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High resolution imaging of immediate foreshocks to microearthquakes in Switzerland

Verena Simon, Toni Kraft, Thessa Tormann, Tobias Diehl, and Marcus Herrmann
Swiss Seismological Service @ ETH Zurich, Zurich, Switzerland (verena.simon@sed.ethz.ch)

Immediate foreshocks are the most direct observation of earthquake nucleation. This has been shown in laboratory experiments and for a small number of large earthquakes. Yet, it is still not known if this precursory phenomenon is better explained by the cascading model - where foreshocks trigger other foreshocks by Coulomb-stress transfer in an accelerating manner - or by the preslip model - in which foreshocks represent breaking asperities in a sub-critically growing nucleation zone.

Here we show for the first time that precursory phenomena can also be observed in detail in well-monitored microearthquake sequences, i.e. on faults with dimensions that links the scales of previous observations (laboratory vs. large earthquakes). Our results illustrate the large potential of our high-resolution analysis workflow to study earthquake nucleation at the field scale for a large number of natural and induced earthquake sequences in well-monitored areas, like Switzerland.

Our workflow combines several well-established seismological analysis techniques [1]. We start from the manually timed routine catalog of the Swiss Seismological Service (SED) and perform a matched filter analysis on the station with the best SNR for the sequence. This usually allows us to detect events several orders of magnitude below the SED catalog detection threshold. The enhanced catalog is then analyzed statistically to derive high-resolution time-lines of the a- and b-value and consequently the occurrence probability of larger events. Many of the detected events are strong enough to be located using the double-difference method and usually improves the number of well-relocated events by a factor 2 - 5 (depending on the quality of the monitoring network at close epicentral distances).

In this study, we present the results of applying our analysis workflow to a microearthquake sequence, which occurred close to the village of Diemtigen, west of lake Thun, between 2014 and 2015. We observe a large number of immediate foreshocks (up to 115) to each of the three largest earthquakes (M_L2.7 - M_L3.2) of the swarm-like sequence. The immediate foreshock sequences are all linked to a decrease in the b-value and a subcritical growth of a foreshock area before the main events. To further investigate the nature of the immediate foreshocks, we perform waiting-time analyses using repeating foreshocks and Coulomb-stress modeling.

We plan to extend our analysis to many more sequences that occurred over the last 15 years in Switzerland. The results will help to improve our understanding of how earthquakes initiate, and may provide new insights whether or not the earthquake nucleation process follows the cascading or the preslip model.

[1] Simon, V., (August 2017). High precision analysis of natural earthquake sequences in Switzerland. Master Thesis, IDEA League, Joint Master Program in Applied Geophysics, ETH Zurich