

DAY 2: ADVANCED MODELS

Builds, Free surface, Plugins, Modifications

Today you will:

- Learn about the different ways to compile ASPECT (debug vs optimized)
- Understand ASPECT's plugin system, which allows to run all models in cookbooks/ and benchmarks/
- Run a model using a free surface
- Modify the free surface model beyond input parameters

- To create an ASPECT executable in release mode type in a terminal:

```
mkdir ~/aspect/release  
cd ~/aspect/release  
cmake ~/aspect  
make release  
make -j2 (takes 30-60 min)
```

- Create a link to the new aspect executable:

```
cd ~/aspect  
ln -sf ~/aspect/release/aspect aspect-release
```

- To run release mode use:

```
~/aspect-release file.prm
```

ASPECT can run in debug or optimized mode:

```
Terminal
File Edit View Terminal Tabs Help
-----
-- This is ASPECT, the Advanced Solver for Problems in Earth's Convection.
-- . version 2.0.0-pre
-- . running in OPTIMIZED mode
-- . running with 1 MPI process
-- . using Trilinos
-----

Line <1> of file <input string>: No entry with name <Output diectory> was declared in the current subsection.

-----

Exception 'dealii::ExcMessage ("Invalid input parameter file.")' on rank 0 on processing:

-----

An error occurred in line <343> of file </home/ubuntu/aspect/source/main.cc> in function
void parse_parameters(const string&, dealii::ParameterHandler&)
The violated condition was:
false
Additional information:
Invalid input parameter file.

-----

Aborting!
-----
```

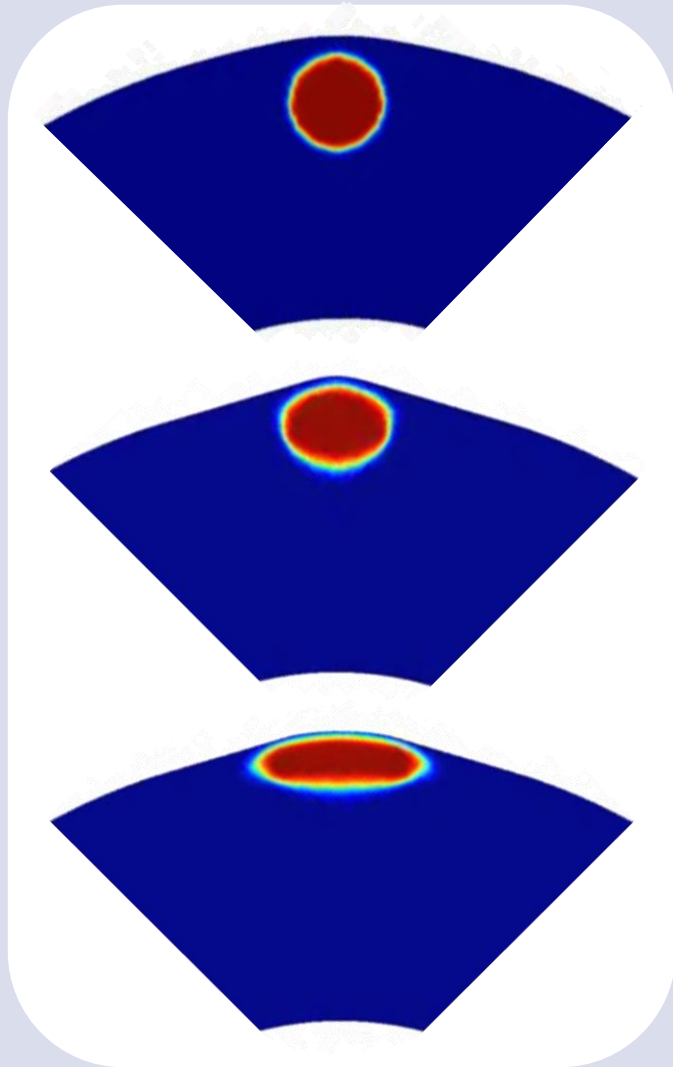
ASPECT can run in debug or optimized mode:

- DEBUG mode:
 - lots of internal checks to verify correctness of algorithms in deal.II, ASPECT, and user-provided plugins
 - no compiler optimizations to make debugging simpler
 - slow
- OPTIMIZED (or RELEASE) mode:
 - most internal checks are switched off
 - use available compiler optimizations
 - fast: about 4-10 times faster
- `~/aspect/aspect` in your VM links to **debug** mode, we will create an optimized executable today

Guidance for debug vs. optimized mode:

