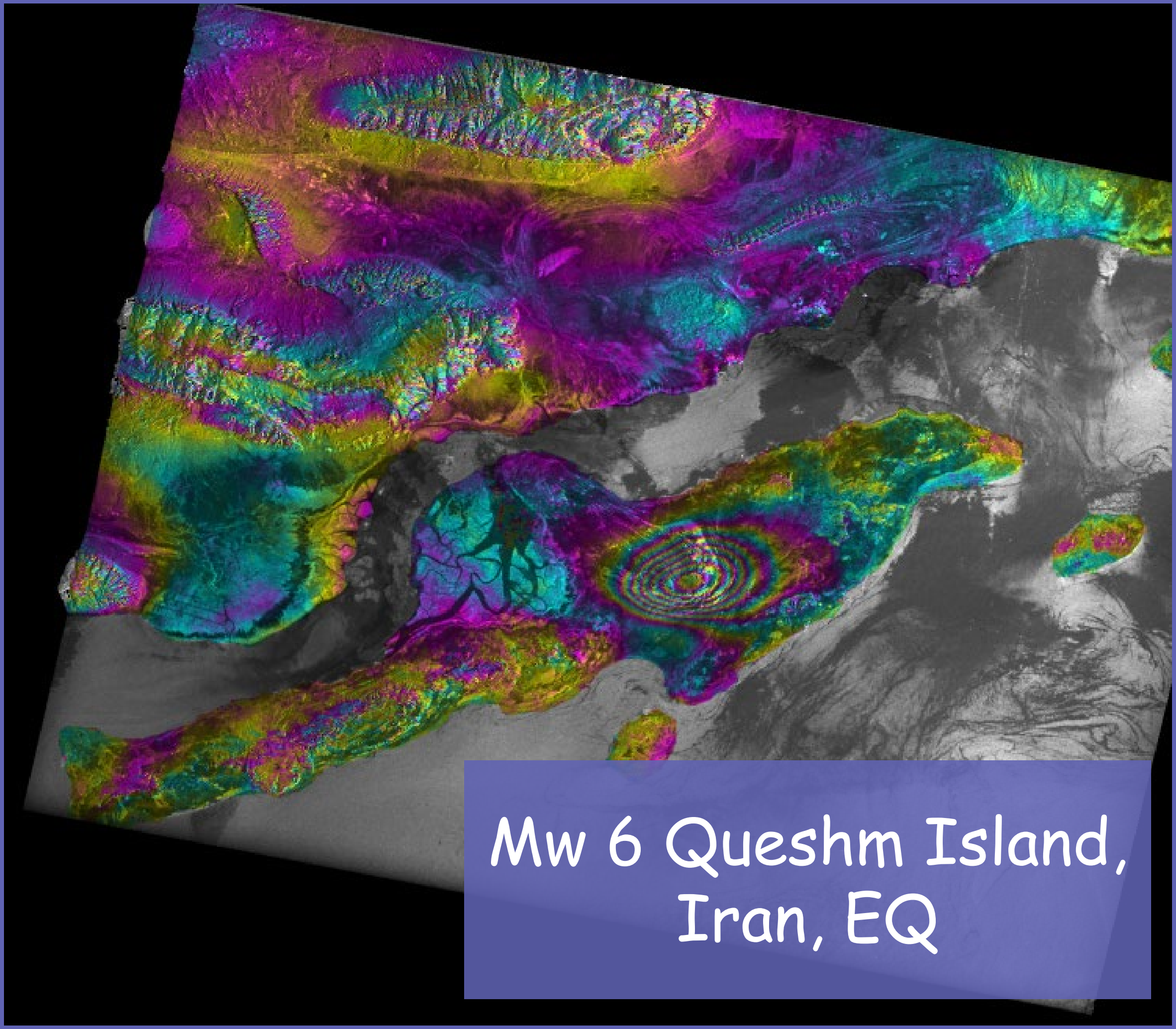
Generating Green's Functions with Pylith



Outline

- Overview/Motivation
  - When/where use FE models?
- Workflow
  - From data to mesh to Green's functions to model
- Examples
  - Bam & Qeshm Island earthquakes, Iran

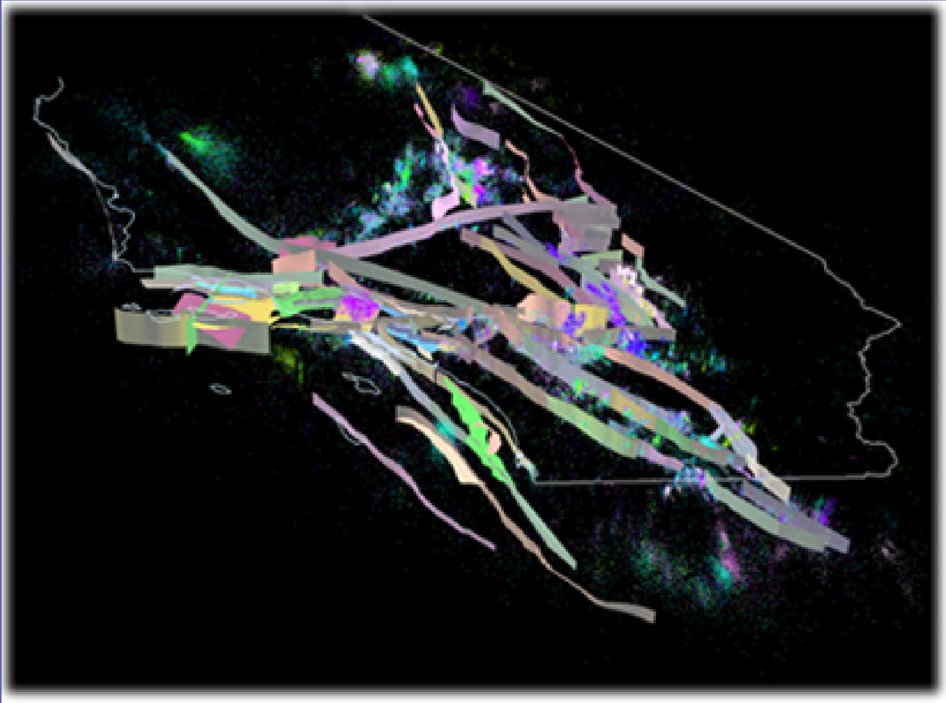
Astronaut photography
http://eol.jsc.nasa.gov/

Effects of Crustal Structure

- Vertical layering (2D)
  - Tends to move apparent source up or down (~10% effect)
- Horizontal contrasts (3D)
  - Map into slip features, inferred geometry
  - Fialko (2006) finds 2-2.5x contrasts in So. Cal
- Goal: For generic settings, what is inversion sensitivity?
  - Generate synthetic data using cross-fault contrast
  - Find best-fit solution in elastic half space
  - Assess bias: Inferred fault dip

Choosing Model Complexity

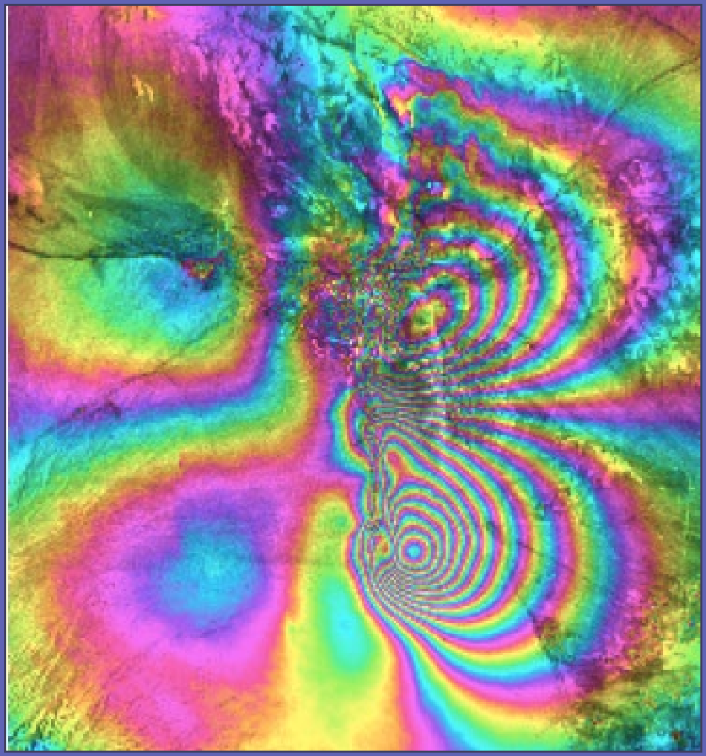
- Case 1
  - Lots of info
    - Seismicity
    - Velocity/rigidity structure
    - Mapped faults
    - Atmospheric water vapor content
  - Computationally expensive….



Community fault model
So. Cal

Choosing Model Complexity

- Case 2:
  - Sparse information
  - Mainly teleseismic EQ locations
  - No continuous GPS
  - Sporadic remote sensing



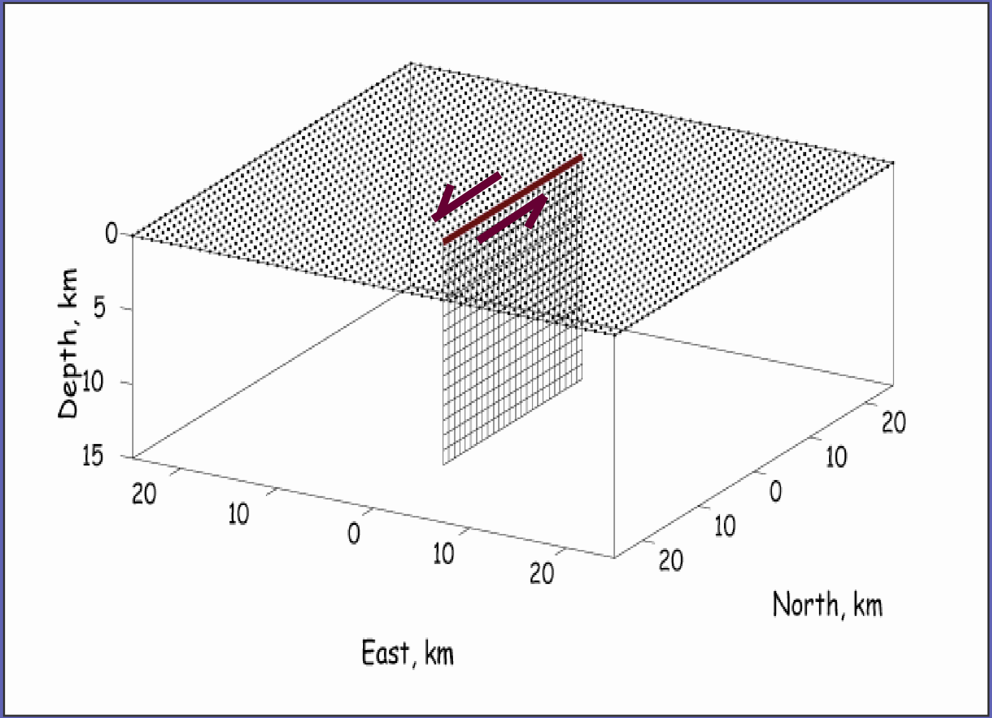
Bam EQ, courtesy E. Fielding

Choosing Model Complexity

- Case 1:
  - How do we use all this information?
  - When do we have to include all info?
  - When does it make sense to simplify?
- Case 2
  - What bias do we introduce by using inadequate models?
  - How should we present this error?
  - Which problems can we still address?

