National Aeronautics and Space Administration

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California Institute of Technology
Pasadena, California

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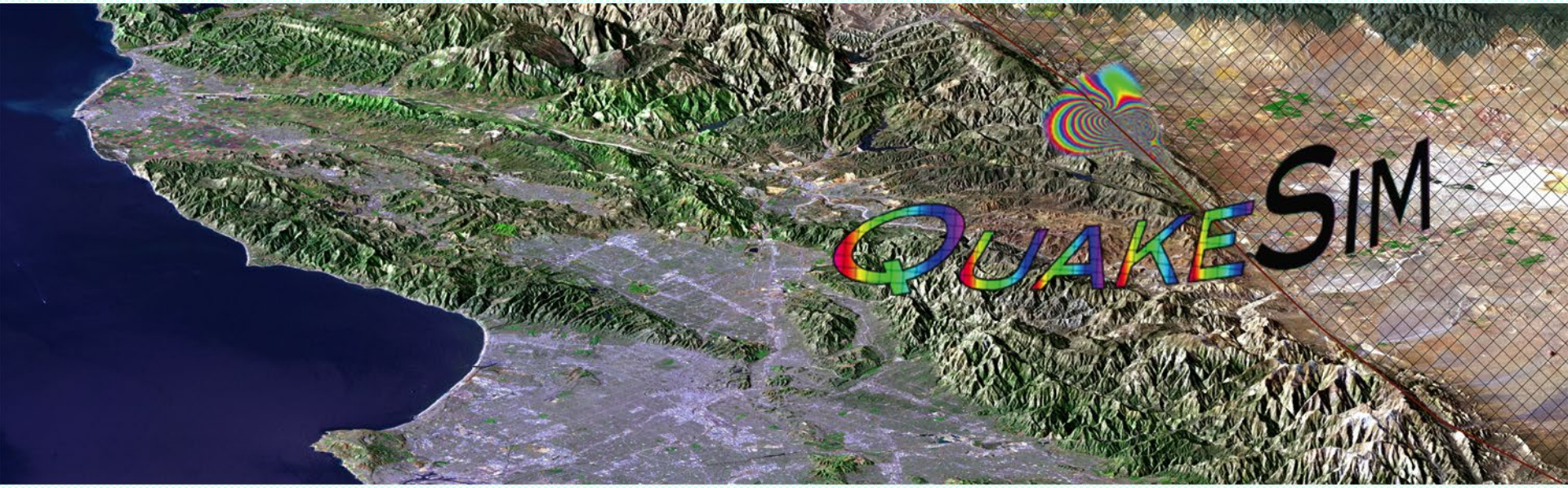
GeoFEST Progress



Jay Parker, Gregory Lyzenga, Charles Norton,
Margaret Glasscoe

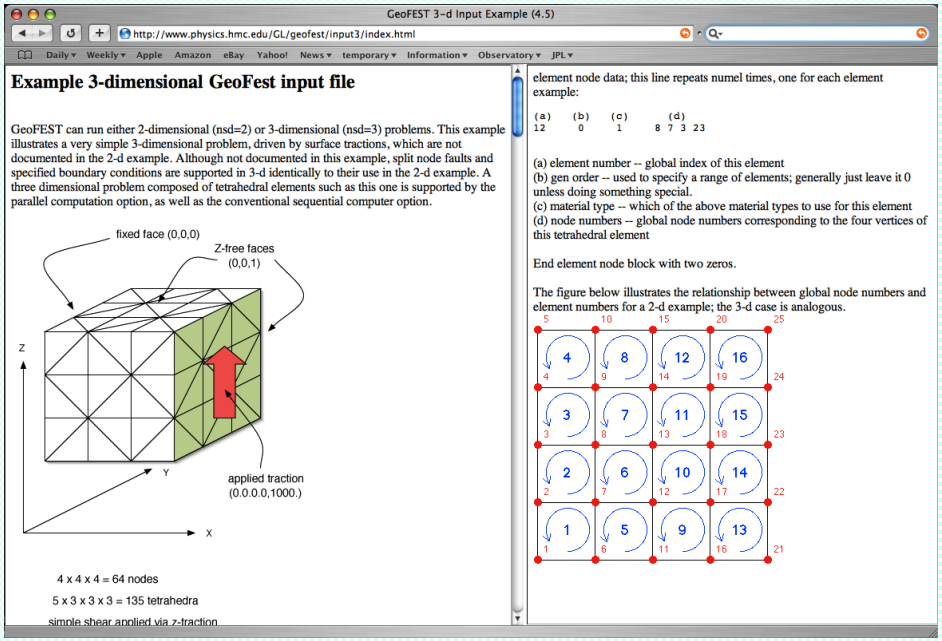
Jet Propulsion Laboratory, California Institute of Technology

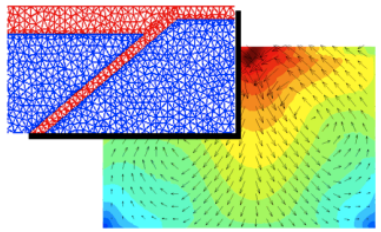
Downloading GeoFEST

- Go to http://openchannelfoundation.com/projects/GeoFEST
- Click on the "GET IT!" button.
- Follow instructions.
- Order everything (do all the check boxes).
- When notified, download everything
- Start by glancing over:
  - GeoFEST User's Guide
  - Version 4.5 of GeoFEST code
- What are the other things good for?
  - 4.5g demonstrates adaptive refinement, but is primitive, hardwired for one case.
  - 4.3p , 4.3 are obsolete, but have additional validation cases.
- For desktop computer, enough. For parallel system, get also:
  - Pyramid-1.1.5 at http://www.openchannelfoundation.org/projects/Pyramid
  - ParMetis-3.1, at http://www-users.cs.umn.edu/~karypis/metis/parmetis/index.html.

