Slow earthquakes in the Guerrero Gap, Mexico

Josimar Alves da Silva Jr

Graduate student
Department of Earth, Atmospheric and Planetary Sciences (EAPS)

In collaboration with William Frank[1], Michel Campillo[2] and Ruben Juanes[1]

[1] EAPS/MIT
[2] Institut des Sciences de la Terre, Grenoble University, France

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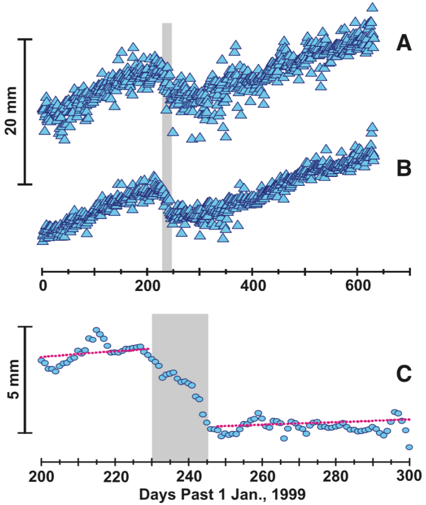
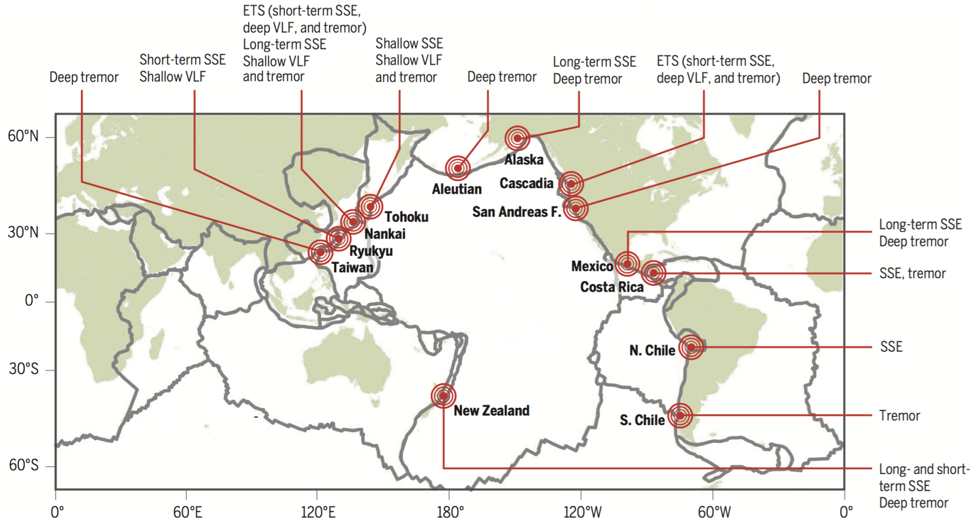
Slow slip earthquakes (SSE)

Dragger et al. (2001)

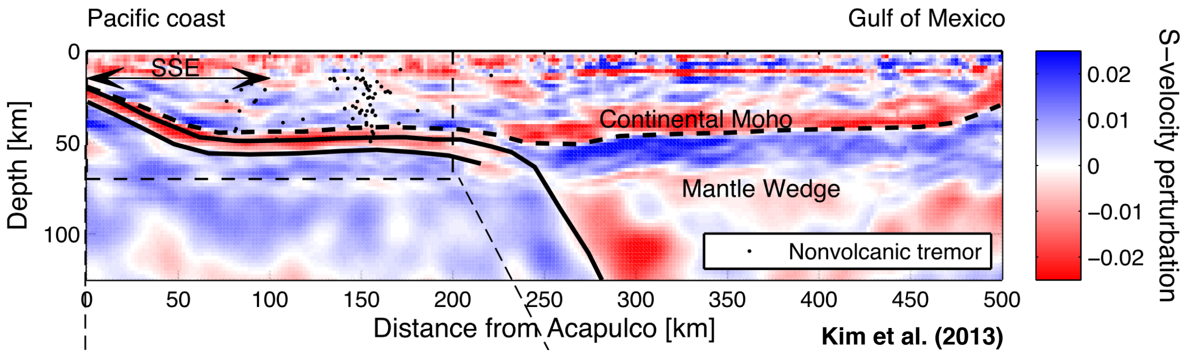


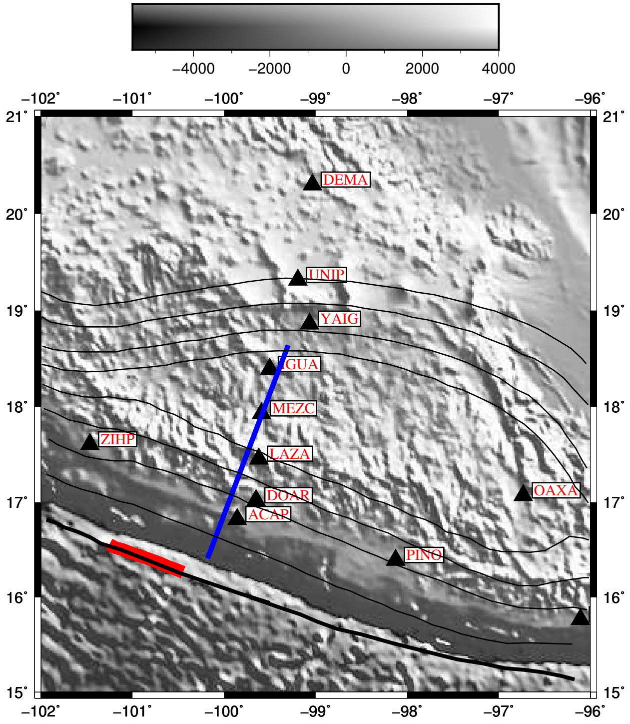


Obara and Kato (2016)

