A Custom Implementation for Visualizing Sub-surface 3D Scalar Fields in GPlates

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ABSTRACT

The ability to visualize sub-surface 3D scalar fields together with traditional geological surface data enables researchers to observe their relationship through geological time in a common plate tectonic reference frame. This is useful in a variety of geoscience scenarios including the visualization of geodynamic simulations in relation to their plate tectonic surface constraints and visualizing 2D cross-sections of sub-surface data along relevant reconstructed geological surface lines.

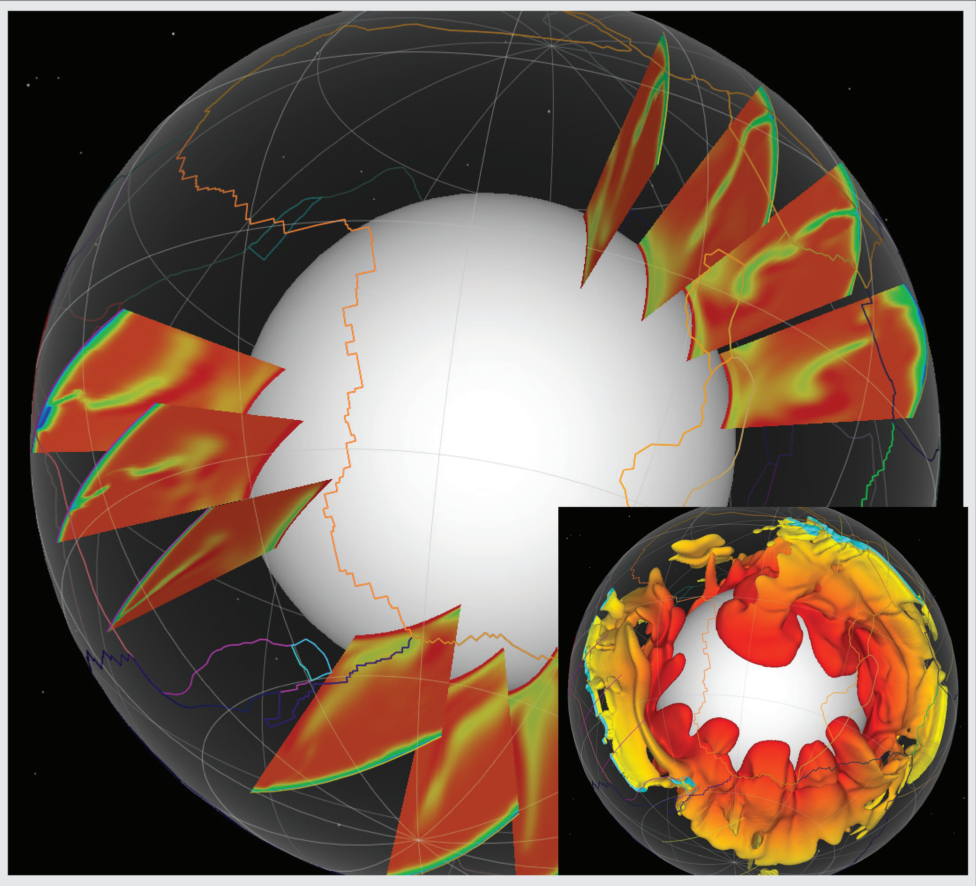
To achieve this, a custom volume rendering solution has been designed for the GPlates software application (http://www.gplates.org) and implemented using the platform-independent OpenGL Shading Language for desktop computing and High Performance Computing (HPC) visualization systems. The existing GPlates hierarchical cube map framework (for surface raster data) has been extended to support sub-surface 3D scalar fields. For the Earth's sub-surface, the cube map structure improves performance over tetrahedral-based structures due to a simpler, more efficient method of retrieving and interpolating 3D scalar data during ray-tracing traversal. This enables interactive visualization on modern desktop Graphics Processing Units (GPUs). In addition, the common cube map framework enables the linking of surface and sub-surface data via detailed surface fill regions (such as tectonic plates) to localize the visualization of the underlying sub-surface data.

