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Geodetic Observations of Strain Accumulation on Faults in the Marmara Seismic Gap Near Istanbul, Turkey

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The devastating 1999 Izmit/Duzce earthquake sequence (Mw=7.4, 7.2) was the most recent in a 20th Century series of predominantly westward migrating, M>7 seismic events that broke an approximately 1000 km section of the North Anatolian Fault (NAF). The only major remaining "seismic gap" along the fault is the ∼150 km long segment under the Sea of Marmara (Main Marmara fault [MMF]) that approaches to within < 15 km of the center of Istanbul, one of the most populous and rapidly expanding cities in the world. Historical documents dating back two millennia indicate that destructive earthquakes have struck Istanbul in the past, raising concern for a potential destructive earthquake in the near future. The probability of a large earthquake within the Sea of Marmara has been estimated to be about 35-70% over the next 30 years. We present an updated GPS velocity field for the Marmara region for the period 1994-2013, removing co- and post-seismic motions for the 1999 earthquake sequence, and use it to estimate secular strain accumulation on mapped, active faults adjacent to and within the Sea. For the Izmit and the Ganos segments, east and west of the Sea respectively, we estimate slip deficit rates (i.e. the rate at which "slip" is accumulating on the upper, locked part of the fault) of ∼ 20 mm/yr, consistent with earlier geodetic results and with the occurrence of M >7 historic earthquakes on both segments, the most recent being the 1999 and 1912 events. We report the first direct observations of strain accumulation on the Princes' Islands segment within the eastern Marmara directly south of Istanbul, constraining the slip deficit rate to 10 – 15 mm/yr, the larger uncertainty due to the limited GPS coverage near the fault trace. In contrast, the central segment of the MMF shows no evidence of strain deficit accumulation, constraining any strain accumulation on the fault to < 2 mm/yr. Although there remains considerable uncertainty about the precise faults that generated pre-instrumental earthquakes, our geodetic results are consistent with historic earthquake studies that report multiple M>7 events on the PI segment, the last large event occurring in 1766, while only 2, M>7 events have been reported in the past 2000 years on the central MMF. On the basis of the time since the prior earthquake on fault segments, and estimated rates of strike-slip strain accumulation, we estimate total slip deficits and conclude that the Princes' Island segment is most likely to generate the next M>7 earthquake along the Sea of Marmara segment of the North Anatolian fault.