ERTH 491-01 / GEOP 572-02
Geodetic Methods

– Lecture 26: Modeling - Slip Inversion cont'd –

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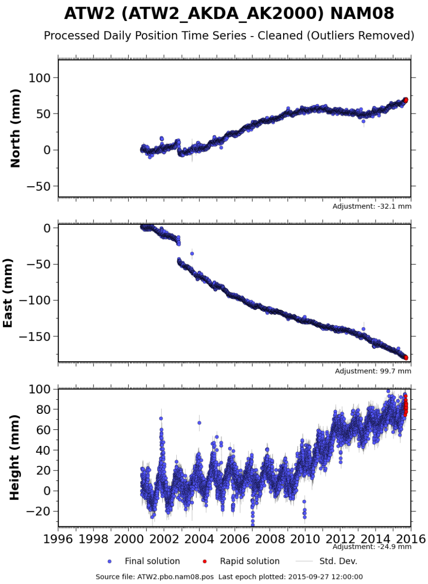
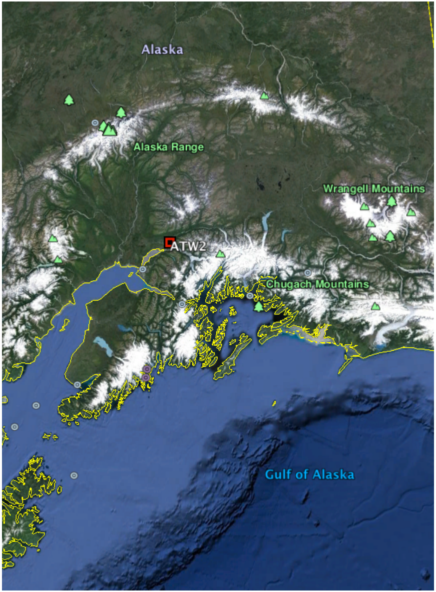
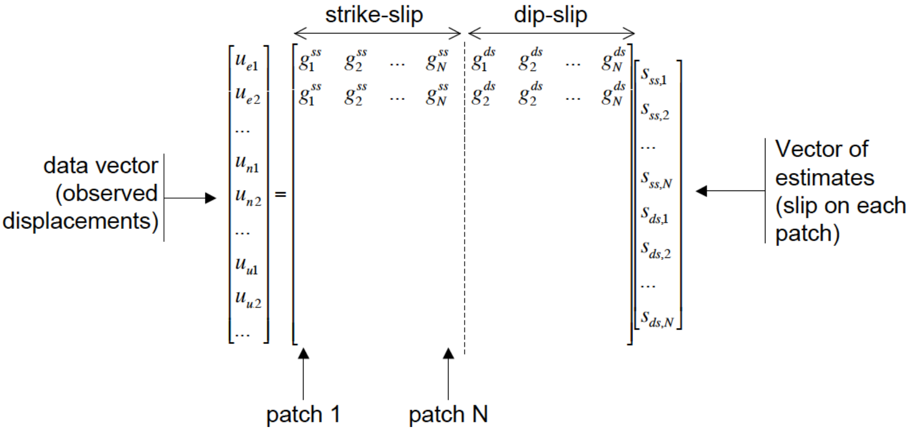
Guess The ≈ 8 Processes



