Earth Science Applications of Space Based Geodesy

DES-7355

Tu-Th 9:40-11:05

Seminar Room in 3892 Central Ave. (Long building)

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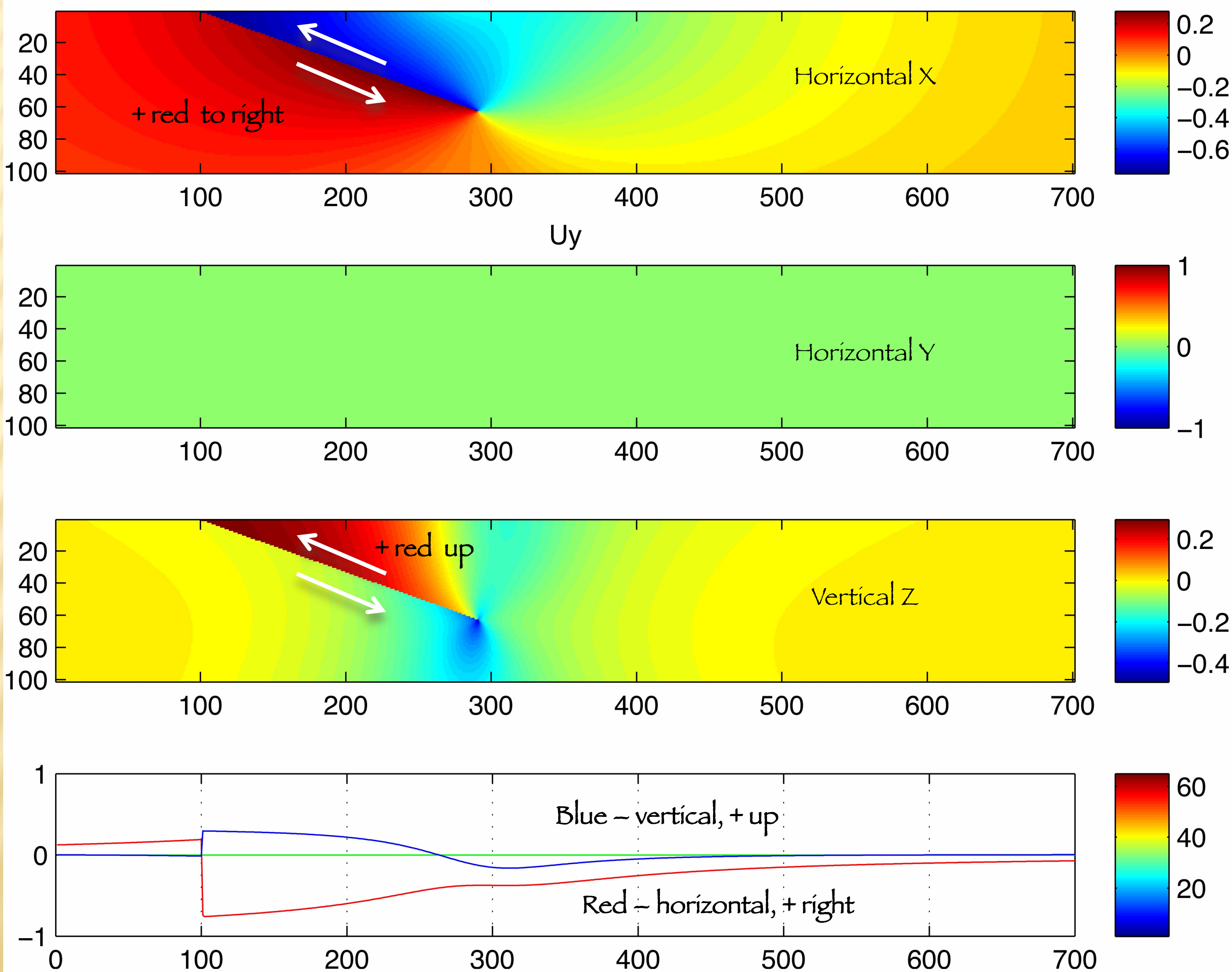
http://www.ceri.memphis.edu/people/smalley/ESCI7355/ESCI_7355_Applications_of_Space_Based_Geodesy.html

Class 21

Interplate thrust faulting.

Co-seismic

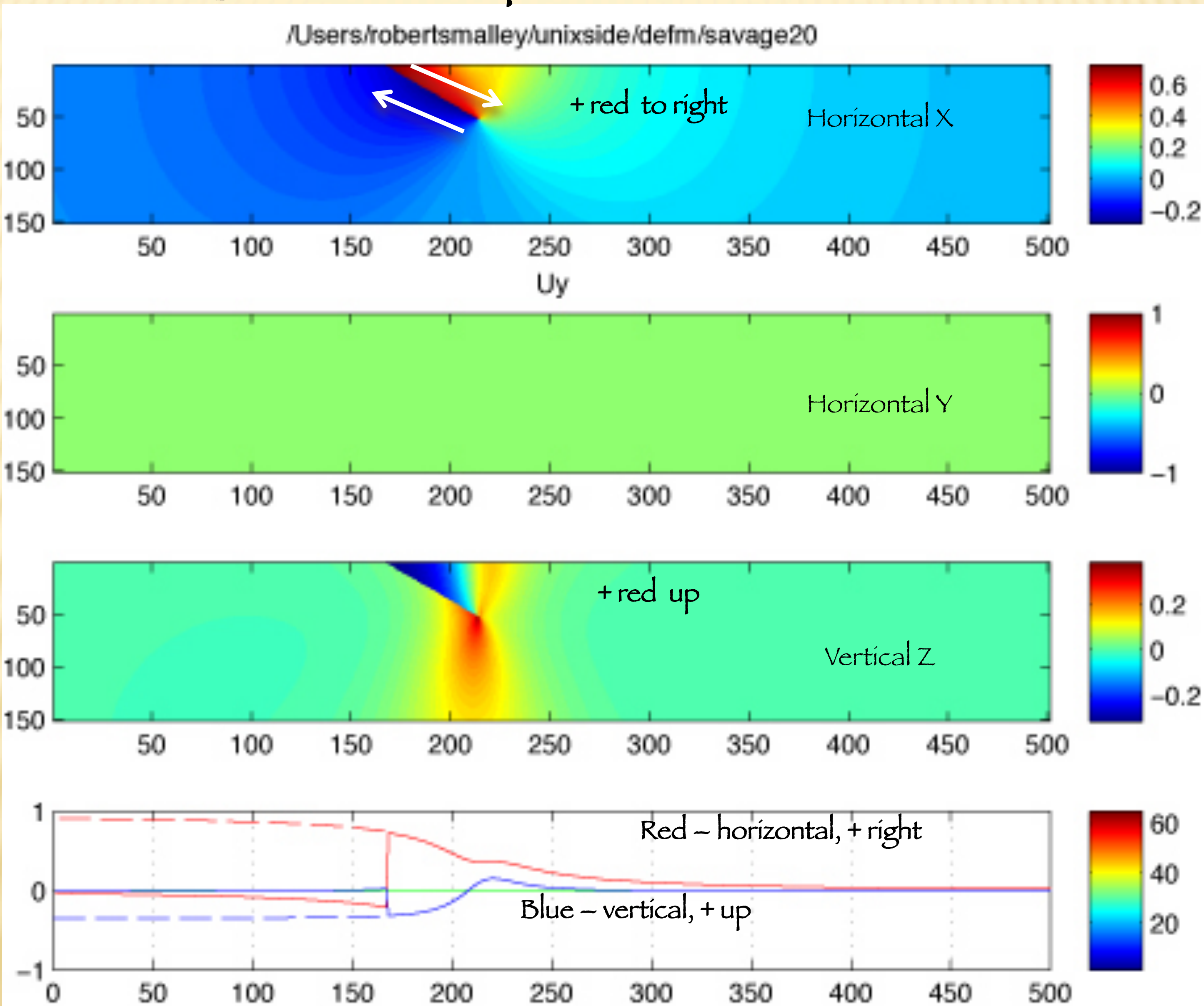
Co-seismic, no tectonics



Interplate interseismic.

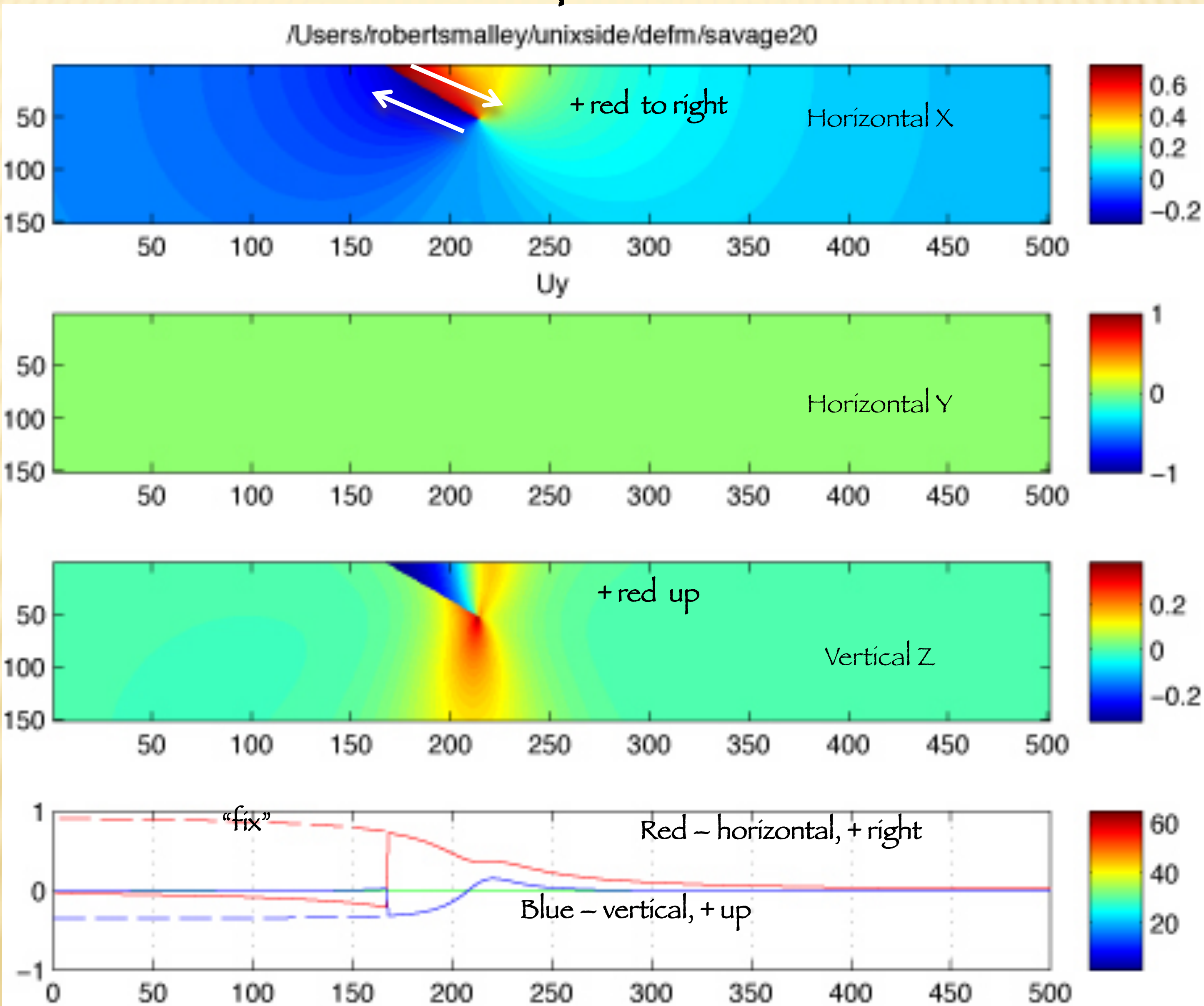
Two ways

Savage back-slip model for interseismic



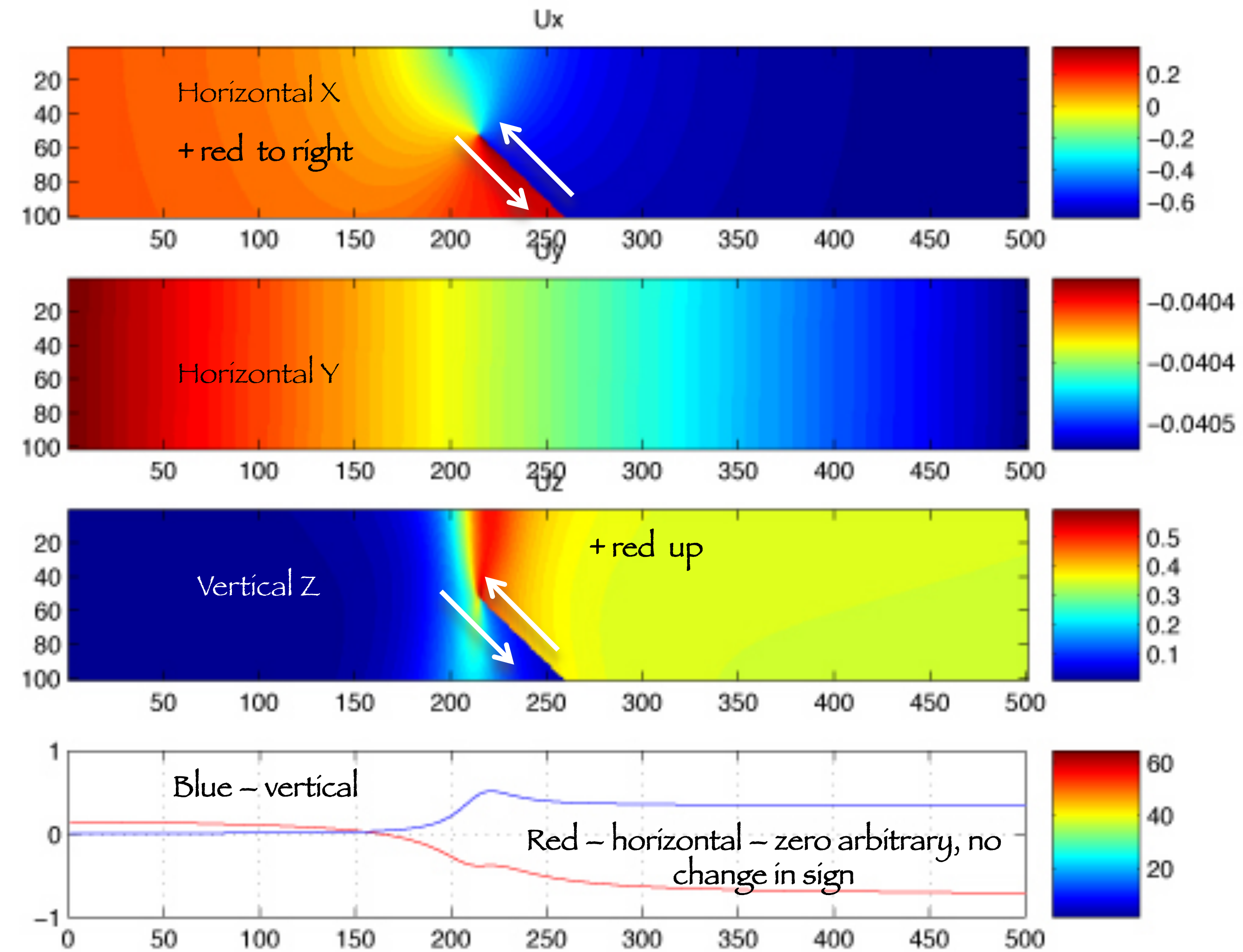
Tectonic + Elastic perturbation

Run the earthquake "backwards"

