



Earthquake nucleation

Nucleation Models

1. SELF – SIMILAR MODEL

- Always fully dynamic process
- Slip velocity linearly increases with time
- Waves emission since initial stages of nucleation



2. CASCADE MODEL

- Small events with mutual triggering accumulate up to a big event
- Only the final stage is fully dynamic with waves emission



3. PRE – SLIP MODEL

- Initially an aseismic process increases the total cracked area
- When a critical dimension is reached the process is spontaneous
- Dieterich and Andrews models

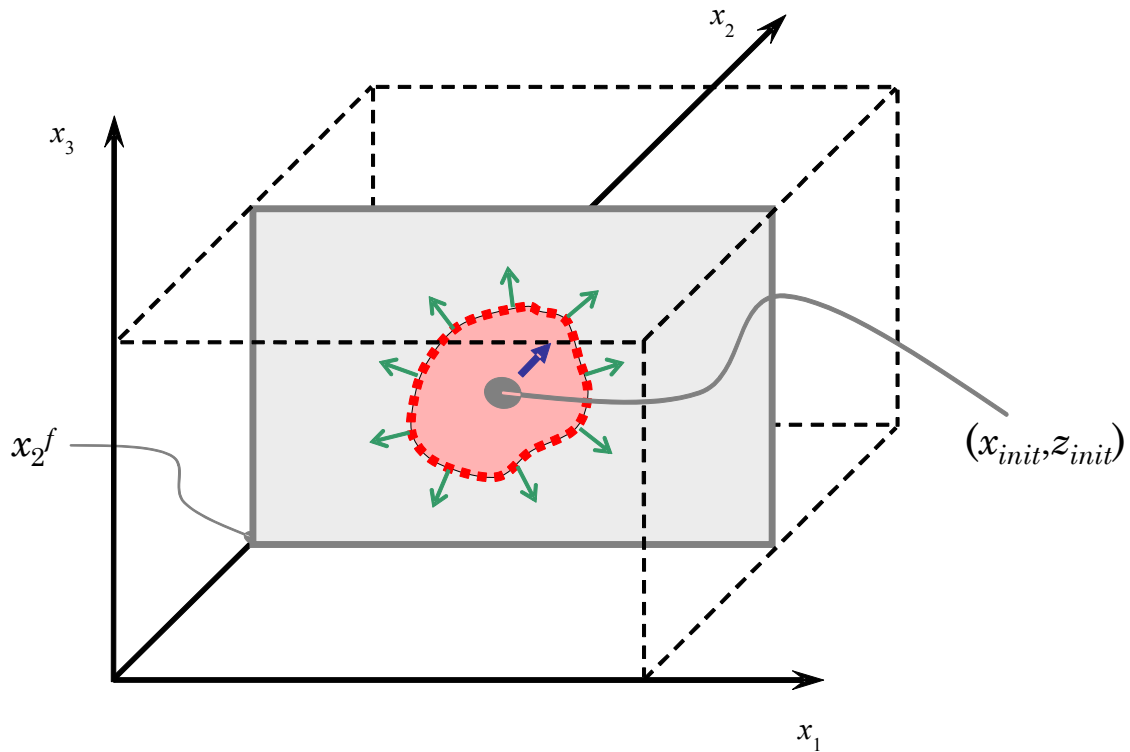


**How to simulate the
earthquake nucleation?**

1. SLIP – WEAKENING CONSTITUTIVE EQUATION

- Linear SW is **un**able to model the nucleation stage and therefore rupture initiation has to be prescribed (i. e. imposed)
- Different nucleation strategy have to be compared in order to see what are the effects of the initialization parameters on the following rupture propagation
- In order to correctly represent a physical process nucleation strategies have to be equivalent results
- The Ohnaka' s SW contain the slip – hardening phase and is able to account for nucleation

Notations and symbols



→ *Local crack enlargement*

→ $T(x_1, x_3, 0)$

Time - weakening

inuclstrat = 1

$$\tau = \begin{cases} \left[\mu_u - (\mu_u - \mu_f) \frac{(t - t_{force})}{t_0} \right] \sigma_n^{eff} & , t - t_{force} < t_0 \\ \mu_f \sigma_n^{eff} & , t - t_{force} \geq t_0 \end{cases}$$

$t_{force} = t_{force}(\xi)$ is the forced rupture onset time in every fault point ξ .

Andrews (1985), Bizzarri et al. (2001) and other following Bizzarri' s papers

t_0 is the characteristic time – weakening duration.

