How does climate affect the evolution of offset channels? Preliminary landscape evolution models

Poster # 016

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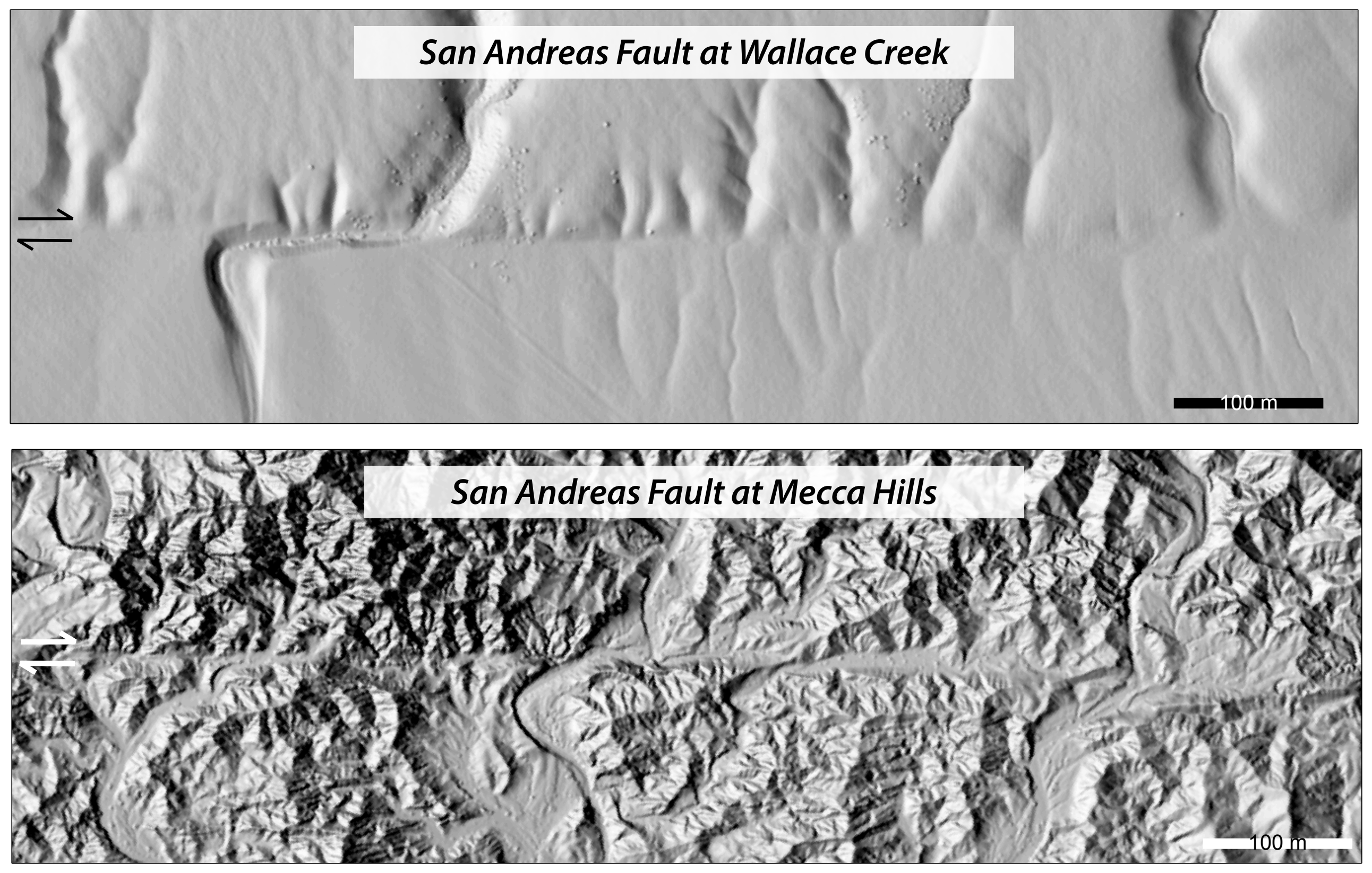
Motivation & Research Questions

Offset channels along strike-slip faults are formed by the interplay of tectonic and gemorphic processes (e.g., Wallace, 1968). Channels offset in strike-slip earthquakes are modified by deposition and incision during the interseismic period. Erosion rate, which depends on the material properties of the fault zone and precipitation rate and distribution, affects the appearance of offset markers. How much do these geomorphic processes affect our ability to interpret the landscape and accurately reconstruct offset markers to estimate slip in past earthquakes? We test the effects of initial topography and drainage direction, storm recurrence, diffusion, and slip rate on the development of offset channels.



