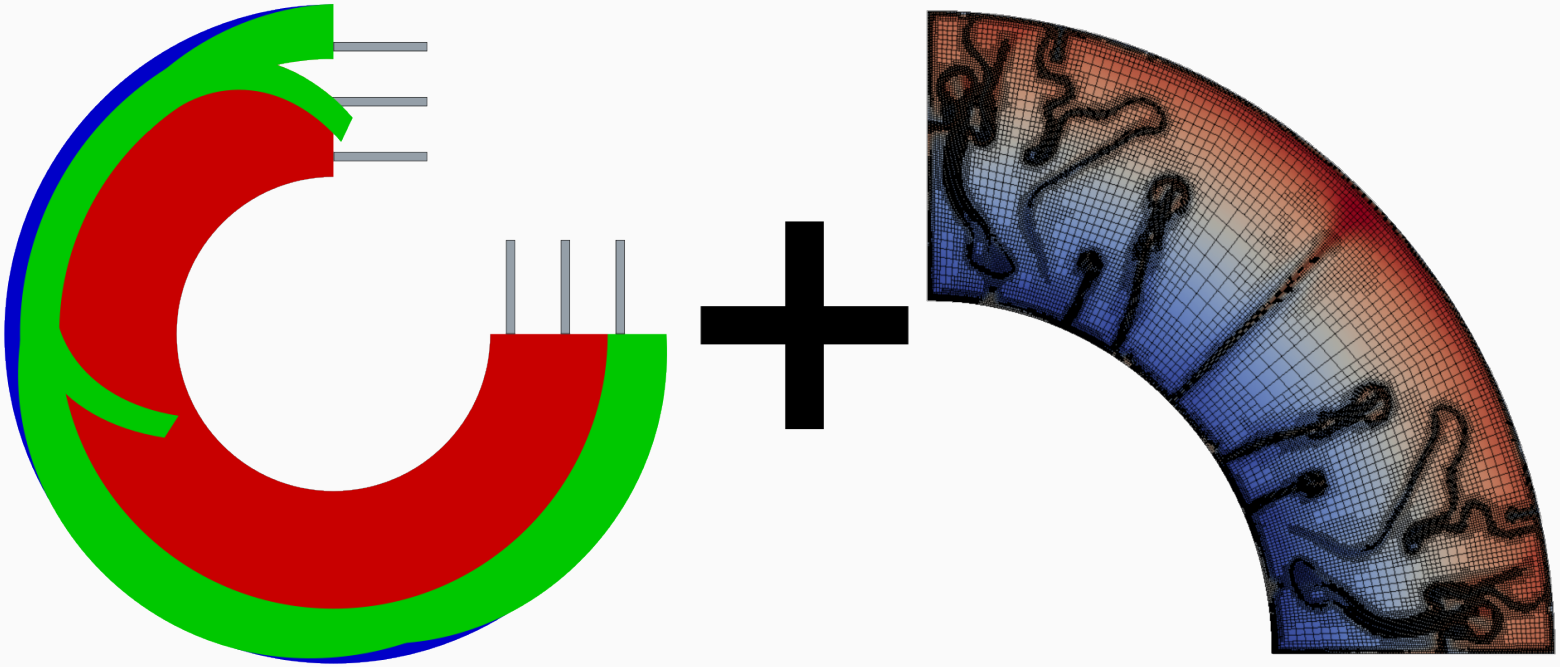

The Geodynamic World Builder in ASPECT

A solution for complex intitial conditions

July 24, 2020

CIG COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

Learning objectives

Questions I hope to answer:

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3. How do you make a model with the World Builder?
4. Where can you find more info about the World Builder?
5. What are the development plans for the World Builder? And how can you contribute?

What is the World Builder?

Background: Generally three types of initial conditions

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   easy to make, good for simplified problems and benchmarks

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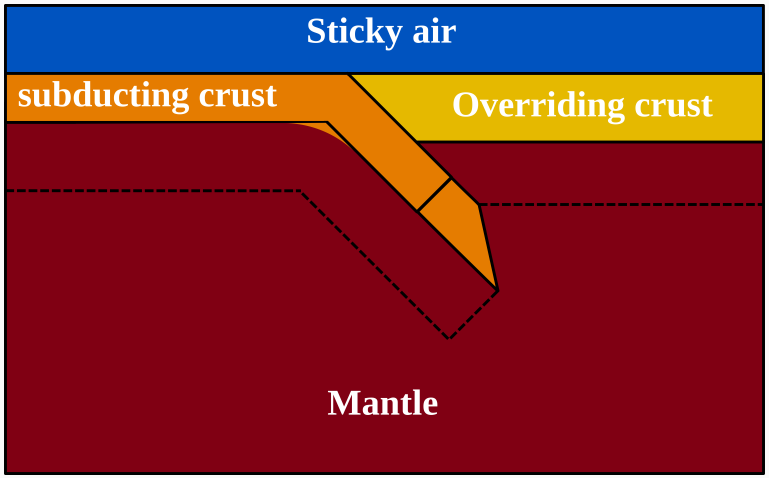
The GWB is designed to make the last case a lot easier

Example: Initial conditions are hard



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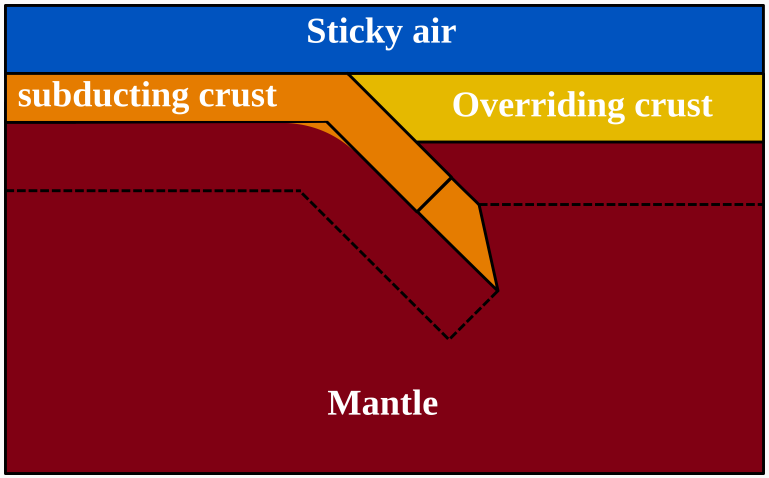


```
subsection Compositional initial conditions
   set Model name = function
   subsection Function
     set Variable names = x,z
     set Function constants  = pi=3.1415926536, Px=800000.0, depth=660000.0, l=80000.0, lcr2=5000, dip=25, d=100000.0,dwz=30000
, lwzcr=10000, lc3=100000, lc3cr=6000, r=75000 #pi is pi, Px is xcoord at the top where it turns, depth is the depth of the mod
el, l is the thickness of the lithosphere of the slabplate, lcr2 is the thickness of the crust of the slabplate, dip is the ang
le the slab dips in in degree's, d is the ammount of meters the slab penetrates into the mantle (from the top point along the p
late), dwz is the thickness of the weakzone (depth of the weakzone is defined by lc3), lwzcr is the thickness of the crust of t
he weakzone, lc3 is the thickness of the overridding slab, lc3cr is the thickness of the crust of the overridding slab

    set Function expression = if(z>=depth|(z>=(depth-lcr2)&x<Px-lcr2*tan(0.5*(dip/180.0)*pi)|(z<x*tan(-(dip/180)*pi)+Px*tan((di
p/180)*pi)+depth&z>=x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth-(lcr2/sin((dip/180.0)*pi)*tan((dip/180)*pi))&x>=Px-lcr2*tan
(0.5*(dip/180.0)*pi)&z>=x*tan(0.5*pi-(dip/180)*pi)-(d*sin((dip/180)*pi)+(Px+d*cos((dip/180)*pi))/tan((dip/180)*pi)-depth))|(z>=
depth-lcr2-r+r*cos((dip/180)*pi)&z<depth-lcr2&x>=Px-sin(0.5*(dip/180)*pi)*lcr2-0.5*r*sin((dip/180)*pi)/(sin(atan((r*sin((dip/18
0)*pi))/(r-r*cos((dip/180)*pi))))^2)&x<Px-sin(0.5*(dip/180)*pi)*lcr2-0.5*r*sin((dip/180)*pi)/(sin(atan((r*sin((dip/180)*pi))/(r
-r*cos((dip/180)*pi))))^2)+r*sin((dip/180)*pi)&((x-(Px-sin(0.5*(dip/180)*pi)*lcr2-0.5*r*sin((dip/180)*pi)/(sin(atan((r*sin((dip
/180)*pi))/(r-r*cos((dip/180)*pi))))^2)))^2+(z-(depth-lcr2-r))^2>=r^2)&z<x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth)|(z>=x
*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth&z<x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth+dwz/cos((dip/180.0)*pi)&z>=dep
th-lc3cr)|(z>=x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth+dwz/cos((dip/180.0)*pi)&z>=depth-lc3cr)),0,1); if(z<depth&(z>=(de
pth-lcr2)&x<Px|(z<x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth&z>=x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth-((lcr2)/si
n((dip/180.0)*pi)*tan((dip/180)*pi))&x>=Px-lcr2*tan(0.5*(dip/180.0)*pi)&z>=x*tan(0.5*pi-(dip/180)*pi)-(d*sin((dip/180)*pi)+(Px+
d*cos((dip/180)*pi))/tan((dip/180)*pi)-depth))|(z>=depth-lcr2-r+r*cos((dip/180)*pi)&z<depth-lcr2&x>=Px-sin(0.5*(dip/180)*pi)*lc
r2-0.5*r*sin((dip/180)*pi)/(sin(atan((r*sin((dip/180)*pi))/(r-r*cos((dip/180)*pi))))^2)&x<Px-sin(0.5*(dip/180)*pi)*lcr2-0.5*r*s
in((dip/180)*pi)/(sin(atan((r*sin((dip/180)*pi))/(r-r*cos((dip/180)*pi))))^2)+r*sin((dip/180)*pi)&((x-(Px-sin(0.5*(dip/180)*pi)
*lcr2-0.5*r*sin((dip/180)*pi)/(sin(atan((r*sin((dip/180)*pi))/(r-r*cos((dip/180)*pi))))^2)))^2+(z-(depth-lcr2-r))^2>=r^2)&z<x*t
an(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth)),1,0); if(z<depth&z>=x*tan(-(dip/180)*pi)+Px*tan((dip/180)*pi)+depth&z>=depth-lc3
cr,1,0); if(z>=depth,1,0) #C1:mantle;C2:slab;C3:overriding plate;C4:weakzoneslab
   end
end
```

Initial conditions for models have (at least one of these) problems...

1. not readable (even hard for developers)
2. not modifiable (even hard for developers)
3. not extendable (even hard for developers)
4. not portable/reproducible in other codes
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The Geodynamic World Builder (GWB) hopes to solve these problems

GWB solves these problems by...

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Implementing a specific coding philosophy
to solve the extendable, portable and shareable issues

together with a specific user philosophy
to solve the readability and modifiable issues

Code philosophy

1. A single text-based input file (Like ASPECT)
2. Code, language and platform independent
   2.1 supports Linux, OSX and Windows
   2.2 can interface with C++, C, Fortran and Python codes
3. Up-to-date user manual and code documentation
4. Safe to use in parallel codes
5. Readable and extensible code
6. Strict version numbering to ensure reproducible of results

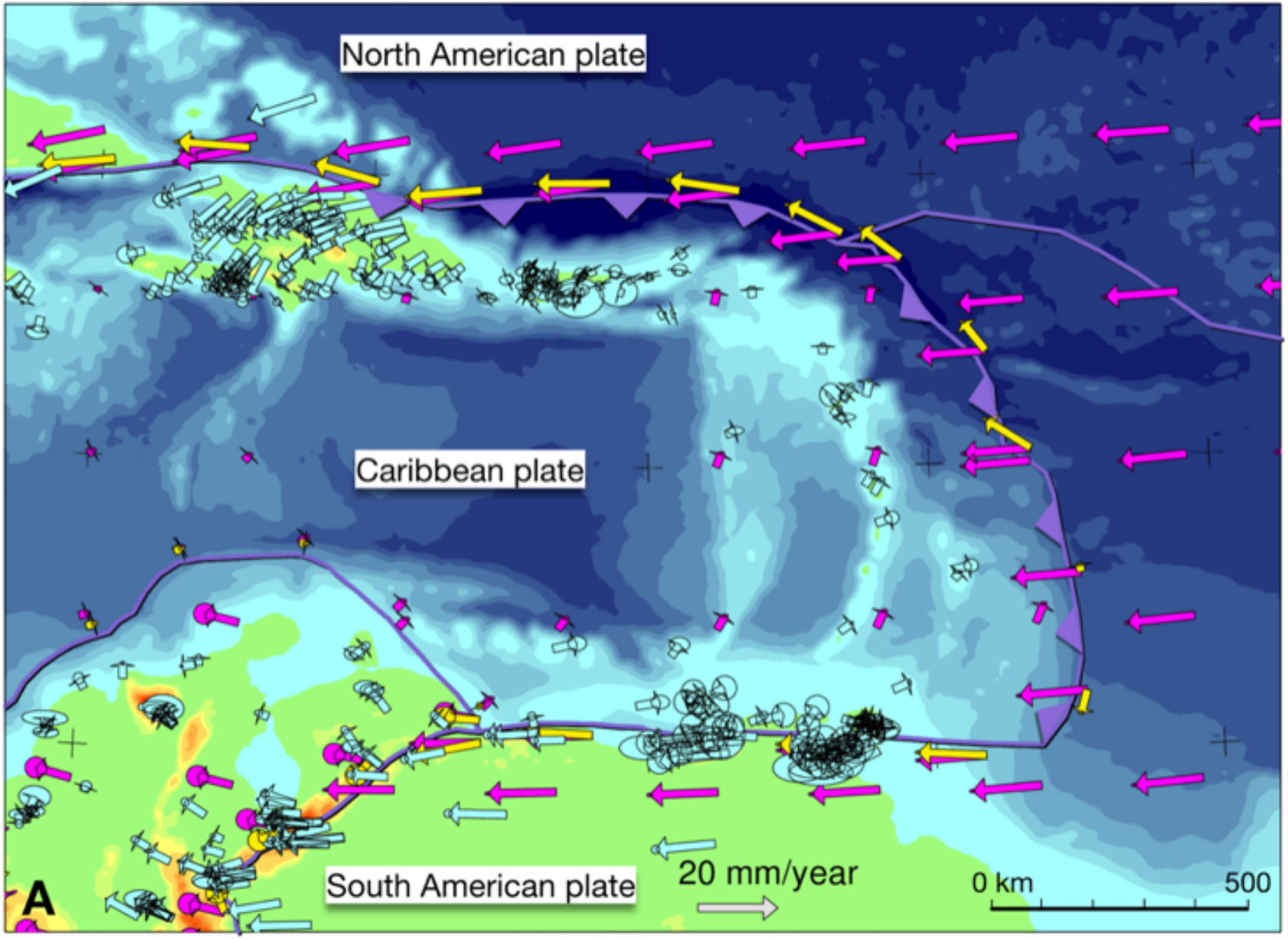
User Philosophy

1. Tectonic features can be parameterized by lines and area
2. These features implicitly define a volume
3. to which a model can be assigned describing
    3.1 temperature
    3.2 composition (a label for a material)
4. Parameterized by human readable JSON file.

How do I make the input file for the World Builder?