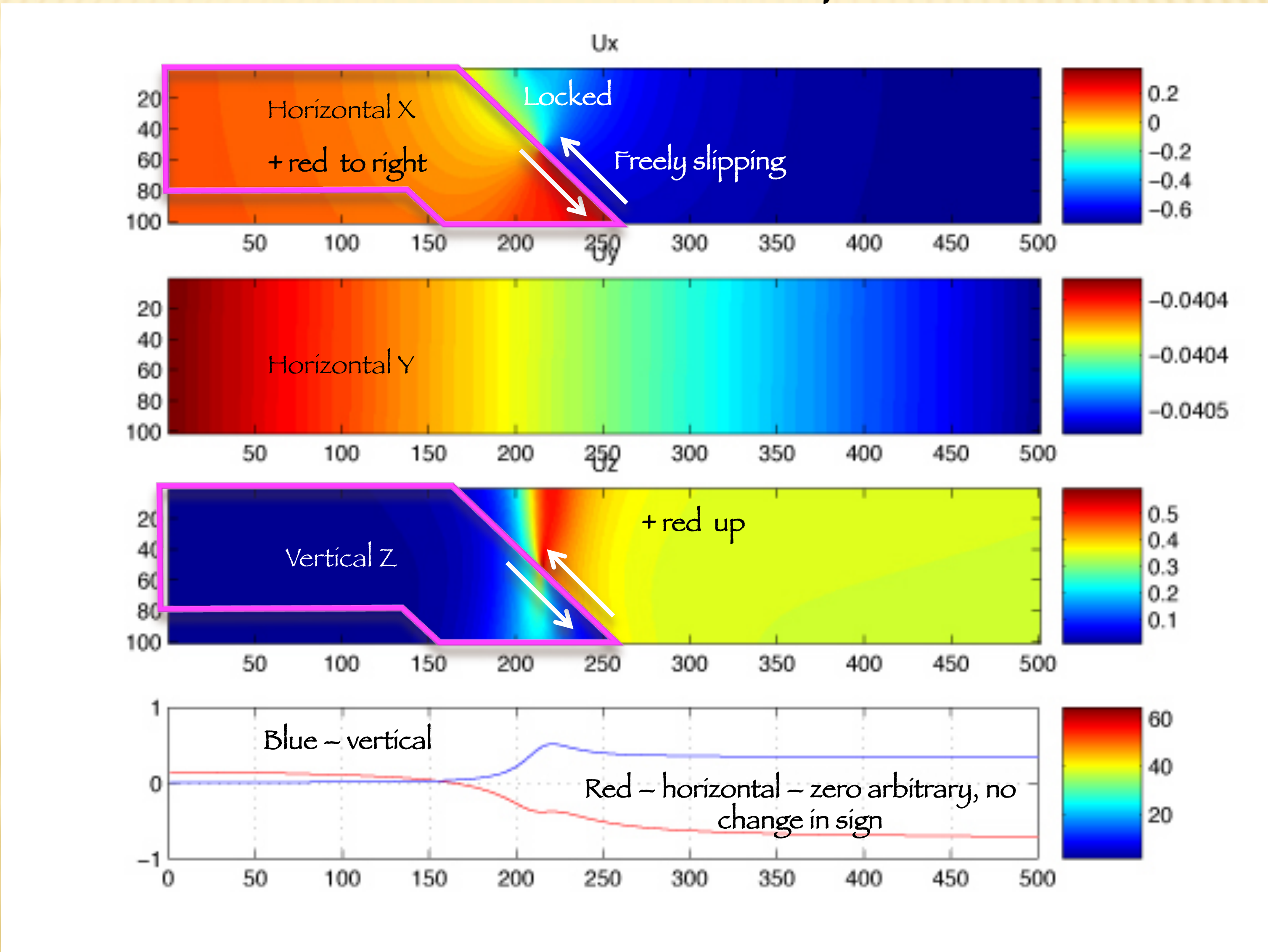


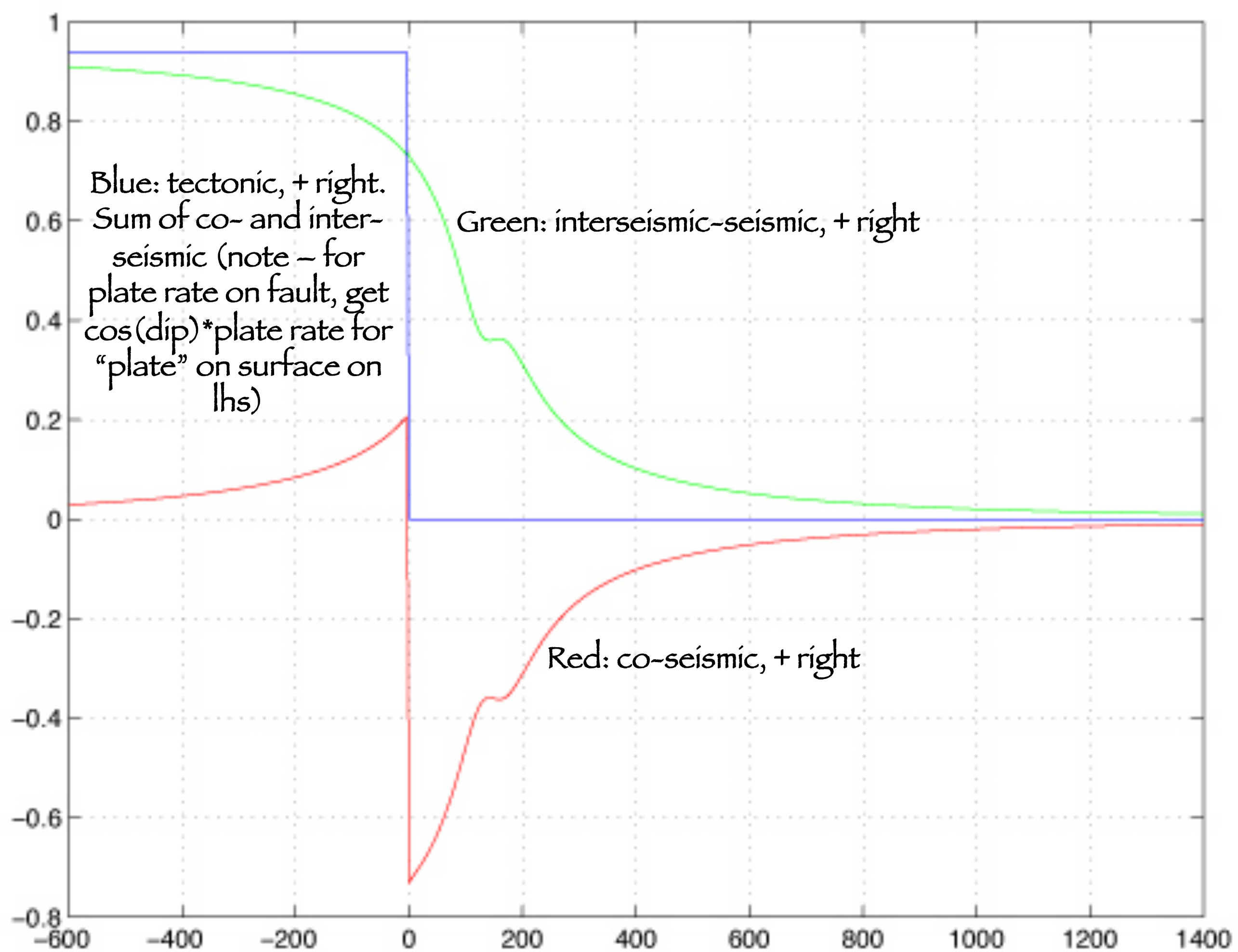
Tectonic + Elastic perturbation (works for horizontal, not vertical)

Down-dip slip model for interseismic (does not have name)

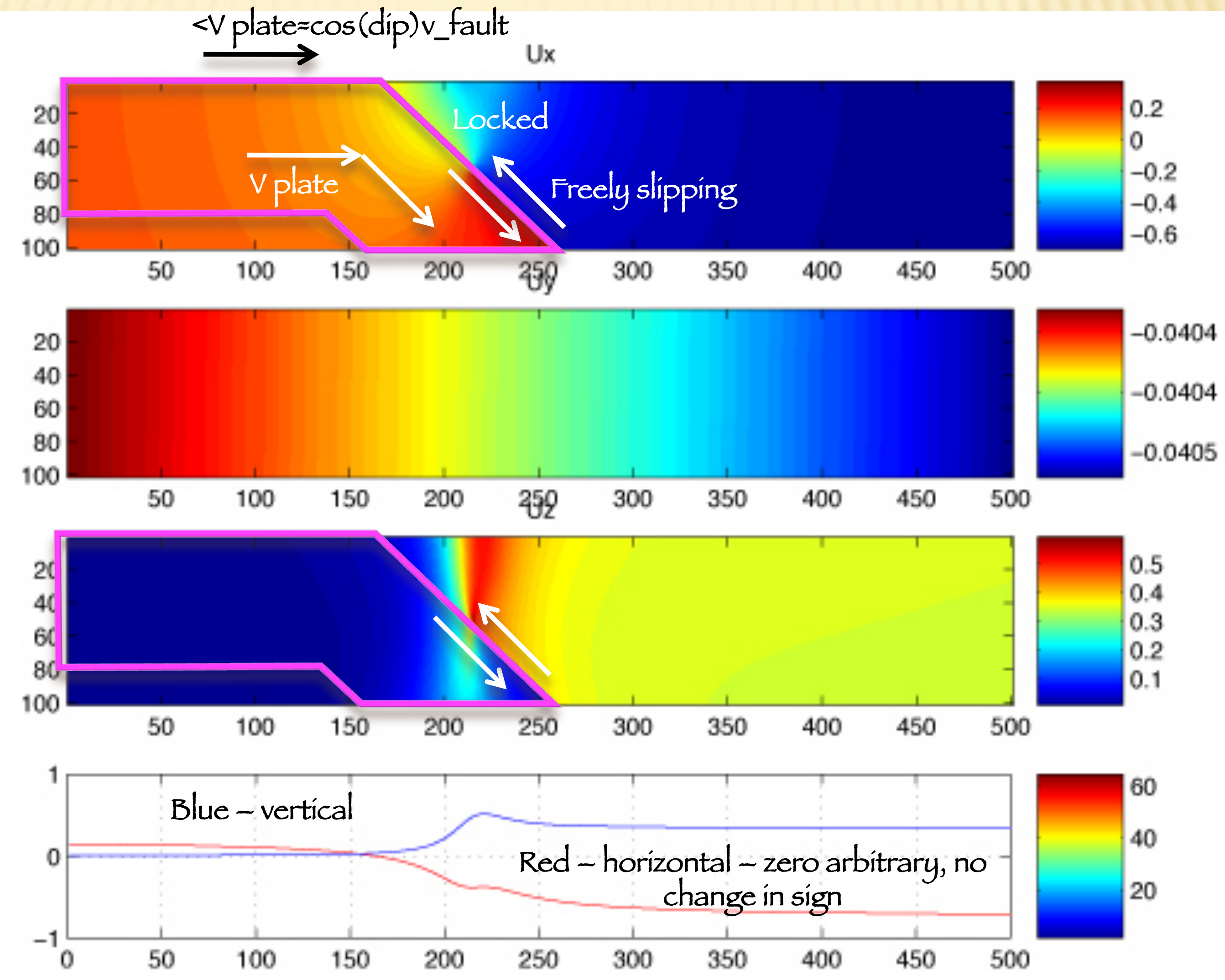


Down-dip slip model for interseismic (based on idea of subducting plate continuing)

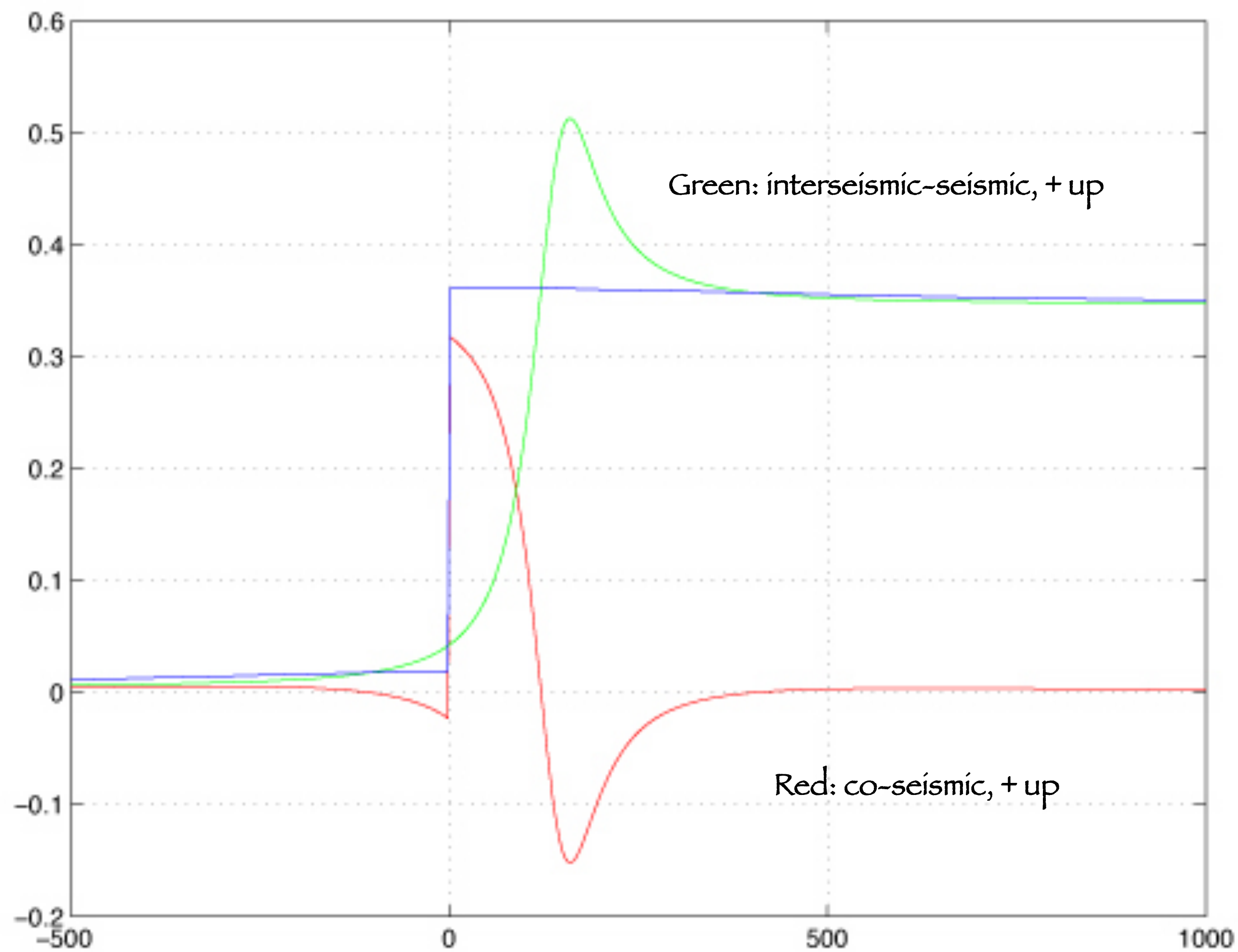



Blue: tectonic, + right. Sum of co- and inter-seismic (note – for plate rate on fault, get cos(dip)*plate rate for "plate" on surface on lhs)
Green: interseismic-seismic, + right
Red: co-seismic, + right
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−600
−400
−200
0
200
400
600
800
1000
1200
1400