1. **SSE is a new type of earthquake where energy is release over long periods of time**
2. **Slow slip events (SSE) occurs in different subduction zones and are mostly detect by GPS observations**
3. **SSE events have been observed prior to large earthquakes**

Slow earthquakes in Guerrero, Mexico





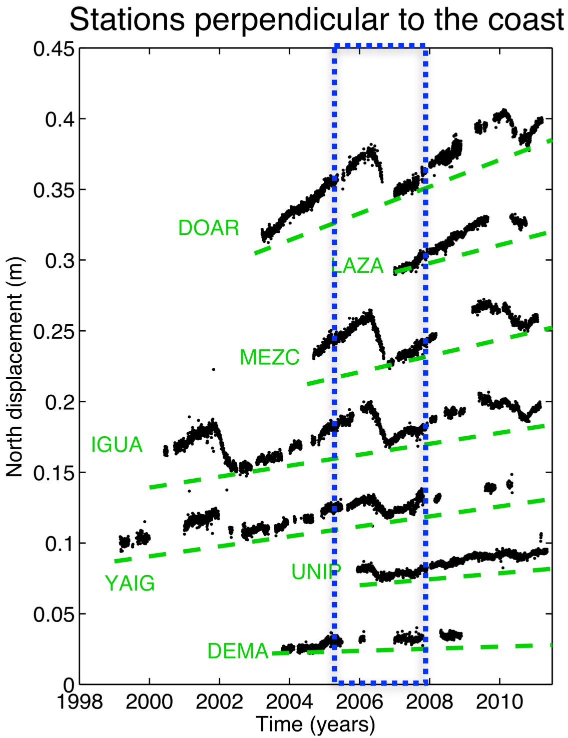
Study area: Cocos subduction zone, Mexico

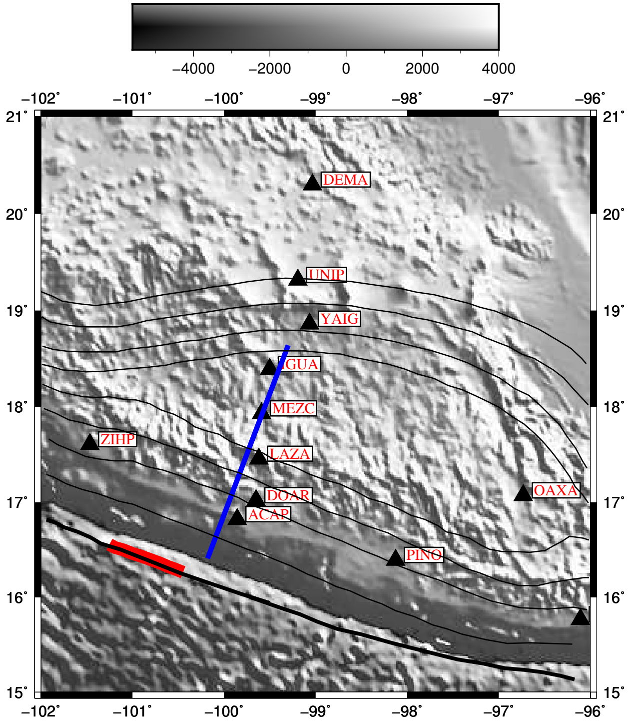
- ✓ **4 SSE events every ~4 years**
- ✓ **SSE magnitude Mw ~ 7.5**
- ✓ **High pore pressure due to mineral dehydration**
- ✓ **Extensive tremor and LEF catalogs (Frank et al.2014, 2015)**
- ✓ **Absence of large megathrust earthquakes (Guerrero Gap) for 400 to 500 years**

Slow earthquakes in Guerrero, Mexico

Research questions:

