Modes of deep slow earthquakes and temperature dependence of brittle-ductile mixed rheology

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A wide spectral range of observations has become to clarify the various modes of slow earthquakes particularly characterized as, from the slow to fast, Long-term Slow Slip Events (LSSEs), Short-term Slow Slip Events (S-SSEs), Low-frequency earthquakes (LFEs) and tremor. Observations show these events tend to exhibit the depth dependence on the locations of their source areas. The slow earthquakes are generally considered as the results of the brittle-ductile transition of the fault rheology due to increasing pressure and temperature in the depths of the earth's surface. However, available physical models propose a variety of mechanisms to explain the slowly slipping behaviors, such as velocity-strengthening and weakening mixed rheology, the dilation induced strengthening and the neutral frictional stability, none of them have successfully explained the intrinsic mechanisms of the depth-dependent features without artificially tuning free model parameters to fit geodetic observations traced these depth-dependent features. We here demonstrate that the depth-dependent characteristics are explained as a natural consequence of the temperature-dependent rheological properties of the fault zones at the transition depth based on the brittle-ductile mixed fault heterogeneity model. We consider the macroscopic brittle and ductile strengths taking into account the temperature dependence in the fraction of the brittle area over the ductile area together with the viscosity. As a result, we successfully reproduce the occurrence of S-SSEs with smaller slip and larger acceleration at the down-dip portion of L-SSEs with larger slip and smaller acceleration. Further deep, stable slide occurs.