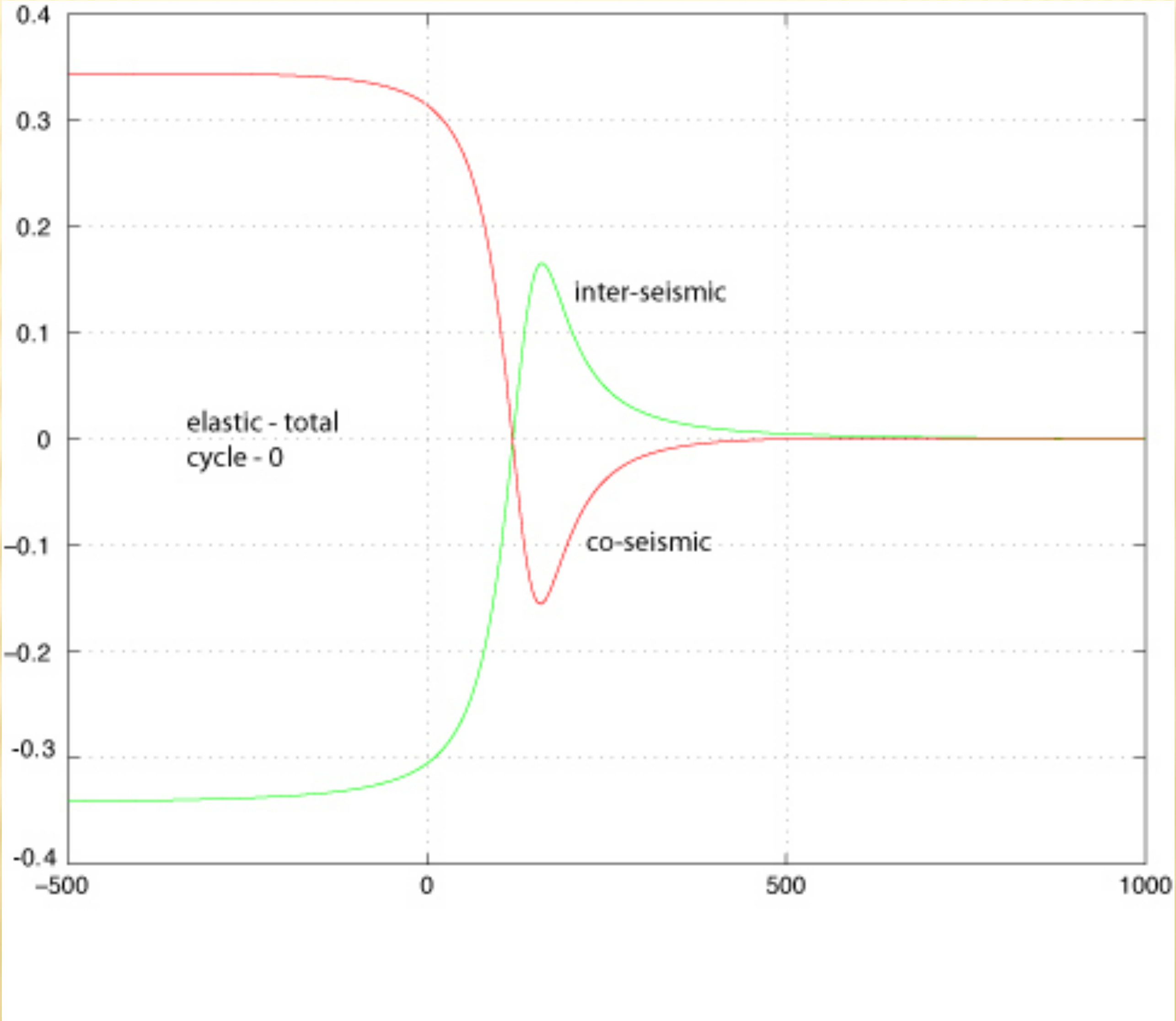
Relative velocity across fault – broken into horizontal and vertical components, so don't get v-plate along surface (the desired physics), get horizontal component.



Vertical – inter-seismic and co-seismic

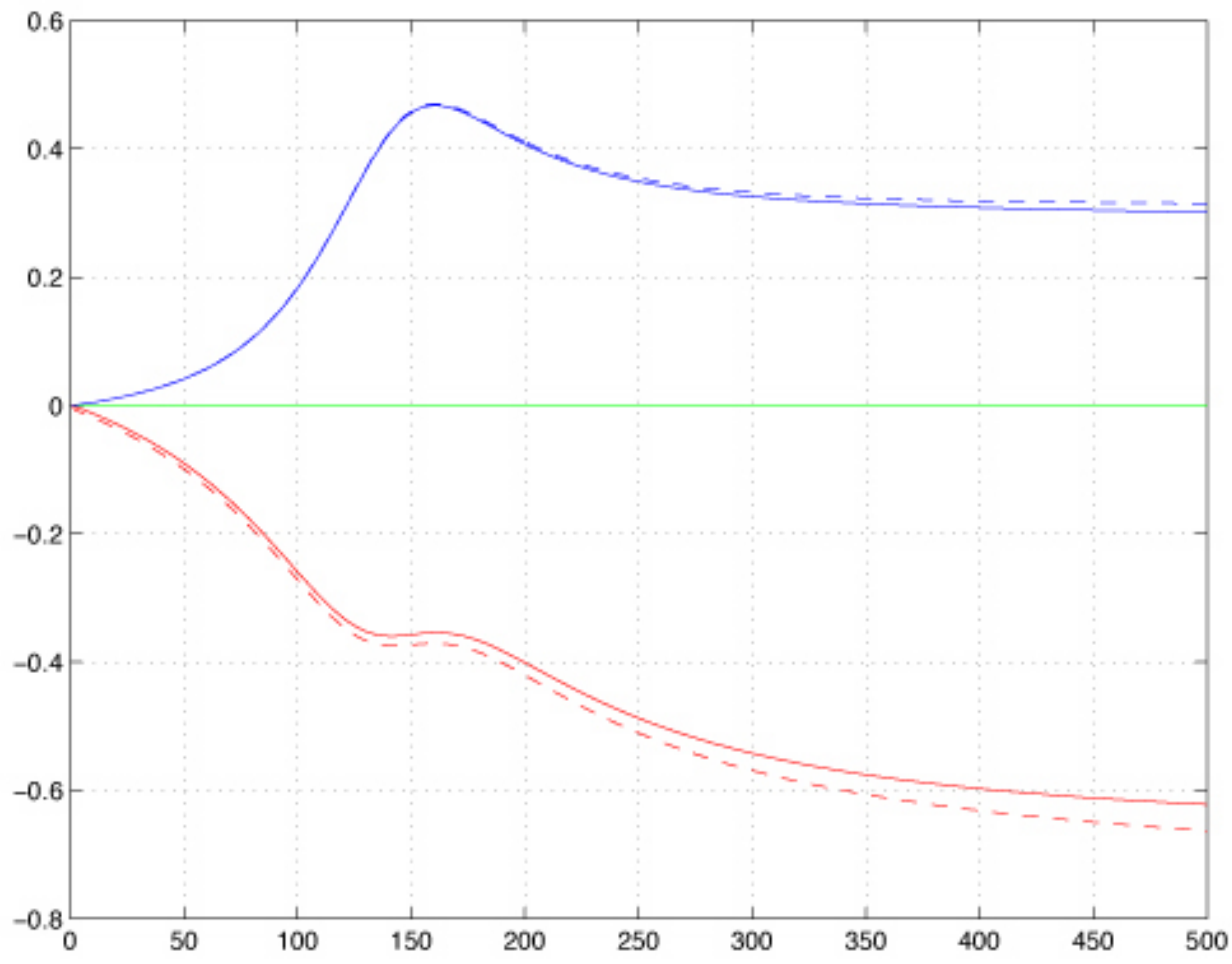


Vertical – inter-seismic and co-seismic, total cycle wrt far field upper plate.