A simple example for making a subduction zone

Creating Lines and Areas



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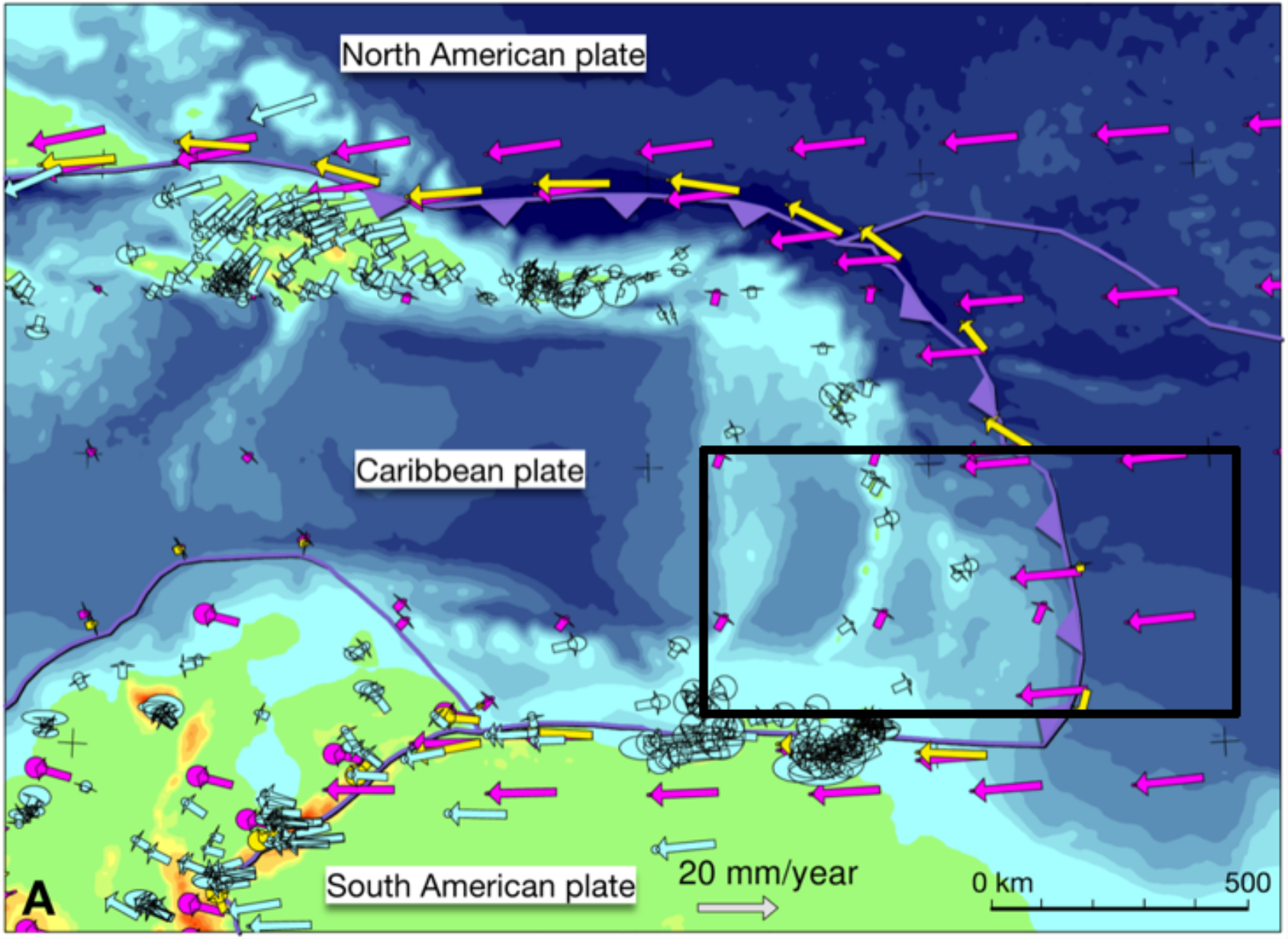

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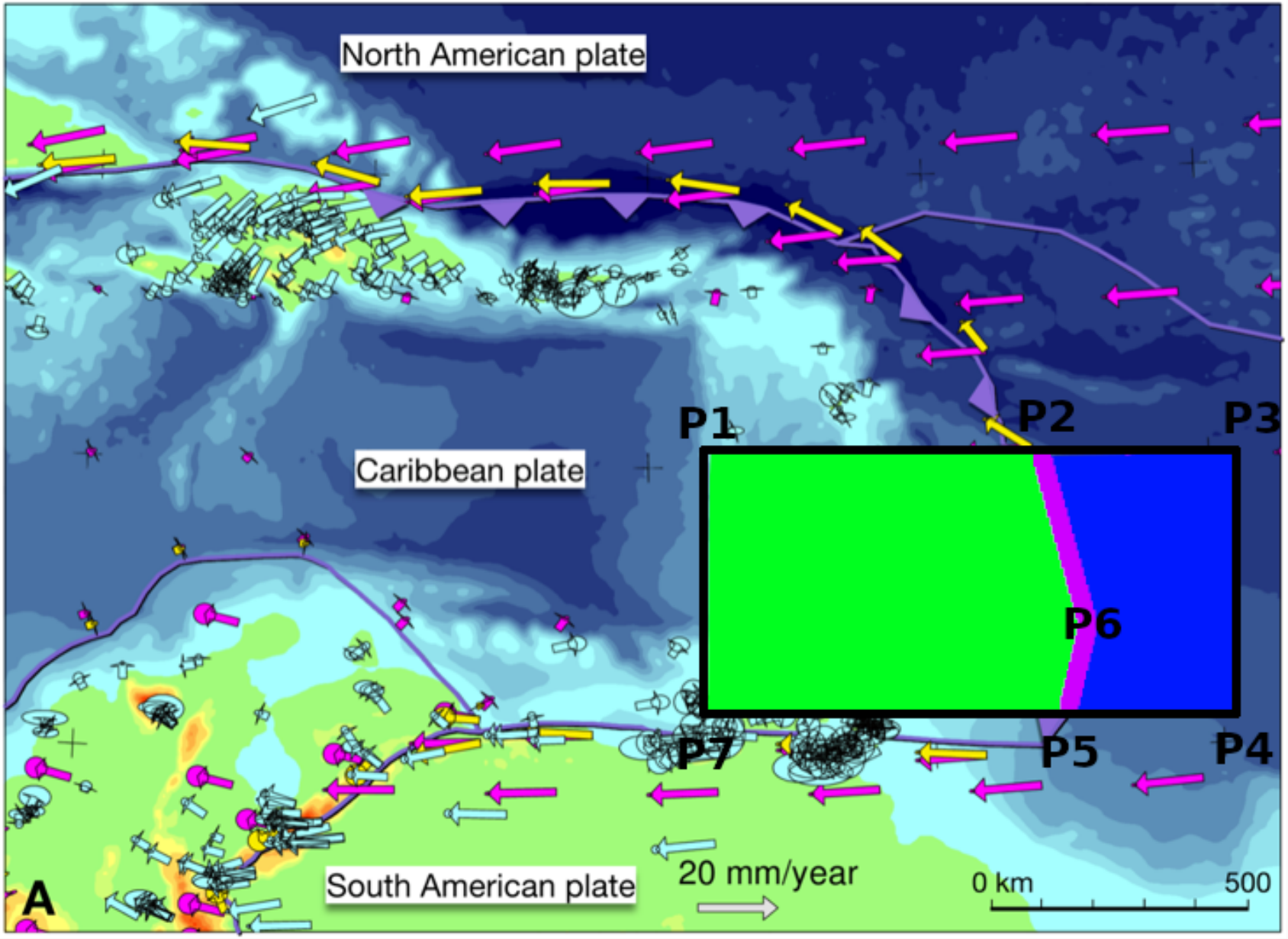
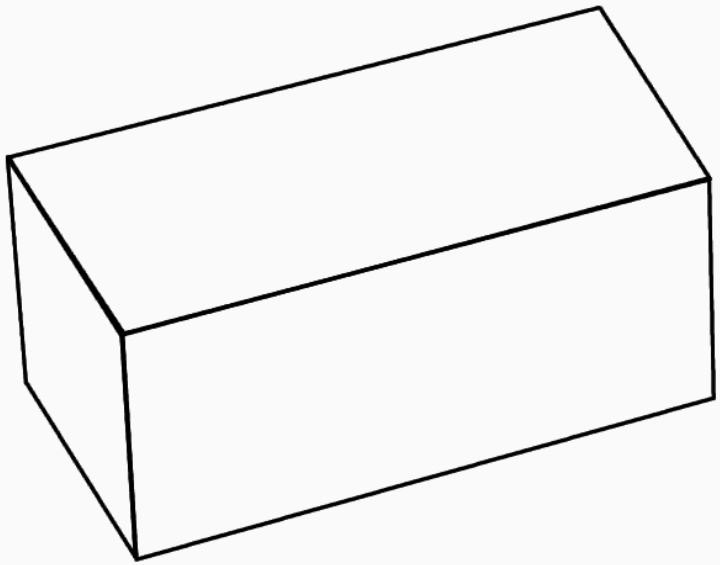
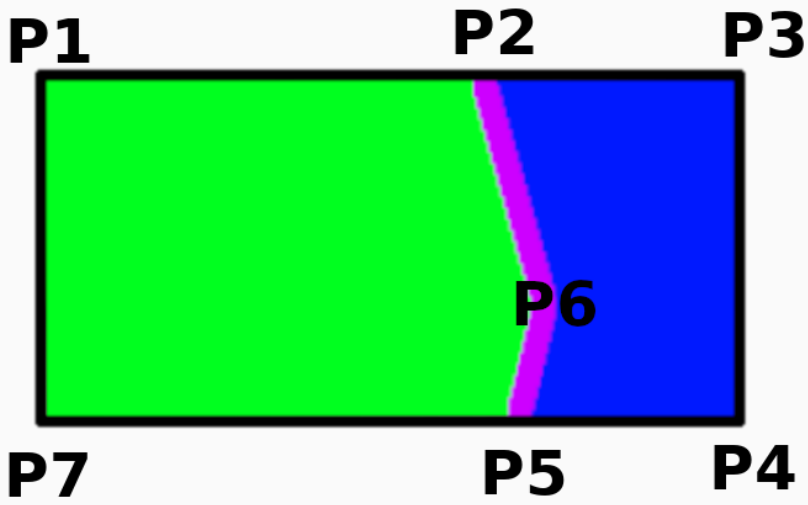


Defining volumes

1. Fill the box with mantle material.
2. Fill Caribbean Oceanic plate.
3. Fill Atlantic Oceanic plate.
4. Fill subducting plate.





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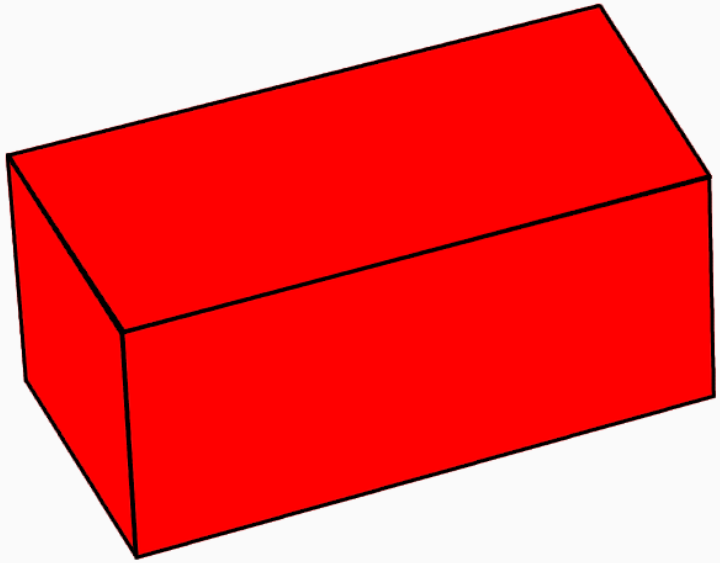

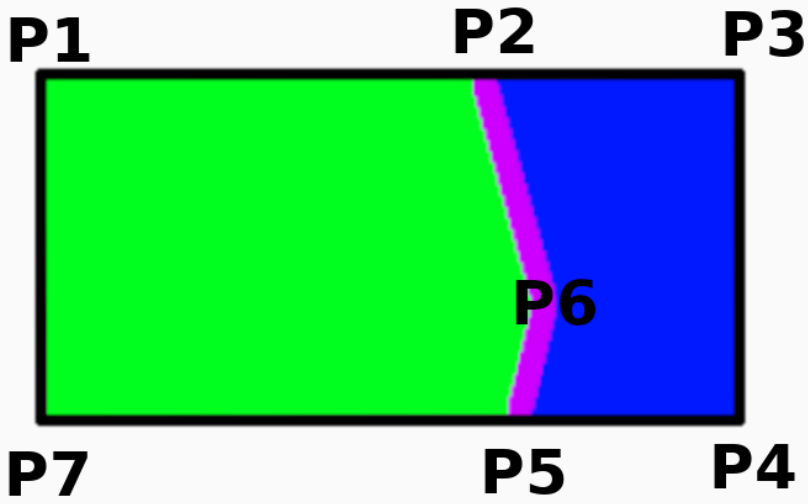

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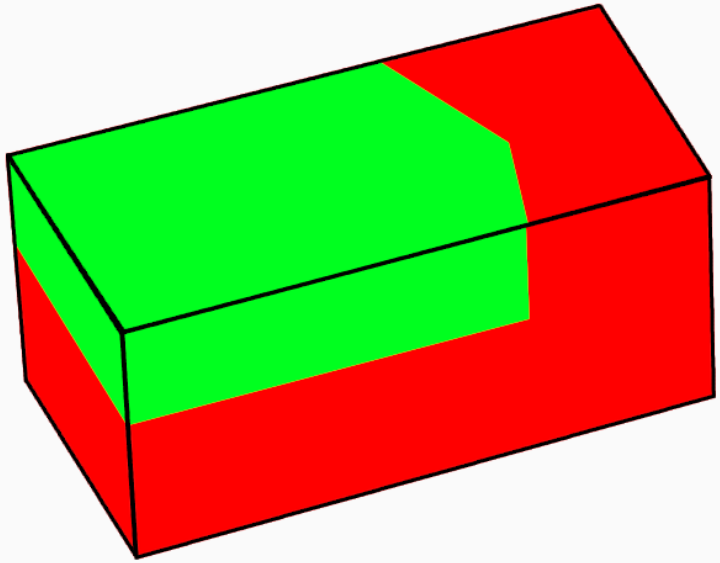

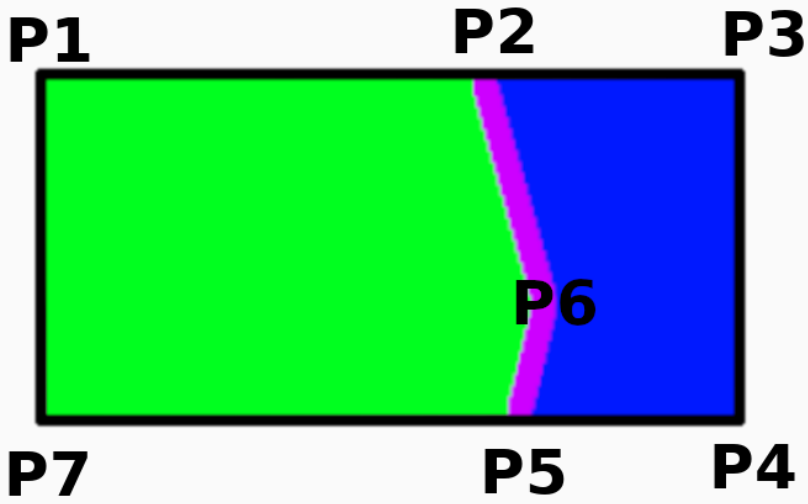

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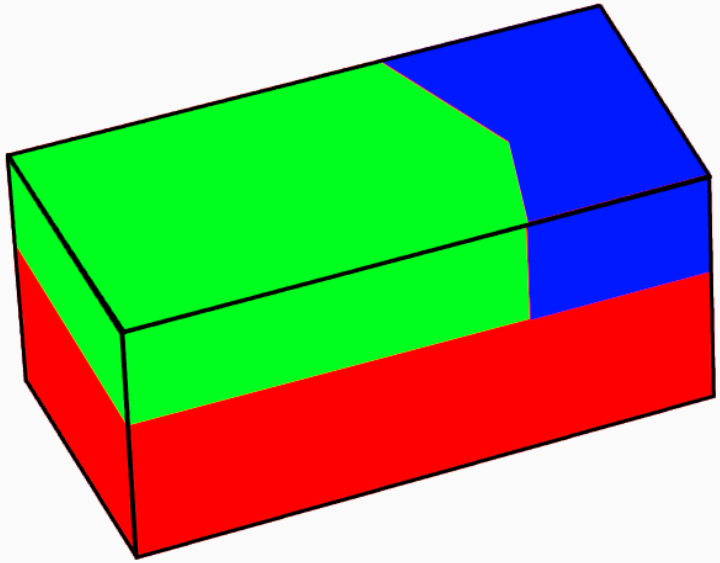

