Developing and Visualizing Community Seismic Velocity Models

Tuesday, April 23 1-4:30 PM
SSA 2019, Seattle, WA

IRIS EMC PARAVIEW PLUGINS

IRIS Data Services, Data Products Team, April 2019, V.2019.091

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Outline:

- IRIS DMC Data Products
- IRIS EMC
- EMC Tools
- ParaView
- ParaView GUI
- EMC ParaView-Plugins Overview
- ParaView-Plugins Exercise 1:
  Using EMC plugins to plot auxiliary data (data other than Earth models)
- ParaView-Plugins Exercise 2:
  Using EMC plugins to plot auxiliary data and Earth models

Data Products are data derived products and tools to facilitate research

- have served the seismology community Since 2009
- 29 products (14 contributed)
- 9 event-based products

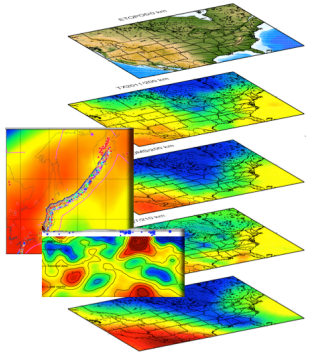
Product list:
http://ds.iris.edu/ds/products/

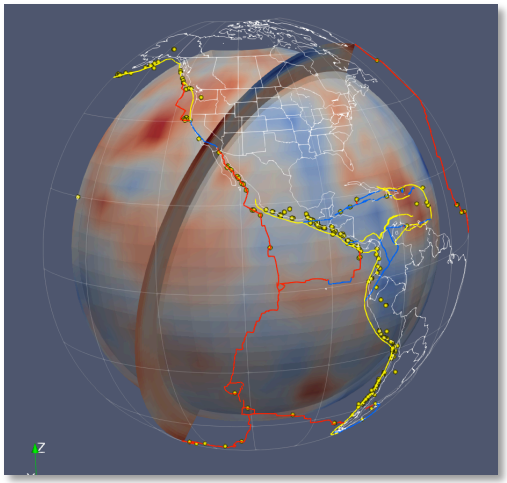
SPUD: The Searchable Product Depository:
http://ds.iris.edu/spud/

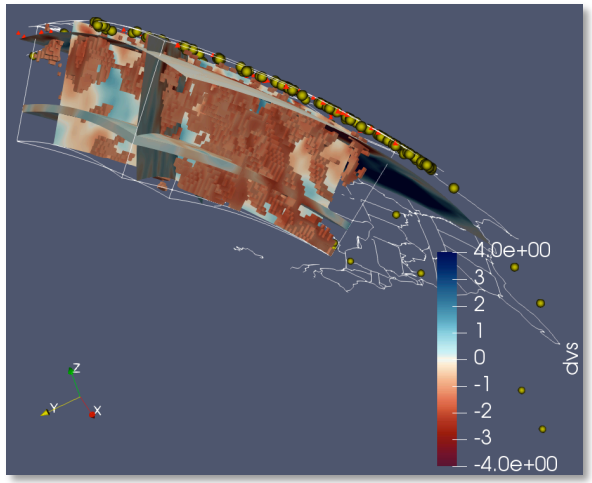
IRIS

A community Earth model repository

- Currently 68 contributed research Earth models in netCDF and GeoCSV formats (58 velocity models)
- EMC-Tools - Python tools for the EMC's netCDF Earth model files
  https://github.com/iris-edu/emc-tools
- 9 reference Earth models
- 5 web browser-based visualization tools
- ParaView plugins for 3D Visualization supporting netCDF & GeoCSV formats (EMC and others)
  https://github.com/iris-edu/EMC-ParaView







IRIS

EMC Repository

- Repository of research Earth models:
  http://ds.iris.edu/ds/products/emc-earthmodels/

- Reference Earth models are also available:
  http://ds.iris.edu/ds/products/emc-referencemodels/

Goals:

- Provide the research community with access to various Earth models under a uniform format
- Visualization tools for model preview
- Access to processing software and scripts

Repository of research Earth models

http://ds.iris.edu/ds/products/emc-earthmodels/

- EMC-hosted Earth Models (68):
  - Velocity Models (58):
    - Africa (1)
      Africa.ANT.Emry-etal.2018 (map)
    - East Asia (3)
      FWEA18 (map)
      - Taiwan — 2:
        Taiwan.TTT.KWR.2012 (map) | TW-PS-H14 (map)
    - Global (22):
      3D2018_08Sv (map) |3D2017_09Sv (map) | 3D2016_09Sv (map) | HMSL-P06 (map) | HMSL-S06 (map) | LLNL-G3DV3 (map, information) | S2.9EA (map) | S362ANI (map) | S362ANI+M (map) | S362WMANI (map)| SAW24B16 (map)| SAW642AN (map) | SAW642ANB (map) | SEISGLOB1 (map)| SEISGLOB2 (map)| SEMum (map) | SGLOBE-rani (map)| SPani (map) | TX2000 (map)| TX2011 (map)
    - Western Eurasia, Arabia, and northern Africa (2):
      EAV09 (map)
      - Anatolia and the Aegean Sea — 1
        ANA2_P_2018 (map)
    - The Americas (29):
      - North America — 4:
        NA04 (map) | NA07 (map) | SAWum-NA2 (map)| SEMum_NA14 (map)
      - Contiguous US — 6:
        DNA13 (map) | PnUS_2016 (map) | US.2016 (map) | US-Crust-Upper-mantle-Vs.Porter.Liu.Holt.2015 (map) | US-CrustVs-2015 (map) | US-SL-2014 (map)
      - Alaska — 2:
        Alaska.ANT+RF.Ward.2018 (map) | Alaska-S+SW-2018 (map)
      - Regional/Local US — 13:
        Cascade.ANT.Gao-Shen.2014 (map)|Cascadia_ANT+RF_Delph2018 (map) |DNA09 (map) | DNA10-S (map) |NEUS-Vs2018 (map)| NWUS11-P (map) | NWUS11-S (map) | OIINK_VS_model (map) | PNW10-S (map) | SoCal.ANT_Vph+HV-1.Berg.2018 (map)| WUS-CAMH-2015 (map) | wUS-SH-2010 (map) | YS-P-H15 (map)
      - South America — 5:
        Andes.ANT.Ward.2013 (map) | APVC.ANT+RF.Ward.2014 (map) | BO.ANT+TPWT.Ward.2016 (map) | APVC+Puna.ANT+RF.Ward.2017 (map) | SAM4_P_2017 (map)
  - Crustal Thicknesses (3):
    Crustal_Thickness_Error (map) | NorthernAppalachians_Moho2018 (map) | OIINK_CUS_Moho2017 (map)
  - Electrical Resistivity/Conductivity (5):
    iMUSH-MT (map) | MCR.MT.Yang-et.al.2015.resistivity (map) |MHCB-MT (map) | SEUS-MT (map)| SRPY-MT (map)
  - Q-Model (1):
    QRLW8 (map)
  - Temperature Model (1):
    Moho_Temperature (map)

- EMC-hosted 2D Earth Models:
  - Crustal Thicknesses:
    CAM2016 (map) | Crustal_Thickness_Error (map) | NorthernAppalachians_Moho2018 (map) | OIINK_CUS_Moho2017 (map) | US-CrustVs-2015 (map)
  - Temperature Model:
    Moho_Temperature (map)

Model Detail Pages

http://ds.iris.edu/ds/products/emc-cascadia_antrf_delph2018/

- Model information with a uniform style
- Model download links

Previous Model	None
Reference Model	None
Model Download	Cascadia-ANT+RF-Delph2018.nc (view metadata)
Model Homepage	
Depth Coverage	-3 to 80 km (bsl)

- References

Data Services Products: EMC-Cascadia_ANT+RF_Delph2018

3D vertical shear-wave velocity model of the Cascadian forearc from the joint inversion of ambient noise dispersion and receiver functions

Summary

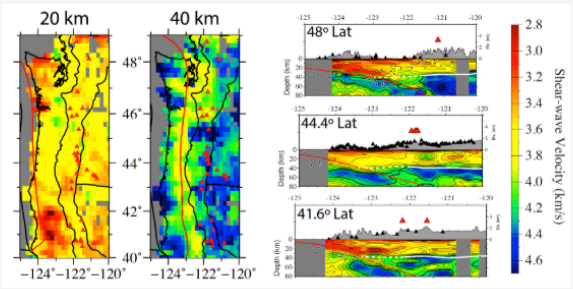
3D vertical shear-wave velocity model of the Cascadian forearc from the joint inversion of ambient noise dispersion and receiver functions

Quicklinks

- EMC home
- Reference Earth models
- Earth models
- EMC Tools
- Earth model download via SPUD
- Earth model visualization
- Citations

Description

Name	Cascadia_ANT+RF_Delph2018
Title	3D vertical shear-wave velocity model of the Cascadian forearc from the joint inversion of ambient noise dispersion and receiver functions.
Type	3-D Tomography Earth Model
Sub Type	Shear-wave velocity (km/s)
Year	2018
Short Description	This model was created from the joint inversion of ambient noise Rayleigh waves dispersion measurements (8-50 seconds) and adaptive CCP-derived receiver functions (see Delph et al., 2015, 2017 for details of methodology; Delph et al., 2018 for details of this model).
Authors:	**Jonathan R. Delph** Department of Earth, Environmental and Planetary Sciences Rice University **Alan Levander** Department of Earth, Environmental and Planetary Sciences Rice University **Fenglin Niu** Department of Earth, Environmental and Planetary Sciences Rice University
Previous Model	None
Reference Model	None
Model Download	Cascadia-ANT+RF-Delph2018.nc (view metadata), is the netCDF file for the model as a function of depth
Model Homepage	
Depth Coverage	-3 to 80 km (bsl)
Areal Coverage	Cascadia forearc to arc (latitude: 40°N to 49°N, longitude: 124.8°W to 120°W)
Data Set Description	This model contains data from roughly 1000 broadband seismic stations distributed throughout the western United States. Time period of data is 1993-1994, 2005-2016.

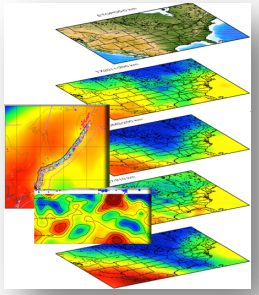


Map slices (left) and cross sections (right) through shear wave velocity model. Red lines correspond to slab model of (McCrory et al., 2012). While line in cross sections corresponds to inferred Moho (dashed where uncertain). Red triangles: Holocene volcanic centers; Black triangles in cross sections: seismic stations used in receiver function analysis.

