INTRODUCTION

On April 6th 2009, a magnitude Mw=6.1 earthquake struck the Abruzzi region in central Italy. Despite its moderate size, the earthquake caused more than 300 fatalities and partially destroyed the city of L’Aquila and many villages in its surroundings. The main shock was preceded by an earthquake swarm which started at the end of 2008. The largest earthquakes of the swarm included a Mw=4.0, occurred on 2009/03/30 at 13:38 (UTC), and Mw=3.9 and Mw=3.5 events that occurred on 2009/04/05 at 20:48 and 22:39 (UTC) respectively. By the end of November 2009, more than 150 aftershocks with Mw>3.0 have been recorded by the INGV seismic network (Figure 1).

Current advances in data transmission and communication yield high quality broadband velocity and strong motion waveforms in near real-time. These data allow for the rapid characterization of earthquake sources in terms of fault geometry, focal depth and seismic moment. For the L’Aquila earthquake the velocimeter data of the Italian National Seismic Network (INSN, code IV), Mednet (code MN, station PGD), the North-East Italy Broadband Network (code NL, stations ACOM and PALA) and the SudTirol Province (code SI, station KOSE) were available in real-time. In the following days, the strong motion data of the RAN network ("Rete Accelerometria Nazionale") and the displacement data recorded by the INGV GPS Network (Anzidei et al. 2009) also became available.

In this study we present the results of the rapid source parameters determination procedure developed at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) (Scognamiglio et al., 2009) as applied to the L’Aquila seismic sequence. Our approach consists of two stages – the near real-time determination of the seismic moment tensor, that is already routinely performed for all M ≥ 3.5 earthquakes, and the rapid imaging of the rupture history on a finite fault for earthquakes with M ≥ 2.0. We present the moment tensor solutions computed for all the earthquakes of the L’Aquila sequence with ML ≥ 3.5, and examine the effect of the velocity structure on the main shock moment magnitude. Then we provide a detailed description of the moment tensor solution to the main shock event including both strong motion and GPS data.

Time Domain Moment Tensor Solutions (TDMT) for ML > 3.5 earthquakes.

We compute 64 moment tensor solutions (Figure 1) using the complete time domain waveform inversion technique proposed by Dreger and Helmberger (1993). The algorithm performs an inversion of band-passed ground motion that starts at about 0.02 Hz (the rise time of the INSN data) and goes up to 0.05 Hz. The Green’s functions (i.e., flat Earth, laterally homogeneous, layered velocity structures) used in this procedure have been previously methodized and stored using frequency-wave number integration code developed by Saikia (1994).

The focal parameters were found to be strike 139°, dip 85°, rake 90°, and focal depth of 13 km for the mainshock (Figure 6). We also find a deeper and smaller patch of slip located at 4 km down-dip from the hypocenter and a second slip patch located 8 km southeast from the hypocenter (Figure 6). We find also a deeper and smaller patch of slip located at 4 km down-dip from the hypocenter. The main patch of slip-up-dip from the hypocenter has a maximum slip of 88.5 cm, as well as a rake of 100°. Figure 7 shows the resulting fits to the recorded velocity time histories. The synthetic seismograms match better the recorded waveforms and the variance reduction is 68%.

Finite Fault Solution for the Main Shock

We use the L’Aquila main shock as a case study to test the potential of the procedure recently implemented at INGV to rapidly determine finite fault rupture models. The code, based on the work of Hartzell and Heaton (1983) and subsequently developed by Dreger and Kavelaars (2000), consists of a non-negative least-squares inversion scheme for estimating slip distribution and source parameters on the fault plane. That is, we can account for the variability and the uncertainties in the moment tensor decomposition. In particular, the slip on the fault plane is discretised into subfaults, each with its own strike, dip, rake, slip magnitude, and slip distribution. The slip on each subfault is determined using a non-linear inversion of the strong motion and GPS data. Geophys. Res. Lett., 38, doi:10.1029/2010GL045569.

CONCLUSION

The obtained Moment Tensor solutions demonstrate that the adopted procedure represents an applicable tool for real time determinations. The differences in fault geometry and scalar seismic moment shown in Figures 2 and 4A-B indicate that for the Italian region the moment tensor computation needs regionalised velocity models.

The rupture history of the L’Aquila main shock looks very complex. The adopted procedure catches the main energy releases of the kinematic rupture. The heterogeneous slip in rupture velocity and rake highlights the interaction of dynamic parameters driving the rupture process, or a complex geometry of the fault.

References: