Problem Set 9

Submission deadline: April 23, 2025

Submission type: Report (soft or hard copy) and source code (soft copy)

Spectral Element Method

Solve the 2D wave equation using SPECFEMPP. Compare the seismograms and wavefield snapshots for simulations with different number of elements and/or GLL points.

Model description

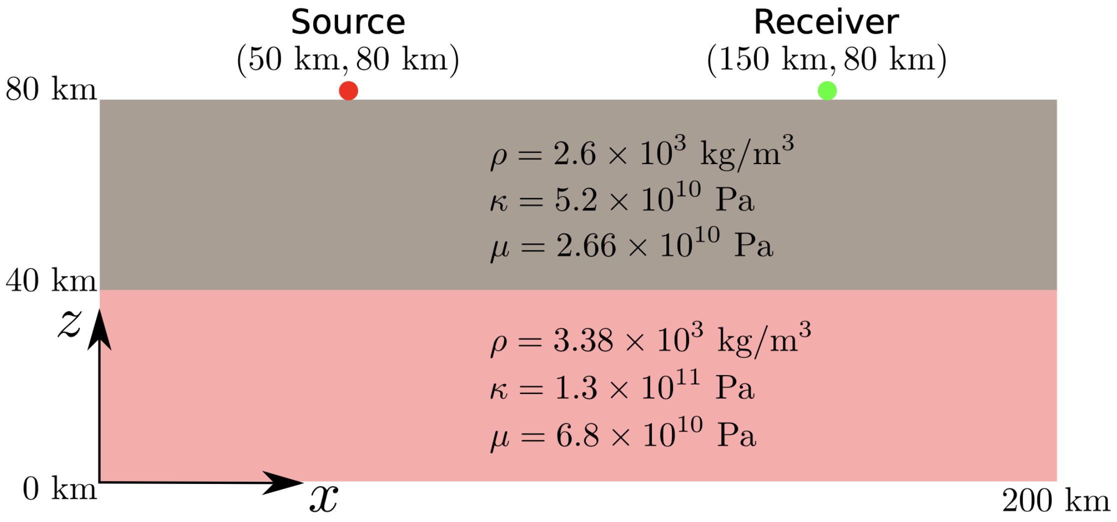
Source
$(50\text{ km}, 80\text{ km})$
Receiver
$(150\text{ km}, 80\text{ km})$
80 km
40 km
0 km
200 km
z
x
$\rho = 2.6 \times 10^3$ kg/m^3
$\kappa = 5.2 \times 10^{10}$ Pa
$\mu = 2.66 \times 10^{10}$ Pa
$\rho = 3.38 \times 10^3$ kg/m^3
$\kappa = 1.3 \times 10^{11}$ Pa
$\mu = 6.8 \times 10^{10}$ Pa

Figure 1: 2D model for the wave propagation.

The model consists of two layers as shown in Figure 1. The elastic properties of each layer are inscribed on the corresponding layer. Similarly, the source and the receiver locations are shown in the model with a red and a green circles, respectively.

Instructions

We will be using the software SPECFEMPP to simulate wave propagation with the spectral-element-method. SPECFEMPP is C++ software relying on Kokkos to implement performance-portable code. To compile the software we need a couple of packages that are standard on most systems:

- `cmake`
- `C` compiler
- `Fortran` compiler
- `C++` compiler
- Optional: `VTK` – the visualization toolkit for plotting snapshots.

Since you will be working with Adroit, you do not have to worry about these dependencies because they are already installed. In fact, this utilities are usually installed by default in most LINUX systems. Under WINDOWS, one may use LINUX Subsytem (WSL) or Cygwin (www.cygwin.com), or MinGW (www.mingw.org) to install the software.

1. Optional: Login to Adroit

   ```
   ssh <NetId>@adroit.princeton.edu
   ```

2. Clone the repository

   ```
   git clone https://github.com/PrincetonUniversity/SPECFEMPP.git
   --branch devel --single-branch
   ```

3. Enter directory

   ```
   cd SPECFEMPP
   ```

4. Export the VTK build directory location for compilation

   ```
   export VTK_DIR=/scratch/network/lsawade/vtk/build
   ```

5. Load appropriate compiler

   ```
   module load gcc-toolset/10
   ```

6. Configure the `SPECFEMPP`

   ```
   cmake --preset release
   ```

7. Compile the `SPECFEMPP`

   ```
   cmake --build --preset release -j
   ```

8. Add the compiled binary folder to PATH variable so that you can use commands **xmeshfem2D** and **specfem2d** directly.

   ```
   export PATH=$PATH:$PWD/build/release/bin
   ```

9. Now before we can run the software we need some parameter files, which are distributed as part of the class, but also are located at **/home/GEO441/hw9_data.tar** on Adroit. So either

   ```
   tar -xvf /home/GEO441/hw9_data.tar
   ```

   Or, copy it from the modules on Canvas and copy it to Adroit.

10. Enter the directory **cd GEO441**

11. Create output folders

    ```
    mkdir -p OUTPUT_FILES/results
    mkdir -p OUTPUT_FILES/display
    ```

12. Run the software

    - Run the mesher:

      ```
      xmeshfem2D -p Par_file
      ```

    - Run the solver:

      ```
      specfem2d -p specfem_config.yaml
      ```

13. Plotting results

    (a) Seismograms (ASCII format) are stored in the folder **OUTPUT_FILES/results**. File names for the seismograms have the form:
    <Network>.<Station>.S2.BX<Component>.semd.
    The files have timestamp in the first and value in the second column, and can be read and plotted using Python or Matlab for example.

    (b) Wave field snapshots (ASCII format) are off by default by if activate stored in the folder **OUTPUT_FILES/display**. If the **specfem_config.yaml** is updated as follows

```
...
writer:
  seismogram:
    format: ascii
    directory: OUTPUT_FILES/results

  display:
    format: PNG
    directory: OUTPUT_FILES/display
    field: displacement
    simulation-field: forward
    time-interval: 100
...
```

These files have the format **wavefield<timestamp>.png** and can be viewed using `myadroit.princeton.edu` and/or copied to your local machine using **scp** or using VSCode remote development.

Further parameters are documented here:
`https://specfem2d-kokkos.readthedocs.io/en/devel/`

Assignment

1. Plot the seismograms and snapshots for both SH and PSV, respectively.
2. Modify number of elements (**NEX**, **NEZ**) to see how the seismograms change for both SH and PSV forces. The "**number of grids per wavelength**" on the screen output is an indication of the accuracy of the simulation.

You are encouraged to play around setting different source and receiver locations, etc.