## The 14 October 2008 moderate magnitude sequence offshore NE Evia Island (Aegean Sea): Fast Time-domain Moment tensors and shake map

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### Abstract

*The sequence of 14 October 2008 Mw 5.1 offshore Evia Island occurred at the westernmost termination of the North Anatolian Fault Zone into the Aegean. The focal mechanisms of six of the stronger events clearly show normal faulting with considerable dextral strike slip component. We obtained the slip model for the strongest GMT 02:06 event, we identified the NE-SW trending plane that dips to the NW as the fault plane, with its slip vector trending N36$^{o}$E following the trend of the shear motion transferred from the east.*

### Introduction

This is a short report for the 14 October 2008 moderate magnitude (Mw5.1) sequence offshore the NE coast of Evia Island, facing the Aegean Sea. Evia Island (Greece) lies in the transition zone from strike-slip faulting in the east, due to the strands of the North Anatolian Fault (NAF) that enter to the Aegean Sea, to normal faulting in the west along central Greece. From this point of view its pattern of deformation is always interesting, to seek for example the mode in which the shear motion from the east is crossing into mainland Greece. As no strong earthquake has occurred in Evia Island during instrumental times, we have to extract tectonic information from moderate size seismicity, like this one. Previous work (Hatzfeld et al., 1999; Kiratzi, 2002) has shown that the deformation in northern Evia Island is taken up mainly by normal and strike-slip faulting. Depending on the orientation of the activated faults, in respect to the present state stress field, dextral or sinistral horizontal motion is observed. The recent earthquakes showed that an almost N-S extensional field prevails in NE Evia Island with a few strike-slip focal mechanisms, suggesting that this part is mostly affected by the normal faulting system of central Greece.

Here, we present fast moment tensor solutions for the stronger events of the sequence and also we provide the shake Map for the strongest Mw 5.1 event, which we obtained from the slip model.

### The focal mechanisms of the 14 October 2008 stronger earthquakes

The computation procedure followed in AUTH (Roumelioti et al., 2008a) is based on the Time-Domain Moment Tensor inversion method (TDMT_INV) developed at the Berkeley Seismological Laboratory (Dreger, 2002, 2003), as it has been further modified for fast applications in Greece (Roumelioti et al., 2008a). Full waveforms of the three recorded components of motion are low-pass filtered and inverted to derive the moment tensor. The tensor is then decomposed into a scalar seismic moment, double couple (*DC*) orientation components and a percentage of compensated linear vector dipole (*CLVD*). All broad band waveforms were retrieved from the Unified Hellenic Seismological Network. Prior to the inversion procedure the waveforms were band-pass filtered between 0.02 – 0.08 Hz and re-sampled to a frequency of 1 Hz. Synthetic Green's functions were constructed using the FKRPROG code of Saikia (1994)and the velocity model of Novotny et al. (2001).

We computed moment tensor solutions for the six stronger earthquakes (**Table 1**) and we indicatively show in **Figure 1** the waveform fit for the strongest Mw5.1 event. Table 2 lists the focal parameters of events on the Evia Island, and all solutions are shown in **Figure 2**.