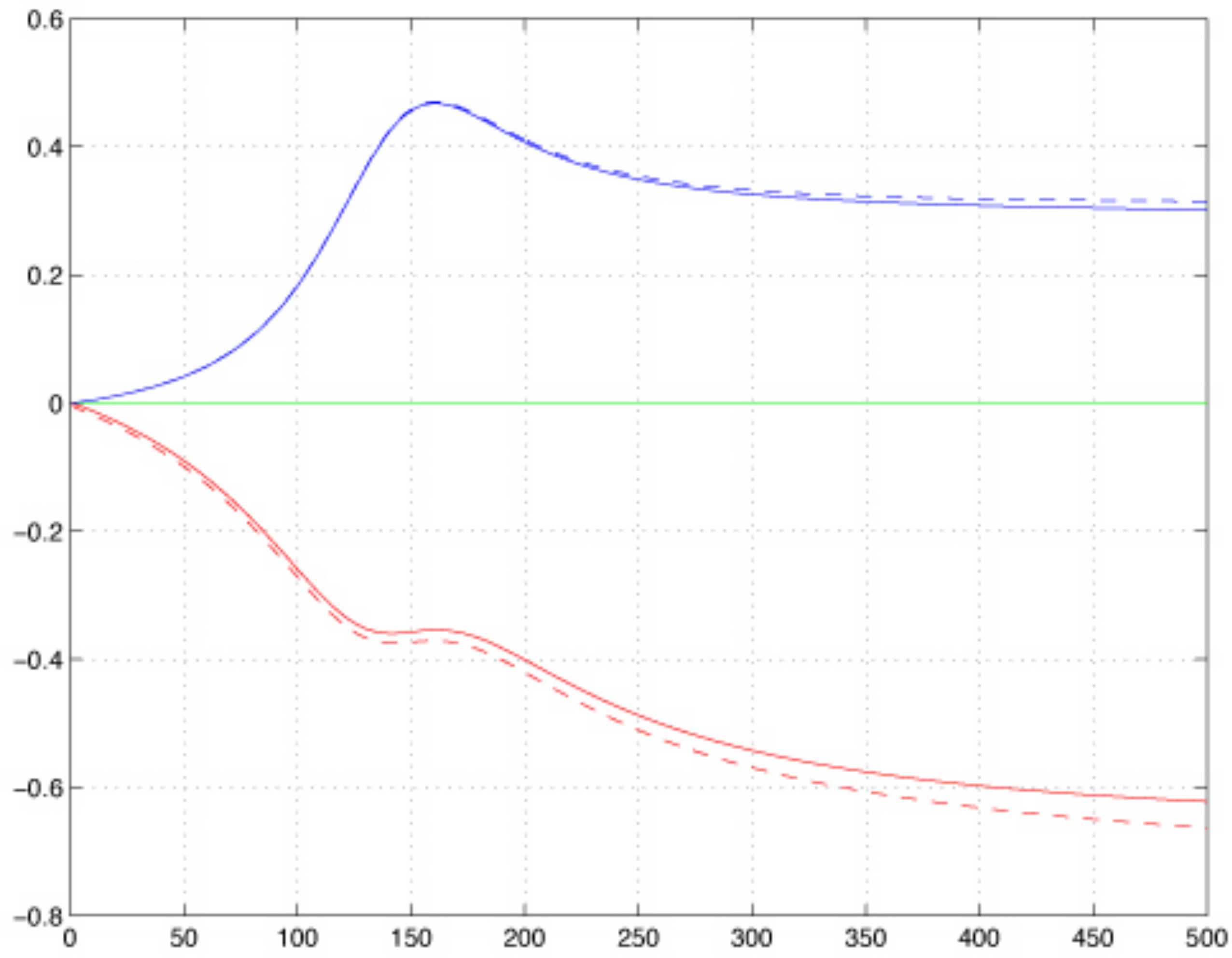


Compare Savage back-slip & down-dip extension model

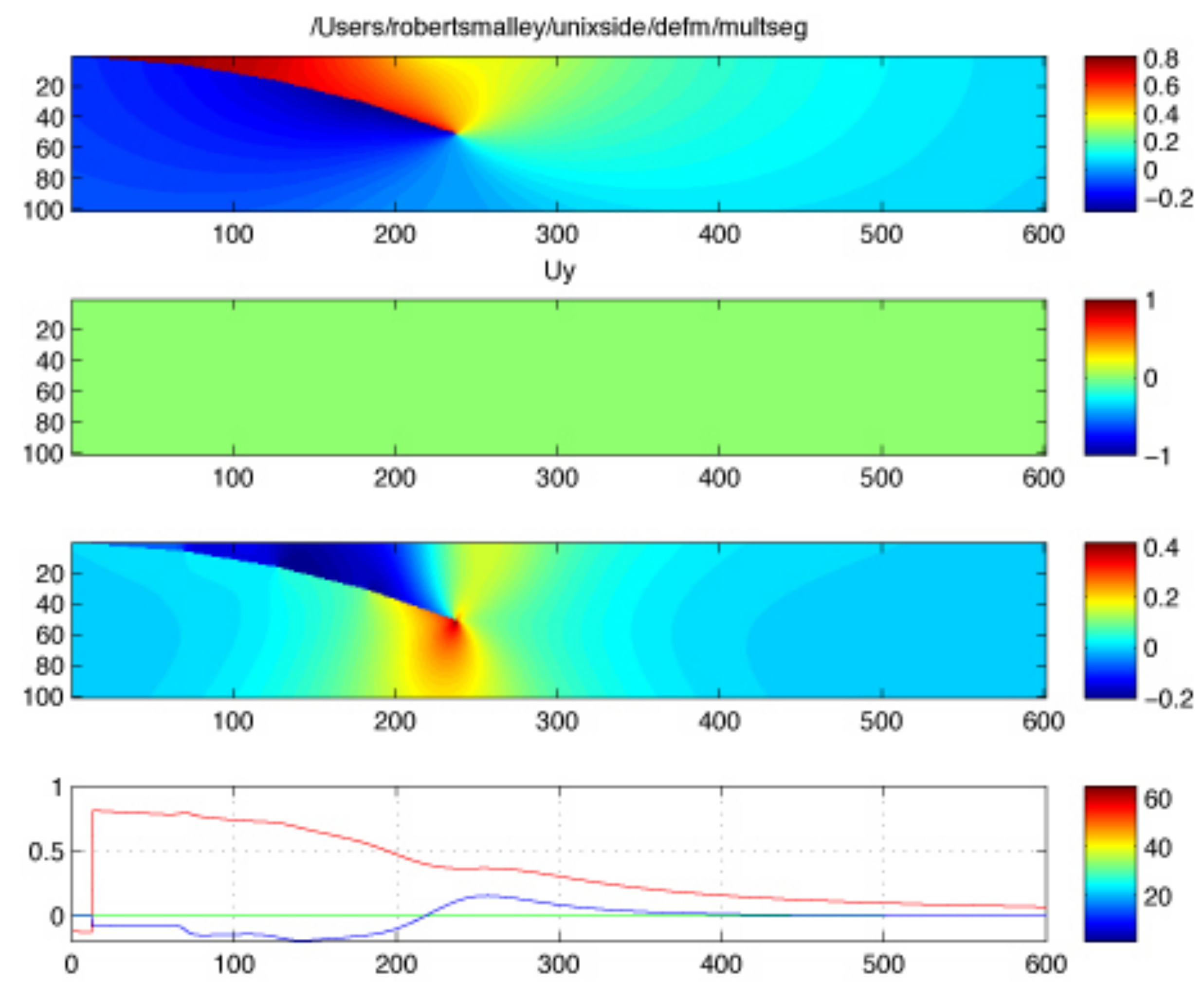
Basically the same



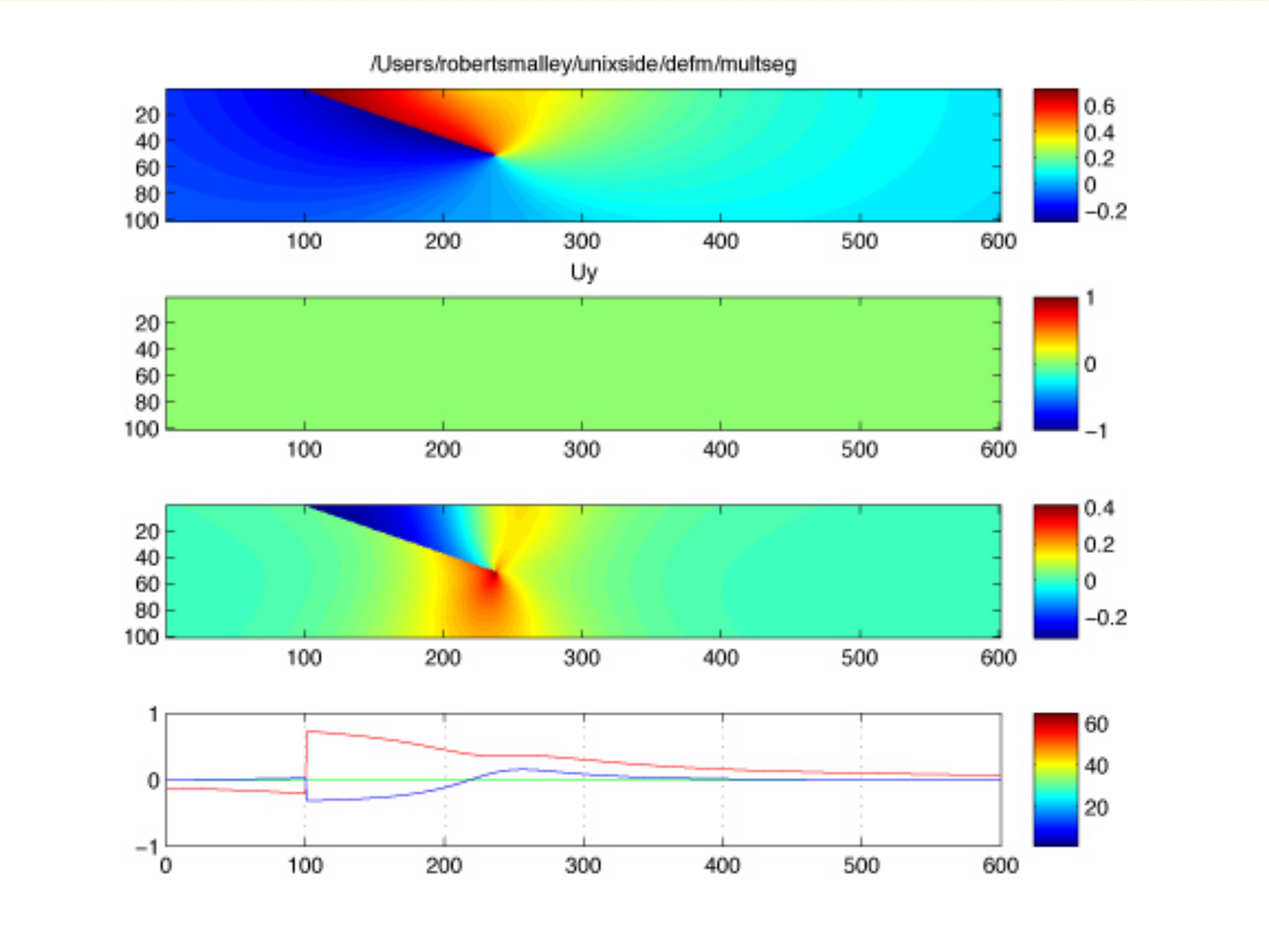
Horizontal has tectonics without "fix" (but at cos of dip angle), but vertical has whole half of medium on hanging wall side going up (at sin of dip angle)



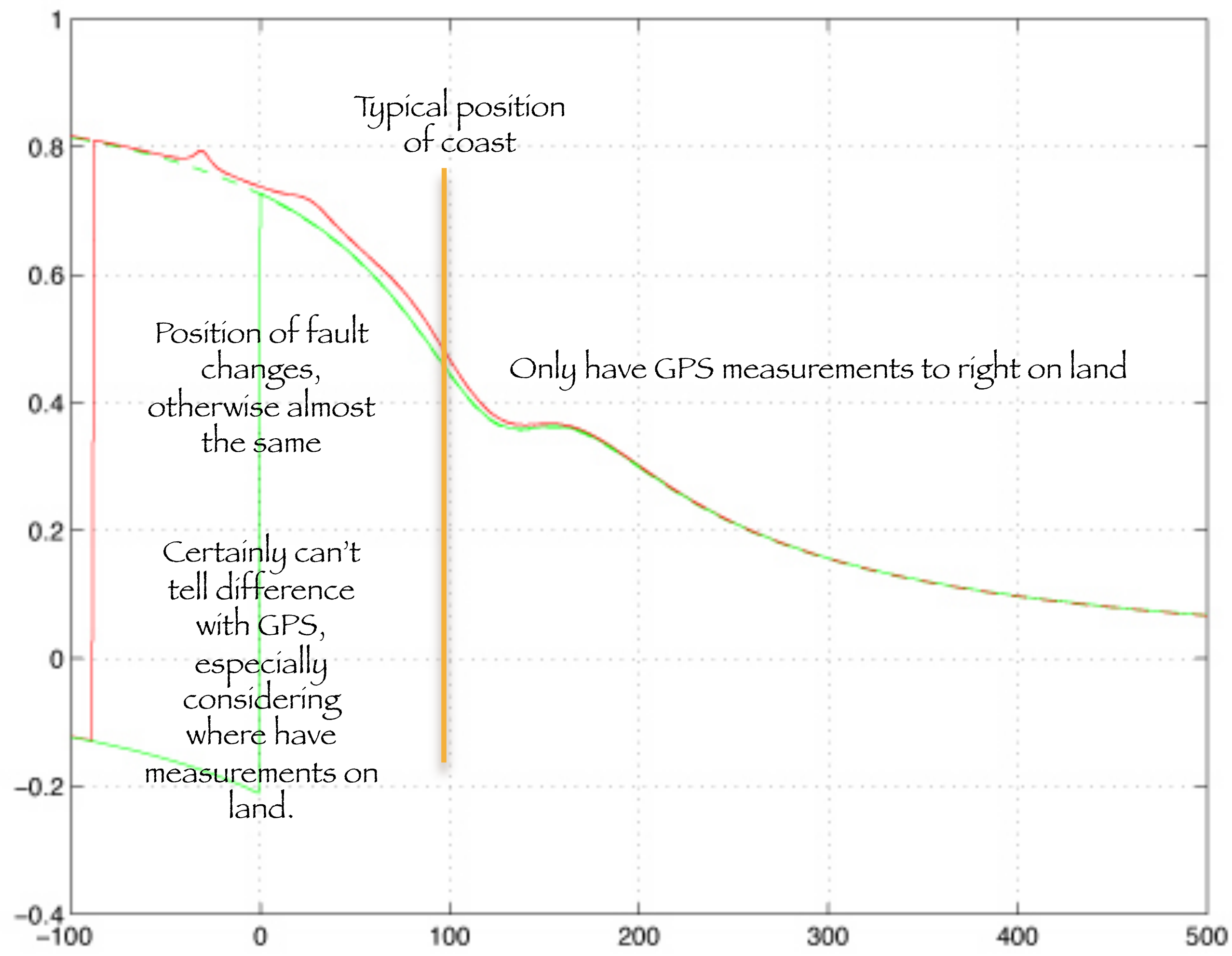
Popular variations – multi-segment interplate interface



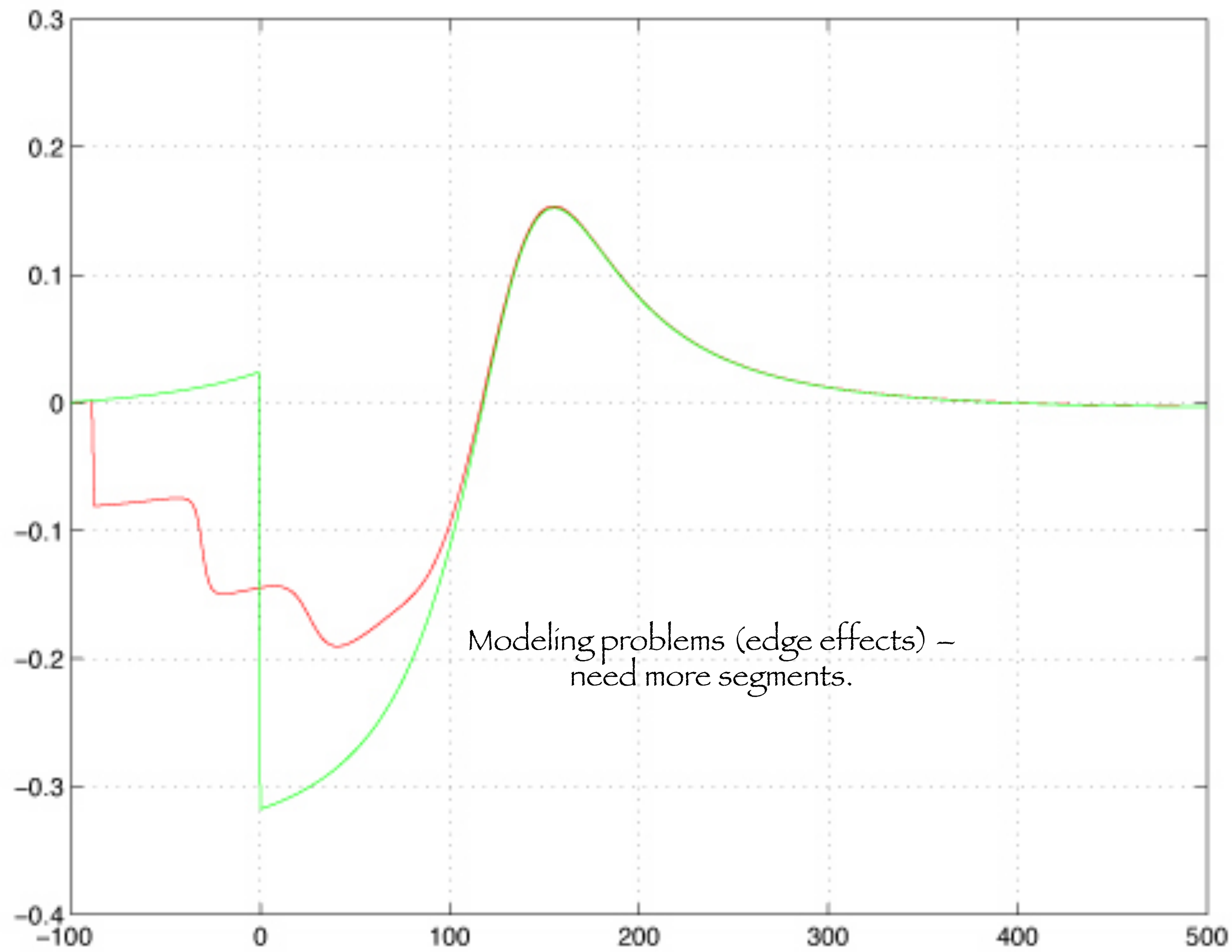
Compare to single-segment interplate interface



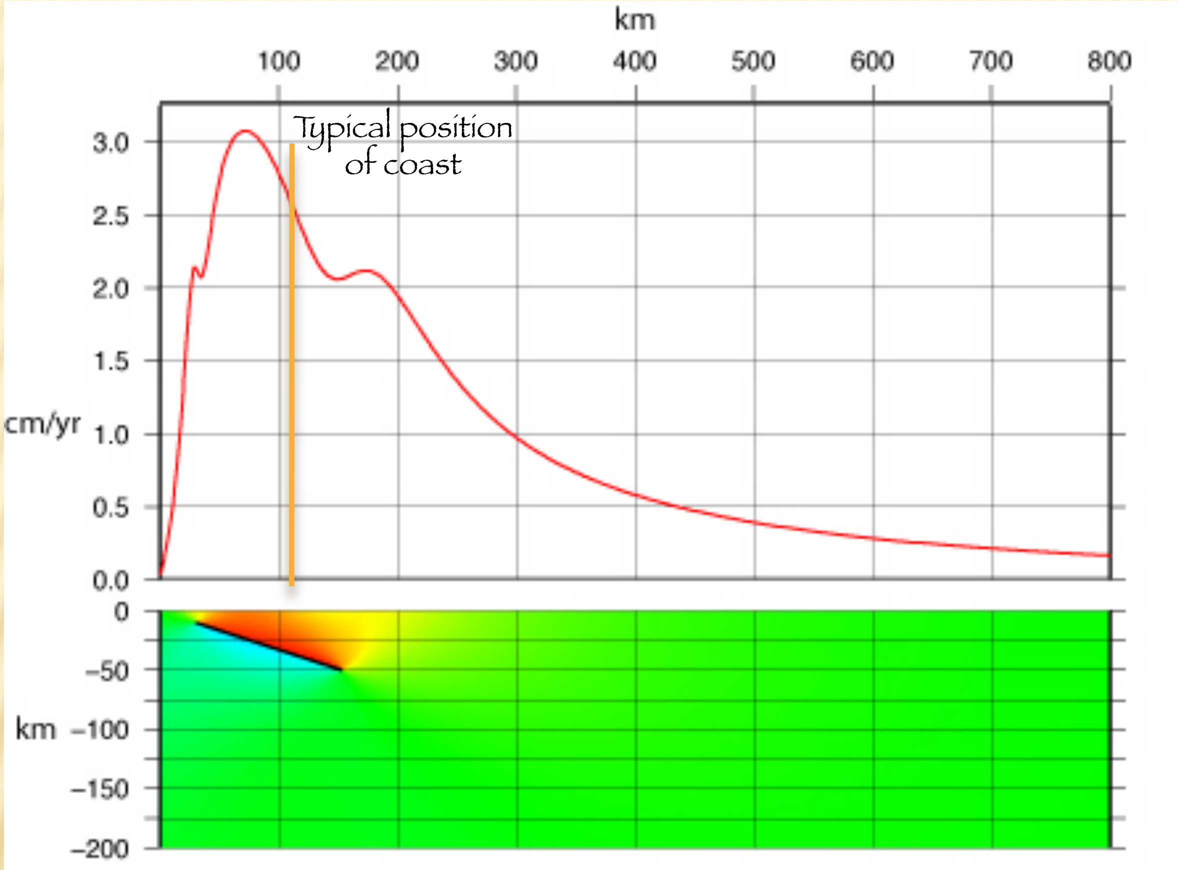
Compare single-, multi-segment horizontal



Compare single-, multi-segment
Vertical

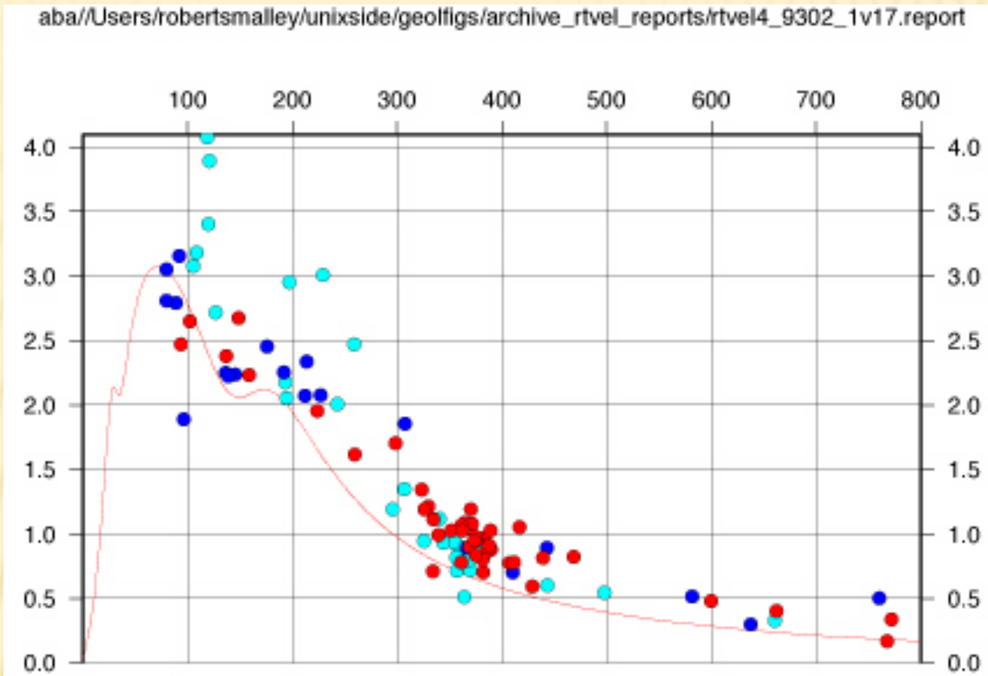


Popular variations – fault does not outcrop (locked at top)

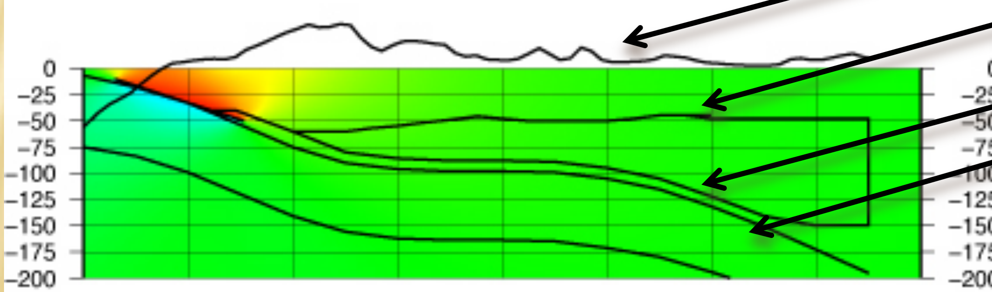


Geology, geophysics modeling support this, geodesy can't see it.