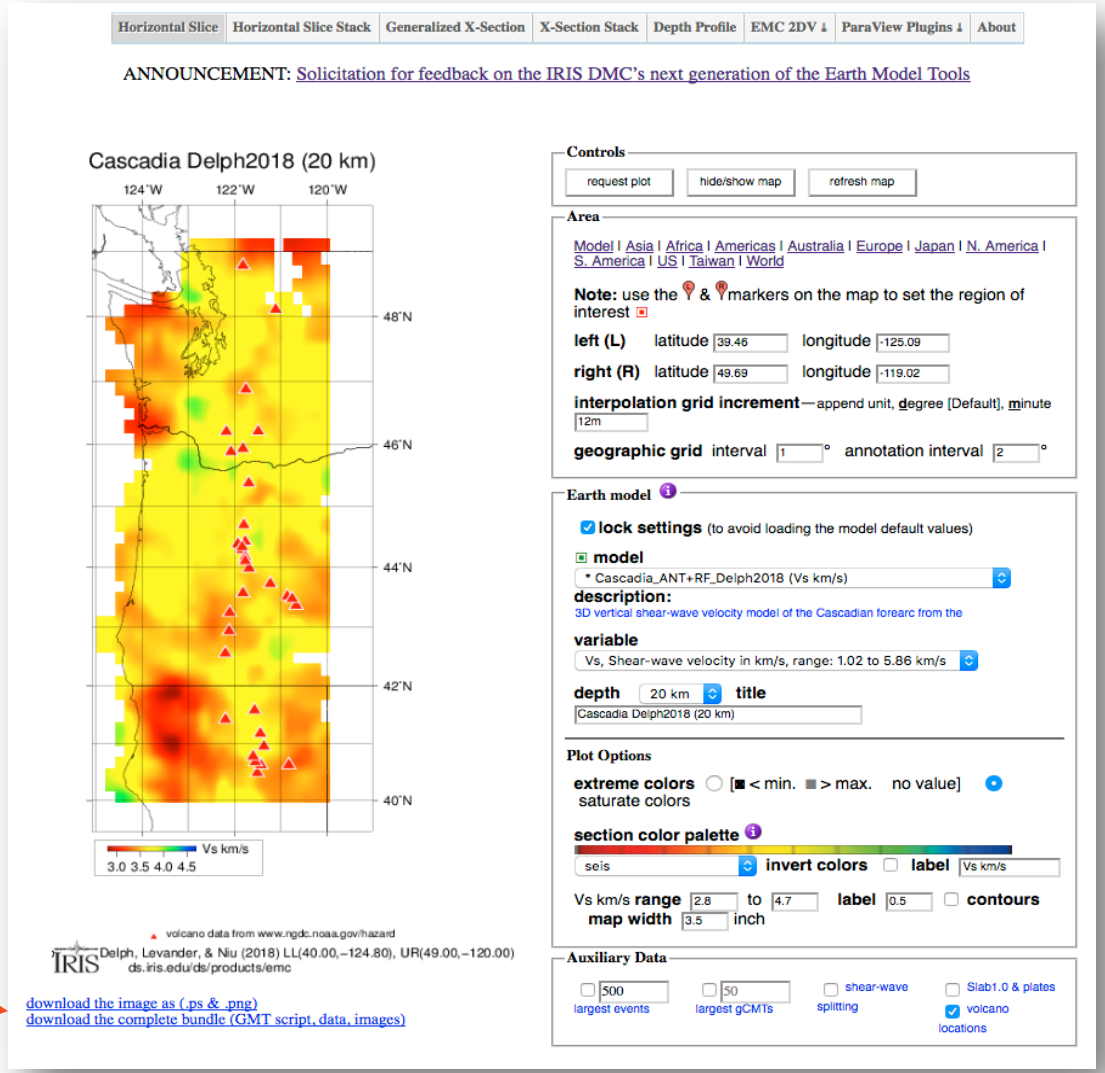
Web-based visualization tools

http://ds.iris.edu/dms/products/emc/horizontalSlice.html

- Model preview
- Five tools are available:
  - Horizontal slice
  - Horizontal slice stack
  - X-sections
  - X-section stack
  - Depth profile



- Downloadable GMT script and images



EMC-Tools

https://github.com/iris-edu/emc-tools

EMC's GitHub repository of Python scripts for converting the EMC's netCDF Earth model files (in netCDF 3 format) to and from GeoCSV format:

Formats:

- netCDF 3 (Network Common Data Form)
  https://www.unidata.ucar.edu/software/netcdf/

- GeoCSV (tabular text formatting for geoscience data)
  http://geows.ds.iris.edu/documents/GeoCSV.pdf

Scripts:

- `netCDF_2_GeoCSV_3D.py`
  read a 3D netCDF Earth model file and display its header/convert it to GeoCSV format

- `GeoCSV_2_netCDF_3D.py`
  read a 3D GeoCSV Earth model file and display its header/convert it to netCDF format

- `netCDF_2_GeoCSV_2D.py`
  read a 2D netCDF Earth model file and and display its header/convert it to GeoCSV format

- `GeoCSV_2_netCDF_2D.py`
  read a 2D GeoCSV Earth model file and display its header information or convert it to netCDF format

ParaView

Open-source, multi-platform data analysis and visualization application for visualizing 2D/3D data.

- Main site: `https://www.paraview.org`
- Download page: `https://www.paraview.org/download/`

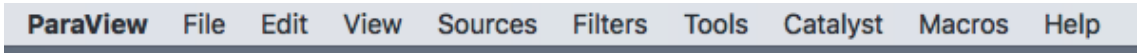
ParaView currently supports Python 2.7 and offers scripting support.
EMC plugins are based on ParaView's support of Python

ParaView Getting Started Guide and GUI:

http://www.paraview.org/files/v5.1/ParaViewGettingStarted-5.1.0.pdf

ParaView

Menu Bars

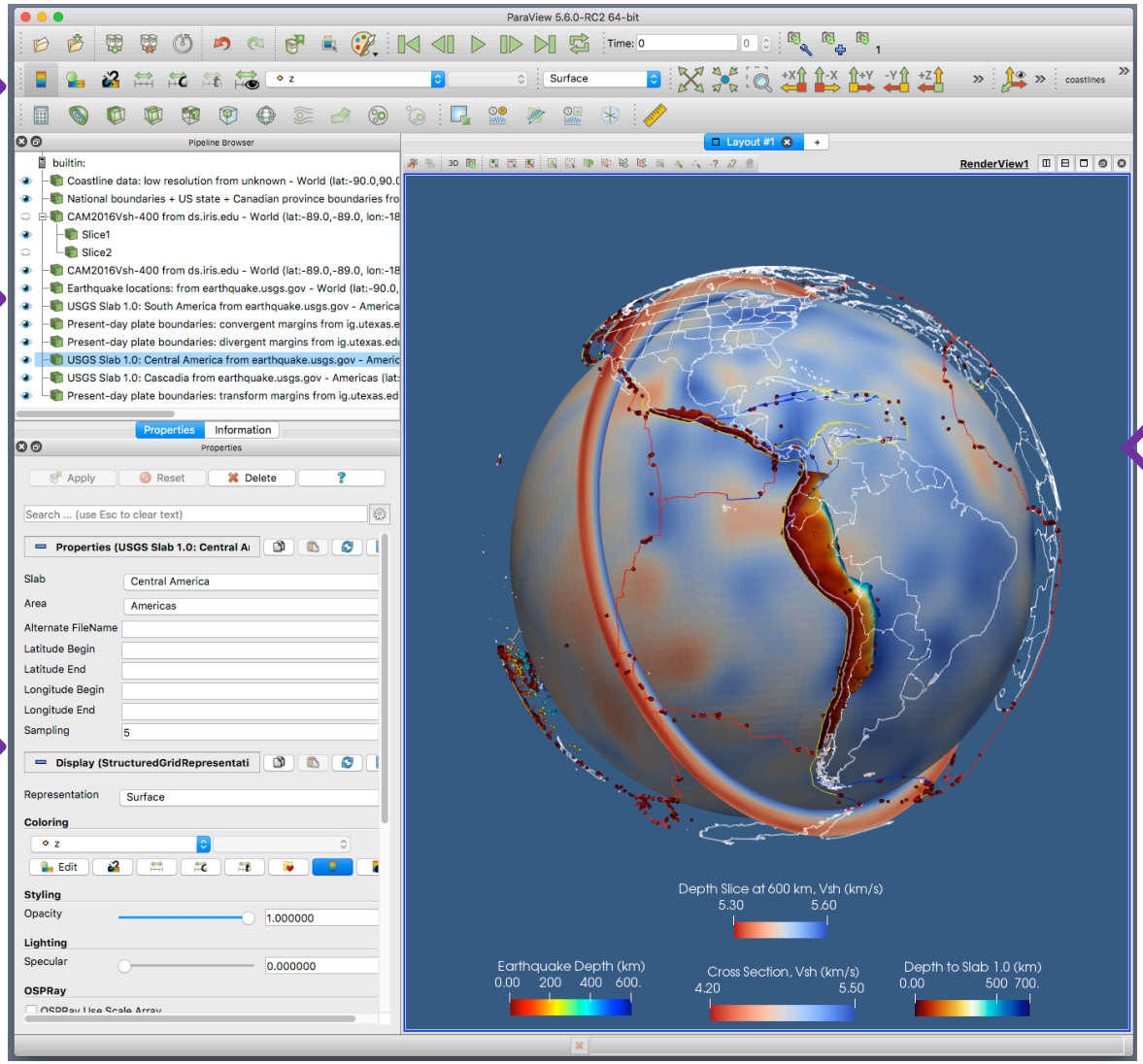


Tool Bars

Pipeline Browser

Properties & Information Panels

Render View



ParaView GUI

IRIS

EMC ParaView Plugins

Python programmable sources/filters that allow ParaView display netCDF/GeoCSV

Earth models along with other auxiliary Earth data

https://github.com/iris-edu/EMC-ParaView

Installing the Plugins is Easy!

