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Mapping the Spatial and Temporal Variation of b-value of the 23 October 2011 M_w 7.1 Van Earthquake Aftershock Activity

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An M_w7.1 earthquake struck on October 23, 2011 the Van Lake region causing vast damage in the cities of Van and Ercis, Eastern Turkey. The main shock was followed by a high number of aftershocks. In this study we take an advantage of this large dataset to examine the spatial and temporal properties of the Van earthquake aftershock activity and to provide a robust representation of the seismicity parameters derived from the Van earthquake aftershocks analysis. We calculate the spatial distribution of *b-value* on the surface projection of the fault responsible for the 23 October 2011 Van Lake earthquake from the Gutenberg–Richter frequency–magnitude relation of the relocated aftershock catalog of AFAD (the Prime Ministry Disaster and Emergency Management Presidency of Turkey). The spatial distribution of seismological parameters is investigated in different periods of the aftershock sequences, after where a stable magnitude of completeness M_c is reached, thus obtaining insight into the transient behavior of *b-values* in the months following this large earthquake. The statistical significance of both spatial and temporal variation of *b-value* is proved by applying the test proposed by Amorèse et al. (2010). Finally, we attempt to correlate the observed *b-value* patterns with slip distribution models of the main shock obtained through the inversion of seismological and geodetic data provided by Hayes (2011) and Irmak et al. (2011).

We compute the distribution of *b-value*—as well as complementary seismicity parameters—on the surface projection of the fault relative to complete catalog, which contains 4,032 earthquakes (magnitude ranging from 2.5 to 5.6). The fault model used in our calculation is that derived by Hayes (2011). Calculations are made by dividing the fault projection into 20x20 km square cells. In each cell containing at least 100 earthquakes M_c, *b-value*, *a-value*, and number of events above M_c (NM_c) are computed following the maximum likelihood estimate approach (Aki, 1965). The 100 events size limit has been chosen by trial as the minimum number of events for stable *b-value* results. Cells are retained only if the error on the *b-value* does not exceed 10% of its estimate (Shi and Bolt, 1982). The grid is then shifted along the directions of the cell edges by a quarter of cell size and calculations are re-made, thus obtaining a 5x5 km pseudo-grid.

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In order to investigate the temporal variation of the *b-value* over the entire catalog period (02/11/2011 - 02/11/2011), we split the aftershocks into two nearly even sub-catalogs, the first one (C1) from the day 02/11/2011 (10 days after the main shock–i.e. when the M_c reaches a steady threshold) to the day of 12/12/2011 (50 days after the main shock), the second one (C2) from day 13/12/2011 to the end of the catalog (02/09/2012). We then compare the distribution of *b-value* on the fault plane relative to C1 (2107 earthquakes) to that obtained for C2 (1925 earthquakes). To check the significance of the observed temporal variation of *b-value* we apply the statistical test proposed by Amorèse et al., (2010). The analysis of the aftershock sequences belonging to the 2011 Van earthquake reveals significant spatial and temporal variation of seismicity parameters along the ruptured fault. The main conclusions are given as the following:

1) The *b-values* computed from the analysis of the sequence of 10 months of aftershocks following the Van earthquake show relevant spatial variation, going from 0.9 to 1.5 along the rupture fault zone (**Figure1a**).

2) There is a clear positive correlation between *b-values* and co-seismic slip release: the *b-value* is higher in the larger slip portions of the fault. The correlation is particularly evident in the first period of the aftershock sequence (**Figure1b**), possibly before post seismic relaxation phenomena take over.

3) The higher *b-values* (>1.1) are observed around the nucleation point. In particular highest values of *b* mark the upper tip of the fault, South-east of the epicenter, where ruptures propagate toward the surface (Emre at al., 2011). On the whole, high values of *b* characterize the higher slip area on the fault surface projection (the highest co-seismic slip; see **Figure 1a, b** and **c**). In this portion of the fault, shear stress is likely to be almost entirely released by the main-shock and no strong aftershocks are likely to occur. By using the *b-value* as a stress-meter, we infer that in the large slipping portion of the fault, the shear stress drops significantly during the main rupture and favors high *b-value* for the aftershocks. The high *b-value* defined by aftershocks that occurred in the high slip area is consistent with observations for other moderate to large earthquakes (Wiemer and Katsumata, 1999; De Gori et al., 2012).