GeoFEST materials

- GeoFEST Documentation and Learning Materials
  - GeoFEST User's Guide
  - GeoFEST Introductory web page





GeoFEST v. 4.5

GEOPHYSICAL FINITE ELEMENT SIMULATION TOOL

User's Guide

rev 5: 04/01/04

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Compiling GeoFEST

- Read the README in GeoFEST-4.5/
- *Desktop version:*
  - tar xvzf GeoFEST-4.5.tgz
  - cd GeoFEST-4.5/geofest
  - make -f Makefile.Sequential
- *Parallel version (identical geofest source):*
  - Download Pyramid-1.1.5
  - Download ParMetis-3.1
  - Have MPI, a Fortran 90 compiler, and a C (99) compiler
  - Perform minor softlink surgery (see the README):
    - cd GeoFEST-4.5
    - mv Pyramid/ Pyramid.old
    - ln -s $HOME/Pyramid-1.1.5/ Pyramid
    - cd geofest
  - Invoke eg. make -f Makefile.Absoft (several make files supplied, can be adapted)

Running GeoFEST

- Uses text input file, described in **GeoFEST User's Guide**
- *Desktop version:*
  - GeoFEST <input.dat>
- *Parallel version (identical geofest source):*
  - Preprocess with gfmeshparse (collates edge face connections): <input.dat.jpl>
  - Create softlinks “input.dat”, “input.dat.jpl” if your name differs (due to hardwired code)
  - Set up queuing system script, if required (eg, direct outputs to scratch disk)
  - GeoFEST input.dat (or invoke queuing system script).
- *Portal version:*
  - Not recommended at this time for performing simulations.
  - May use portal to do automatic mesh generation for simple problems.

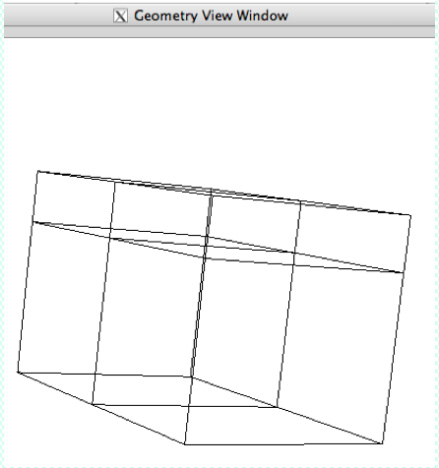
Lessons, common problems, bugs

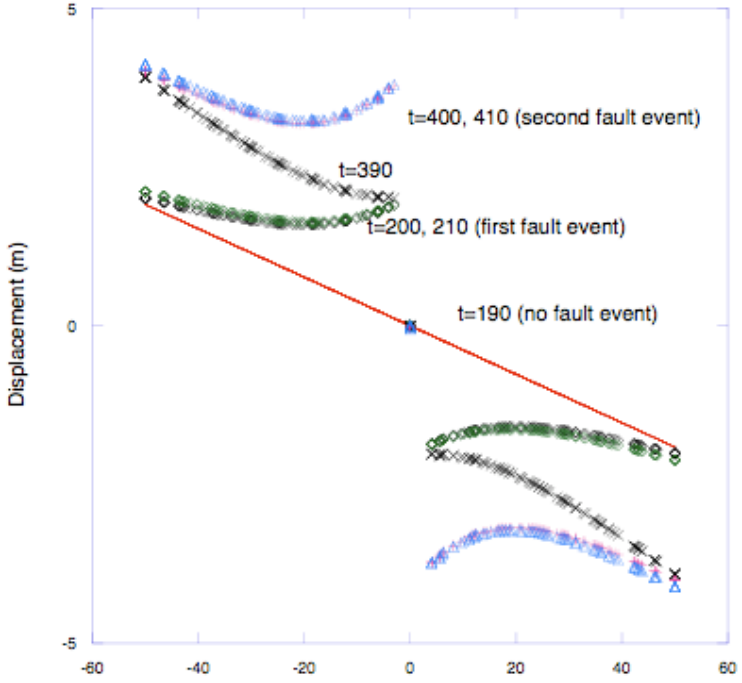
- When making plot, output and mesh must match.
  - Keep all files for one problem under one directory name
- Convergence limit in v4.5 sometimes faulty
  - May display oscillating time history or ragged plots
  - Check cghist.txt for spikes in final residual
    - starting=3.0339e-06 , ending=2.85117e-19 *<=a good residual*
    - Change CGTOL in finel.h, or modify code (ask us how).
- Thrust faults require deeper domains
  - 120 km or more?
- Beware soft materials near faults - needs fine mesh
- Relaxation after earthquake - use fine mesh near fault tips to represent VE strain that drives problem