- Make sure you have Python 2.7 installed on your system
- Download the EMC-ParaView GitHub repository and unpack it. This will result in a directory structure like:

```
IRIS_EMC_Paraview  The root directory of the plugins
|
|____plugins  This directory is created and populated during the build and will contain plugings for ParaView
|____xml  This directory contains an XML file for seis color palette
|____macros  This directory is created and populated during the build and will contain macros for ParaView
|____data  This directory and its subdirectories (where your data will be stored) are created during the build
| |____boundaries
| |____models
| |____volcanoes
| |____scratch
| |____slabs
| |____earthquakes
|   |____animation
|____src  This directory and its subdirectories contain the plugin bundle code
  |____filters
  |____IrisEMC_Paraview_Param.py  plugins parameter file
  |____macros
  |____build_plugins_macros.py  Installation script
  |____readers
```

- Read the *INSTALL.txt* file
- Run the *build_plugins_macros.py* script under the *src* directory

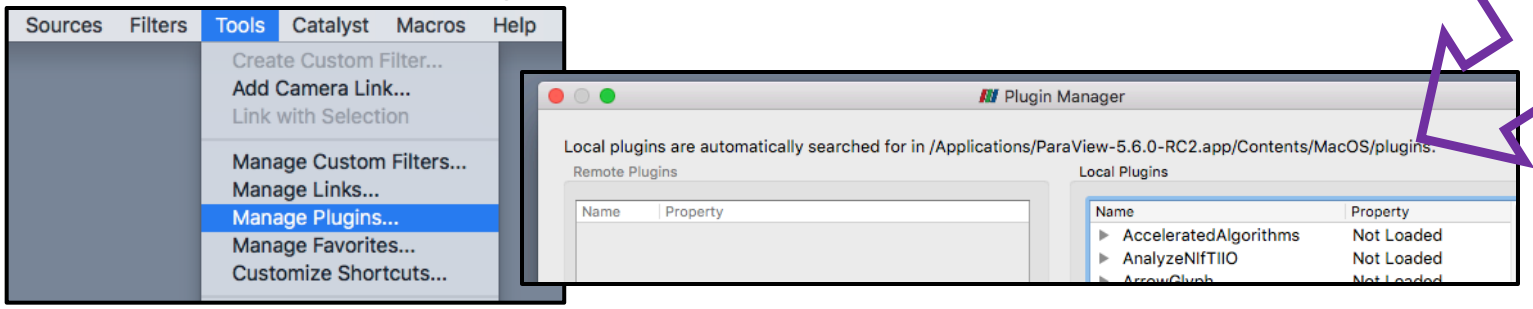
Adding Plugins to ParaView

During the build process, the *`plugins`* directory gets populated

```
IRIS_EMC_Paraview  The root directory of the plugins
|
|____plugins
   |____read_boundaries.xml
   |____read_3d_models.xml
   |____read_coordinates_converter.xml
   |____read_earthquakes.xml
   |____read_grids.xml
   |____read_etopo.xml
   |____filter_view_coordinates.xml
   |____read_2d_models.xml
   |____read_volcanoes.xml
   |____read_usgs_slab.xml
```

You need to load the content of the above directory to ParaView

Where? To find out, go to the `Tools` in ParaView menu



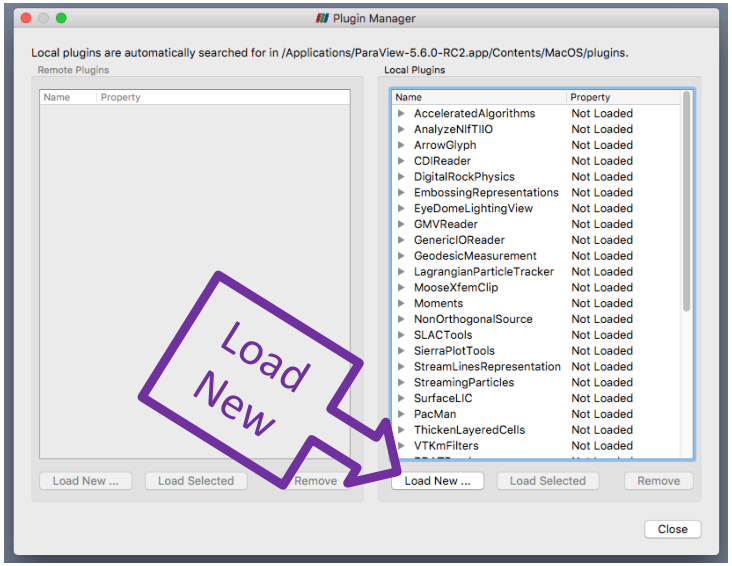
This is where ParaView is looking for them

Two options for adding Plugins to ParaView

1. On *`Plugin Manager`* window click on the *`Load New`* button and change the file type to *`xml`* and load plugins from the *`IRIS_EMC_Paraview/plugins`* directory. These plugins will remain active during this ParaView session but you have to reload them after each ParaView restart

2. Manually copy your plugin files under the designated plugin directory so they would be loaded automatically.

   Restart ParaView

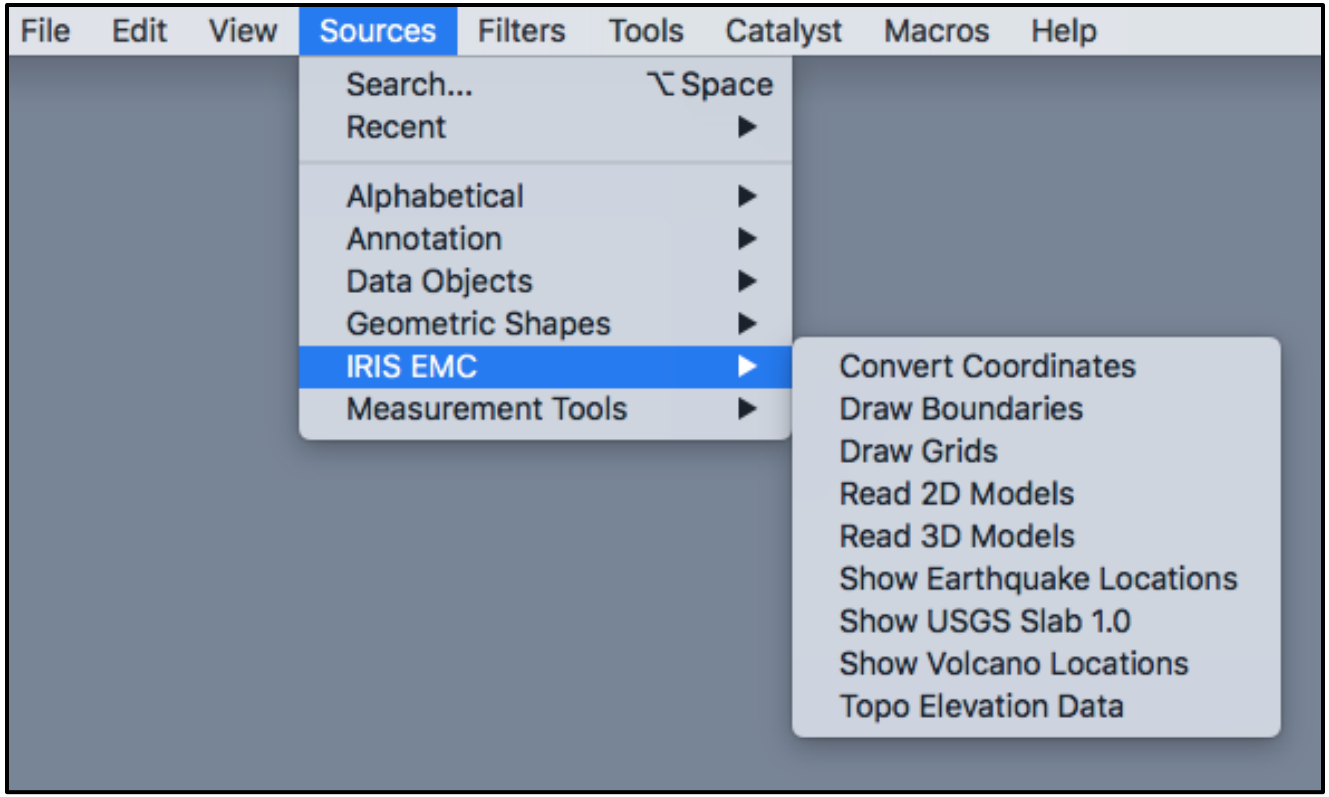


You need to rebuild your plugins every time you update them or add a new one

EMC ParaView Plugins

Once the plugins are added to ParaView and ParaView is restarted

EMC plugins will appear under Sources/Filters on ParaView menu bar



Data Files

Where the data come from?

When you select a dataset to plot, plugin goes through a few checks in the following order to find the data. The first place it finds the data, it will use that data:

1. Checks the corresponding directory under the `data` directory
2. Checks if the file name provided is a full path to the file
3. Checks IRIS EMC's file repository
4. Assumes the file name is a URL to the file you want to download

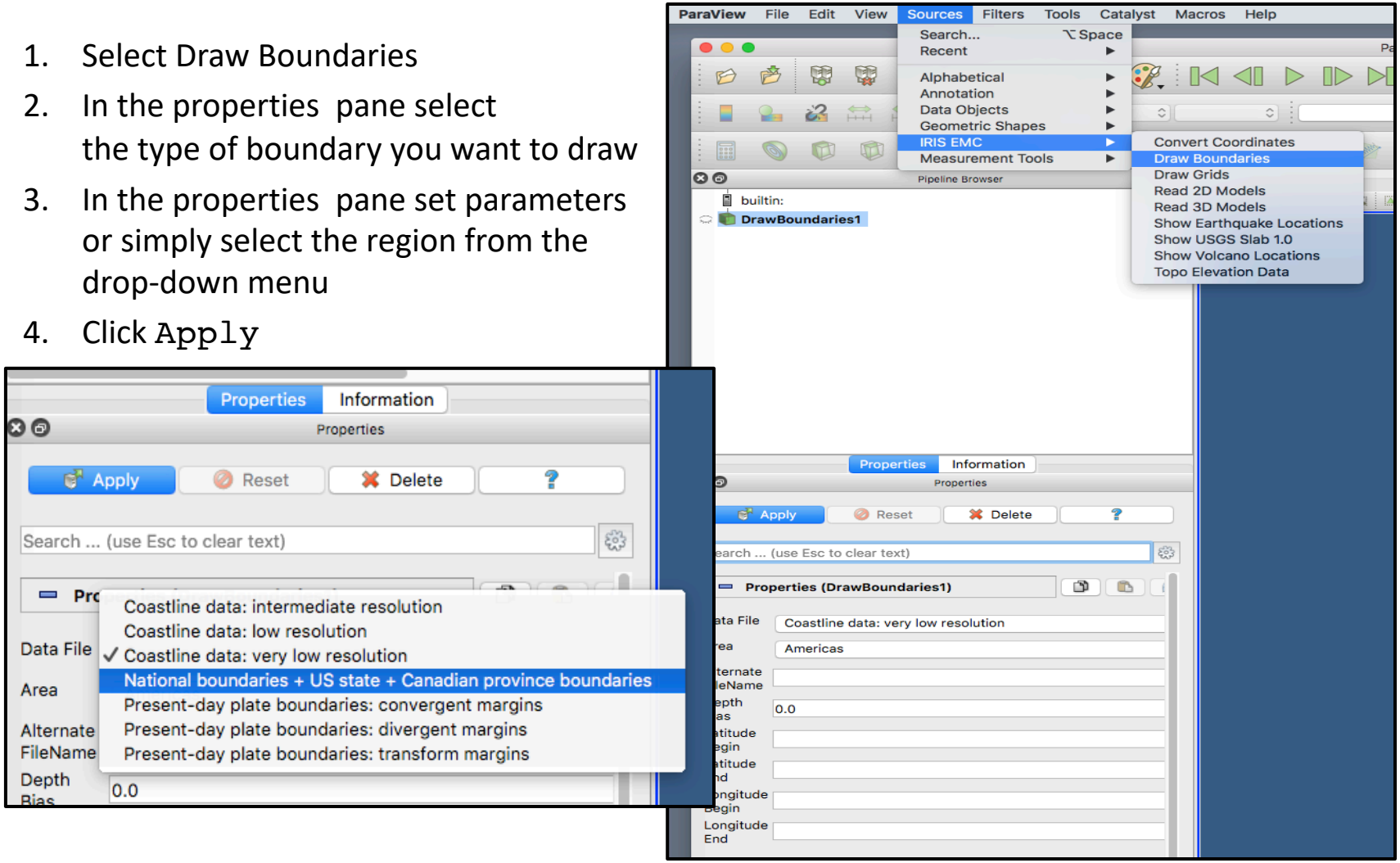
Notes:

- If the `Alternate File` box is populated in the property panel of the plugin, this alternate file name will override the default file name.
- If file matching your request is found under the data directory that matches your request, it will use it. To force the plugin to download it again, remove the file from the data directory
- If you want to work offline with the plugins, make sure first connect to the Internet and visit all the plugins that you want to use and select the file you want to use (you do not need to go through complete processing sequence, just the first `Apply` should be sufficient). This will ensure that files are available under the data directory when you are offline or connected to a slow Internet.