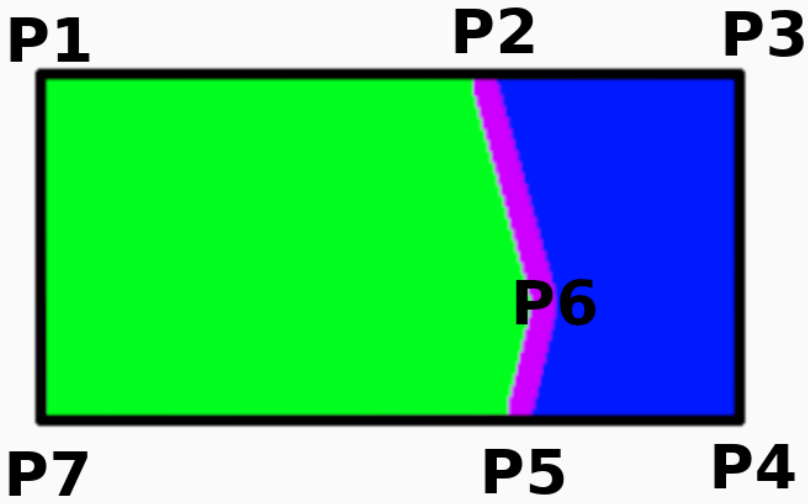

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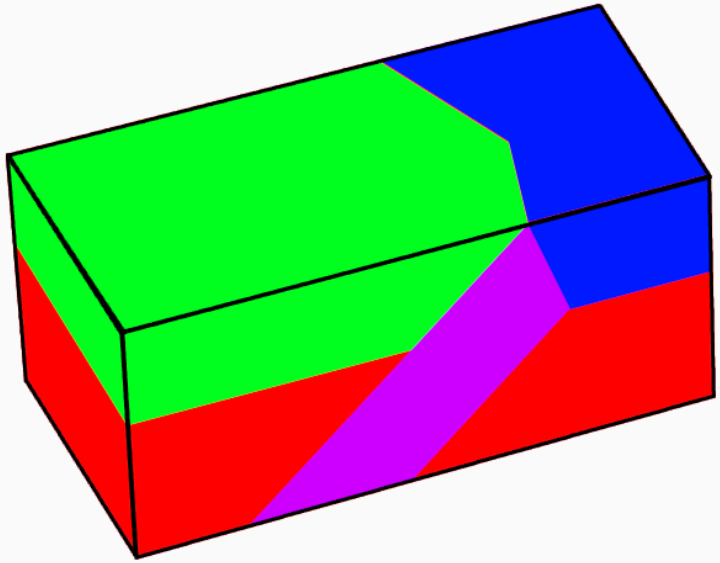
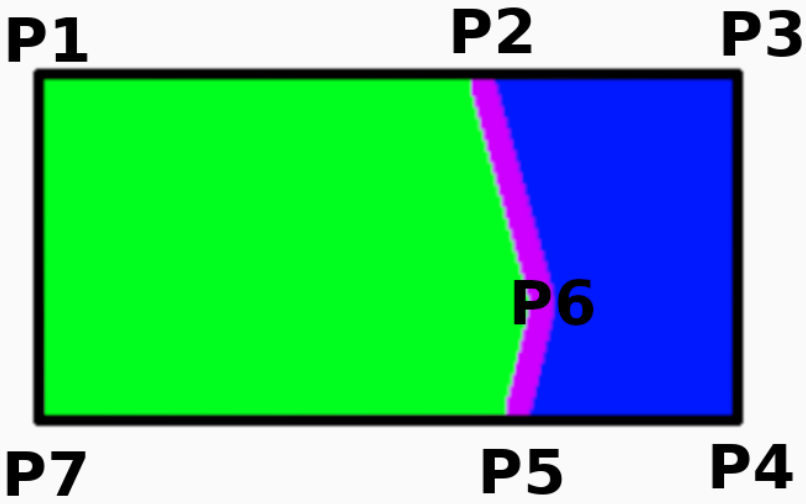
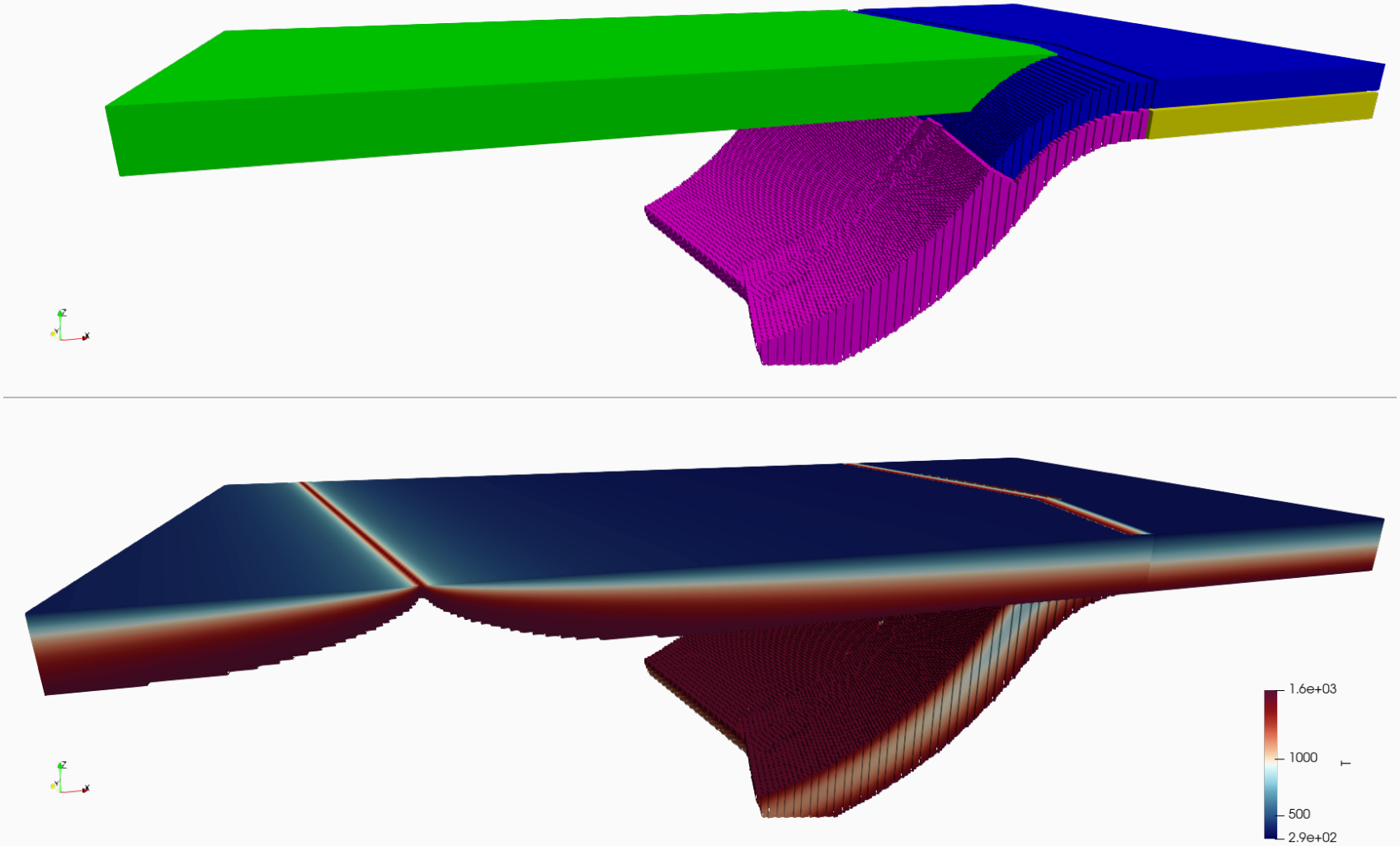




We can use these concepts to build this with the world builder



Making the World Builder file from lines, areas and volumes

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [









  ]
}
```

Making the World Builder file from lines, area's and volumes

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {"model":"mantle layer", "name":"upper mantle", "min depth":100e3, "max depth":660e3,
       "coordinates":[[0,0],[0,1000e3],[2000e3,1000e3],[2000e3,0]],
       "composition models":[{"model":"uniform", "compositions":[4]}]},
  ]
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    {"model":"oceanic plate", "name":"Overriding plate", "max depth":100e3,
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       "temperature models":[{"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
                              "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
       "composition models":[{"model":"uniform", "compositions":[0], "max depth":100e3}]},

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       "temperature models":[{"model":"linear", "max depth":100e3}],
       "composition models":[{"model":"uniform", "compositions":[3], "max depth":50e3},
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       "segments":[{"length":300e3, "thickness":[100e3], "angle":[0,60],









                                                                  ],
       "temperature models":[{"model":"plate model", "density":3300, "plate velocity":0.02 }],
       "composition models":[{"model":"uniform", "compositions":[2], "max distance slab top":100e3}]}
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                    {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
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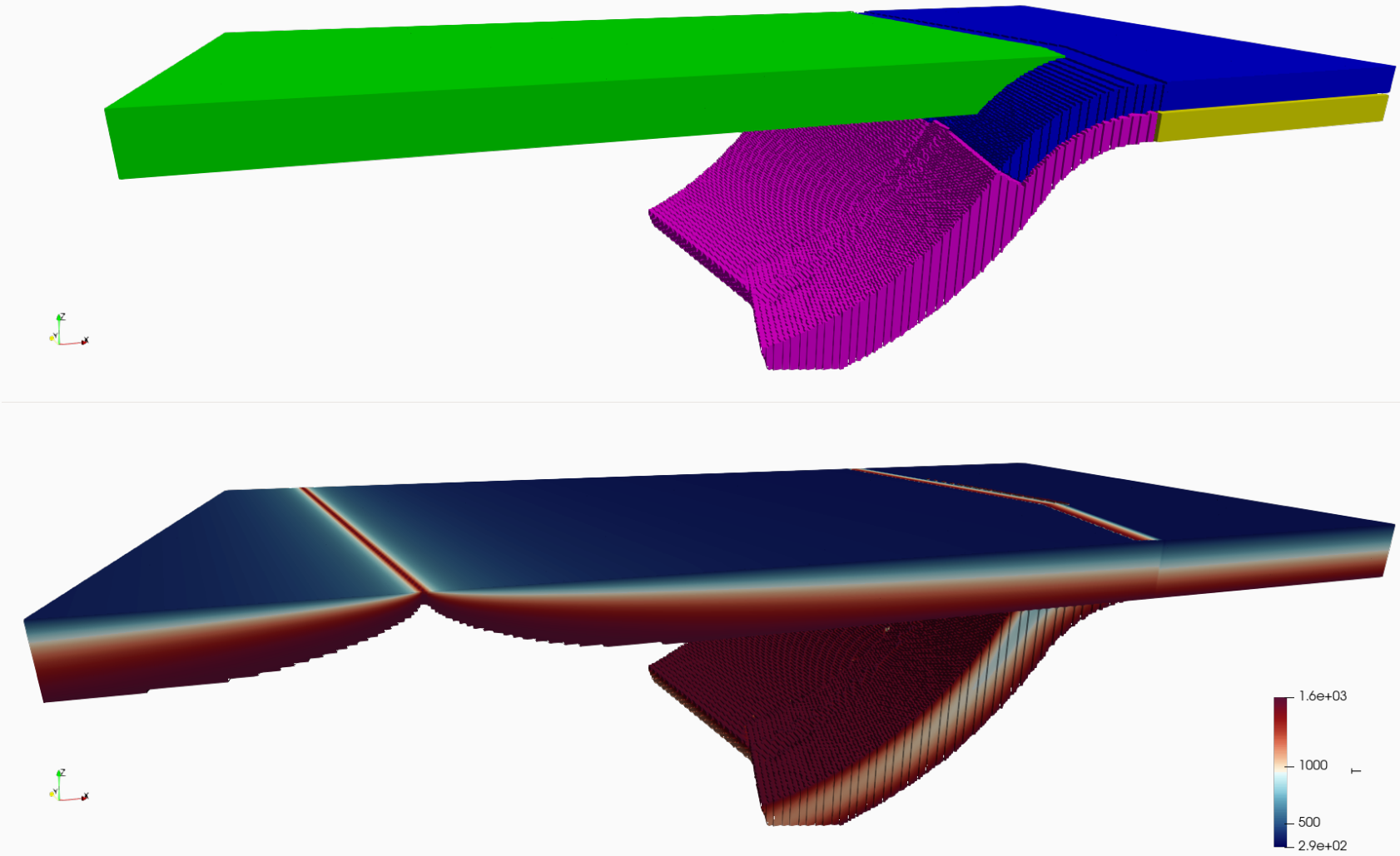
Resulting model, this is what we are going to build today!



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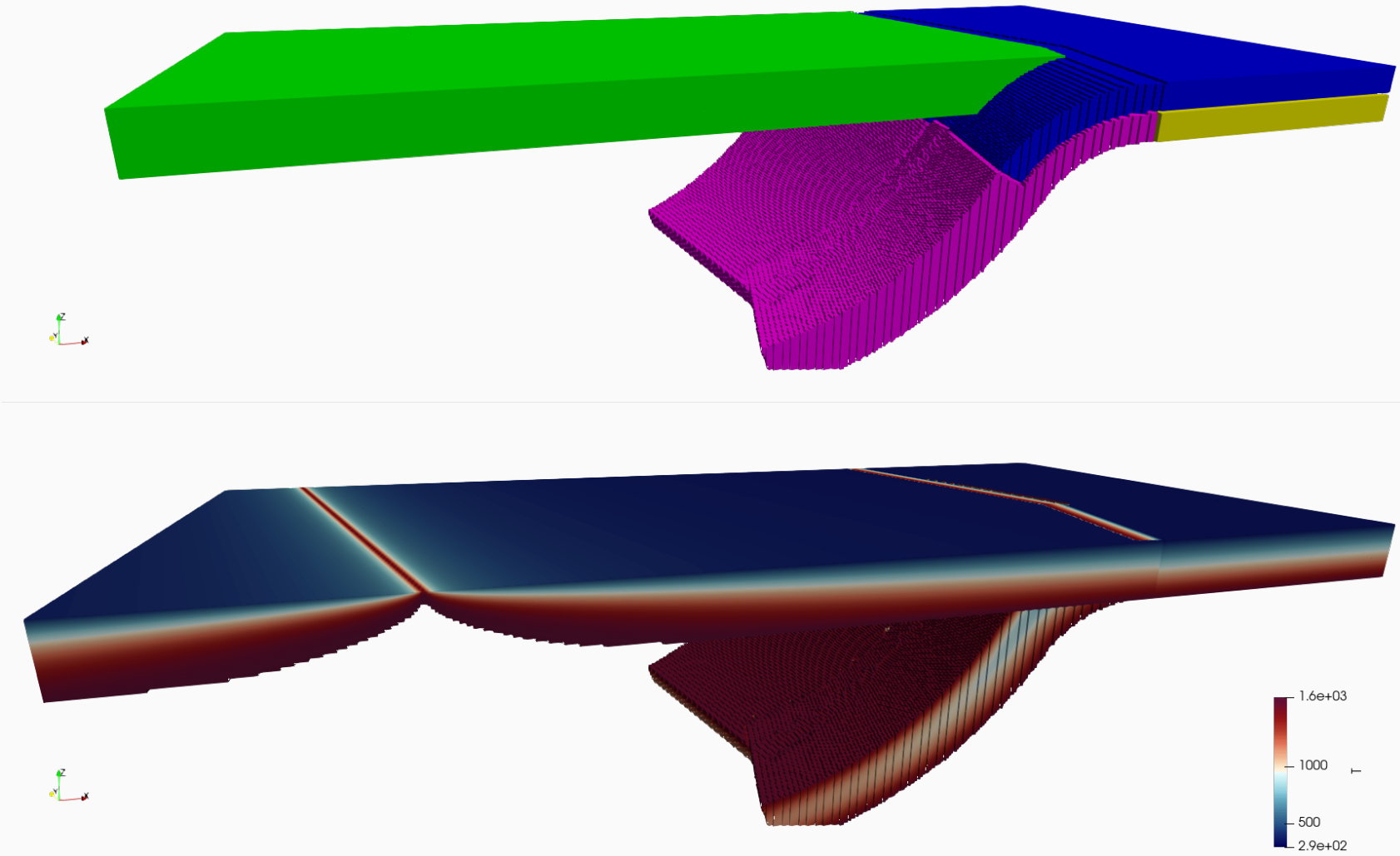
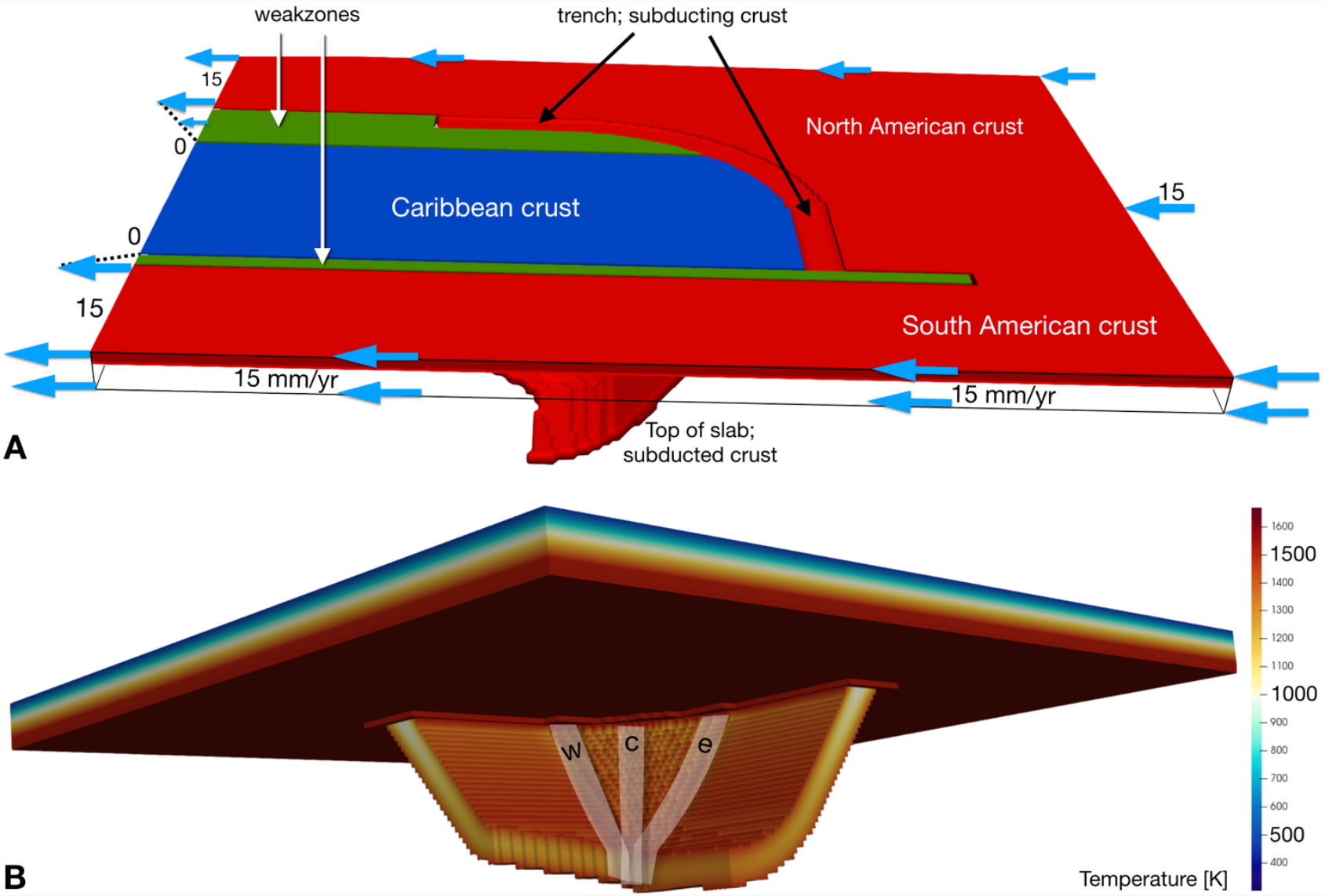
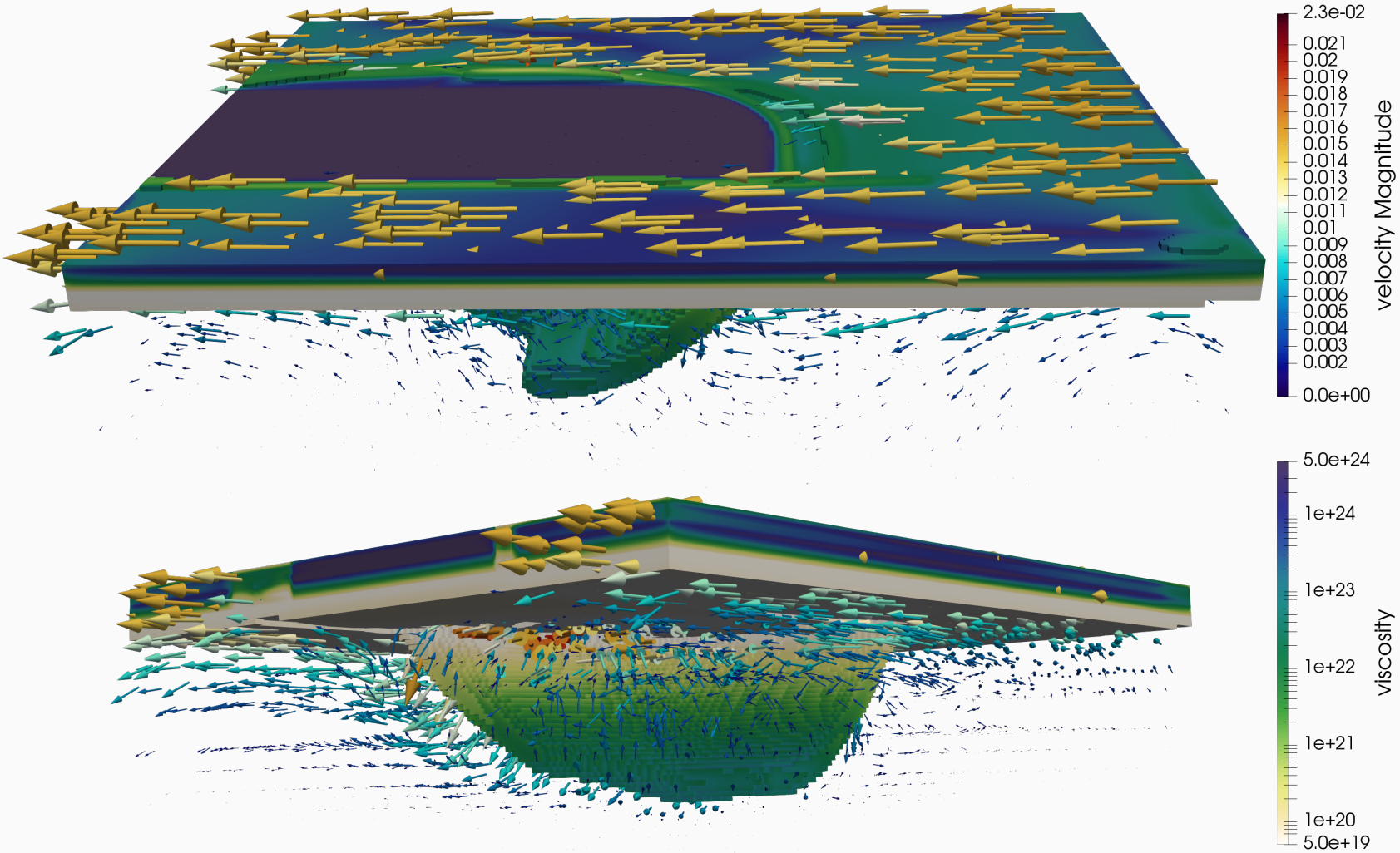


This is only a very simple example. There are many more possibilities!

A model of the Carribean for example!



And here are model results with with ASPECT!



(GWB input file for this model at the end of the presentation)

Building the subduction example with World Builder in ASPECT

What does ASPECT need?

1. location of the world builder file
2. to be set for use as an initial temperature/composition model

What does ASPECT need?

1. location of the world builder file
2. to be set for use as an initial temperature/composition model

ASPECT listing 1: Activating the world builder in ASPECT

