Linking CitcomS and SPECFEM3D

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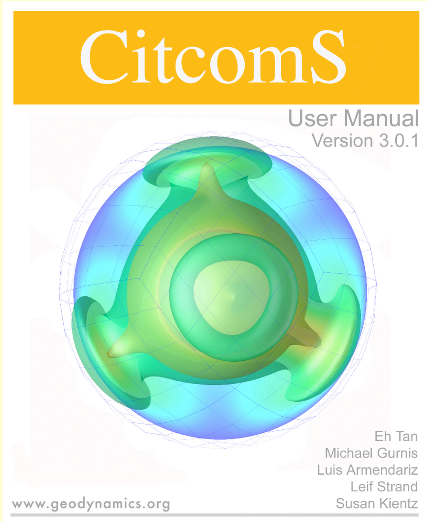
NSF Award 0426271



Procedure

1. set outpvut directory and filename prefix

```
[CitcomS.solver]
datafile = foo
```

2. set seismic output

```
[CitcomS.solver.output]
output_optional = seismic
```

3. choose mineral physics model

```
[CitcomS.solver.param]
mineral_physics_model = 3
```

4. run CitcomS development version (to be released as v3.1)
5. exam model results, pick a time step (ex: step *10000*) for generating synthetic seismograms.

Mineral Physics Models

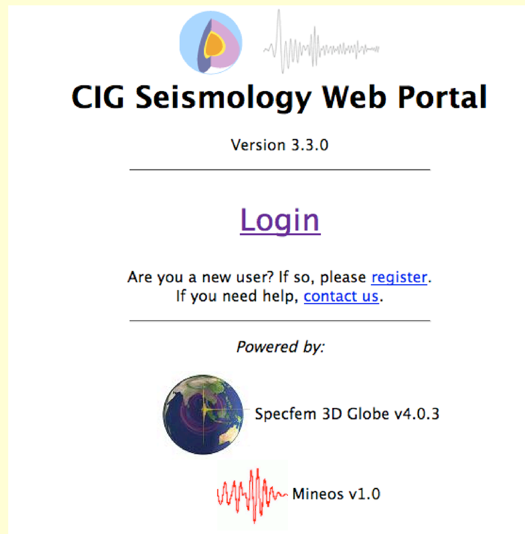
Implemented:

- Trampert, Vacher, and Vlaar, PEPI, 2001

Planned:

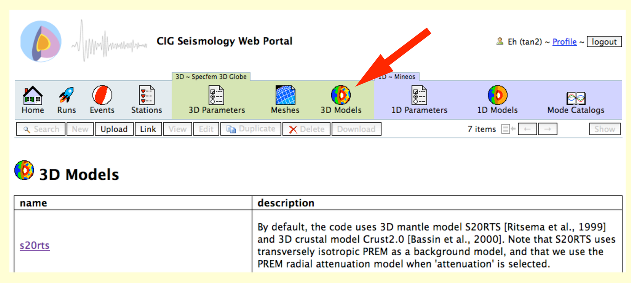
- Karato, GRL, 1993
- Stacy, PEPI, 1998
- Stixrude and Lithgow-Bertelloni, GJI, 2005

Others? (suggestions welcomed)



Procedure (cont'd)

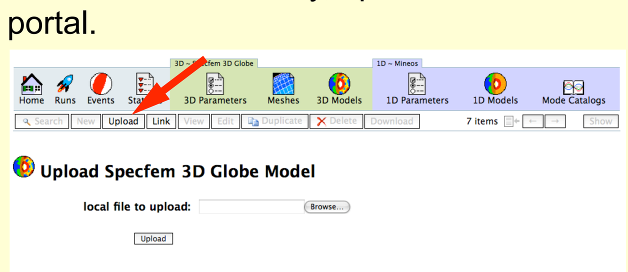
6. log in **CIG Seismology Web Portal**: *https://crust.geodynamics.org/portals/seismo/*
7. click **3D Models** tab, download the model **citcoms_isotropic_no_crust**