Draw Boundaries

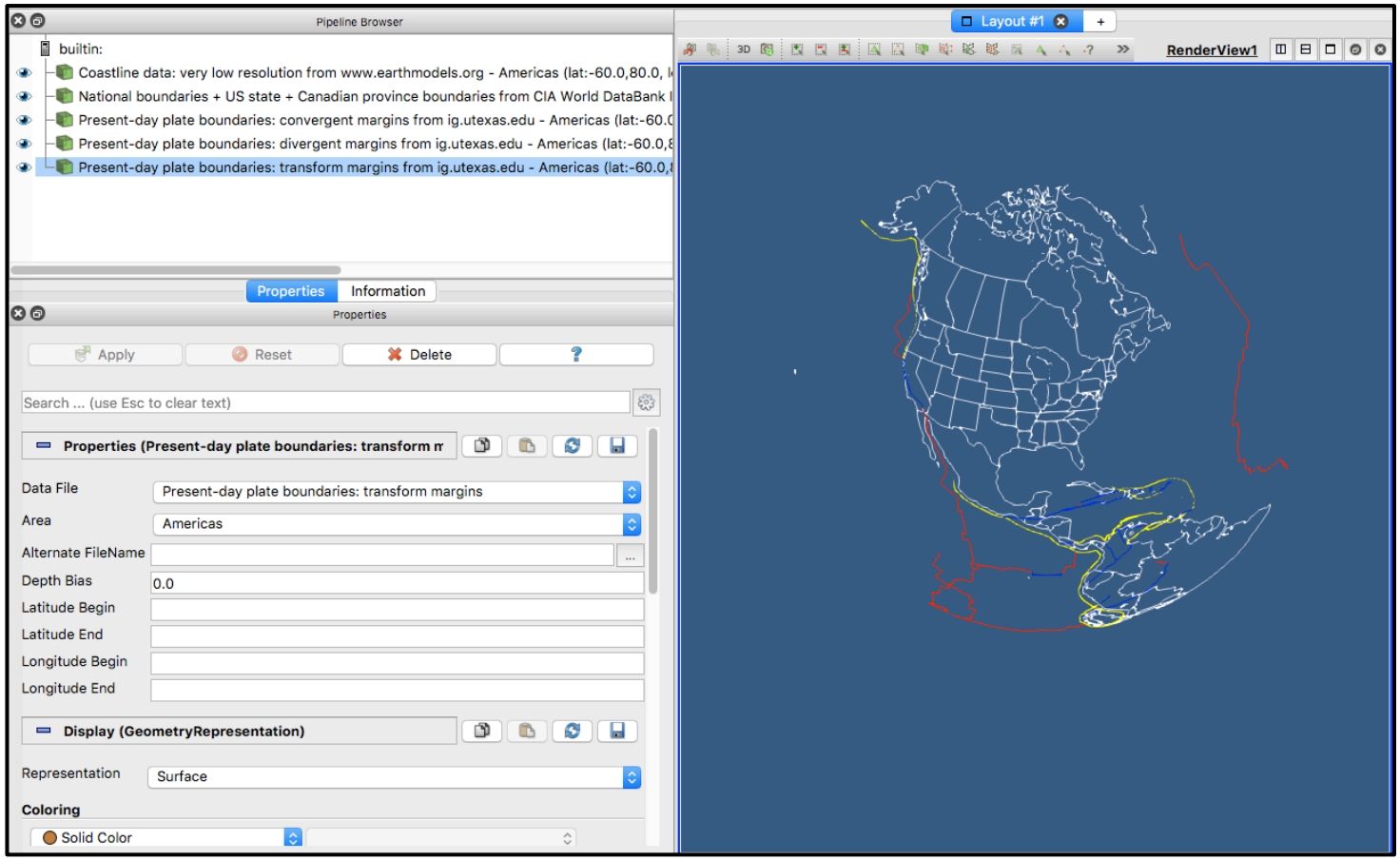
Allows you to draw boundaries (lines) from IRIS EMC's coastlines, national, US states and Canadian provinces, present-day plates (divergent, transform or convergent margins) boundary files or from your own GeoCSV boundary files:

1. Select Draw Boundaries
2. In the properties pane select the type of boundary you want to draw
3. In the properties pane set parameters or simply select the region from the drop-down menu
4. Click `Apply`



Draw Boundaries (Cont'd)

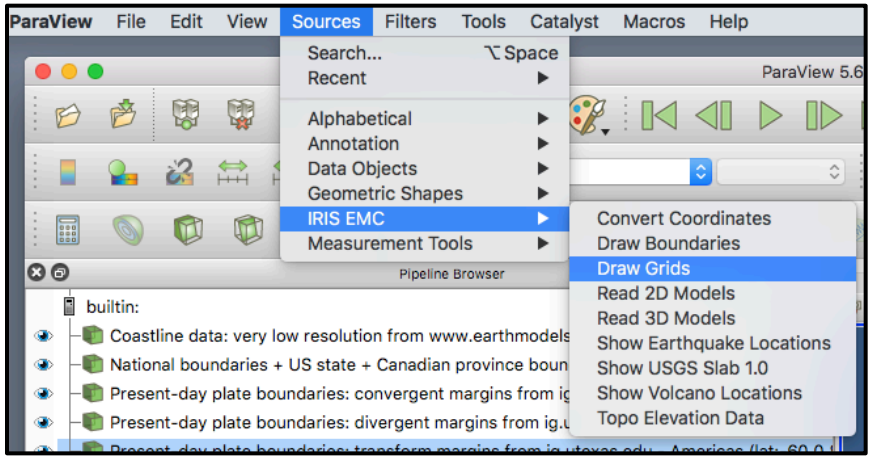
- Draw as many boundary lines you want to draw
- Each boundary line will appear as an object in the `Pipeline Browser`
- You can tune each boundary line later by selecting it in the Pipeline Browser

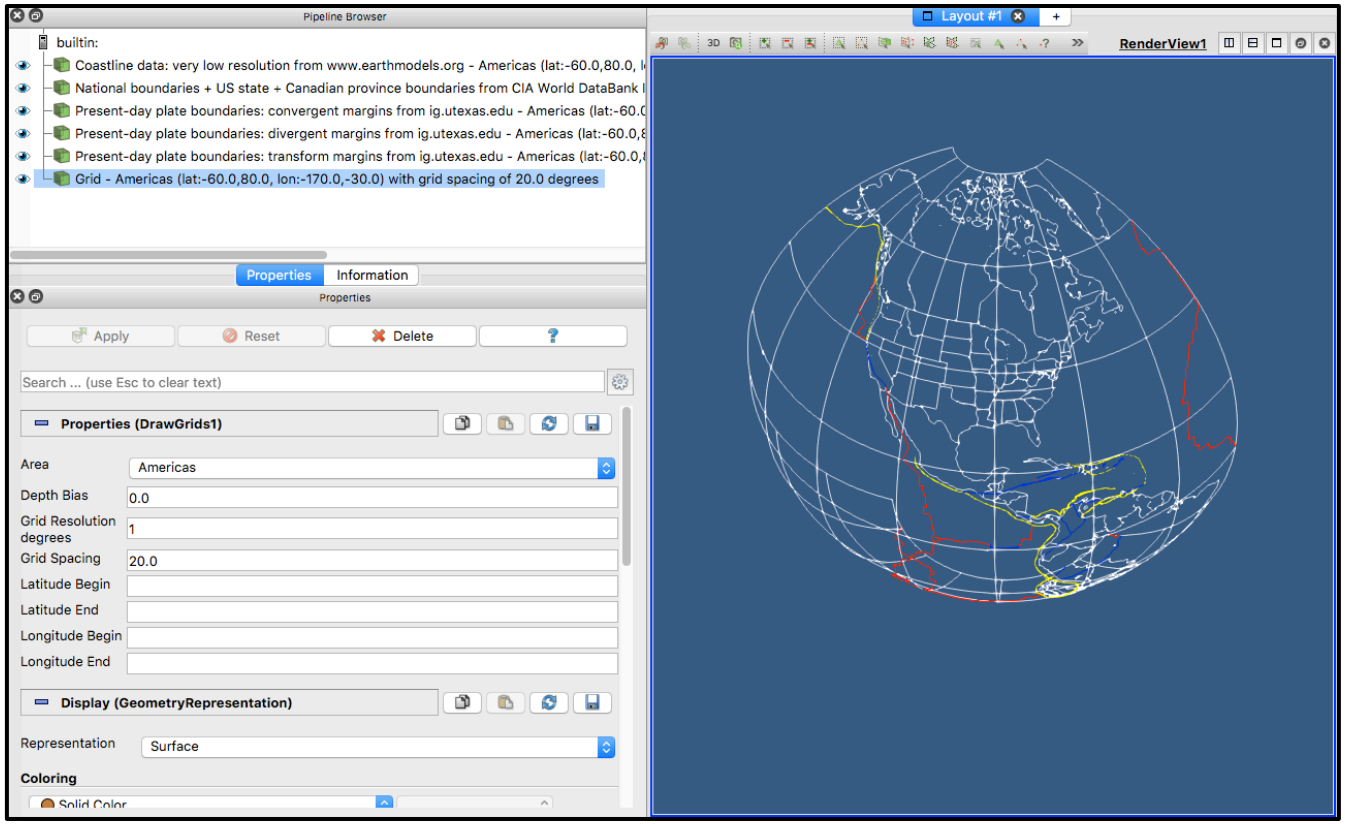


Draw Grids

Draw latitude/longitude grid lines:

1. Select `Draw Grids`
2. In the properties pane set parameters or simply select the region from the drop-down menu
3. Click `Apply`





