Crustal Deformation Modeling Tutorial

PyLith/CUBIT: 2-D Subduction Zone with Coseismic and Interseismic Deformation

Brad Aagaard
Charles Williams
Matthew Knepley

June 19, 2012

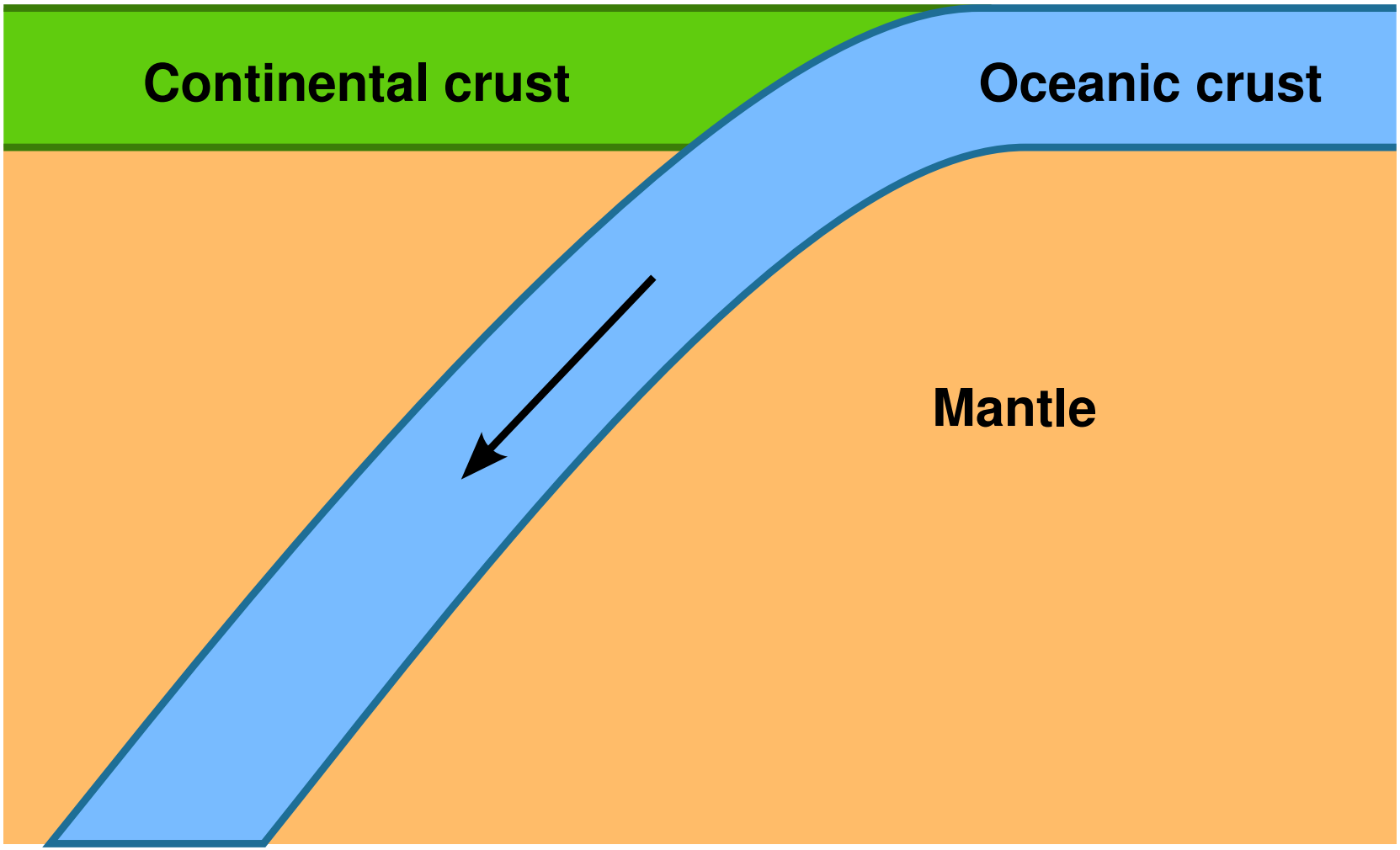
2-D Subduction Zone Example

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 `src/pylith/examples/2d/subduction`
- `Steps 1-3`: This tutorial
- `Step 4`: Tomorrow's afterslip tutorial