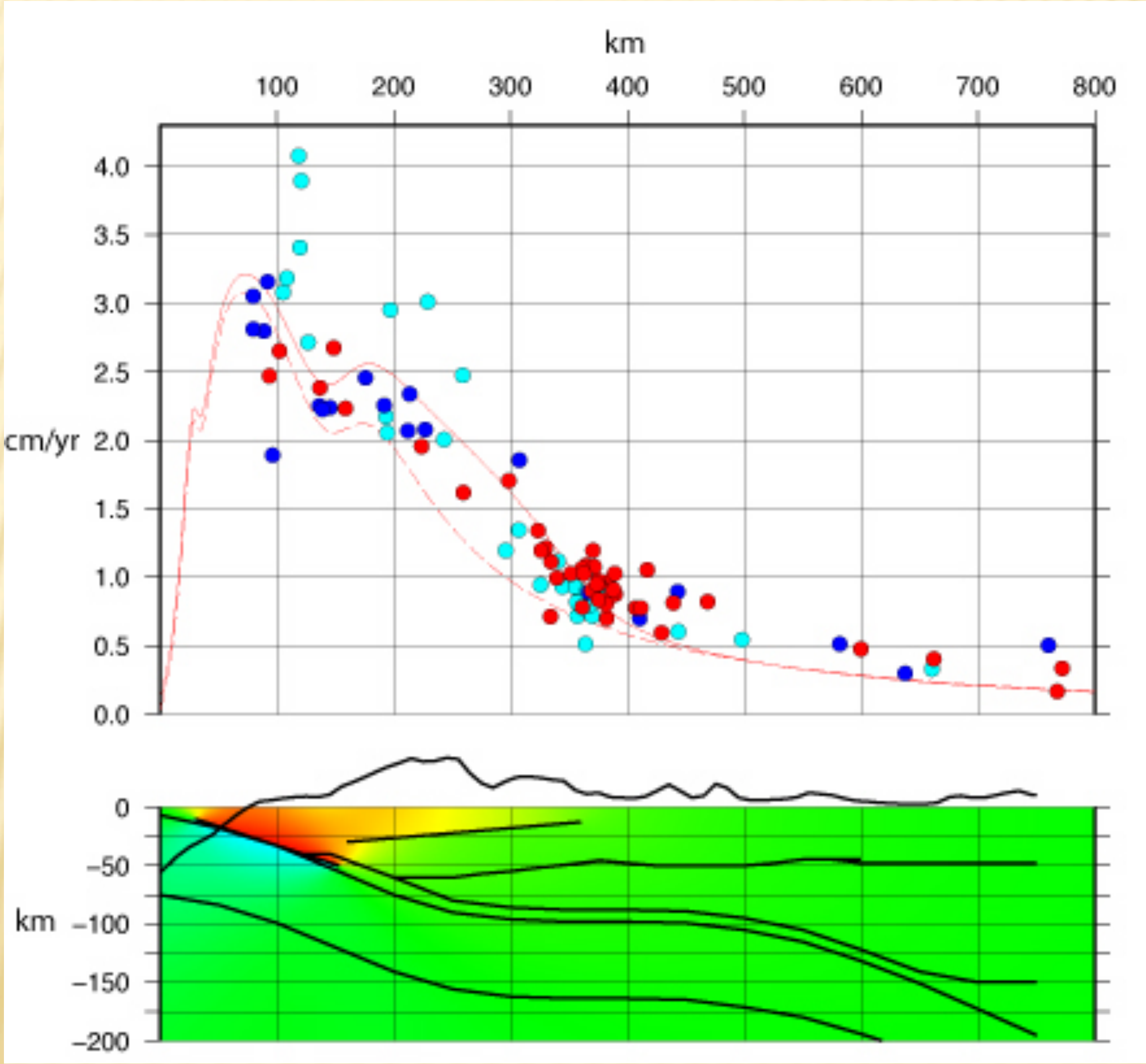
Going overboard



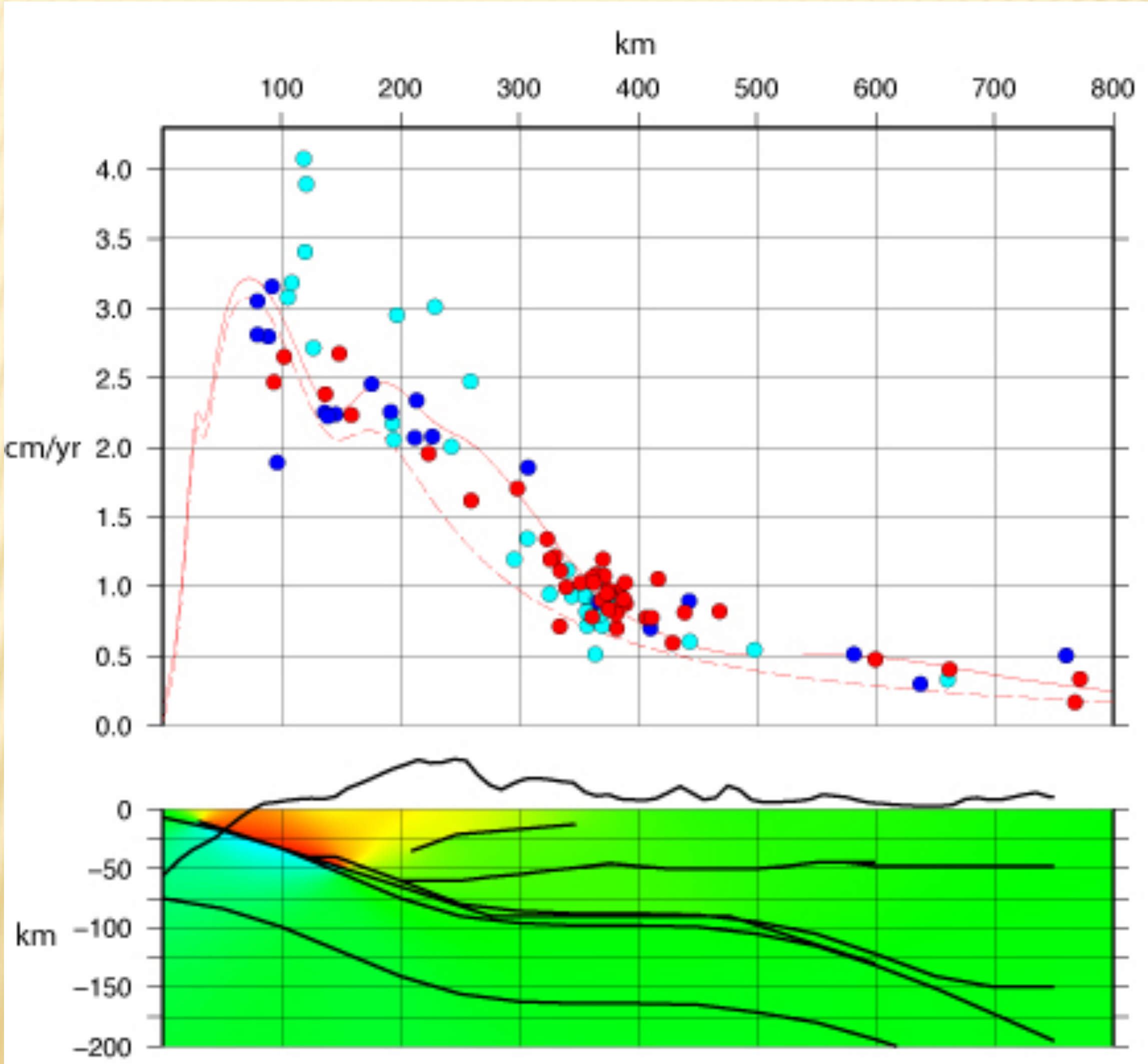
Single locked fault, does not match GPS data in central part of profile.



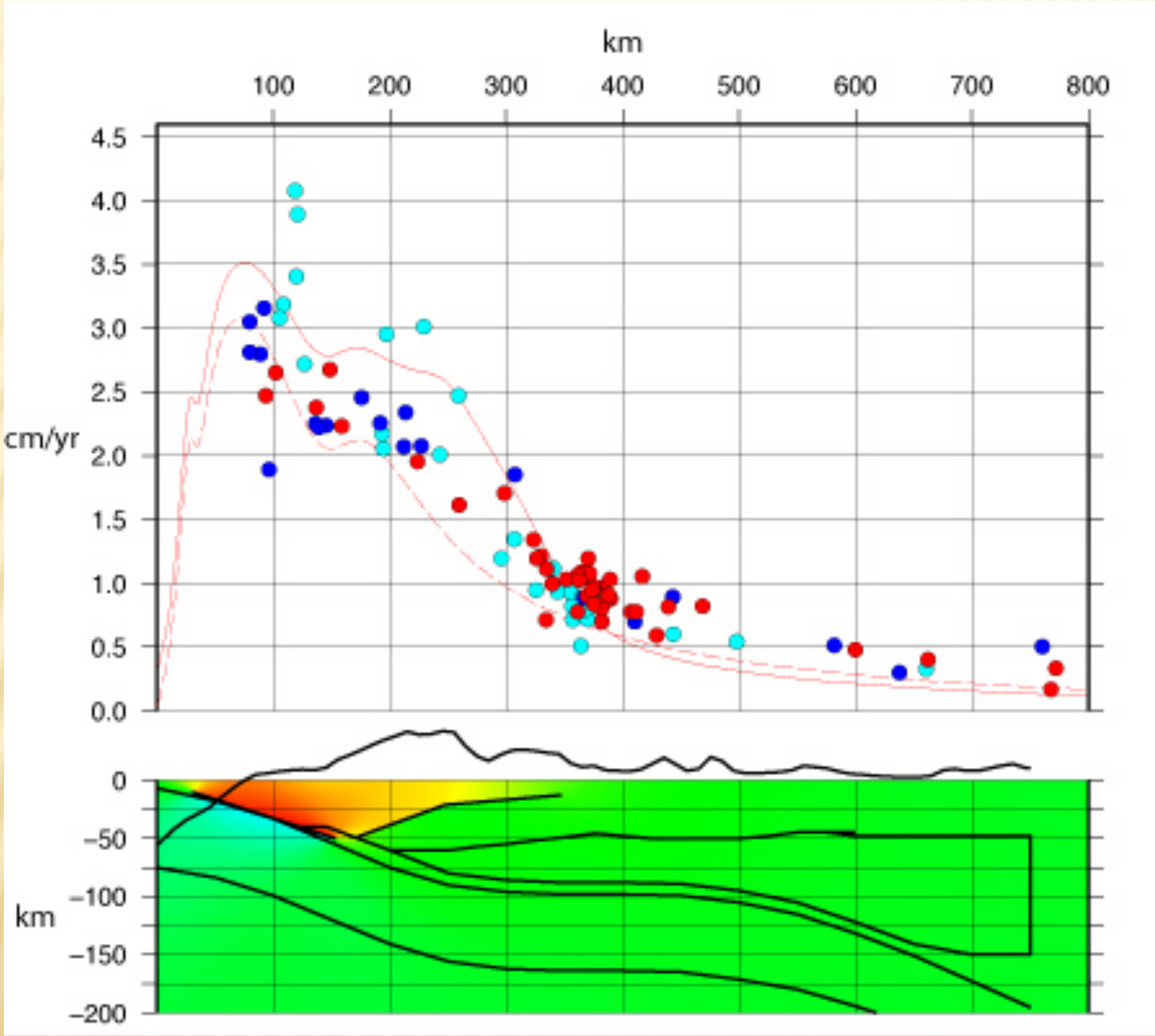
Add friction free fault representing decollement beneath thin-skinned thrust belt.

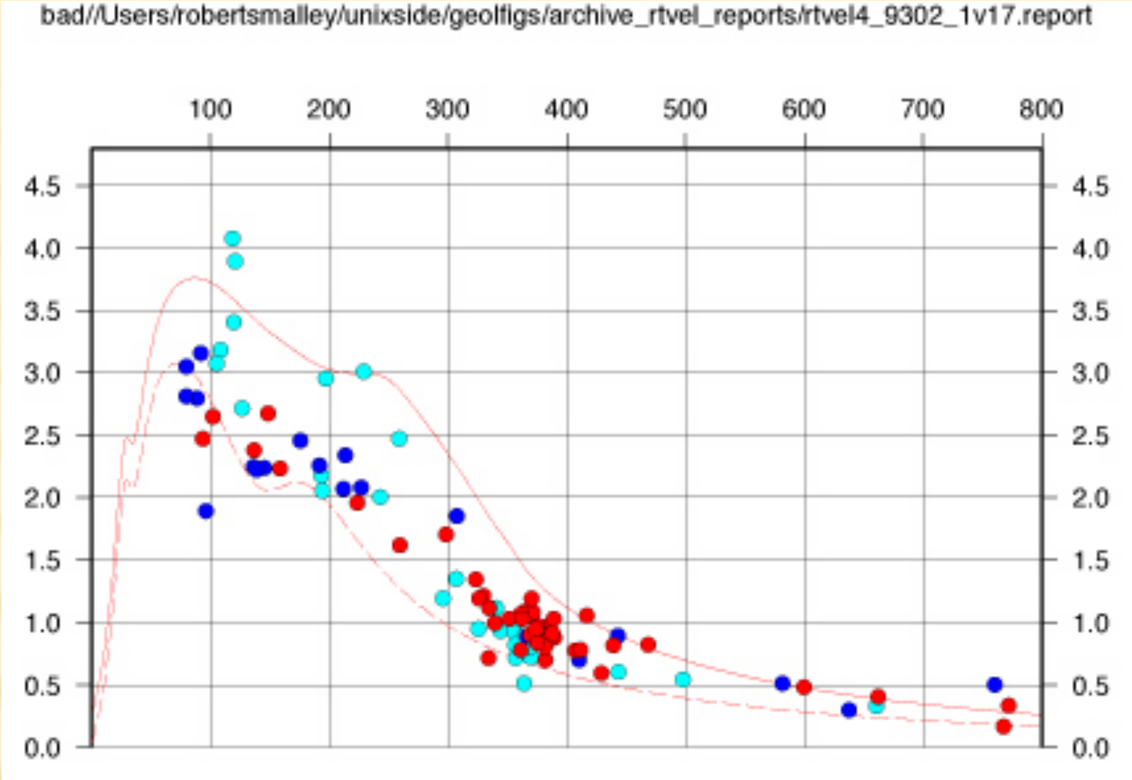


Add friction free fault representing decollement beneath thin-skinned thrust belt and "scoop" below main mountains (the dashed line geologists are wont to draw there).

