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Stress inversion from initial polarities of a population of earthquakes: application to the Irpinia region (Southern Apennines)

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The Southern Apennines are an active tectonic region of Italy that accommodates the differential motions between the Adria and Tyrrhenian microplates. Large destructive earthquakes occurred both in historical and recent times, the last of which occurred on 1980 (Ms = 6.9). Even more than 30 years after the main event, the seismotectonic environment that encompasses the fault system on which the 1980 earthquake occurred shows continued background seismic activity including moderate-sized events such as the 1996 (M 5.1), 1991 (M 5.1) and 1990 (M 5.4) events. The in-situ stress data analysis and the analysis of seismological data for earthquake location, size and mechanisms have recognized that this area are characterized by an extensional stress regime that is responsible of the present-day seismicity.

We analyzed the instrumental seismicity of the Irpinia region (Southern Apennines), recorded by the ISNet (Irpinia Seismic Network, AMRA) and the nearby Italian National Seismic Network (Istituto Nazionale di Geofisica e Vulcanologia) stations during the last five years. We re-picked P- and S wave arrival times for a total of 8663 P- and 4358 S- phases on an high-quality waveform dataset consisting of 62430 traces, for 980 microearthquakes with a local magnitude range of $0.1 \leq ML \leq 4.8$, occured from August 2005 to April 2010. The seismic events inside the network have a maximum local magnitude of 3.2.

To improve the quality of the hypocentral locations we computed a one-dimensional (1D) velocity model and we relocated the earthquakes using a double differences (DD) technique. The relocated seismicity is more concentrated within the upper crust and it is mostly clustered along the Apennine chain.

The use of focal mechanisms to estimate the nature of the stress tensor in the seismogenic zone has been frequently used to study the state of stress acting in a region. The best stress tensor that fits the data is represented by the orientation of the three principal stress axes, and a scalar which describes the relative magnitudes of the principal stresses. We used the method of Rivers and Cisternas (1990) in which the raw first-motion polarities for a set of events are directly used for inversion.

In order to obtain a more realistic error estimation on the orientation of the three principal axes we decided to compute the confidence limits on the parameters of the model by using bootstrap resampling (Efron and Tibshirani, 1993). To simulate a repetition of an experiment, we resample data (polarities) randomly from the original dataset. This new dataset will have the same number of data as the original dataset, but will have same polarities repeated two or more times while other polarities will be absent. We re-grouped the polarities for event and we inverted this dataset for the stress field, and repeated this process several times. We obtain three distributions of points for the three principal axes and across the definition of the eigenvalue and eigenvector of the inertia tensor for each population of the corresponding axis we obtain the center of the distribution and confidence regions (e.g. 1-sigma, 2-sigma). The eigenvector of the inertia tensor gives information about the orientation of the ellipses and the eigenvalue controls the dimension of the semi-axis. The method we are using to define the ellipse works properly if the distribution is not very different from a gaussian.

All these analysis have allowed us to study in detail the spatial variations of stress field. In particular we identified the inner portion of the chain caracterized by shallow earthquakes (depths < 20 km) distributed along the axis chain (Irpinia area) with general NE-SW extension and the external margin (Potentino area) characterized by dextral strike-slip kinematics with a seismicity generally deeper.