ParaView

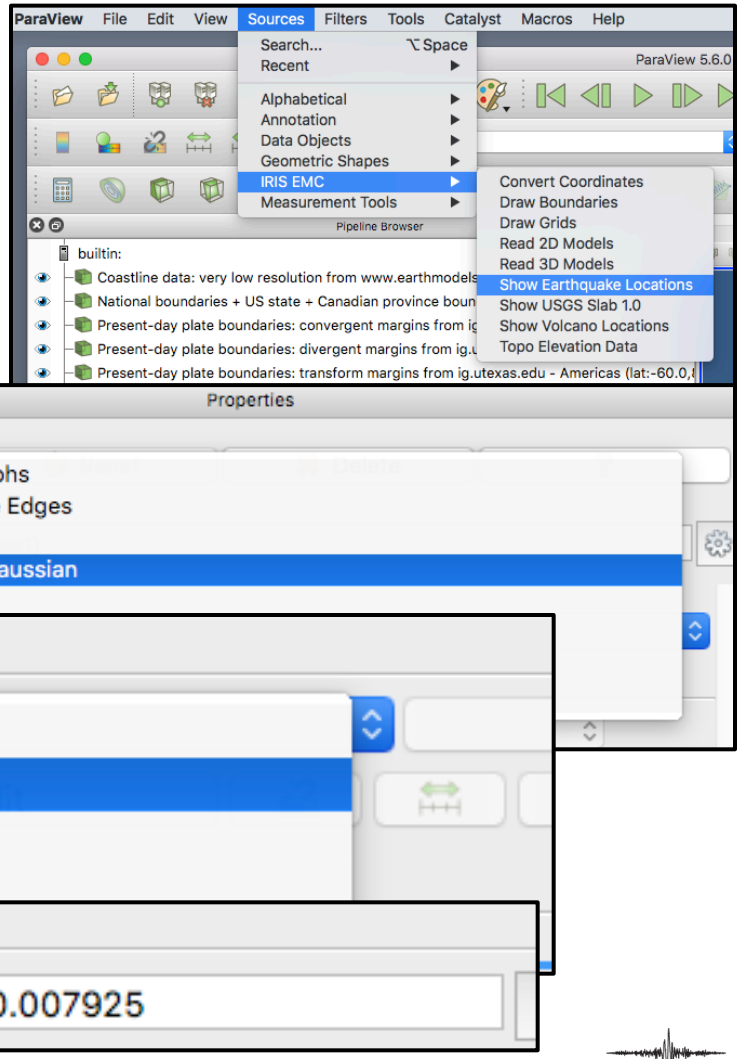
EMC ParaView Plugins – Draw Grids

IRIS

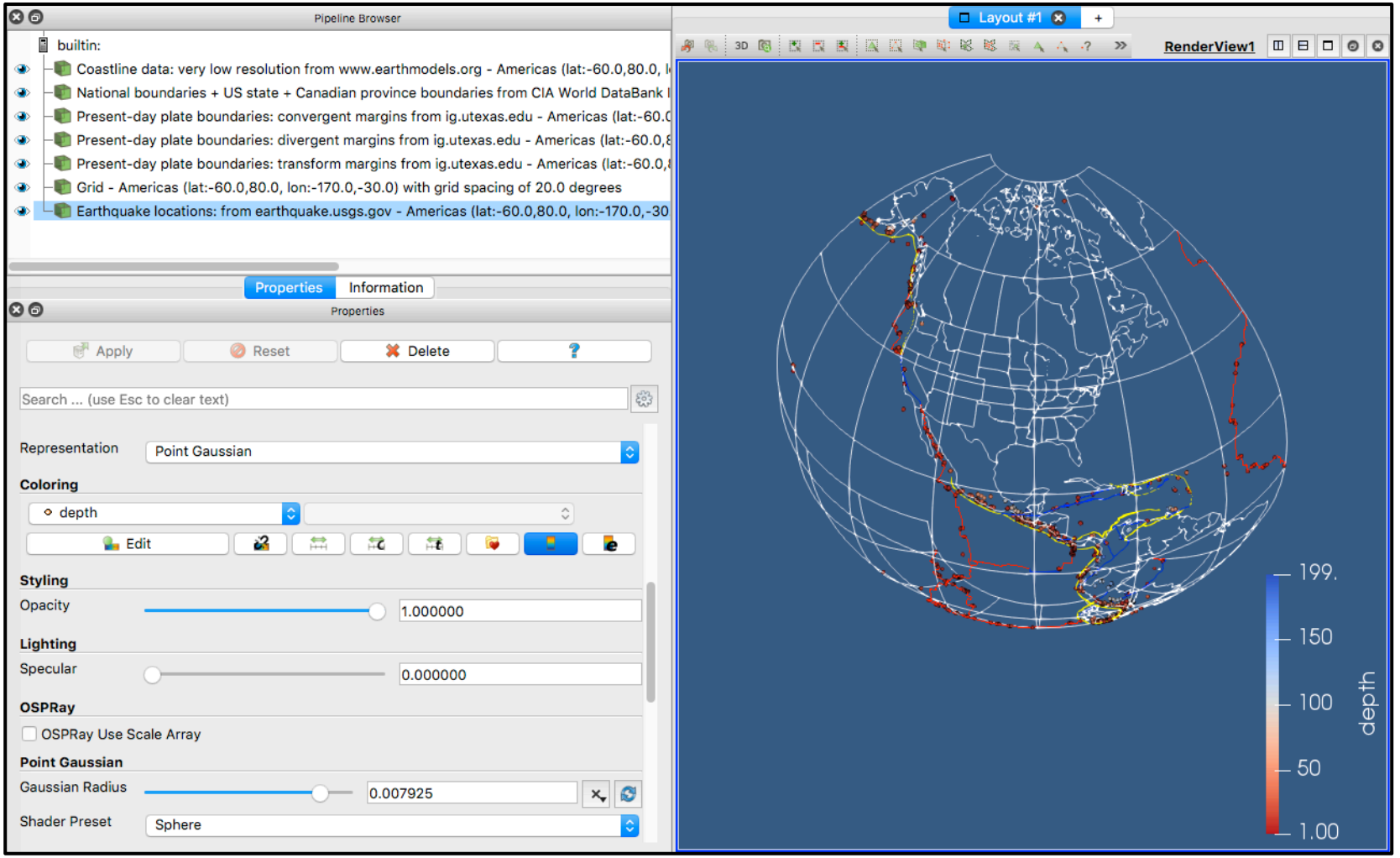
Show Earthquake Locations

Plot earthquake locations based on the FDSN event services or your local GeoCSV earthquake location files

1. Select `Show Earthquake Locations`
2. In the properties pane set parameters or simply select the region from the drop-down menu (use your own data file by specifying it in the `Alternate File` box).
3. Click `Apply`
4. In the properties pane set:
   - `Representation` to `Point Gaussian`
   - Select `Coloring` based on a parameter or leave it as solid
   - Set the marker size via `Gaussian Radius`



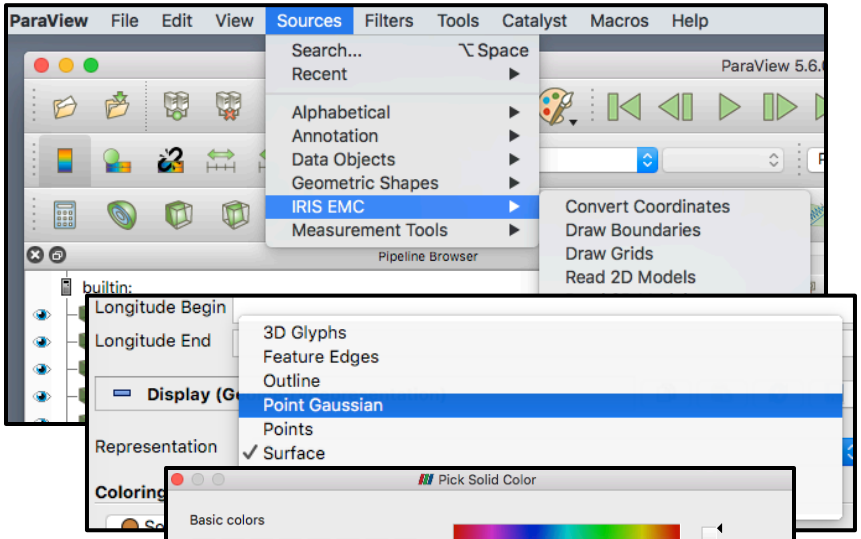
Show Earthquake Locations (Cont'd)

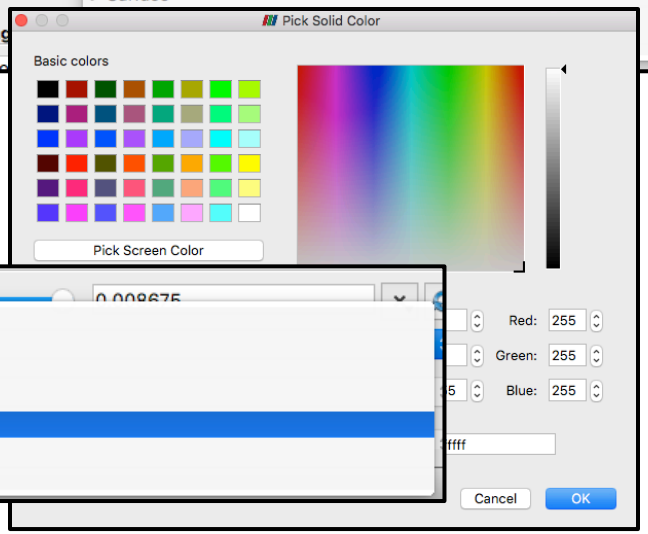


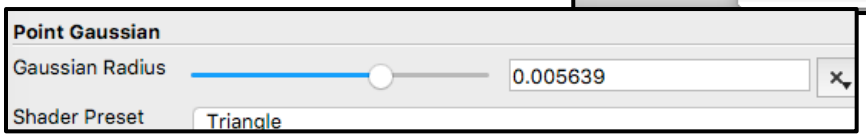
Show Volcano Locations

Plot location of volcanoes using WOVOdat location data (https://wovodat.org/) from `ds.iris.edu` or using your own GeoCSV volcano location or other point data files

