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The crustal viscosity gradient measured from post-seismic deformation: a case study of the 1997 Manyi (Tibet) earthquake

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It is by now widely accepted that viscosity in the lithosphere has a significant variation with depth because of its temperature dependence, which should be involved for studying viscous relaxation in a geodetically observed post-seismic deformation. Using 3-D finite element model, we previously described the surface displacement history of a linear Maxwell visco-elastic model with depth-dependent viscosity (DDV) following a strike-slip fault event, in comparison of a uniform viscosity (UNV) model behaviour, showing that an apparent UNV (Eta_u) that best-fits the DDV model displacement at each surface point decreases with distance from fault, and the rate of the change of Eta_u with distance from fault reflects the vertical gradient of the viscosity. In the present study, we analyse an InSAR dataset of the surface deformation in a three year period following the 1997 Manyi (Tibet) earthquake [Ryder et al., GJI, 169, 1009 - 10027, 2007] in order to estimate the vertical viscosity gradient beneath the region. We first adopt UNV model to the surface displacements observed after an initial period (t $>$ 165 days) in which post-seismic slip is probably significant, which reveals a clear signature of the vertical viscosity gradient in the crust: Eta_u with which the UNV model prediction best-fits the observed displacement decreases with distance from fault. The rate of the change in Eta_u with distance from fault then derives a crustal DDV structure which indicates that the 1997 Manyi event occurs within an upper layer that effectively deforms in elastic on the time-scale of the inter-seismic period, ~ 420 - 850 yrs [van der Woerd et al., GRL, 27, 2353-2356, 2000] and whose vertical gradient is consistent with the empirically derived steady-state power law creep of the upper crustal materials. The viscosity structure of the Tibetan crust constrained in this study advances the knowledge of the crust and assist in better understanding of the stress redistribution during the earthquake cycle.

Keywords: Post-seismic deformation, Viscous relaxation, Linear Maxwell visco-elasticity, Depth-dependent viscosity, Effective elastic thickness