Portions of the San Andreas Fault at Wallace Creek and the Mecca Hills illustrate differences in erosion rate. The slip rate at Wallace Creek is ~34 mm/yr. The slip rate at Mecca Hills is ~25 mm/yr. Topographic data from the B4 lidar collection.

Numerical Landscape Evolution Model Setup

Numerical simulations allow us to test scenarios that are hard to control in the natural world, and compare apparent offset amounts to the imposed slip history.

change in elevation of the landscape with time is governed by (Duvall and Tucker 2015):

$$\frac{\partial z}{\partial t} = \underset{\text{baselevel lowering}}{U} - \overbrace{V(y)\frac{\partial z}{\partial x}}^{\text{lateral deformation}} - \overbrace{\left(\underset{\text{erodibility}}{K_{sp}}A^{1/2}S - E_{crit}\right)}^{\text{incision}} + \overbrace{\underset{\text{diffusivity coefficient}}{D}\nabla^2 z}^{\text{diffusion}}$$

Base Setup

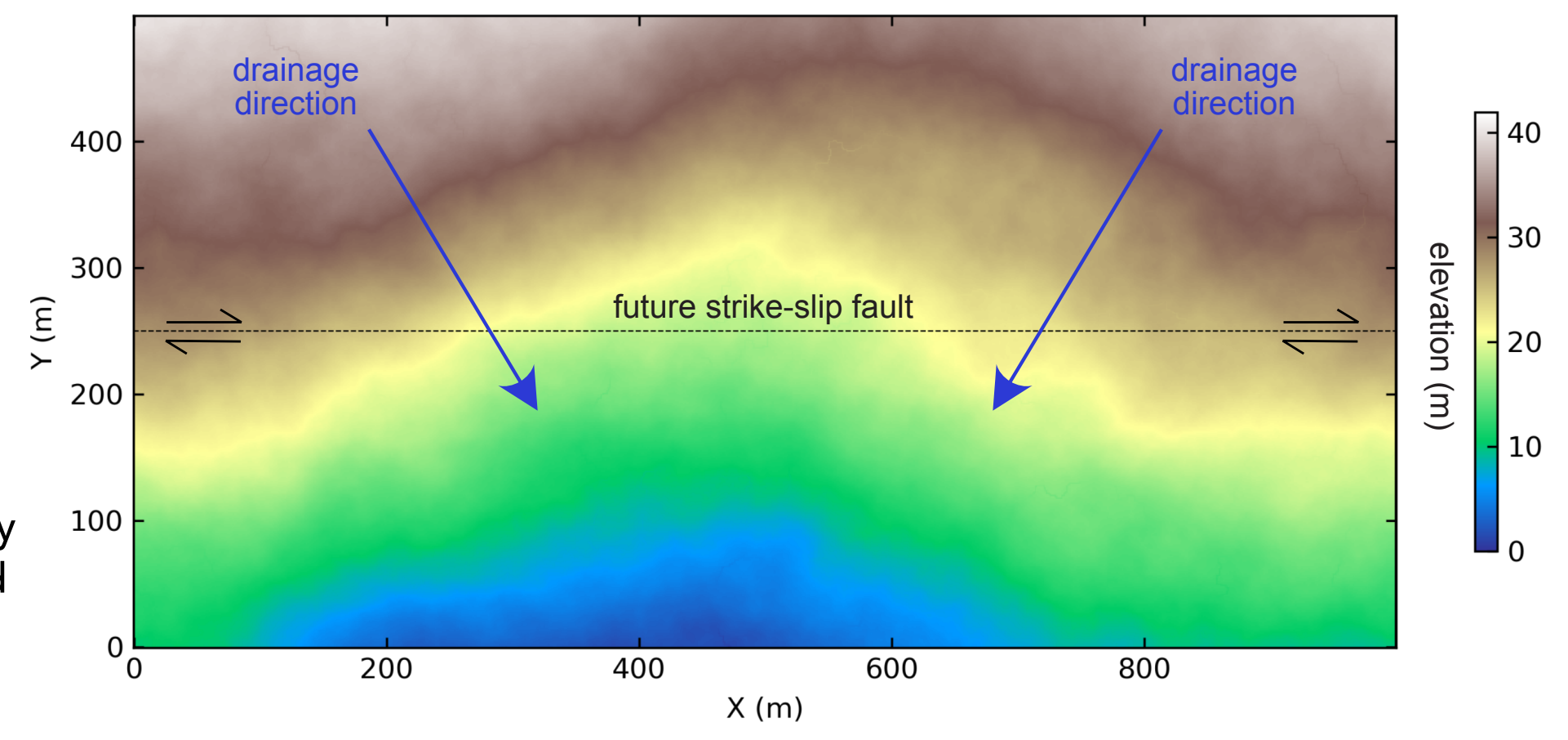
- Periodic earthquakes
- 6 m slip per earthquake
- Right-lateral slip
- 10 kya run time
- Constant diffusion
- Constant and variable incision

