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Present-day kinematics in the Eastern Mediterranean and Caucasus from dense GPS observations

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ABSTRACT

The Eastern Mediterranean and Caucasus are located among the Eurasian, African and Arabian plates, and tectonic activities are very complex. In this paper, the kinematics and strain distribution in these regions are determined and investigated from dense GPS observations with over 1000 stations and longer observations. The elastic block model is used to constrain present-day plate motions and crustal deformation. The relative Euler vectors between the Nubian, Arabian, Caucasus, Anatolian and Central Iranian plates are estimated. The Arabian-Eurasia, Anatolian-Eurasia, Nubian-Eurasia, Caucasus-Eurasia and Central Iranian Euler vectors are 0.584 ± 0.1 Myr^{-1}, 0.825 ± 0.064 Myr^{-1}, 0.35 ± 0.175 Myr^{-1}, 0.85 ± 0.086 Myr^{-1} and 0.126 ± 0.016 Myr^{-1}. The strain rate in the East Mediterranean and Caucasus has been estimated from the GPS velocity field. The results show that the thrust dominated areas, the eastern Mediterranean-Middle East-Caucasus and Zagros have negative dilatation and the western Anatolia region has positive 2D dilatation rate with significant rotation. The west Anatolian shows the extension in NW-SE with about 150–199 nstrain/yr in the W-E direction. The Central Anatolia shows compression rate below 50 nstrain/yr and extensional strain rate adjacent to East Anatolian Fault and Dead Sea Fault is about 0–100 nstrain/yr. The contraction strain rate is higher in Zagros and Caucasus between 100–150 nstrain/yr and contraction orientation is along the NE-SW direction in Caucasus. The north part of Iran shows less contraction rate below 50 nstrain/yr but North-East Zagros Mountains, Tabriz fault and Chalderan fault show extensional rate between 50–110 nstrain/yr and principal axes rotation in the N-S direction. The maximum contraction observed in the Kopek Dag is about 100–194 nstrain/yr and orientated in the NE-SW direction. East Zagros Mountain and Makran subduction zone have a large clockwise rotation with 70–85 nradian and principal axes remains mostly along the N-S direction. The observed extension is along N-S by about 0–100 nstrain/yr with counter clockwise rotation in Dead Sea Fault. The Sinai block shows shortening rate in the range of 0–100 nstrain/yr.

1. Introduction

The Eastern Mediterranean and Caucasus are located among the Eurasian, African and Arabian plates with complex tectonic activities, e.g., volcanic eruptions, mountain building and a large part of all earthquakes (Fig. 1) (McKenzie, 1972, 1978; Le Pichon and Angelier, 1979). The eastern Anatolian, the Caucasus, and the Bitlis-Zagros are active continental collision zones due to contemporary tectonic settings and structures. The Eastern Mediterranean is one of the important regions to understand the fundamental tectonic processes like continental rifting, passive margins, subduction and accretion, both collision and post collision (Robertson and Mountrakis, 2006). These general processes, in principle, are investigated for large areas of continental lithosphere to predict whether the region is aseismic and not deforming at present day. The plate tectonic perception provides a helpful description of continental deformation. In the Eastern part of the Anatolian block the plate motion is taken up by thrust faults associated with the Caucasus block. All the faults motion is approximately in the same direction as that of Arabia and Eurasia. The result of this geometry is that the continent, throughout the active region (McKenzie, 1972), continues to elevate the Caucasus. Eastern Mediterranean is centered on the interconnection of the Arabian with Eurasia and Anatolia plates towards the west from

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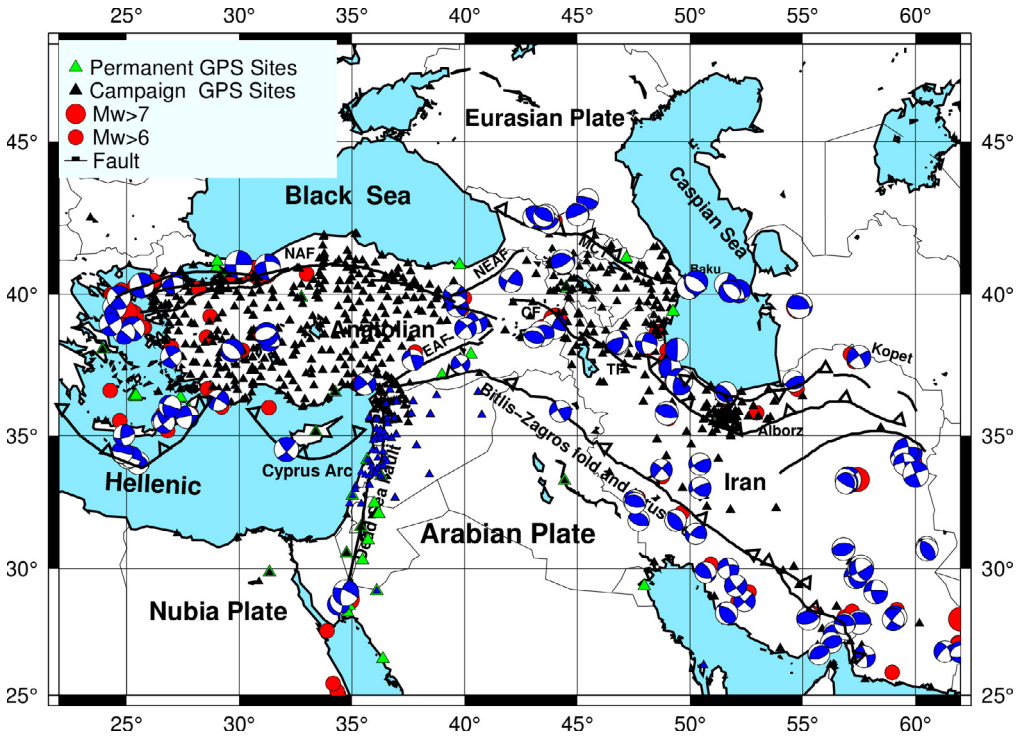

