ascending orbit scenes can be used.

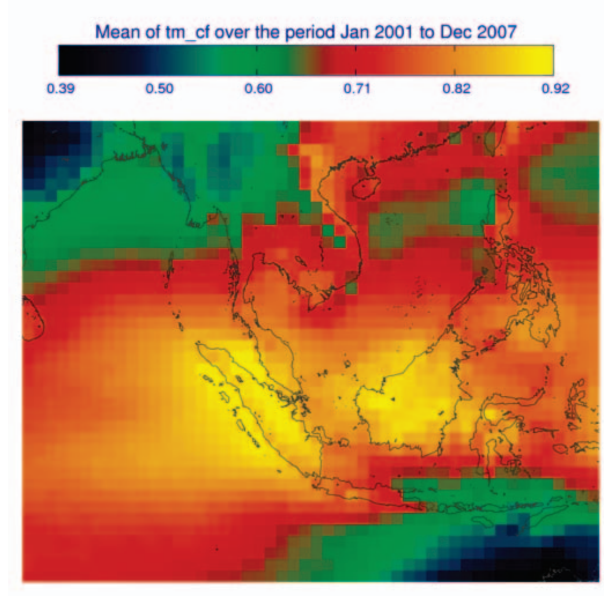


Fig. 2. Average cloud fraction over Southeast Asia computed from Modis Terra data. With a cloud fraction around 0.85-0.90, it is particularly difficult to have clear optical images of the west coast of Sumatra.

The coherence is computed from the interferogram and filtered with an adaptive function based on the local interferogram fringes.

4. DISPLACEMENT MEASUREMENT

4.1. Results on similar ground conditions

Earlier work on the earthquake that happened in January 2009 near the north coast of Papua, Indonesia shows that even in similar difficult conditions (but with more suitable baselines), it is possible to obtain good results. Fig. 4 shows the differential interferogram obtained with a temporal baseline of 92 days. However, the conditions here are quite favorable with a perpendicular baseline of 20 m and a good orbit determination.

4.2. First results over Padang

Acquisition over Padang does not present such an ideal configuration. The perpendicular baseline between the images taken before and after the earthquake is very small: less than 2 m at near range. This short baseline amplifies the errors in the interferogram due to an imperfect knowledge of the orbit. The classical method using the FFT for the estimation of the residual phase trend does not work in these conditions.

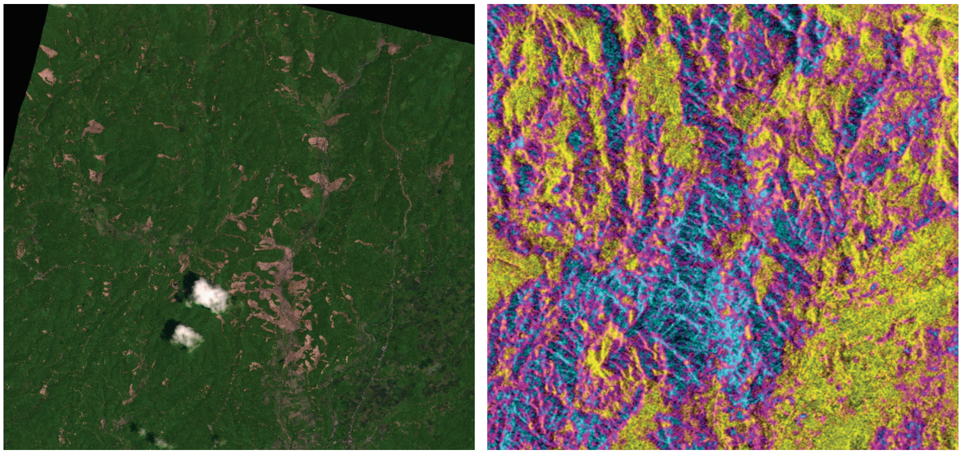
A more complicated process using ground control points (GCP) after complete processing (interferogram generation, phase unwrapping) is used to estimate the baseline (Least square estimation) and obtain more accurate results.

One of the differential interferograms obtained over the city of Padang is presented in Fig. 5.

5. CONCLUSION

L-band interferometry is a useful tool to help the study of earthquakes and the assessment of the resultant damage in tropical regions. It can be used at different levels: using only the coherence or fully processing the differential interferogram.

The differential interferogram is particularly sensitive to baseline precision, but even in difficult conditions and if the coherence is high enough, the high number of points and the stability of the orbit of spaceborne sensors allow for a better estimation and results can be obtained.



(a) SPOT5 (b) Palsar coherence

Fig. 3. Images (a) and (b) show roughly the same area with a SPOT5 image where the landslides are obvious and a colour composite of the multilook palsar image of the same area and the coherence computed between two images before and after the earthquake. Areas of low coherence appear in blue and indicate the landslides.