Variable Parameters

- 1 - 30 mm/yr slip rates
- 0.0001 - 0.01 /yr erodibility
- 0.001 - 0.01 m²/yr diffusivity
- Storm recurrence more and less frequently than earthquake recurrence

Initial Topography

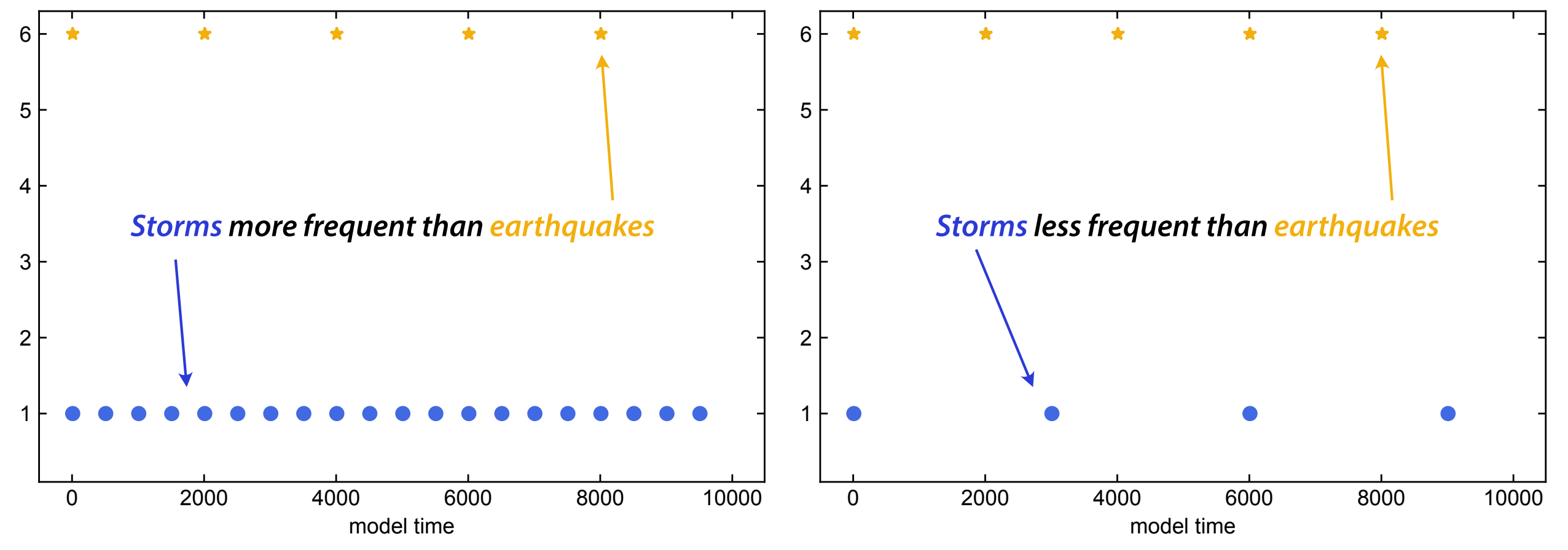
Each simulation begins with the same initial topography with self-similar random roughness and a ramp in the y-direction.