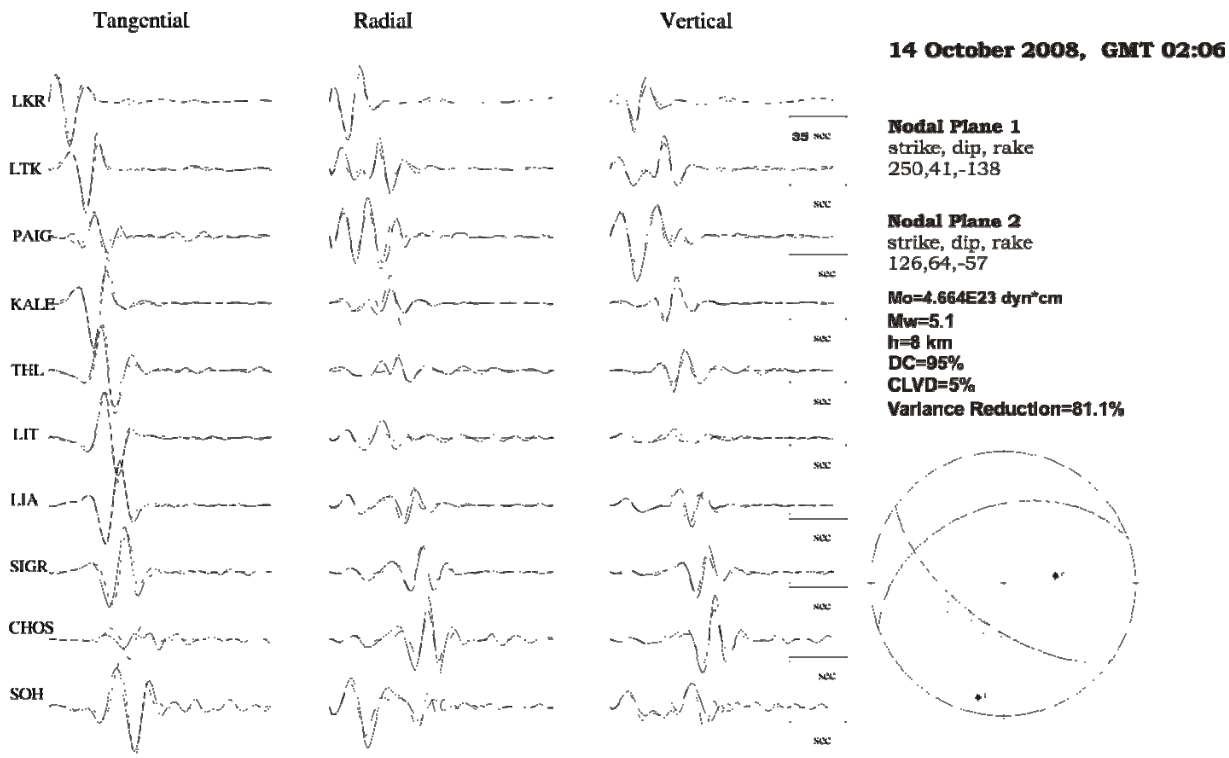


**Figure 1.** Waveform fit for the 14 October 2008 GMT 02:06 earthquake (No 1 in Table 1). For each station the vertical, tangential and radial components are shown. Observed waveforms are represented with solid lines and synthetics with dashed lines.