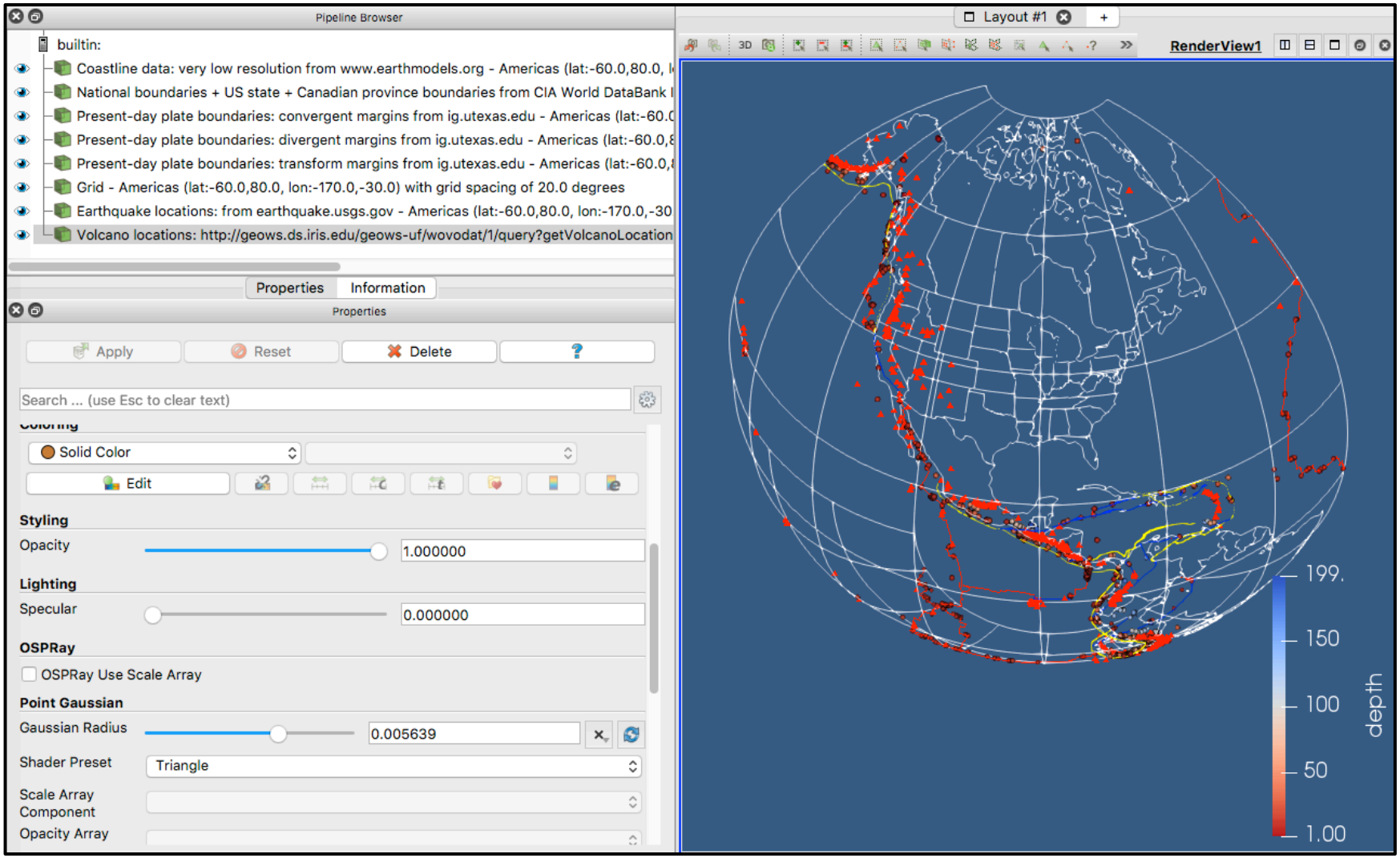
1. Select `Show Volcano Locations`
2. In the properties pane set parameters or simply select the region from the drop-down menu (use your own data file by specifying it in the `Alternate File` box).
3. Click `Apply`
4. In the properties pane set:
   - `Representation` to `Point Gaussian`
   - Select `Coloring` using the `Edit` button
   - set marker shape to triangle using `Shader Preset` option
   - Set the marker size via `Gaussian Radius`





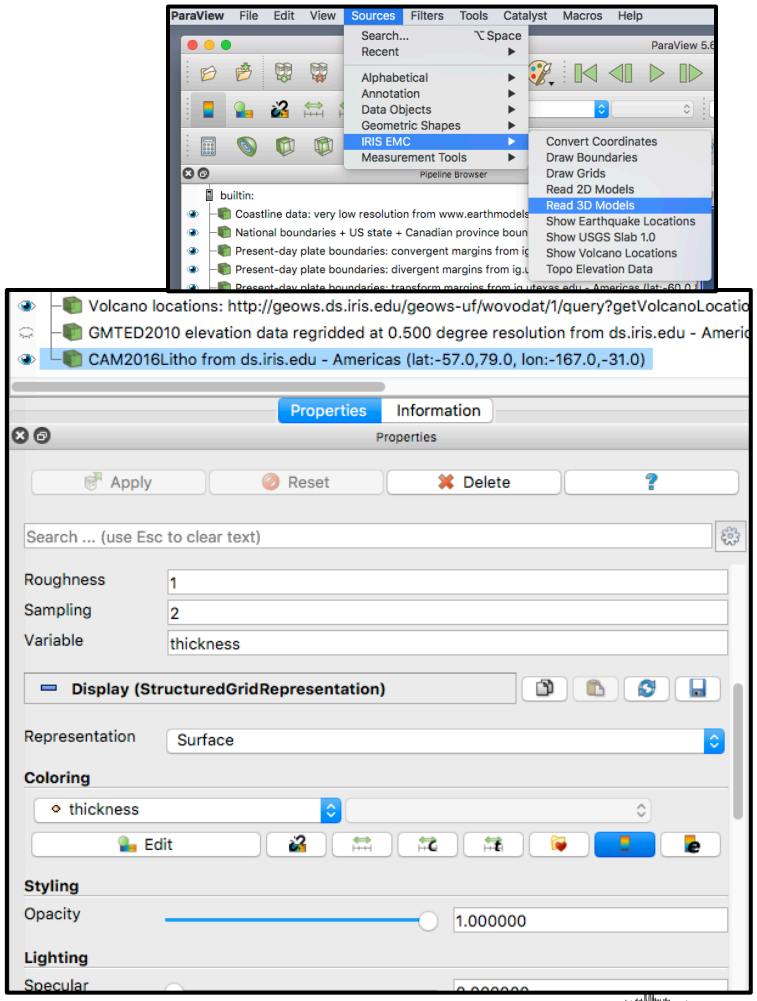


Show Volcano Locations (Cont'd)



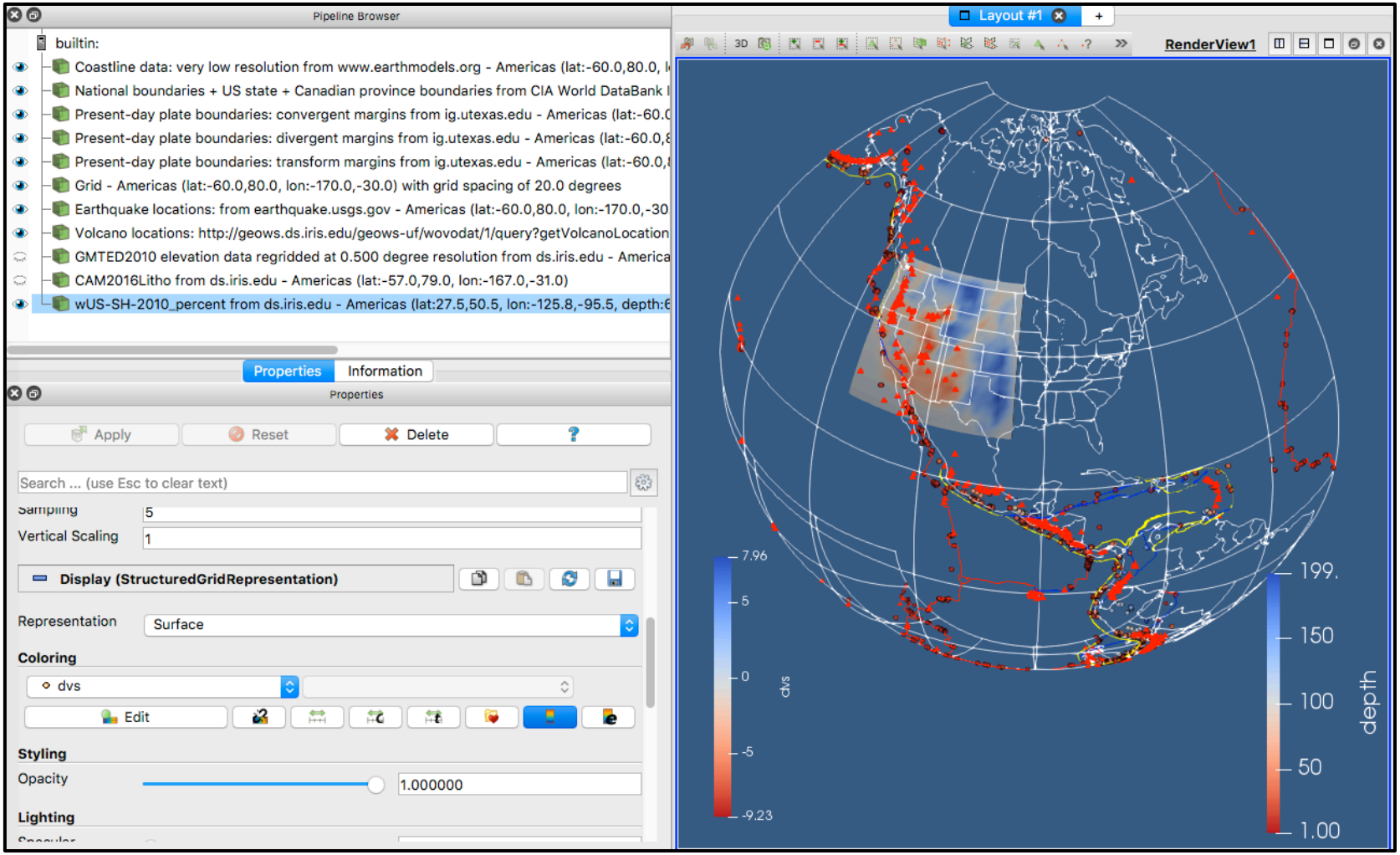
Read 3D Models

Read and plot 3D Earth model files in netCDF and GeoCSV file format (**NOTE**: Plugins can read netCDF files only under Mac and Linux. Under Windows, plugins automatically try to find the GeoCSV version. You can leave the file extension out to let the plugin choose the format based on your OS).