```
1  set World builder file = world/builder/file/location.wb
2
3  subsection Initial temperature model
4      set Model name = world builder
5  end
6
7  subsection Initial composition model
8      set Model name = world builder
9  end
```

A minimal World Builder file example

1. You **need** to provide the world builder version: 0.3
2. You **need** to define a features object.

A minimal World Builder file example

1. You **need** to provide the world builder version: 0.3
2. You **need** to define a features object.

GWB listing 1: A minimal World Builder file example: RFM-1-minimal.wb

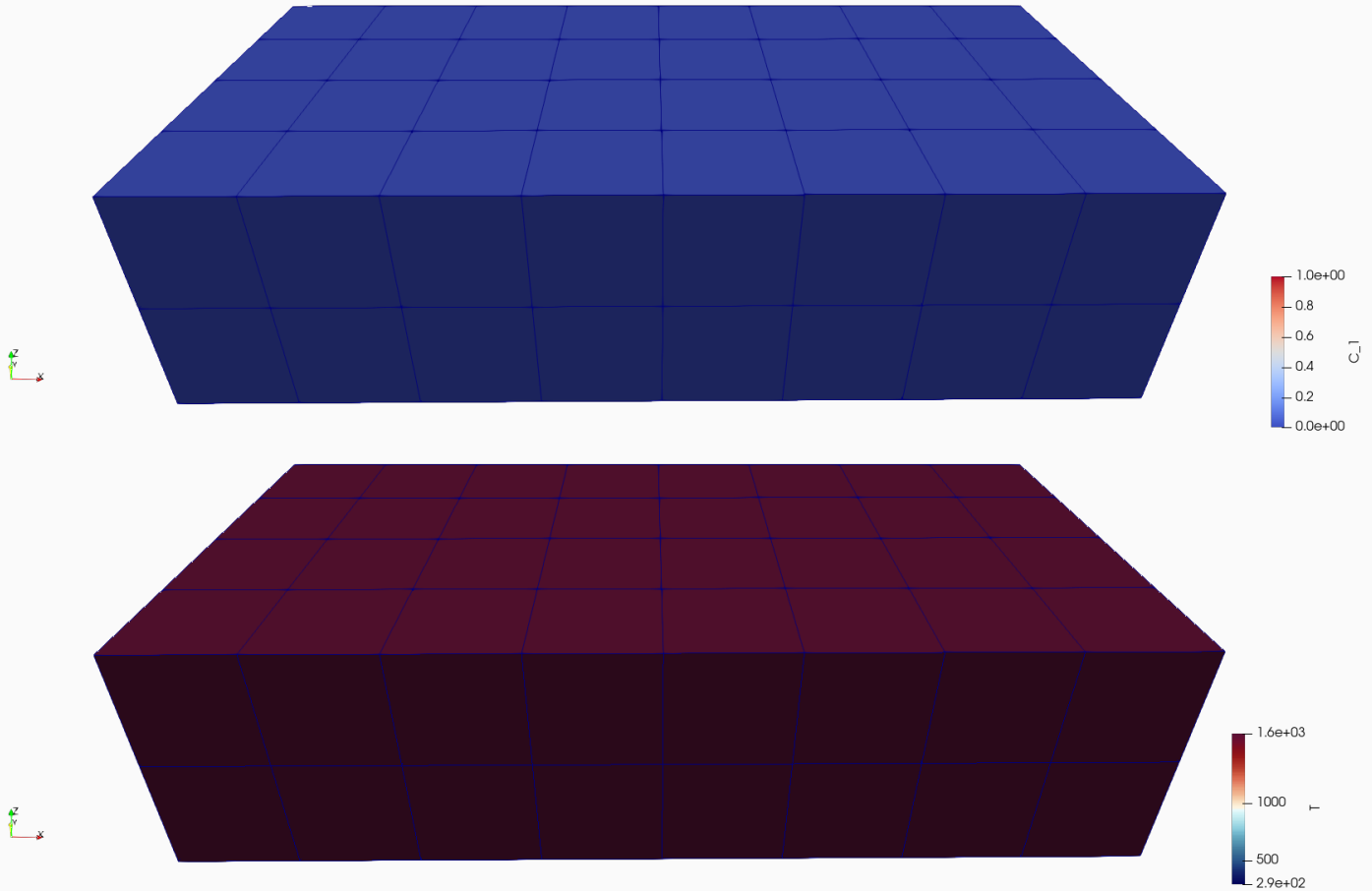
```
{
    "version":"0.3",
    "features":[ ]
}
```

1. Make sure you are in the directory session-5:
   `cd ~/aspect-tutorials/2020-tectonics-modeling-tutorial/session-5`
2. You can now run `../aspect-release RFM-1-minimal.prm`
3. Load state in Paraview:
   `pv_view_full_c1_T.pvsm`, use
   `search files under specified directory` and set the directory to
   `RFM-1-minimal`

A minimal World Builder file example visualized

You can now run `../aspect-release RFM-1-minimal.prm`

Paraview Load state: `pv_view_full_c1_T.pvsm`, use `search files under specified directory` and set the directory to `RFM-1-minimal`



Optional parameter: coordinate system

1. You **can** provide the coordinate system.
2. The cartesian coordinate is the **default**

GWB listing 2: A minimal World Builder file example: RFM-1-minimal.wb

```
1  {
2      "version":"0.3",
3
4      "features":[ ]
5  }
```

Optional parameter: coordinate system

1. You **can** provide the coordinate system.
2. The cartesian coordinate is the **default**

GWB listing 3: A minimal World Builder file example

```
{
    "version":"0.3",
    "coordinate system":{"model":"cartesian"},
    "features":[ ]
}
```

Adding a generic feature

1. Code in **red** boxes will give you errors when used literally!
2. The code below doesn't work because there is no feature called "feature model 1", or a temperature model called "temp. model 1", etc.

GWB listing 4: Adding a generic feature

```
{
  "version":"0.3",
  "features":
  [
    {
      "model":"feature model 1",
      "name":"Eurasia",
      "coordinates" :[[0,0],[0,100e3 ],[200e3,100e3 ],[200e3 ,0]],
      "temperature models":[{"model":"temp. model 1"}],
      "composition models":[{"model":"comp. model 1"}]
    }
  ]
}
```

Optional exercise: Run the code above and see if you can understand the error message.

Adding two generic features

GWB listing 5: Adding two generic features

```
{
  "version":"0.3",
  "features":
  [
    {
      "model":"feature model 1",
      "name":"Eurasia"
      "coordinates" :[[0,0],[0,100e3 ],[200e3,100e3 ],[200e3 ,0]],
      "temperature models":[{"model":"temp. model 1"}],
      "composition models":[{"model":"comp. model 1"}]
    },
    {
      "model":"feature model 2",
      "name":"Africa",
      "coordinates":[[0,0],[0,-100e3],[-200e3,-100e3],[-200e3,0]],
      "generic feature option 1":1000.0,
      "generic feature option 2":"value 2",
      "temperature models":[{"model":"temp. model 2", "temp. par.":100e3}],
      "composition models":[{"model":"comp. model 2", "comp. par.":1}]
    }
  ]
}
```

What features are available?

1. **Area features**:
    - Continental plate
    - Oceanic plate
    - Mantle layer
2. **Line features**:
    - Subducting plate
    - Fault

What features are available?

1. **Area features**:
    - Continental plate
    - Oceanic plate
    - Mantle layer
2. **Line features**:
    - Subducting plate
    - Fault

With **area features** the coordinates parameter describes an area.

With **line features** the coordinates parameter describes a line

Adding a oceanic plate feature

1. This add a oceanic plate feature
2. But no temperature or compositional models have been added!

GWB listing 6: Adding a oceanic plate feature

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [



  ]
}
```

Adding a oceanic plate feature

1. This add a oceanic plate feature
2. But no temperature or compositional models have been added!

GWB listing 7: Adding a oceanic plate feature

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate",
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],



    }
  ]
}
```

Adding temperature and composition models

Here we add temperature and compositional models to the continental plate feature.

GWB listing 8: RFM-2-overriding_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate",
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
      "temperature models":[{"model":"uniform", "temperature":293}],
      "composition models":[{"model":"uniform", "compositions":[0]}]
    }
  ]
}
```

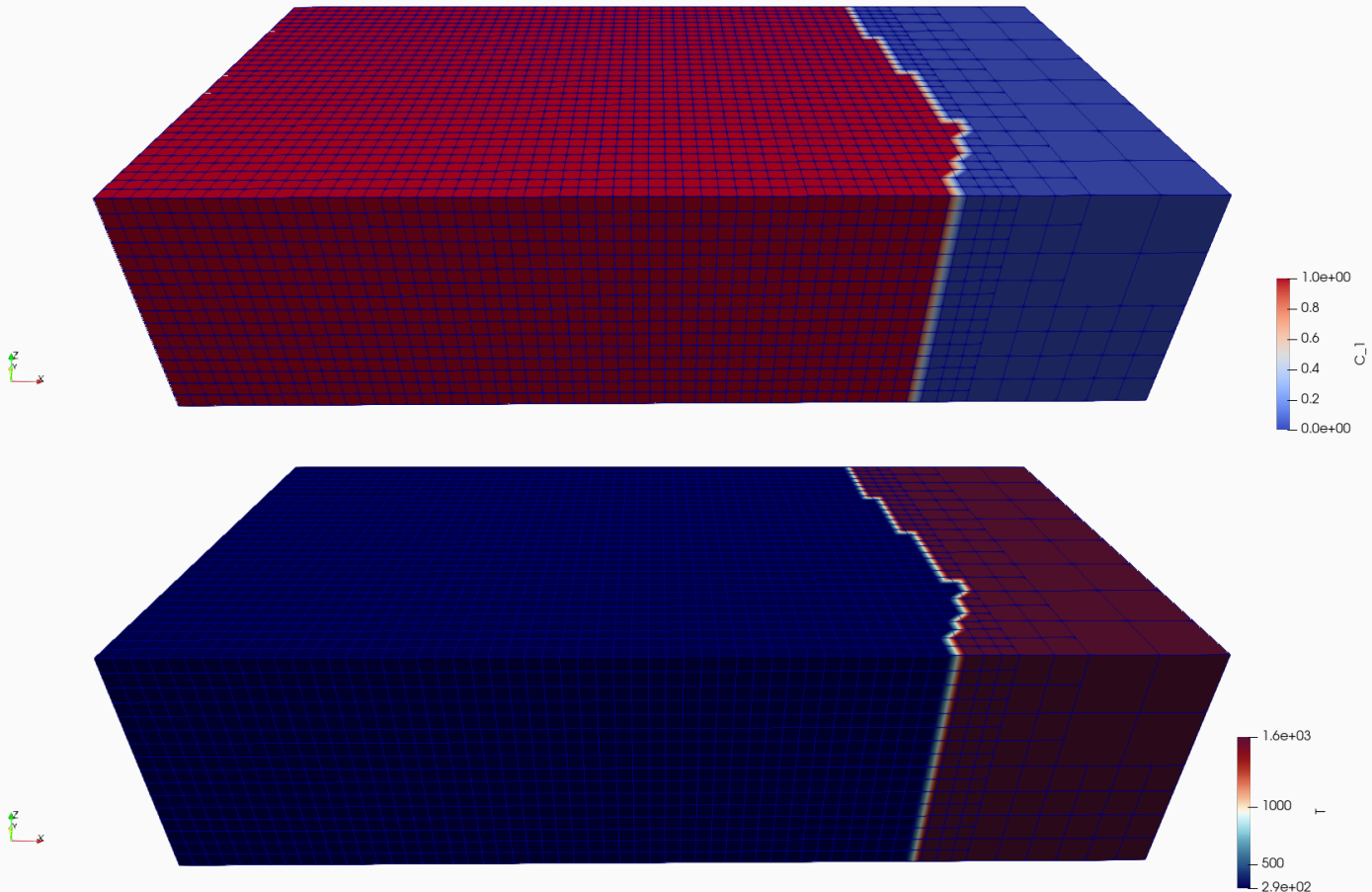
You can now run `../aspect-release RFM-2-overriding_plate.prm`

Load state: `pv_view_full_c1_T.pvsm`, `search files under specified directory` and set the directory to `RFM-2-overriding_plate`

An oceanic plate

You can now run `../aspect-release RFM-2-overriding_plate.prm`

Load state in Paraview: `pv_view_full_c1_T.pvsm`, use `search files under specified directory` and set the directory to `RFM-2-overriding_plate`



Adding maximum depths

GWB listing 9: RFM-2-overriding_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate",
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
      "temperature models":
      [
        {"model":"uniform", "temperature":293                    }
      ],
      "composition models":[{"model":"uniform", "compositions":[0]}]
    }
  ]
}
```

Adding maximum depths

GWB listing 10: RFM-3-overriding_plate_depths.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
      "temperature models":
      [
        {"model":"uniform", "temperature":293, "max depth":50e3}
      ],
      "composition models":[{"model":"uniform", "compositions":[0]}]
    }
  ]
}
```

