# SAR AND OPTICAL SATELLITE IMAGES FOR CO-SEISMIC HORIZONTAL OFFSETS ESTIMATE AND FAULT TRACE MAPPING USING PHASE-CORR TECHNIQUE

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## 1. INTRODUCTION

Recent applications of global image disparity measurements [1-2], assuming rigid body motions (translation, rotation and change of scale), has emerged as a wealth of new branch of geodetic data. It highly complements DInSAR and advanced DInSAR ground motion imaging (highly sensitive to vertical components), because optical and SAR image correlation methods are able to sense the horizontal components of the ground motion [3-4].

In this work, we present several examples of using optical and SAR data in a new robust unwrapping-free phase correlation method, Phase-corr method [5], for retrieving the coseismic displacement field and the surface rupture fault-trace mapping of three different earthquakes.

The work is organized as follows. In section 2, we briefly describe Phase-corr method and some performance tests. Then, Sections 3, 4 and 5 are dedicated to show results for the application of Phase-corr to IRS (Indian Remote Sensing) satellite images to determine coseismic effects due to the Izmit earthquake, ASTER and ASAR data to Kashmir earthquake and, finally, PALSAR and COSMO-SkyMed data to L'Aquila earthquake, respectively. Finally, in Section 6, we discuss the applications and provide some final remarks.

## 2. PHASE-CORR: A ROBUST PHASE CORRELATION METHOD

We applied a new robust phase fitting correlation method [5]. The algorithm starts from already orthorectified images, either using conventional or sophisticated methods [2]. Then, the roughly corregistered images (to the same reference system) are correlated using a small sliding window, to which a Tukey window filtering is applied to make the signal circularly symmetric. Then, we compute the discrete Fourier transform of the individual images and their cross product. We extract the phase difference of the cross product, using a masking to a cut-off half of the normalized sampling frequency, then we detect in- and outliers using the RANSAC algorithm. Finally, we solve for the best fitting plane using a re-weighting iterative least squares with bisquare weights. The method has been tested under several relevant performance scenarios to show its robustness (addition of white noise, aliasing and bits quantization).

## 3. 1999, Mw 7.4, IZMIT (TURKEY) EARTHQUAKE

On August 17, 1999, a strong earthquake (Mw 7.4) occurred along the western sector of the North Anatolian Fault System in Turkey. The epicenter was located nearby the city of Izmit, 50 km east of Istanbul (Fig. 1). In 1999, the orbiting highest spatial resolution camera was the panchromatic sensor (PAN), a 5.8 m pixel on-board of IRS (Indian Remote Sensing) satellite. We have correlated the images using a correlation window of 64 by 64 pixels, with a step of 16 pixels (ground resolution of 80 m). The EW offset map shows clearly a straight slip discontinuity roughly oriented E-W (Fig. 1) the magnitude of the slip offset has been validated against ground and space-based measurements, showing a fairly good agreement. In [5], we present a longer discussion on the coseismic effects and more details about the processing using Phase-corr technique.

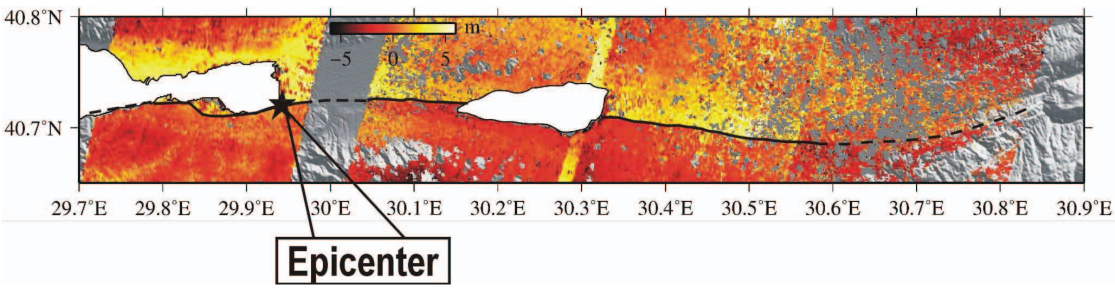
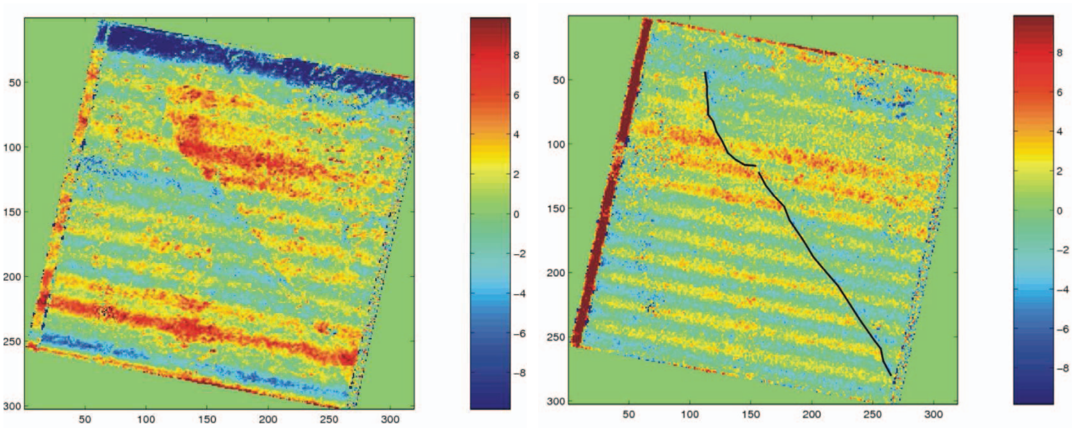



**Fig. 1**. Coseismic displacement field measured by IRS correlation images. We show with a star the location of the located epicenter. Note the step-over structure West of the epicenter, this area recorded the largest vertical motions (subsidence).

## 4. 2005, Mw 7.6, KASHMIR (PAKISTAN) QUAKE

On the 8 October 2005, a moment magnitude earthquake of 7.6 struck a large are in Kashmir (North Pakistan) causing a toll dead of more than 74,500 (14th deadliest earthquake of all time) and 106,000 injured [6]. There is a large consensus on the earthquake faulting mechanism that generate the earthquake and several groups have studied the quasi-static ground deformation field [7-8]. It makes a good test event for application and comparison to similar ground resolution horizontal deformation estimates from SAR and optical correlation products. For this study, we used the same pre- and post-event ASTER images used by [8].

In Figures 2a and 2b is shown the obtained co-seismic ground deformation field using ASTER images. The two images have been firstly orthorectified using the COSI-CORR software [9]. Once the images have a common reference system (either cartographic or image-based) we applied the Phase-corr. Although correlation results, we found that inaccurate sensor attitude information are needed to fully correct the orthoimages [10].




a) b)

**Fig. 2**. a) North-South component of the coseismic displacement field measured by correlation of ASTER images due to the 2005 Kashmir earthquake. Note the clear unmodeled roll variations [10]; b) East-West component of the coseismic displacement field measured by correlation of ASTER images due to the 2005 Kashmir earthquake. The black line highlights the surface trace of the fault identified as a clear strong gradient change in the measured displacements.

## 5. 2009, Mw 6.3, L'AQUILA (ABRUZZI) QUAKE

The Mw 6.3 L'Aquila earthquake occurred during the night of the 6 of April 2009 (01:32 GMT); it hit a densely populated region of the Apennines and was felt all over Central Italy. About 300 people lost their lives and more than 60,000 people were evacuated from the City of L'Aquila and several nearby towns. The earthquake caused the partial or complete collapse of a significant number of highly vulnerable, historical buildings.

In this case COSMO-SkyMed X-band SAR and ALOS L-band SAR have been used for measuring the horizontal displacement by the Phase-corr algorithm. This test case has been more challenging since the horizontal deformation occurred has been smaller.

## 6. CONCLUSIONS

We present several examples of application to earthquake and seismic activity using a new robust unwrapping-free phase correlation method, Phase-corr method [5] to optical (IRS and ASTER) and SAR (ASAR, PALSAR and COSMO-SkyMed) images for the retrieval of the coseismic displacement field and the surface rupture fault-trace mapping.

Results indicate that phase correlation methods are suitable to complement the ground deformation data provide by DInSAR displacement maps with information about the horizontal components of the ground motion. As previously reported [10], accurate ephemerides and attitude sensor data is a sensitive step to obtain precise orthoimages useful to correlation. In this paper, we show that that correlation of SAR images is also highly complementary to optical correlation products.

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