The model setup simulates an interior portion of a linear strike-slip fault with constant slip along fault strike and without distributed deformation.

Landscape evolution models use the Landlab model building toolkit (Hobley et al., 2017; Barnhart et al., 2020).

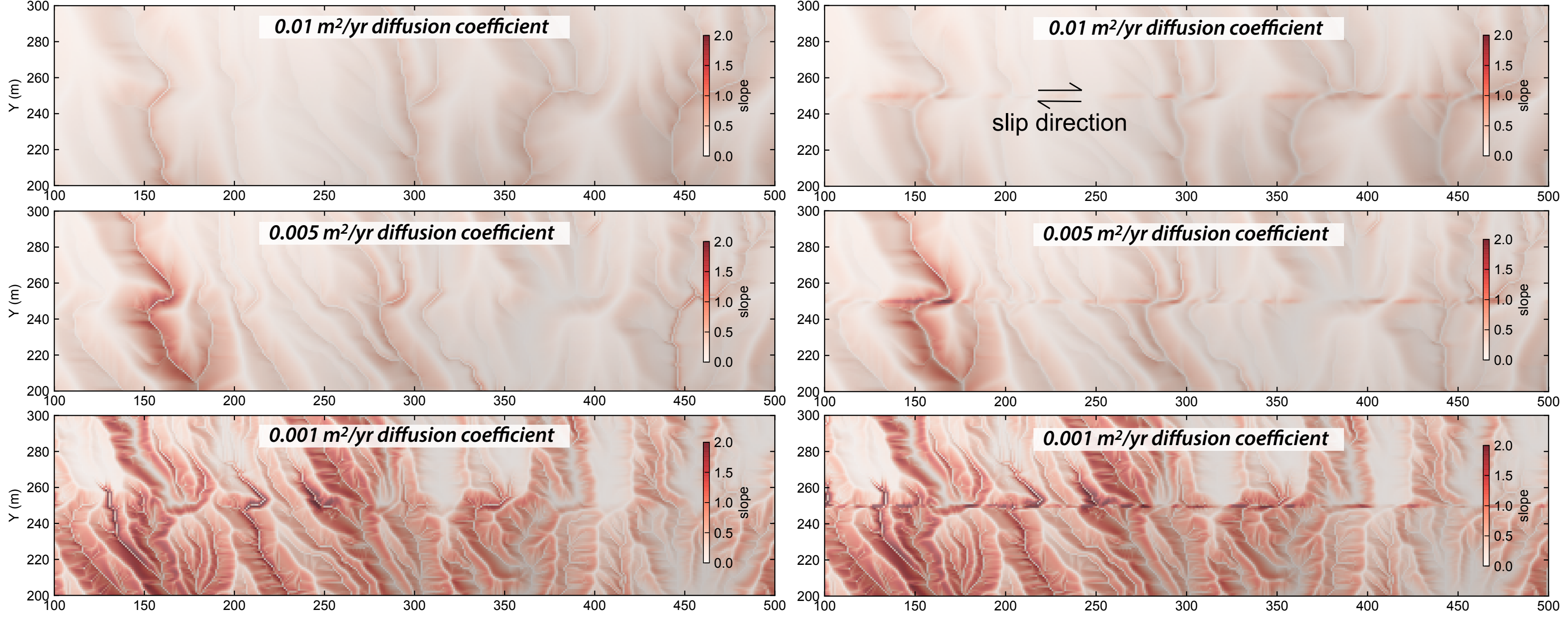
Example storm recurrence vs. earthquake recurrence for the 3 mm/yr slip rate simulations



