Revisiting the January 3rd, 2017 Maranhão intraplate earthquake

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Knowledge of the regional stress field is fundamental for understanding the causes of intraplate seismicity and assessing seismic hazard. In Brazil this has been a particularly challenging task, as intraplate earthquakes well recorded at regional distances have been generally scarce. On January 3rd 2017, a Mw 4.3 earthquake occurred in the northern part of the Parnaíba basin, near the equatorial margin of Brazil, which was well recorded by up to 30 seismic stations belonging to the Brazilian Seismographic Network (RSBR) and two nearby temporary broadband deployments. A previous moment-tensor inversion of this earthquake in the 0.07-0.1 Hz frequency range revealed a strike-slip mechanism of (339°, 83°, -2°) and a source-depth of 7.5 km. Strikingly, that study utilized just 4 seismic stations and, despite excellent waveform fitting from path-dependent Green's functions, this preferred solution contained a 40.6% non-double-couple (NDC) component, which is generally not expected for shallow crustal earthquakes. An NDC component can be either an artifact due to poor azimuthal coverage or inaccurate velocity models, or result from the occurrence of earthquake doublets with different double-couple (DC) focal mechanisms close in time and space. To investigate this unexpected NDC contribution, we performed several moment-tensor inversions for this earthquake using all available seismic data. We attempted full-waveform fitting through either a linearized least-squares inversion for the deviatoric moment tensor components (MTINV), or a systematic grid-search for the three fault angles (SRCGRD). A simple layered velocity model - common to all stations - was used to compute the Green's functions, which was based on published wide-angle reflection-refraction data for the Parnaíba basin. First, we investigated the role of azimuthal coverage by performing the SRCGRD and MTINV inversions for depths between 1 and 19 km and frequencies between 0.02 and 0.05 Hz. Such a low-frequency range was chosen to prevent cycle-skipping and reduce artifacts from inaccurate Green's functions. The SRCGRD inversions led to a solution of (240°, 80°, 170°) for a preferred depth of 11 km; the MTINV results were consistent with those from the SRCGRD inversion, but showed a 58.7% NDC component for the same depth, larger than that obtained by the independent moment tensor study. Second, we investigated the influence of inaccuracies in our velocity model by performing the MTINV and SRCGRD inversions with time-shifted Green's functions. We modified the SRCGRD approach to allow for relative time shifts between observed and synthetic seismograms before computation of the least-squares misfit (SRCGRD2) and, to improve signal-to-noise ratio, the SRCGRD2 approach was applied at a higher frequency range of 0.05-0.1 Hz. SRCGRD2 yielded a best solution of (340°, 80°, 0°) for 11 km depth, also consistent with previous solutions. Most interestingly, performing the MTINV inversion within the higher frequency range on the time-shifted Green's functions resulted in a significant reduction of the NDC down to 4.1%. Thus, we conclude that uncertainties in the velocity model, rather than azimuthal coverage, were the main cause of the high NDC component in the independent earthquake moment tensor inversion.