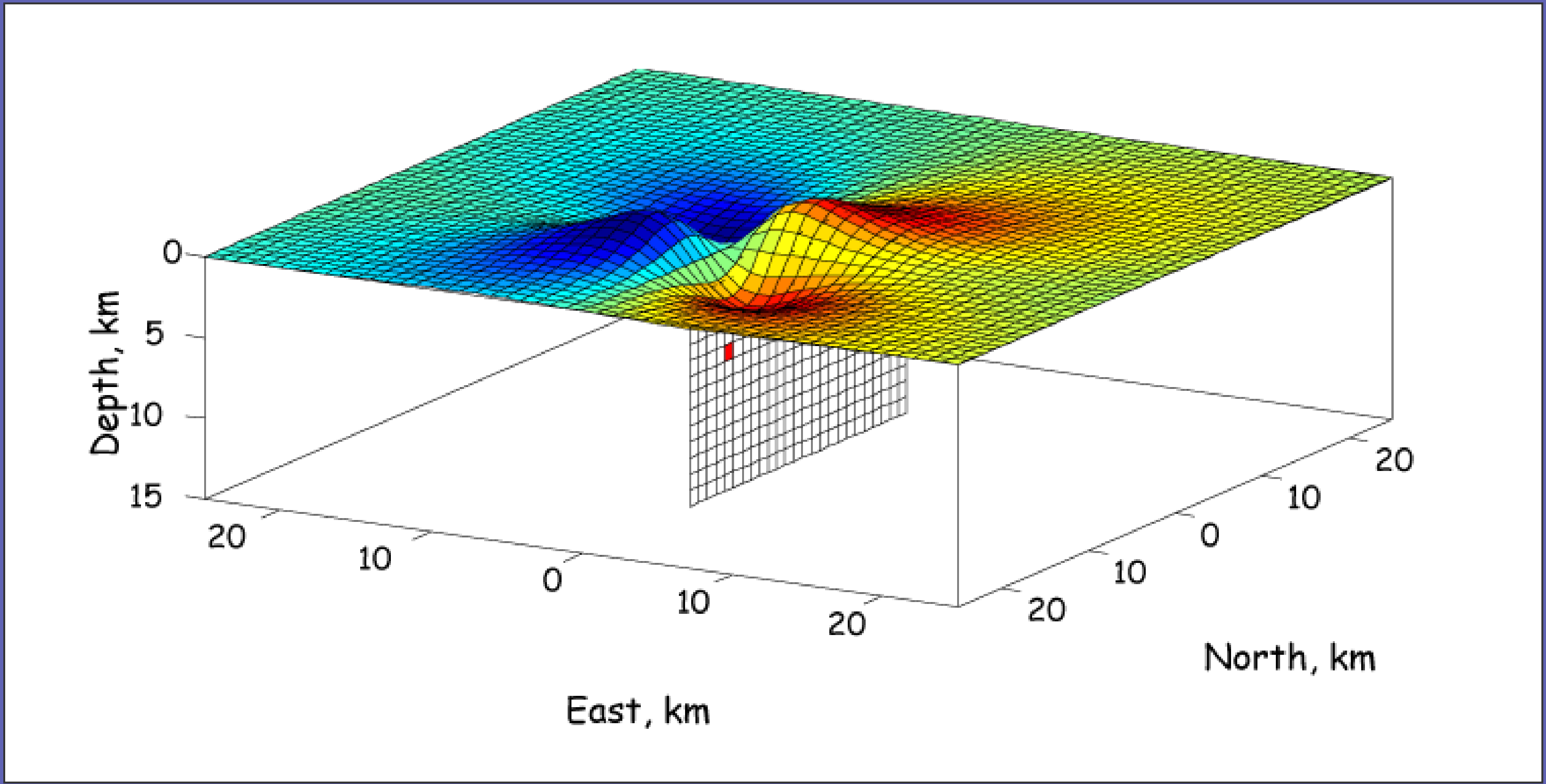
FE Workflow

- Step 1: Matlab
  - Define data/fault geometry
  - Define crustal structure
  - Subdivide fault
  - One patch at a time, build Cubit, Pylith input files



Vertical, strike-slip fault, divided into patches

Okada-based Green's functions



Slip on shallow fault patch

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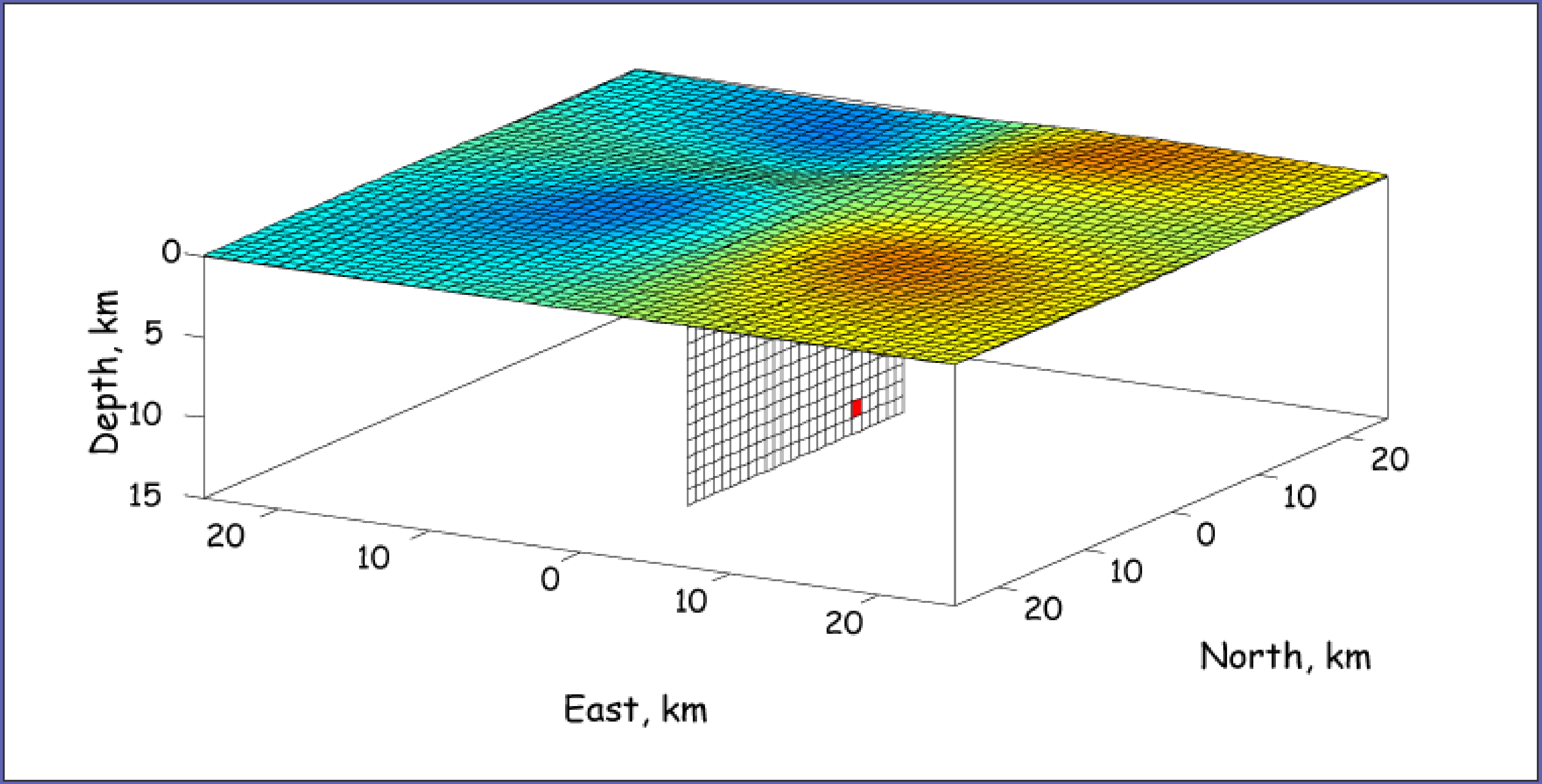
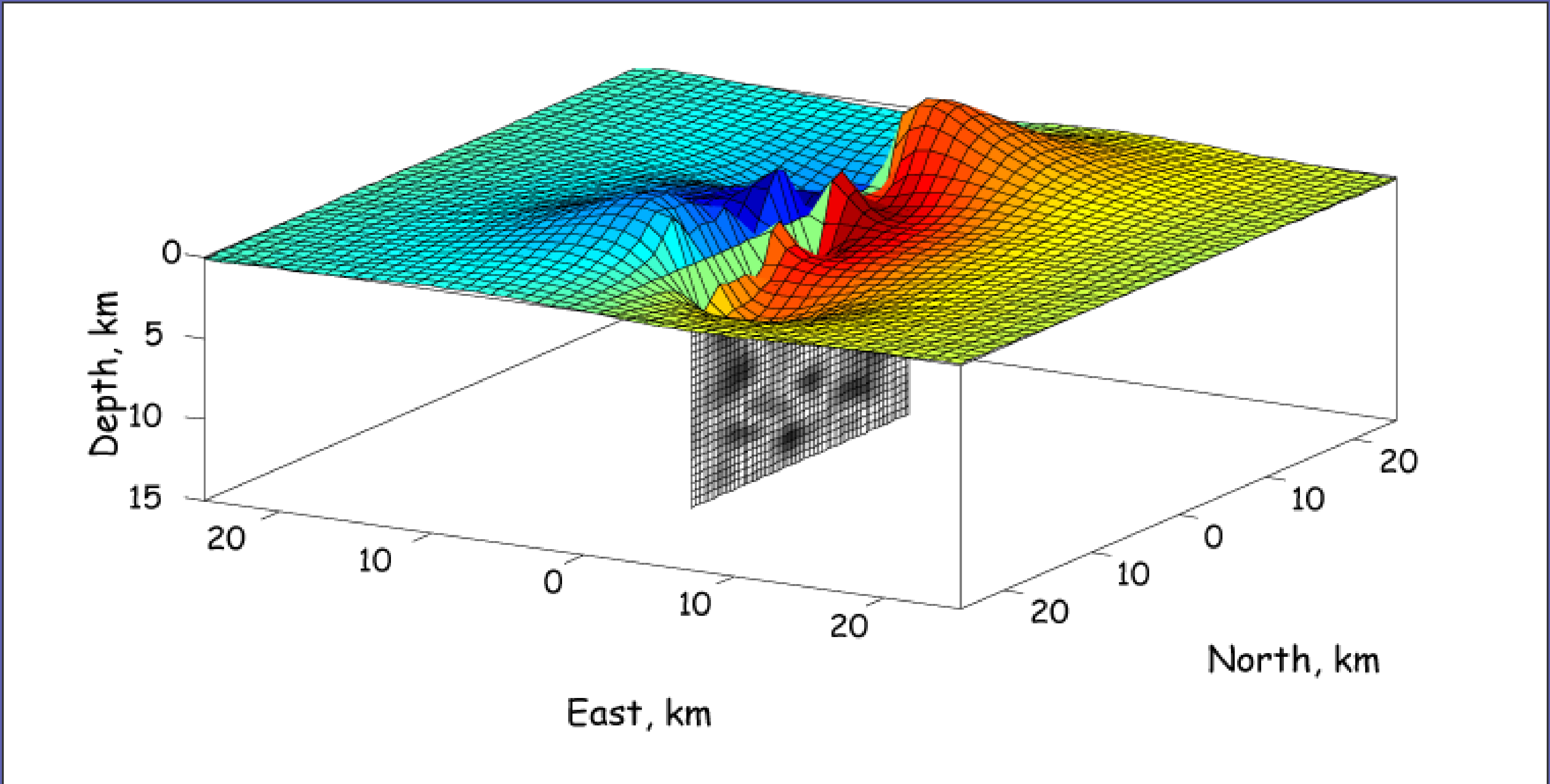


