
# Using Interactive Visualization to Analyze Solid Earth Data and Geodynamics Models

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## Introduction

Solid earth geophysics is becoming increasingly "data-rich."

New observations provide an unprecedented 3-D and 4-D view of the solid earth:

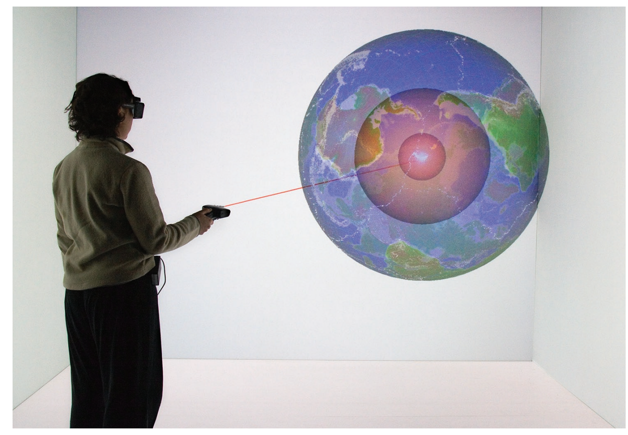
- 3-D imaging of Earth's interior using EarthScope, GSN, PASSCAL, and other sources
- Ground and airbased LiDAR, Satellite InSAR, GeoEarthScope
- Other 3-D imaging: neutron imaging, etc.

Large scale models and simulations add to the data tsunami:

- Computational geodynamics
- Molecular dynamics models of Earth materials
- Weather and climate models

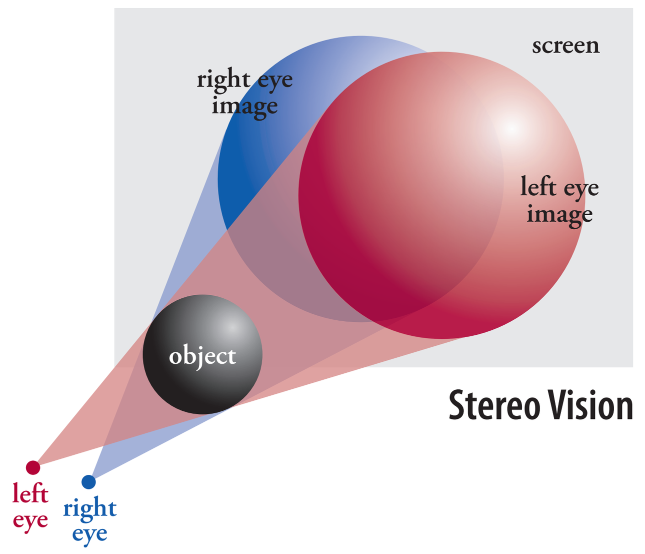
Using Interactive Visualization and Virtual Reality for Data Exploration and Discovery

- We established a multidisciplinary collaboration between Geoscientists and Computer Scientists to develop new methods
- Our method takes advantage of the geoscientists' training in interpreting spatial data
- We adapted immersive, interactive visualization (virtual reality for science)
- The software is open source and runs on a number of platforms, including desktop, GeoWall, and full immersive environments.

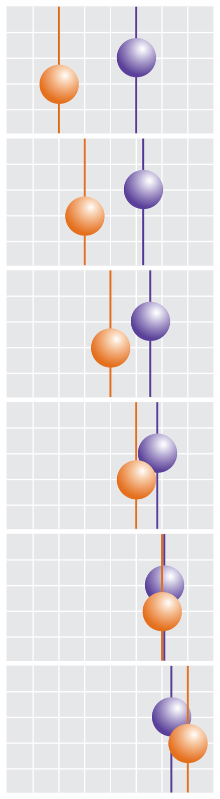


## Interactive Visualization

Tracking system enables interaction.