Rendering of cross sections and isosurfaces of 3D scalar fields is currently supported. Also supported are time sequences of 3D scalar fields (to visualize sub-surface evolution). In the future we plan to support tectonic reconstruction of present day scalar fields to geological times (in a similar manner to reconstructed surface rasters).

References:
Li, C., van der Hilst, R. D., Engdahl, E. R., and Burdick, S.: A new global model for P wave speed variations in Earth's mantle, Geochem. Geophys. Geosys., 9, Q05018, doi:10.1029/2007GC001806, 2008.

Cross sections

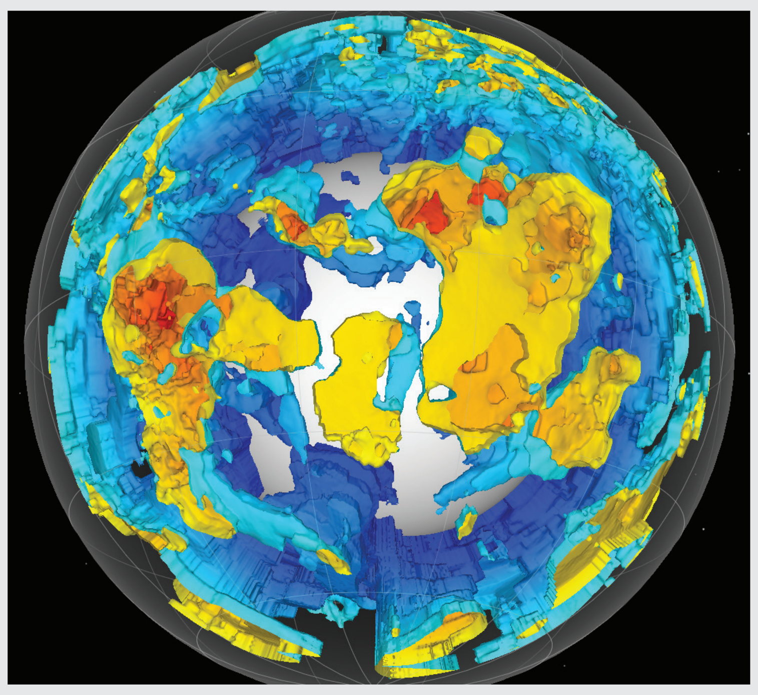
Isovalues can be visualised along depth extruded surface cross-sections that can be digitized directly in GPlates or loaded as point, polyline or polygon geometries.



Cross sections through the mantle temperature scalar field coloured by isovalue (temperature) with topological plate boundaries overlaid on top. Cooler sections show up as green/yellow and highlight subducting plates. Also shown in the inset image is the associated mantle temperature mean-value isosurface with depth mapped to colour.