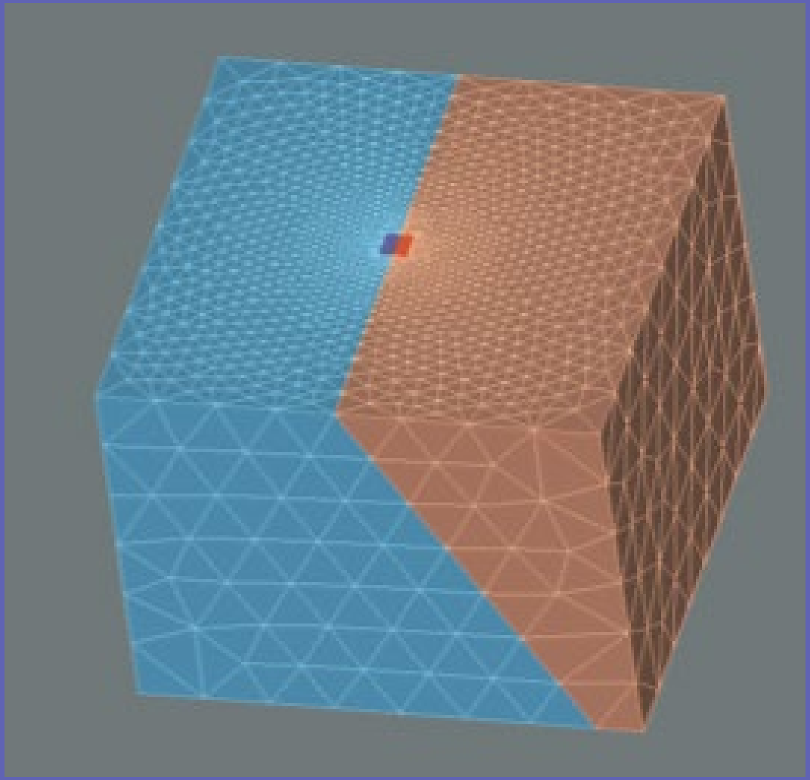
Slip on deep fault patch

Inversion



FE Workflow

- Step 2: Cubit
  - Build mesh
- Step 3: Pylith
  - Generate Green's functions
- Step 4: Matlab
  - Assemble all patches, perform inversion



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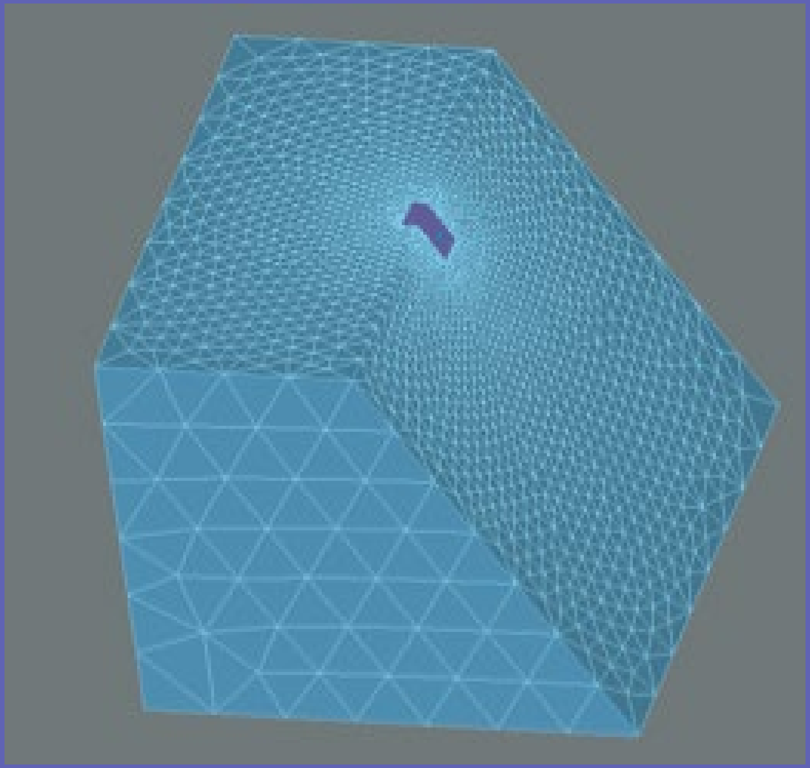

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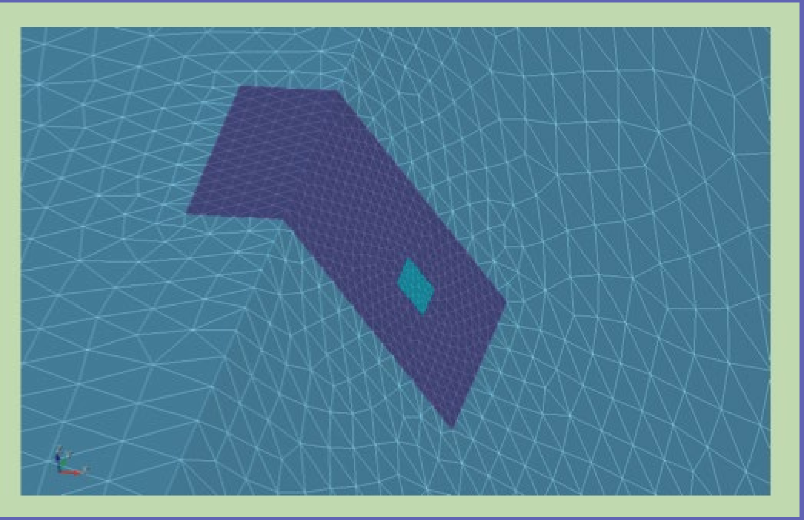
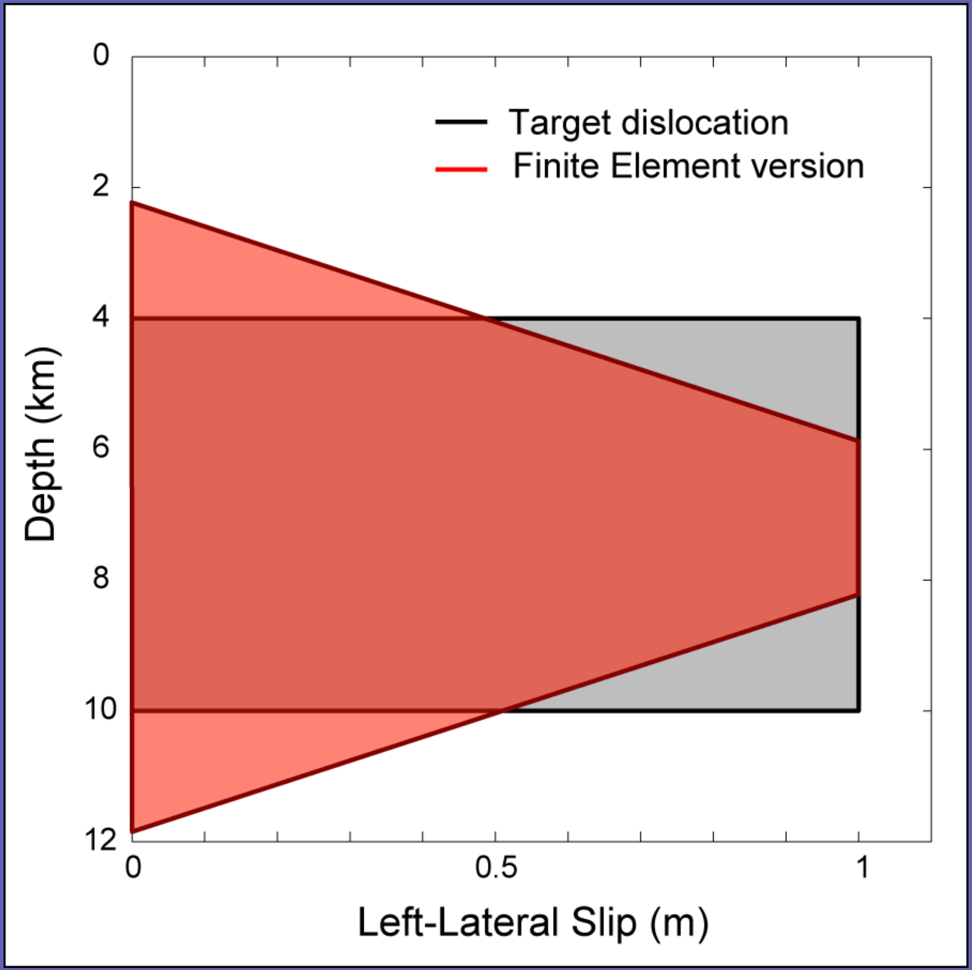


Mesh quality/density?

