The effects of flash heating on earthquake sequences
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Introduction
High-velocity rock friction experiments demonstrate that at high slip velocities dynamic weakening processes are activated, causing the frictional resistance of faults to drop to very low values. This reduction in frictional resistance in turn reduces the coseismic frictional heat generation of the fault. It also allows the fault to operate at lower background stress levels, which reduces the cycle-averaged thermal anomaly from frictional heat generation. Additionally, dynamic weakening enables earthquakes to propagate further into velocity-strengthening (VS) regions, potentially leading to much deeper down-dip rupture propagation limits.

There are a number of different dynamic weakening mechanisms, including thermal pressurization and flash heating. We focus on flash heating, in which high slip velocities during an earthquake cause local temperature increases at asperity contacts, weakening the asperities and leading to a macroscopic drop in frictional strength.

Flash Heating Formulation
The fault is governed by rate-and-state friction. We use a simplified form of flash heating from Rice (2006), holding the weakening velocity \( V_w \) constant (that is, \( V_w \) is not a function of temperature). When the slip velocity \( V \) is less much less than \( V_w \), the set of equations reduces to that of standard rate-and-state friction with the slip law:

\[
\psi = \frac{\sqrt{|V|}}{D_v} (f - f_{ss})
\]

friction
\[
f = a \sinh^{-1} \left( \frac{|V|}{2V_0} \right) \]

without flash heating
\[
f_{ss} = f_{LV}
\]

with flash heating
\[
f_{ss} = \begin{cases} 
    f_{LV} & V < V_0 \\
    f_{w} - (f_{LV} - f_{w}) \frac{V}{V_0} & V > V_0
\end{cases}
\]

Model
We use the finite-difference code SCycle to simulate a vertical strike-slip fault in 2D embedded in an elastic medium. The method is extended from Erickson and Dunham (2014) and Duru et al. (2019). We use constant normal stress of 50 MPa and a plate velocity \( v_p \) of \( 10^{-9} \) m/s. We limit flash heating to a region within the seismogenic zone, turning it off outside this region by setting \( V_w \) to \( 10^9 \) m/s.

Elastic Earthquake Cycles

- Effects of flash heating:
  - larger earthquakes that rupture more of the fault
  - much longer recurrence interval
  - lower residual shear stress
  - the interseismic shear stress in the VS region never fully recovers

<table>
<thead>
<tr>
<th>case</th>
<th>recurrence interval (yrs)</th>
<th>down-dip eq limit (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>18.5</td>
</tr>
<tr>
<td>2</td>
<td>220 – 225</td>
<td>20.5</td>
</tr>
<tr>
<td>3</td>
<td>300 – 450</td>
<td>29.5</td>
</tr>
</tbody>
</table>