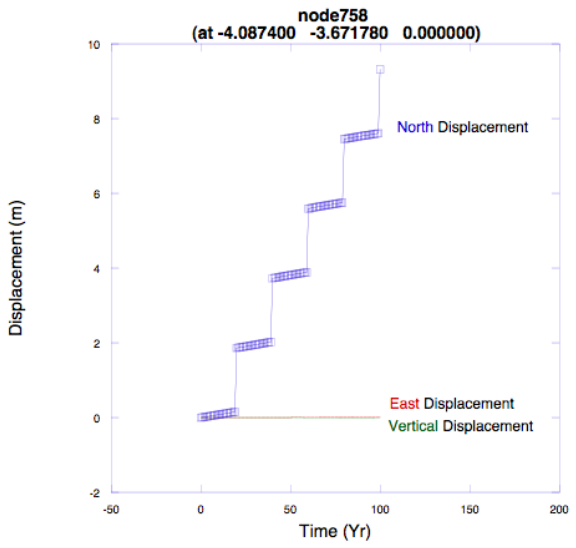
- What is GeoFEST?
  - Geophysical Finite Element Simulation Tool
  - GeoFEST solves solid mechanics forward models with these characteristics:
    - 2-D or 3-D irregular domains
    - 1-D, 2-D or 3-D displacement fields
    - Static elastic or time-evolving viscoelastic problems
    - Driven by faults, boundary conditions or distributed loads
  - GeoFEST runs in a variety of computing environments:
    - UNIX workstations (including LINUX, Mac OS X, etc.)
    - Web portal environment
    - Parallel cluster/supercomputer environment

Simple San Andreas Case

- GeoFEST improved support for tectonic shear velocity
- Uses unreleased v4.6pre-beta: multiple fault slip histories
- Crust fault slips 4 m every 200 years, sides move 0.01 m every year.
  - Lower crust locked (case 1)
  - Lower crust slips 0.02 m every year (case 2)
  - Free-slipping fault in progress



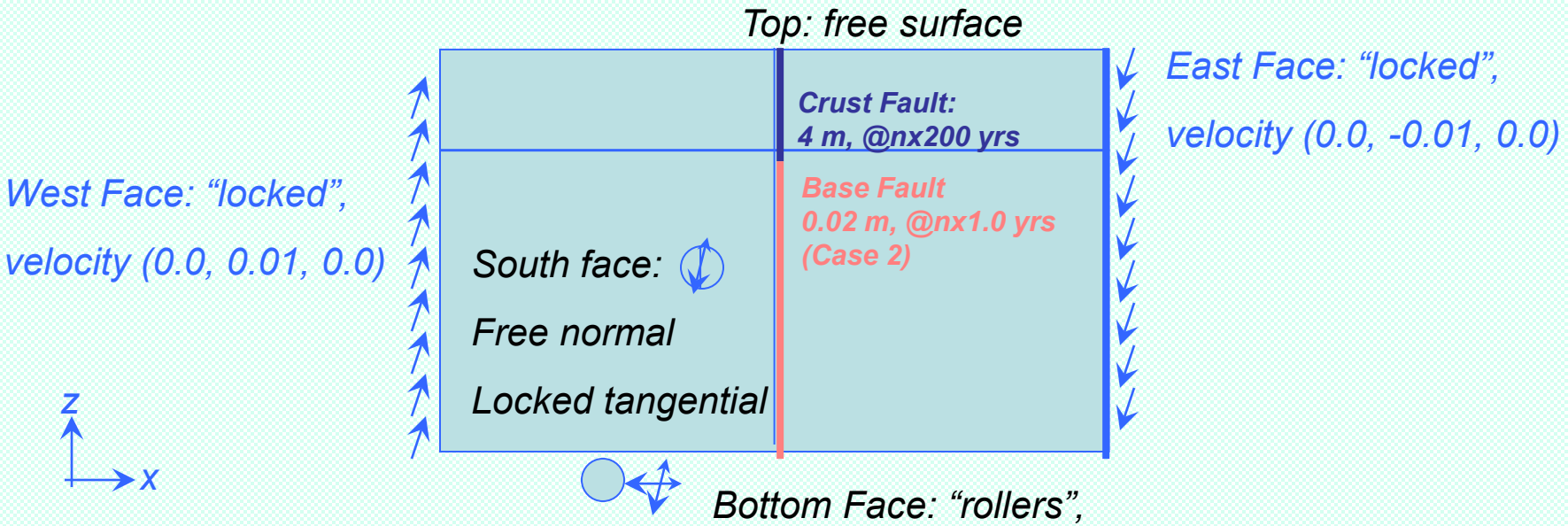




Work done with Paul Lundgren, Tectonics Laboratory R&TD

Simple San Andreas (cont)

- Boundary conditions:

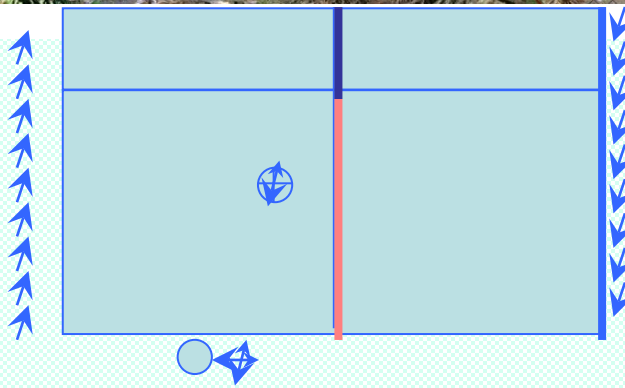


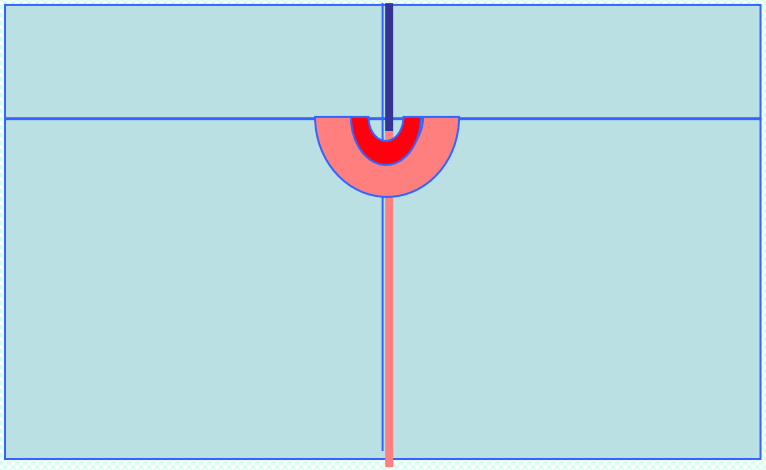
- Benchmark?
  - Really a 2D problem
  - But using a 3D mesh