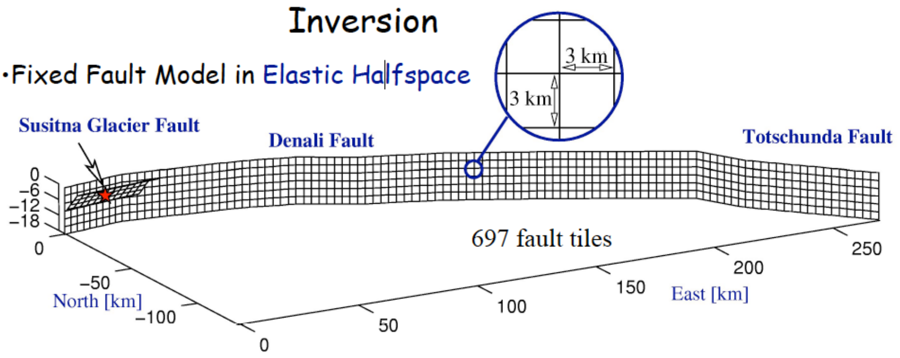


Solving for Slip



Eric Calais

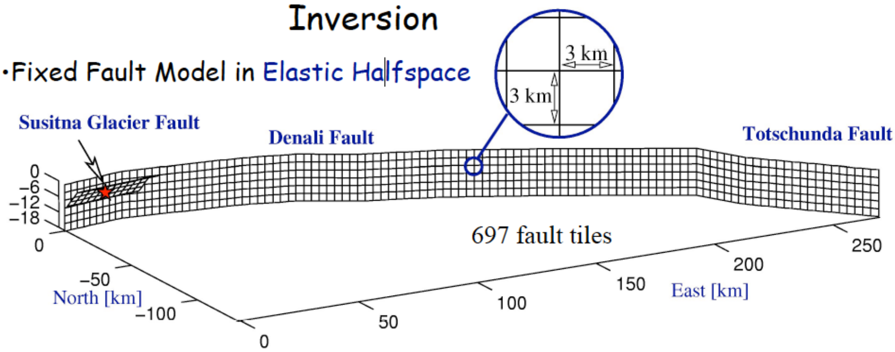
Solving for Slip



Sigrun Hreinsdottir

With 224 GPS sites and 697 fault tiles solving for dip-slip and strike-slip, what problem are we running into?

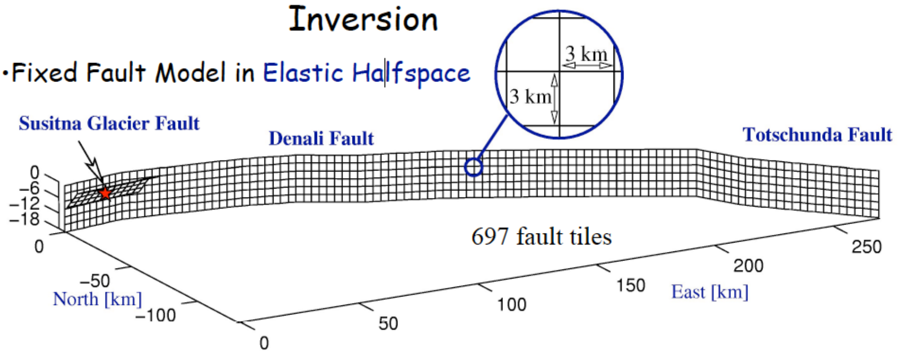
Solving for Slip



Sigrun Hreinsdottir

With 224 GPS sites and 697 fault tiles solving for dip-slip and strike-slip, what problem are we running into?
Underdetermined system.

Solving for Slip



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- observations at 225 GPS sites: 675 data (if vertical helps)
- 697 fault tiles, ss, ds: 1394 unknowns
- no enough data to constrain number of unknowns
- also often an issue: unphysical oscillatory slip

Regularization / Smoothing

- Idea: Minimize the rate of change of slip with position
- “rate of change of slip” is curvature
- Laplacian:

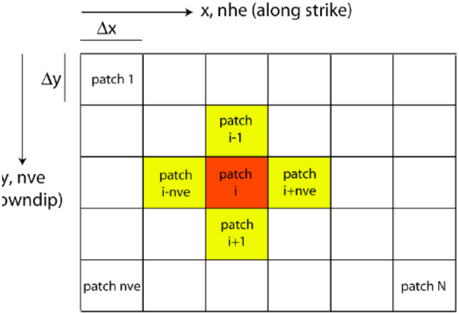
$$\nabla^2 = \frac{\delta^2}{\delta x^2} + \frac{\delta^2}{\delta y^2} + \frac{\delta^2}{\delta z^2}$$

- Practice: Minimize sum of partial second differentials of slip for each fault patch
- Can be solved using finite-difference method for a function P

$$\frac{\delta^2 P(x)}{\delta x^2} \approx \frac{P(x - \Delta x) - 2P(x) + P(x - \Delta x)}{\Delta x^2}$$

Regularization / Smoothing

- Our function $P(x)$ is slip s which varies along-strike (x) and down-dip (y)
- For patch i finite difference approximation of Laplacian is (nve = number of vertical elements, nhe = horiztonal):



Eric Calais

$$l_i = \frac{s_{i-nve} - 2s_i + s_{i+nve}}{\Delta x^2} + \frac{s_{i-1} - 2s_i + s_{i+1}}{\Delta y^2}$$