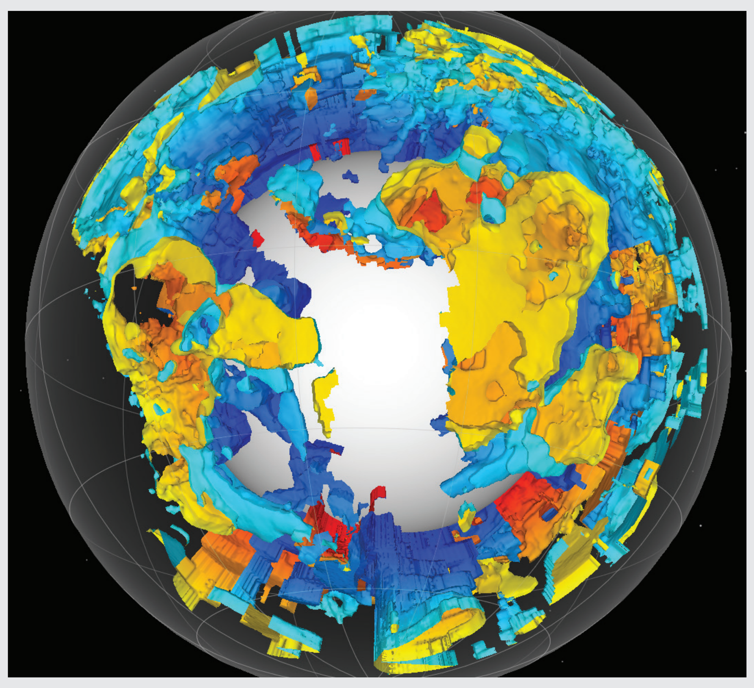
Surface and depth restriction

Isosurface visualization can be constrained to sub-surface regions using the two degrees of freedom on the spherical surface and the depth below the surface. Only isosurface regions directly beneath the surface mask and within the depth range are rendered. A surface mask is defined as the concave interior of one or more surface polygon geometries. And the depth range is defined by a minimum and maximum radius.

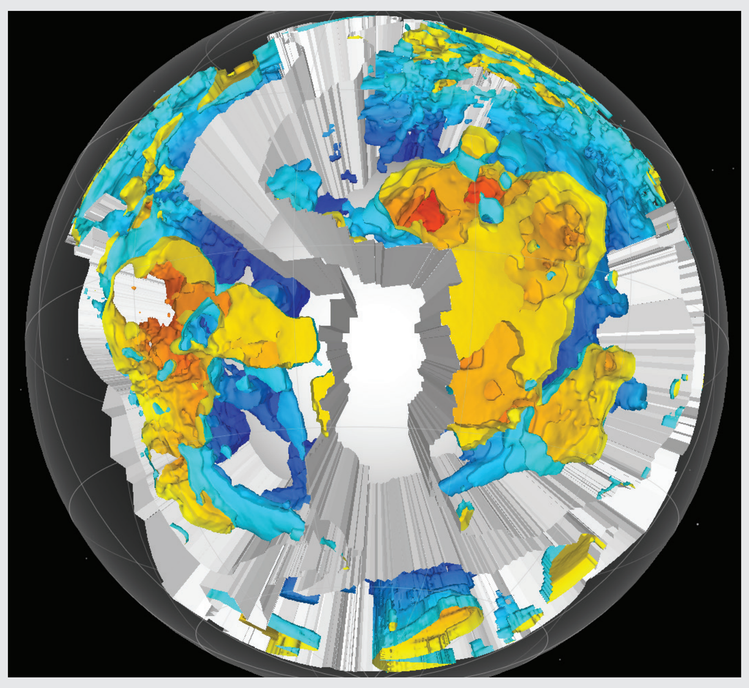


An isosurface of the MIT-P08 tomographic model rendered without surface restriction.

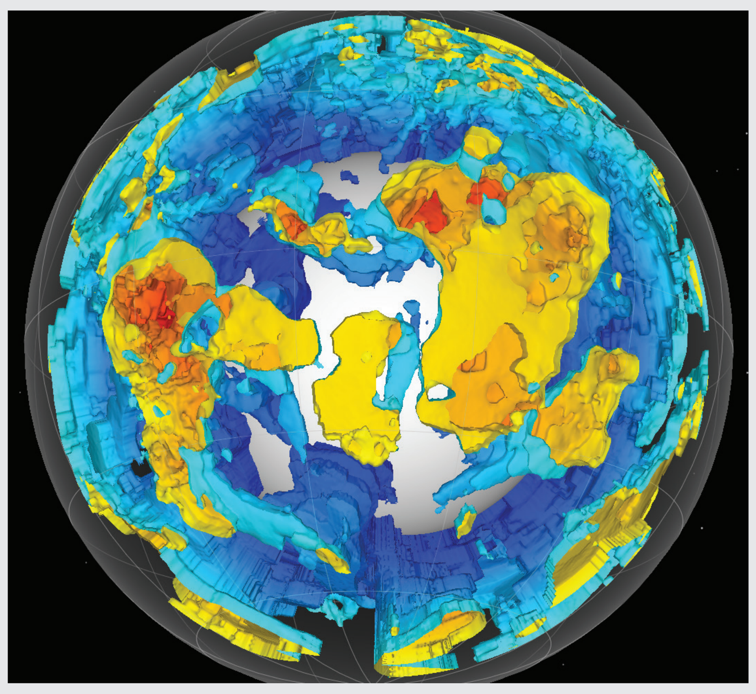
Filled surface polygons and vertically extruded boundary walls are shown to help illustrate how the surface mask works.



