Abstract
We study the evolution of seismicity and seismic/aseismic slip partitioning on a fault using a generalized version of the Ben-Zion and Rice (1993) model for a discrete cellular fault in elastic halfspace. Previous versions of the model were shown to produce a wide variety of realistic results (e.g., frequency-size statistics, hypocenter distributions, slip distributions and temporal occurrence) using distributions of static and kinetic friction levels and creep properties that vary in space but are fixed in time. In the present study we incorporate heat generation due to slip within a 10 cm wide zone, subsequent diffusion into the surrounding halfspace, and related changes of temperature and temperature-dependent creep on the fault. We assume a power law dependency of creep on the local shear stress, with temperature-dependent parameters based on the Arrhenius equation. Temperature rises due to slip episodes lead to increased seismic slip, which can lead to further stress concentration in a feedback loop. The partitioning of seismic/aseismic slip and the temporal distribution of seismicity are strongly affected by the activation energy in the Arrhenius equation, and frictional parameters that control the local stress drop after failure. Our initial investigations attempt to clarify changes of the fault behavior associated with variations of these two parameters.

Strength change parameter
Brittle failure occurs when the local stress at a cell reach the static strength level. The strength drops to dynamic level $\tau_d$ and the difference $\tau_s - \tau_d$ gives a transient stress drop during one composite brittle failure episode, where $\tau_s$ is stress before failure.

$$E_D = (\tau_s - \tau_d) / (\tau_s - \tau_d)$$

$\tau_s$: static brittle failure strength
$\tau_d$: dynamic brittle failure strength
$\tau_d$: stress remaining on a cell during a composite brittle event

Frictional strength healing
To apply a more realistic friction law, we introduce a time-dependent healing of the form

$$\tau(t) = \tau_d + C \ln(1 + \frac{t}{t_{Hool}})$$

where $\tau_d$ is the initial dynamic strength, and $t_{Hool}$ gives the time interval required for complete healing to static level.

Strength profile
The failure envelope of the model is illustrated by the collection of minima between the static brittle strength $\tau_s$ and $\tau_d$, the stress required for a creep-slip at plate velocity.

$$\tau_s(x, z) = \frac{\mathbf{v}_p / w}{AE(x, z) \exp(-E(x, z)/RT(z))}$$

$\tau_s$: cohesion
$\tau_d$: rock and water density respectively
$\mathbf{v}_p$: plate velocity
$w$: fault loading width
$A$: Arrhenius amplitude
$E$: fault activation energy
$T$: temperature, linear with depth

Thermal mechanism and rock healing
We assume a temperature dependent creep based on Arrenius equation below.

$$\mathbf{v}_s(x, z) = wAe^{E(x, z)/RT(z)}$$

Post-seismic temperature increase will raise the creep velocity, which leads to further stress concentration around fracture area. We apply a cooling function from Cardwell et al., 1978, assuming constant heat rate during each step and 1D diffusion from fault surface into the half-space. On the right we are showing temperature changes from three events with same slip $= 1m$ and different durations.

$$T = T_0 + \frac{D}{2\rho c_p w T} \int_0^t \frac{\text{erf} \left[ x + \frac{w}{2} \right] - \text{erf} \left[ \frac{x - w}{2} \right]}{(4\kappa [t - t_0])^2} dt, t > t$$

$D$: diffusivity of the half-space
$w$: width of the slip zone

Results
Top left panel: model hypocenters for the case of uniform brittle properties. Color bar indicates the time of each event. The number of earthquakes generated during a 100 year simulation is over 14000.

Middle left panels: coupling coefficient on the fault one month before and after a Magnitude = 6.2 event.

$$Z = \frac{\Delta \mathbf{e}_{\text{strain}}}{\Delta \mathbf{e}_{\text{source}} + \Delta \mathbf{e}_{\text{source}}}$$

Coupling coefficient drops significantly after a large events due to the post-seismic temperature increase and rock damage.

Bottom left and middle: Moment magnitude vs. time and cumulative frequency-size statistics are plotted. Larger events tend to trigger more aftershocks.

Bottom right: Case with slower strength healing. More aftershocks are generated. However, no aftershock decay is observed.

Right panel: two individual cells are selected to demonstrate two types of fault behavior. Top one is a brittle cell and bottom is a conditionally stable creeping cell.