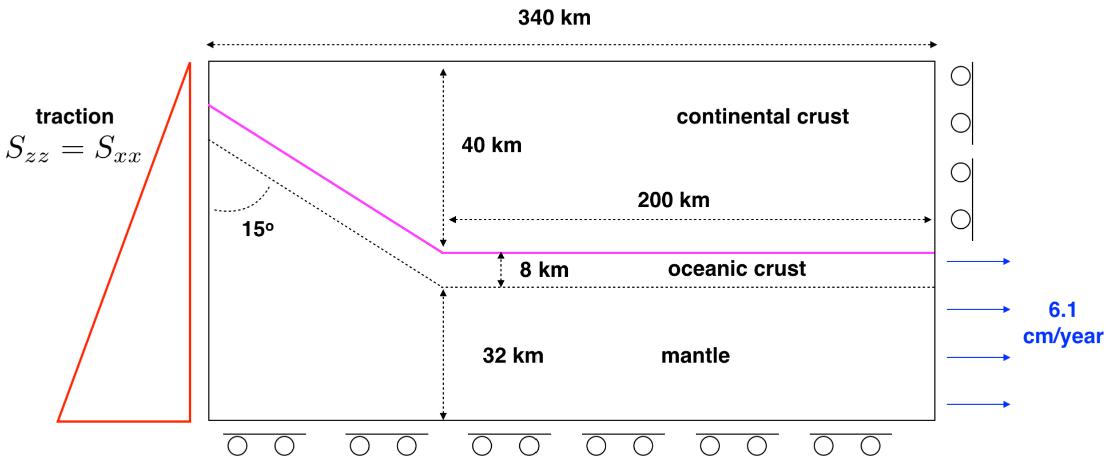
1. What causes periodic SSE events ?
2. Is the geometry of the Guerrero Gap important for SSE nucleation and arresting ?
3. What is the implication of SSE occurrence for large, megathrust earthquakes in this area ?





Model Geometry and elastic properties

1. **Quasi-static finite element with gravity (PyLith)**
2. **All layers are elastic**
3. **Constant loading rate equal to plate subduction rate (6.1 cm/year)**

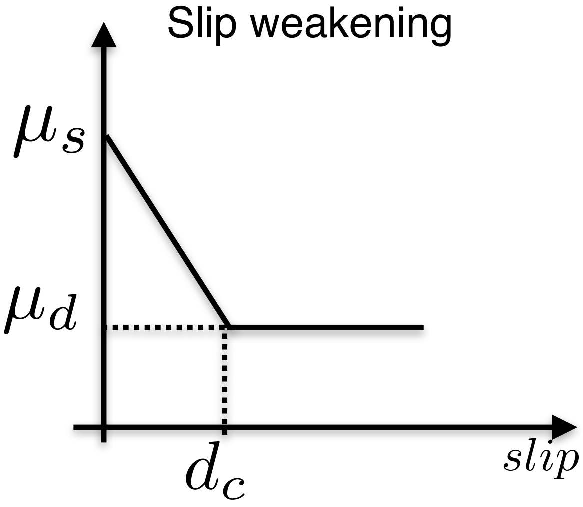


$$\nabla \cdot \sigma = \rho g$$

with boundary conditions and contact problem at the fault

	Vp (m/s)	Vs (m/s)	density (kg/m3)	poisson's ratio	Young Modulus (GPa)
continental crust	7500	4000	3000	0.30	124
oceanic crust	5500	3000	3100	0.28	71
mantle	8000	4620	3370	0.25	179

Fault constitutive model

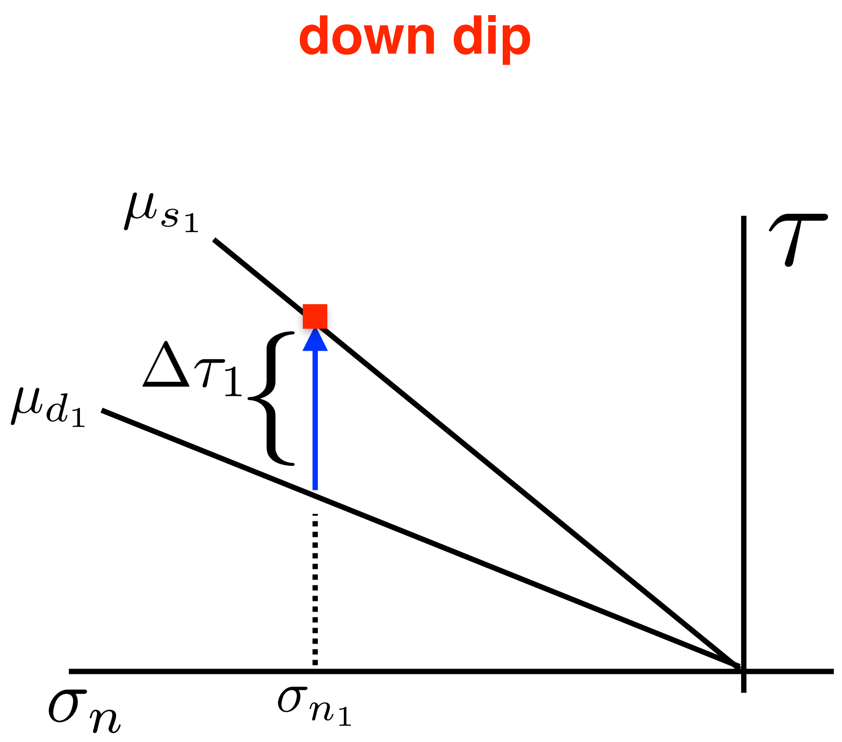


- Healing occurs every 6 months (duration of the SSE event)
- Heterogeneities are included by spatially varying the dynamic and static friction coefficient