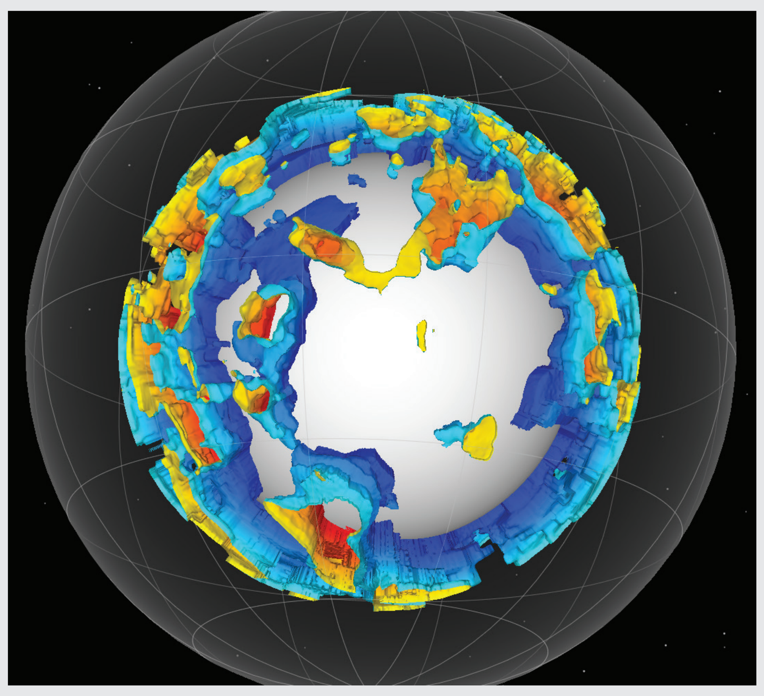
Present day isosurface rendered only below surface regions that existed prior to 50Ma.



Present day isosurface rendered only below surface regions that existed prior to 50Ma. Also rendered are the surface polygon walls.



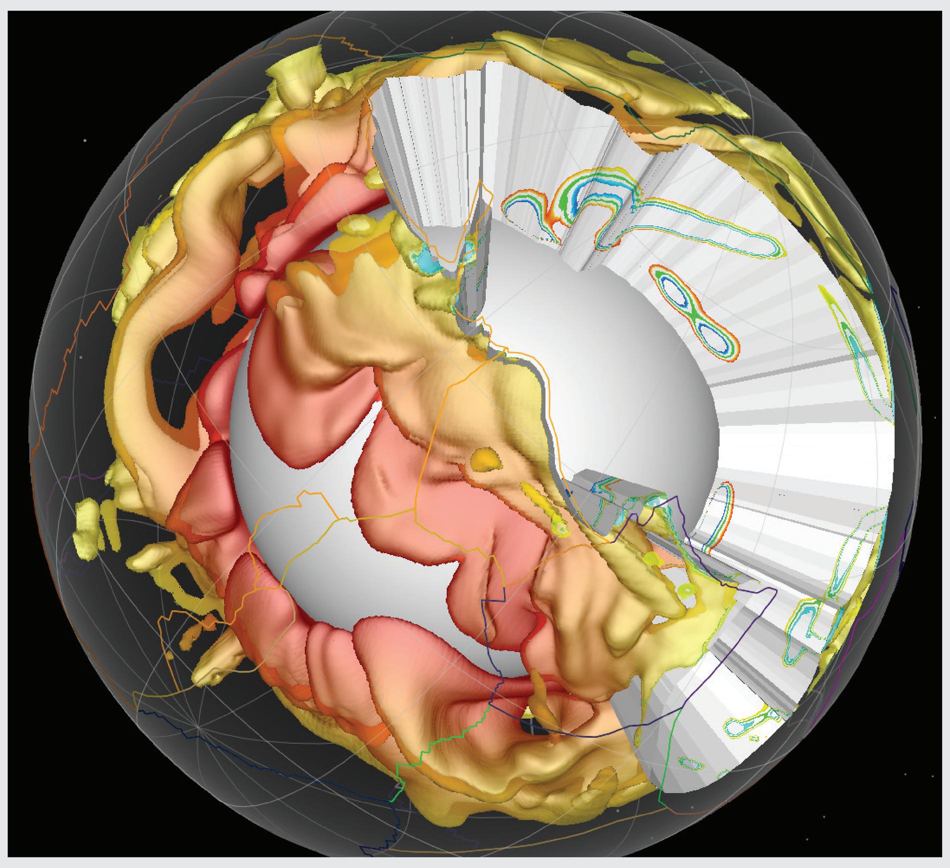
Isosurface rendered without depth restriction. A white sphere is rendered at the maximum depth of the scalar field dataset.