Stereo Vision



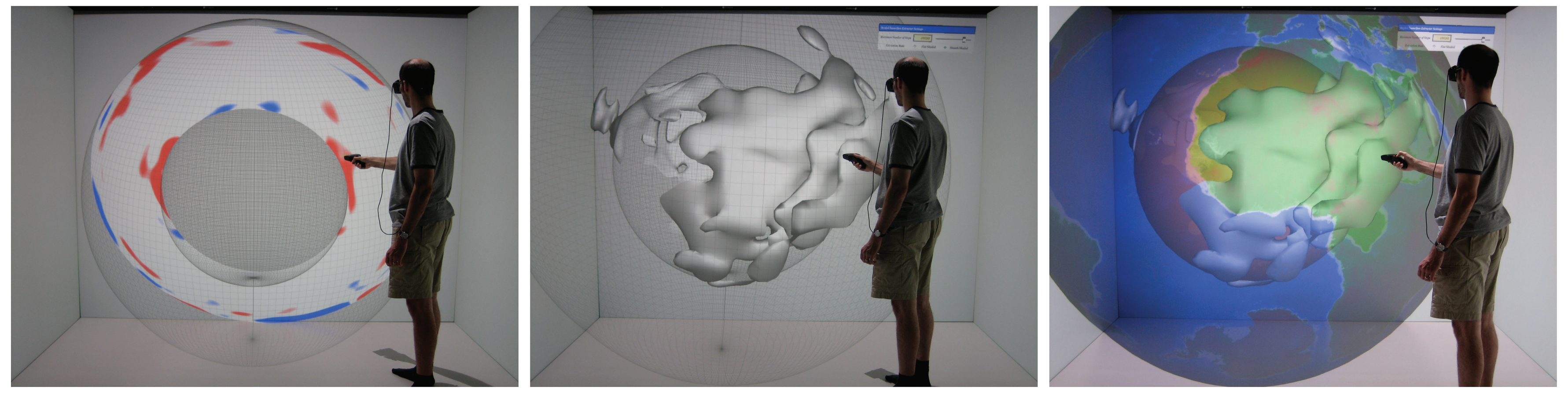
Motion parallax

We take advantage of the human capacity for depth perception. With stereo-enabled projection systems, we have a full 3-D view. On non-stereo platforms, motion parallax provides depth information.

## Volumetric Data

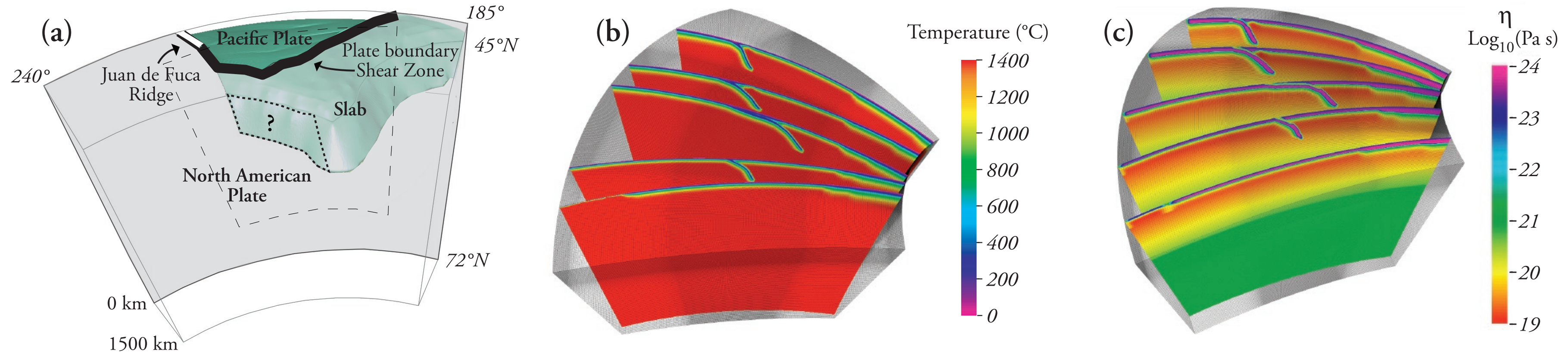
Using Visualizer to explore a whole mantle shear velocity model SAW24B16 *(C. Megnin and B. Romanowicz).*