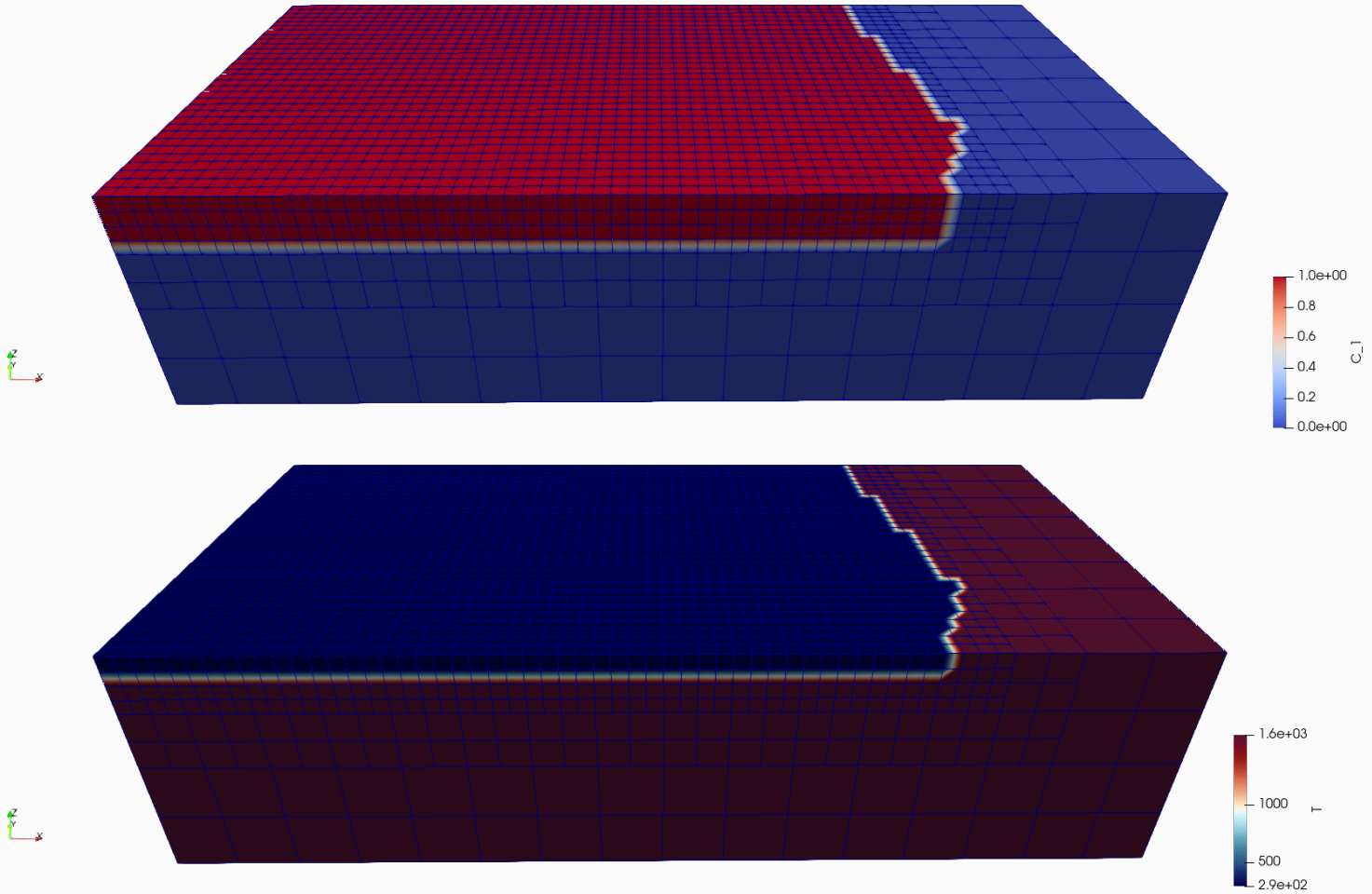
Run: `../aspect-release RFM-3-overriding_plate_depths.prm`

View: `pv_view_full_c1_T.pvsm`, dir: `RFM-3-overriding_plate_depths`

A continental plate

Run: `../aspect-release RFM-3-overriding_plate_depths.prm`

View: `pv_view_full_c1_T.pvsm` , dir: `RFM-3-overriding_plate_temp`



More interesting oceanic plate temperature

GWB listing 11: RFM-3-overriding_plate_depths.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
      "temperature models":
      [
        {"model":"uniform", "temperature":293, "max depth":50e3}

      ],
      "composition models":[{"model":"uniform", "compositions":[0]}]
    }
  ]
}
```

More interesting oceanic plate temperature

GWB listing 12: RFM-4-overriding_plate_temp.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {
      "model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
      "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
      "temperature models":
      [
        {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
         "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}
      ],
      "composition models":[{"model":"uniform", "compositions":[0]}]
    }
  ]
}
```

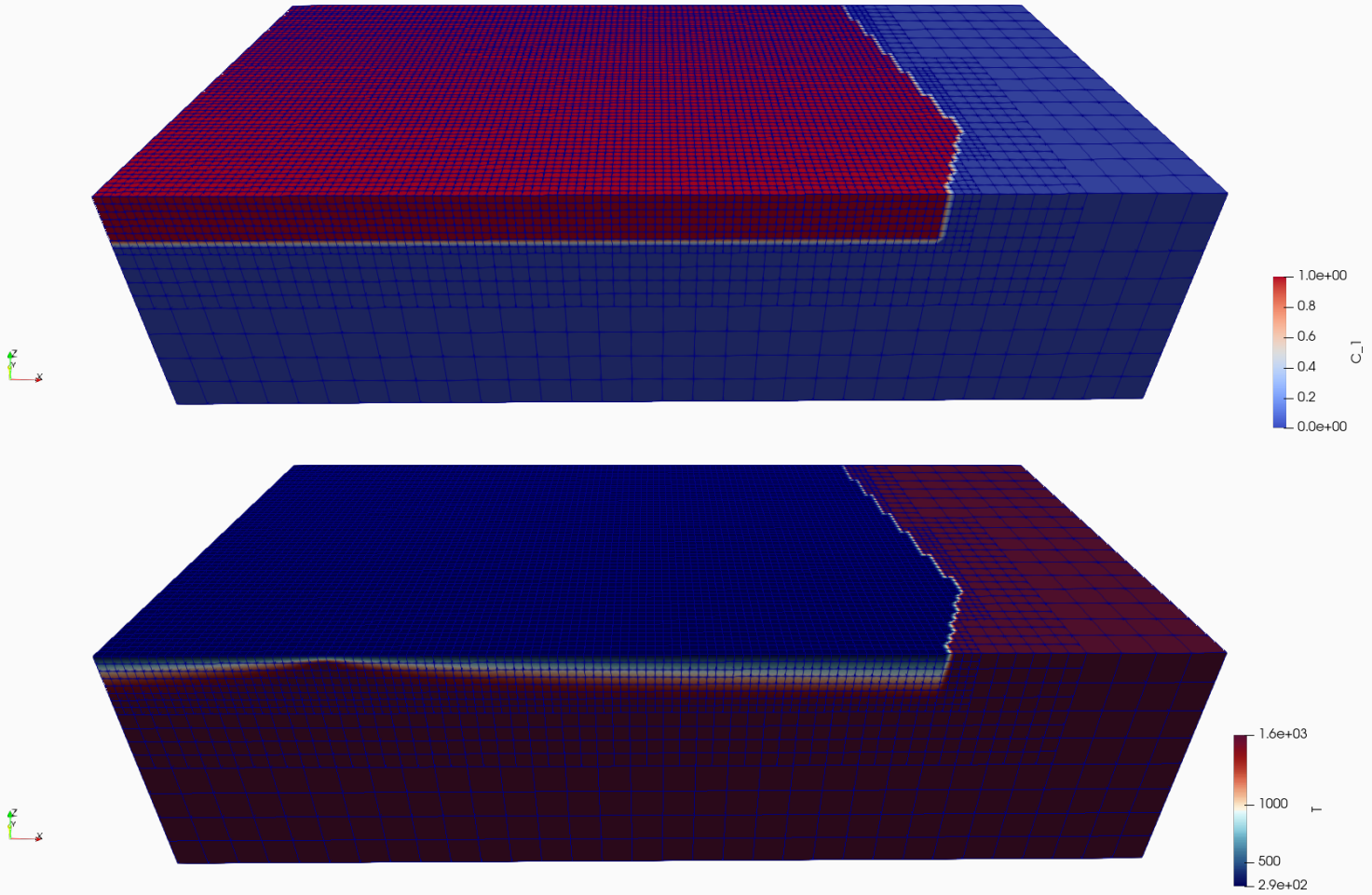
Run: `../aspect-release RFM-4-overriding_plate_temp.prm`

View: `pv_view_full_c1_T.pvsm`, dir: `RFM-4-overriding_plate_temp`

A continental plate

Run: `../aspect-release RFM-4-overriding_plate_temp.prm`

View: `pv_view_full_c1_T.pvsm`, dir: `RFM-4-overriding_plate_temp`



Adding the Atlantic

GWB listing 13: RFM-4-overriding_plate_temp.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {"model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
     "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
     "temperature models":[
       {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
        "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
     "composition models":[{"model":"uniform", "compositions":[0]}]
    }



  ]
}
```

Adding the Atlantic

GWB listing 14: incomplete RFM-5-atlantic.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {"model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
     "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
     "temperature models":[
       {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
        "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
     "composition models":[{"model":"uniform", "compositions":[0]}]
    },
    {"model":"oceanic plate", "name":"Atlantic Plate", "max depth":100e3,
     "coordinates":[[200e4,0],[200e4,100e4],[150e4,100e4],[160e4,35e4],[150e4,0]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[

                                                              ]}
  ]
}
```

Adding the Atlantic

GWB listing 15: RFM-5-atlantic.wb

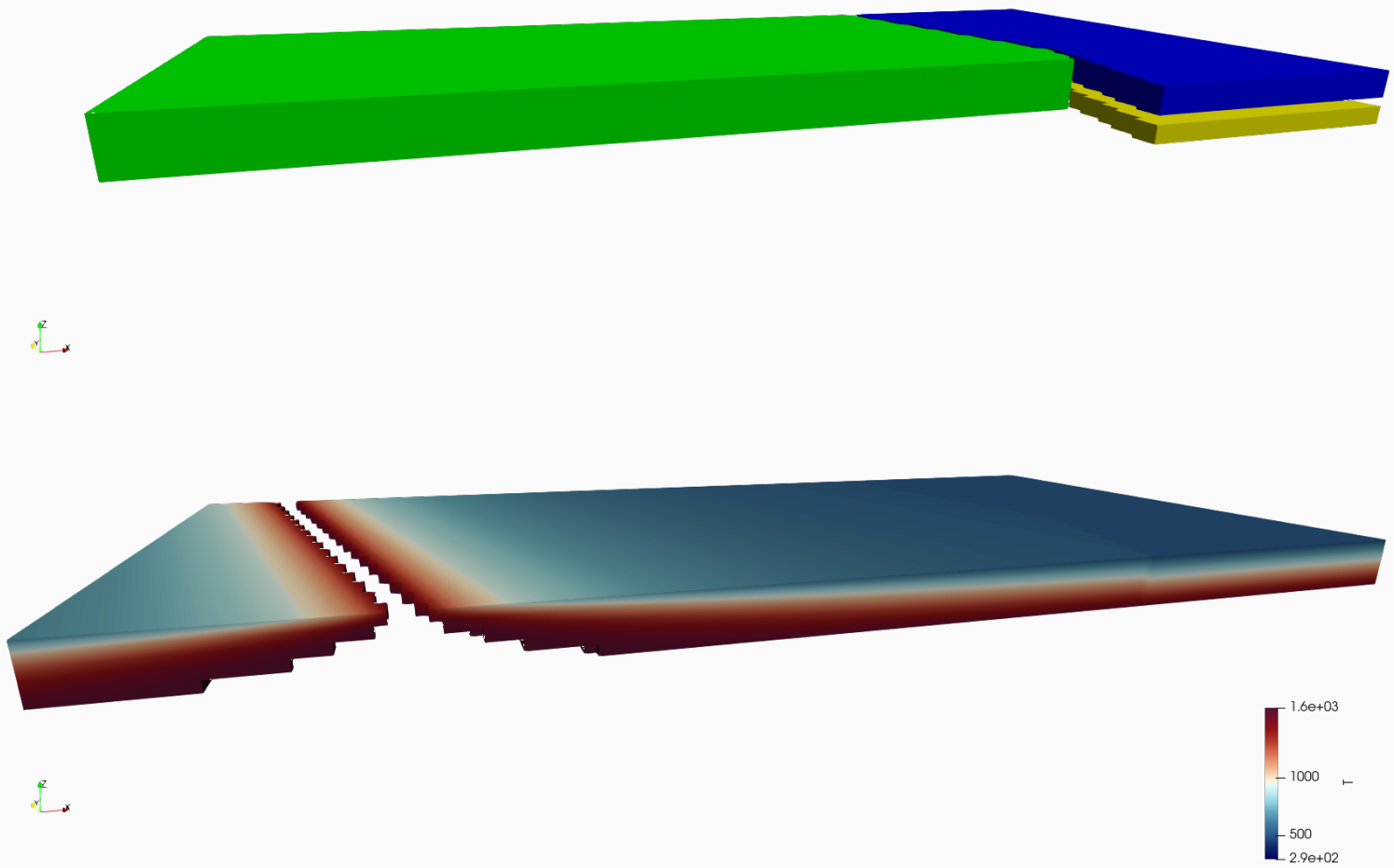
```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {"model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
     "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
     "temperature models":[
       {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
        "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
     "composition models":[{"model":"uniform", "compositions":[0]}]
    },
    {"model":"oceanic plate", "name":"Atlantic Plate", "max depth":100e3,
     "coordinates":[[200e4,0],[200e4,100e4],[150e4,100e4],[160e4,35e4],[150e4,0]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[
       {"model":"uniform", "compositions":[3], "max depth":50e3},
       {"model":"uniform", "compositions":[1], "min depth":50e3}]}
  ]
}
```

Run: `../aspect-release RFM-5-atlantic.prm`

Add the Atlantic

Run: `../aspect-release RFM-5-atlantic.prm`

View: `pv_view_mixed_c1_T.pvsm` , dir: `RFM-5-atlantic`



Optional adding a mantle layer

GWB listing 16: RFM-5-atlantic.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [



    {"model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
     "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
     "temperature models":[
       {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
        "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
     "composition models":[{"model":"uniform", "compositions":[0]}]},
    {"model":"oceanic plate", "name":"Atlantic Plate", "max depth":100e3,
     "coordinates":[[200e4,0],[200e4,100e4],[150e4,100e4],[160e4,35e4],[150e4,0]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[
       {"model":"uniform", "compositions":[3], "max depth":50e3},
       {"model":"uniform", "compositions":[1], "min depth":50e3}]}
  ]
}
```

Optional adding a mantle layer

GWB listing 17: RFM-6-mantle.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    {"model":"mantle layer", "name":"upper mantle", "min depth":100e3,
       "max depth":660e3, "coordinates":[[0,0],[0,1000e3],[2000e3,1000e3],[2000e3,0]],
       "composition models":[{"model":"uniform", "compositions":[4]}]},
    {"model":"oceanic plate", "name":"Overriding Plate", "max depth":100e3,
     "coordinates":[[0,0],[0,1000e3],[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
     "temperature models":[
       {"model":"plate model", "max depth":100e3, "spreading velocity":0.01,
        "ridge coordinates":[[400e3,-1],[-100e3,2000e3]]}],
     "composition models":[{"model":"uniform", "compositions":[0]}]},
    {"model":"oceanic plate", "name":"Atlantic Plate", "max depth":100e3,
     "coordinates":[[200e4,0],[200e4,100e4],[150e4,100e4],[160e4,35e4],[150e4,0]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[
       {"model":"uniform", "compositions":[3], "max depth":50e3},
       {"model":"uniform", "compositions":[1], "min depth":50e3}]}
  ]
}
```

Exercise: add a lower mantle composition and visualize it.