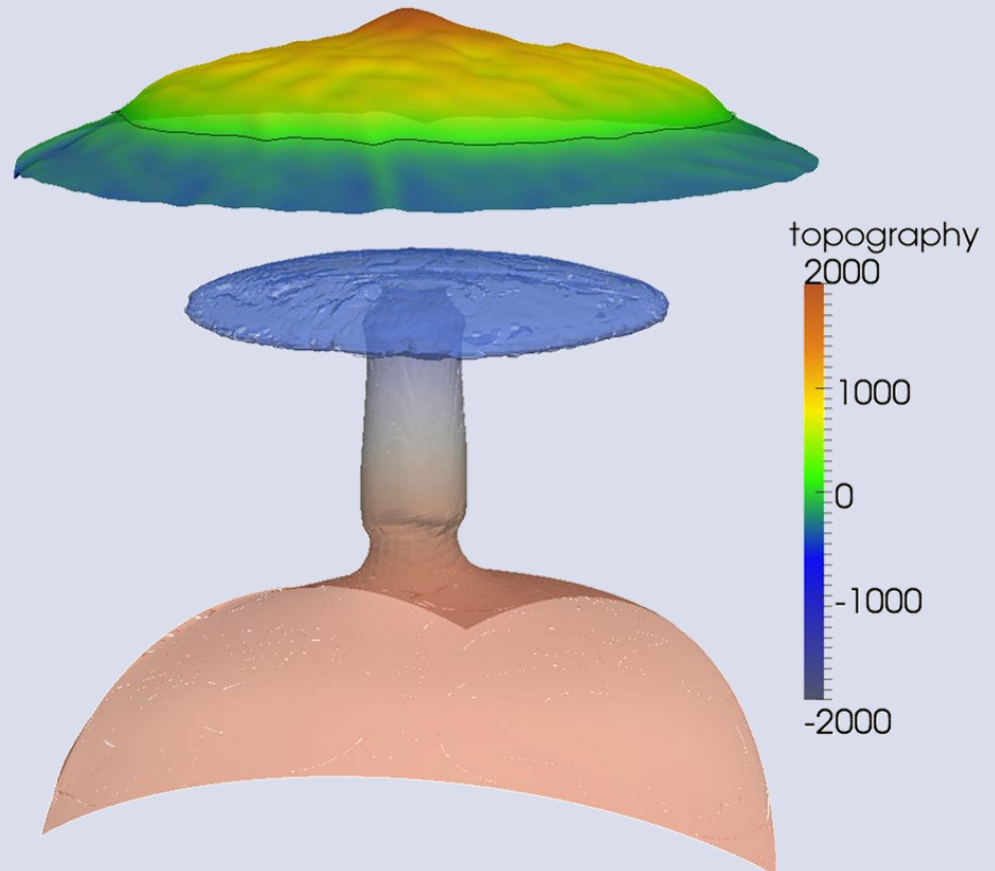
- ***Always*** test new models in debug mode
 - This makes finding bugs *much, much simpler!*
- ***Afterwards*** run optimized models with
 - more mesh refinement
 - longer model run time
- ***Try*** to reproduce a crash in debug mode
- ***Never*** run production runs in debug mode
 - it wastes CPU time and your time (=money)

Surface topography

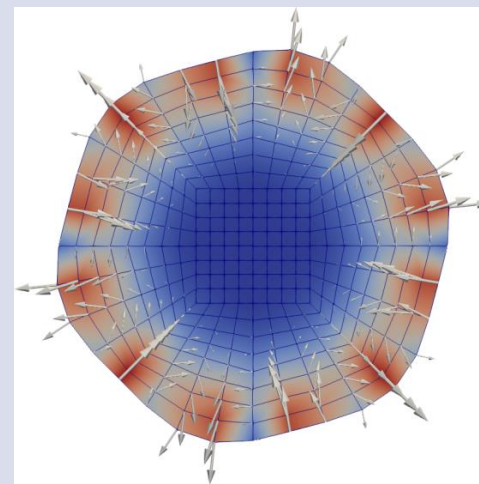
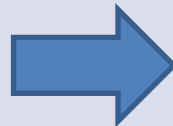
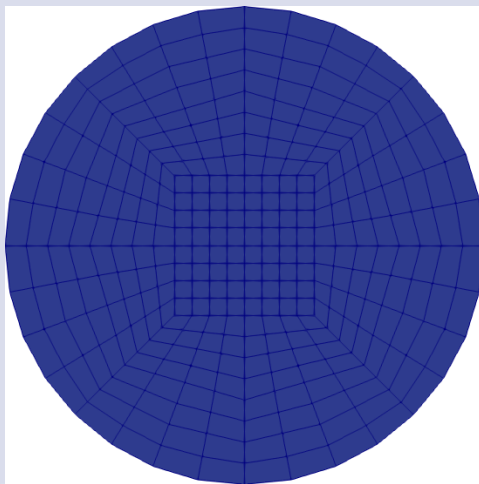