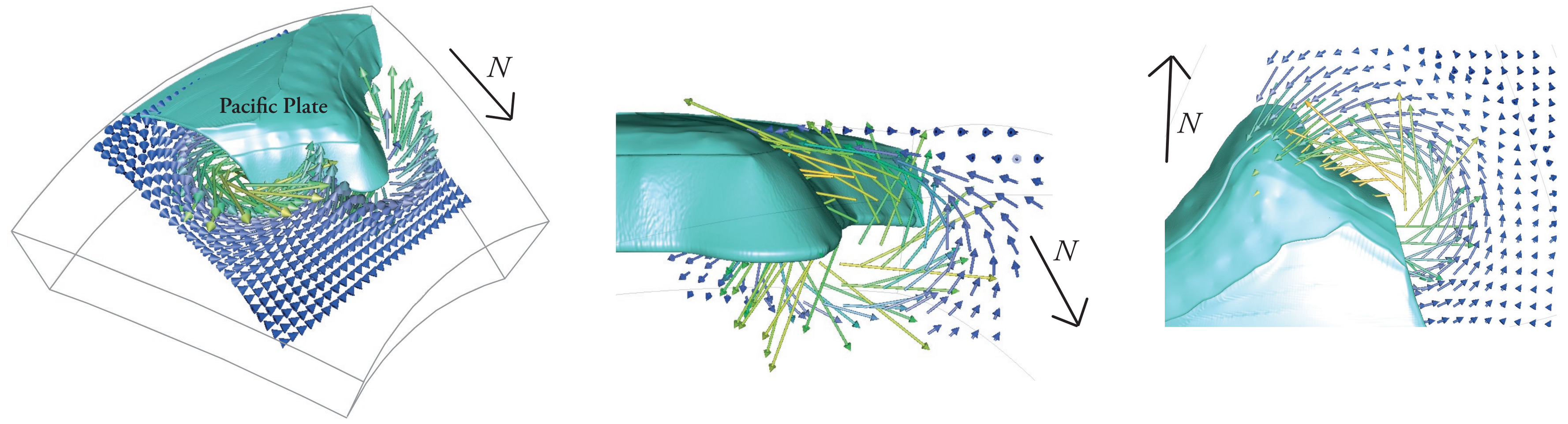
- **(left)** The slicer tool reveals the superplume at the base of the mantle under Africa (red region where the hand-held wand is located).
- **(middle)** The isosurface tool reveals the full, 3D structure of this feature.
- **(right)** A location map showing the feature.



Viewing Geodynamic Models with Visualizer. Aleutian subduction model. *Models by M. Jadamec and M. Billen.*

- (a) Schematic of the Aleutian subduction zone
- (b) Slices through the structure showing temperature.
- (c) Slices showing viscosity.




Isosurfaces and velocity arrows used to show flow around the Aleutian slab.

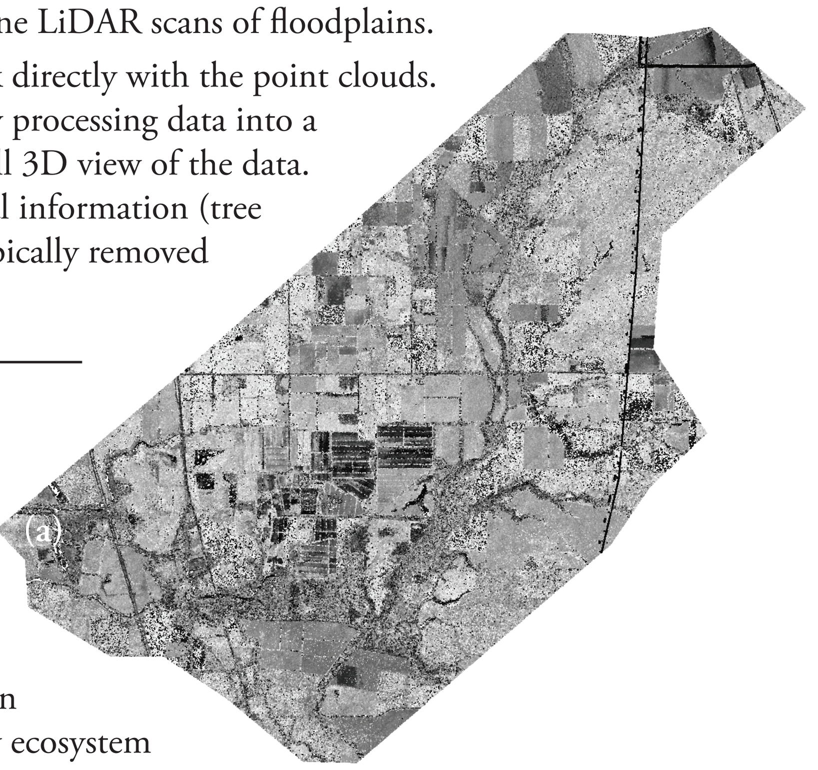
The isosurface shows the slab structure. The length of the arrows represents velocity magnitude. The model exhibits flow around the edge of the slab and complex flow near the slab. This model uses non-Newtonian viscosity.