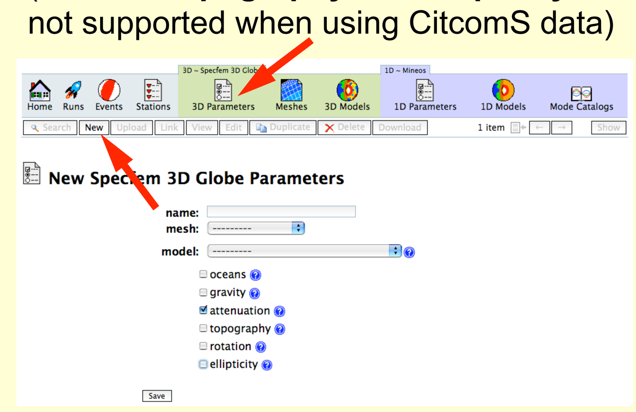
8. extract the downloaded tar file.
9. copy citcoms files *foo.domain, foo.coord_bin.*, foo.seismic.*.10000* to directory **shared/** inside the extracted directory.
10. edit citcoms_parm.h

```
const char citcoms_model_filename_base[] =
    "@THIS_DIR@/shared/foo";
const int citcoms_step = 10000;
```

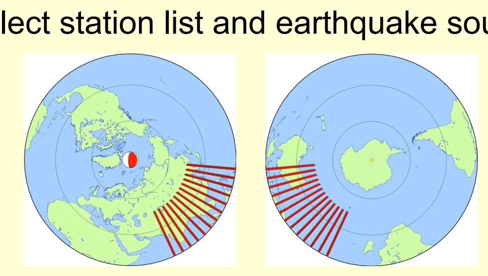
11. tar the whole directory, upload the tar file to the portal.



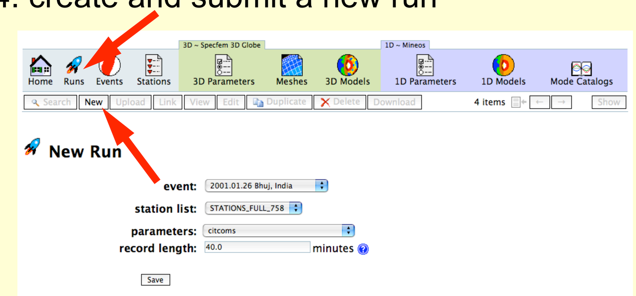
12. select model parameters: mesh size (controlling the shortest period in the seismograms), model (choose the model uploaded in step 5), and other flags (**oceans**, **topography**, and **ellipticity** are not supported when using CitcomS data)



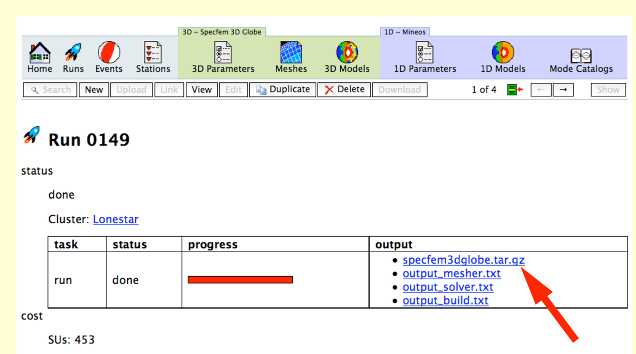
13. select station list and earthquake source

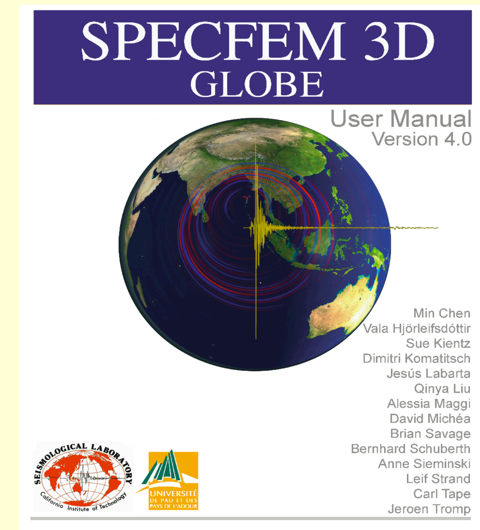


14. create and submit a new run



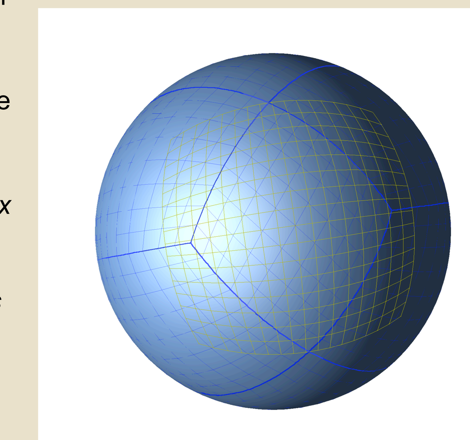
15. at a later time, retrieve the results



