A multiple-event interpretation of the 2003 Lefkada earthquake

J. Zahradnik [1], A. Serpetsidaki [2], E. Sokos [3], G-A. Tselentis [2]

[1] Charles University, Prague; [2] The University of Patras; [3] National Observatory of Athens

The objective of this paper is to give a preliminary explanation of the source process of the M~6 earthquake close to Lefkada island, Greece (August 14, 2003). The mainshock and about 300 aftershocks (Aug. 14 - Aug. 30) were located by the short-period telemetered network of the Patras Univ. (PATNET). Relocation by the double-difference method provided a well focused pattern composed of two spatially separated clusters (Fig. 1). The clusters operated practically in the same time (the first M~4 aftershock at Cephalonia occured 15 minutes after mainshock).

Five broad band stations were selected for the waveform modeling (Fig. 1): 4 stations belonging to the Nat. Obs. of Athens (KER, JAN, EVR, RLS), Lennartz 20 sec sensors, and 1 station jointly operated by the universities in Prague and Patras (SER), Guralp 100 sec sensor. The body wave part of records is dominated by complicated high frequency phases. In later arrivals, low frequency wave trains are significant. We concentrated on periods 10 sec and larger. Waves like that enable a closer look at the source process than long-period waves routinely analyzed in major seismological centers. At the same time, knowledge of the crustal structure is sufficient at periods larger than 10 seconds. We proved this by successful forward modeling of a M~5 aftershock. Two crustal models were tested, viz. Haslinger et al. (1999) and Novotny et al. (2001); the aftershock fit was a bit better for the latter, thus it was chosen for this paper. (The true focal depth is problematic, since the optimum model depth varies with the assumed crustal structure.) The Lefkada mainshock was also subjected to forward single point-source modeling but the dominant late arrivals remained strongly unexplained, thus indicating importance of the finite-extent source effect.

The multiple source method (Kikuchi and Kanamori, 1991) has been chosen for this study. A new code was written allowing modeling of full wavefield at regional distances, based on discrete wavenumber method. The method inspects a set of pre-defined point source positions along a fault plane or line. Each point may have several rupture episodes, called subevents. The moment rate of subevents is of triangular shape with a pre-defined duration. Active source positions and their onset times are found by grid search in which we maximize correlation between records and synthetics (in time domain). The deviatoric moment tensors of the subevents are found by minimizing L2 misfit between records and synthetics.

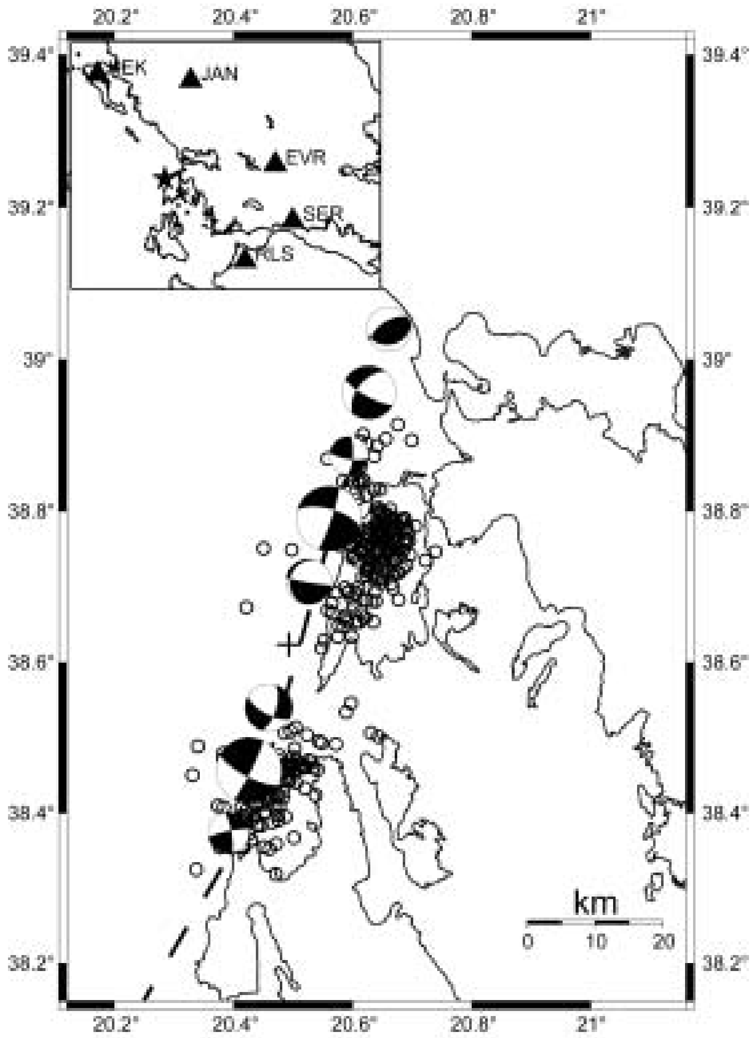

Figure. 1. Multi-event (basically double-event) interpretation of the Lefkada mainshock.

