VISES Workshop (9/29/14, Monday afternoon)

3D Structural Velocity Modeling/USR Framework

Tutorial Instructions

SCEC-VDO: Structural components

- *Basics: navigation, loading data sets*

    Follow SCEC-VDO guide below

- *Visualizing faults*

    Goal: Explore the 3d fault model and identify major fault system using the techniques outlined in the SCEC-VDO guide.

    Steps:

    - select Community Fault Model (CFM) tab
    - select “San_Andreas_Fault_system” group
    - switch to “Earthquake Catalog” tab
    - switch on most or all Lin et al. catalog hypocenters
    - Observe how little seismicity is associated with sections of the San Andreas fault system
    - select “Peninsular_Ranges” group
    - discuss briefly with your neighbours which fault zones seem to have the most seismicity associated with them

- *Visualizing geologic surfaces: Basement and Moho surfaces*

    Goal: We will load and explore the geometry of two main acoustic velocity interfaces in the crust, the sediment-basement boundary (the Basement surface), and the Moho discontinuity at the base of the crust. We will see how the basement surface defines major sedimentary basin and how faulting can affect the geometry of this interface in a significant way.

    Steps:

    - switch off hypocenters if displayed
    - select “Community Fault Model (CFM)” tab
    - switch off most faults: select “Basin_and_Range” group
    - click on “+” button below list of faults

- navigate to /home/cme/CME/data-folder
- select CVMH_Basement64.ts and CVMH_Moho64.ts and click "Open" to load
- fill in "scec" for "group name"
- fill in "scec" for "citation"
- find CVMH_Basement64 and CVMH_Moho64 in alphabetical fault list and check to display
- change display style and color
- show only the basement surface
- switch to "Surfaces" tab to avoid highlighting while navigating
- use perspective views to locate deep portions of the surface. These are the centers of sedimentary basins.
- [Option: in "Surfaces" tab select "NationalAtlasRelief1km.." and click on "eye" button to display
- compare how low lying areas compare with geologic basins]

Exercise: Examining faults that affect the basement surface

We will focus on the Basement surface in the Los Angeles basin and examine how faults help define the basin shape.

Steps:

- switch off shaded relief map in "Surfaces" tab if displayed by toggling the "eye" button
- switch off all faults and surfaces in CFM tab
- switch on the following faults:
    - all four segments of "WTRA-SBTS-PHLS-Puente Hill Thrust .."
    - "PNRA-ELSZ-WHIT-Whittier Fault-CFM"
- define a new fault group for these faults:
    - click on the "+" button below the groups list
    - enter a name for the new group: "LA-North" and click "OK"
- switch on the basement surface
- switch to "Surfaces" tab to avoid highlighting while navigating
- center view on selected faults and zoom in. It helps to use the advanced navigation techniques as outlined in the SCEC VDO guide below.
- toggle off and on individual faults and observe how they offset the basin surface. Based on their displacement patterns what type of faults are they?
- [Option: identify other faults (for example the Santa Susana and San Cayetano faults) which intersect and offset the basement surface and observe how they help define the shape of a basin.]

SCEC-VDO: Exploring velocity models

Goal: We will learn how to display the velocity structure of the crust as it is represented in a 3d velocity model. For this purpose we will use prepared cross-sectional and map views. We will then analyse the 3d velocity structure by comparing it with the geologic surfaces which define important velocity interfaces.

Examining velocity cross-sections and maps

Steps:

- select UCVM plugin under Display - Surface Imagery - UCVM Slice Viewer
- a new tab appears under “UCVM Slice Viewer”
- switch off all faults and surfaces if displayed
- select “UCVM Slice Viewer” tab
- scroll down and click on the “+” button at the bottom of the tab
- navigate to `/home/cme/CME/data-folder/vertical-cross-sections`
- select cross-section data file “cvmh_vertical_slice_la_basin_san_gabriel.txt” and click “Open” to load
- Locate the cross-section in the viewer
- select a high contrast color scale (such as GMT-seis) and adjust the color palette max. to 8000
- click “Update Display” to apply the new color scale to the view
- show Vs: Select “Vs” from “Displayed Dataset” list and click “Update Display”
- adjust color scale as appropriate
- display second cross-section by repeating above steps for data file “cvmh_vertical_slice_santa_monica_la.txt”
- observe similarities and differences between the two cross-sections
- Select both cross-sections and “Toggle Visibility” off with button
- Open “cvmh_horizontal_slice_0m_elev_gtl.txt” in `/home/cme/CME/data-folder/horizontal-slices`
- Add -2500m, -5000m, and -10000m slices. Observe basin shapes and sizes with increasing depth