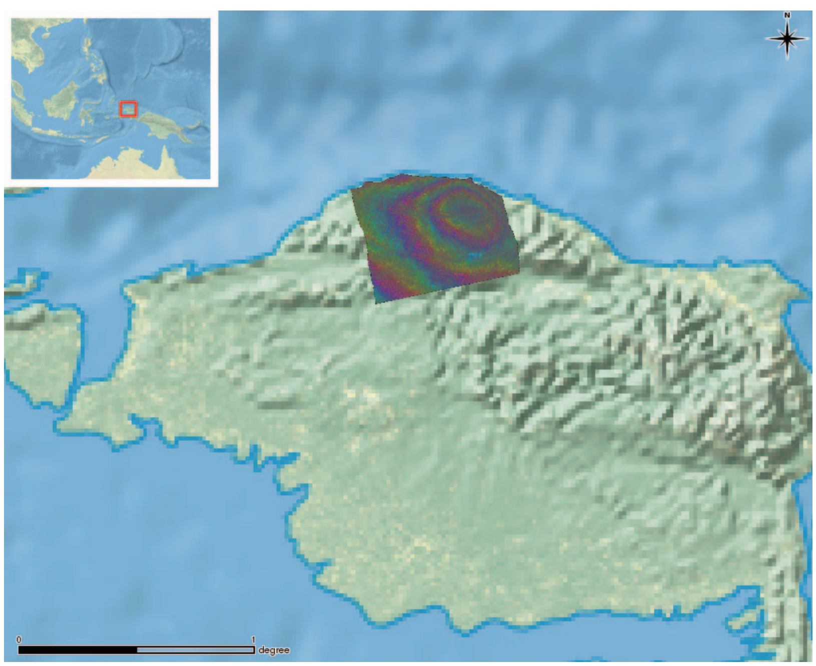


Fig. 4. Example of a differential interferogram obtained on the double earthquake (magnitude 7.6 and 7.4) near the North coast of Papua, Indonesia on January, 3^{rd}, 2009.

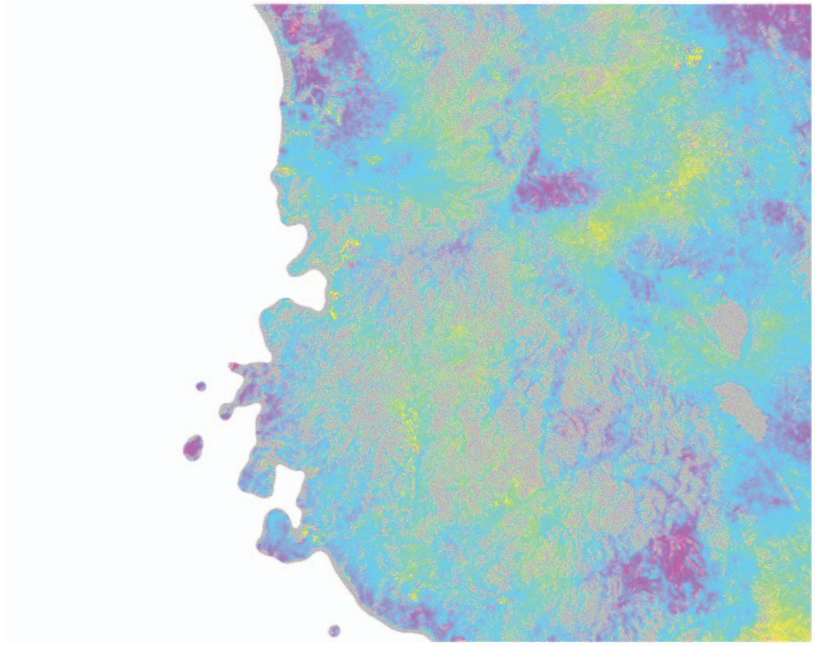


Fig. 5. Preliminary result over the city of Padang after the earthquakes of September 30 and October 1, 2009. One cycle represents a motion in the line of sight of 10 cm.

6. REFERENCES

[1] A. Ozgun Konca, Jean-Philippe Avouac, Anthony Sladen, Aron J. Meltzner, Kerry Sieh, Peng Fang, Zhenhong Li, John Galetzka, Jeff Genrich, Mohamed Chlieh, Danny H. Natawidjaja, Yehuda Bock, Eric J. Fielding, Chen Ji, and Don V. Helmberger, "Partial rupture of a locked patch of the Sumatra megathrust during the 2007 earthquake sequence," *Nature*, vol. 456, pp. 631–635, Dec. 2008.

[2] Didier Massonnet, Marc Rossi, César Carmona, Frédéric Adragna, Gilles Peltzer, Kurt Feigl, and Thierry Rabaute, "The displacement field of the Landers earthquake mapped by radar interferometry," *Nature*, vol. 364, pp. 138–142, July 1993.

[3] Morteza Talebian, Eric J. Fielding, Gareth J. Funning, Manoucher Ghorashi, James Jackson, Hamid Nazari, Barry Parsons, Keith Priestley, Paul A. Rosen, Richard Walker, and Tim J. Wright, "The 2003 Bam (Iran) earthquake: Rupture of a blind strike-slip fault," *Geophysical Research Letters*, vol. 31, 2004.

[4] Richard Bamler and Philipp Hartl, "Synthetic aperture radar interferometry," *Inverse Problems*, vol. 14, 1998.