Lamba = mu = 70 GPa
Viscosity ~1e20 GPa-s

Simple San Andreas - new issues

- Two strands, schedules (v4.6beta)
- Concentrated RHS source
- Requires high convergence
- Requires spin-up (5 cycles?)
- Post-event surface velocity
  - Sample of rapid decay
  - Reaching new equilibrium





Velocity profile at 810 years, ten years after a seismic event in the crust fault. Velocity is in m/yr.

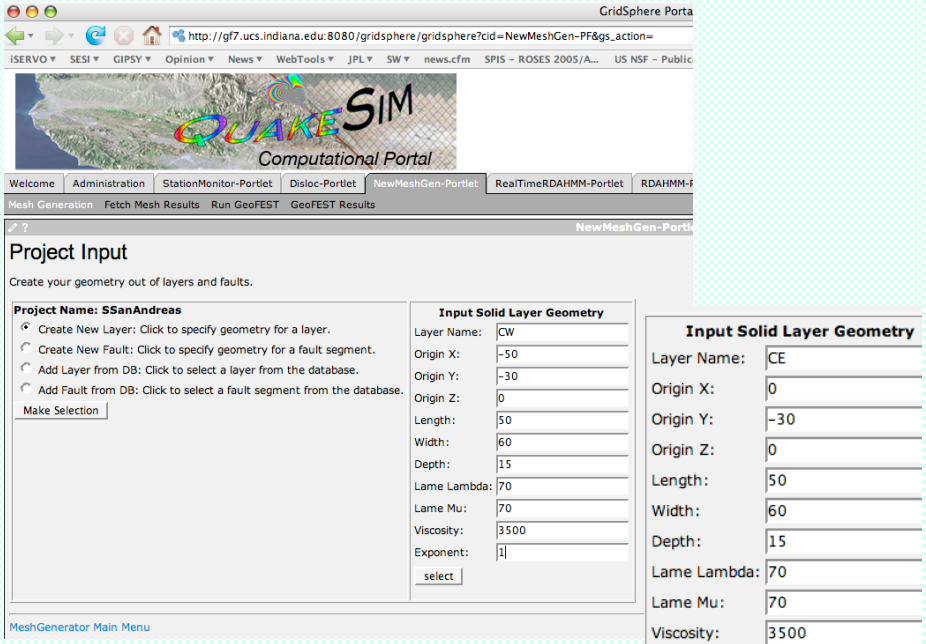
Time history of accumulated displacement (left axis, red) and instantaneous velocity (right axis, blue) based on node 405 history file. Displacement is in m, velocity in m/yr

Scatter plot
using **all** *surface nodes.*

Good: smooth
(->converged)
Poor: shape wrong
(->base mesh density)

Creating input with portal (soon)

- http://gf7.ucs.indiana.edu:8080/gridsphere/gridsphere
- Get login (even if you had one in old portal)



Generating GeoFEST input: guiVISCO route

- guiVISCO generates <proj>.node, <proj>.tetra, solids files listed in <proj>.grp: pure geometry.
- Portal allows download of these.
  - (but only for layered model, isolated faults)
- Also supply small text files:
  - Materials properties - <sld>.materials text file
  - Fault conditions - <flt>.params file
  - Boundary conditions, run details - keyword file
- geotrans: perl program that stitches all into input.dat
  - (v4.7 release)

GeoFEST Problem Definition

Faults, Layers

Solid Geometry

Tetrahedral Mesh

Simulation Specification

Material Properties

Boundary Conditions

Input File

Run GeoFEST

Visualization

Setting geometry (QuakeTables fault database)

Mesh generation

GeoFEST simulation, job sumbission and control

Quick-view visualization

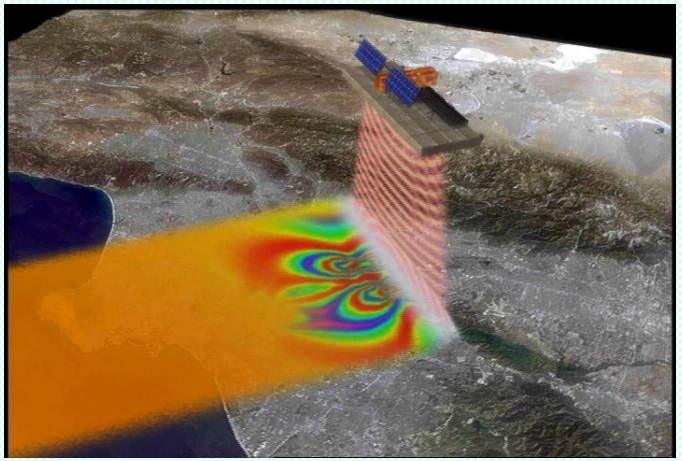
Next Release v4.7 by October 2007

QUAKESIM

- Buoyancy elements, multiple independent fault strands
- Verify adapted mesh with surface velocities
- Improved iterative convergence control, do-slip flag control
- Automatic refinement, percentage control
- Upgraded *geotrans* tools for input generation
- Documentation: SimSanAn driven crust 2-rate problem
- Validation of build packages - many parallel systems

Later release: 4.8?