Break

Finishing the model: Subducting plates

Adding a basic subducting plate

A subducting plate requires:

1. coordinates -> The trench of the subduction zone
2. a dip point -> The direction in which the plate is dipping
3. segments -> downwards parts of the plate

GWB listing 18: partial RFM-7-basic_subducting_plate.wb

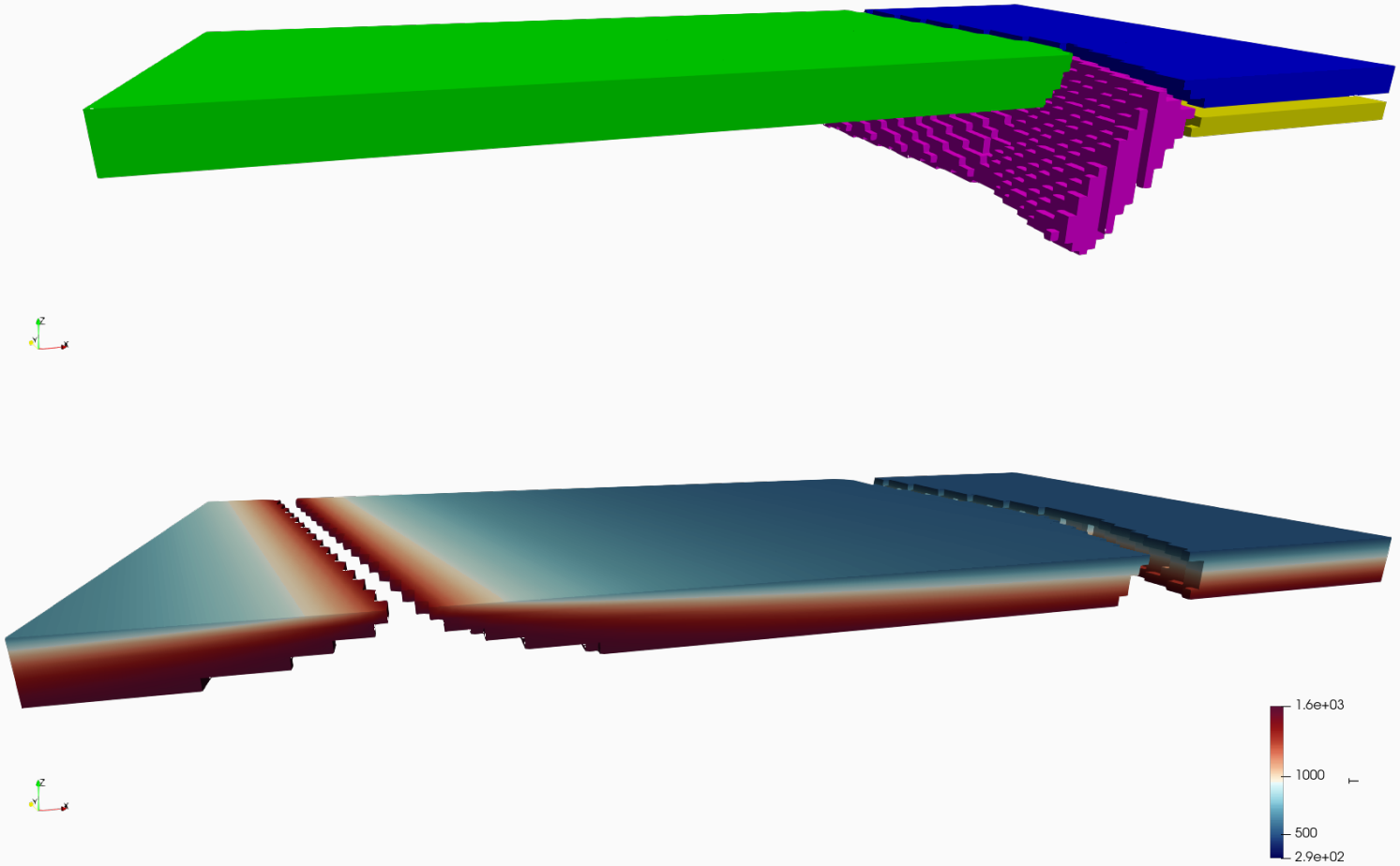
```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
     ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[60]}],
       "temperature models":[{"model":"uniform", "temperature":293 }],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Run: `../aspect-release RFM-7-basic_subducting_plate.prm`

Adding a basic subducting plate

Run: `../aspect-release RFM-7-basic_subducting_plate.prm`

View: `pv_view_mixed_c1_T.pvsm` , dir: `RFM-7-basic_subducting_plate`



Curving and adding temperature to the subducting plate

GWB listing 19: partial RFM-7-basic_subducting_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
     ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[60]}],
       "temperature models":[
         {"model":"uniform", "temperature":293 }],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Curving and adding temperature to the subducting plate

GWB listing 20: partial RFM-8-curved_temp_subducting_plate.wb

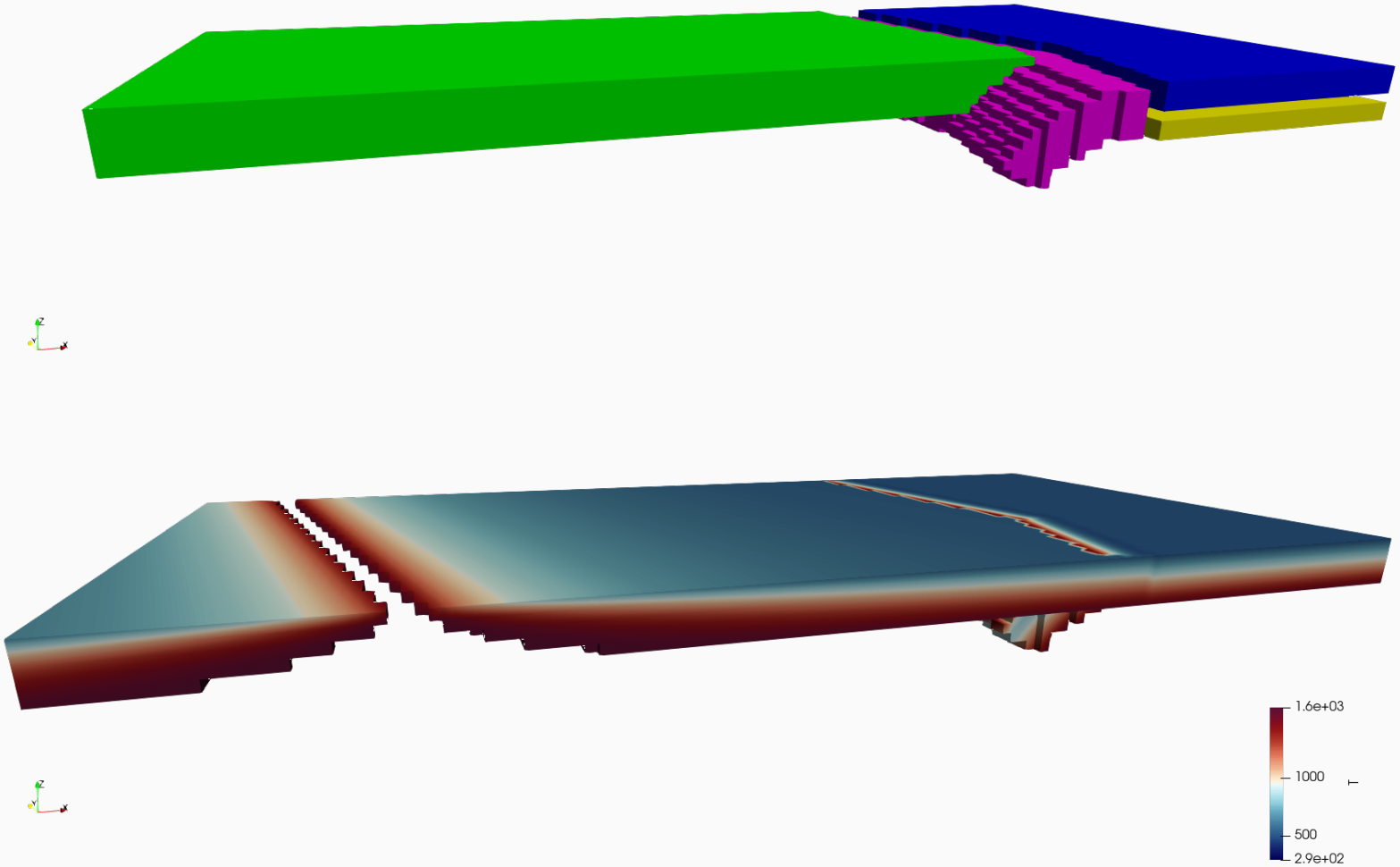
```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[0,60]}],
       "temperature models":[
         {"model":"plate model", "density":3300, "plate velocity":0.02}],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Run: `../aspect-release RFM-8-curved_temp_subducting_plate.prm`

Adding a basic subducting plate

Run: `../aspect-release RFM-8-curved_temp_subducting_plate.prm`

View: `pv_view_mixed_c1_T.pvsm` , dir: `RFM-8-curved_temp_subducting_plate`



Adding a segment to the subducting plate

GWB listing 21: partial RFM-8-curved_temp_subducting_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[0,60]}
                                                              ],
       "temperature models":[
         {"model":"plate model", "density":3300, "plate velocity":0.02}],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Adding a segment to the subducting plate

GWB listing 22: partial RFM-9-segments_subducting_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[0,60]},
         {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
       "temperature models":[
         {"model":"plate model", "density":3300, "plate velocity":0.02}],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

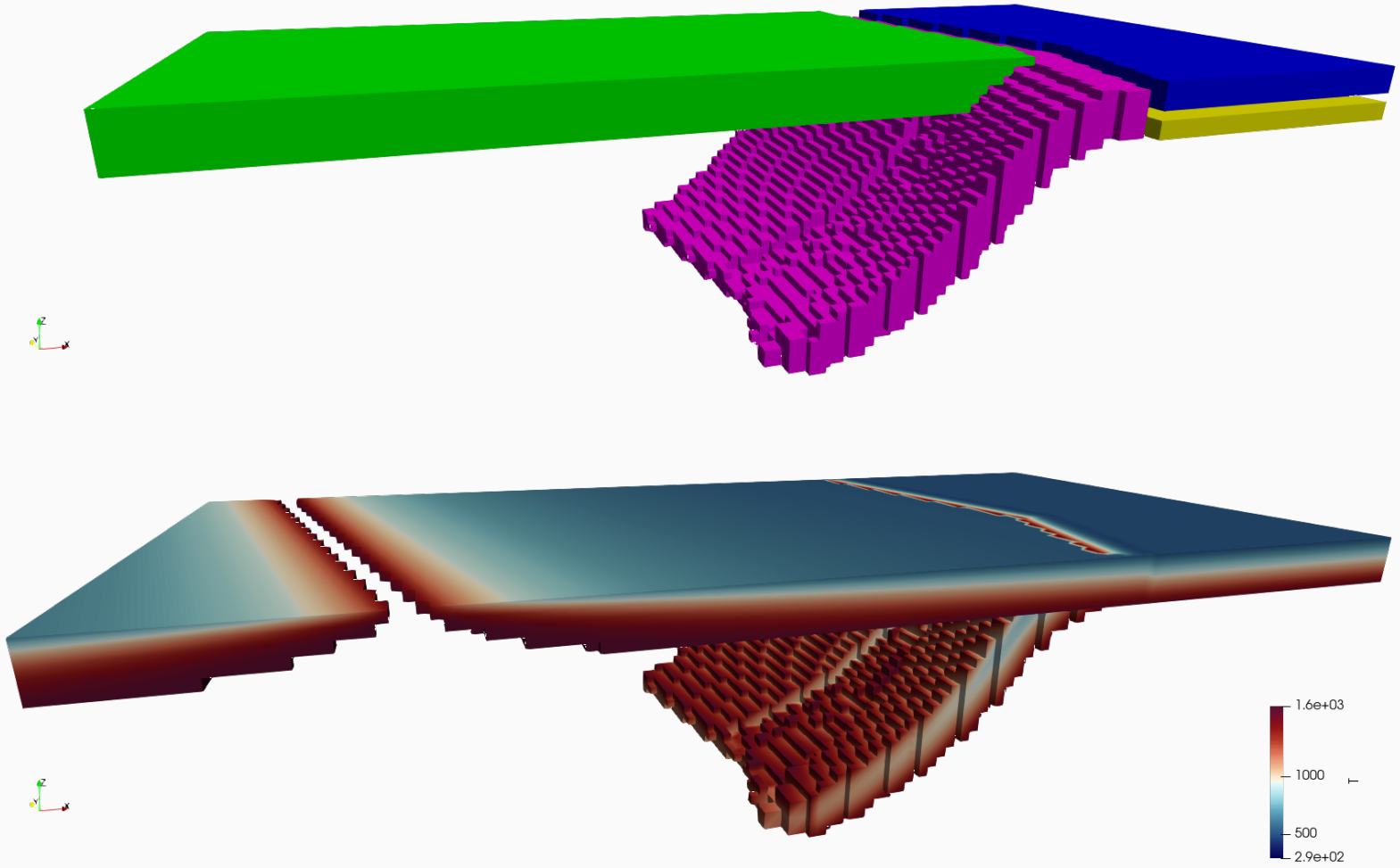
Run: `../aspect-release RFM-9-segments_subducting_plate.prm`

Exercise: Turn the subduting plate in the other direction.

