Visualization of simulated convection dynamics in Earth's mantle

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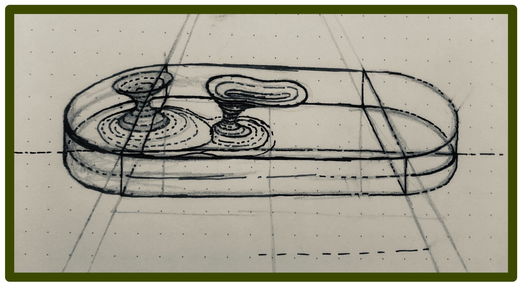
① Intro.

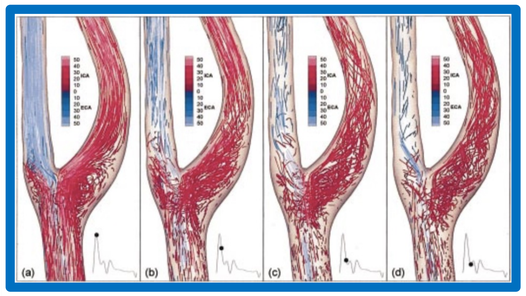
- Inspired by representational techniques developed during our longstanding art-science collaboration for representing blood flow dynamics [1], we created four different visualization approaches.
- Each representation is designed to fulfill a specific task by manipulating **space** and/or **time.**

1. **3D cartographic projection** for showing **transverse stagnation** patterns
2. **Particle pathlines** for showing **radial movement** and **3D convection cells**
3. **Multivariate glyphs** for showing **correlations** in the **radial direction**
4. **4D extrusion** for showing for **temporal change** and **correlation**

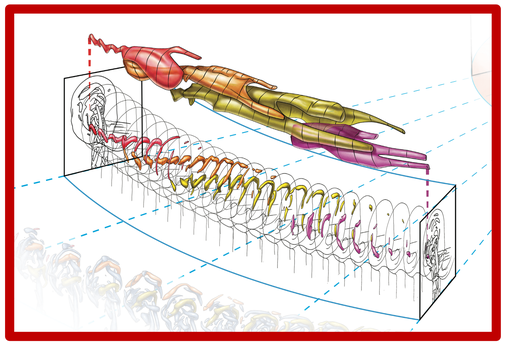
② Selected Inspirations



Artist sketches used to prototype 3D cartographic projection visualizations



Pathlines of massless particles seeded into CFD data, animated to visualize complex, time-varying blood flows [2]

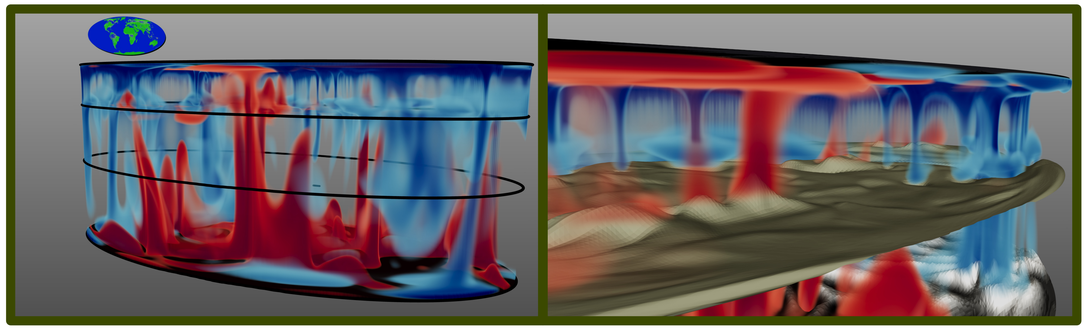


'Freezing time', to highlight repeating vortical structures in 'turbulent-like' aneurysm blood flows [3]

