

Crustal Deformation Modeling Tutorial

Using Gravity and Initial Stresses

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Concepts Covered in this Session

- When are gravitational stresses necessary?
- Usage of gravitational body forces in 3D
- Usage of initial stresses
- Usage of small strain formulation in 3D
- Viscoelastic relaxation with a linear Maxwell model
- Spatial database with irregular distribution of points in 3D

NOTE: Accuracy and convergence for gravitational problems will be much improved once PyLith includes higher-order elements.

When Do We Need to Use Gravitational Stresses?

- Pressure/stress-dependent rheology
 - Pressure-dependent bulk rheology (e.g., plasticity)
 - Stress-dependent fault rheology (e.g., friction)
- Viscoelastic simulations where we care about vertical deformation
- Other simulations where we care about the absolute stress state

Other Gravity Examples

- 2-D examples: [examples/2d/gravity](#)
 - Steps 1-3: Body forces, initial stresses, infinitesimal strain
 - Step 1: Body forces + infinitesimal strain
 - Step 2: Body forces + infinitesimal strain + initial stress
 - Step 3: Step 2 + local density variation
 - Steps 4-7: Body forces, initial stresses, finite/infinitesimal strain with postseismic relaxation
 - Step 4: Relaxation with infinitesimal strain and no gravity
 - Step 5: Relaxation with finite strain and no gravity
 - Step 6: Relaxation with infinitesimal strain and gravity
 - Step 7: Relaxation with finite strain and gravity
 - Step 8: Usage of initial state variables and density variation
- 3-D examples: [examples/3d/hex8/step15-17](#)

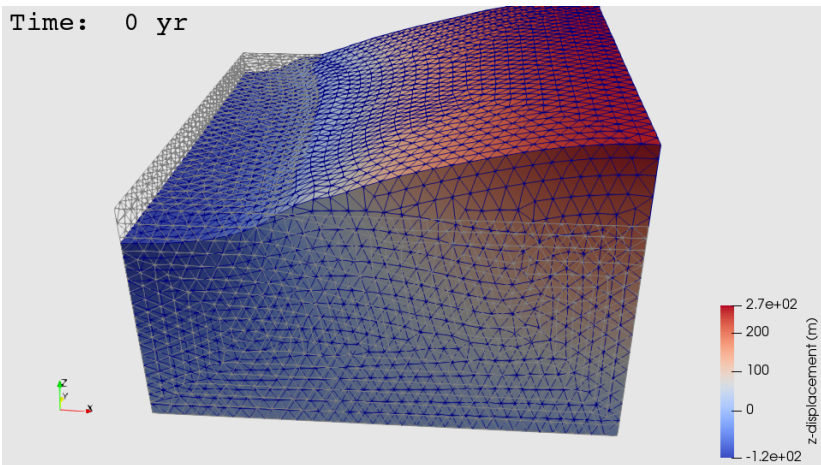
Cascadia Gravity Simulations

Files are in `examples/3d/subduction` None of these problems involve faulting.

- 1 **step08a** Use gravitational body forces for an elastic problem and balance them with initial stresses computed for a constant mantle density.
 - Stresses are out of balance and there is significant deformation.
- 2 **step08b** Use gravitational body forces for an elastic problem and balance them with initial stresses from **step08a**.
 - Stresses are in balance and there is no deformation.
- 3 **step08c** Use gravitational body forces for a viscoelastic problem with finite strain and balance them with the same initial stresses as for **step08b**.
 - Stresses are in balance for the elastic solution but viscous flow in the time-dependent solution results in large deformations.

Step 8a

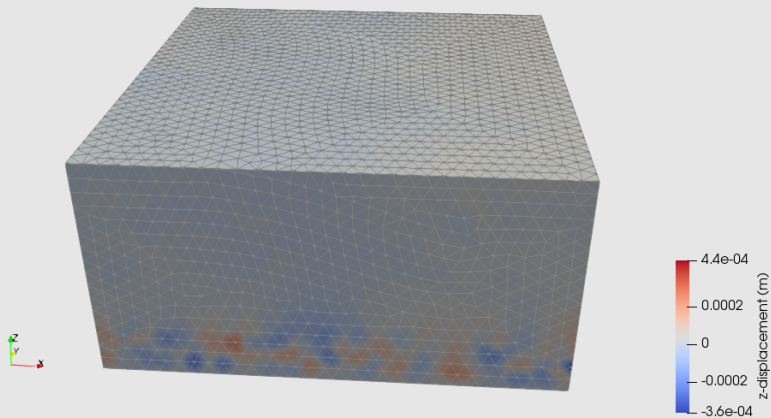
Elastic infinitesimal strain with initial stress from mantle density



Step 8b

Elastic infinitesimal strain with correct initial stress

Time: 0 yr



Step 8c

Viscoelastic finite strain with correct initial elastic stress

Time: 100 yr