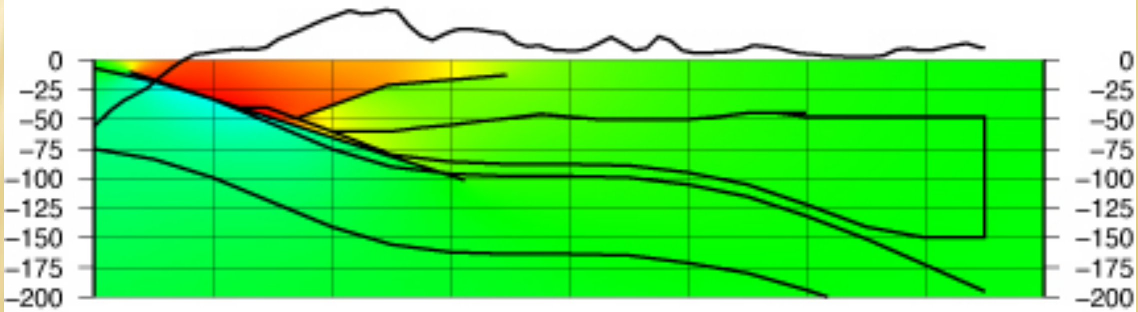


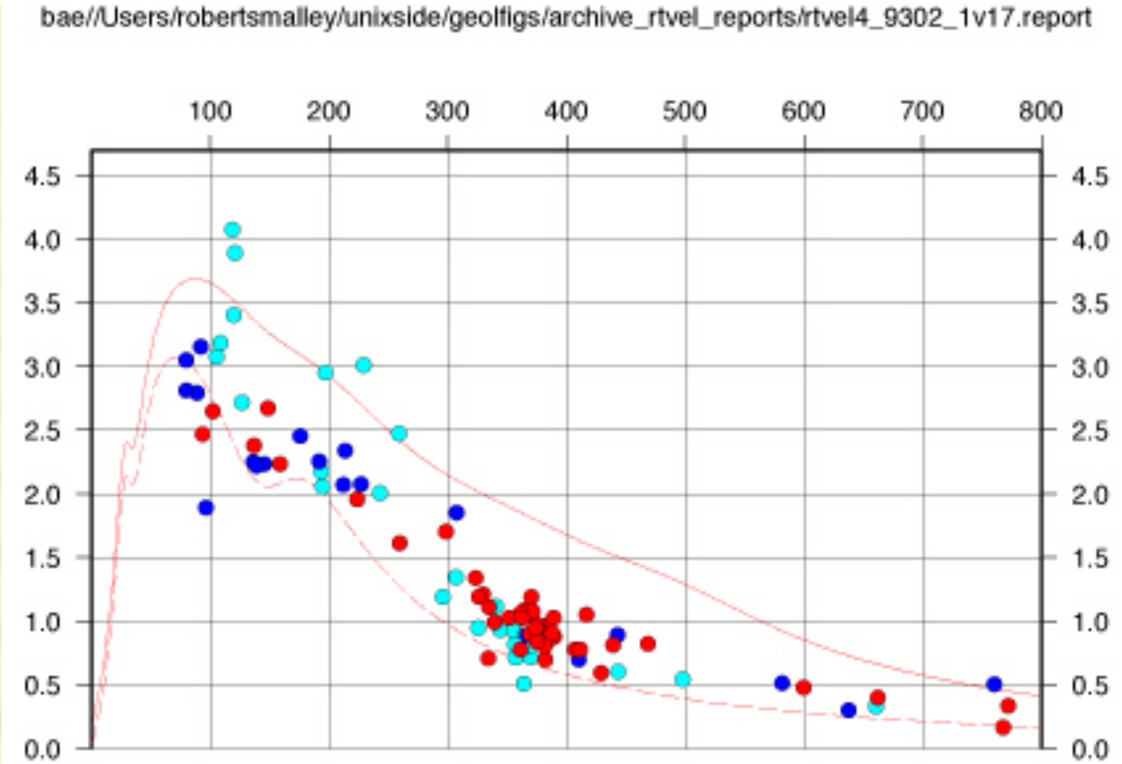
Send "scoop" all the way to the moho/intersection with subducted plate..



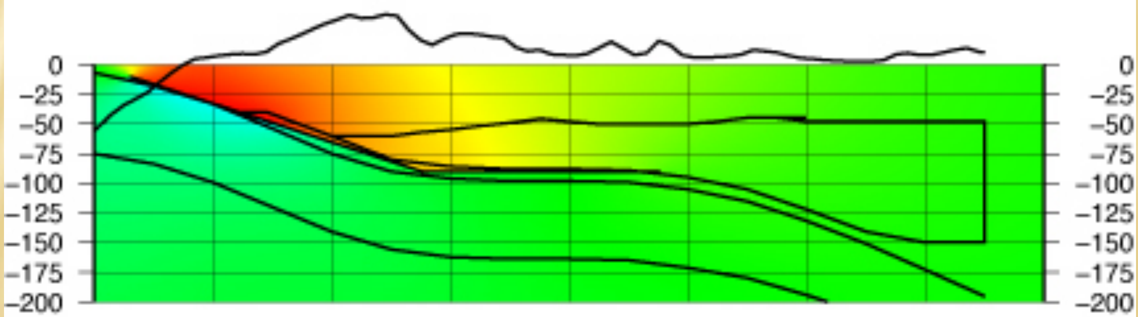


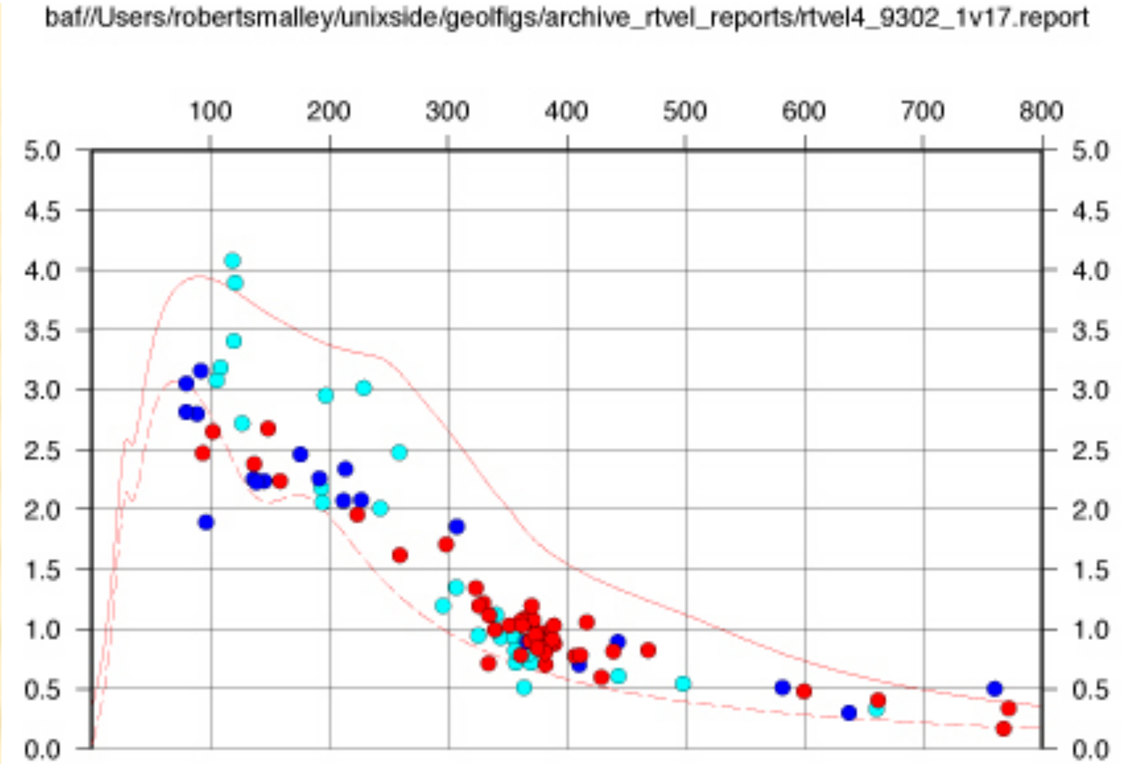
Add friction free extension of plate boundary.



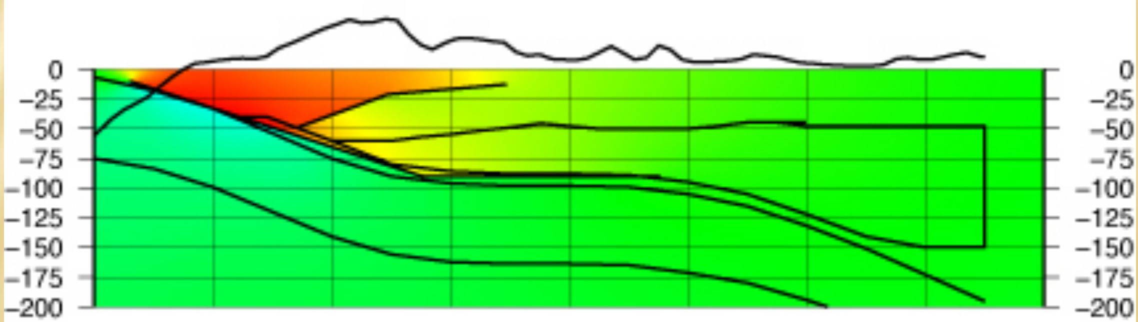


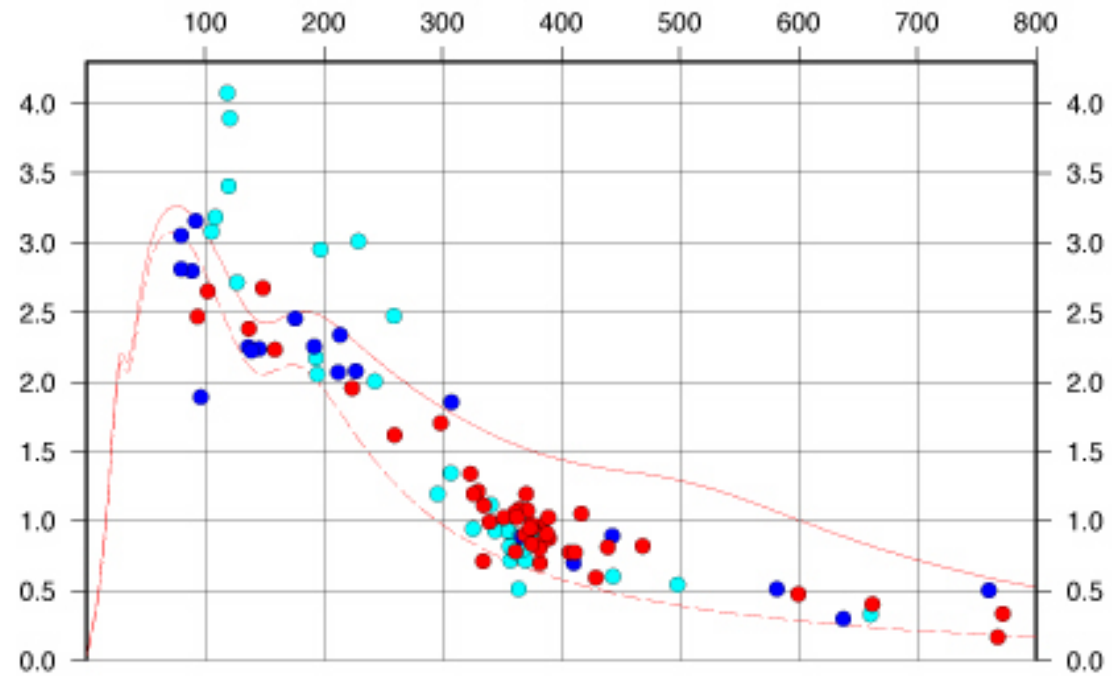
Add friction free extension of plate boundary and friction free base of upper lithosphere, not crustal structures.



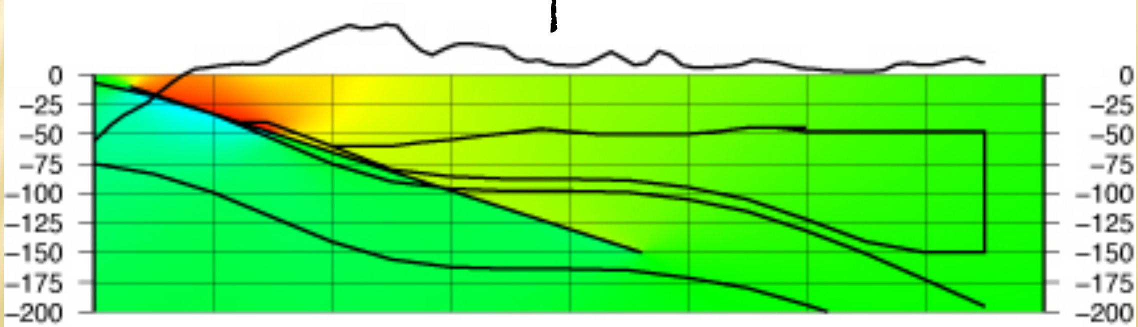


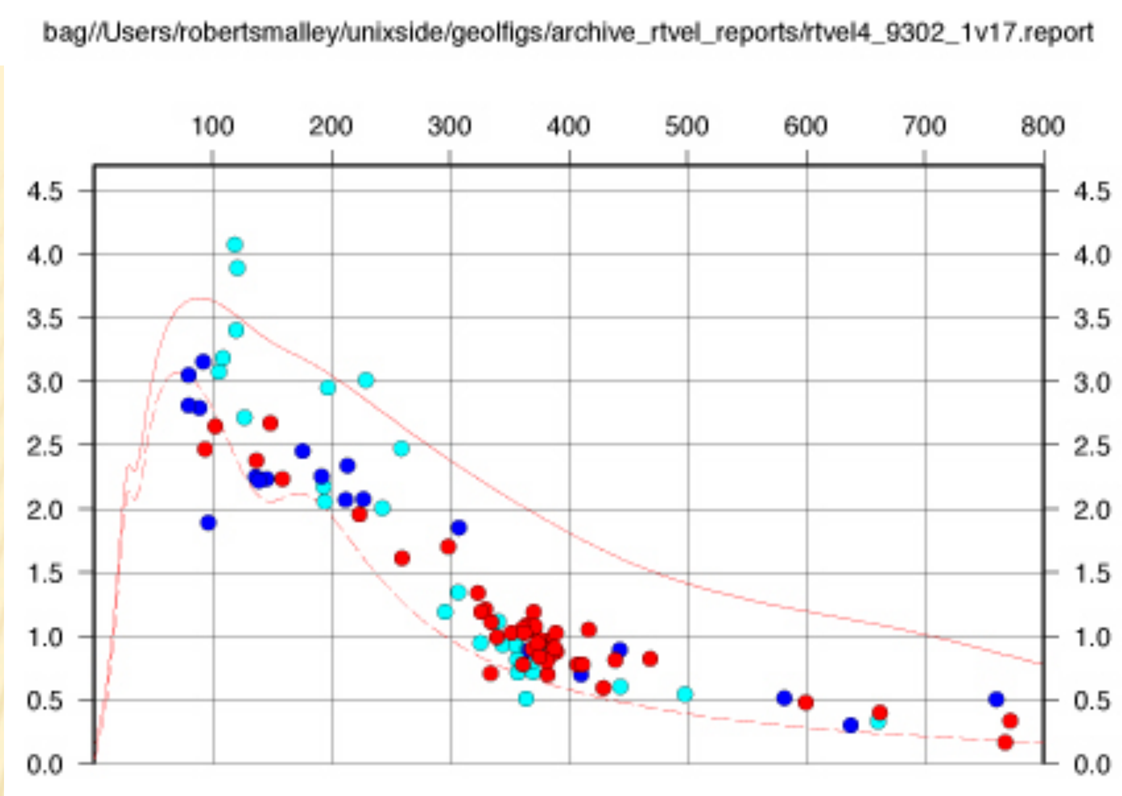
Friction free extension of plate boundary and friction free base of upper lithosphere, with crustal structures.