4) Likewise, significant variations are found in the analysis of *b-value* through time, between periods–or aftershock sub-catalogs–C1 and C2 (**Figure1a** and *b*). Though being the nucleation and high slip areas characterized by constantly high *b-value* in the entire analyzed period, we observe a generalized increase of *b-value* over the ruptured fault with time. In the first 50 days (C1 sub-catalog), the *b-value* is highest upward of the main shock nucleation zone and in almost all the high slip area of the main shock, but remains lower in the Southwestern and Northeastern portion of the fault plane surface projection (**Figure 1b**). Therefore, we infer that in the high slip area most of the stress has been co-seismically released by the main shock, while on the edges of this high slip area stress remains high (**Figure 1b**), thus in these early stages post main shock, higher levels of stress are found where rupture does not propagate. The *b-values* then considerably increase in the C2 period spreading around the nucleation and high slip areas over larger portions on the ruptured fault, occupying it almost entirely (**Figure 1c**).

Under the assumption that *b-value* mapped by aftershock holds information about the distribution of heterogeneities and stress before the main-shock, it is important to compare these results with those from other studies like the heterogeneities defined by seismic tomography studies. De Gori et al., (2012) showed that the low *b-values* area close to the nucleation, strictly coincides with a high V_p, low Poisson ratio volume, while the high *b-values* in the upper portion of the fault corresponds to high Poisson ratio, hence high fluids content in the L'Aquila fault plane (Di Stefano et al., 2009). This suggests that seismic behavior is strongly controlled by material and rheological properties of the upper crust. This kind of study needs more data to come from a very dense seismological network. Moreover, Eastern Turkey has experienced several destructive strong earthquakes during last decades, so that the evaluation of the seismicity parameters, especially *b-value,* is very important for regional seismic hazard studies, development of earthquake prediction models and mitigation purposes. Time and space scanning of *b-value* may provide spatial and temporal evidence for the forthcoming strong earthquakes consistently in both of long-term and short-term periods. As a final consideration we wish to say that given the extreme characteristics of the earth crust in eastern Anatolia, new monitoring campaigns are needed to study regions seismicity in greater detail.

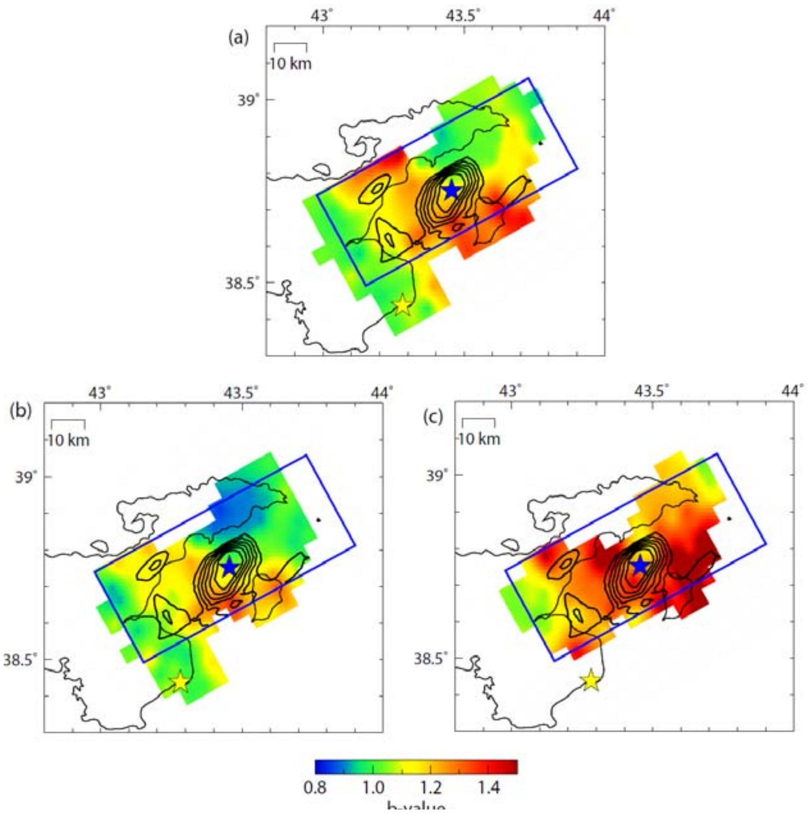

Figure 1 Continuous representation of *b-value* on the surface projection of the Van earthquake fault computed for a) complete, b) C1 and c) C2 aftershock catalog obtained through a common minimum curvature gridding method (Smith and Wessel, 1990). Blue star shows the epicenter of the Van main shock and the yellow one shows the epicenter of the largest aftershock, 9 November 2011, M_w 5.6 of the Van earthquake. The black contours indicate the co-seismic slip by Hayes (2011) drawn within the 0.5 – 3 m interval.

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