- Fix for Columbia communications bottleneck
- Any-time AMR (directives, psuedo-strain energy)
- Truss (free-slip) elements validation and support tools
- Additional fault-slip models
- Conversion from Cubit, LaGrit mesh generation
- Major changes to inputs/outputs using XML, netCDF



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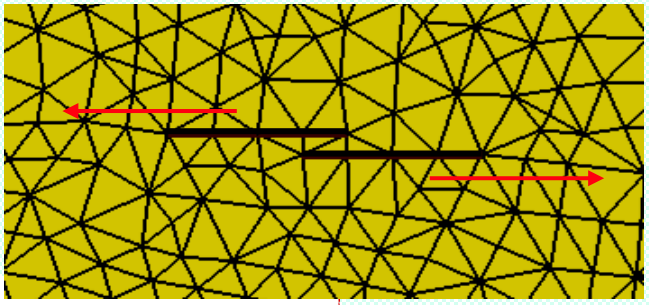
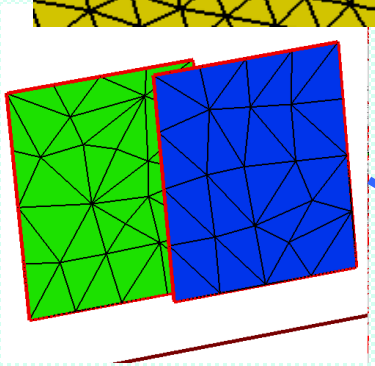
Adaptive Meshing

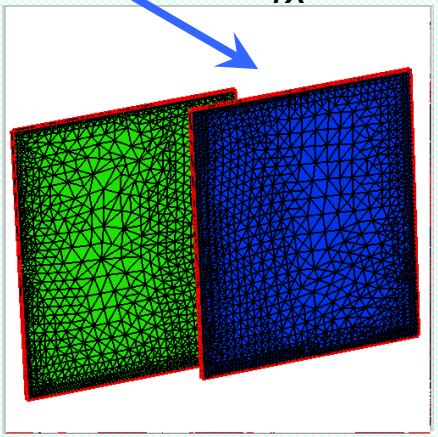
Initial surface mesh (center portion):





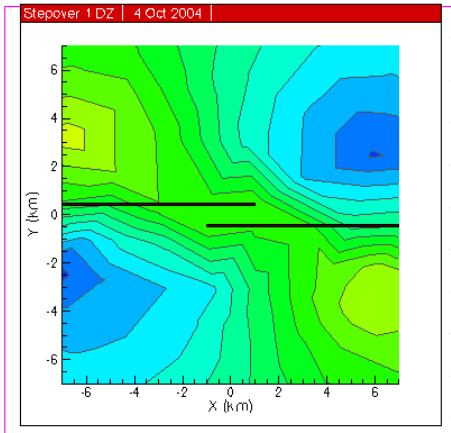
Obtain elastic solution
Strain energy
Refine
4x

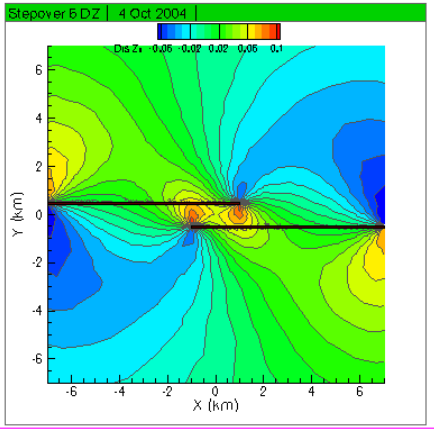
Mesh on faults (side view)



- guiVISCO method (preprocess)
- PYRAMID parallel library *(NASA ESTO CT Project)*
  - Changes mesh after import to cluster
  - Strain energy guides 3D refinement