Slip velocity perturbation

`inuclstrat = 3`

$$V \begin{Bmatrix} 1 \\ 2 \\ 3 \end{Bmatrix} (x_1, x_2, x_3, 0) = \frac{1}{2} \text{sign}(x_2 - x_2^f) v_{init} \begin{Bmatrix} \cos \varphi \\ 0 \\ \sin \varphi \end{Bmatrix} e^{-\frac{(x_1 - x_{init})^2}{(x_1 - x_{init})^2 - (i_{nucl} \Delta x_1)^2}} e^{-\frac{(x_2 - x_2^f)^2}{(r j_{nucl})^2}}$$

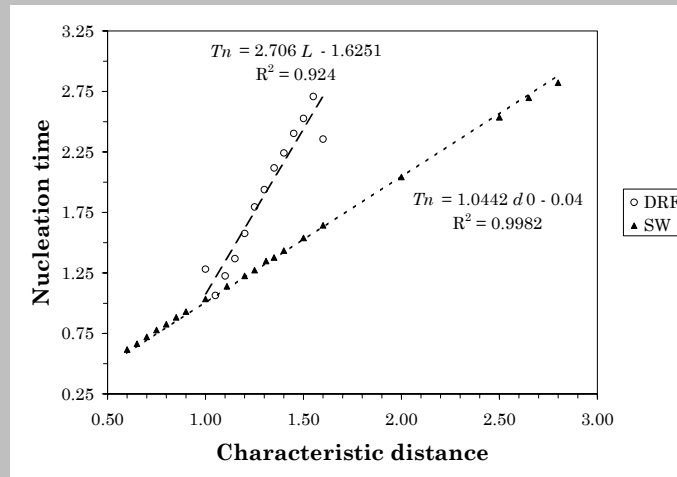
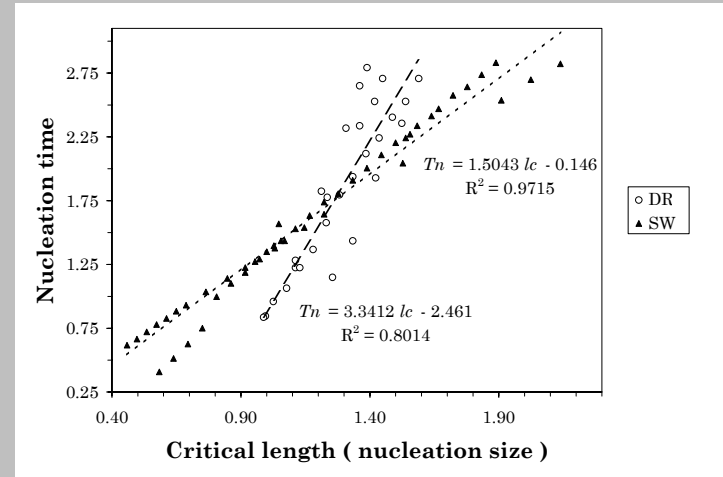
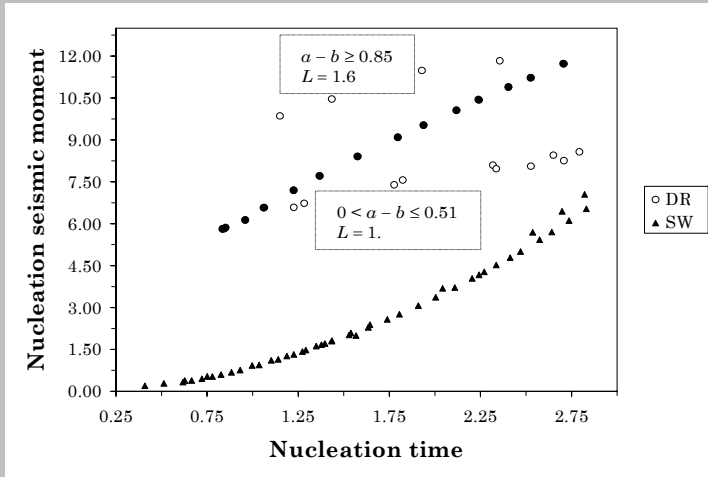
φ is the rake angle, measured from x_1 in anti – hourly sense; $\varphi = 0$ represents a left – lateral strike slip fault

With opportune corrections and modifications of *Ionescu and Campillo (1999)* and *Badea et al. (2004)*

v_{init} is the maximum imposed fault slip velocity; j_{nucl} is a sensitivity factor



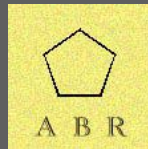
SW vs. DR law #4: The nucleation



2. RATE AND STATE CONSTITUTIVE EQUATIONS

- Rate – and state – dependent friction laws are able to describe the nucleation stage
- The **spontaneous** rupture nucleation is modeled through the evolution of the state variable
- The earthquake initiation is promoted in a nucleation path assuming a different distribution of the contact time of the micro – asperities

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Support Slides: Parameters, Notes, etc.

To not be displayed directly. Referenced above.