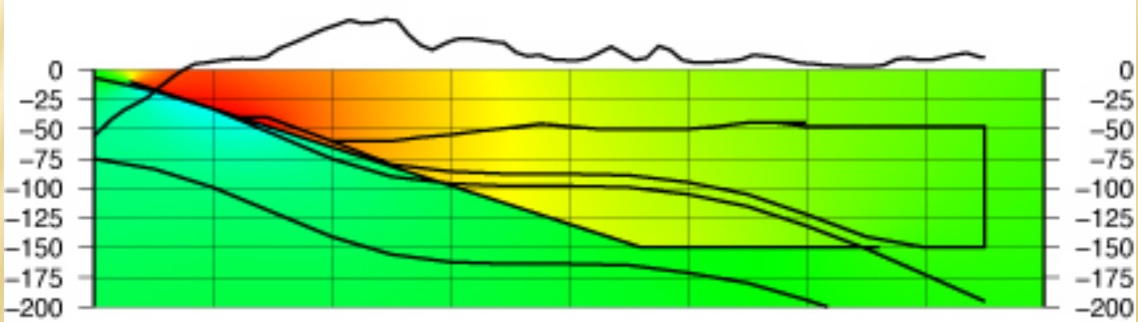


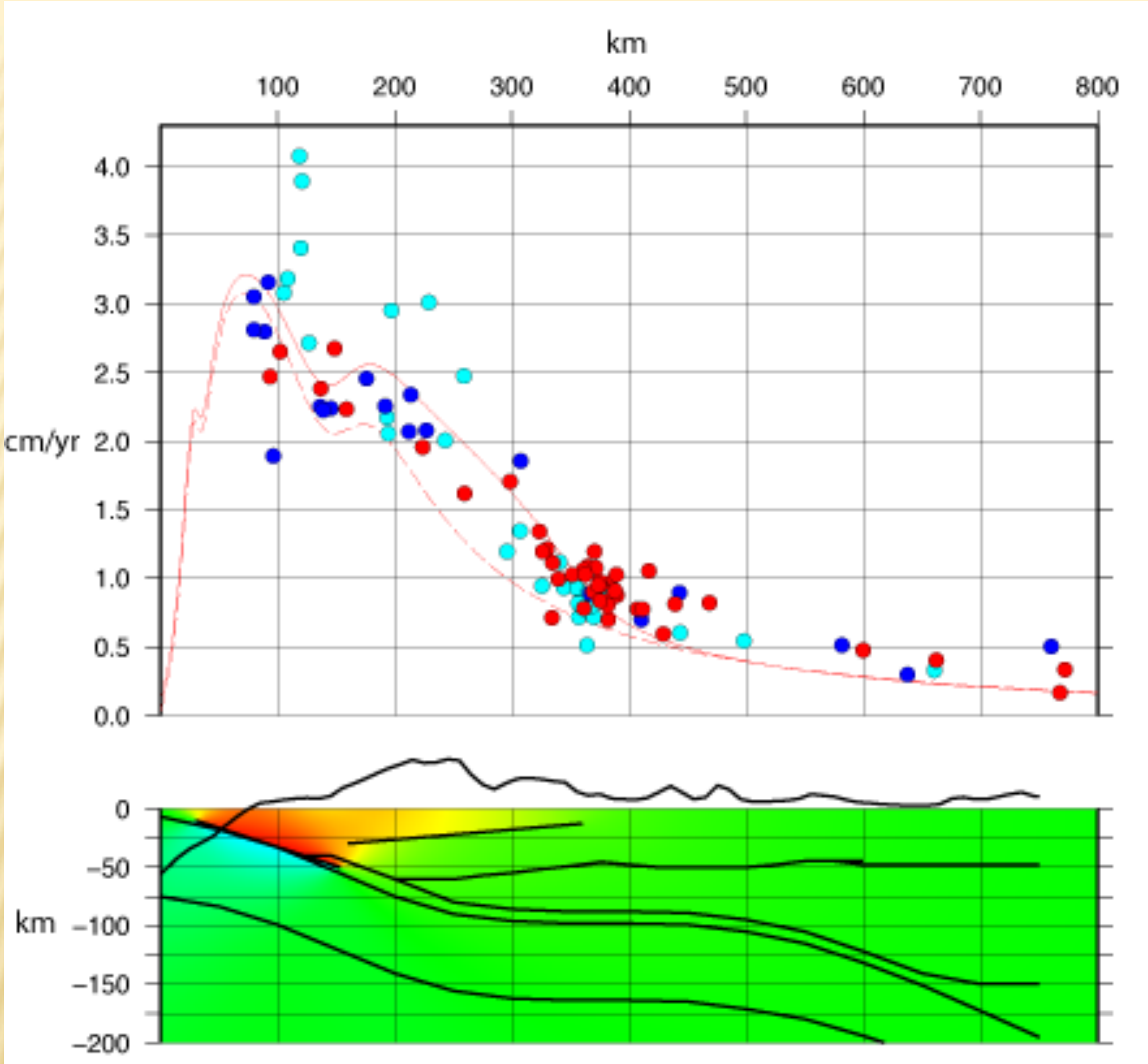
Friction free extension of plate boundary to 150 km depth.





Friction free extension of plate boundary and friction free base of upper lithosphere at 150 km depth.



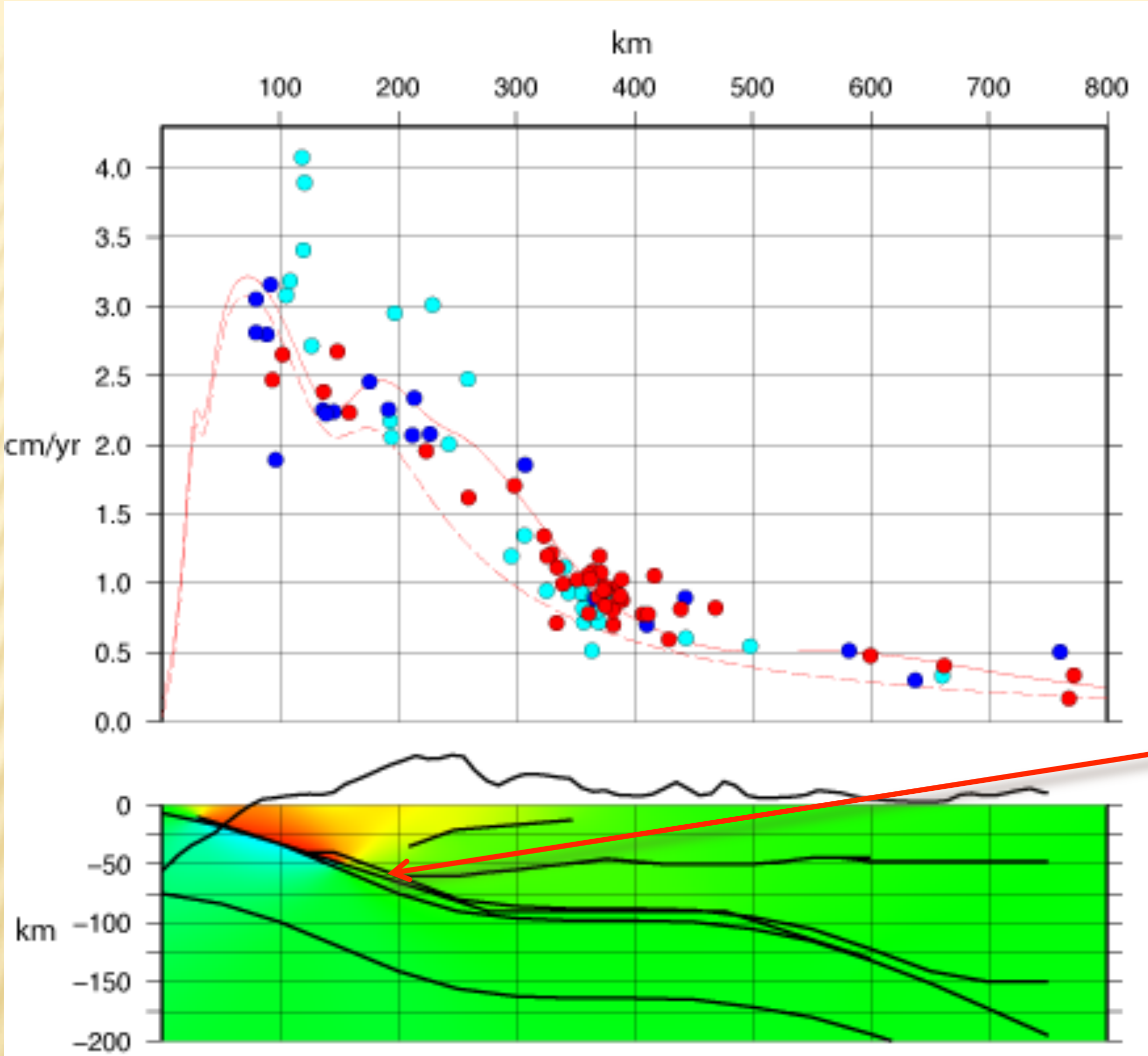


Horizontal displacement

Add freely slipping décollement in back arc crust.

"sucks-up" deformation into crust above décollement to match GPS data.

Still too slow at greater distances.



Horizontal displacement

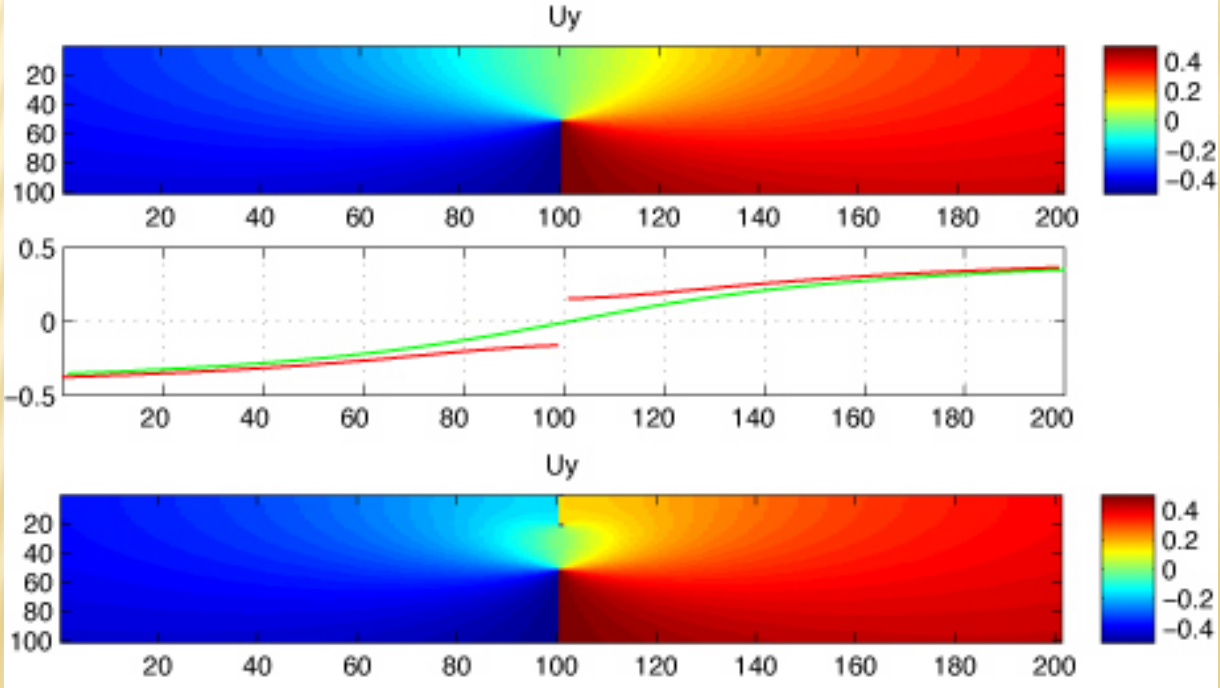
Add "push" from relative plate convergence (normal force only on dipping plate interfaces at >50 km depth).

"throws" deformation to greater distances.

Other popular variant.

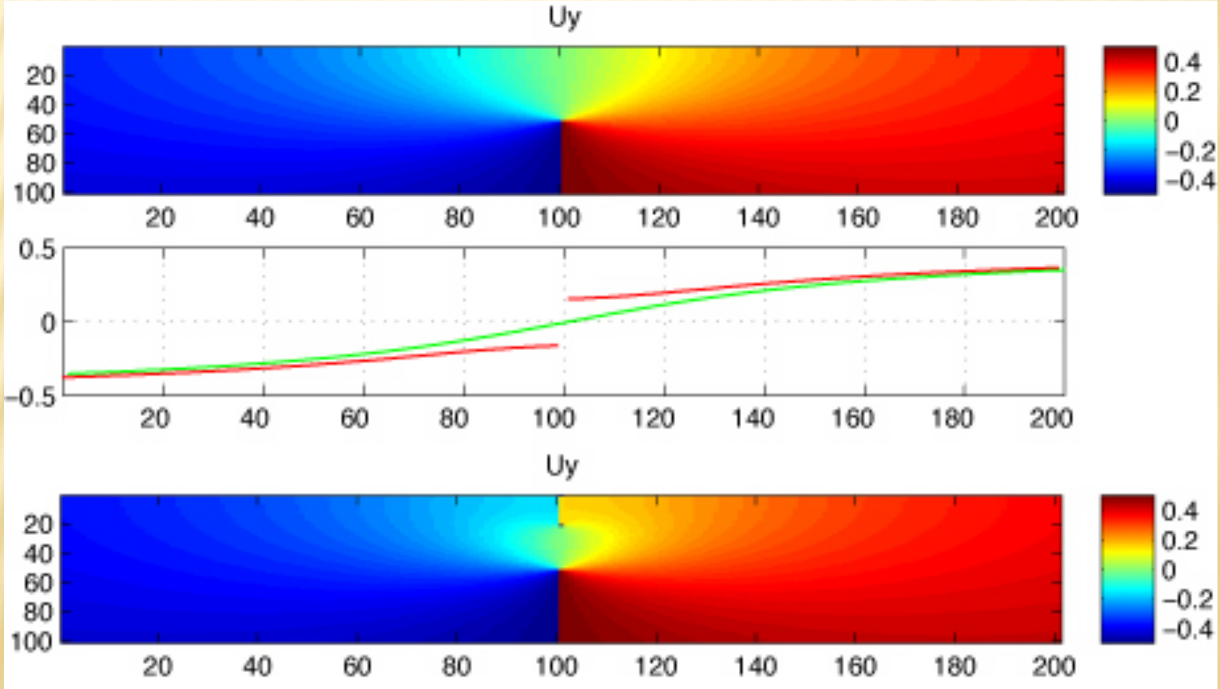
Creeping section at surface on otherwise locked fault.

Can do it by putting in fault with specified slip, or in a self-consistent manner by putting in frictionless fault and letting it find equilibrium.