Z component at surface
Refinement cycles 1 and 6





Detailed Validation
GeoFEST vs. Analytic Fault Stepover

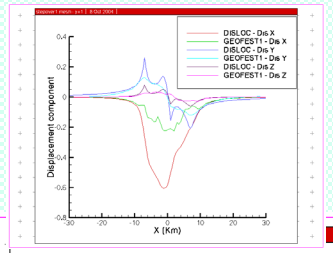
QUAKESIM

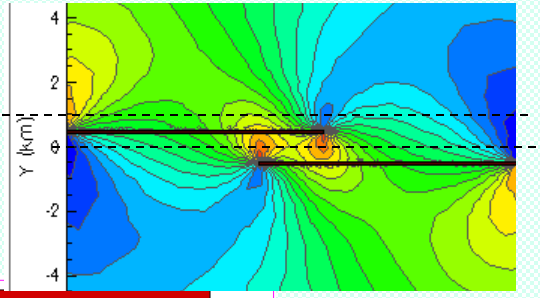
First Refine:
143,000 Elements

Second Refine:
195,000

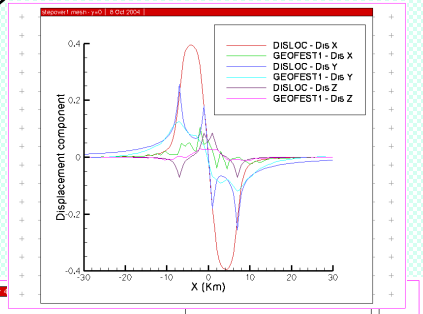
Third Refine:
263,000

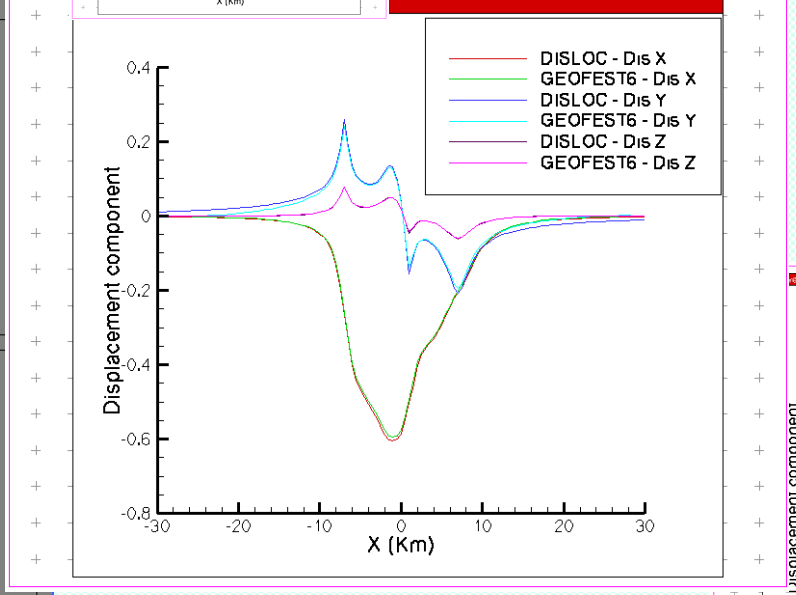
X,Y, Z components
Surface, horizontal line at y=1
Iteration 1 vs. 6

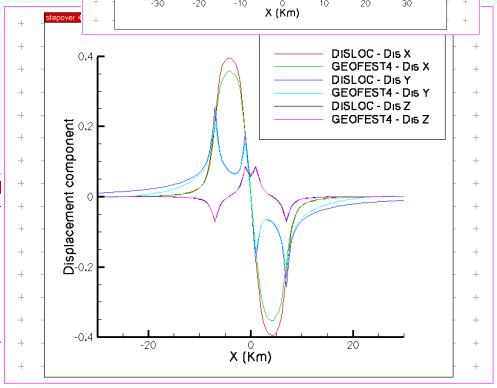


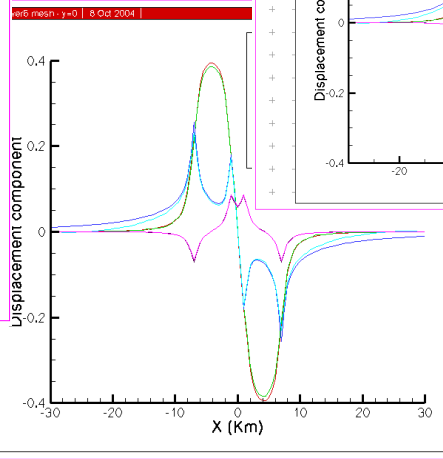


X,Y, Z components
Surface, horizontal line at y=0
Iterations1,4,6









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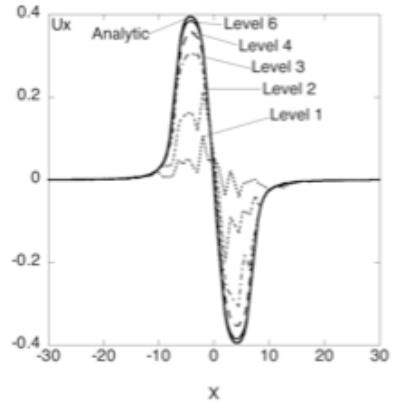
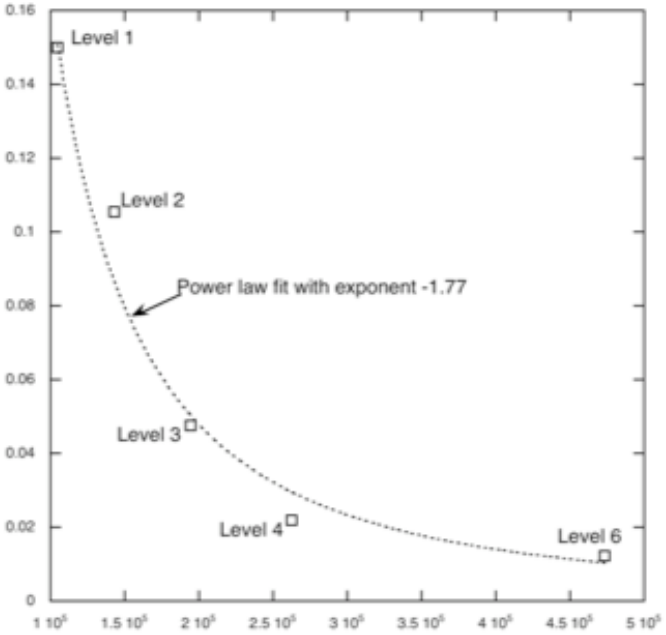
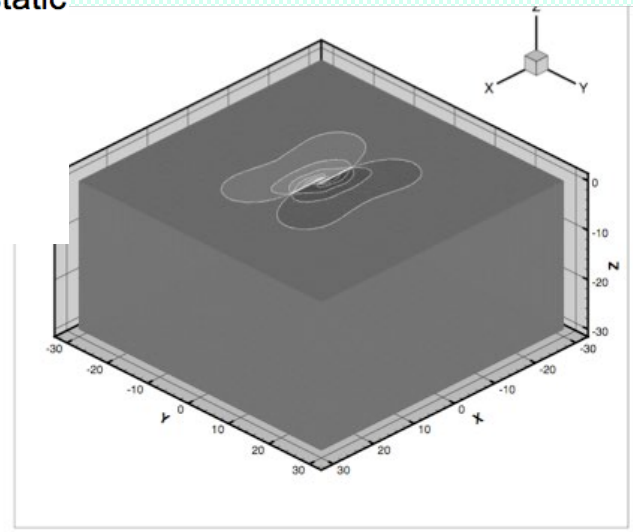
Stepover validation Pure and Applied Geophys. ACES issue (In review)