Comparison w/Okada

- Discrete fault patches
  - Readily available (Okada, Poly3D)
  - Easy to visualize
  - Historical:compare with previous work
- Node, points
  - More natural comparison once Pylith Green's functions mode



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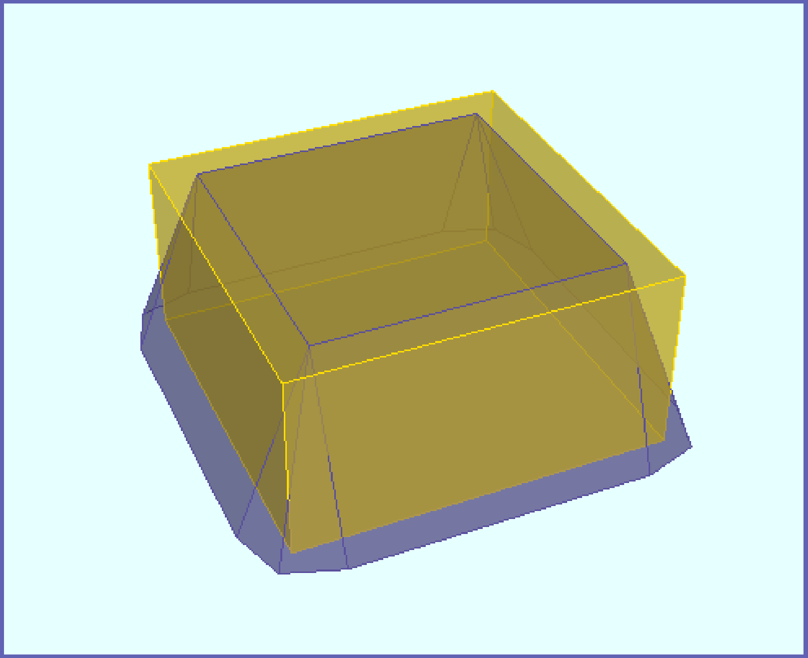
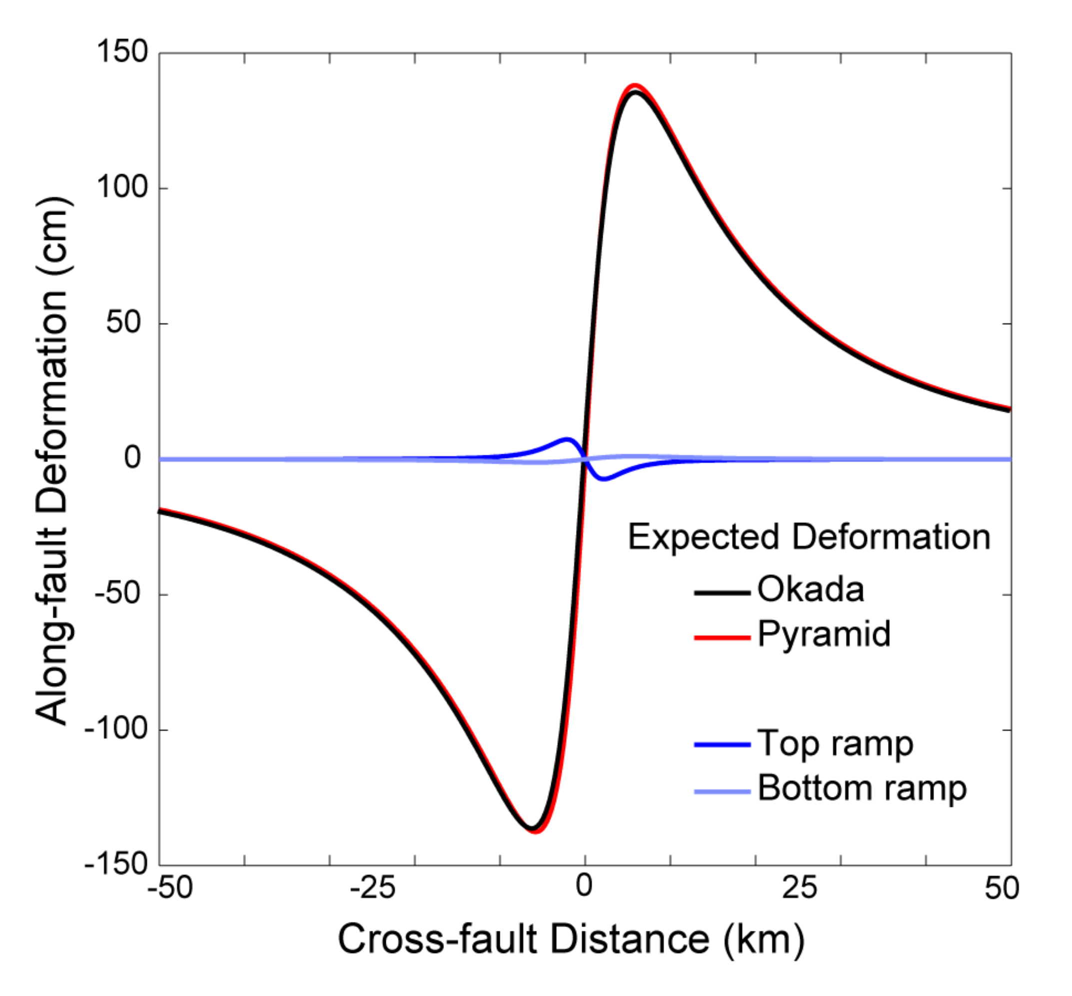
3D version



Comparison w/Okada

- More misfit from shallower ramp
- Can fit almost exactly with different fault patch



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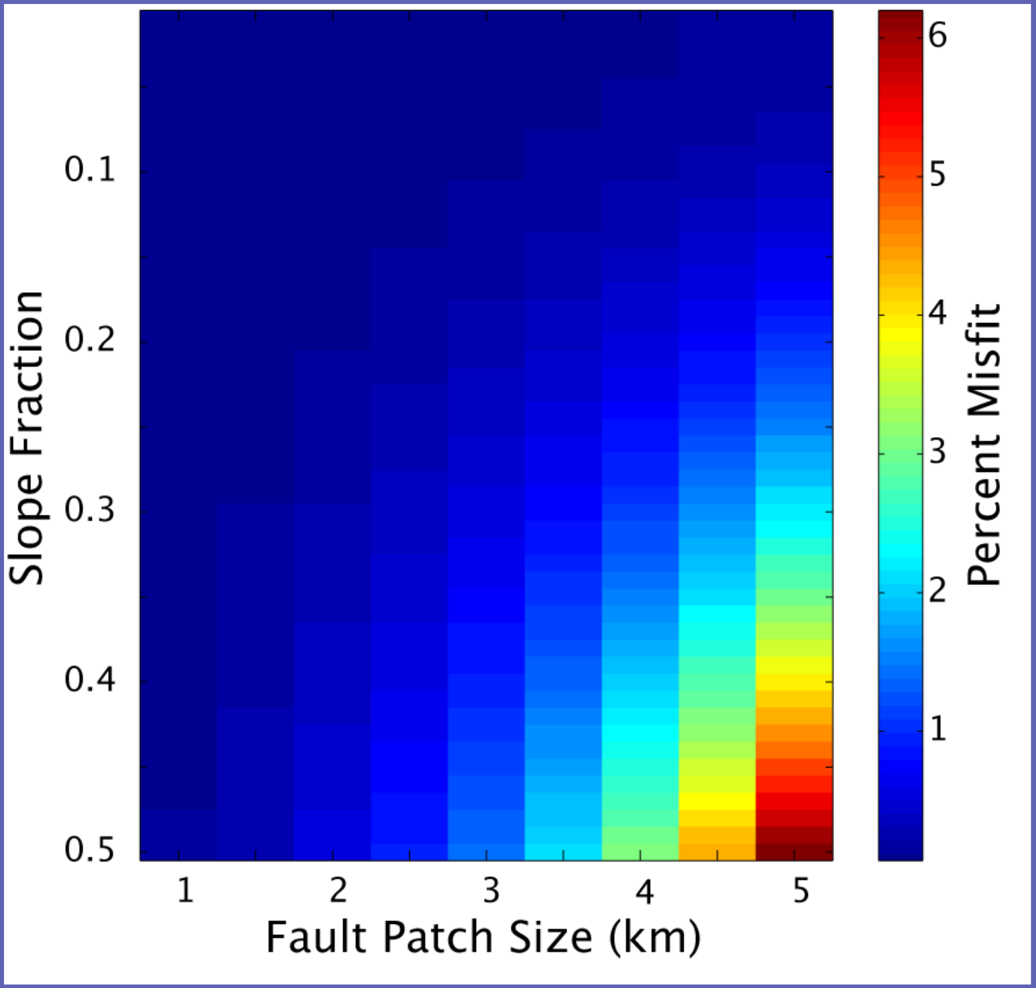