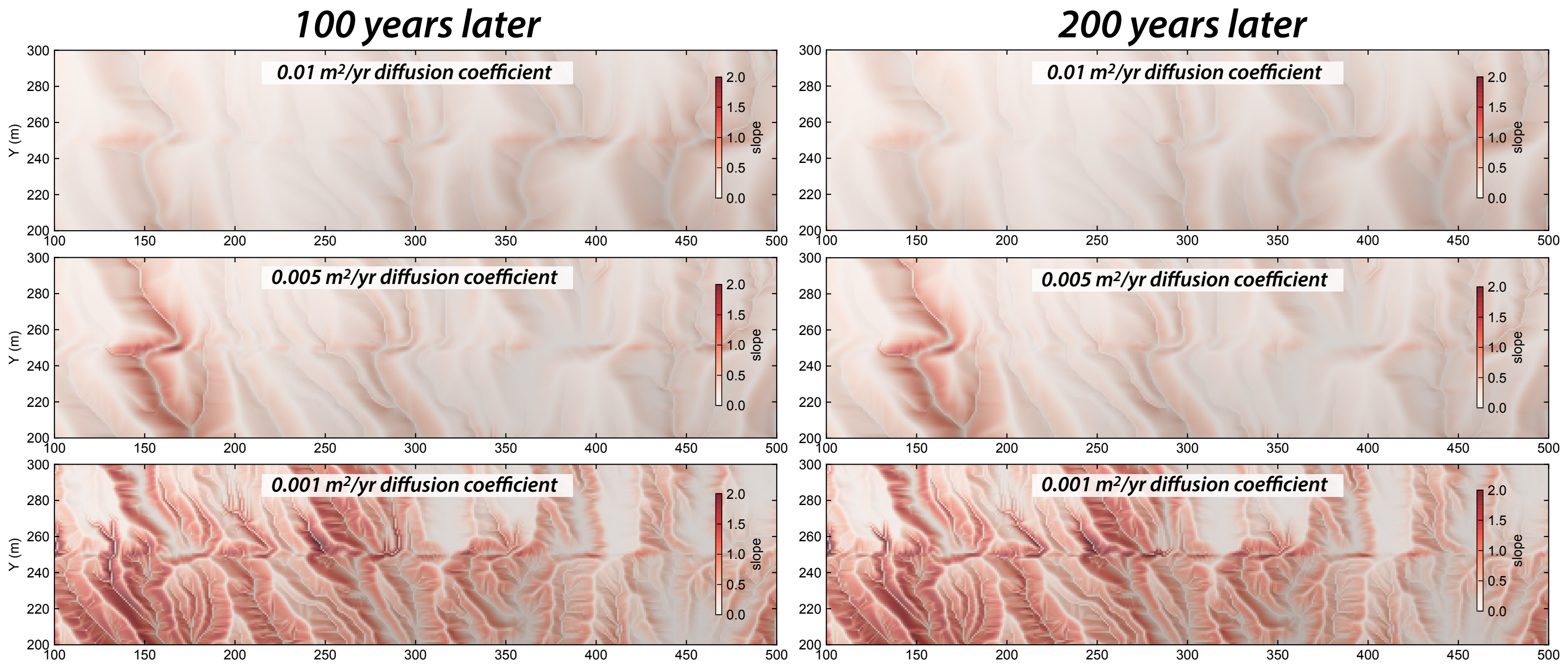
Constant, Variable Diffusion

The effect of different diffusion rates, with constant diffusion throughout each simulation.