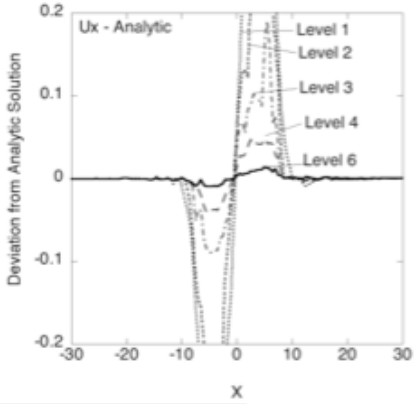
(GeoFEST): algorithms and validation for quasistatic regional faulted crust problems.

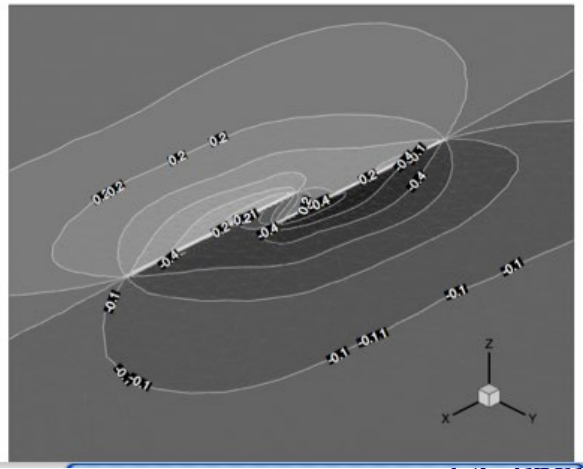
Jay Parker[(1)], Gregory Lyzenga[(1)], Charles Norton[(1)], Cinzia Zuffada[(1)], Margaret Glasscoe[(1)], John Lou[(1)], Andrea Donnellan[(1)].