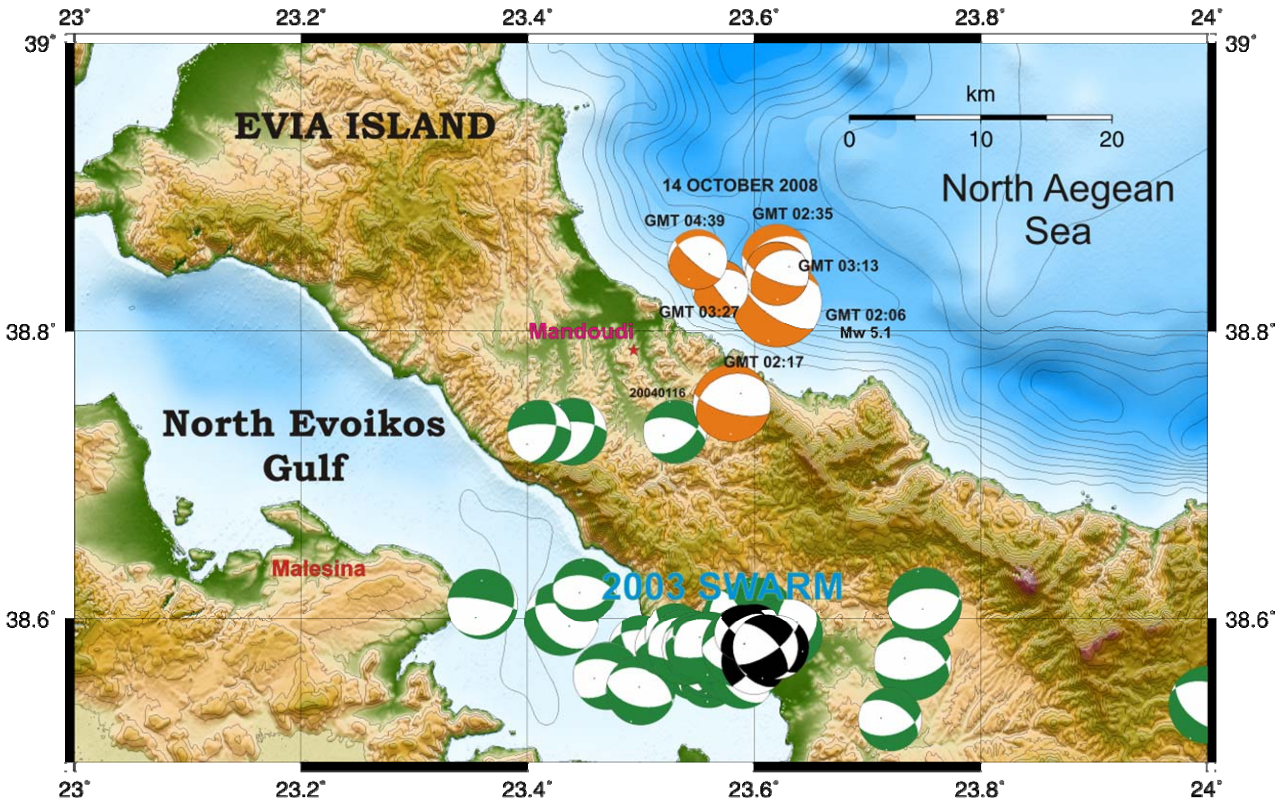


**Figure 2.** The 14 October 2008 focal mechanisms (orange beach-balls) and previous focal mechanisms determined by waveform modelling available for Evia Island (Table 1 and 2). Clearly normal faulting is prevailing combined with strike-slip motions. For the 2008 events the fault plane for the Mw 5.1 event is the one that dips to the NE, implying dextral strike-slip motion and a slip vector trending N36$^{O}$E. Note also the mechanisms connected with the most recent 2003 swarm near the town of Psaxna, a rock burst region in Evia, like the twon of Mandoudi which was close to the 2008 events.

## Slip model for the Oct 14, GMT 02:06 Mw 5.1 event

To obtain the slip distribution model for the GMT 02:06 Mw 5.1 event (**Figure 3**) we used the methodology of Dreger and Kaverina (2000) and Kaverina et al. (2002), in which regional distance ground motions recorded on broadband instruments are inverted for slip following the representation theorem for an elastic dislocation. We use a variety of simplifying assumptions including constant rupture velocity and dislocation rise time. We further apply slip positivity, seismic moment minimization and smoothing constraints to provide stability to the inversion. The description of the application of the method in Greece is described in Roumelioti et al. (2008b) and Kiratzi et al. (2008).

Both nodal planes are tested and the methodology applied is capable of uniquely determining the causative fault plane of the earthquake, the dimensions of the slip patches (both along strike and down dip), the earthquake rupture velocity, and a reasonable characterization of the gross slip distribution, suggesting that the derived source parameters may be used to simulate near-source strong ground motions. For the Mw 5.1 event the nodal plane that dips to the NW (that is the one with strike 250$^{o}$) was statistically detected as the fault plane. This implies that the azimuth of the slip vector is N36$^{o}$E and its plunge 26$^{o}$. Thus the slip vector is in accordance with the direction of the shear motion transferred from the east (Kiratzi, 2002).