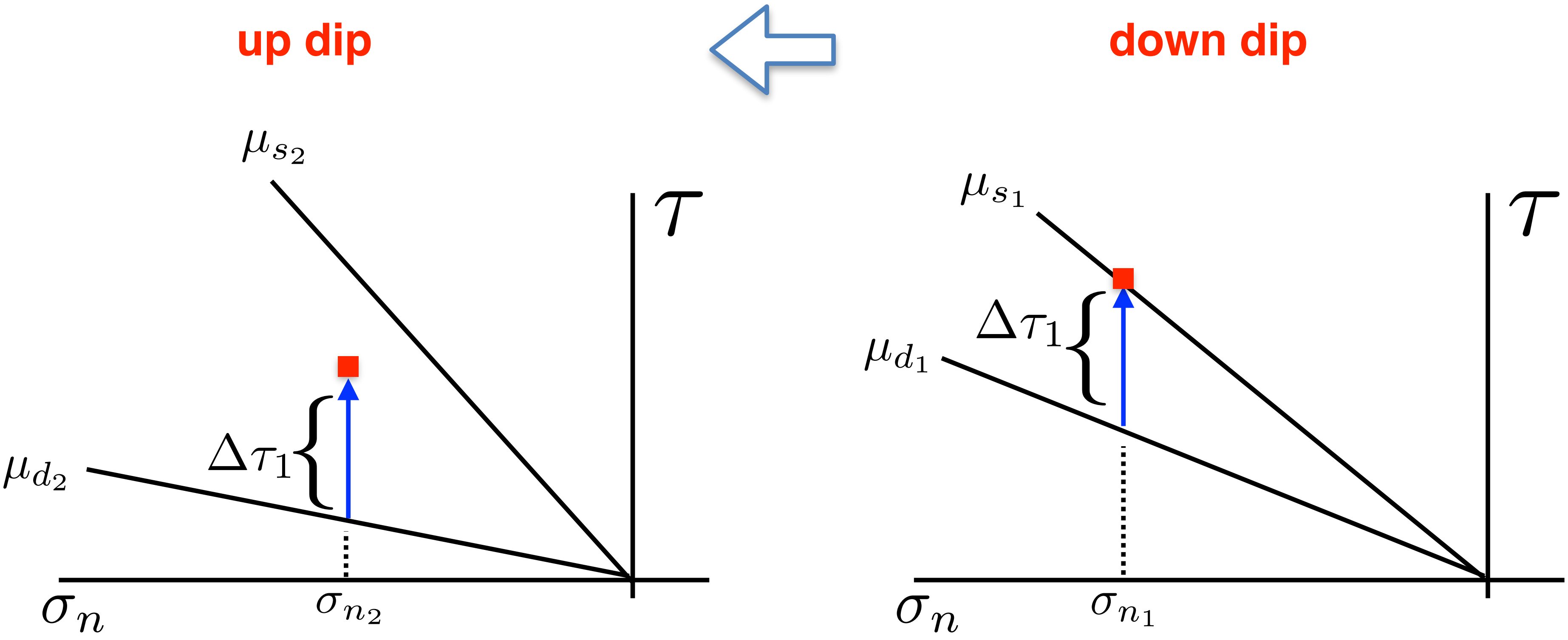
Fracture energy (Rupture resistance)

$$G_c = \frac{1}{2}\sigma_n(\mu_s - \mu_d)d_c$$

Frictional heterogeneity: mechanism for slip arresting



Frictional heterogeneity: mechanism for slip arresting



Designing an asperity model for SSE arresting

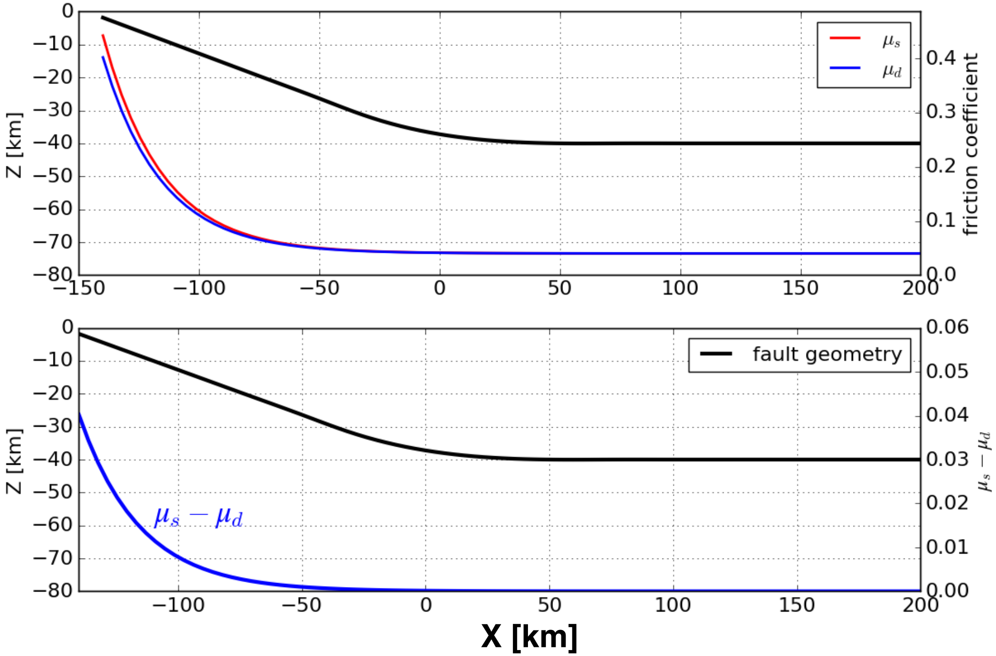
Exponentially decaying friction coefficient