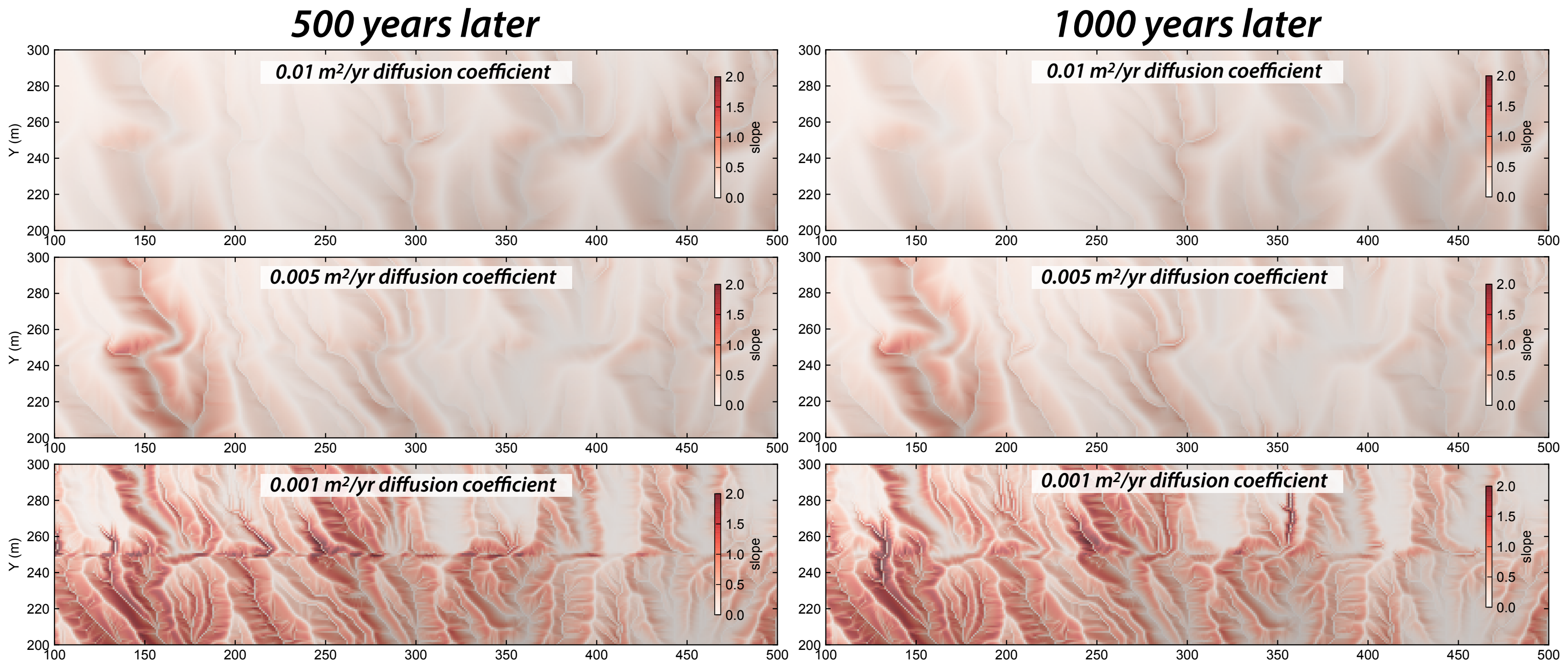
prior to earthquake *after earthquake*



100 years later *200 years later*



500 years later *1000 years later*

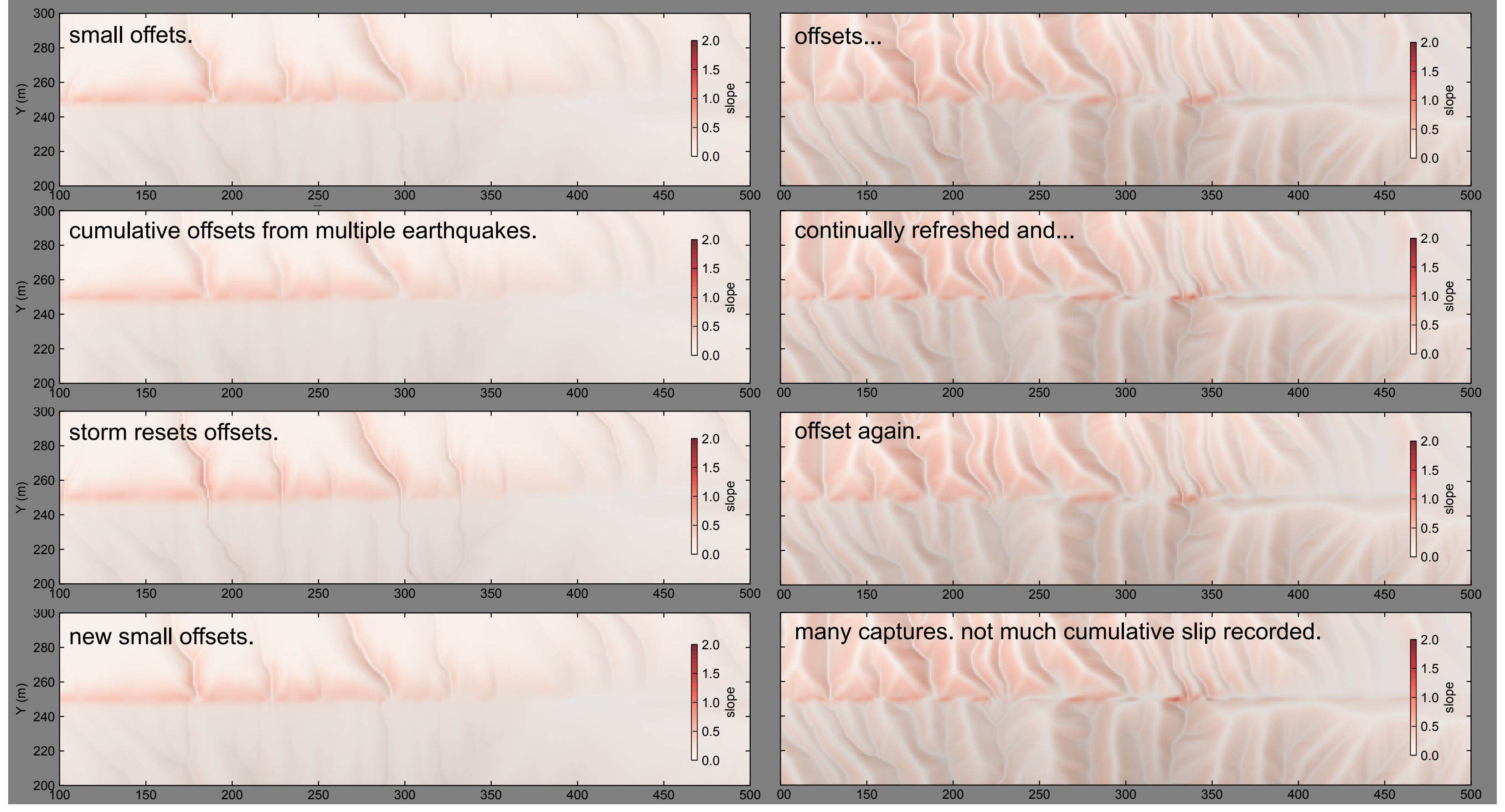


Incision Events (Storms)

When storms are more frequent than earthquakes, some offset channels should record slip from the most recent earthquake. When storms are less frequent than earthquakes, offset channels should record cumulative slip from multiple earthquakes, depending on storm and earthquake frequency.