## Point Cloud Visualization

A number of scanning methods (including LiDAR) generate a large number of individual points (returns from a laser scan). For airborne LiDAR these are typically used to derive a gridded digital elevation model (DEM).

Examples include GeoEarthScope scans of fault systems, terrestrial LiDAR scans of landslides, unstable slopes, and the like, and airborne LiDAR scans of floodplains.

We have developed several tools to work directly with the point clouds. This eliminates any errors introduced by processing data into a DEM, and enables us to work with a full 3D view of the data. In addition, we retain the environmental information (tree cover, engineered structures) that are typically removed when generating a bare-earth DEM.

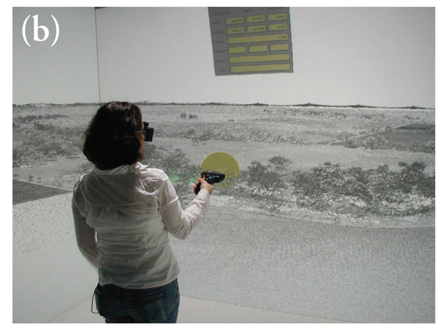



**(a) Point cloud visualization of Cosumnes River, California.**

This is an unregulated river - a natural lab for study of flooding. Levee stability in floods and earthquakes is a major concern. Environmental scientists are interested in extracting biomass information to study ecosystem recovery after floods.

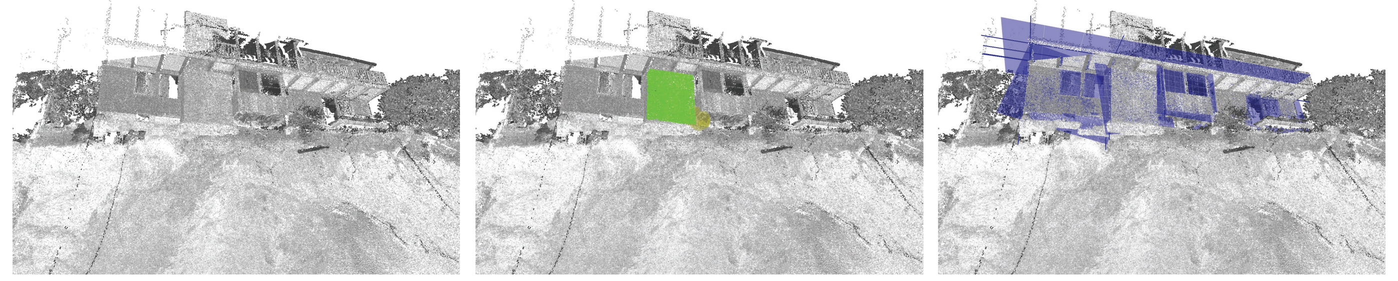
**(b) A user in an immersive CAVE selecting points**

**(c) An oblique view of the flood plane.** Shades are intensity of return.





**Feature extraction from point clouds. Left:** Part of a LiDAR scan showing a house undermined by a landslide. **Center:** the user isolated one wall of the house by selecting its defining points using a 3D selection brush (yellow sphere). **Right:** an architectural skeleton extracted from the plane equations describing several manually isolated walls. Accurately isolating the walls took only a few minutes in a CAVE environment.