Exercise: Comparing velocity structures and geologic surfaces

Steps:

- toggle off any display horizontal slices
- display cross-sections with UCVM slice viewer
- display Moho surface in CFM tab
- switch back to UCVM slice viewer to avoid highlighting surface while navigating
- identify Moho interface in cross-sections
- display basement surface in CFM tab
- identify basement-sediment interface in cross-sections

- observe how the geometry of the basement surface introduces strong lateral gradients and vertical inversions
- toggle back on -2500m slice

UCVM

Introduction to the UCVM framework

UCVM is a tool for integrated access to a variety of velocity models. It consists of an API which can be used in custom software and a set of command line utilities for data extraction. In depth documentation is available at http://scec.usc.edu/scecpedia/UCVM.

Extracting and plotting cross-sections and maps

Goal: We will use UCVM to reproduce the cross-sections and maps that we analysed with SCEC-VDO

Steps:

- open a terminal window: Applications - System Tools - Terminal
- at the command prompt type:

```
cd /home/cme/CME/ucvm-14.3.0/utilities
```

- type `./cross_section.py`
- follow prompts:
  - `starting longitude: -118.5`
  - `starting latitude: 33.6`
  - `ending longitude: -117.8`
  - `ending latitude 34.2`
  - `starting depth: 0`
  - `ending depth: 35000`
  - `horizontal spacing: 200`
  - `vertical spacing: 200`
  - `what to plot: vp`
  - `select CVM: 2`
  - `color scale: s`
  - `wait ..`
  - `save or plot: 2`

- compare generated plot with “cvmh_vertical_slice_la_basin_san_gabriel.txt” in SCEC VDO
- produce plot for second cross-section with these coordinates:
  - `starting longitude, latitude: -118.45, 33.8`
  - `ending longitude, latitude: -118.45, 34.6`

- `other parameters the same as above`
- produce a horizontal slice:
- type `./horizontal_slice.py`
- follow prompts:
    - `bottom-left longitude: -121`
    - `bottom-left latitude: 32`
    - `top-right longitude: -114`
    - `top-right latitude: 36`
    - `grid-spacing: 0.01`
    - `depth: 5000`
    - `what to plot: vp`
    - `select CVM: 2`
    - `color scale: s`
    - `wait ..`
    - `save or plot: 2`
- compare generated plot with "cvmh_horizontal_slice_-5000m_elev.txt" in SCEC VDO
- produce map (horizontal) plot at 2500 m depth with the same corner points.

Exercise: Comparing alternative velocity parameterizations (CVM-H with and without GTL,CVM-S,CVM-S 4.26)

- reproduce cross-sections with CVM-S 4 (option 1) by following the steps above
- reproduce 2500 m depth slice with CVM-S 4 by following the steps above
- discuss how CVM-S 4 differs from CVM-H 11.9
- produce high resolution LA basin cross-section of upper 600m:
- use 500m horizontal, and 10m vertical spacing.
- with GTL (option 1)
- observe how the GTL mimics deeper layers
- [option: load in SCEC-VDO and visualize: use cross_section_eri.py; very similar procedure to cross_section.py]

Exercise: produce LARSE cross-sections

- LARSE I: -118, 34 to -117.3, 35.2
- LARSE II: -118.5, 34 to -118.4, 35.2
- Compare with published cross-sections in handout.

Extracting 1-D velocity profiles

Goal: It is often useful to work with 1-D velocity profiles. For example, the Broadband Platform typically would use vertical profiles to characterize velocity structure. We will use UCVM to extract 1-D profiles different locations. We will then use the extracted data to see how the geotechnical layer affects the upper 300m. Finally, we will compare the extracted profiles in three basins with averaged basin profiles, and discuss the geologic processes which are responsible for characteristics of the basin profiles.