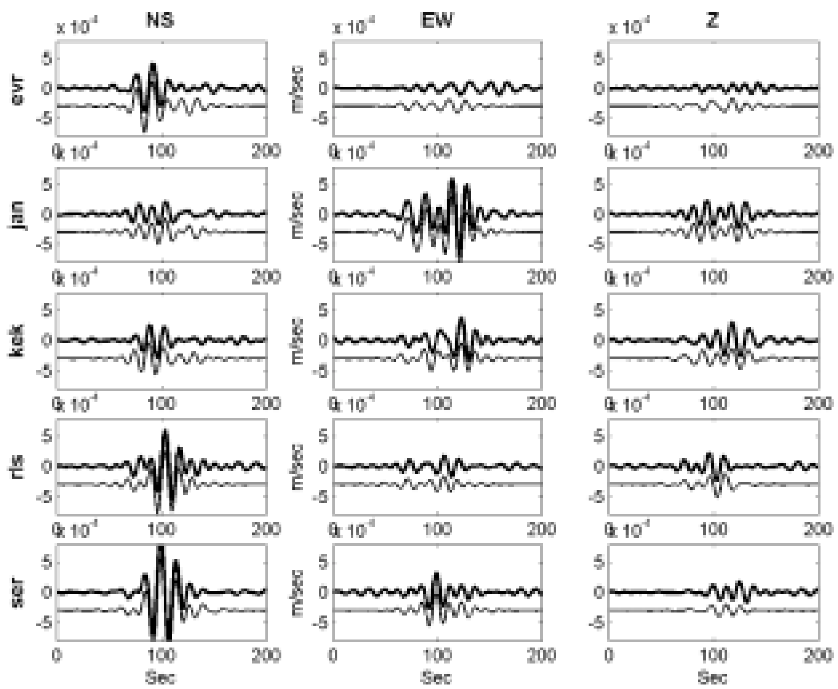

Figure 2. Comparison between records (thick line) and synthetics (thin line) for T>10 sec.

For the Lefkada mainshock, we pre-defined 9 point sources at a fixed depth (10 km), separated from each other horizontally by 10 km. In map view, these trial source positions (marked by crosses or beach-balls in Fig. 1) form a line passing through the NOA epicenter (lat. 38.79^o, lon. 20.56^o). The line has strike corresponding to one of the published fault plane solutions (ETH, Zurich), consistent with the Lefkada segment of the Cephalonia transform fault (Louvari et al., 1999), marked by a thick dotted line in Fig. 1. We searched for 12 possible subevents. Presented here are the best double couple solutions corresponding to the deviatoric moment-tensor analysis. The strongest subevents belonging to each source position are shown in Fig. 1. The agreement between records and synthetics (T>10 sec) is very good, Fig. 2, including strong late phases previously unexplained by a single point source model.

Using various data subsets, or different source line, we get similar solutions: There are several small subevents, representing a less stable, "noisy" part of the solution, and two stable major subevents, at source position 4 (Lefkada) and 8 (Cephalonia, 14 seconds later), spatial separation 40 km. Position 4: two subevents, one with strike 19^o, dip 83^o, rake -155^o, moment 0.43e18 Nm, and the other subevent at the same position with strike 22^o, dip 65^o, rake -178^o, moment 0.24e18 Nm. Position 8: strike 26^o, dip 84^o, rake 164^o, moment 0.67e18 Nm. Both correspond to a steeply dipping fault, with predominant right-lateral strike-slip motion.

The whole mainshock moment in this model is 2e18Nm, i.e. moment magnitude Mw=6.2, and the two major contributions (position 4 and 8) represent more than one half of the total moment. In other words, there were two main slip patches and a low slip region between them. Then, perhaps, we can speculate about a single-event interpretation, with a highly heterogeneous slip distribution, concentrated in two main asperities (Somerville et al. 1999). However the total fault length about 40 km is probably too large for a single M~6 earthquake (Papazachos and Papazachou, 1997). Therefore, an alternative explanation is that Lefkada mainshock was predominantly a double earthquake. Most importantly, both interpretations provide an explanation of the two aftershock clusters seen in Fig. 1.

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