MODELING OF DEFORMATION SOURCES BASED ON A NON-LINEAR INVERSION APPROACH

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ABSTRACT

A new modeling of deformation sources based on a non-linear inversion approach is proposed. The forward modeling is provided by the semi-analytic deformation model for point sources and finite faults. The parameters of the fault are inverted using a combination of non-linear optimization algorithms. The misfit function defined for the optimization is based on the L2 norm of the error weighted by the coherence of the considered spatial point. In order to explain our modeling procedure we propose the inversion of a single descending pass differential interferogram of the Bam 2003 earthquake.

1. INTRODUCTION

In the field of European Space Agency Category-1 Project 5834, we have established a processing chain of Synthetic Aperture Radar (SAR) data for identification and parametrisation of deformation sources in areas of active ground deformation (e.g. seismogenic areas, volcanic districts). SAR data from European Space Agency (ESA) satellites ERS-2 and ENVISAT are used.

2. ADVANCED DATA PROCESSING

We perform an advanced data processing using Doris [2,3] a single program that can do most common steps of the interferometric radar processing starting from SLC data to generation of interferometric products and geocoding. Unwrapping of interferometric phase is performed using the public domain software snaphu [1].

3. DATA

To test our modeling procedure we chose three study areas, refer to seismogenic sources with different orientation to respect satellite Line Of Sight (LOS): December 26 2003 Iranian earthquake, data from both ascending and descending passes of ENVISAT ASAR narrow swath IS2; August 17 1999 Turkey earthquake, data from both ascending and descending passes of ERS-2 AMI SAR; June 17-21 2000 Iceland earthquakes, data from both ascending and descending passes of ERS-2 AMI SAR.

4. DATA INVERSION

The inversion of complex fault patterns requires a realistic distribution of the slip value over the fault surface. The ground deformations can be used to retrieve the slip distribution taking into account that the resolution level is limited by various factors. We propose a method for imaging the slip distribution over the fault using an adaptive resolution approach.

The basic principle of the method is that the fault surface is progressively split into smaller subfaults until all the information has been retrieved by the data. This is achieved using the Akaike Information Criterion (AIC) in order to prevent an overfit of the data with faulting patterns of arbitrary complexity.

The whole procedure consists in three steps. In the first step a trial-and-error approach is used to get a rough fault model. In the second step the model is improved using a local optimization algorithm (the Nelder & Mead Simplex method) which optimize the 9 considered basic fault parameters: position of the center (x,y,z), lenght, width, strike, dip, rake angle and slip.The misfit function is defined as the sum of the residuals square. This basic solution is used as a starting model for the following step. The third step is the most important and consists in repeated iterations. The fault is progressively split in subfaults, each having its own slip value. During an iteration, each subfault is split in two symmetric parts, first along the dip direction and then along the strike direction. Each time a subfault is split a new inversion of the whole slip distribution over the fault is performed using a linearized approach and the final misfit function is computed.

The linearized approach consists in reformulating the inverse problem as shown in Eq. 1.

$$d = G(m_0) + \frac{\partial G}{\partial m} \Delta m \qquad (1)$$

d are the observations, *m* is the model, which in this case is the slip value for each subfault and *G* is the forward operator which is the mathematical relationship between the data and the model parameters. We have used an Okada fault model for each subfault [4]. The derivative appearing in the equation is computed by

Proc. 'Fringe 2009 Workshop', Frascati, Italy,
30 November – 4 December 2009 (ESA SP-677, March 2010)

numerical differentiation. Starting from a reference model m_0 this approach furnished the model perturbation Δm which minimizes the misfit function. At the end of each iteration the fault model which makes the misfit function minimum is chosen. Then the AIC is computed and the iterative procedure is stopped when the AIC does not decrease.

5. THE BAM CASE

We have applied this approach for the inversion of a single descending pass differential interferogram of the Bam 2003 earthquake (orbits 9192_9693, 3 dec 2003_7 jan 2004). The AIC is minimum for the model having 7 subfaults which has been chosen as final model (Fig. 1). The slip distribution over the fault is highly heterogeneous with most of the deformation concentrated over two asperities. The resulting seismic moment is 5.3×10^{18} Nm ($\mu = 3.3 \times 10^{10}$).

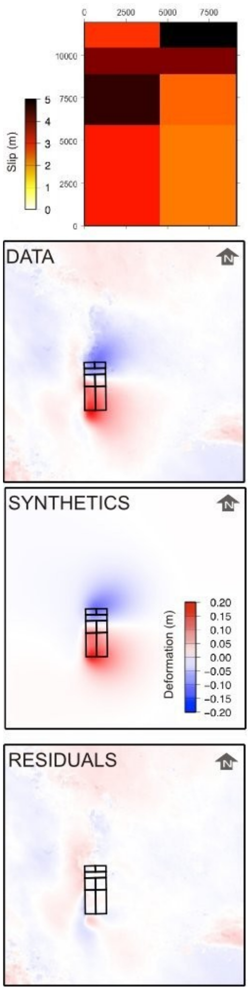

Figure 1. 7-subfaults model. The top image represents the slip distribution over the fault. The following three images represent respectively the original dataset, the synthetic deformations and the residuals. The represented area is about 80x100 km. The subfaults are projected on the topographic surface. Fault parameters: length 11940 m, width 9166 m, strike -0.72°, dip 54.50°, rake 187.92°, average slip 2.615 m.

6. ACKNOWLEDGEMENTS

Data provided by the European Space Agency (ESA CAT-1 Project 5834, P.I. B. Massa).

7. REFERENCES

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