1. Select Read 3D Models
2. In the properties pane set parameters or simply select the region from the drop-down menu and enter a 3D model file name (or use the default model) and click apply. For EMC model repository visit : http://ds.iris.edu/ds/products/emc-earthmodels/
3. In the Pipeline pane, if there are any objects that may block this model, either reduce their opacity in their Properties pane or select the blocking pipeline objects and change their visibility by clicking on the eyeball icon next to them.
4. Click `Apply`
5. In the properties pane set:
   - `Representation` to `Surface`
   - Select `Coloring` variable and set other parameters as desired

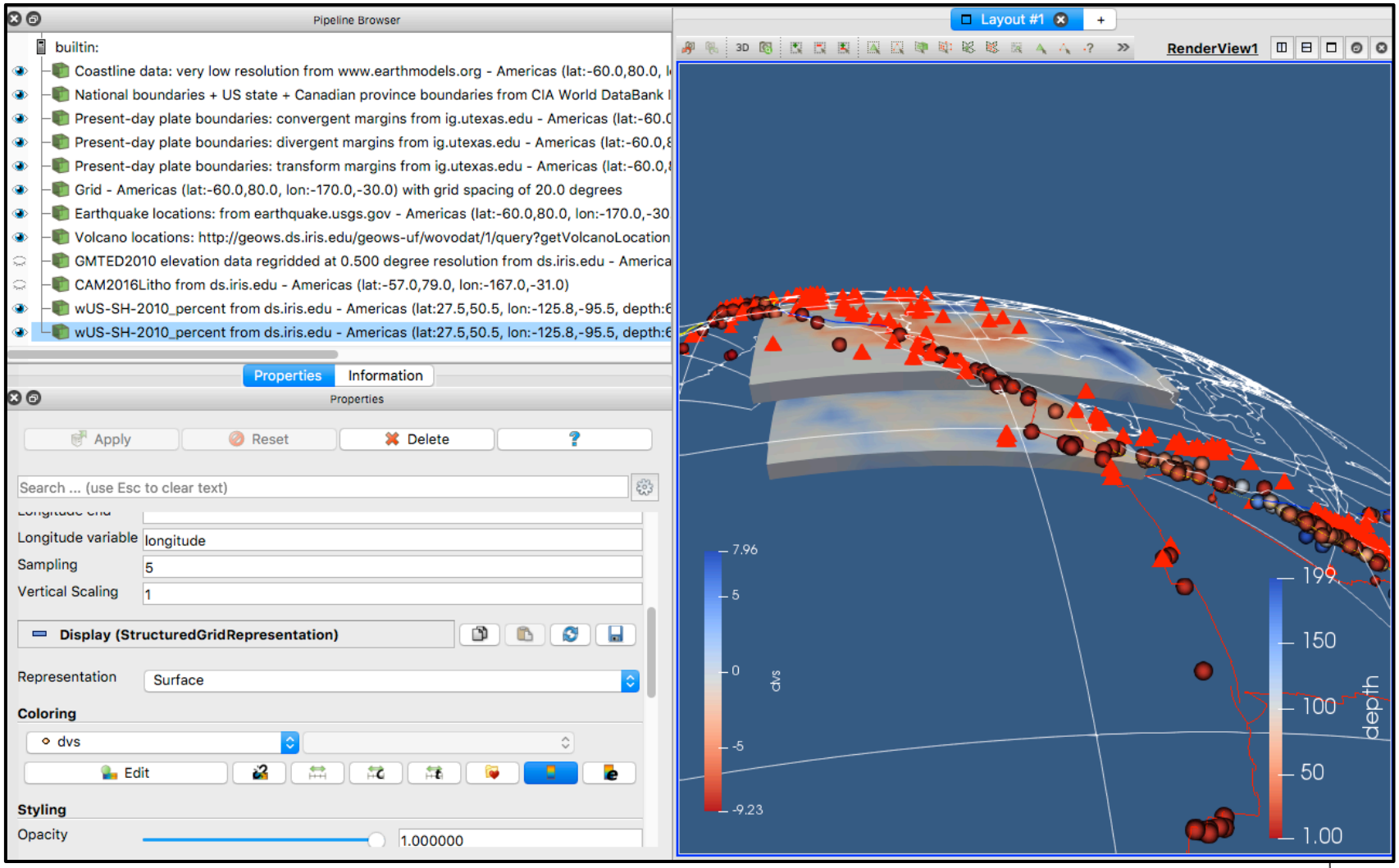
Read 3D Models (Cont'd)



Read 3D Models – Horizontal Slices

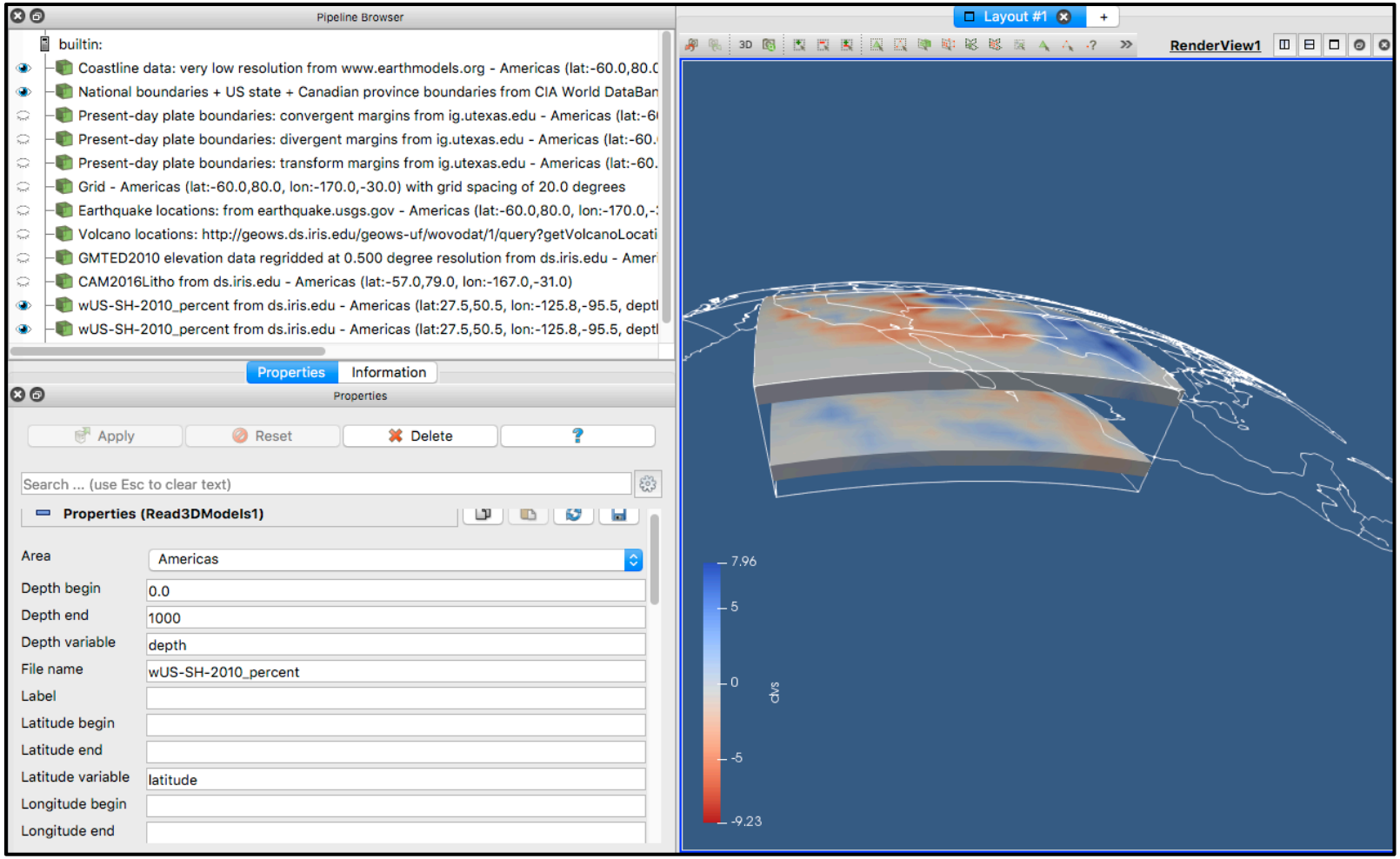
Repeat the steps for reading a 3D model but each time use different depth ranges.

This will result in a stacked horizontal slice view:



Read 3D Models – Cross-Sections

Again, read the same 3D model but this time set the depth ranges to cover the entire model. You should see outline of the loaded model volume

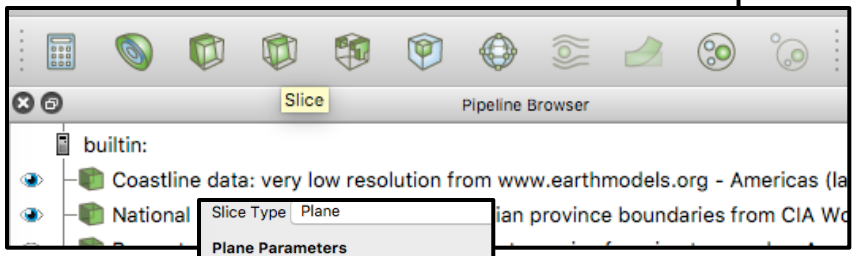


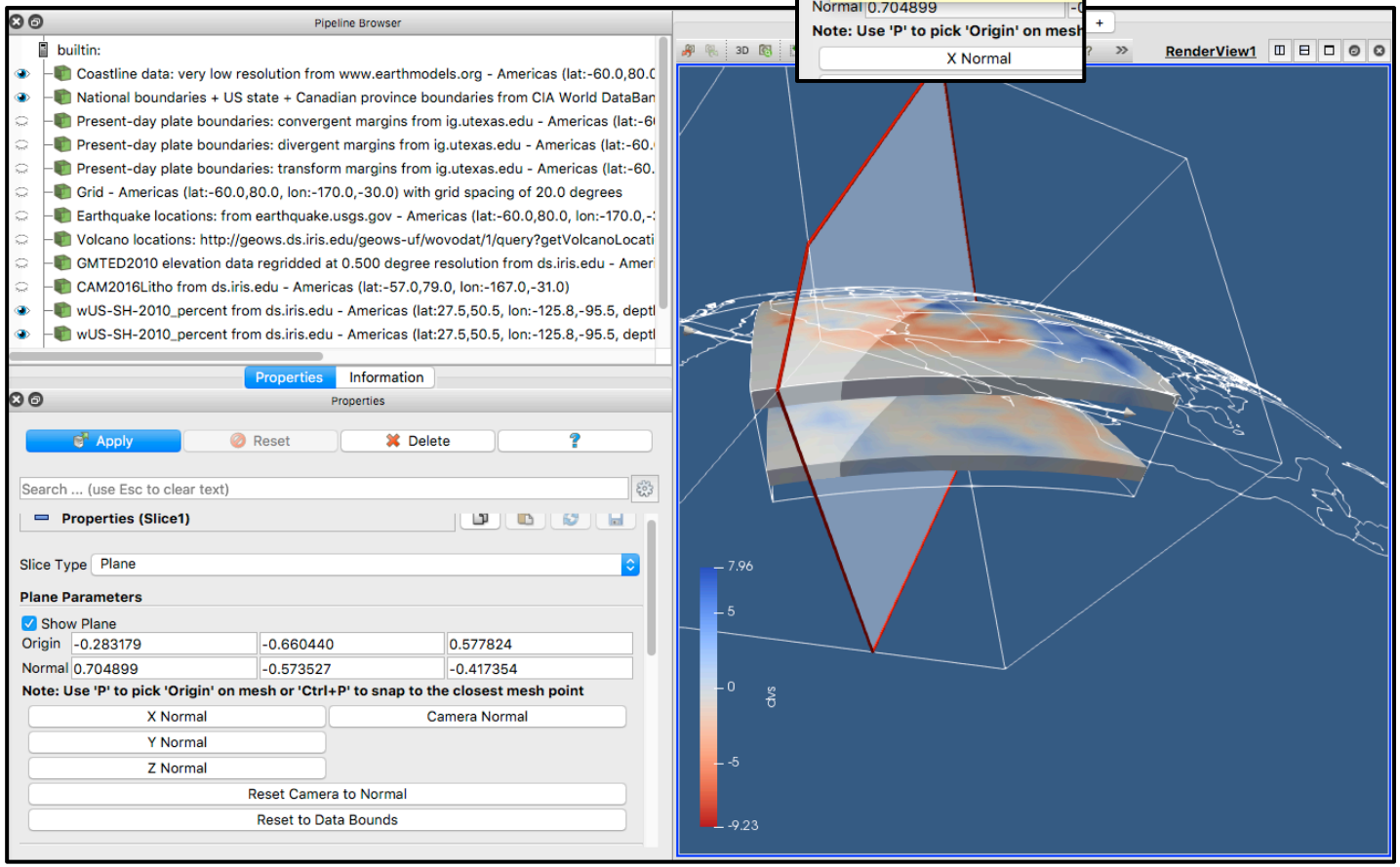
Read 3D Models – cross-sections (Cont'd)