From I. Rose

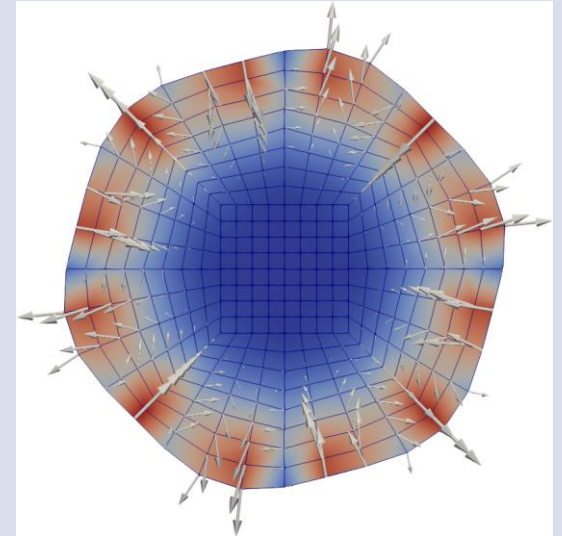
- session-2/free_surface.prm
- session-2/free_surface_with_crust.prm



- Surface topography in ASPECT can be modeled in three different ways:
 - Dynamic stress on a fixed boundary
 - A “sticky air” layer
 - Actual mesh deformation



- What does free surface mean?
 - A stress-free boundary condition for velocity
 - A mesh that is deformed according to the velocity (an “arbitrary Lagrangian-Eulerian” mesh, or ALE formulation)
- A stabilization to prevent oscillations of the mesh (see Rose, I., Buffett, B., & Heister, T. (2017). *PEPI*, 262, 90-100 and Kaus, B. J., Mühlhaus, H., & May, D. A. (2010). *PEPI*, 181(1-2), 12-20.



- **Let's open it:**

```
cd ~/aspect-tutorials/2020-tectonics-  
    modeling-tutorial/session-2
```

```
leafpad free_surface.prm
```

- **Let's not run it (117 timesteps, takes too long in debug mode):**

```
mpirun -np 2 ~/aspect/aspect  
free_surface.prm
```

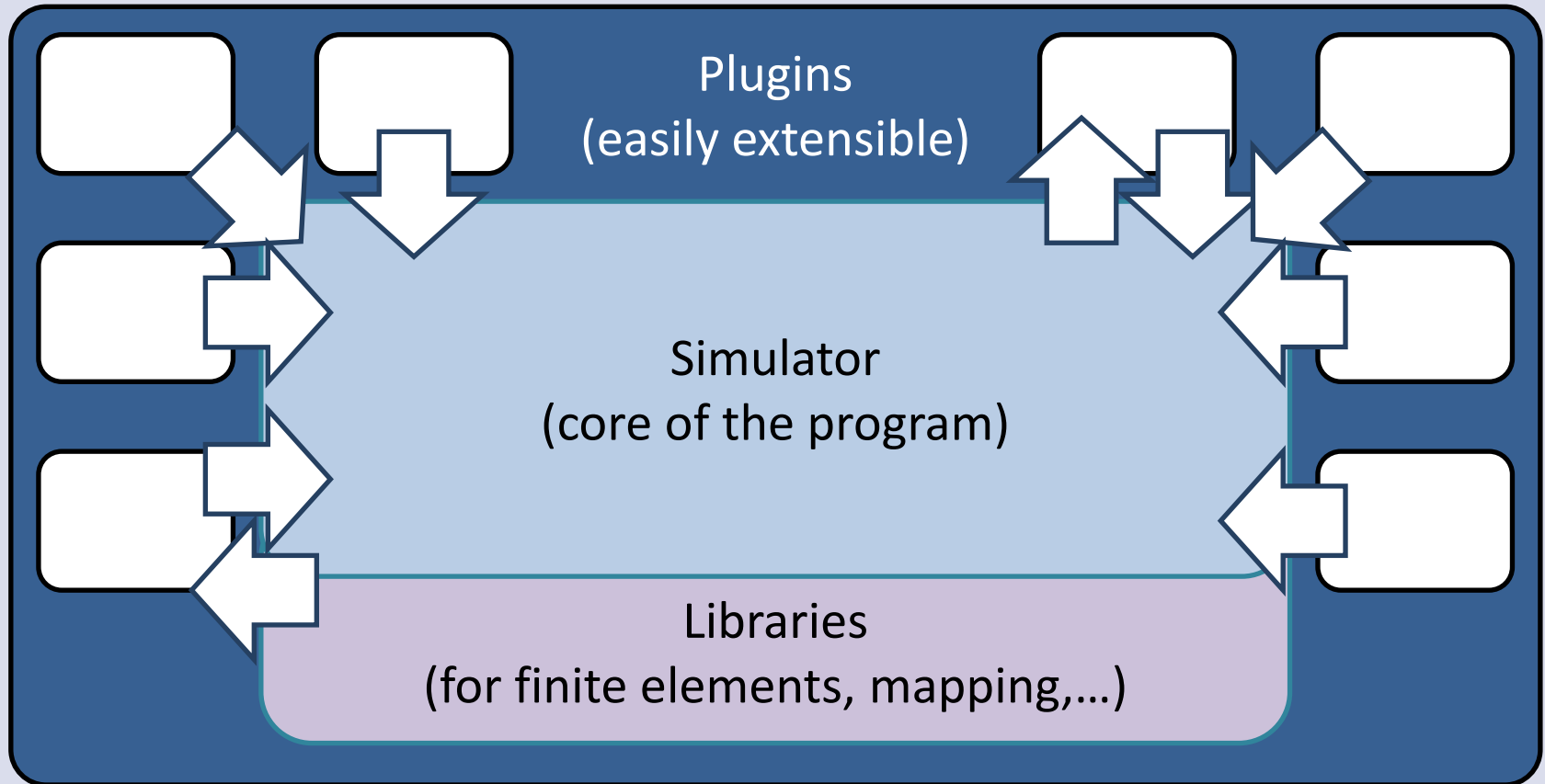
Compile Release mode:

```
mkdir ~/aspect/release  
cd ~/aspect/release  
cmake ~/aspect  
make release  
make -j2  
cd ..  
ln -sf ~/aspect/release/aspect aspect-release
```