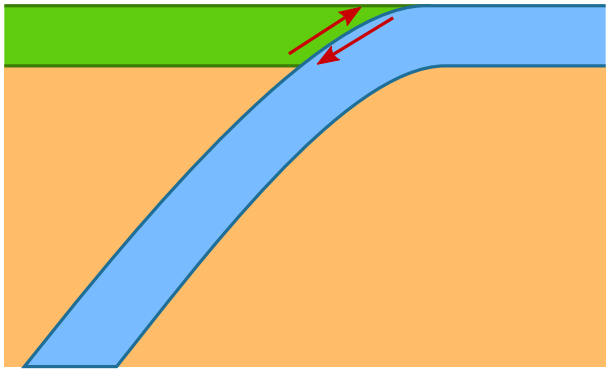
2-D Subduction Zone Example

Based on 2011 M9.0 Tohoku, Japan, earthquake

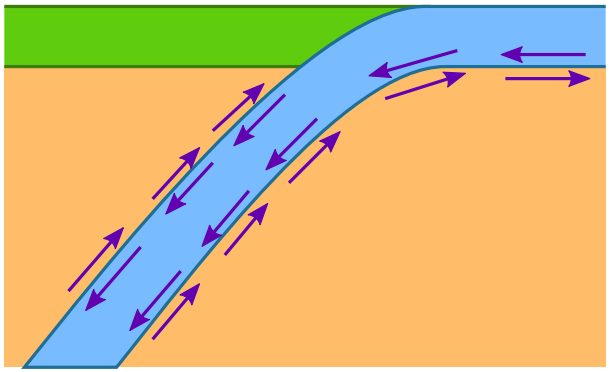


Steps in Subduction Zone Example

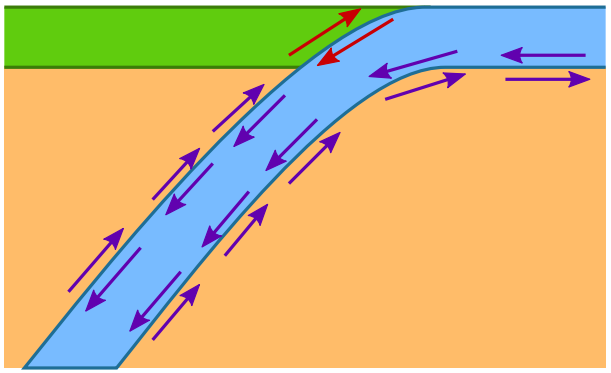
Step01: Coseismic slip



Step02: Interseismic deformation



Step03: 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)