③ Resulting Visualizations

Spatial ← CORRELATION → Temporal

Transverse ↑ DIRECTION ↓ Radial

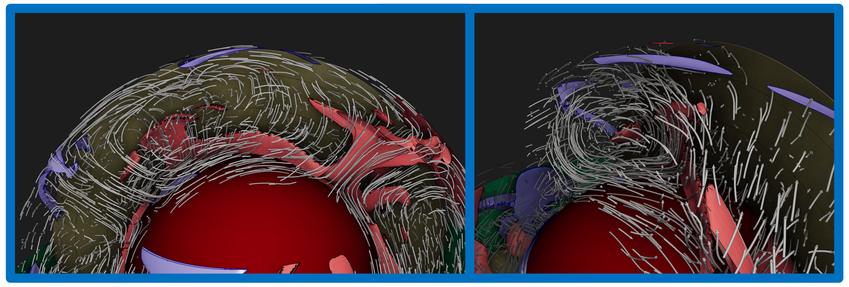


3D cartographic projection eliminates spherical occlusion, allowing for tracking of temperature anomalies over large areas.

Volume rendered temperature anomalies are combined with **warped planar surfaces** of thermodynamic variables to visualize correlations. In the image to the left, the plane has been warped proportional to anomalies in thermal conductivity.

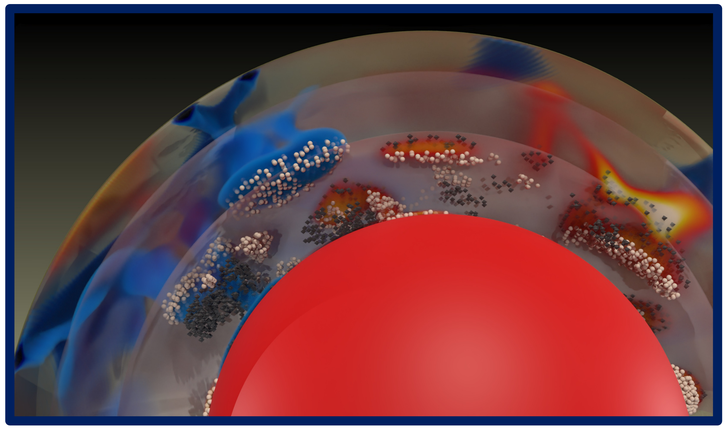
Particle pathlines set against a 2.5D relief of temp. anomaly show the directionality of convection cells.

In the two images to the right, we can see convection cells that rotate **orthogonally** along both the radial and transverse directions.



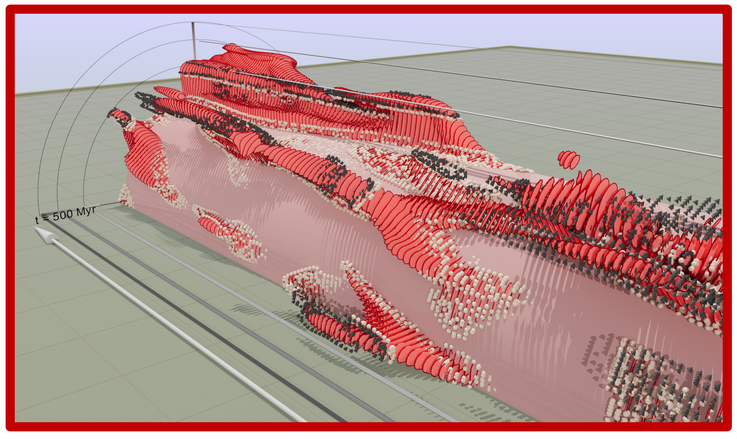
Spatial data are "compressed" to a 2D structure and **extruded over time** into the 3rd spatial dimension, visualizing temporal change.

By adding **glyphs**, below we can see how hot plumes can converge and accelerate upwards in regions of low density anomaly and decelerate and stagnate in regions of high density anomaly.



"Heavy" (dark) and "light" **glyphs** visualize distinct regions of density anomaly along with volume-rendered temperature anomaly.

To the left we see, for example, how a sinking cold slab has stagnated in a pocket of low density anomaly.



[1] Steinman DA, et al. "Narcissus and Echo: Reflections on an art-science collaboration", Leonardo 2021, In Press.
[2] Steinman DA. "Simulated pathline visualization of computed periodic blood flow patterns" J Biomech 2000; 33(5): 623-628.
[3] Coppin PW, et al. "'Freezing time' to show 4D evolution of vortex cores in an aneurysm that is undergoing highly unstable flow" Entry to 2013 NSF Vizzies Challenge.

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