Run free surface model:

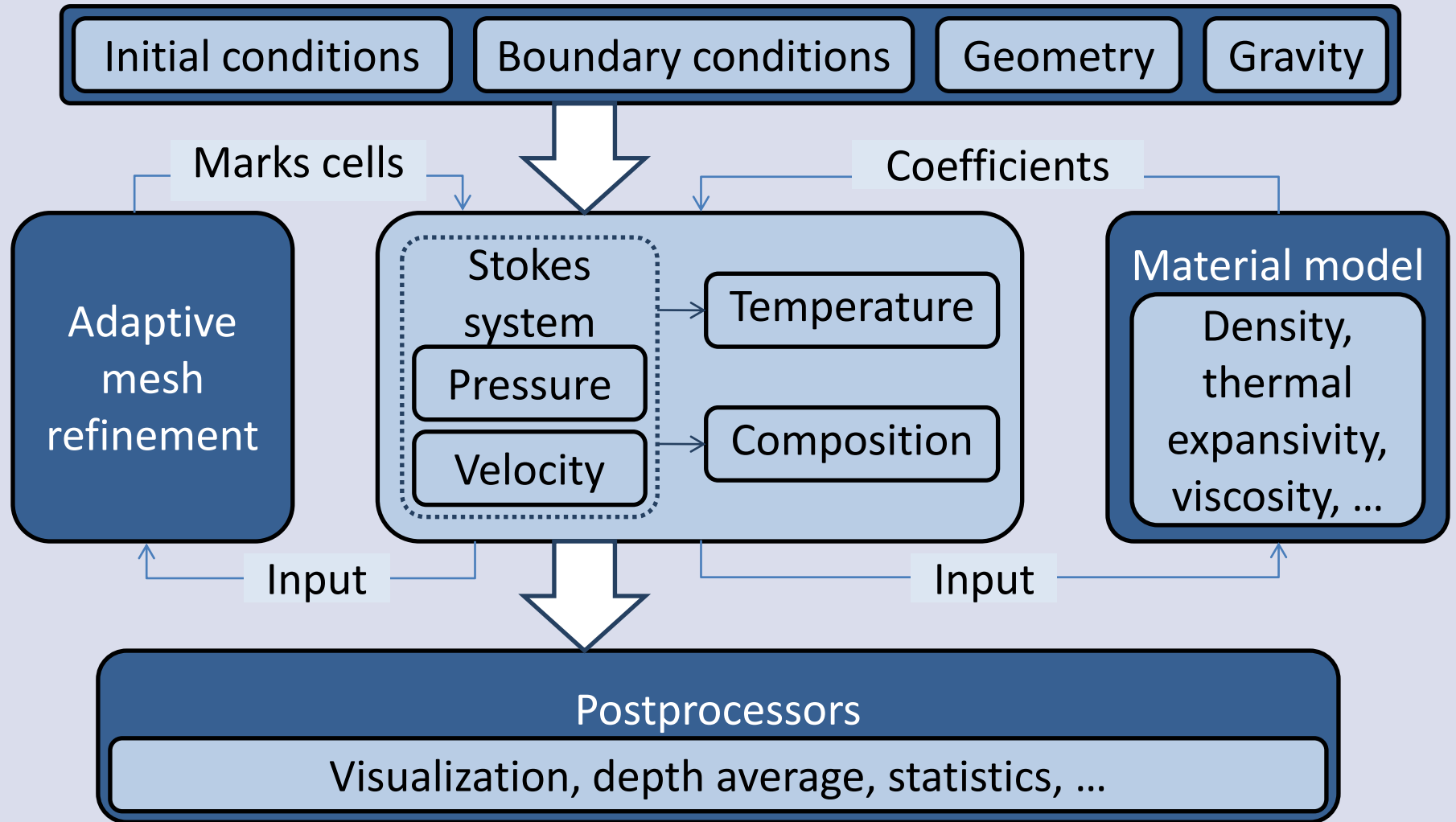
```
cd ~/aspect-tutorials/2020-tectonics-  
    modeling-tutorial/session-2  
  
mpirun -np 2 ~/aspect/aspect free_surface.prm
```

