Crustal Deformation Modeling Tutorial

Example: 2-D Subduction Zone with Coseismic and Interseismic Deformation

Brad Aagaard
Charles Williams
Matt Knepley

CIG
Computational Infrastructure for Geodynamics

June 22, 2011
2-D Subduction Zone Example

Features illustrated in this example

- Generating a finite-element mesh using CUBIT
  - Nonplanar geometry
  - Variable mesh resolution
- Spatially variable coseismic slip
- Maxwell viscoelastic relaxation
- Files are located in examples/2d/subduction (v1.6.0 and later)
2-D Subduction Zone Example
Based on 2011 M9.0 Tohoku, Japan, earthquake
Steps in Subduction Zone Example

Step 01: Coseismic slip

Step 02: Interseismic deformation

Step 03: Seismic cycle
Parameters Common to All Steps

- **Bulk constitutive models**
  - **Crust**: Linear elastic w/plane strain (ElasticPlaneStrain)
  - **Mantle**: Linear Maxwell viscoelastic w/plane strain (MaxwellPlaneStrain)

- **Faults w/prescribed slip**
- **Fixed boundaries (except subducting slab)**
Mesh Generation via CUBIT
Include topography/bathymetry and slab geometry

1. Create geometry
   1. Create points
   2. Connect points into spline curves
   3. Split curves to form bounding curves
   4. Connect curves into surfaces
   5. Stitch surfaces together

2. Define meshing scheme and cell size variation
   1. Define cell size along curves near fault
   2. Increase cell size away from fault at geometric rate (bias)

3. Generate mesh

4. Create boundary conditions

5. Export mesh
Step01: Coseismic Slip
Prescribed slip based on Gavin Hayes’s rupture model
Step02: Interseismic Deformation
Aseismic creep along interface between slab and mantle

Steady aseismic creep
Step03: Seismic Cycle
Interseismic deformation with coseismic slip at 150 years

Earthquake @ t=150 yrs

Steady aseismic creep
Suggested Modifications

Examples of how to work towards real research problems

- Add depth dependent viscosity to the mantle
- Add viscosity to the oceanic crust to permit relaxation at depths below 50 km
- Modify the spatial database files for the material properties to use depth-dependent elastic properties based on PREM
- Mesh the geometry using quad4 cells rather than tri3 cells
- Add multiple, repeated earthquake ruptures and examine spinup towards a steady-state solution