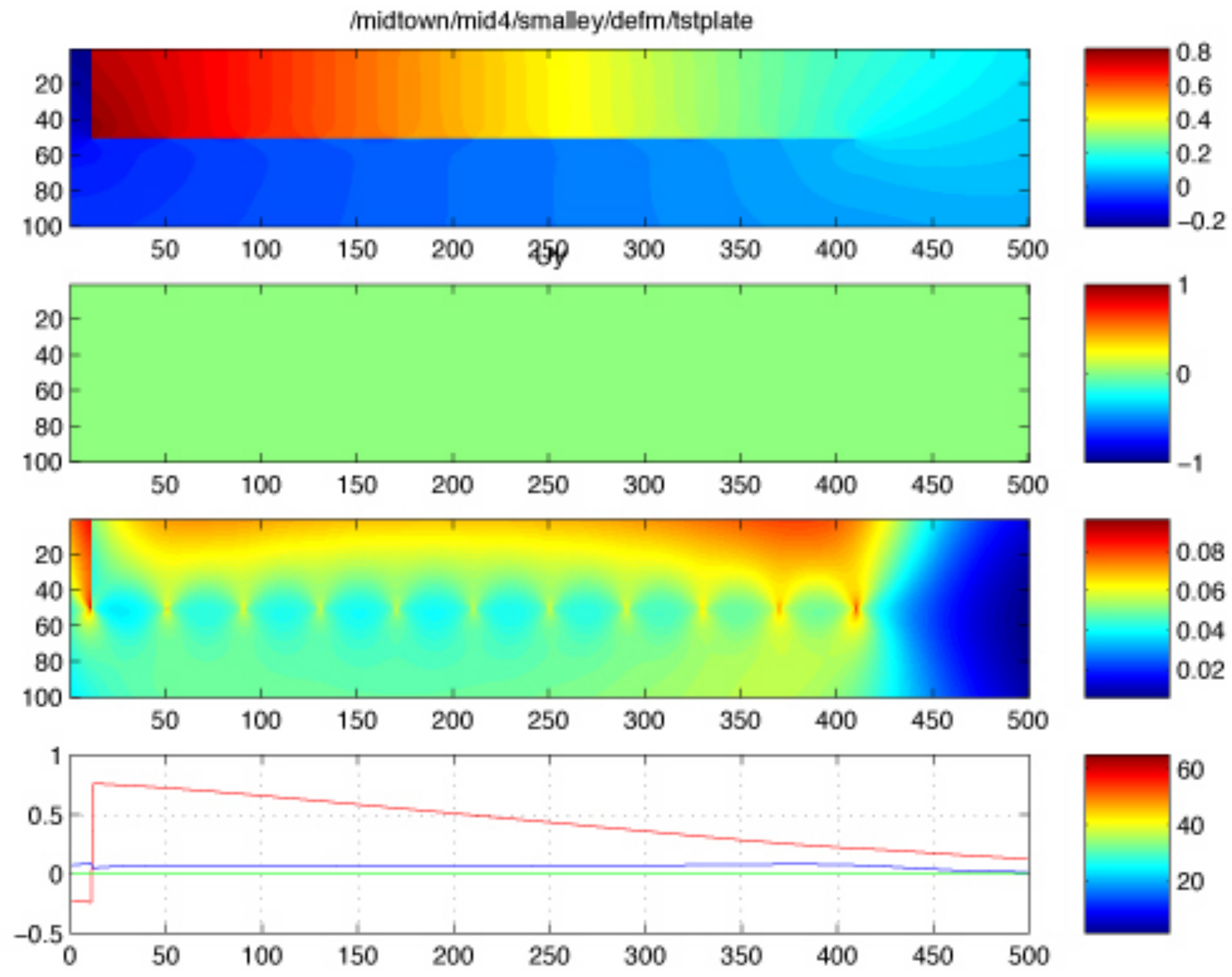
Use physically based model (slip on fault starting at locking depth and going to "infinity) rather than backslip (top, green line), with friction free fault (bottom, red line).

Now have offset across fault trace (from creep).

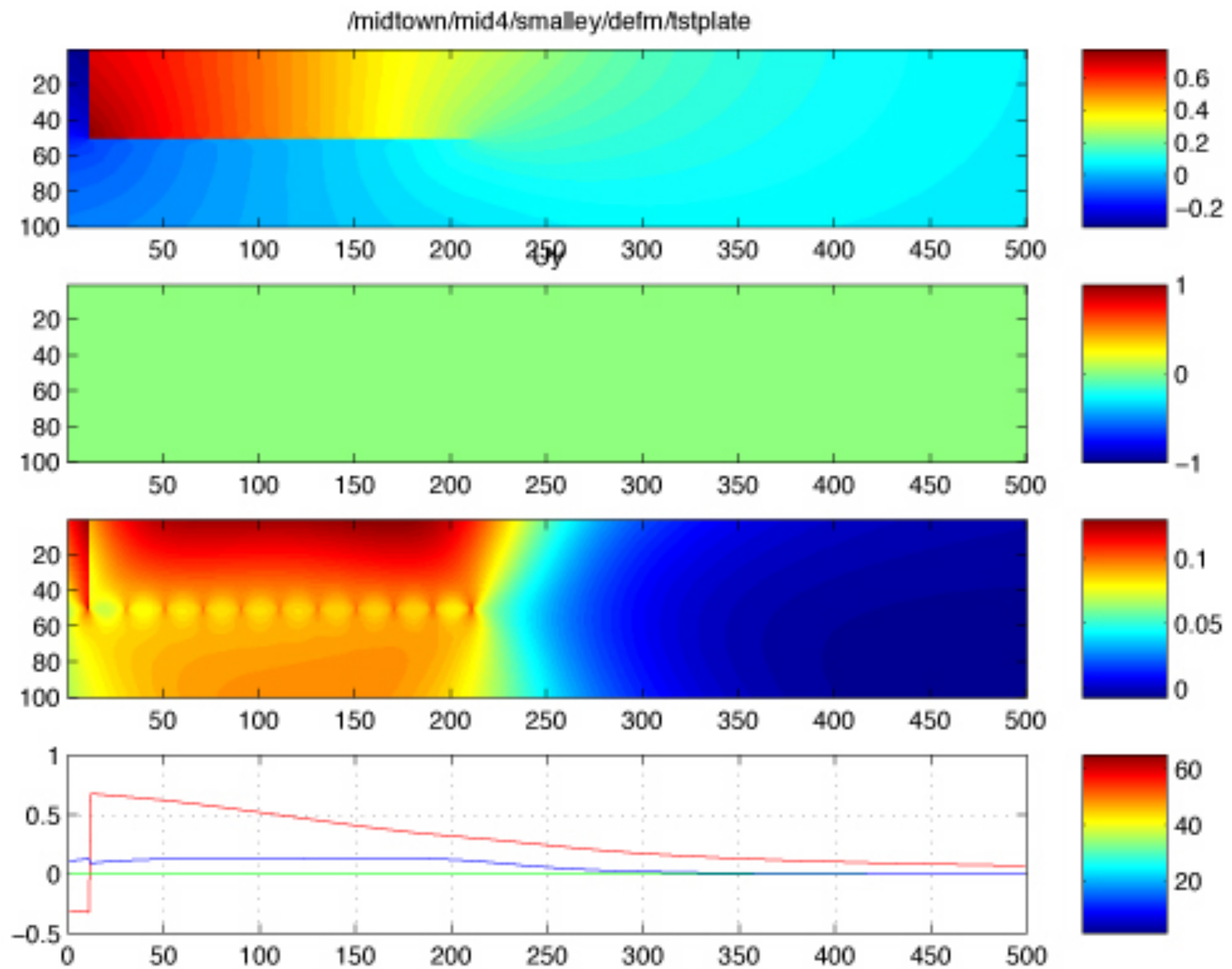


Random Stuff:

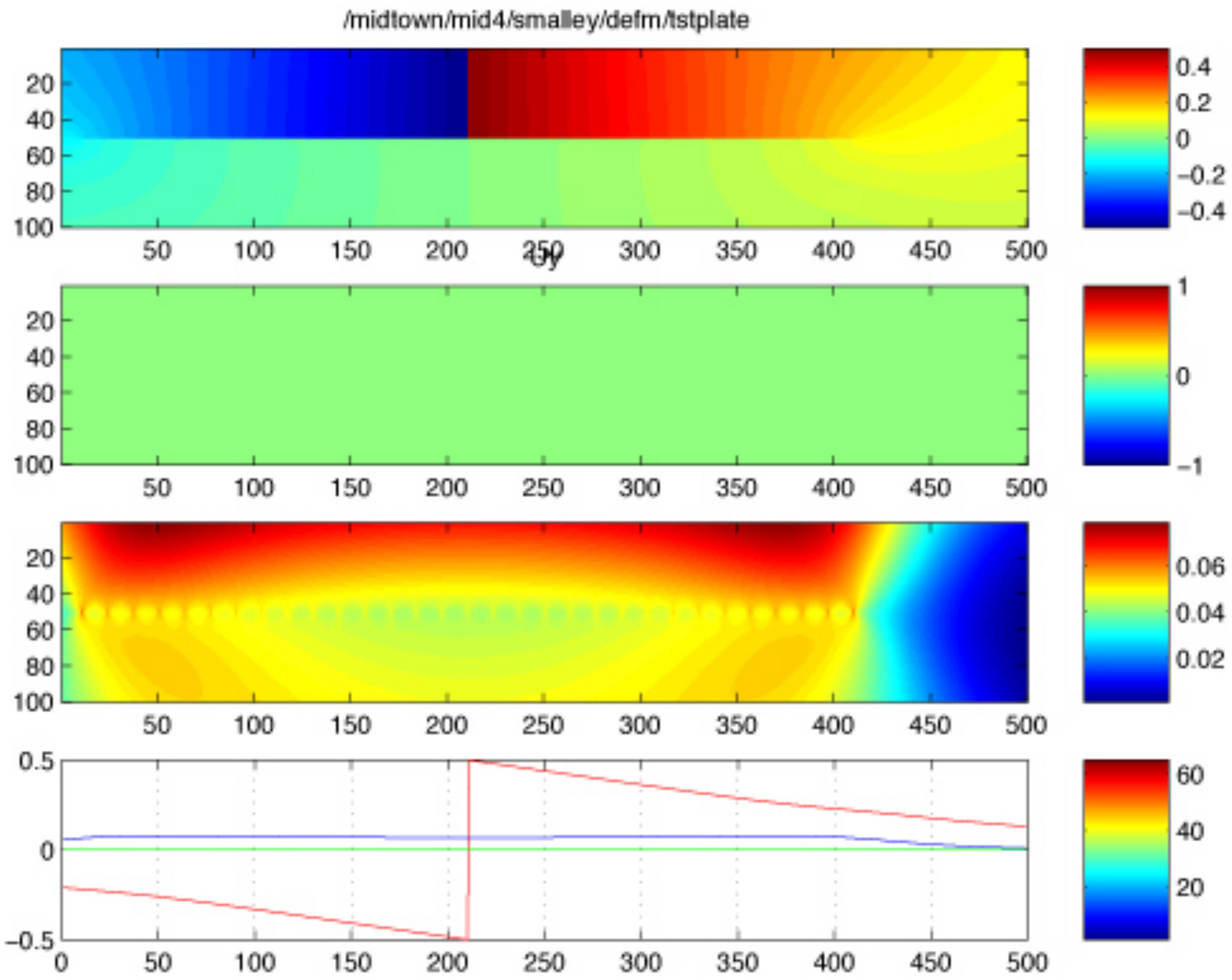
Simulate end loaded plate (right end not rigidly mounted). "smoothness" of result depends on number subelements.



Smaller elements



Push out



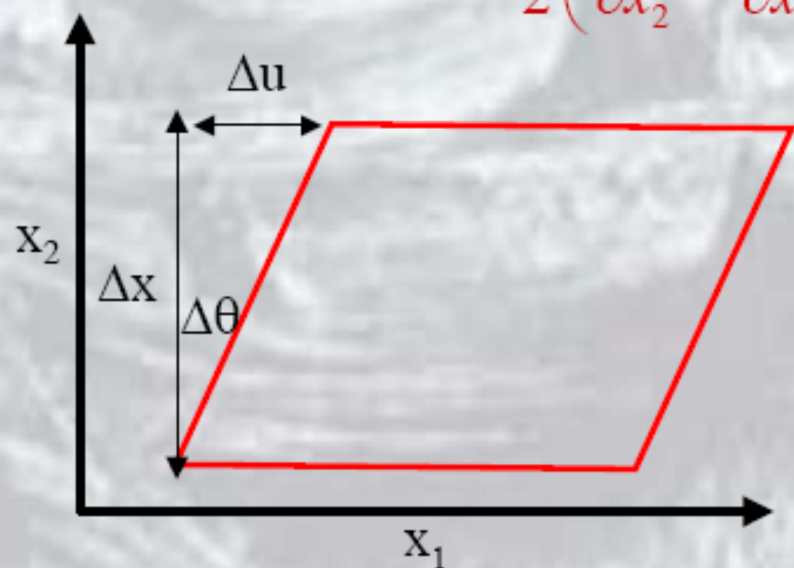
/midtown/mid4/smalley/defm/tstplate
20
40
60
80
100
50 100 150 200 250 300 350 400 450 500
0.4
0.2
0
−0.2
−0.4
Uy
1
0
−1
0.06
0.04
0.02
0.5
0
−0.5
0
60
40
20

Components of strain: simple shear

- Mixed strain and rotation - *simple shear*

$$\varepsilon_{12} = \frac{1}{2}\left(\frac{\partial u_1}{\partial x_2} + \frac{\partial u_2}{\partial x_1}\right) = \frac{\Delta\theta}{2}$$

$$\omega_{12} = \frac{1}{2}\left(\frac{\partial u_1}{\partial x_2} - \frac{\partial u_2}{\partial x_1}\right) = \frac{\Delta\theta}{2}$$



$\varepsilon_{12} = 1/2\ (\Delta u_1/\Delta x_2 + 0) = \Delta\theta/2$

$w_{12} = 1/2\ (\Delta u_1/\Delta x_2 + 0) = \Delta\theta/2$

Strain rates

- Now we have to consider the time taken for the displacement field **u(x)** to develop. If this time interval Δt is known, we can instead use the define velocity field **v(x)**, where

$$v_i = \frac{u_i}{\Delta t}$$

- The development is identical, producing a velocity gradient tensor and the following strain-rate and rotation-rate tensor:

$$\dot{\varepsilon}_{ij} = \frac{1}{2}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right)$$

$$\dot{\omega}_{ij} = \frac{1}{2}\left(\frac{\partial v_i}{\partial x_j} - \frac{\partial v_j}{\partial x_i}\right)$$

The 'dot' is shorthand for $\partial/\partial t$

Using survey data

If the displacement gradient tensor D_{ij} were known, we could calculate the relative displacement **u** between a pair of points separated by the vector **x** by using the chain rule:

$$u_1 = \frac{\partial u_1}{\partial x_1} x_1 + \frac{\partial u_1}{\partial x_2} x_2$$

$$= D_{11} x_1 + D_{12} x_2$$

and similarly $u_2 = D_{21} x_1 + D_{22} x_2$

In surveys (satellite or terrestrial) we measure **u** and **x** and want to calculate D_{ij} . The same equations can be used to solve for the components D_{ij} .

Using survey data

In 2-D, solving for the 4 independent components D_{ij} requires surveys of displacements between two pairs of points, e.g. $\mathbf{u}^a(\mathbf{x}^a)$ and $\mathbf{u}^b(\mathbf{x}^b)$:

$$u_1^a = D_{11} x_1^a + D_{12} x_2^a$$
$$u_2^a = D_{21} x_1^a + D_{22} x_2^a$$

$$u_1^b = D_{11} x_1^b + D_{12} x_2^b$$
$$u_2^b = D_{21} x_1^b + D_{22} x_2^b$$

This is a set of 4 simultaneous equations in 4 unknowns. After solution the stain and rotation tensors can be obtained from D_{ij}.