Use ParaView's slice tool to slice the model and use the controls to position it as desired

Once in position:

- Click `Apply`
- Uncheck Show Plane to remove the guides

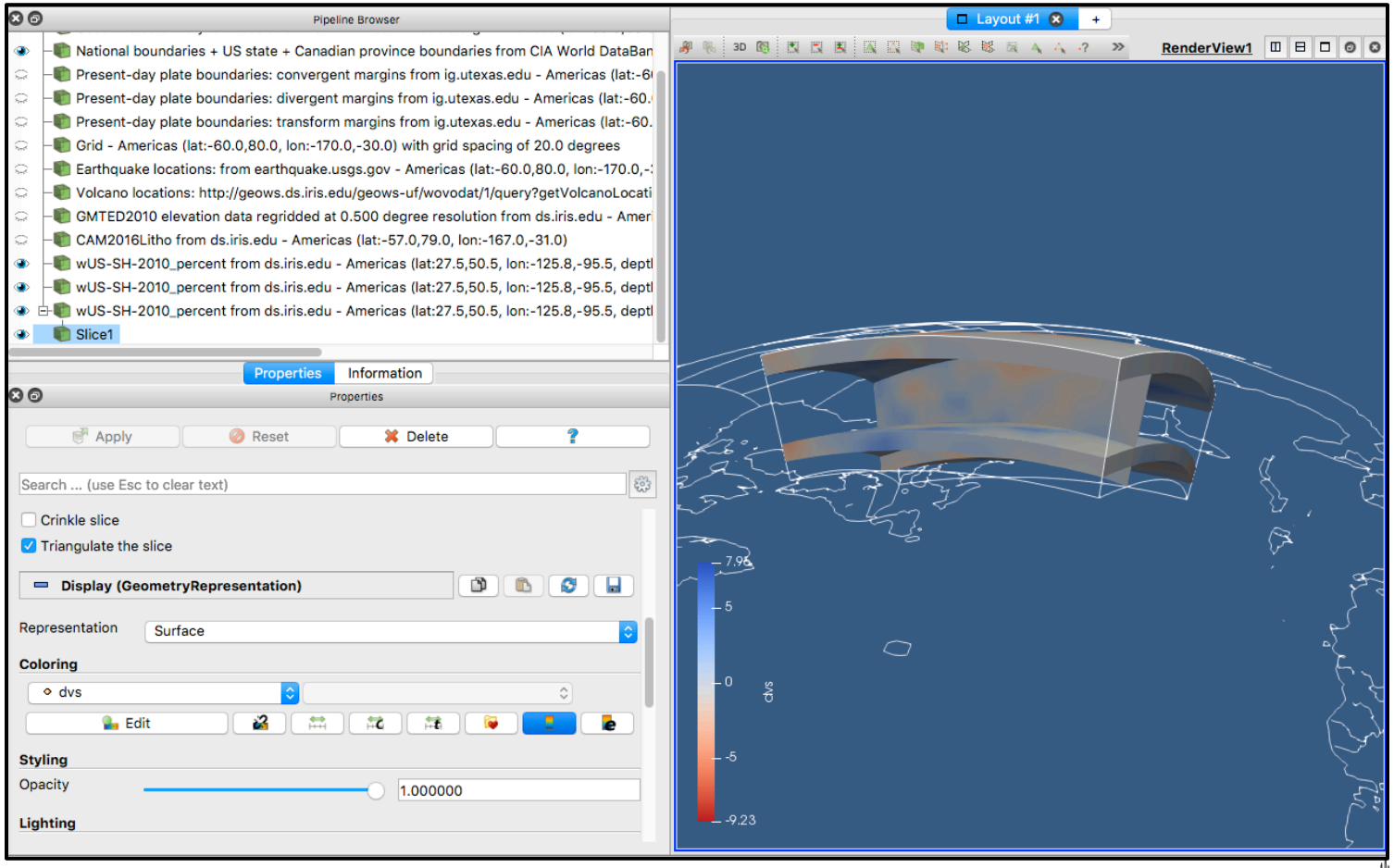




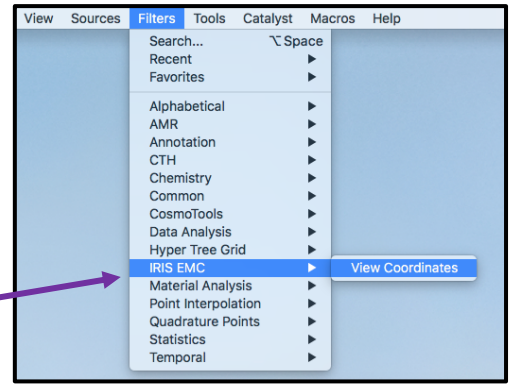
Read 3D Models – cross-sections (Cont'd)

Select surface as the representation and select the variable for coloring. This results in a cross section.

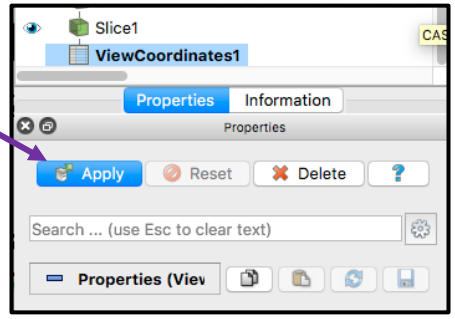
NOTE: Since model volume is already in the pipeline, you can draw as many slices as desired



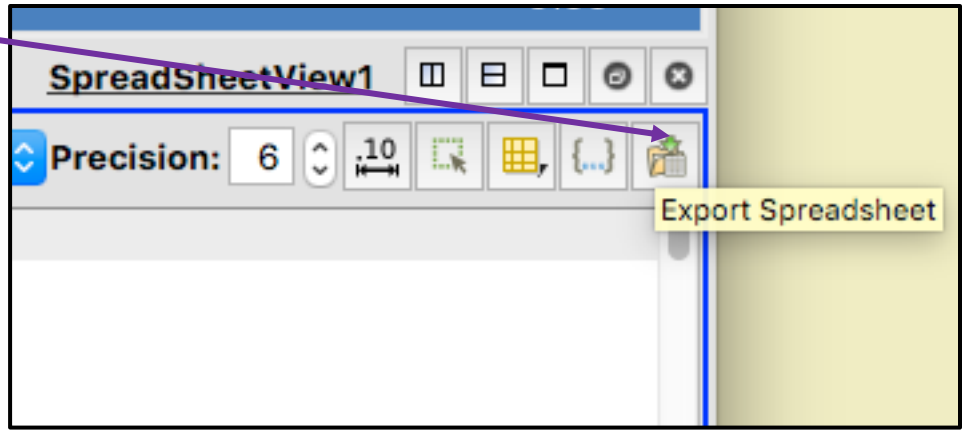
Save Cross-Section Data



- Data in ParaView are stored as X, Y, Z coordinates. To convert them to latitude-longitude-depth, select the cross-section object in Pipeline, then select the `View Coordinates` Filter:
- Click `Apply`



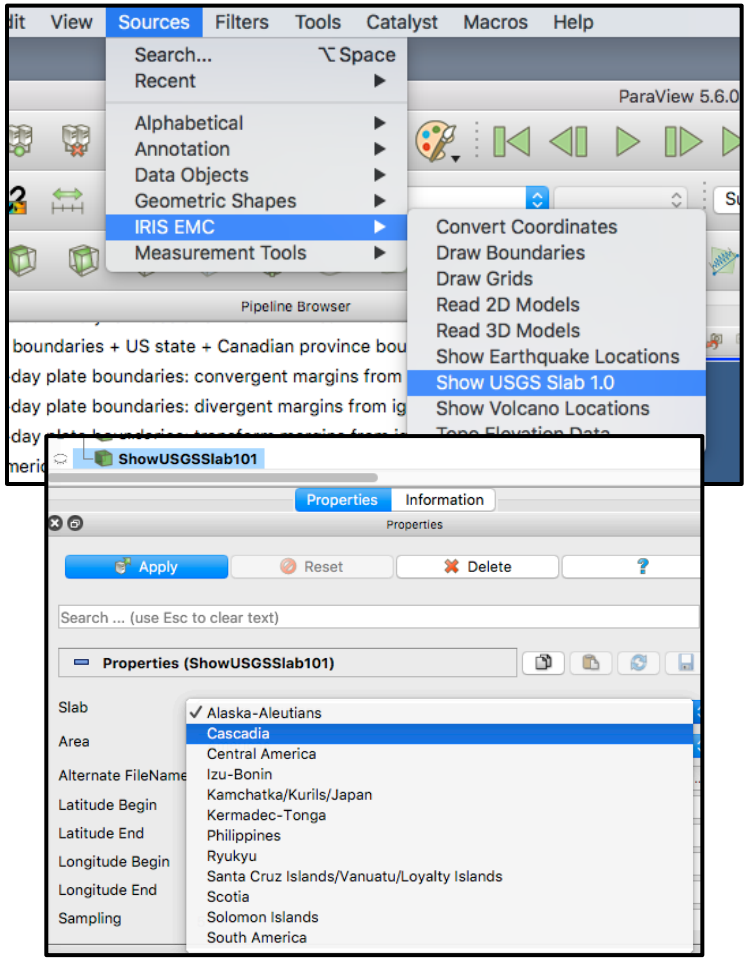
- This will open a `SpreadSheetView` that contains the data for the section.
- Use the `Export Spreadsheet` button on the upper right of the view to export the data



Show USGS Slab 1.0 Model

Display USGS Slab 1.0 models (`https://earthquake.usgs.gov/data/slab/`)

1. Select `Show USGS Slab 1.0`
2. In the properties pane set parameters or simply select the region and slab area from the drop-down menu
3. Click `Apply`
4. In the properties pane set:
   - `Representation` to `Surface`
   - Select `Coloring` as `z` (depth to slab)
   - `Unit Factor` to convert elevation unit for example from meters to km
   - `Sampling` for different resampling/ resolution



Show USGS Slab 1.0 Model (Cont'd)