$$\mu_s = \mu_{s_0} e^{-\alpha(x-x_0)} + \mu_{s_{min}}$$

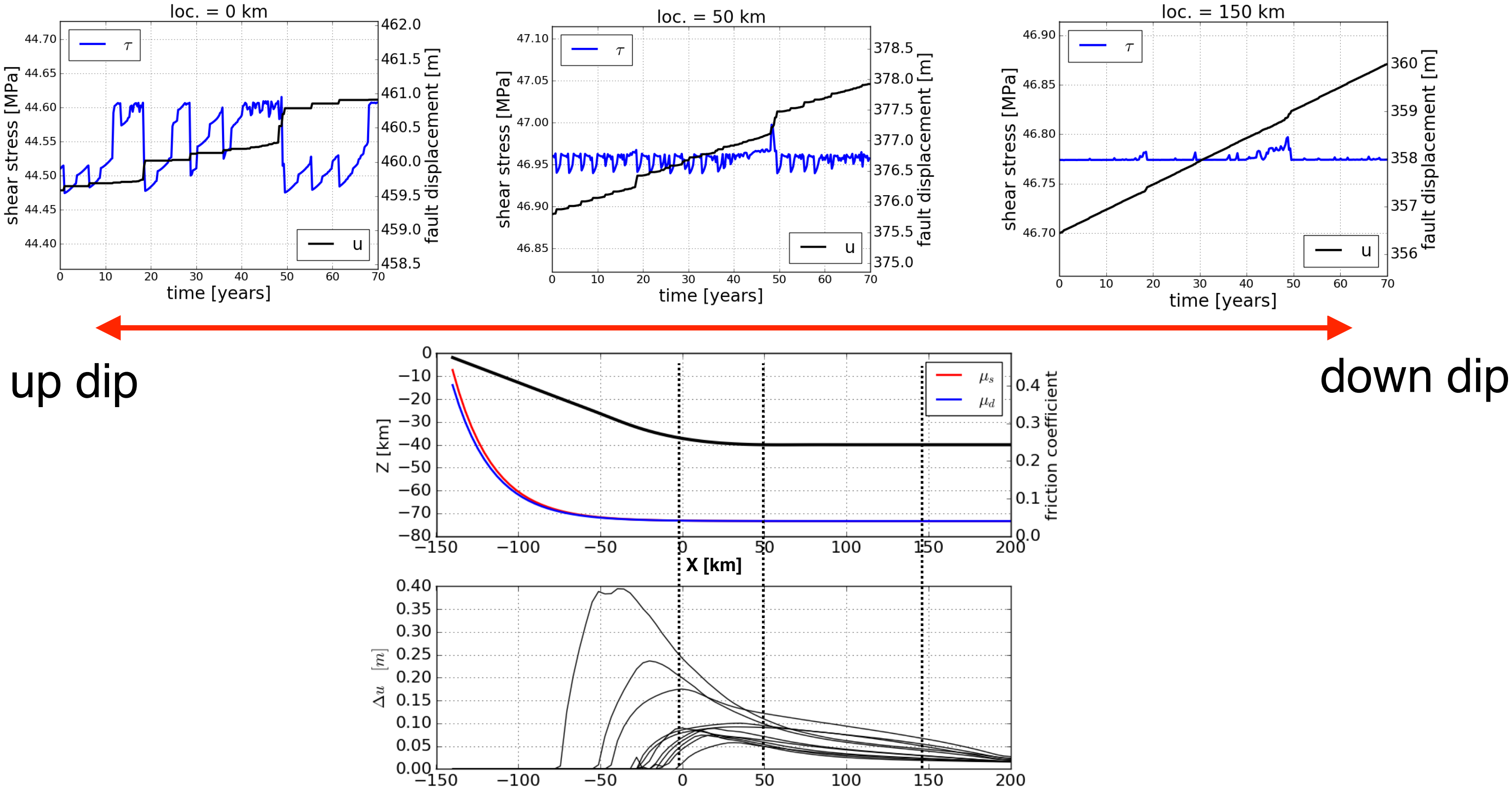
$$\mu_{s_0} = 0.4 \quad \mu_{s_{min}} = 0.04$$

$$\mu_d = p\mu_s \quad ; 0 < p < 1$$

SSE events stop due to increase in the fracture strength up dip on the fault



SSE stick-slip behavior



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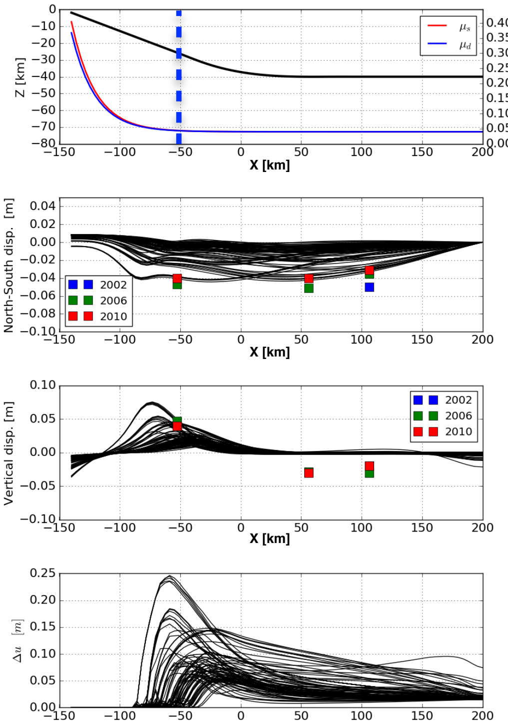
Frictional properties control on SSE arresting

Strain accumulation and SSE nucleation depends on the onset of the increase of friction coefficient

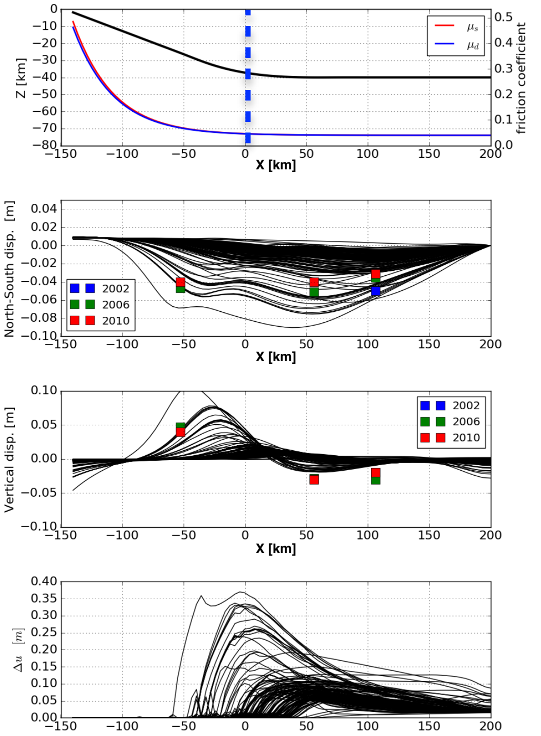
Surface displacement during SSE events are on the same order of magnitude as the observed GPS displacements

SSE arresting occurs due to increase in the fracture strength up dip

friction coeff. with faster decay



friction coeff. with slower decay



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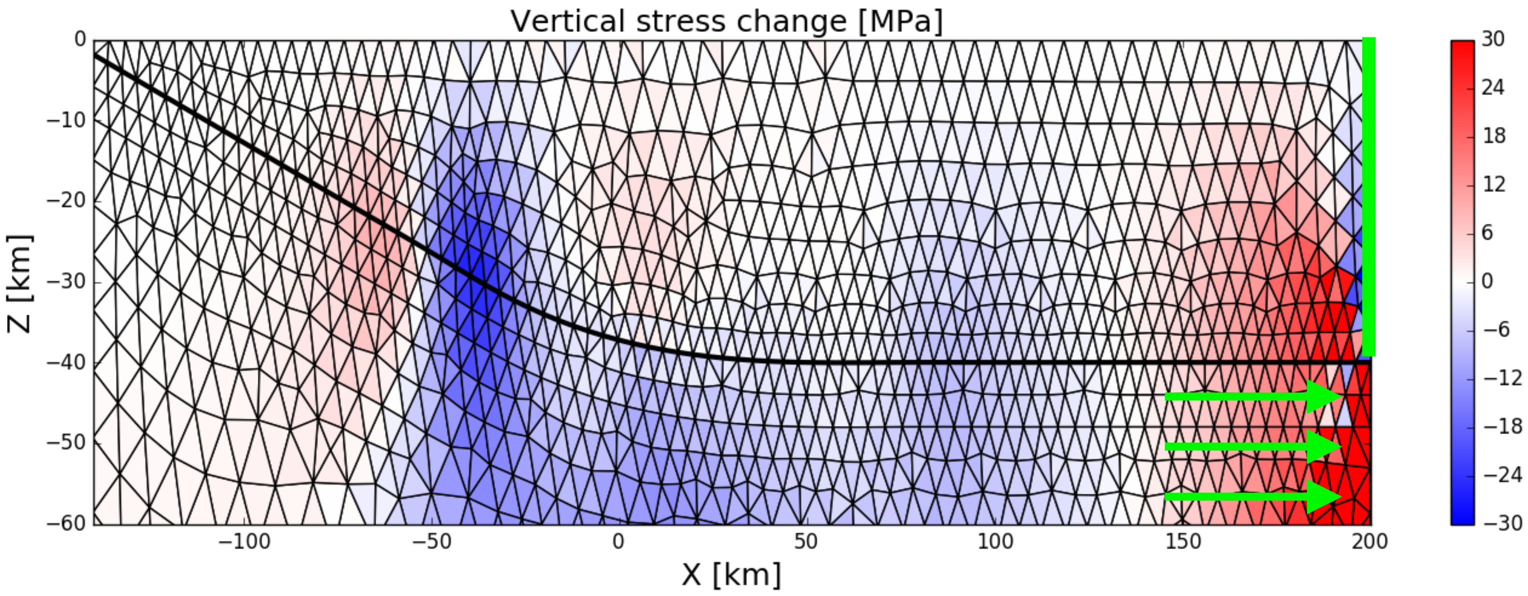
Impact of fault Geometry