- Sometimes input parameters are not enough
- You can compile additional plugins outside of ASPECT
- These plugins can be loaded and used during the model run, specified in the input file
- We will use such a plugin at the example of the cookbook `free_surface_with_crust.prm`



- ASPECT is written in C++ and uses object-oriented design, and advanced language features (e.g. templates) to keep it manageable despite its size
- You need to understand C++, and deal.II (our main library) if you change the Simulator class / core part
- Most of the plugins are much simpler to understand, and all you need to deal with

Modularity

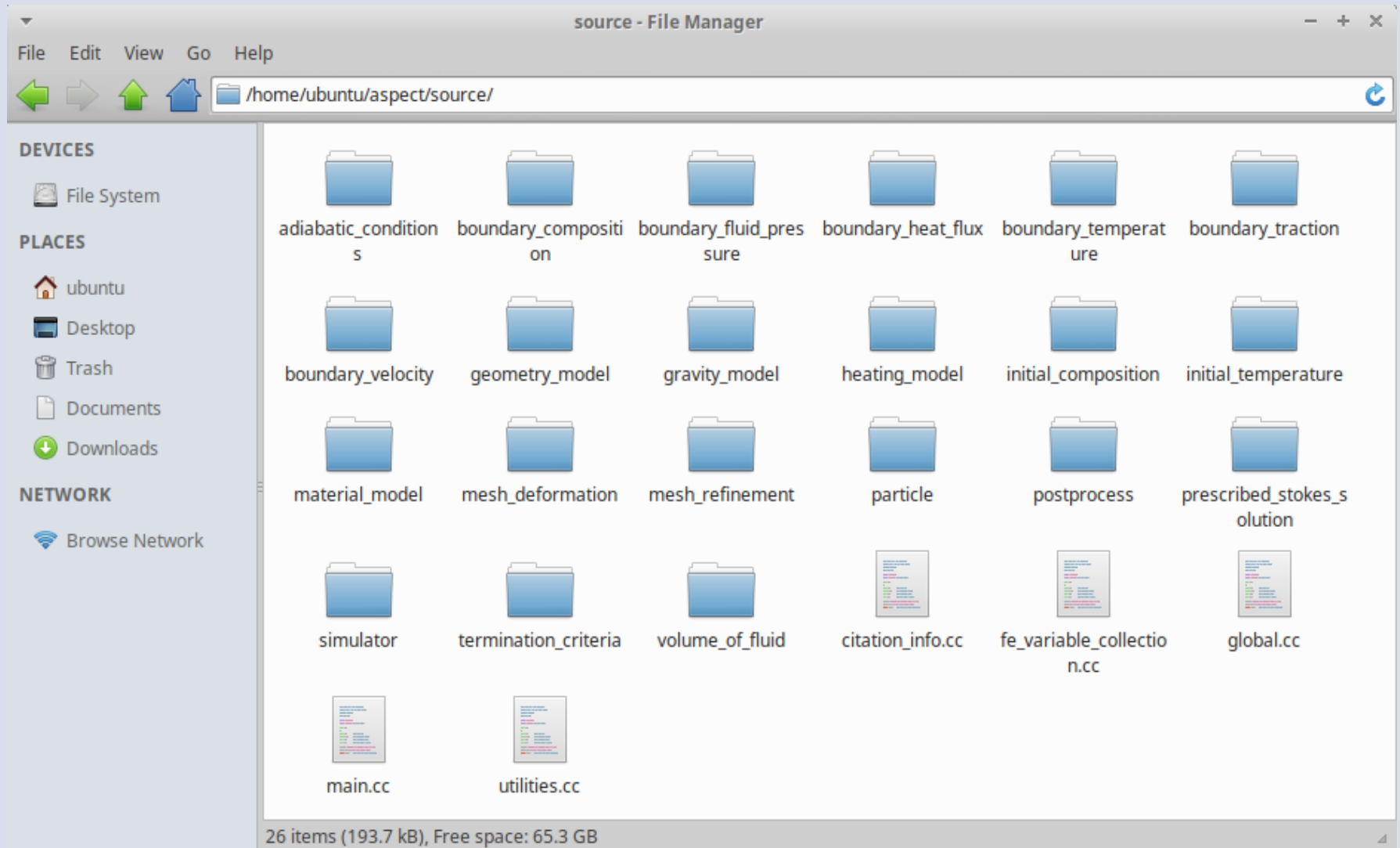


```
subsection Geometry model
  set Model name = spherical shell

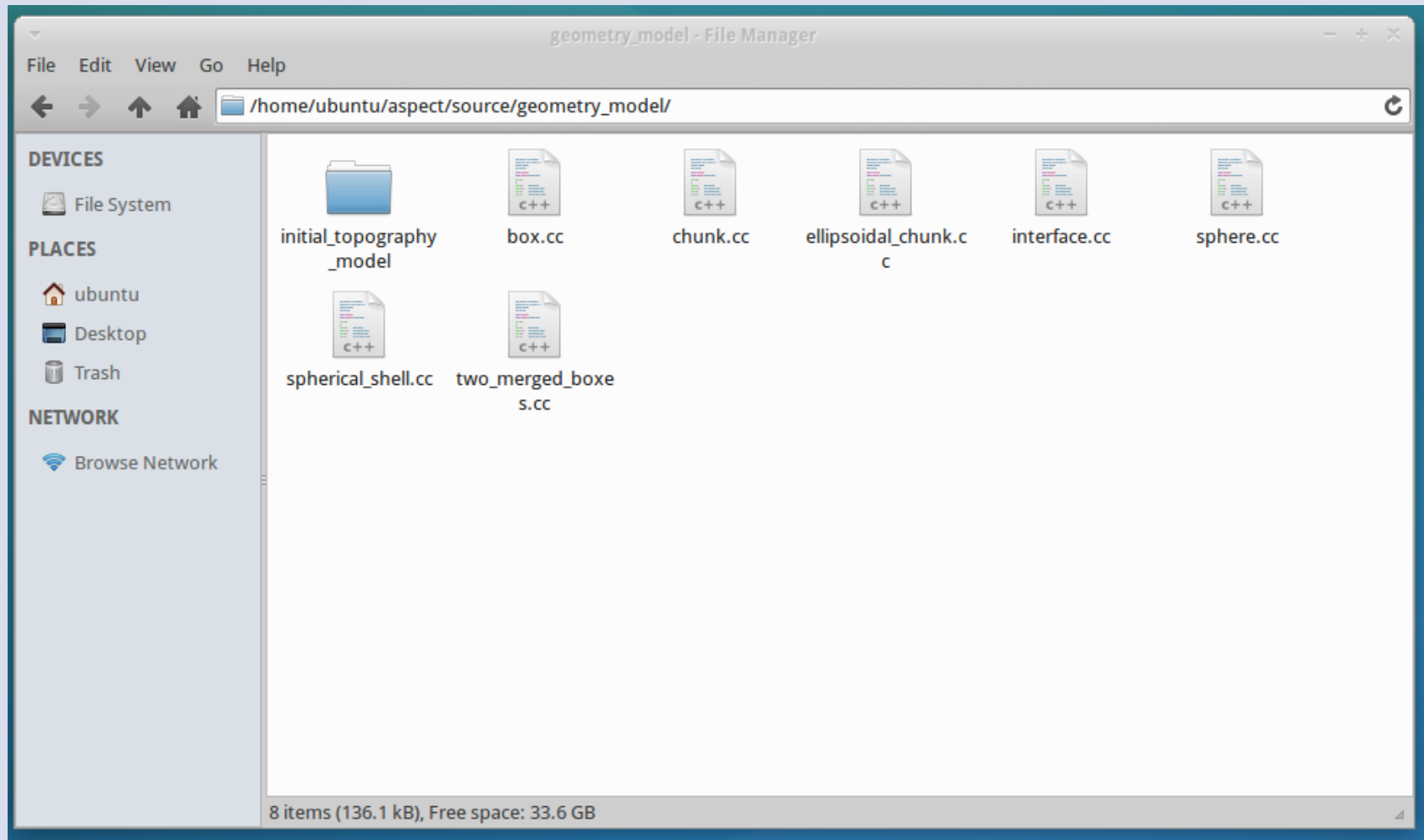
  subsection Spherical shell
    set Inner radius   = 3481000
    set Outer radius   = 6336000
    set Opening angle  = 90
  end
end

subsection Gravity model
  set Model name = radial constant
end
```