Steps:

- in the utilities directory, launch the 1d-profile python utility: type `./depth_profile_eri.py`
- follow the prompts
- use these parameters:
    - `longitude: -118.2`
    - `latitude: 33.95`
    - `starting depth: 0`
    - `ending depth: 5000`
    - `discretization level: 20`
    - `what to plot: vp`
    - `select CVM: 3 (without GTL)`
    - `save or plot: 2`
- in the plot window, click the zoom button and zoom into the upper 1000m
- repeat the plot for CVMH-11.9 with GTL (option 2)
- observe how the GTL defines the uppermost layer and how it is smoothly interpolated with the deeper profile
- repeat the extraction for this location down to 30000 m and save the data:
    - `save or plot: 1`
    - `file name: LA.txt`
- plot the data file with gnuplot:
    - at the command prompt type `gnuplot`
    - at the gnuplot prompt type: `plot “LA.txt” using ($4):(-$3)`
    - This plots column four (Vp) on the X axis and the inverted column three (depth) on the Y.
    - type `quit` to exit gnuplot
- extract and plot similar profiles for these locations by following the same steps:
    - San Fernando basin: -118.45, 34.22
    - Salton Trough: -115.13, 32.56
    - S. Maria basin: -120.43, 34.77
    - western S. Gabriel Mts.: -118.23, 34.25

    - in gnuplot, overlay multiple profiles by using the “replot” command repeatedly after the initial plot
- compare the profiles
- Which profile is not located in a sedimentary basin ?

Exercise: Evaluating basin velocity structures

We will plot average vp basin velocity functions and compare our extracted profiles with those. Then we will use the average functions to characterize basins relative to each other.

Steps:

- at the command prompt first make sure you are still in the `/home/cme/CME/ucvm-14.3.0/utilities` directory
- copy average basin functions: type

```
cp ~/CME/data-files/average-1D-basin-velocity-functions/* .
```

- enter gnuplot: type `gnuplot`
- plot average function for Los Angeles basin: type `plot “LABasin2.dat” using ($2):(-$1)`
- overlay extracted function: type `replot “LA-center.txt” using ($4):(-$3)`
- compare average with extracted function.
- repeat for a few more basins. Here is the mapping between extracted profiles and average basin functions:

    San Fernando Basin - VenturaBasin2.dat
    Salton Trough - SaltonTrough2.dat
    S. Maria basin - SMBasin2.dat

- the extracted profiles should closely track the average functions.
- use a prepared gnuplot command script to plot all average vp basin functions on top of each other:
  at the command prompt type: `gnuplot -p plot_basin_averages.plot`
  To rescale the plot adjust plot window size, then click “Apply autoscale” button at top
- discuss similarities and differences between the basin profiles and what larger scale, geologic processes may explain those:

Ventura and LA basins very similar: share the same geologic history
Salton Trough has steeper gradient: enhanced geothermal gradient leads to lithification and beginning metamorphosis to denser rocks all at shallower levels
S. Maria basin is faster: sediments have longer deformational history which leads to older sedimentary being exposed at the surface

SCEC-VDO guide

1. First steps

   SCEC VDO will present you with a perspective view of CFM4 primary fault representations in the main viewer area on the left and tabs on the right. The CFM tab is open and shows the list of loaded faults. The displayed faults are checked.

   1. First try navigating the view with the mouse. The left mouse button rotates, the right mouse button translates and the middle mouse zooms in and out the view while moving the mouse up and down. On Macs tapping with two finger is the equivalent to holding down the right mouse button (translation) or middle mouse button (zoom) on older models. The W and S keys or Up and Down keys allow for zooming in and out with the keyboard. The left and right arrow keys translate the view. It is most convenient to simply connect a 3 button mouse to a Mac. For a more extensive User Guide consult the SCEC VDO documentation at the SCEC at the SCEC UseIT web presence.

   2. Press the Escape key on the keyboard to get back to the initial view. See below for more advanced navigation techniques which are helpful but more difficult to control.