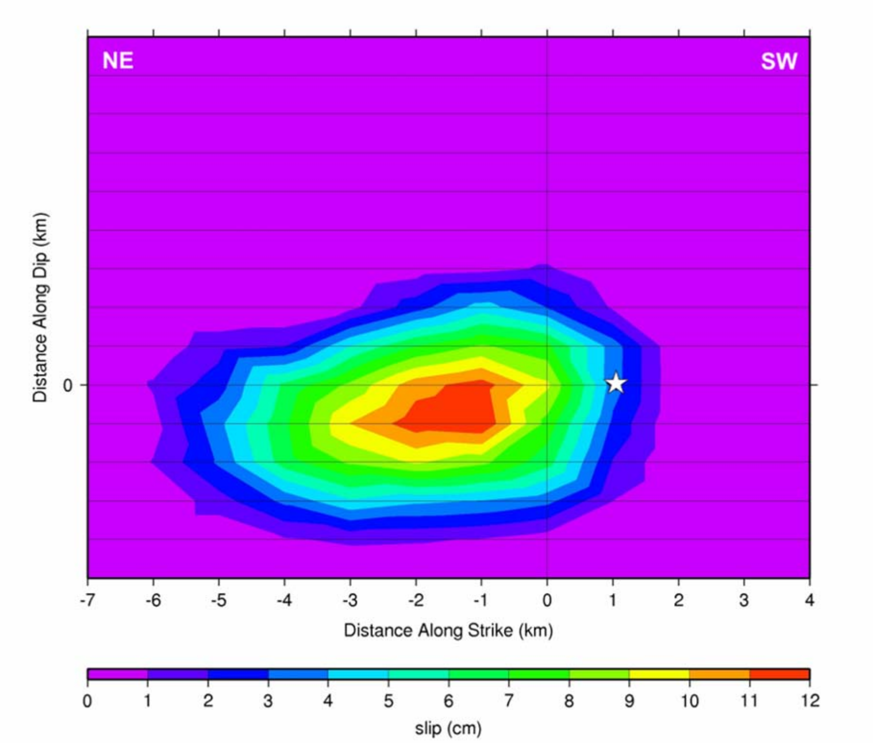


**Figure 3.** Slip distribution (slip in cm) for the October 14, 2008; GMT 02:06 Mw5.1 event, onto the fault plane (e.g. the nodal plane that dips to the NW in Fig. 1). The area of strongest slip is ~ 4 km x 4 km and is not collocated with the initiation of the rupture (asterisk). Note that the 0 in this figure corresponds to the depth of 8 km obtained from the MT solution.

## Deterministic Computation of PGV maps (Shake Map) for the strongest Mw 5.1 event

We used the regionally derived slip model (Fig. 3) to simulate the distribution of near-source strong ground motion and obtain PGV and intensity maps (**Fig. 4**). The method as applied in Greece is described in Roumelioti et al., 2008b and Kiratzi et al., 2008. The predicted strong motion parameters are improved by applying site corrections to the synthetic ground motions, based on the procedure implemented by Wald and Allen (2007) who classified the site geology based on the topography gradient as a proxy. For reasons of comparison we also compute PGV, PGA maps using empirical relations applicable to Greece, as proposed by Skarlatoudis et al. (2003, 2007).