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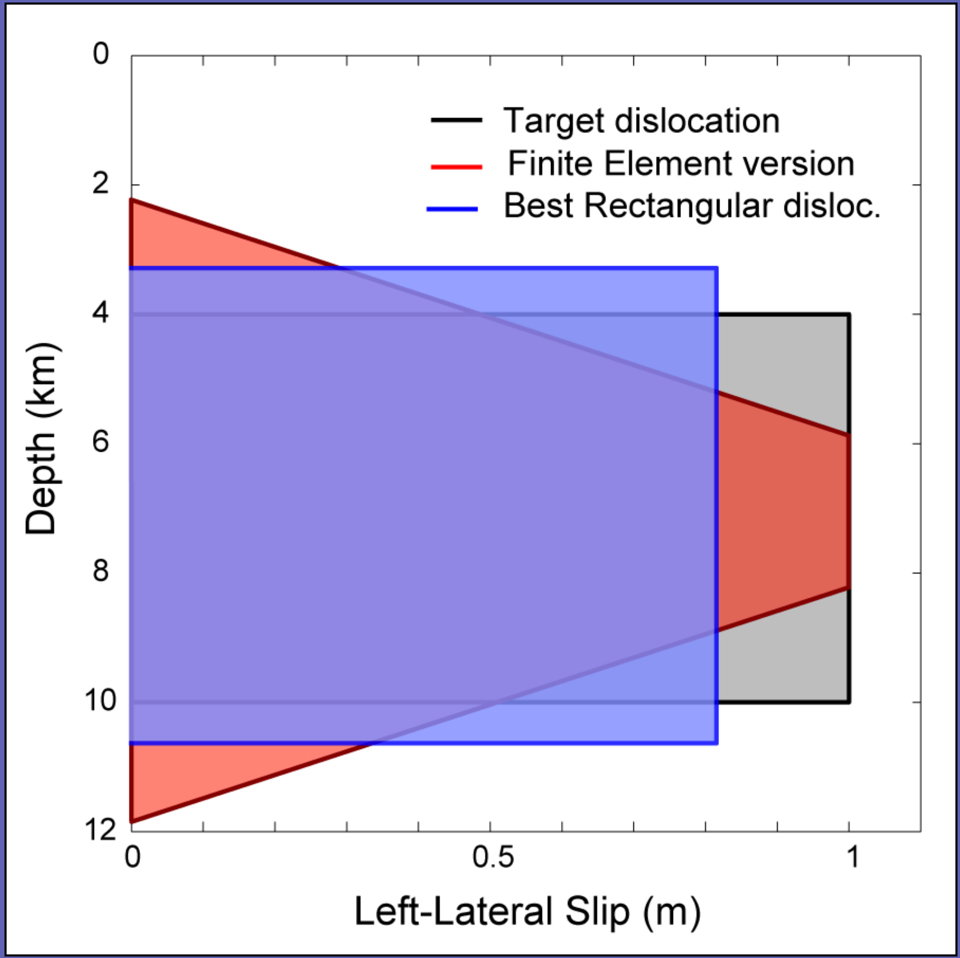
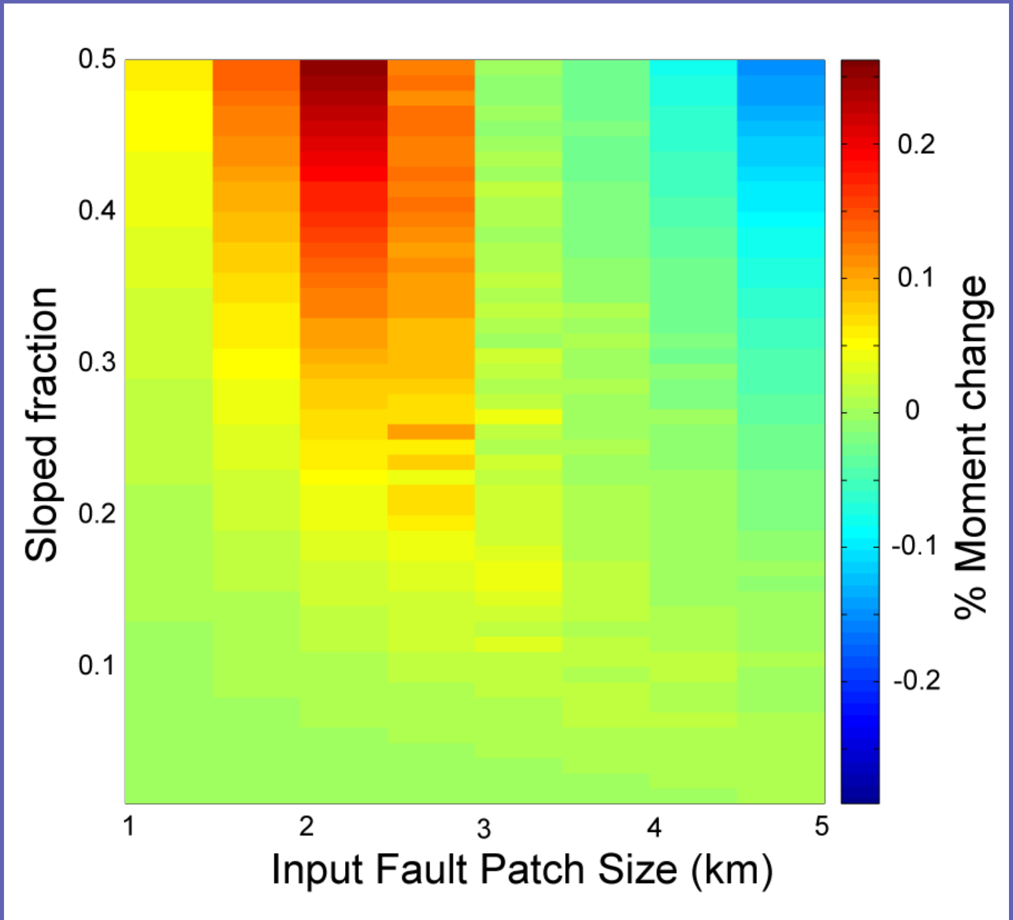


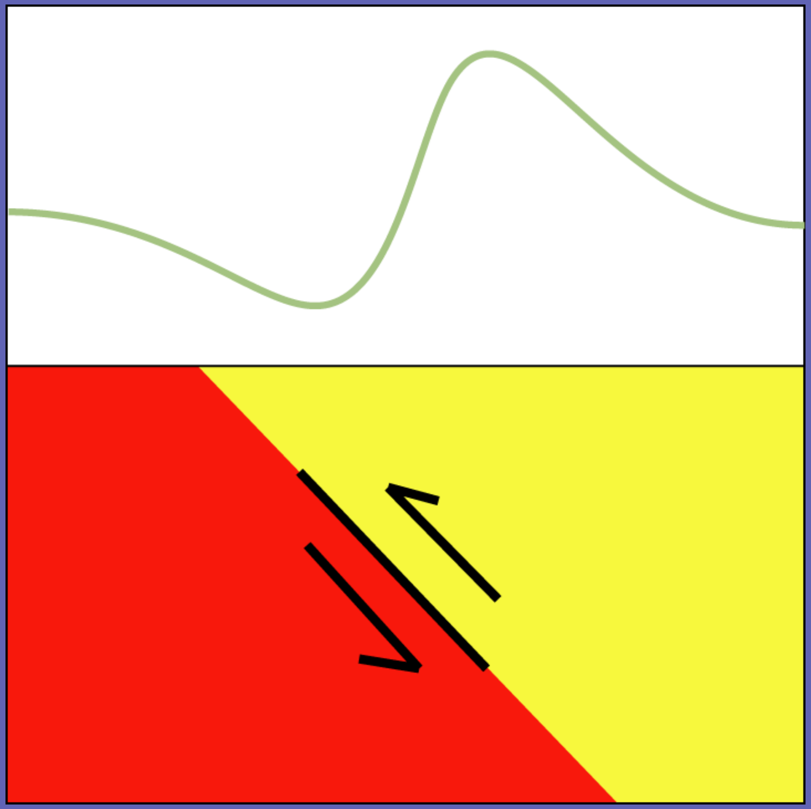
Comparison w/Okada

- More triangular -> wider patch w/ less slip
- Moments/centroid almost identical



Examples: Sensitivity Tests

1. Generate synthetic data using cross-fault contrast (slow)
2. Invert using half space (fast)
3. Assess potential bias



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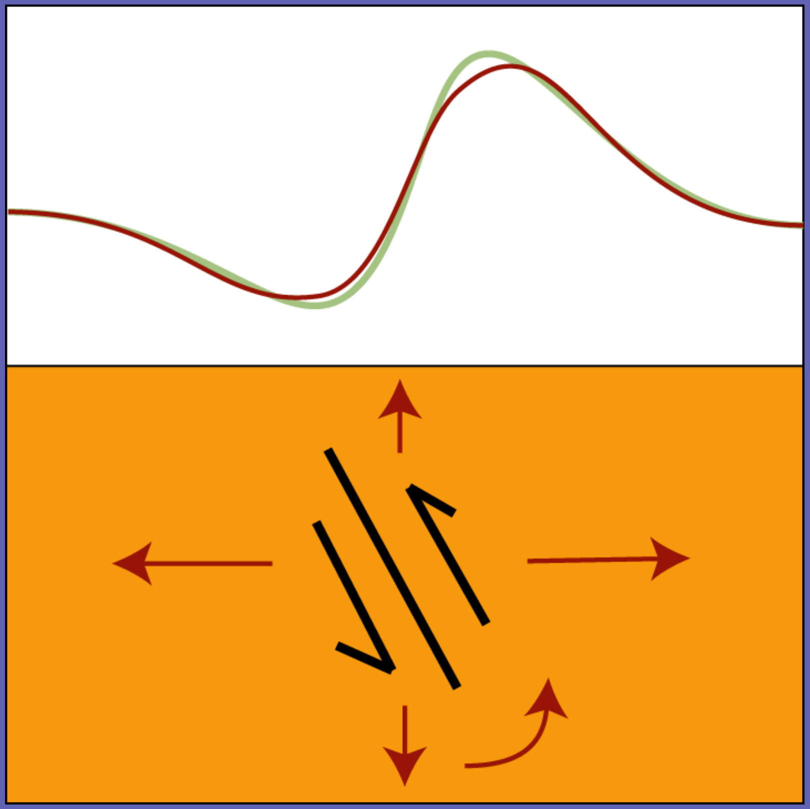