Modularity



Modularity



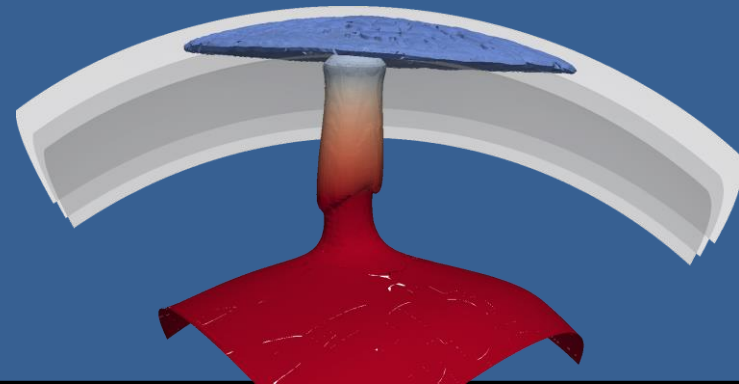
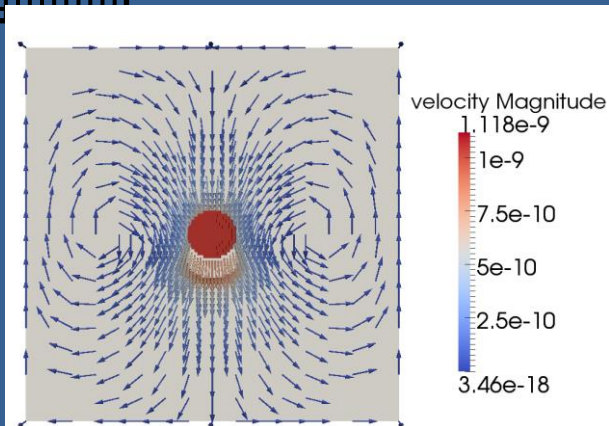
Geometry model

2D or 3D?

Geometry model

Box

Spherical shell



- A look into `free_surface_with_crust.prm`:

```
cd ~/aspect-tutorials/2020-tectonics-  
modeling-tutorial/session-2
```



```
leafpad free_surface_with_crust.prm
```
- Notice the differences to `free_surface.prm`

- A look into the plugin/ directory:
 - CMakeLists.txt: configuration file that tells how to compile plugin
 - simpler_with_crust.cc: source file that contains the additional plugin
- A look into simpler_with_crust.cc

- Typical functions in plugins:
 - `initialize()` : is called after `parse_parameters`
 - `update()` : is called at the start of all time steps
 - `evaluate/initial_temperature/
boundary_velocity/etc.` : functions that are called during model runtime
 - `declare_parameters()` : function that declares what parameters are allowed
 - `parse_parameters()` : function that reads parameters and stores them internally

- Developer documentation:

<https://aspect.geodynamics.org/doc/doxygen/index.html>

- **To compile the specific plugins:**

```
cd ~/aspect-tutorials/2020-tectonics-modeling-  
tutorial/session-2/plugin/
```

- **To compile plugin for optimized mode:**

```
cmake -DAspect_DIR=~/.aspect/release .
```

- **To compile plugin for debug mode:**

```
cmake -DAspect_DIR=~/.aspect/build .
```

```
make
```

- **To run model (4 min / 27 min):**

```
cd ..  
mpirun -np 2 ./plugin/aspect  
free_surface_with_crust.prm
```