Regularization / Smoothing

- In practice, equation:

$$l_i = \frac{s_{i-nve} - 2s_i + s_{i+nve}}{\Delta x^2} + \frac{s_{i-1} - 2s_i + s_{i+1}}{\Delta y^2}$$

is written in matrix form, for the along-strike and down-sip components:

$$\begin{bmatrix} \cdots \\ 0 \\ \cdots \end{bmatrix} = \underbrace{\begin{bmatrix} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ (0) & \frac{1}{\Delta x^2} & (0) & -\frac{2}{\Delta x^2} & (0) & -\frac{1}{\Delta x^2} & (0) \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{bmatrix}}_{L_x} \begin{bmatrix} \cdots \\ s_{i-nve} \\ \cdots \\ s_i \\ \cdots \\ s_{i+nve} \\ \cdots \end{bmatrix} \qquad \begin{bmatrix} \cdots \\ 0 \\ \cdots \end{bmatrix} = \underbrace{\begin{bmatrix} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ (0) & \frac{1}{\Delta y^2} & (0) & -\frac{2}{\Delta y^2} & (0) & -\frac{1}{\Delta y^2} & (0) \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{bmatrix}}_{L_y} \begin{bmatrix} \cdots \\ s_{i-1} \\ \cdots \\ s_i \\ \cdots \\ s_{i+1} \\ \cdots \end{bmatrix}$$

- The 2 Laplacian matrices are then added:

$$L = L_x + L_y$$

Regularization / Smoothing

- The original problem was:

$$[u] = \begin{bmatrix} G_{ss} & G_{ds} \end{bmatrix} \begin{bmatrix} s_{ss} \\ s_{ds} \end{bmatrix}$$

- now it becomes:

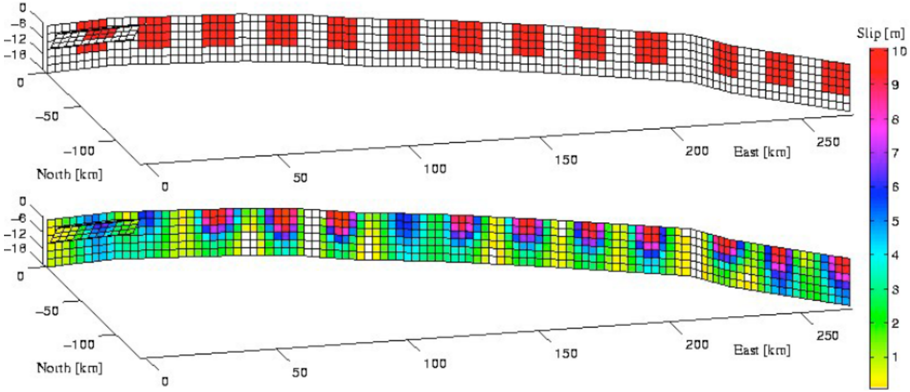
$$\begin{bmatrix} u \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} G_{ss} & G_{ds} \\ L & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} s_{ss} \\ s_{ds} \end{bmatrix}$$

- amount of smoothing can be tuned using scalar smoothing factor κ:

$$\begin{bmatrix} u \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} G_{ss} & G_{ds} \\ \kappa L & 0 \\ 0 & \kappa L \end{bmatrix} \begin{bmatrix} s_{ss} \\ s_{ds} \end{bmatrix}$$

- $\kappa = 0$: no smoothing, $\kappa = 1$ maximum smoothing

What can you recover? Checker board / Resolution test:



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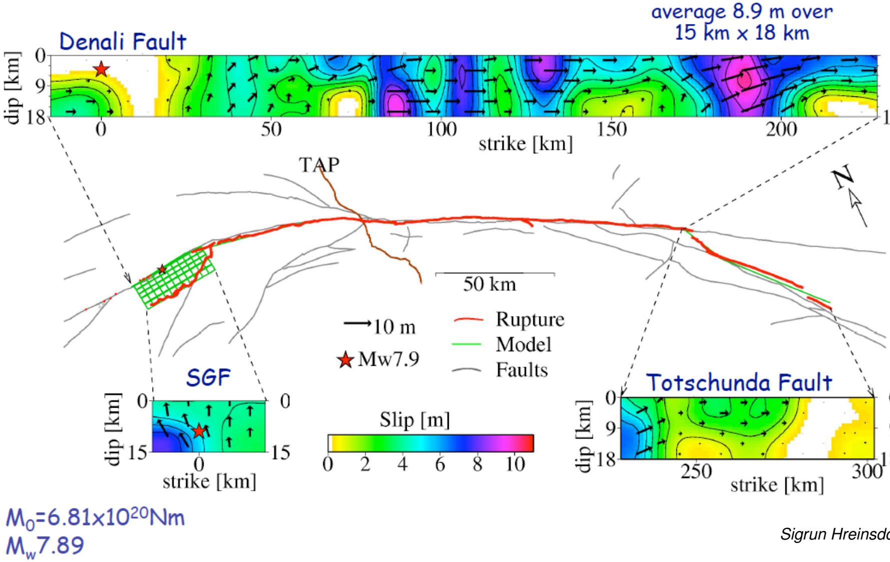
Distributed Slip Inversion

This is how you get this:



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