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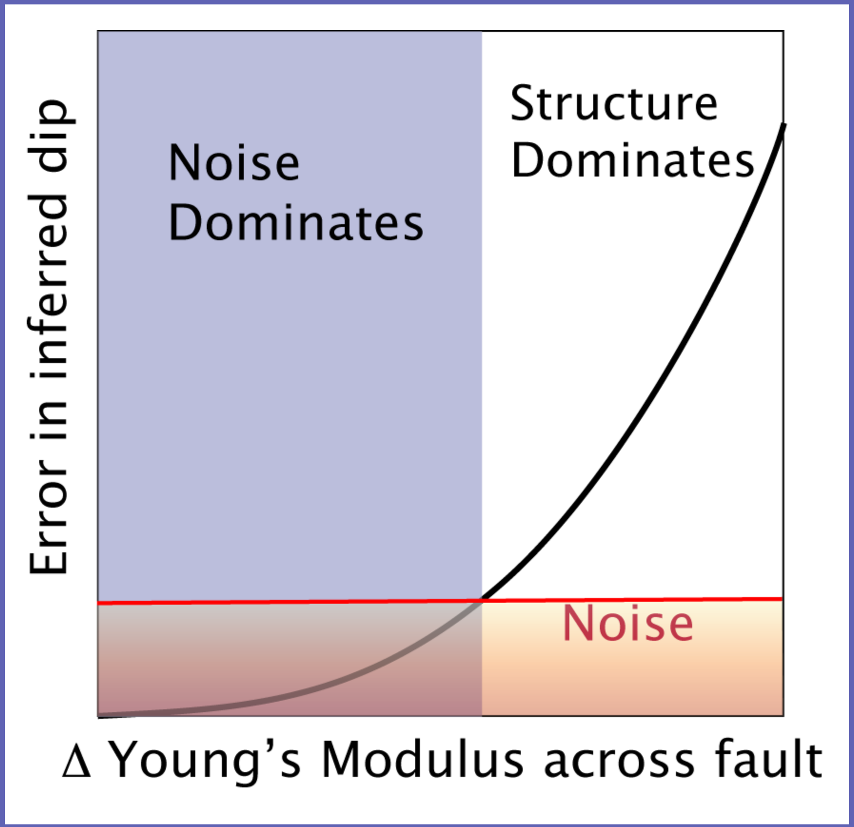
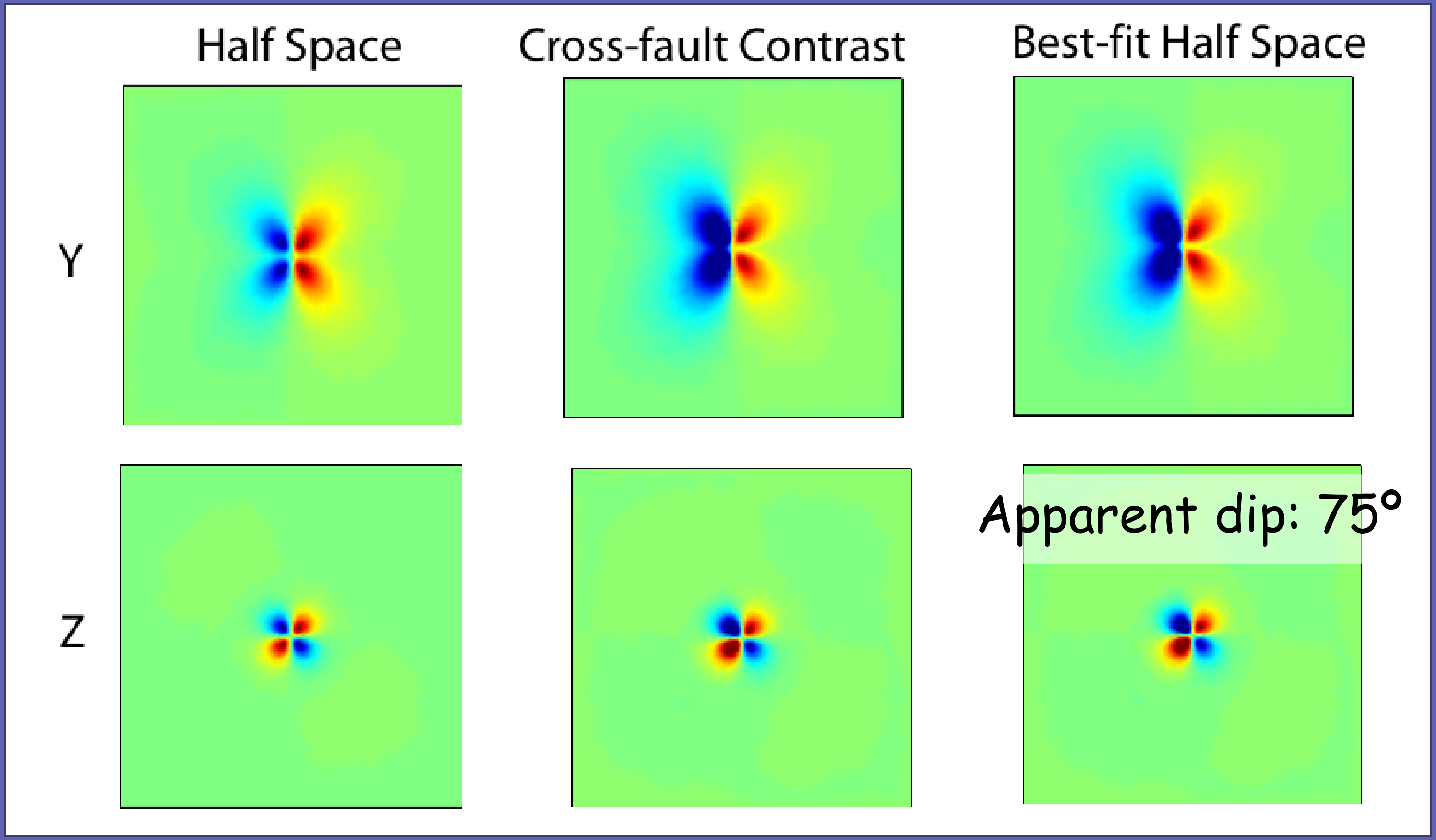
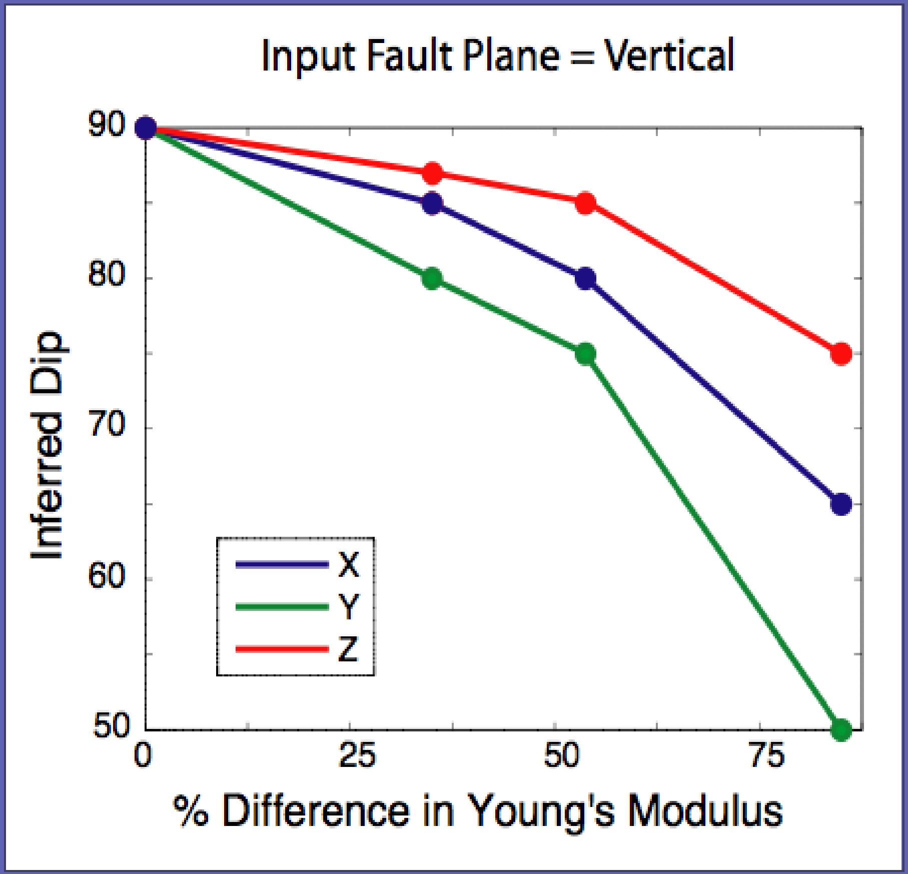


Vertical Fault Deformation Patterns

Can't fit asymmetric pattern with vertical fault



Cross-Fault Contrast Results



- Retrieve input geometry when contrast=0
- Up to 20 degree error for reasonable values
- Sensitivity depends on noise RMS, viewing geometry

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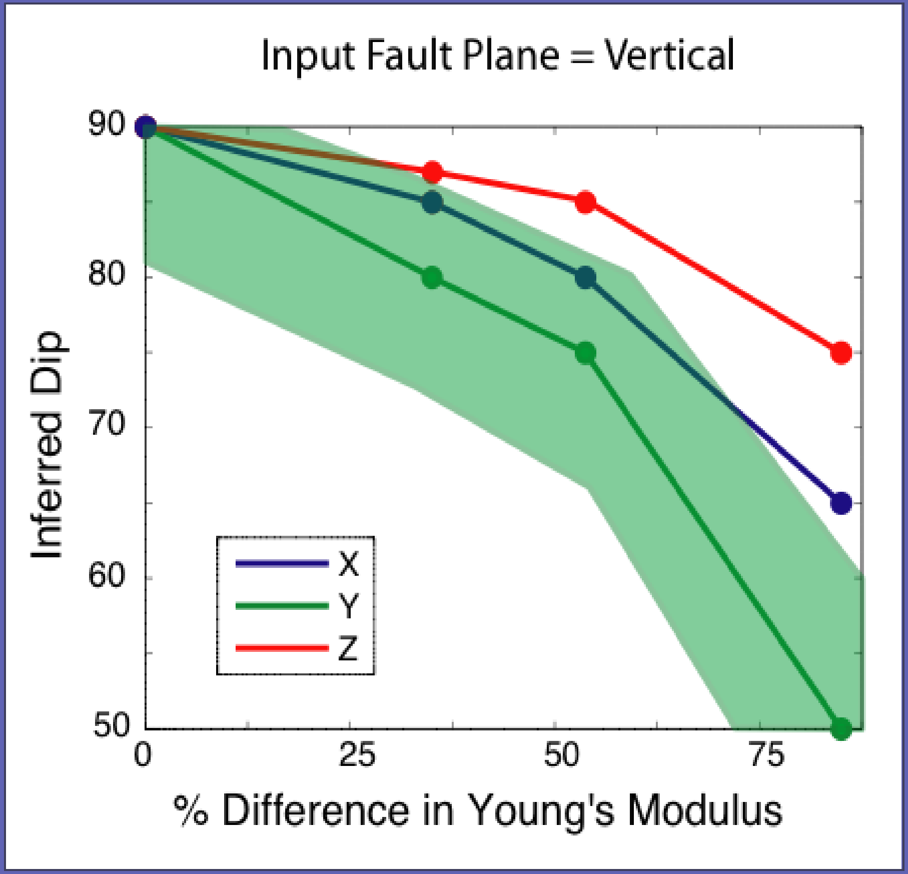