- ASPECT will check its build type against the plugin:

```
Loading shared library <./plugin/lib simpler_with_crust.so>

-----
Exception 'dealii::ExcMessage (error.str())' on rank 0 on processing:
-----

An error occurred in line <242> of file </home/ubuntu/aspect/source/main.cc>
ion
    void validate_shared_lib_list(bool)
The violated condition was:
    false
Additional information:
    .....
ASPECT currently links against different versions of the
deal.II library, namely the ones at these locations:
    /home/ubuntu/deal.II/installed/lib/libdeal_II.g.so.9.2.0
    /home/ubuntu/deal.II/installed/lib/libdeal_II.so.9.2.0
This can not work.

Since this is happening after opening additional shared
library plugins, this likely means that you have compiled
ASPECT in release mode and the plugin in debug mode, or the
other way around. Please re-compile the plugin in the same
mode as ASPECT.
```

Compile plugin:

```
cd ~/aspect-tutorials/2020-tectonics-modeling-  
tutorial/session-2/plugin/  
cmake -DAspect_DIR=~/aspect/release .  
make
```

Run free surface model:

```
cd ~/aspect-tutorials/2020-tectonics-  
modeling-tutorial/session-2  
  
mpirun -np 2 ~/aspect/aspect-release  
free_surface_with_crust.prm
```

- Let us check the output in paraview:

```
cd output-free_surface_with_crust  
paraview solution.pvd
```
- Let us plot the topography:

```
gnuplot  
plot "statistics" using 2:15
```

- **Modify the plugin:**

```
cd plugin  
leafpad simpler_with_crust.cc
```

- **Add a crustal density parameter**

- **Recompile the plugin:** `make`

- **Re-run the model (change output dir):**

```
cd ..  
leafpad free_surface_with_crust.prm  
mpirun -np 2 ./plugin/aspect  
    free_surface_with_crust.prm
```

- Let us plot the topography:

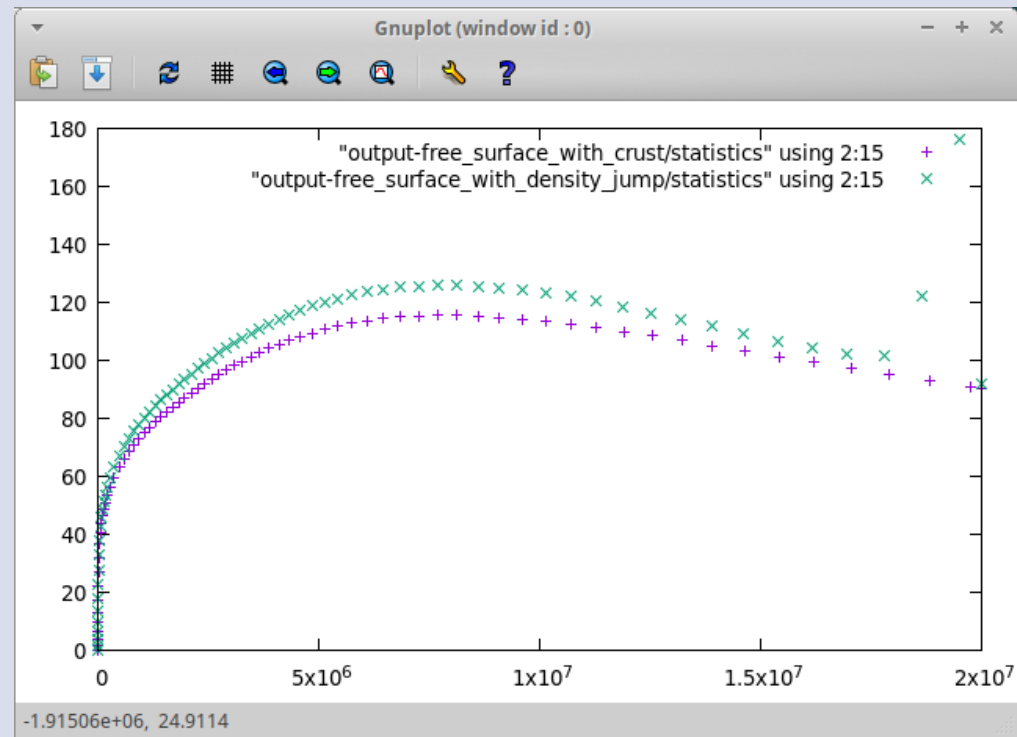
```
gnuplot
```

```
plot "output-free_surface_with_crust/statistics"
```

```
using 2:15,
```

```
"output-free_surface_with_density_jump/statistics"
```

```
using 2:15
```



- Compiling ASPECT and additional plugins
- Using the free surface
- Using additional plugins
- A glimpse into modifying plugins

Exercises:

- Modify `free_surface_with_crust.prm` to use different crustal densities
- Modify `free_surface_with_crust.cc` to use viscosity based on temperature