Fig. 1. Tectonics setting with main faults, earthquakes and GPS sites in East Mediterranean and Caucasus region. Focal mechanims of Mw ≥ 6 Earthquakes in this studied area are from Harvard Catalog (www.globalcmt.org/CMTsearch.html, 1976–2015). North Anatolian Fault (NAF), East Anatolian Fault (EAF), North East Anatolian Fault (NEAF), Main Caucasus Thrust (MCT), Chalderan Fault (CF), and Tabriz Fault (TF) are presented. Black lines faults and lines with triangle are thrust.

the most intense convergence zone. The collision of Saudi Arabia with Eurasia is reducing in the area of lithosphere within the deforming region. This reduction occurs with lateral transform of lithosphere by lithospheric shortening, supposedly associated with thickening of the captured lithosphere (e.g., McKenzie, 1972; Tenzer et al., 2015).

The Global Positioning System (GPS) has provided a new opportunity to directly observe the present day crustal motions and deformations as well as seismo-ionospheric disturbances (e.g., Hager et al., 1991; Afraimovich et al., 2010; Jin et al., 2007a, 2014, 2015). Previous GPS studies have helped to quantify regional deformation in the plate interaction zone (McClusky et al., 2003; Jin and Park, 2006; Jin et al. 2007b, 2013; Alchalbi et al., 2010; Le Pichon et al., 1995; Reilinger et al., 1997, 2006; Vernant and Chéry, 2006; Nyst and Thatcher, 2004; Mahmoud et al., 2005; Aktug et al., 2009; Aktuğ et al., 2013a,b). The regional plate motion studies use the fault orientation, local observations and constraints from the relative plate motion. The Eastern Mediterranean region experienced many destructive earthquakes throughout its recorded history. The earthquake activity observed around the Aegean Sea comprising a large part of Greece and Western Anatolia has been the most remarkable geodynamics phenomenon in the Eastern Mediterranean region. The tectonic evolution of the Eastern Mediterranean region is dominated by the effects of subduction along the Hellenic (Aegean) arc and of continental collision in eastern Turkey (Anatolia) and the Caucasus. Northward subduction of the African plate, western Turkey and the Aegean region is an extension of the continental crust (McClusky et al., 2000, 2003). In terms of historical seismicity, large earthquakes have been occurred with magnitudes greater than (M_w) 6 in East Mediterranean and Caucasus. The Anatolia plate has been of interest for more than two decades of GPS studies, mostly concentrated on the seismical and tectonic active Marmara region, Western Anatolia, Central Anatolia and North Anatolian Fault System with determining the strain and slip rates (Reilinger et al., 1997; Aktuğ et al., 2013a,b). However, detailed deformation and active tectonics in these areas are still not clear due to short time observations and limted stations.

In this paper, more than 1000 continuous GPS (CGPS) and survey-mode GPS (SGPS) stations velocity field with longer observations is collected to study the spatial distribution of present-day crustal deformation and tectonic plate motion in the eastern Mediterranean and Caucasus regions. In Section 2, tectonics setting is introduced, dense GPS-derived velocity field collected from recent studies is presented in Section 3, the kinematic results of continental deformation in the Eastern Mediterranean and Caucasus region are presented and discussed in Section 4, and finally the conclusions are given in Section 5.

2. Tectonic setting

The eastern Mediterranean is the favorable place to investigate plate tectonics with three major tectonic plates, Arabia, Nubia, and Eurasia. The Caucasus is located in continental collision zone between Arabia and Eurasia between the Black and the Caspian Sea. The oceanic collision occurs in the Hellenic and Cyprian Arcs between Nubia and Anatolian as a subduction. As a result, the Arabian plate is separating from the Sinai sub-plate with the Dead Sea Fault (DSF) transform plate boundary. Seismic activity is distributed over a wide area in the North of the Dead Sea, reflecting spreading out deformation in northern Israel and Lebanon.

Arabia-Nubia divergent motion in the Red Sea into the convergence motion between Eurasia and Arabia is currently expressed by extrusion of Anatolia. However, not all the African-Arabian divergent motion is transferred (Wdowinski et al., 2004) northward to the convergence zones. The southwestern boundary between Nubia and Sinai of the divergent motion in the Red Sea propagates into the Gulf of Suez. Extensive variety exists the tectonic development in the Anatolia and the surrounding regions