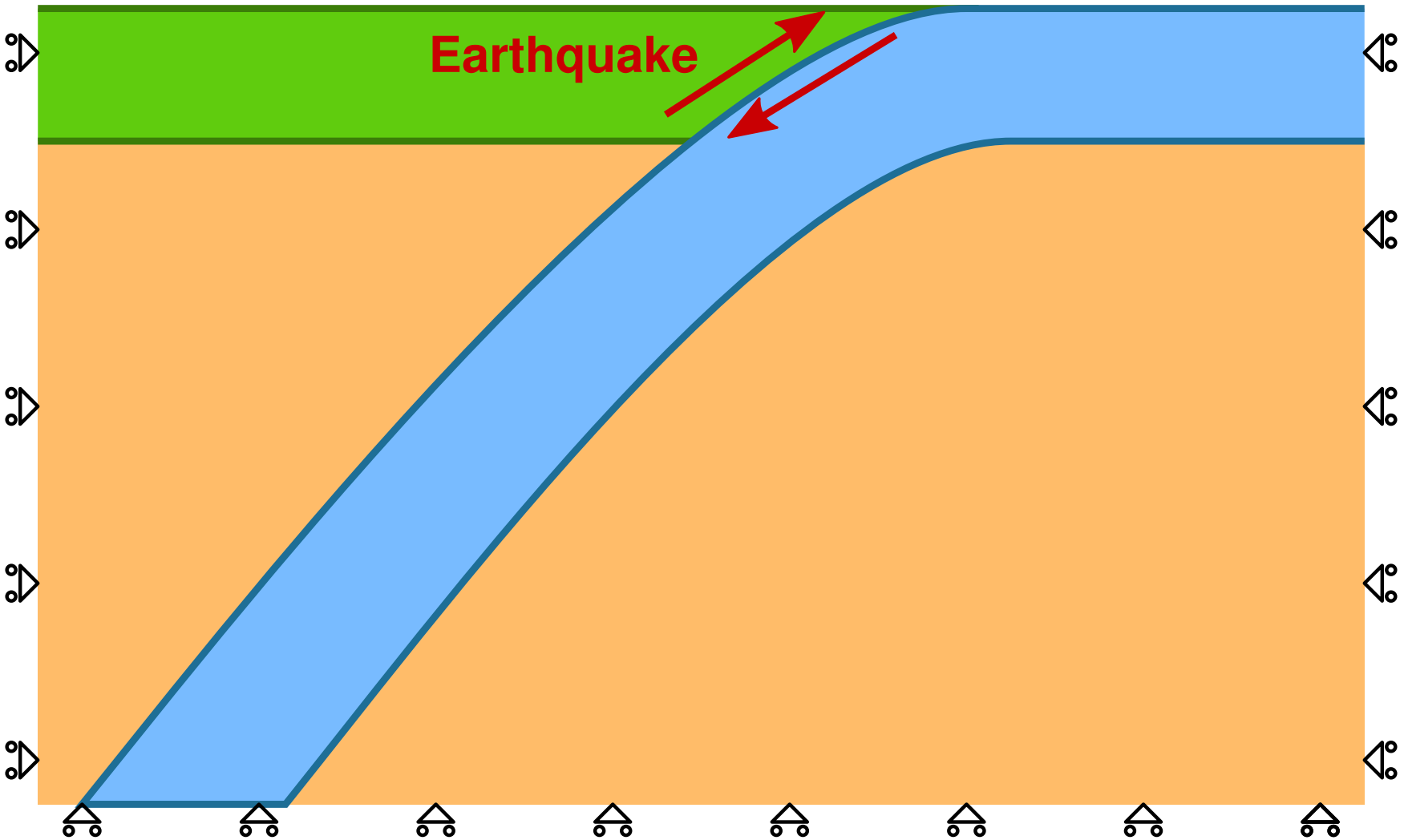
Mesh Generation via CUBIT

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

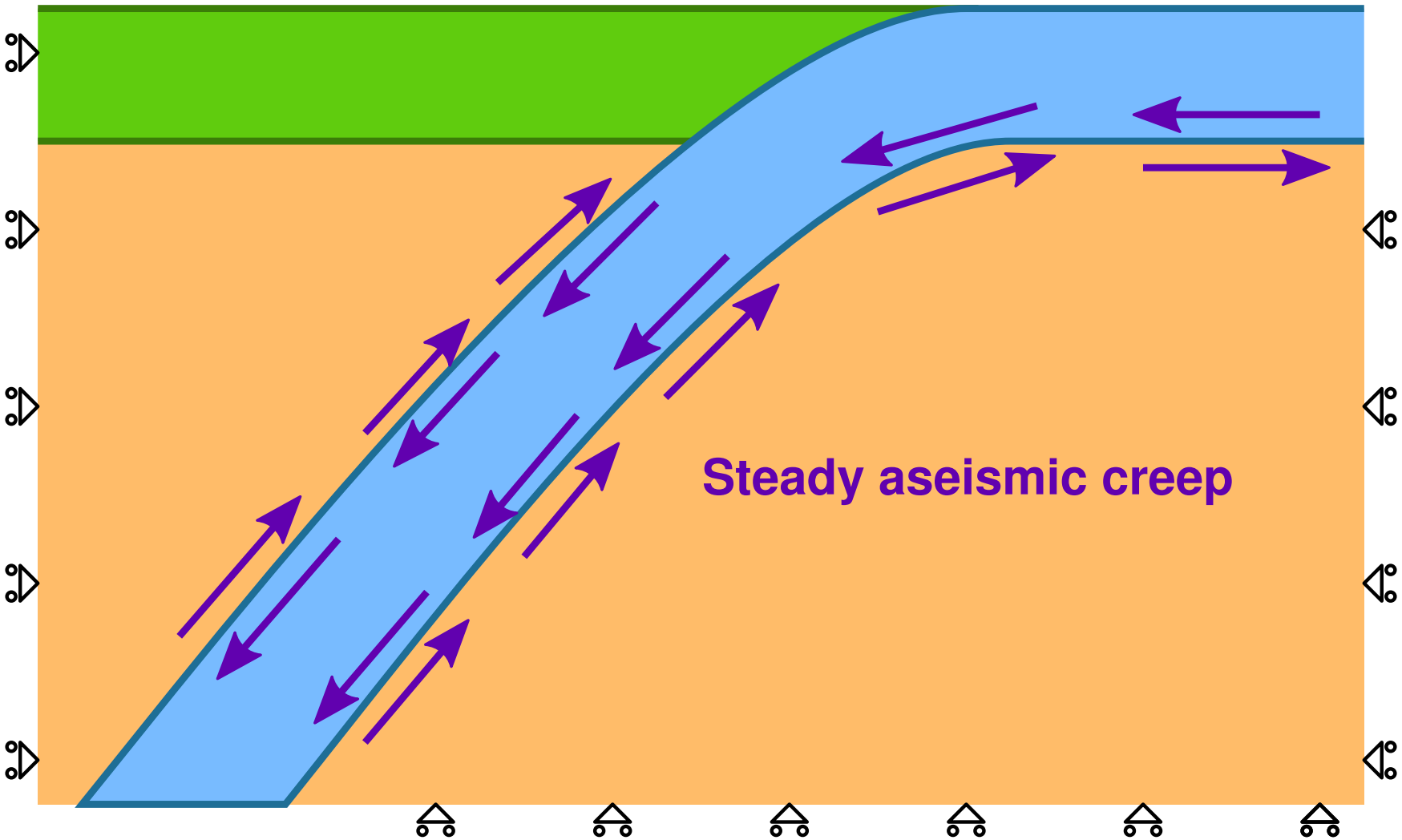
Step01: Coseismic Slip

Prescribed slip based on Gavin Hayes's rupture model



