Interactive Multidimensional Visual Analytics for Earth's Mantle Convection

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Abstract

This project creates an interactive visualization of the Earth's mantle convection. We first process the data using Python; then, the processed data is visualized in the browser using JavaScript. The application uses parallel coordinates, a correlogram, a line graph, cross-sections and volume renderers for visual comparison and qualitative analysis of the Earth's mantle convection.

Data Processing

Data converted into a 50x50x50 grid to make file sizes smaller for interaction.

Parallel Coordinates

- Data was visualized using parallel coordinates in D3 [1, 3] for variable manipulation.
- Color map: ParaView's Rainbow Desaturated
- Parallel coordinates can be brushed to filter and recolored by variables.

Volume Rendering

- Visualization of spherical model of the Earth using the Three.js library [2].
- Rendered using data texture
- Responds to selections on parallel coordinates.
- A depth slider at the bottom acts as a guide for different depths.

Cross Sections

- Cross sections to analyze the correlation between variables.
- Variables binned into 10 bins to make the time animation faster.
- Differences between timesteps, 3D velocity field, and high-quality options available on cross sections

Correlations

- Pearson correlation coefficient calculated between variables for every time step, plotted on line graph.
- Line of correlation between two variables selected is emphasized
- Correlation matrix created in D3 to visualize the correlations at a single time. Represents correlation coefficients with numbers and circles for quick comparison.

Limitations

- Compressed data made visualizations more blocky and less precise
- Were not able to synchronize the arrows, cross-sections, and volume renderer, limiting analytics.
- Were not able to highlight the hot plumes and cold slabs intelligently to allow user to locate these quickly.

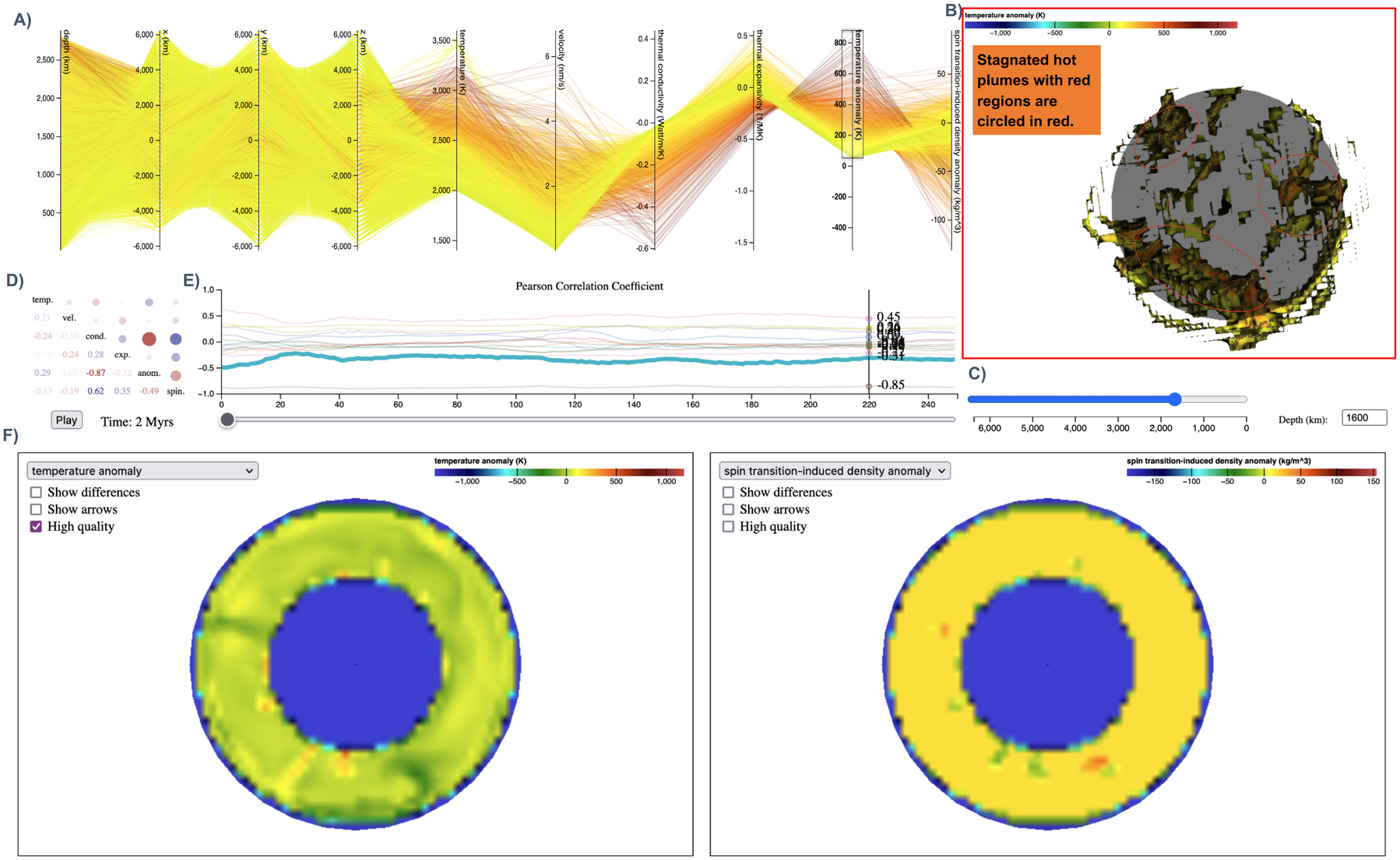

Figure 1. Screen capture of full application with parallel coordinates, volume renderer, correlogram, line graph, and two cross sections.
A) Parallel coordinates colored by temperature anomaly, with positive values brushed and filtered.
B) Volume renderer display of filtered temperature anomaly data from Figure 1A. Stagnated hot plumes with red regions are circled in red.
C) Depth guide slider controlling the dark gray circle that shows where 1600 km depth is.
D) Correlogram of the correlations between variables in current time step.
E) Interactive line graph of Pearson correlation coefficients over time with a time slider on the bottom for animation. On hover, the values of each of the lines are displayed.
F) Display of two cross sections showing temperature anomaly data on the left and spin transition-induced density anomaly on the right, allowing for visual comparison of the data.

References

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[3] M. Bostock, V. Ogievetsky, and J. Heer, "D3 Data-Driven Documents," IEEE Trans. Visual. Comput. Graphics, vol. 17, no. 12, pp. 2301–2309, 2011, doi: 10.1109/TVCG.2011.185.
[4] M. H. Shahnas, W. R. Peltier, Z. Wu, and R. Wentzcovitch, "The high-pressure electronic spin transition in iron: Potential impacts upon mantle mixing," J. Geophys. Res., vol. 116, no. B8, p. B08205, Aug. 2011, doi: 10.1029/2010JB007965.