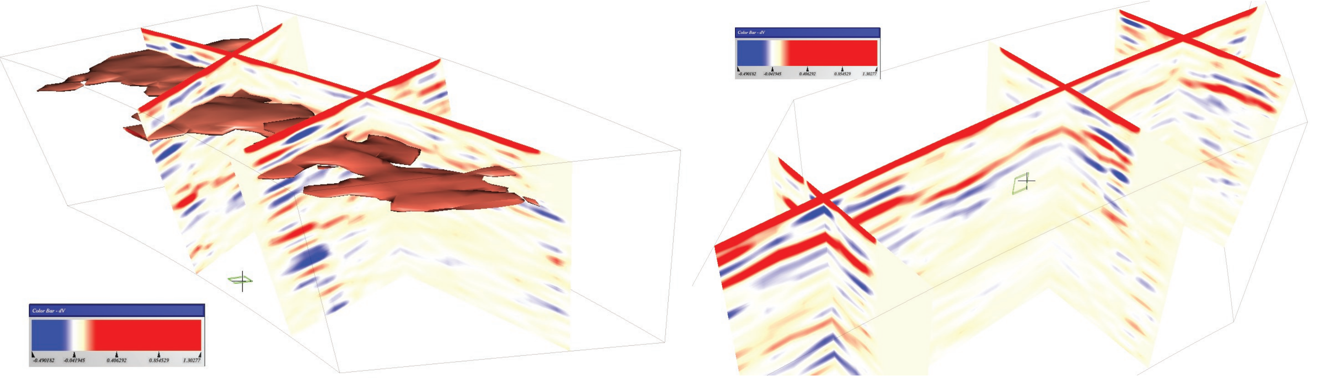
Closeup of a precarious house undermined by a landslide (Laguna Beach, CA).

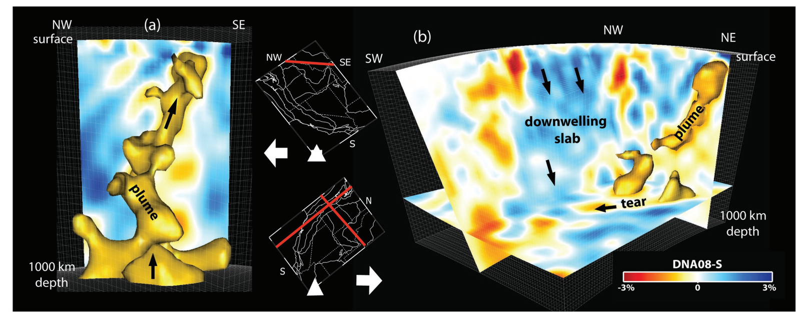
The terrestrial scan enables us to preserve a record of the landslide and to work on a hazardous landscape from the safety of the virtual reality environment (the house was demolished shortly after this scan was taken).

## Visualizing EarthScope-derived models

Visualizer can be used to explore and analyze seismic models obtained using EarthScope's US Array.

The example below shows Visualizer images of models under the Sierra Nevada derived using receiver functions. The data were presented earlier at this meeting: A. Frassetto, H. Gilbert, G. Zandt, T.J. Owens, and C. Jones, Seismic character of the crust and upper mantle beneath the Sierra Nevada, Eos Trans. AGU, 89(53), Fall Meet. Suppl. Abstract S23B-05. 11:20 am, Wed.






Using Visualizer to view mantle structure under the western US from US Array data showing possible downwelling slab and upwelling plume structures. The model is DNA08; data courtesy of Richard Allen, UC Berkeley.

## Software and Hardware Platforms

KeckCAVES' visualization applications, such as 3D Visualizer and LiDAR Viewer, are based on a common underlying virtual reality toolkit (aka "CAVE OS"). This toolkit, Vrui (Virtual Reality User Interface) was developed to support portable VR applications that can run on the widest range of visualization hardware platforms available. Vrui is layered between the base OS – most Unix variants including Linux and Mac OS X – and the applications on top of it. By providing powerful display and user interaction abstractions, Vrui allows applications to run unchanged on most visualization systems from simple laptop or desktop computers over stereoscopic screens such as GeoWalls or high-resolution powerwalls to fully-immersive virtual reality environments like head-mounted displays or CAVEs, or even low-cost immersive environments such as 3D televisions (**http://idav.ucdavis.edu/~okreylos/ResDev/LowCostVR**).

More information about KeckCAVES' applications and Vrui is available at **www.keckcaves.org** or **http://idav.ucdavis.edu/~okreylos/ResDev**, and some software packages are available for download at **www.keckcaves.org/software/VISUALIZERCG**.

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### Acknowledgements

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