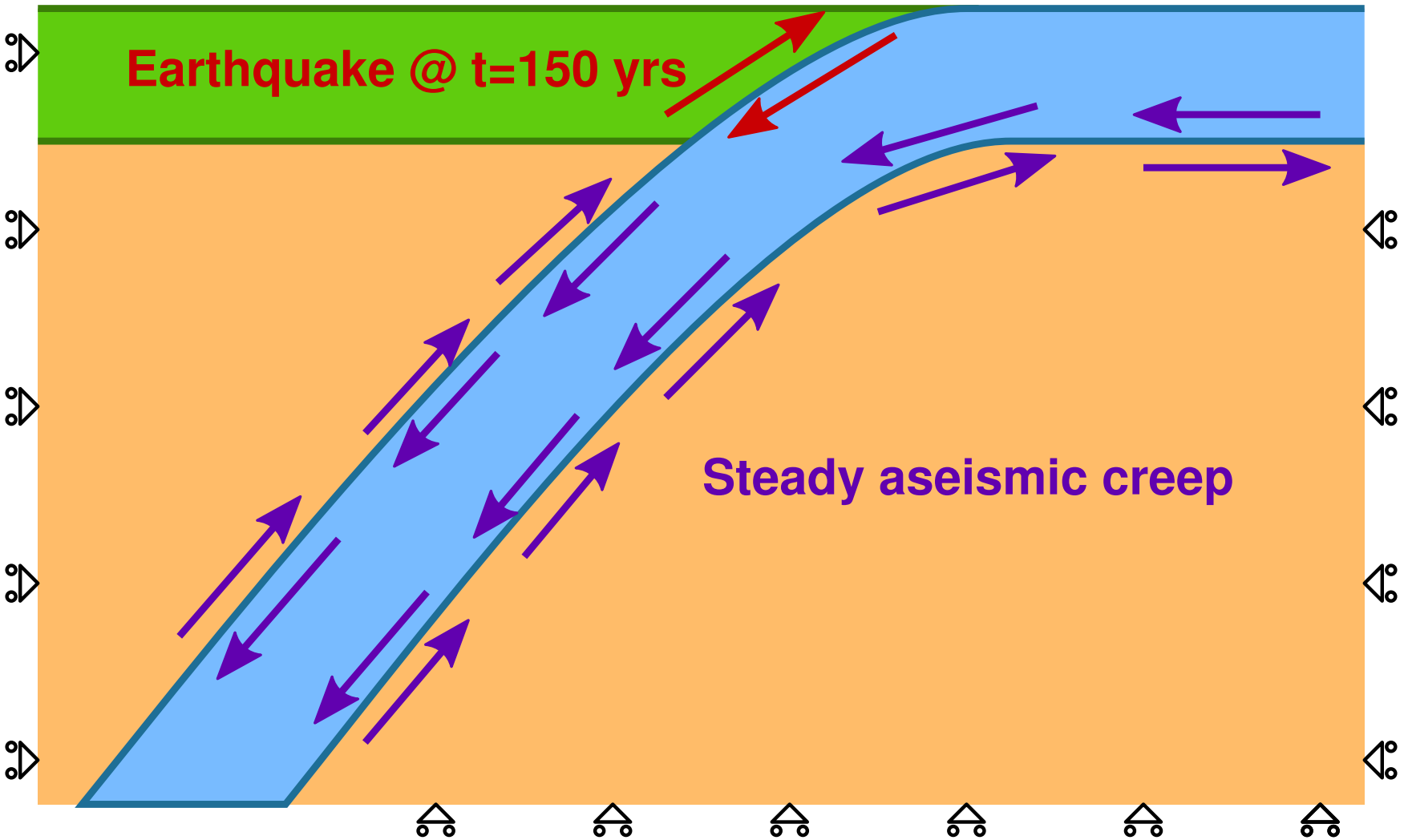
Step02: Interseismic Deformation

Aseismic creep along interface between slab and mantle



Step03: Seismic Cycle

Interseismic deformation with coseismic slip at 150 years



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