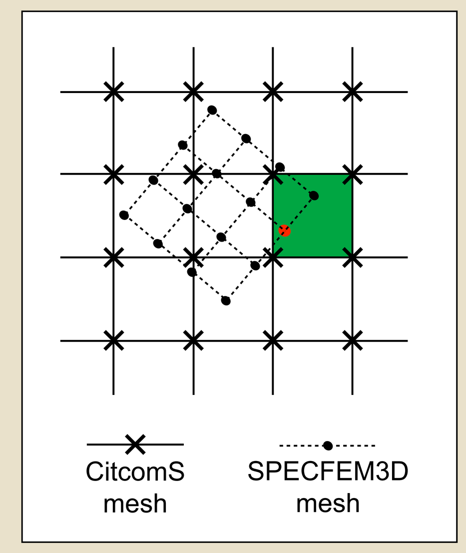


Domain Decomposition

- CitcomS uses rhombic dodecahedron projection to divide the sphere into 12 caps. (Blue mesh in the figure. Thick lines mark the cap edges.)
- SPECFEM3D uses cubic sphere and divides the sphere into 6 caps. (Yellow mesh in the figure. Only one cap is shown.)
- Both codes can subdivid the caps further into *Nx* × *Ny* subcaps. Each subcap is assigned to one CPU. In total, CitcomS uses *Nc* CPUs, and SPECFEM3D uses *Ns* CPUs, where *Nc* and *Ns* can be as large as ~1000.
- There are *Nc* files to be read by *Ns* processes. This will crash the filesystem!
- Solution: each SPECFEM3D subcap only reads the files of the overlapping CitcomS subcaps.

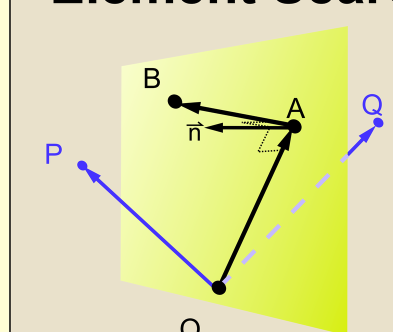


Interpolation



For each SPECFEM3D point (red dot in the figure), we need to figure out which CitcomS element (green patch) the point falls on. The element search algorithm must be efficient and scales well with the size of CitcomS and SPECFEM3D meshes. A trilinear interpolation is used to interpolate fields defined on CitcomS elements to SPECFEM3D point.

Element Searching



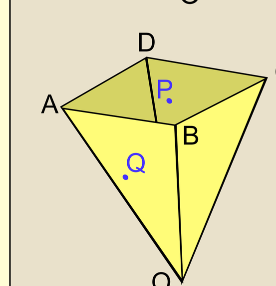
Three points O, A, and B define a flat plane, whose normal is:

$$\vec{n} = \overrightarrow{OA} \times \overrightarrow{OB}$$

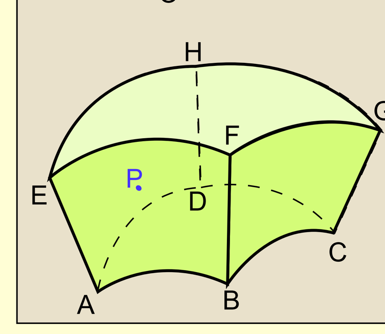
Point P is said on the "positive" side of plane OAB, if and only if

$$\overrightarrow{OP} \cdot \vec{n} > 0$$

Point Q is on the "negative" side of plane OAB.



Points ABCD, ordered counterclockwisely, and point O form a pyramid without a base. Point P is on the "positive" sides of all planes OAB, OBC, OCD, and ODA. We can conclude that P falls within the pyramid. On the other hand, point Q is on the "negative" side of plane OCD, and is outside the pyramid as a result.

