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Numerical model of the glacially-induced intraplate earthquakes and faults formation

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According to the plate tectonics, main earthquakes are caused by moving lithospheric plates and are located mainly at plate boundaries. However, some of significant seismic events may be located far away from these active areas. The nature of the intraplate earthquakes remains unclear. It is assumed, that the triggering of seismicity in the eastern Canada and northern Europe might be a result of the glacier retreat during a glacial-interglacial cycle (GIC). Previous numerical models show that the impact of the glacial loading and following isostatic adjustment is able to trigger seismicity in pre-existing faults, especially during deglaciation stage. However this models do not explain strong glaciation-induced historical earthquakes (M5-M7). Moreover, numerous studies report connection of the location and age of major faults in the regions undergone by glaciation during last glacial maximum with the glacier dynamics. This probably imply that the GIC might be a reason for the fault system formation.

Our numerical model provides analysis of the strain-stress evolution during the GIC using the finite volume approach realised in the numerical code Lapex 2.5D which is able to operate with large strains and visco-elasto-plastic rheology. To simulate self-organizing faults, the damage rheology model is implemented within the code that makes possible not only visualize faulting but also estimate energy release during the seismic cycle. The modeling domain includes two-layered crust, lithospheric mantle and the asthenosphere that makes possible simulating elasto-plastic response of the lithosphere to the glaciation-induced loading (unloading) and viscous isostatic adjustment.

We have considered three scenarios for the model: horizontal extension, compression and fixed boundary conditions. Modeling results generally confirm suppressing seismic activity during glaciation phases whereas retreat of a glacier triggers earthquakes for several thousand years. Tip of the glacier localizes strain and may provoke a fault formation under certain state (extension or compression). The most preferable condition for the deep fault formation is an oscillation of the glacier's edge at a narrow zone during relatively long time, which depends on the rate of horizontal extension (compression) of the lithosphere. The most powerful and deep (up to 30 km) earthquakes are possible under horizontal compression whereas models with the fixed boundary condition produce only weak and shallow seismic events.