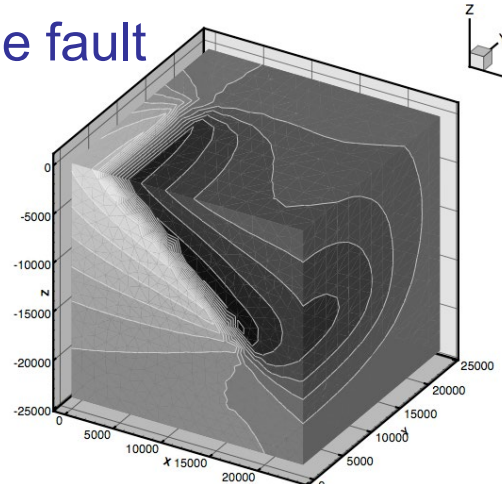


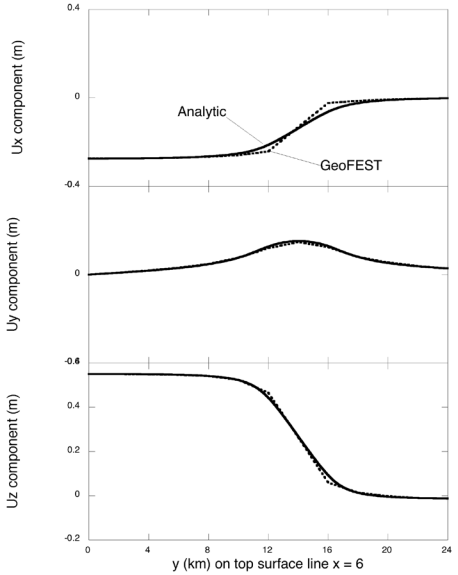




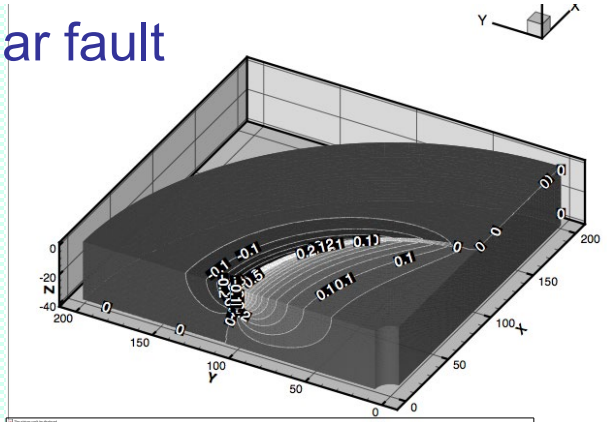
CFEM Workshop Cases

Reverse fault





Circular fault

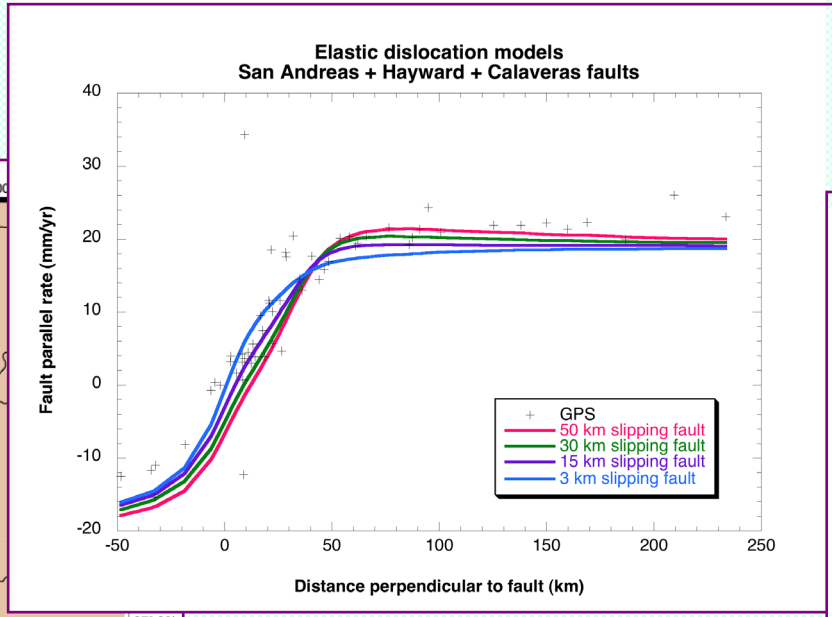


--Workshop on Community Finite Element Models for Fault Systems and Tectonic Studies

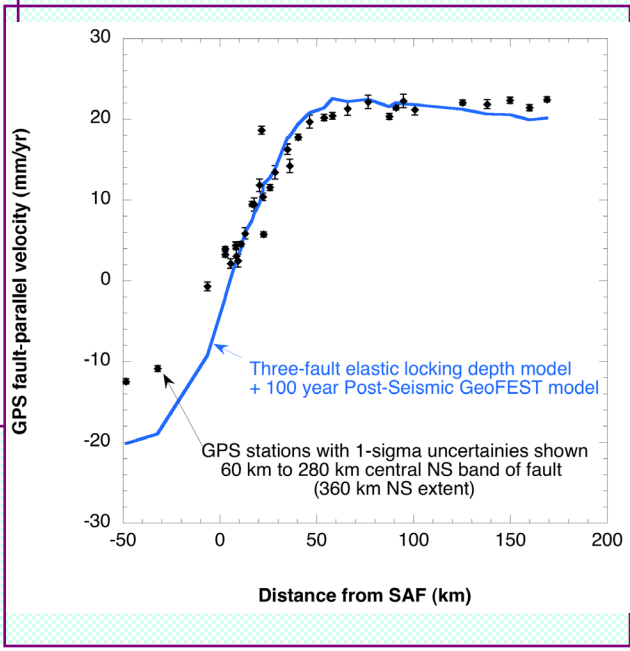
1906 Earthquake Models

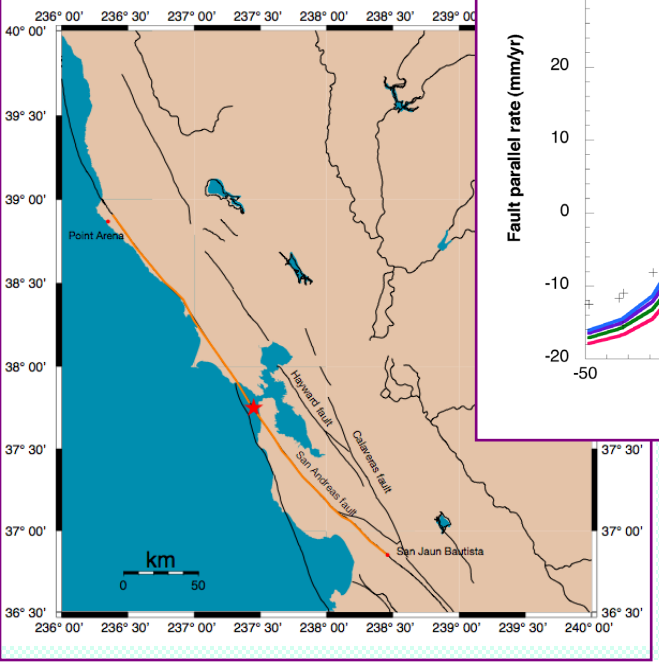
The effects of the earthquake may still be detectable in the crust 100 years after the event. GeoFEST results indicate 2-6 mm/yr of postseismic velocities for lower-crust Maxwell times of order 50 years.

Right: Elastic dislocation results, note they do not match GPS perfectly



Below: Combined elastic and viscoelastic model results. These results provide a better match to the GPS data.





Left: Location map of the 1906 rupture (orange) and epicenter (red star) and faults in this study.

100 Million Elements?

- C. Norton has set up runs on Project Columbia
  - up to 100 million elements
  - 2000 processors
  - working through speed, disk access issues
- Automated mesh refinement
  - Parallel refinement key to these very large runs
  - Demonstrated on initial elastic solution strain energy metric
  - Working toward percent-refinement where needed
  - Multiple stage refinement
  - Separate refinement criterion for first VE step after event

How using Pyramid

- v4.5 (Sequential code): skips (and won't refine)
- (parallel) Pyramid handles partition, MPI communication (won't refine)
- v4.5g: demonstrates Pyramid refinement 10M->16M
- v4.6beta: initial elastic energy (threshhold)
- v4.7: Pyramid x% refinement on initial elastic energy
  - October 2007
- v4.8: Pyramid x% times n, events and 1st post-event
  - Spring 2008?

Summary

- Downloading, compiling and running GeoFEST
- Lessons, mistakes and bugs
- Simple San Andreas geometry - simple, but issues
- Doing SimSanAn case: portal for initial mesh, GeoFEST tools for solution and visualization
- Accuracy: Validations submitted to Pageoph. special issue
- More robust features in v4.7 release, October (?)
- Convenient features in v4.8 release (Spring ‘08?)
- More SF quake simulations, 100M element Columbia run, AMR extensions in progress (Glasscoe, Norton).