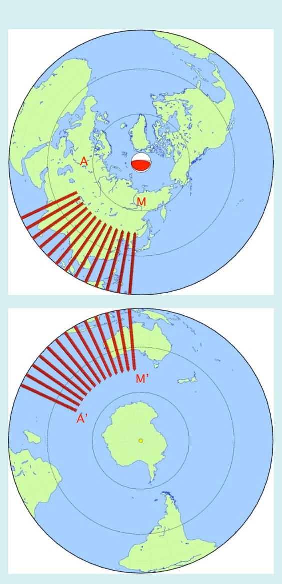


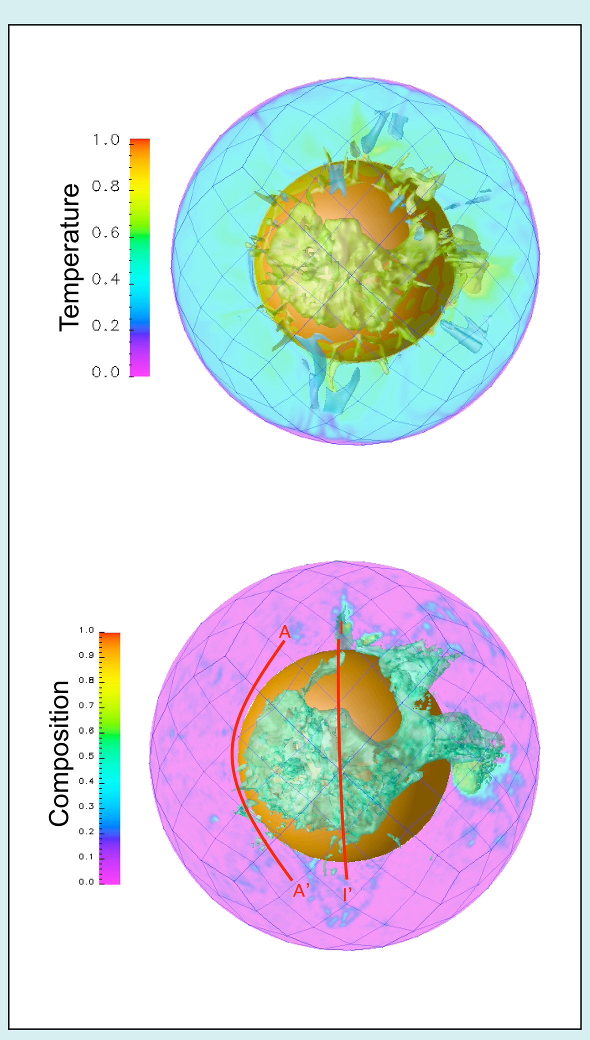
Points ABCD are of the same distance to point O (not shown). Ditto for points EFGH. If point P falls within the pyramid OABCD, and the length of OP is between the length of OA and OE, P is inside the element ABCDEFGH.