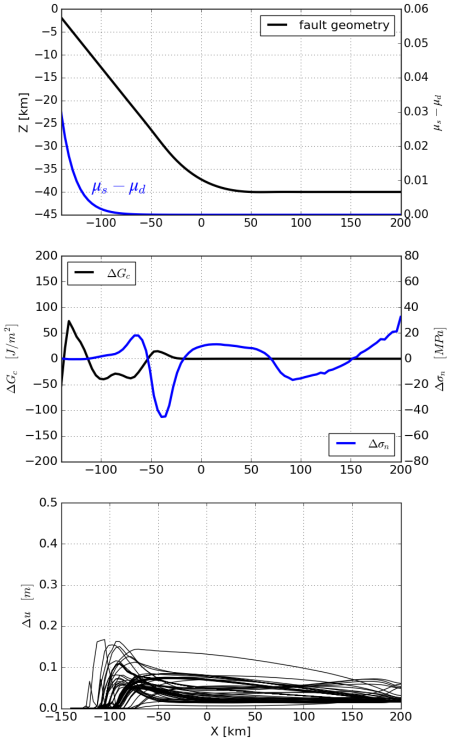
blue = negative values = increase in compressive stress
red = positive values = decrease in compressive stress



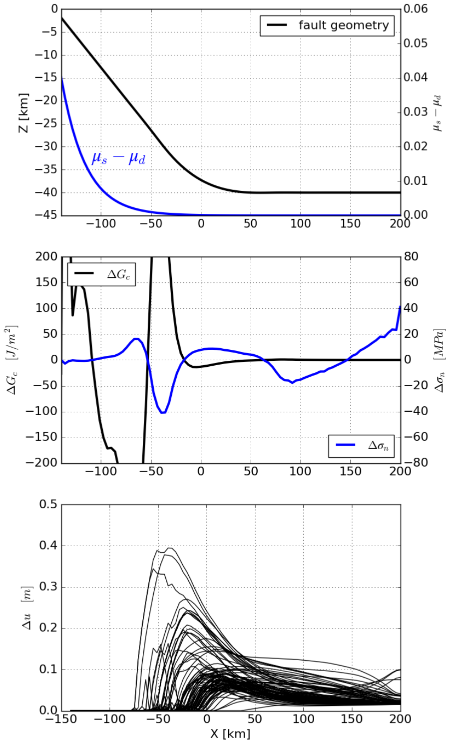
Impact of fault Geometry

$$G_c = \frac{1}{2}\sigma_n(\mu_s - \mu_d)d_c$$

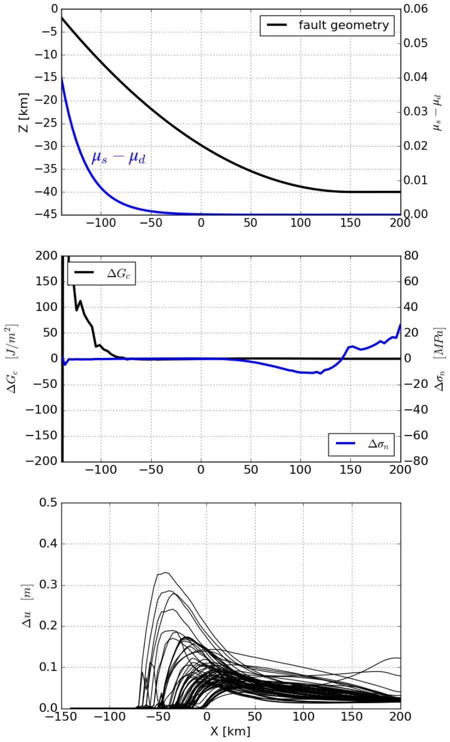
Geometry 1
friction 1



Geometry 1
friction 2

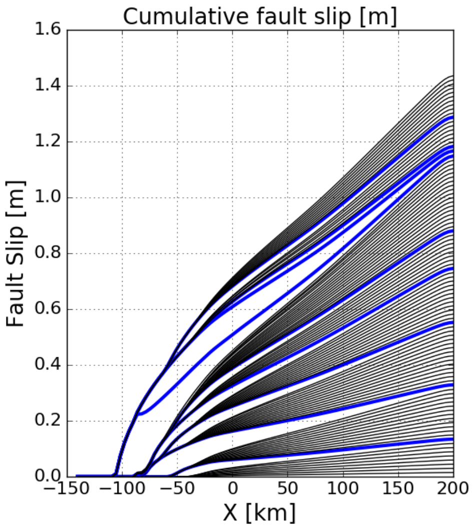


Geometry 2
friction 2

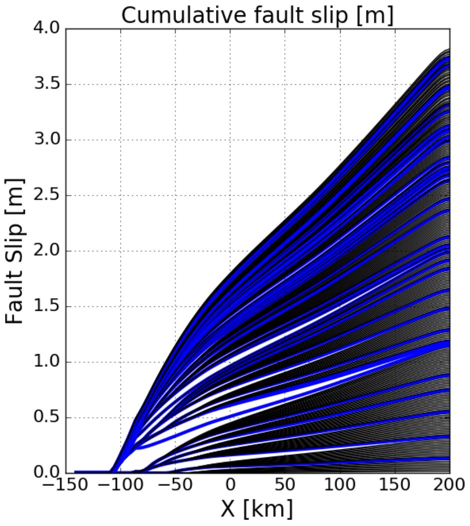


SSE events and seismic cycle

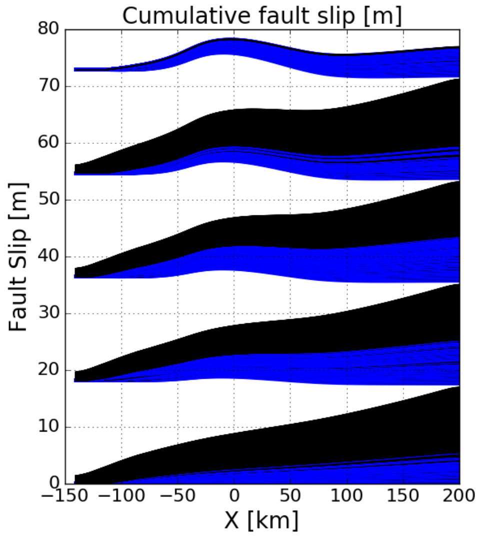
Time window: 25 years



Time window: 70 years



Time window: 1300 years



1. Strain accumulates due to seismic creeping and is released as SSE events
2. Short terms seismicity in agreement with GPS observations