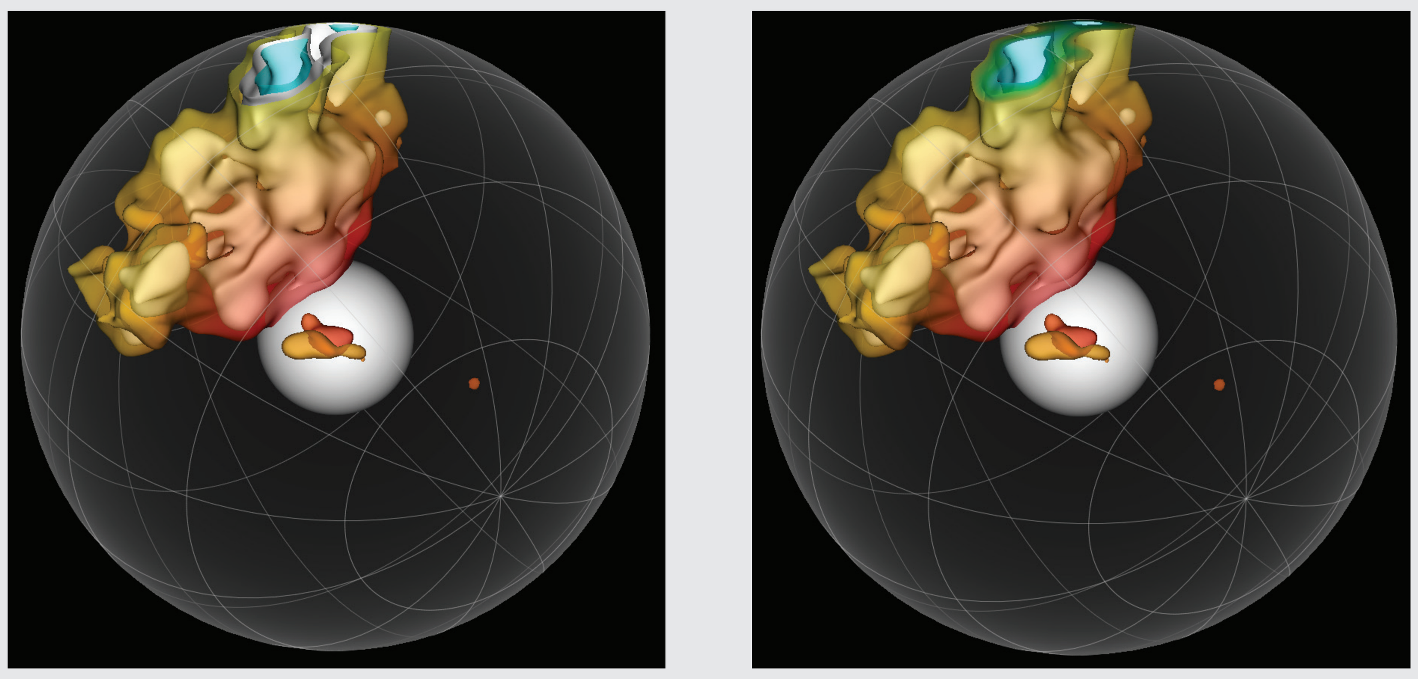
Isosurface rendered within a restricted depth range.