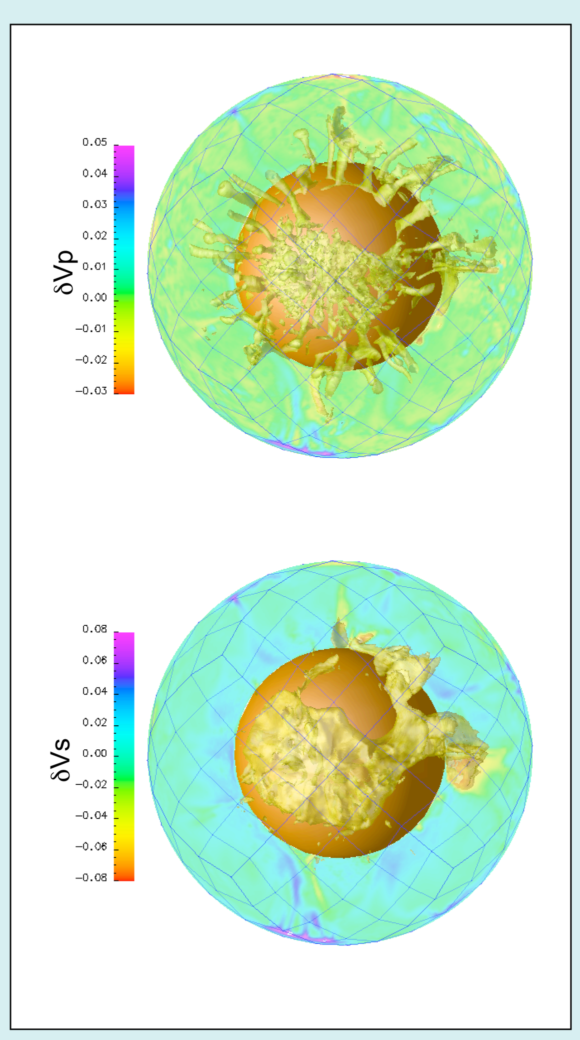
Results

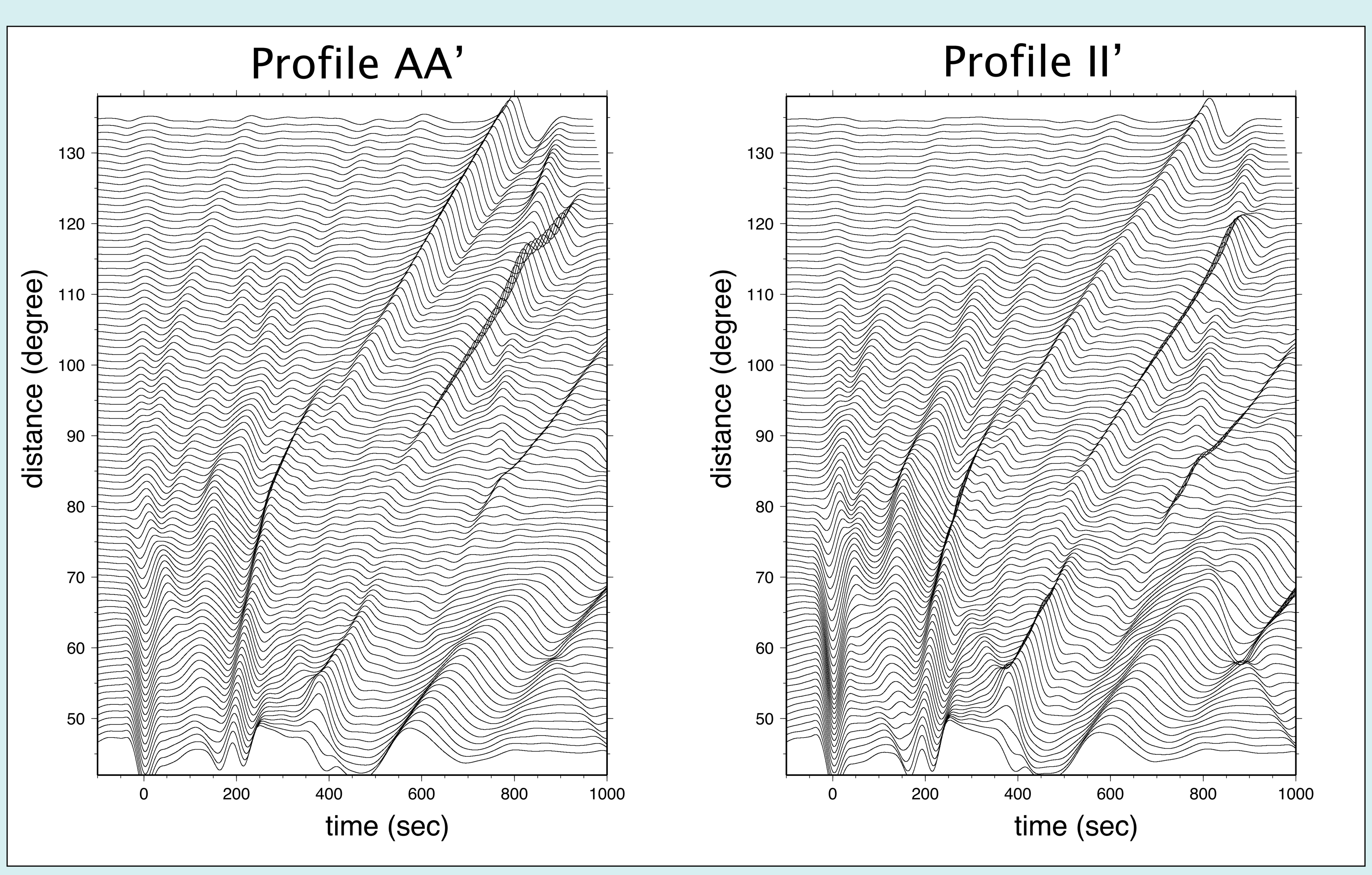
CitcomS: 64x64x64x12 elements, 20 tracers per element, 4x4x1x12 CPUs, Ra=1.38x10[9], compressible convection, high bulk modulus and high density material, temperature-dependent viscosity (1000x), no phase changes,

SPECFEM3D: 11696 elements per CPU, 384 CPUs, with attenuation. Earthquake source at North pole, 600 km depth. Stations at 45-135 degree. Record section aligned on S arrivals.