   3. Try clicking on a fault in the viewer. The fault turns white, and its name is shown in the line below the viewer.

   4. Then switch on and off a couple of faults by clicking the checkmark. You can also change the color of the fault by clicking on the color box, or cycle through display styles (mesh, transparency) by clicking on the grey solid box.

   5. You can also operate on multiple faults by highlighting them using Control- and Shift-clicking in the list, and then using the eye, color ring and mesh buttons under the list to change attributes for all selected faults simultaneously. Control-A selects all the faults in the list.

2. Groups

   Below the fault list there is a list of predefined fault groups. A group is just a selection of faults. A fault can be in multiple groups. Here is an explanation of the group names:

   1. CFM-4-1st: primary fault representations in CFM-4
   2. CFM-4-alt: alternative fault representations in CFM-4
   3. CFM-4-all: all fault representations in CFM-4
   4. regions: primary fault representations in geographic regions
   5. Qfaults: fault traces of the USGS Quarternary fault and fold database, generalized to about a 100m resolution for efficient display. The qfault traces are also available as a “fault” in the fault list under Qfaults [USGS] or as an image in the Surfaces tab.

Selection of a group results in switching off all displayed faults and in switching on only the faults in the group. Unfortunately, it is not possible to highlight multiple groups. After clicking on a group, the faults in the group will become selected in the fault list. This lets you identify which faults belong to a group, and change the display attributes of these faults.

3. Contextual displays
   Beside the CFM tab, four other tabs are open which let you display additional data.

    1. Surfaces: The Southern California Map option provides nice satellite imagery shaded by topography. After checking it, you can adjust the transparency. The California Map option is modified from the UseIT SCEC-VDO distribution and shows 1km resolution satellite imagery from the National Atlas. In addition, two shaded relief images from the National Atlas and a qfaults trace map are preloaded in the Image(s) list. Highlight a image name and click on the eye button below the transparency slider in order to view. The higher resolution image (200m) may overwhelm your computer's resources.
    2. Earthquake Catalog: The Lin et al. (2007) catalog is provided in magnitude segments, along with some other catalogs including one with focal mechanisms. Try switching on mag. >=4, and then keep adding hypocenters of smaller magnitudes. Since the magnitude range 1 to 2 contains about 240000 hypocenters, the display might overwhelm the resources of your computer. If you want to change colors, or other display attributes you can do so in the Display tab.
    3. Political Boundaries: the outline of California is switched on.
    4. Grids: Try displaying a 1 x 1 degree grid. There is also a compass option. Click **Apply** to display.

4. Advanced navigation

   SCEC-VDO has the ability to focus the view on a fault which is useful for closer examination because then the mouse navigation tools are all relative to the picked point on a fault. However, it is not easy to accomplish this task. Try to follow these steps.

    1. In the Window menu, check on “Globe Transparency”
    2. Under Window → Advanced, check on “Show Focal Point”. You should see now a white sphere at the center of your view. This is the point relative to which rotation and zoom works. By translating the view, you can move the focal point to another fault.
    3. With the focal point switched on, notice how translating the model shifts the position of the focal point relative to the model. A useful technique is to reposition the focal point horizontally and vertically by translating (right mouse button) the model in map view and in cross-section view, respectively. By using these view orientations it is possible to control positioning of the focal point fairly accurately.
    4. Another, optional technique is available under Window → Advanced, “Nav-by-Pick”. This option lets you position the focal point by double clicking on a fault. Unfortunately, the

picked point is not always on the fault but in fact sometimes on the other side of the earth (!). This is hit and miss and hard to predict.

5. Try now to double click with the left mouse button on a fault in the LA basin. The screen will turn black. Now zoom out – for example with the S key – until the focal point and the faults reappear. The focal point will be either close to a fault, or it will be very far away from the faults (on the antipodes of California).
6. If the focal point is close to a fault, zoom back in and use standard navigation to examine the fault. If the the focal point is very far away, carefully double click on any point in on the small fault model to bring back the focal point to California by repeating the procedure.

5. Additional Tips

Switch off all faults: Select a group (for example the “Basin_and Range” group); click the “eye” button to toggle (switch off) the selected faults

Avoid highlighting faults during navigation: Switch to another tab before navigation