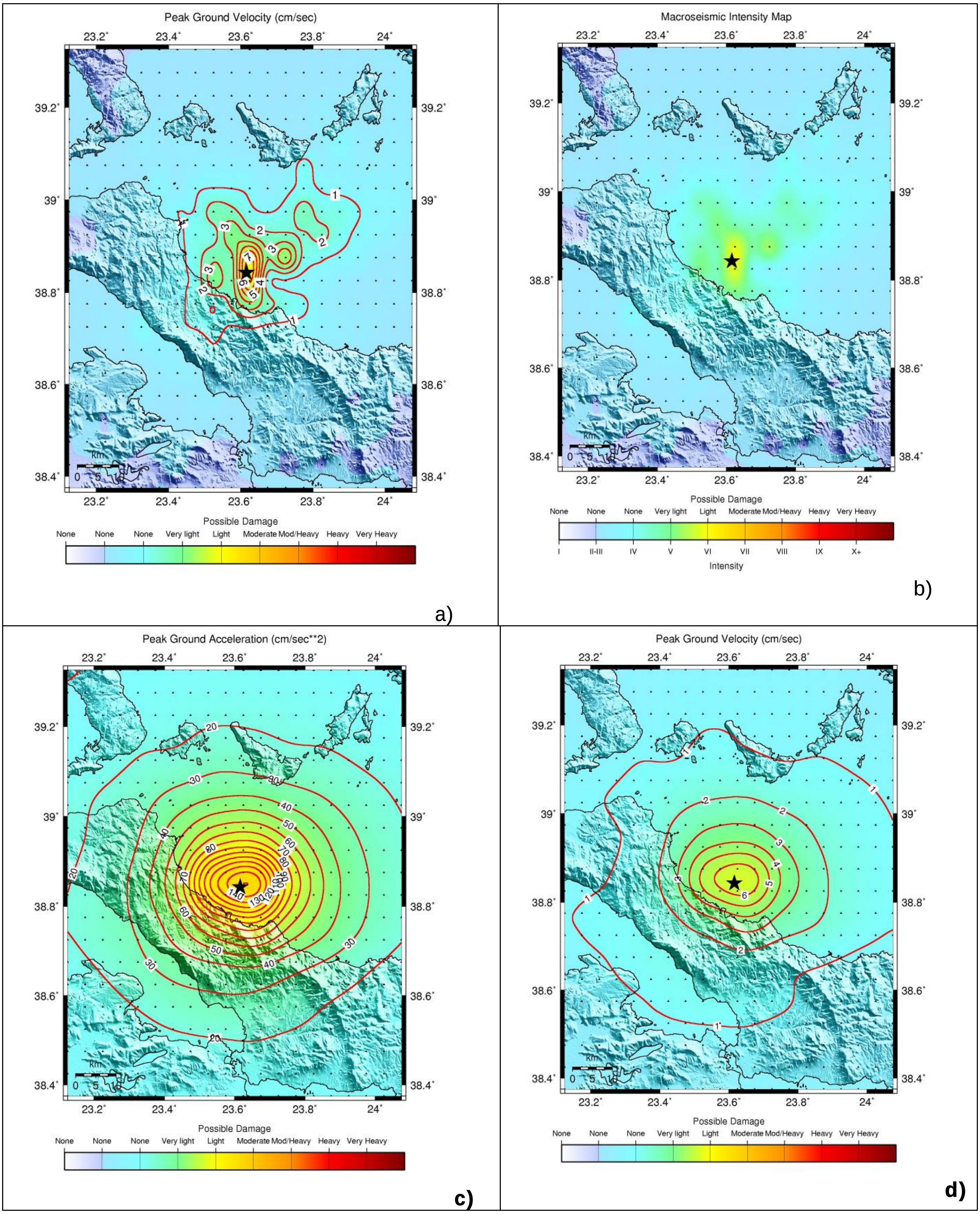


**Figure 4.** Top panels: Left - Distribution of synthetic PGV's for the 14 Oct. 2008 Mw5.1 event, based on the slip model of Fig. 3. Right- Distribution of macroseismic intensities calculated from the PGV values. The intensities are moderate due to the moderate size of the event. Lower panels: Distribution of PGA and PGV's obtained using the empirical relations of Skarlatoudis et al. (2003, 2007) for comparison.

**Table 1** Focal mechanism parameters of the 14 Oct 2008 sequence offshore Evia Island determined here

| | Date | hh:mm:ss | Lat N | Lon E | h (km) | Mw | strike1 | dip1 | rake1 | strike2 | dip2 | rake2 | Paz | Ppl | Taz | Tpl | CLVD % | VR % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 20081014 | 02:06:36.5 | 38.820 | 23.620 | 8.00 | 5.10 | 250 | 41 | -138 | 126 | 64 | -57 | 82 | 57 | 193 | 13 | 5 | 81 |
| 2. | 20081014 | 02:17:01.7 | 38.750 | 23.580 | 9.00 | 4.40 | 244 | 28 | -128 | 106 | 68 | -72 | 45 | 62 | 182 | 21 | 6 | 83 |
| 3. | 20081014 | 02:35:47.0 | 38.850 | 23.620 | 7.00 | 4.00 | 244 | 41 | -117 | 98 | 54 | -68 | 62 | 71 | 173 | 7 | 3 | 97 |
| 4. | 20081014 | 03:13:32.5 | 38.840 | 23.620 | 7.00 | 3.60 | 230 | 37 | -146 | 112 | 70 | -58 | 61 | 53 | 179 | 19 | 7 | 93 |
| 5. | 20081014 | 03:27:29.4 | 38.830 | 23.570 | 7.00 | 3.20 | 249 | 37 | -161 | 144 | 79 | -54 | 89 | 44 | 207 | 25 | 14 | 86 |
| 6. | 20081014 | 04:39:41.0 | 38.850 | 23.550 | 7.00 | 3.40 | 252 | 25 | -146 | 131 | 76 | -69 | 67 | 54 | 204 | 28 | 1 | 99 |

**Table 2** Focal mechanism parameters of previous earthquakes on the Evia Island, as determined elsewhere. All mechanisms are based on waveform inversion.