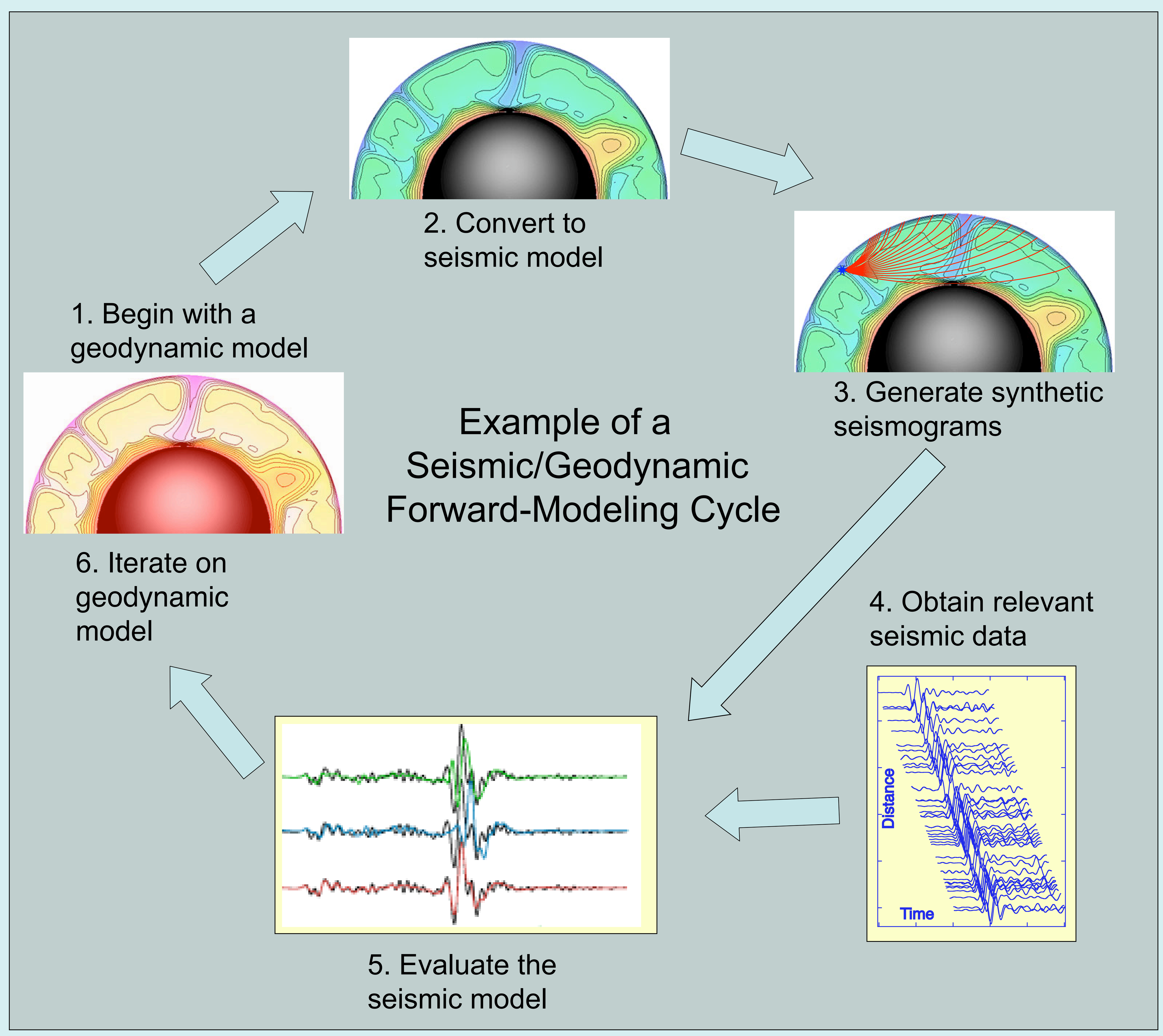








Long-Term Goal



Comparison of Earth structure from a mantle convection model with seismic data

In the diagram above, a code generates a geodynamics model such as temperature, pressure, and composition. These parameters would be converted into a set of seismic parameters (isotropic or anisotropic elastic constants, density, and attenuation) by a user-specified mapping. Values from the geodynamic mesh would be sent to another mesh to be used by a synthetic seismogram program. A data-searching program (like the IRIS "WEED" tool) would be accessed to identify and obtain real seismic data for this geographic region. The earthquake-station geometries would be the input for a 3-D synthetic seismogram code, and synthetic counterparts would be generated using the 3-D geodynamics-based velocity model. The fit of the geodynamics model would be determined at the project-specific level through comparison between the seismic data and synthetics using a cost function such as crosscorrelation coefficients. This cost function would then serve as a guide in the formulation of successive geodynamic models.

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