Postseismic afterslip following the 2023 Kahramanamraş Mw 7.6 and 7.8 earthquakes

Encadrement: Frédéric Masson (HDR) and Baptiste Rousset

Context: On February 6, 2023, the Kahramanmaras earthquakes of Mw 7.8 and 7.6 ruptured a 300 km-long section of the East Anatolian Fault, as well as a secondary fault, the Cardak Fault. The stresses generated by such earthquakes produce post-earthquake deformation, which can last for several years. It can be divided into three processes: slow aseismic slip on the fault called afterslip, viscoelastic deformation at the base of the continental crust and upper mantle, and surface poroelastic deformation linked to the rebalancing of pore pressure. The Ph.D.thesis will focus on the analysis of afterslip to understand the rheology of the faults zone and shed lights on the interaction processes between afterslip and aftershocks. The dataset used in the Ph.D. includes the ensemble of available continuous and campaign GNSS measurements, as well as all InSAR Sentinel 1 acquisitions available. Notably, eight near-fault stations installed by our team which in Hassa and Golbasi in August 2023 will be added to the analyses as well as dozen campaign GNSS measurements done by our Turkish colleagues.

Detailed methodology: The Ph.D. student will first isolate the afterslip component, by processing and post-processing the GNSS and InSAR time series. He will employ signal separation techniques such as Independent Component Analysis (ICA) or Maximum Singular Spectrum Analysis (MSSA). These methods are adept at differentiating afterslip, which has a shorter relaxation time, from viscoelastic deformation with a longer relaxation time. Once isolated, the afterslip time series will be used to determine the location of afterslip on the fault planes through slip inversions. The initial analysis will involve a static inversion to determine the cumulative afterslip. For the exploration of slip models, the Ph.D. student will perform a Bayesian analysis to derive the ensemble of possible slip models and their uncertainties. This will allow for a robust assessment of the most likely afterslip distribution and its associated variability. Additionally, a comparison will be made between the afterslip distribution and the interseismic and coseismic slip to understand the overall slip budget throughout the earthquake cycle. Following the static inversion, the Ph. D. will delve into time-dependent slip inversions to investigate the possibility of afterslip migration, meaning the movement of afterslip over time. Similar to the static inversions, these will be conducted using a Bayesian approach, with a dictionary of spline functions employed to represent the time-varying slip. On top of the slip inversions, the Ph.D. will perform direct models of the afterslip for rate-strenghening faults. The loading of the fault will be done with coseismic stress perturbation derived from published coseismic slip model. By doing a grid search he will derive the best frictional parameters of the fault that best explain the geodetic time series. The resulting afterlip will be discussed in the light of the afterlip obtained with the inverse method. Finally, the Ph.D. student will investigate the relationship betwen afterslip and aftershocks. The interaction will be modelled in the frame of the rate-and-state friction laws to relate the stress change produced by the afterslip to the nucleation of the aftershocks. A particular attention will be paid on afterslip and aftershock migrating fronts.

Schedule of the Ph. D. thesis:

Year 1: GNSS and InSAR processing and post-processing

Year 2: Bayesian inverse slip models and physics-based directstress-driven afterslip models

Year 3: Modeling the interactions between afterslip and aftershocks

Collaborations assocaiated with the Ph.D. project: The modeling between aftershocks and afterslip will be done in collaboration with Dr. William Frank, Seismologist at the Massachusetts Institute of Technology (MIT). Funded by the International Research Project (IRP) SlowFaults (PIs: Radiguet M., Frank W., Rousset B. & Jolivet R.), the Ph.D. student will have the opportunity to go to MIT for about one month during his Ph.D. The Ph.D. student will also collaborate closely with our Pr. Hakan Yavasoglu and Dr. Ali Ozkan who are in charge of doing post-seismic GNSS campaign measurments. The InSAR analysis will be performed in collaboration with Pr. Romain Jolivet at Ecole Normale Supérieure (Paris).

Within ITES, the Ph.D. student will collaborate with Cécile Doubre in the team DADR for the InSAR analysis as well as other members of the team who worked on the coseismic analysis. He will also interact with seismologists for the aftershocks study and the inverse modeling including Luis Rivera and Olivier Lengliné.

Candidate's expected skills:

- Strong foundations in Earth Sciences including earthquake cycle and geodesy.
- Expertise in scientific computing (Python and/or Matlab).
- Excellent written and oral communication skills to present results publications and international conferences.
- Strong motivation and a passion for learning.

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