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11/27/05, Mw 6 Qeshm Island EQ

Astronaut photography
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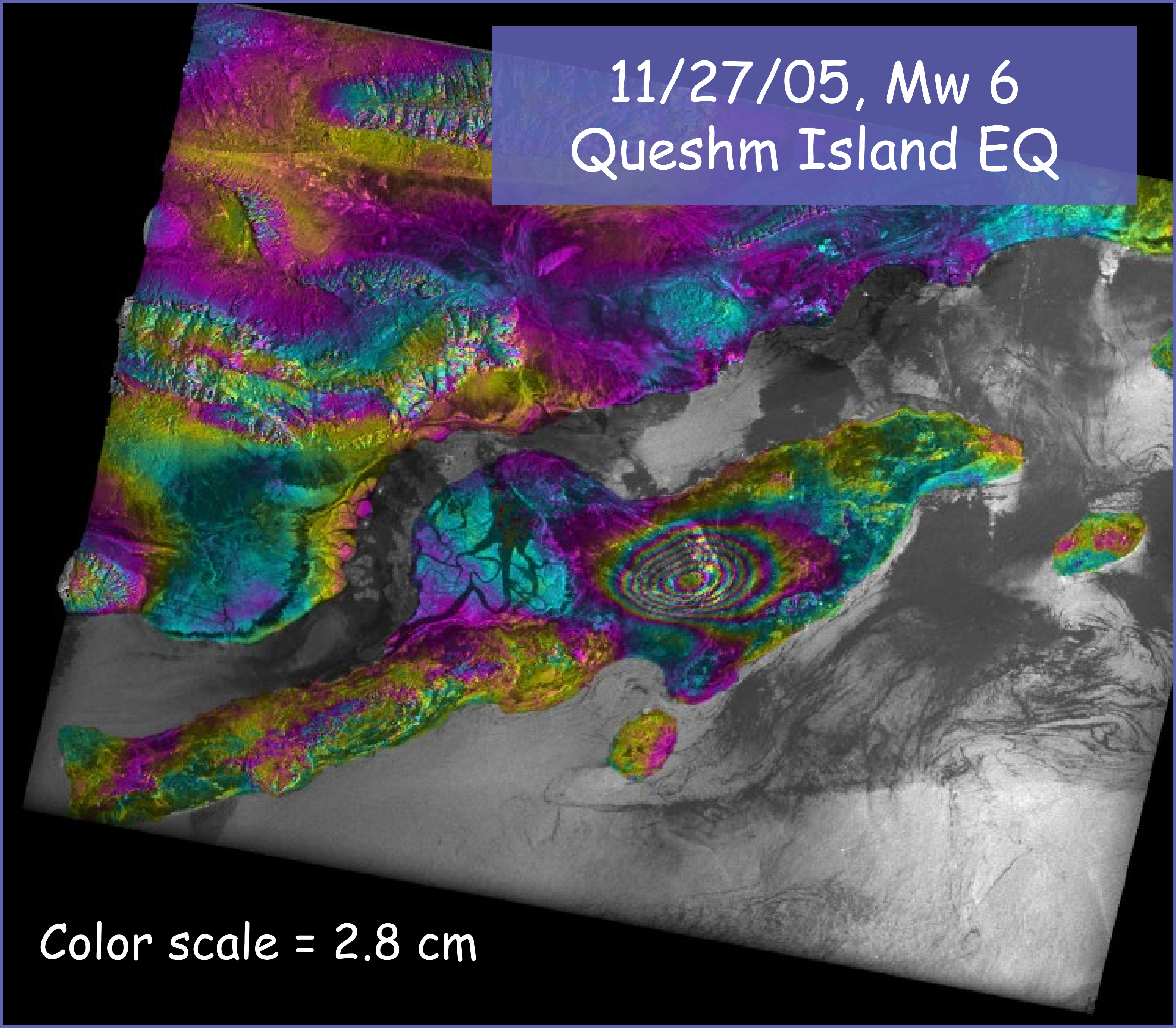
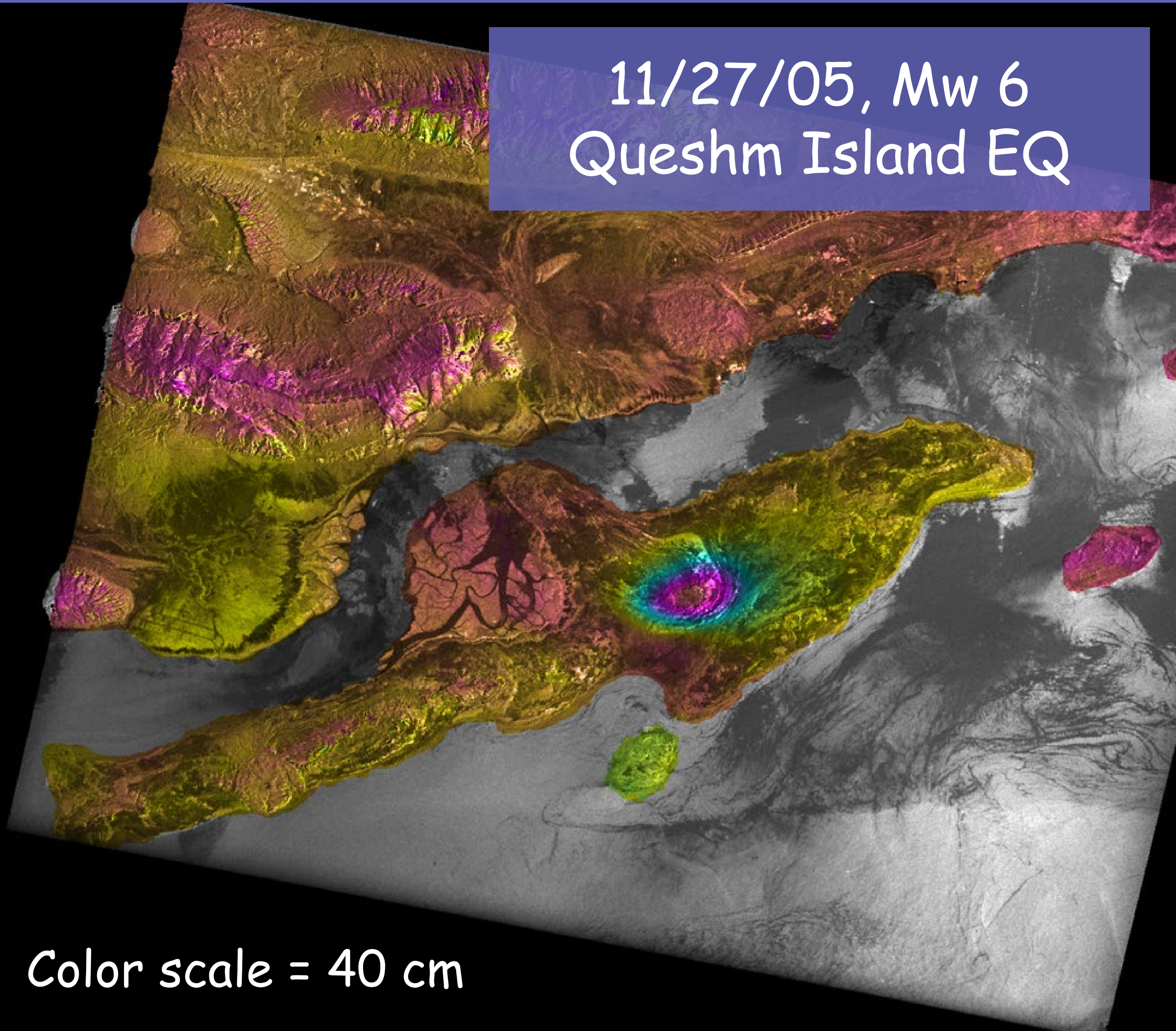