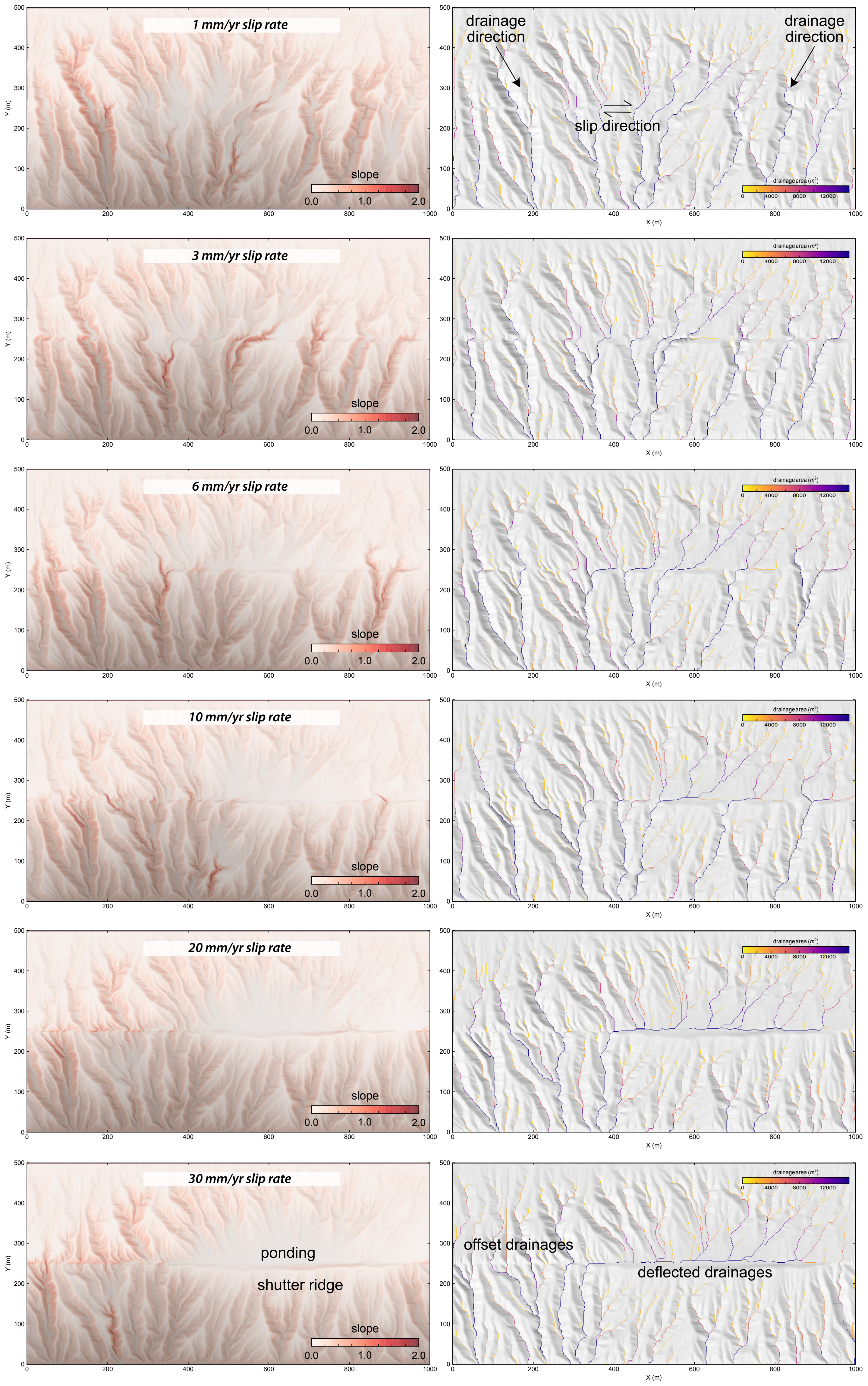
storms less frequent than earthquakes
500-year storms; 200-year earthquakes

storms more frequent than earthquakes
100-year storms; 200-year earthquakes



Slip Rate, Initial Topography, Drainage Direction

Output from the final timestep of simulations with 10 kya run time and 1-30 mm/yr slip rates, for 10-300 m total accumulated slip. The influence of the intial topography and drainage direction is evident in the shutter ridge that develops with the faster slip rates and a few apparent left-lateral offsets.



The San Andreas Fault south of the Bidart Fan. A shutter ridge somewhat similar to the 30 mm/yr numerical simulation. Both illustrate how the deflected and ponding drainages affect the upstream landscape and can make it difficult to interpret cumulative slip.

Observations & Conclusions

Initial topography and drainage direction relative to slip direction have a large effect on the appearance of offset channels and how the strike-slip landscape forms in multiple earthquakes.

As slip accumulates, the difference between deflection and cumulative offset becomes increasingly hard to distinguish.

Erosion rate relative to slip rate should be considered when interpreting a strike-slip landscape.

With support from:

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