Adding a basic subducting plate

Run: `../aspect-release RFM-9-segments_subducting_plate.prm`

View: `pv_view_mixed_c1_T.pvsm` , dir: `RFM-9-segments_subducting_plate`



Adding different models to segments

GWB listing 23: partial RFM-9-segments_subducting_plate.wb

```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[0,60]


                                                                    },
         {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
       "temperature models":[
         {"model":"plate model", "density":3300, "plate velocity":0.02}],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Adding different models to segments

GWB listing 24: partial reference_model.wb

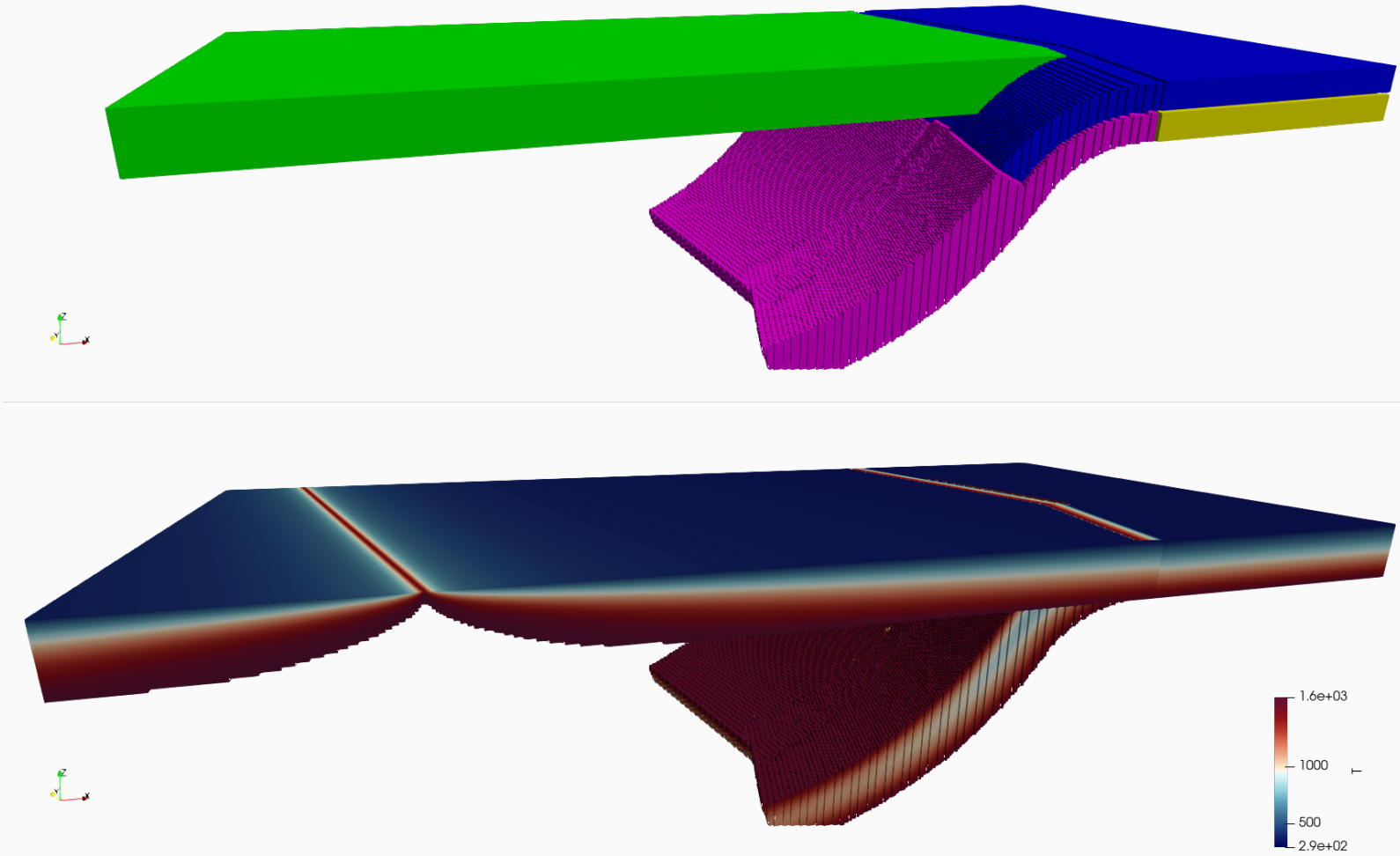
```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "features":
  [
    ...,
    {  "model":"subducting plate", "name":"Slab",
       "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
       "dip point":[0,0],
       "segments":[
         {"length":300e3, "thickness":[100e3], "angle":[0,60],
          "composition models":[
            {"model":"uniform", "compositions":[3], "max distance slab top":50e3},
            {"model":"uniform", "compositions":[2], "min distance slab top":50e3}]},
         {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
       "temperature models":[
         {"model":"plate model", "density":3300, "plate velocity":0.02}],
       "composition models":[{"model":"uniform", "compositions":[2]}]}
  ]
}
```

Run: `../aspect-release reference_model.prm`. (Note: highres!)

This is the reference model I showed you!

Run: `../aspect-release reference_model.prm` (Highres: $\sim$ 50M DOFs)

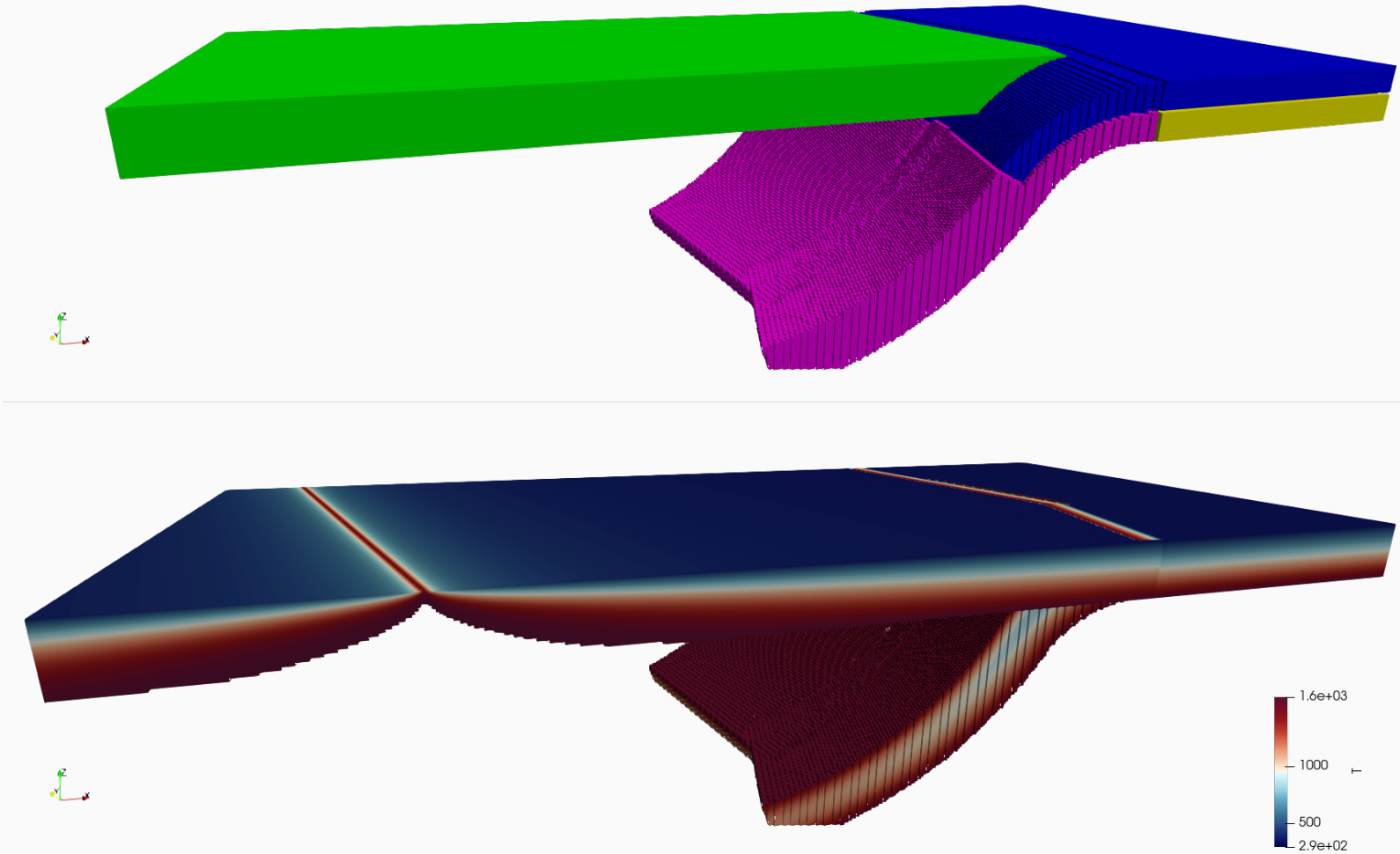
View: `pv_view_mixed_c1_T.pvsm`, dir: `reference_model`



This is the reference model I showed you!

Run: `../aspect-release reference_model.prm` (Highres: $\sim$ 50M DOFs)

View: `pv_view_mixed_c1_T.pvsm`, dir: `reference_model`



So are we done?

Not quite yet: 2D models and more complicated slabs

Two more things to cover:

- How to make 2D models
- How to make slabs which differ along strike

Topics not covered today:

- Spherical geometries
- How to deal with artifacts in the initial condition
- Interpolation of coordinates
- Global parameters vs local parameter
- How to read error messages

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- How to make 2D models
- How to make slabs which differ along strike

Topics not covered today:

- Spherical geometries
- How to deal with artifacts in the initial condition
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- Global parameters vs local parameter
- How to read error messages

See the manual for more information on those topics or ask during discussion session.

2D models

2D models are a cross-section through 3D models

- 2D models are a cross-section through 3D models
- Therefore you need to define the coordinates of the cross-section
- You need to define the start (which is $x = 0$) and a second point along the cross-section (direction).

GWB listing 25: Partial RFM-11-2D.wb

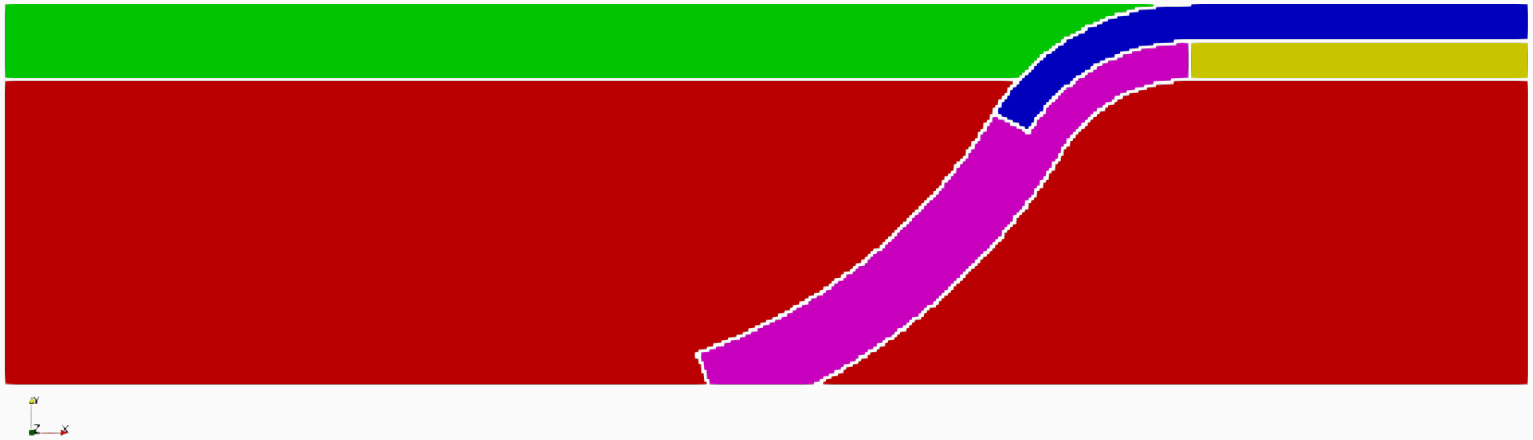
```
{
  "version":"0.3",
  "coordinate system":{"model":"cartesian"},
  "cross section":[[0,50e3],[100e3,-50e3]],
  "features":
  [
    ...
  ]
}
```

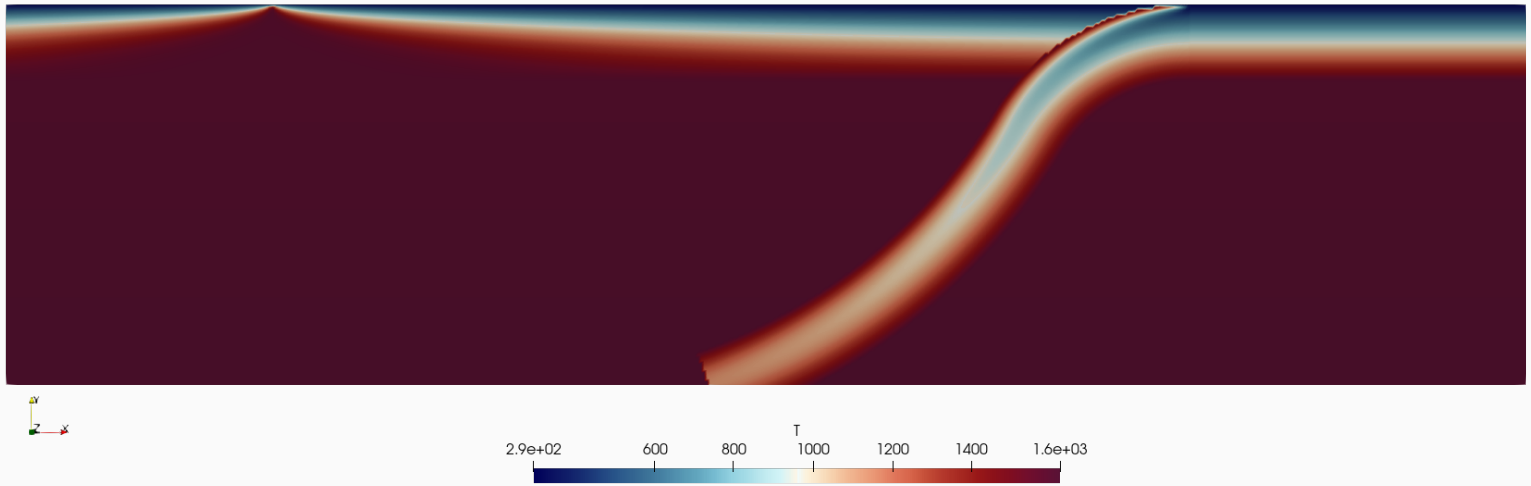
Run: `../aspect-release RFM-11-2D.prm`

A 2D model in ASPECT build with the World Builder

Run: `../aspect-release RFM-11-2D.prm`

View: `pv_view_2D_mixed_c1_T.pvsm` , dir: `RFM-11-2D`

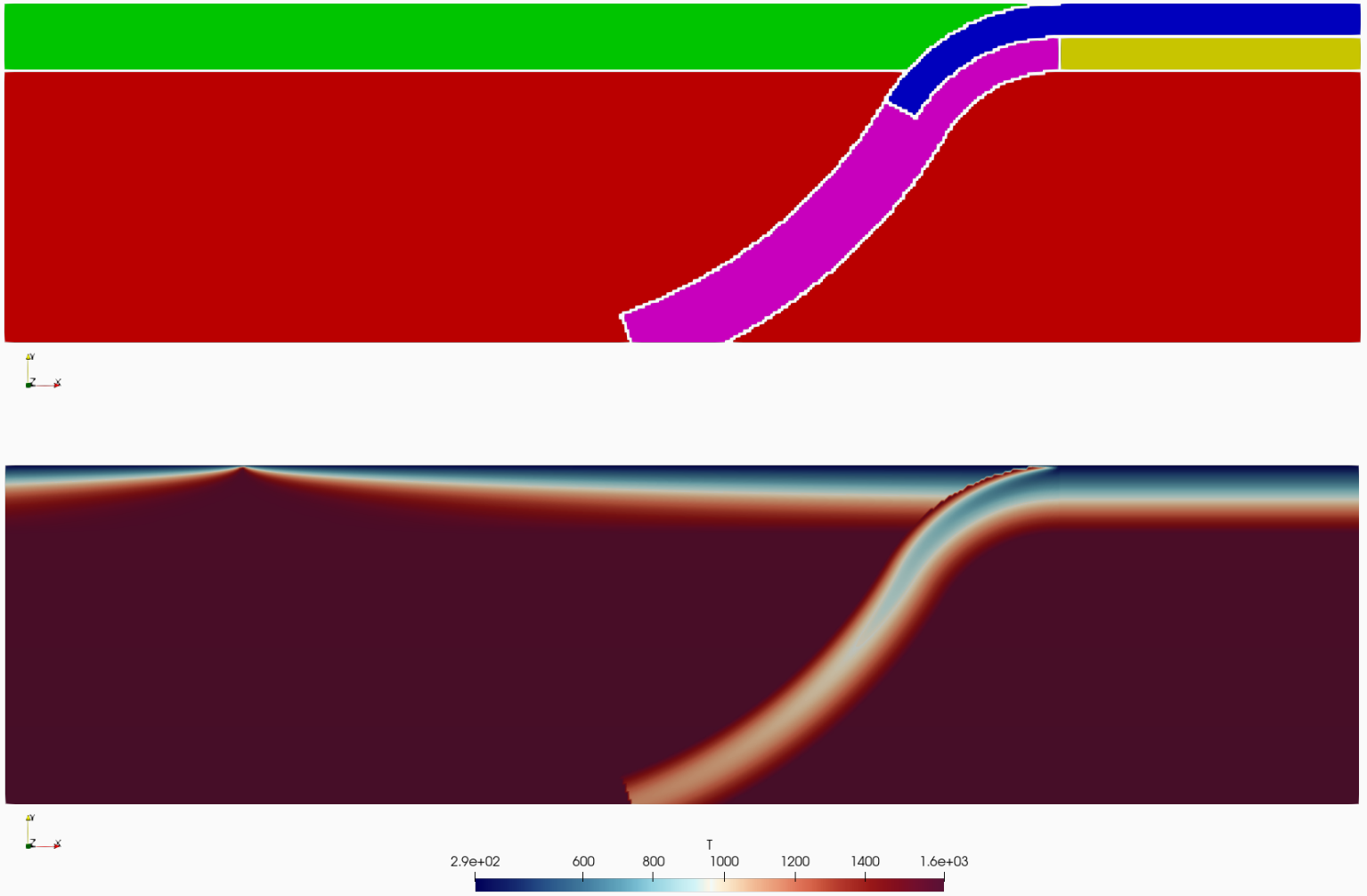




A 2D model in ASPECT build with the World Builder

Run: `../aspect-release RFM-11-2D.prm`

View: `pv_view_2D_mixed_c1_T.pvsm` , dir: `RFM-11-2D`



Exercise: can you make the slab tip thinner?

Changing slab properties between trench coordinates

Segments and sections

A subducting plate can be divided in **segment** and **sections**, which each can have their own properties:

1. **Segment** are down dip
2. **Sections** are parts between the coordinates.
3. All **sections** need to have the same amount of **segments** (But their length may be zero)

Adding a new section to a slab

GWB listing 26: partial RFM-12-sections.wb

```
...
{  "model":"subducting plate", "name":"Slab",
   "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
   "dip point":[0,0],
   "segments":[
     {"length":300e3, "thickness":[100e3], "angle":[0,60],
      "composition models":[
        {"model":"uniform", "compositions":[3], "max distance slab top":50e3},
        {"model":"uniform", "compositions":[2], "min distance slab top":50e3}]},
     {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
   "temperature models":[
     {"model":"plate model", "density":3300, "plate velocity":0.02}],
   "composition models":[{"model":"uniform", "compositions":[2]}]
}
...
```

Run: `../aspect-release RFM-12-sections.prm` .

Adding a new section to a slab

GWB listing 27: partial RFM-12-sections.wb

```
...
{  "model":"subducting plate", "name":"Slab",
   "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
   "dip point":[0,0],
   "segments":[
     {"length":300e3, "thickness":[100e3], "angle":[0,60],
      "composition models":[
        {"model":"uniform", "compositions":[3], "max distance slab top":50e3},
        {"model":"uniform", "compositions":[2], "min distance slab top":50e3}]},
     {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
   "sections":[
     {"coordinate":0,