| 1. | Date | hh:mm:ss | Lat N | Lon E | h (km) | Mw | strike1 | dip1 | rake1 | strike2 | dip2 | rake2 | Paz | Ppl | Taz | Tpl | Ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2. | 20030613 | 16:06:34.0 | 38.580 | 23.590 | 4.00 | 4.30 | 90 | 60 | -117 | 316 | 39 | -51 | 313 | 64 | 199 | 11 | 1 |
| 3. | 20030613 | 16:30:29.0 | 38.580 | 23.580 | 5.00 | 4.30 | 97 | 51 | -96 | 286 | 39 | -83 | 335 | 83 | 191 | 6 | 1 |
| 4. | 20030613 | 20:22:02.0 | 38.570 | 23.550 | 8.00 | 4.40 | 135 | 44 | -120 | 354 | 53 | -64 | 323 | 69 | 66 | 5 | 1 |
| 5. | 20030616 | 15:18:57.0 | 38.580 | 23.570 | 5.00 | 4.00 | 84 | 64 | -106 | 297 | 30 | -61 | 324 | 67 | 186 | 18 | 1 |
| 6. | 20030618 | 05:25:02.0 | 38.600 | 23.600 | 5.00 | 4.70 | 51 | 43 | -138 | 288 | 63 | -55 | 246 | 57 | 354 | 11 | 1 |
| 7. | 20030619 | 01:00:04.0 | 38.570 | 23.560 | 5.00 | 4.00 | 99 | 57 | -85 | 270 | 33 | -98 | 25 | 77 | 185 | 12 | 1 |
| 8. | 20030619 | 01:03:56.0 | 38.570 | 23.580 | 5.00 | 4.30 | 92 | 52 | -86 | 266 | 38 | -95 | 22 | 82 | 179 | 7 | 1 |
| 9. | 20030619 | 03:38:22.0 | 38.570 | 23.580 | 4.00 | 4.50 | 89 | 51 | -100 | 285 | 40 | -78 | 311 | 80 | 186 | 6 | 1 |
| 1( | 20030621 | 03:29:19.0 | 38.580 | 23.590 | 4.00 | 3.60 | 125 | 66 | -77 | 275 | 27 | -117 | 59 | 66 | 205 | 20 | 1 |
| 1: | 20030626 | 13:45:58.0 | 38.570 | 23.740 | 4.00 | 4.40 | 78 | 54 | -111 | 291 | 41 | -64 | 294 | 72 | 183 | 7 | 1 |
| 1: | 20030701 | 06:22:50.0 | 38.580 | 23.540 | 5.00 | 4.30 | 80 | 69 | -103 | 293 | 25 | -59 | 328 | 64 | 180 | 23 | 1 |
| 1: | 20030704 | 03:24:36.0 | 38.580 | 23.550 | 5.00 | 4.00 | 71 | 66 | -110 | 293 | 31 | -52 | 308 | 63 | 176 | 19 | 1 |
| 1/ | 20030705 | 13:00:13.0 | 38.580 | 23.550 | 4.00 | 3.60 | 132 | 46 | -65 | 278 | 49 | -114 | 119 | 72 | 25 | 2 | 1 |
| 1! | 20040116 | 17:10:25.0 | 38.580 | 23.560 | 4.00 | 4.00 | 77 | 71 | -111 | 307 | 28 | -44 | 318 | 59 | 183 | 23 | 1 |
| 1( | 20060608 | 14:38:37.0 | 38.610 | 23.750 | 8.00 | 4.20 | 264 | 55 | -83 | 72 | 36 | -100 | 201 | 79 | 349 | 10 | 2 |
| 1: | 20060701 | 14:36:48.0 | 38.730 | 23.530 | 8.00 | 3.60 | 286 | 57 | -52 | 51 | 49 | -133 | 253 | 58 | 350 | 5 | 2 |
| 1{ | 20060816 | 18:56:41.0 | 38.540 | 24.000 | 12.00 | 4.40 | 125 | 49 | -79 | 288 | 42 | -103 | 95 | 81 | 207 | 4 | 2 |
| 1! | 20070814 | 06:09:31.0 | 38.530 | 23.720 | 10.00 | 3.60 | 299 | 49 | -58 | 75 | 50 | -122 | 278 | 66 | 187 | 1 | 3 |

1 Benetatos et al., 2004; 2 Roumelioti et al., 2008 *in prep* ; 3 National Observatory of Athens (NOA)

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