Isosurface deviation window

The deviation window consists of the main isosurface and two deviation isosurfaces with isovalues relative to the main isosurface (lower and higher). The main isosurface is opaque and white. The two deviation isosurfaces are coloured according to the colour mode and can be semi-transparent. For the depth colouring mode, as shown in these images, the colour varies with depth from red (at inner sphere) to yellow (at outer sphere) for the upper isosurface and from blue (inner sphere) to cyan (outer sphere) for the lower isosurface.

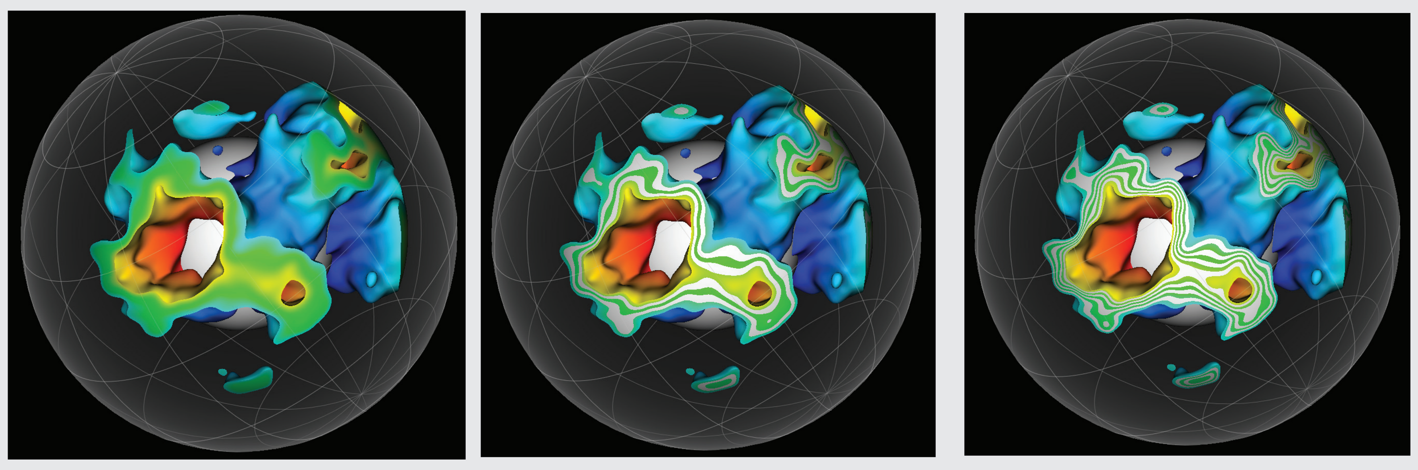


Mantle temperature isosurface with semi-transparent deviation window. The surface mask includes the entire surface of the globe except the Eurasian plate. The polygon walls show isolines where the isosurface and its two deviation isosurfaces intersect the wall.



A test fractal scalar field showing a white isosurface and two depth-coloured deviation isosurfaces that are semi-transparent in order to visualize the deviation from the main isosurface. The second image also renders the deviation window on the outer *surface* of the depth range (blending to green at the main isosurface).

The deviation window can be rendered at the outer spherical depth surface with isoline contours as shown in the three images below. The deviation window can also be rendered on the polygon walls (vertically-extruded boundary of the surface mask) as shown in the image to the left.



Opaque deviation window showing outer surface isoline frequencies 0, 1 and 2.

Double deviation window

Double deviation mode consists of two non-overlapping deviation windows. The animation shows the isovalue variation of one window towards the other window in the test fractal scalar field.