      "composition models":[{"model":"uniform", "compositions":[1]}]}
   ],
   "temperature models":[
     {"model":"plate model", "density":3300, "plate velocity":0.02}],
   "composition models":[{"model":"uniform", "compositions":[2]}]
}
...
```

Run: `../aspect-release RFM-12-sections.prm` .

Adding a new section to a slab

GWB listing 28: partial RFM-12-sections.wb

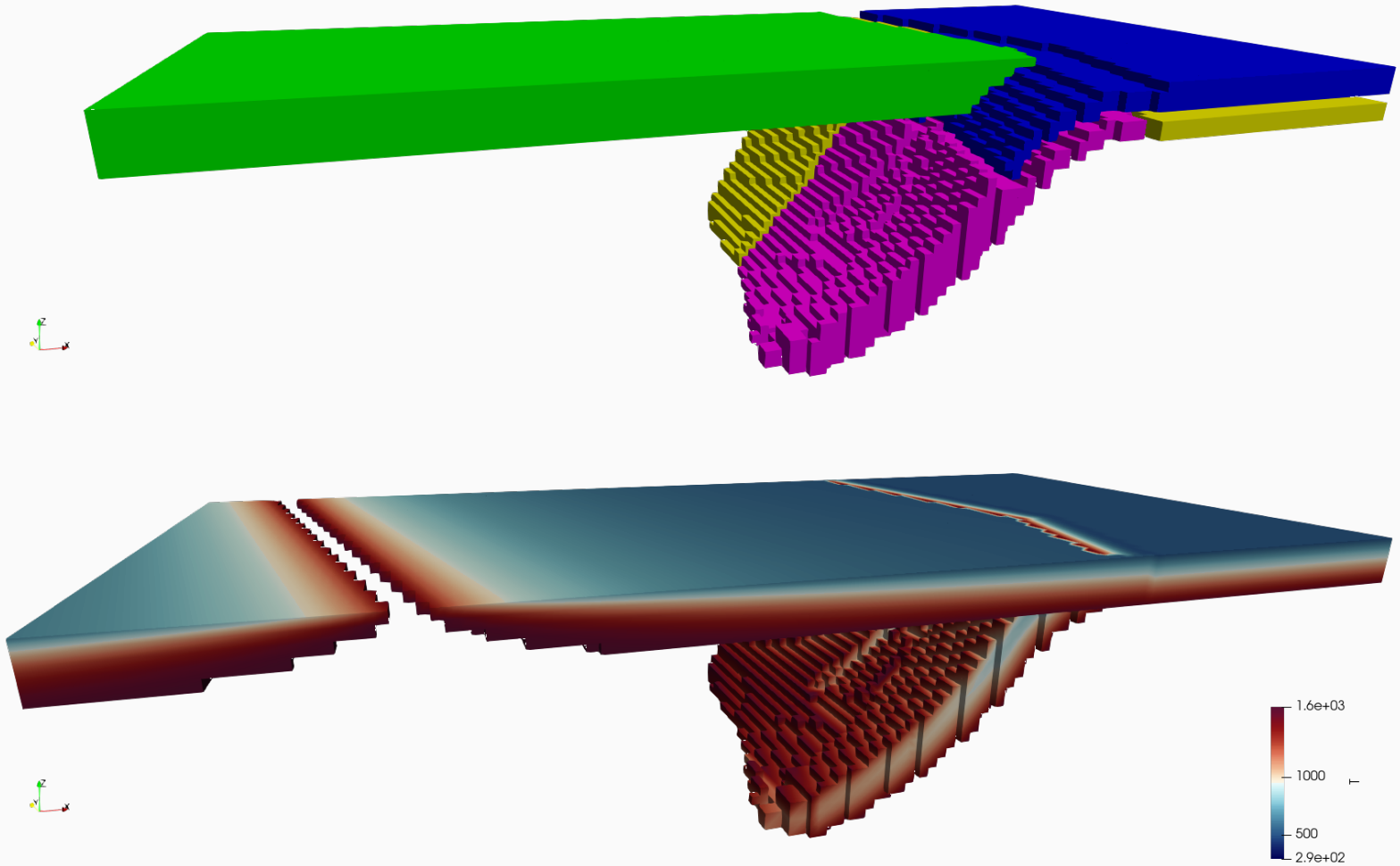
```
...
{  "model":"subducting plate", "name":"Slab",
   "coordinates":[[1500e3,1000e3],[1600e3,350e3],[1500e3,0]],
   "dip point":[0,0],
   "segments":[
     {"length":300e3, "thickness":[100e3], "angle":[0,60],
      "composition models":[
        {"model":"uniform", "compositions":[3], "max distance slab top":50e3},
        {"model":"uniform", "compositions":[2], "min distance slab top":50e3}]},
     {"length":500e3, "thickness":[100e3], "angle":[60,20]}],
   "sections":[
     {"coordinate":0,
      "segments":[{"length":300e3, "thickness":[100e3], "angle":[0,60]},
                  {"length":400e3, "thickness":[100e3,50e3], "angle":[60]}],
      "composition models":[{"model":"uniform", "compositions":[1]}]}
   ],
   "temperature models":[
     {"model":"plate model", "density":3300, "plate velocity":0.02}],
   "composition models":[{"model":"uniform", "compositions":[2]}]
}
...
```

Run: `../aspect-release RFM-12-sections.prm` .

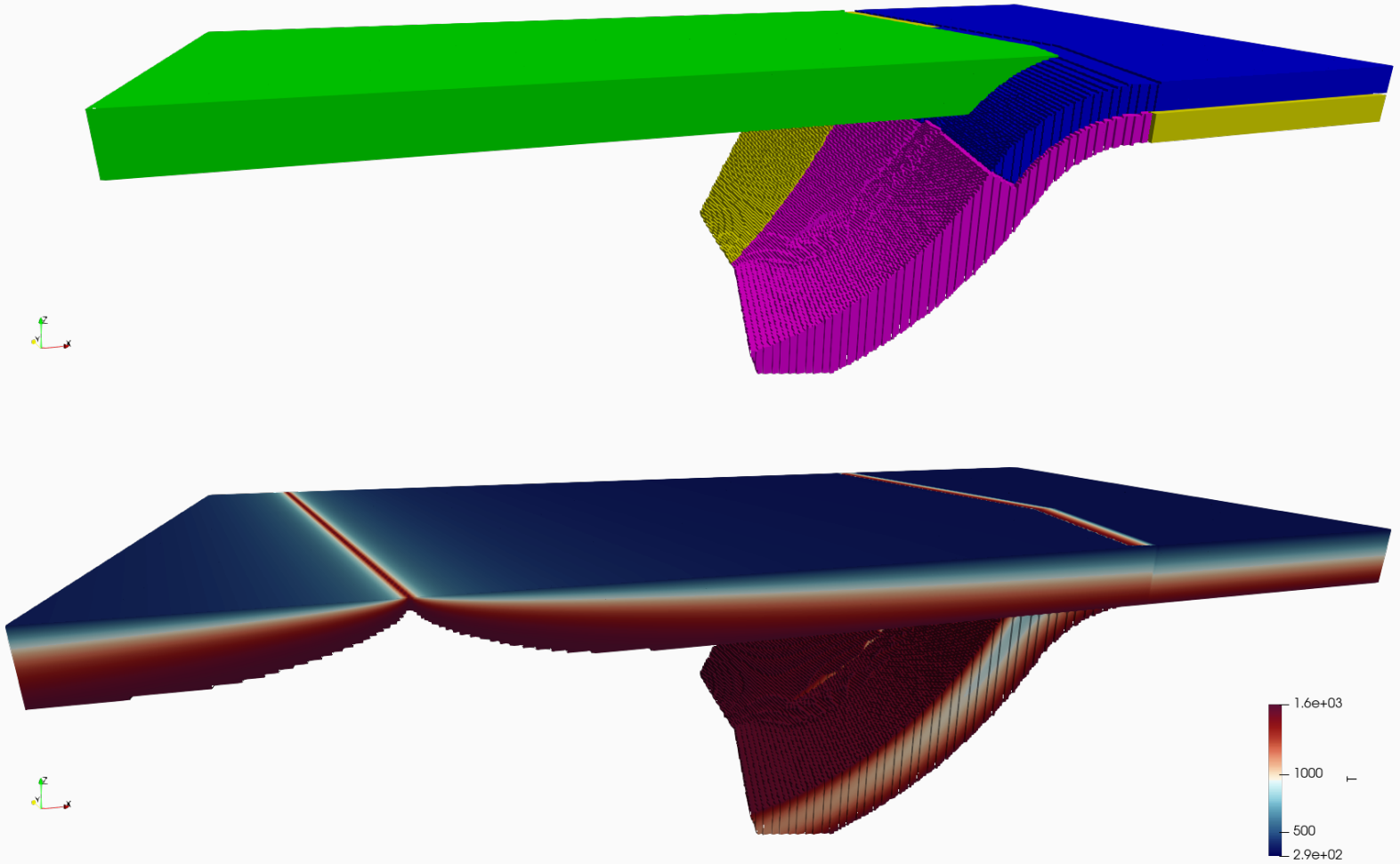
Sections in action

Run: `../aspect-release RFM-12-sections.prm` (Highres: $\sim$ 50M DOFs)

View: `pv_view_mixed_c1_T.pvsm`, dir: `RFM-12-sections`



Sections in action (highres)



In closing

How do I find more information?

- Website: geodynamicworldbuilder.github.io
- Manual on the website
- Developer documentation: codedocs.xyz/GeodynamicWorldBuilder/WorldBuilder/
- Paper: doi.org/10.5194/se-10-1785-2019
- Questions, issues and contributions: github.com/GeodynamicWorldBuilder/WorldBuilder/

Development

Examples:

- Lattice Prefered Orientation output -> Experimental interface done
- Improved coordinate interpolation -> proof of concept done
- Initial topography output -> several concept ideas, input needed
- Better JSON parser error messages -> several concept ideas
- Allow the subducting plate to influence overriding plates -> todo

Development

Examples:

- Lattice Prefered Orientation output -> Experimental interface done
- Improved coordinate interpolation -> proof of concept done
- Initial topography output -> several concept ideas, input needed
- Better JSON parser error messages -> several concept ideas
- Allow the subducting plate to influence overriding plates -> todo

See more development and ask your questions on

https://github.com/GeodynamicWorldBuilder/WorldBuilder/issues

Contributions are also very welcome!

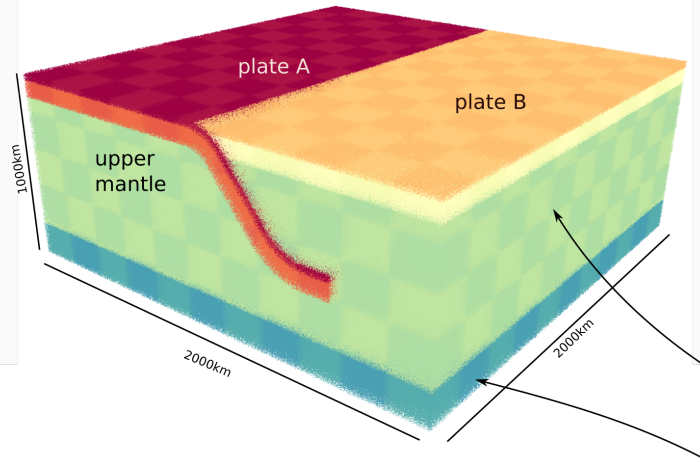
Bonus 1: The World Builder Paraview file creator

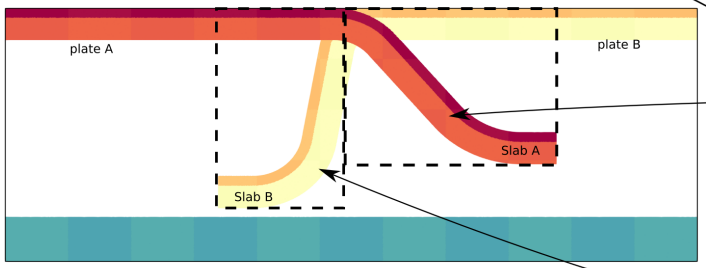
Compiling the World Builder seperately

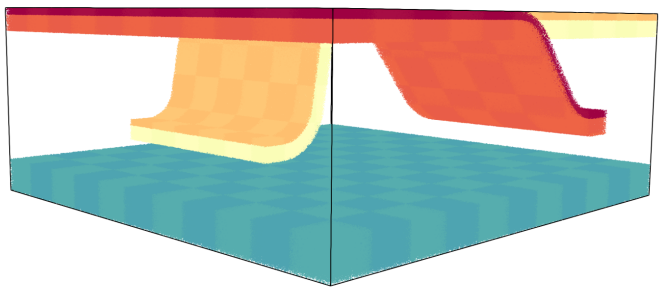
1. Go the the world builder folder in contrib
2. run `cmake .`
3. run `make`
4. cd bin
5. `./WorldBuilderVisualization wbfile.wb wb-gridfile.grid`
6. look in the cookbook folder for examples

Bonus 2: Medium complexity case

Medium complexity case







```
{
"version":"0.2",
"coordinate system":{"model":"cartesian"},
"features":
[

 {"model":"oceanic plate", "name":"Plate A", "max depth":100e3,
   "coordinates":[[-1e3,-1e3],[1000e3,-1e3],[1000e3,2001e3],[-1e3,2001e3]],
   "temperature models":[{"model":"linear", "max depth":100e3}],
   "composition models":[{"model":"uniform", "compositions":[0], "max depth":30e3},
                         {"model":"uniform", "compositions":[1], "min depth":30e3}]},

 {"model":"oceanic plate", "name":"Plate B", "max depth":100e3,
   "coordinates":[[1000e3,-1e3],[2001e3,-1e3],[2001e3,2001e3],[1000e3,2001e3]],
   "temperature models":[{"model":"linear", "max depth":100e3}],
   "composition models":[{"model":"uniform", "compositions":[2], "max depth":30e3},
                         {"model":"uniform", "compositions":[3], "min depth":30e3}]},

 {"model":"mantle layer", "name":"upper mantle", "min depth":100e3, "max depth":660e3,
   "coordinates":[[2001e3,2001e3],[-1e3,2001e3],[-1e3,-1e3],[2001e3,-1e3]],
   "composition models":[{"model":"uniform", "compositions":[4]}]},

 {"model":"mantle layer", "name":"lower mantle", "min depth":660e3, "max depth":1160e3,
   "coordinates":[[2001e3,2001e3],[-1e3,2001e3],[-1e3,-1e3],[2001e3,-1e3]],
   "composition models":[{"model":"uniform", "compositions":[5]}]},

 {"model":"subducting plate", "name":"Slab A",
   "coordinates":[[950e3,-1e3],[950e3,800e3]],
   "dip point":[2000e3,0],
   "segments":[{"length":200e3, "thickness":[100e3], "angle":[0,50]},
         {"length":298e3, "thickness":[100e3], "angle":[50]},
         {"length":200e3, "thickness":[100e3], "angle":[50,0]},
         {"length":100e3, "thickness":[100e3], "angle":[0]}],
   "temperature models":[{"model":"plate model", "density":3300, "plate velocity":0.02 }],
   "composition models":[{"model":"uniform", "compositions":[0], "max distance slab top":30e3},
                         {"model":"uniform", "compositions":[1], "min distance slab top":30e3}]},

 {"model":"subducting plate", "name":"Slab B",
   "coordinates":[[1050e3,1000e3],[1050e3,2001e3]],
   "dip point":[-2000e3,0],
   "segments":[{"length":200e3, "thickness":[100e3], "angle":[0,80]},
         {"length":298e3, "thickness":[100e3], "angle":[80]},
         {"length":200e3, "thickness":[100e3], "angle":[80,0]},
         {"length":100e3, "thickness":[100e3], "angle":[0]}],
   "temperature models":[{"model":"plate model", "density":3300, "plate velocity":0.01 }],
   "composition models":[{"model":"uniform", "compositions":[2], "max distance slab top":30e3},
                         {"model":"uniform", "compositions":[3], "min distance slab top":30e3}]}

 ]
}
```

Bonus 3: Carribbean model World Builder input file

Part 1

```
{
  "version":"0.2",
  "potential mantle temperature":1500,
  "thermal expansion coefficient":2.0e-5,
  "maximum distance between coordinates":100000,
  "interpolation":"monotone spline",
  "surface temperature":293.15,
  "force surface temperature":true,
  "coordinate system":{"model":"cartesian"},
  "features": [
    {"model":"oceanic plate", "name":"Caribbean plate",
     "coordinates":[[-1e3,0],[1700e3,0],[1700e3,650e3],[1686e3,750e3],[-1e3,750e3]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[{"model":"uniform", "compositions":[1],"max depth":30e3}]},

    {"model":"oceanic plate", "name":"Carribean weak zone",
     "coordinates":[[-1e3,1000e3],[-1e3,750e3],[1536e3,749e3],[1450e3,836e3],[1350e3,906e3],[1239e3
         ,958e3],[1122e3,989e3],[1000e3,1000e3],[650e3,1000e3]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[{"model":"uniform", "compositions":[2], "max depth":30e3},
                           {"model":"uniform", "compositions":[3], "min depth":30e3, "max depth"
                               :100e3}]},

    {"model":"oceanic plate", "name":"NS American plate",
     "coordinates":[[1700e3,0],[1700e3,300e3],[1689e3,422e3],[1658e3,539e3],[1606e3,650e3],[1536e3
         ,749e3],[1450e3,836e3],[1350e3,906e3],[1239e3,958e3],[1122e3,989e3],[1000e3,1000e3],[700
         e3,1000e3],[-1e3,1000e3],[-1e3,1501e3],[2501e3,1501e3],[2501e3,-501e3],[-1e3,-501e3],[-1
         e3,0]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[{"model":"uniform", "compositions":[0], "max depth":30e3}]},

   {"model":"mantle layer", "name":"660", "min depth":660e3,
     "coordinates":[[-1e3,-500e3],[-501e3,2500e3],[2501e3,2500e3], [2501e3,-501e3]],
     "composition models":[{"model":"uniform", "compositions":[4]}]},
```

Part 2

```
    {"model":"subducting plate", "name":"Lesser Antilles slab",
     "coordinates":[[1700e3,0],[1700e3,300e3],[1689e3,422e3],[1658e3,539e3],[1606e3,650e3],[1536e3,749
           e3],[1450e3,836e3],[1350e3,906e3],[1239e3,958e3],[1122e3,989e3],[1000e3,1000e3],[700e3
           ,1000e3]],
     "dip point":[-1,-1], "min depth":0, "max depth":660e3,
     "segments": [{"length":300e3, "thickness":[100e3], "angle":[0,55]},
                  {"length":375e3, "thickness":[100e3], "angle":[55]},
                  {"length":225e3, "thickness":[100e3,75e3], "angle":[55,10]}
                 ],
     "sections":[
        {"coordinate":11,"segments": [{"length":300e3, "thickness":[100e3], "angle":[0,55]},
                                      {"length":375e3, "thickness":[100e3], "angle":[55]},
                                      {"length":50e3, "thickness":[100e3,75e3], "angle":[55,10]}]}
                ],
     "temperature models": [
       {"model":"plate model", "density":3300, "plate velocity":0.0200, "thermal conductivity":2.5, "
            thermal expansion coefficient":2e-5 }
     ],
     "composition models":[{"model":"uniform","compositions":[0], "max distance slab top":30e3},{"
           model":"uniform","compositions":[0,1,2,3,4,5,6], "fractions":[0,0,0,0,0,0,0], "min
           distance slab top":30e3}]
    },

    {"model":"continental plate","name":"South Weakzone",
     "coordinates":[[-1e3,0e3],[-1e3,-50e3],[2501e3,-50e3],[2501e3,0e3]],
     "temperature models":[{"model":"linear", "max depth":100e3}],
     "composition models":[
       {"model":"uniform", "compositions":[2], "max depth":30e3},
       {"model":"uniform", "compositions":[3], "min depth":30e3, "max depth":100e3}]}
  ]
}
```