11/27/05, Mw 6
Queshm Island EQ
Color scale = 2.8 cm

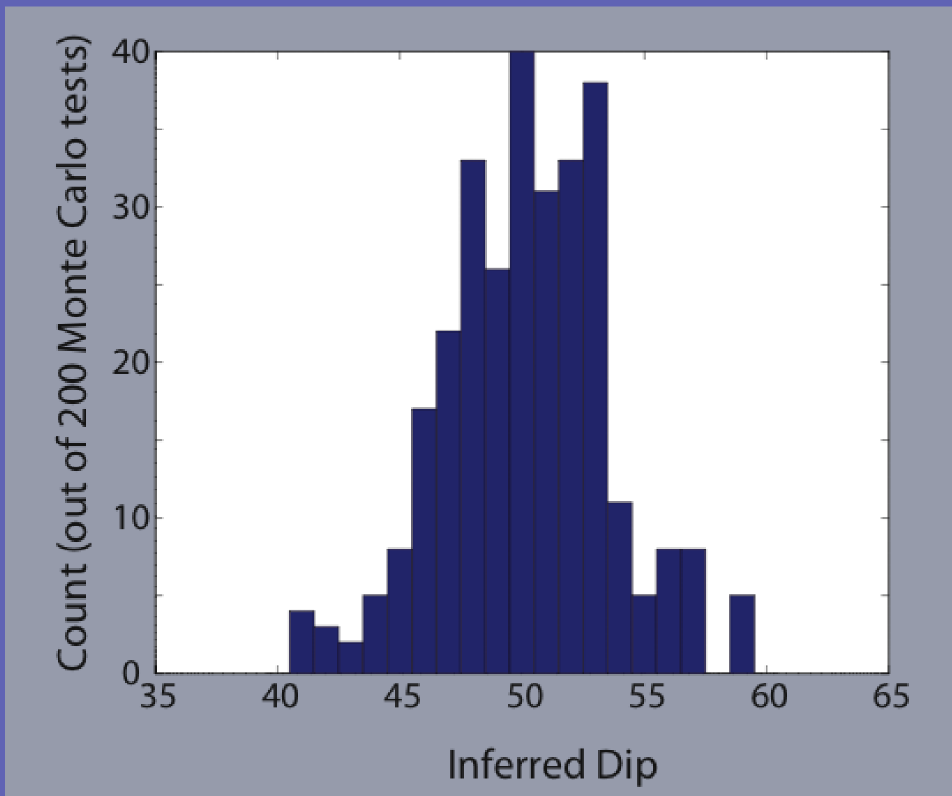
11/27/05, Mw 6 Queshm Island EQ



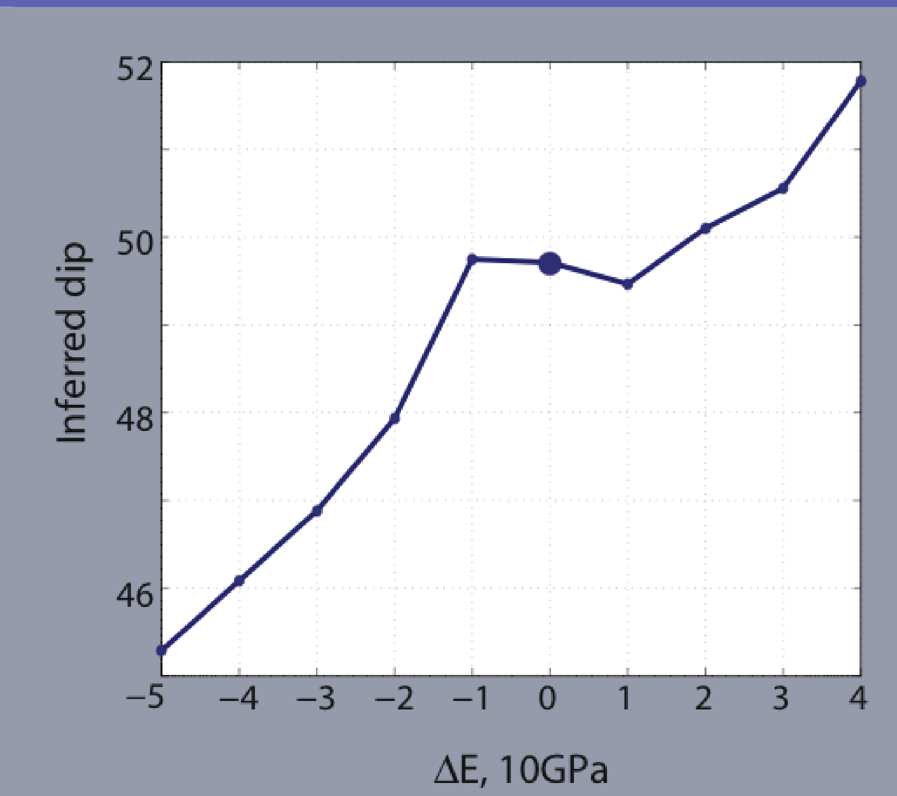
Color scale = 40 cm

Assessing Potential Bias in Inferred Dip

Error from noise



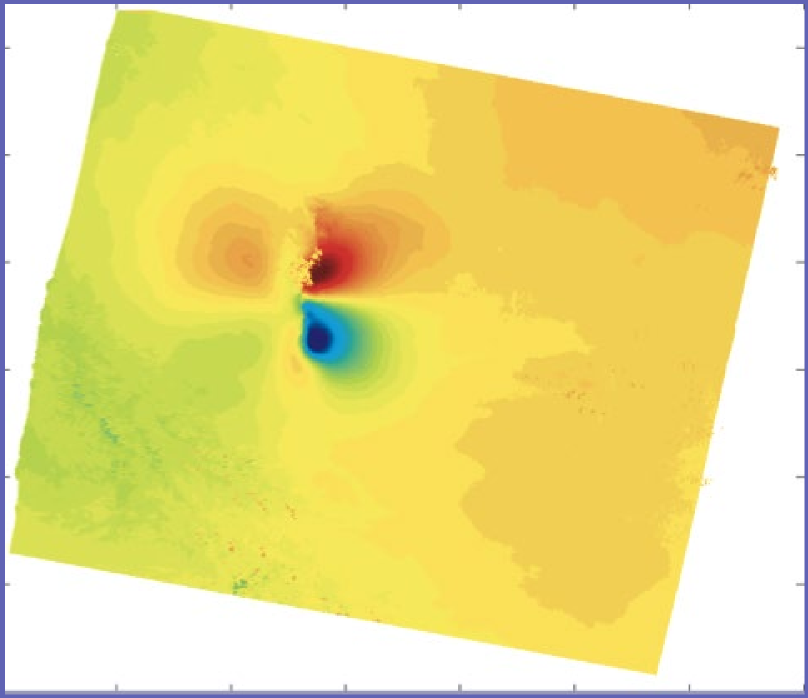
Error from structure



Atmospheric noise > Structure error

2003 Bam, Iran, Earthquake

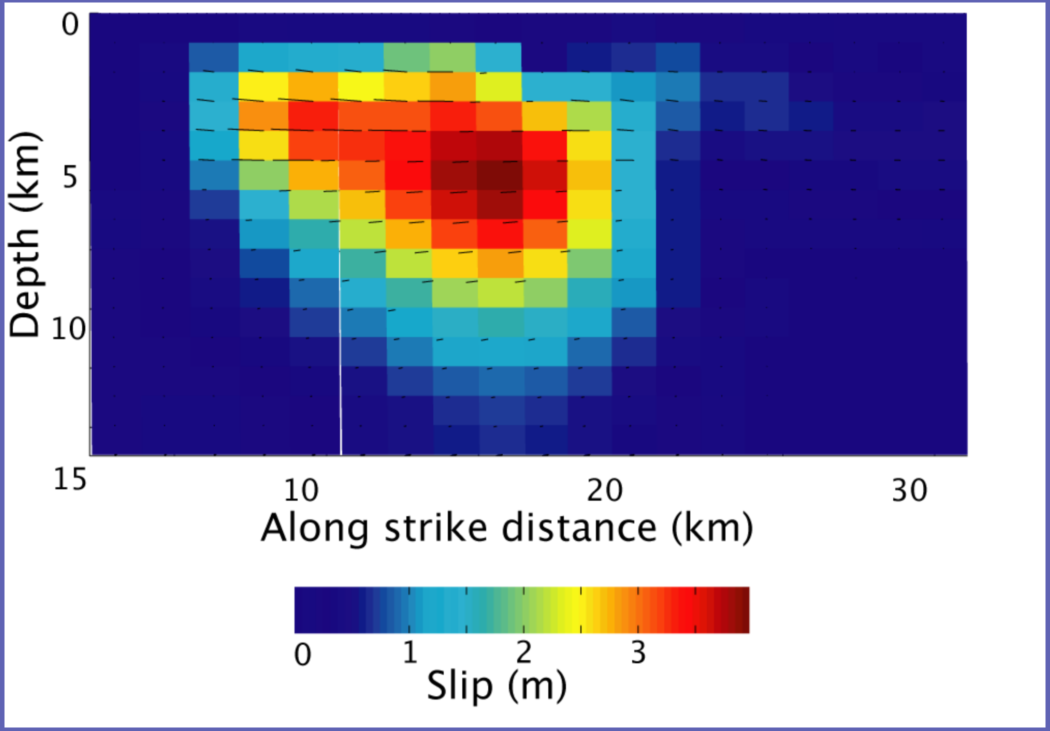
- > 40 cm line-of-sight deformation
- Not much structural/fault location info
- How well do inversions for fault dip perform?



Data courtesy Eric Fielding

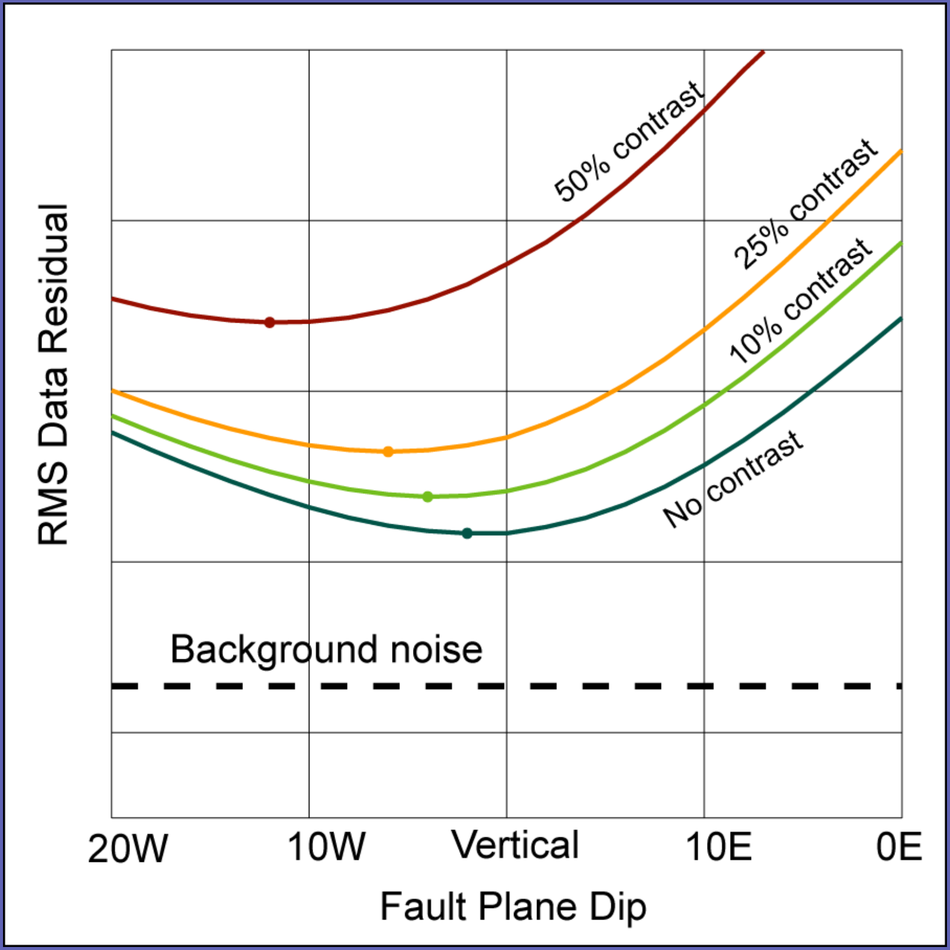
2003 Bam, Iran, Earthquake

- Pylith:
  - Generate Green's functions for distributed slip inversion
  - Repeat for various dip angles, cross-fault contrasts



2003 Bam, Iran, Earthquake

- Increased contrast = increased dip
- Best fit still no-contrast solution, near-vertical dip
- Geometrical irregularities = large residual
- Need more complicated geometry before can assess crustal contribution



Conclusions

- Sensitivity tests can largely be done with analytic inversions
- More time consuming FE modeling (especially inversions) can be avoided for many problems
  - Large atmospheric noise
  - Known fault plane geometry
- Patch by patch Green's function generation very time consuming
  - Can be a bit more efficient, use redundant dip/strike info
  - Internal Pylith Green's function producer very desirable