Conclusions

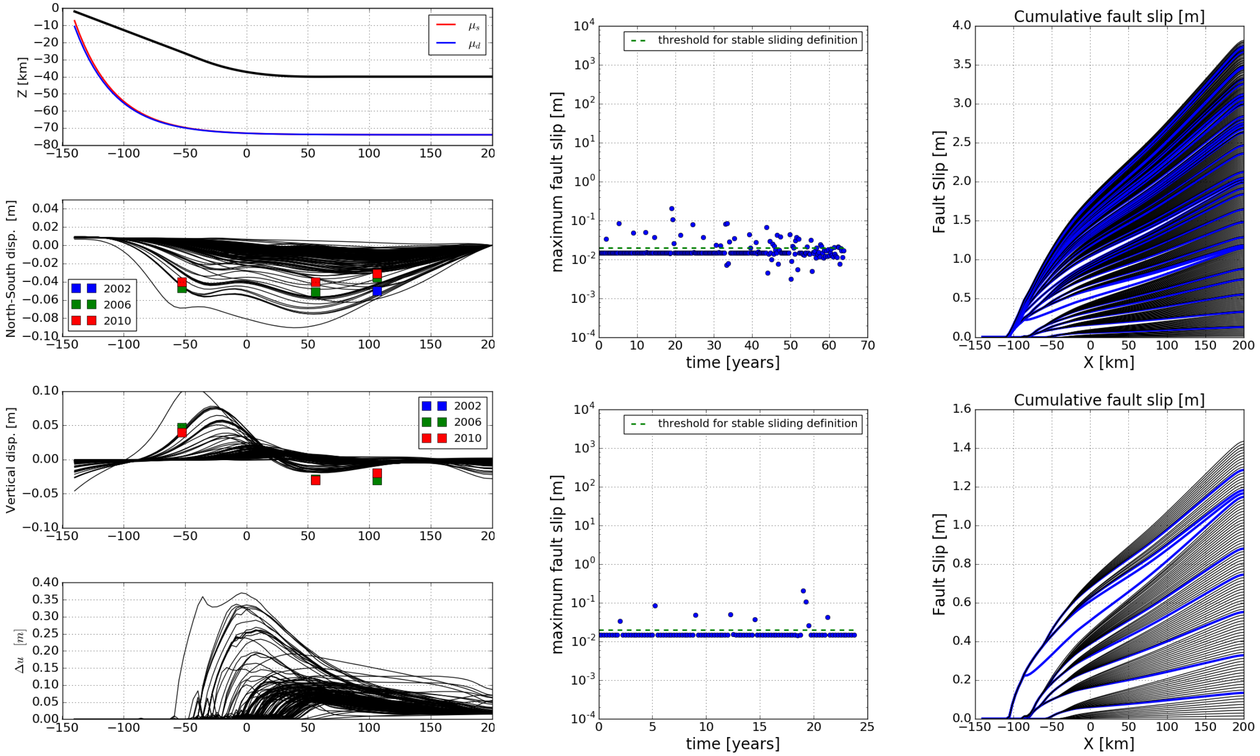
1. The fault frictional properties controls SSE nucleation and arresting, with geometry having minor impact

2. SSE events nucleate down dip from the trench due to strain accumulation on the onset of the friction increase

3. SSE events are arrested by increasing the fracture strength up dip

4. The current model predict short terms seismicity correctly, however, long term seismicity show opposite behavior compared with GPS observations

Thank you !!!



Z [km]
μ_s
μ_d
North-South disp. [m]
2002
2006
2010
Vertical disp. [m]
Δu [m]
maximum fault slip [m]
threshold for stable sliding definition
time [years]
Cumulative fault slip [m]
Fault Slip [m]
X [km]