Highlights from the 2021 SciVis Contest

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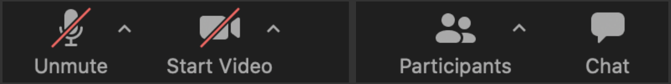
Zoom controls

- Please mute your microphone and camera unless you have a question
- To ask questions at any time, type in Chat, or Unmute to ask via audio
  - please address chat questions to "Everyone" (not direct chat!)
- Raise your hand in Participants



- Email training@westgrid.ca
- Link to these slides below

2021 SciVis Contest

https://scivis2021.netlify.app

Partnership between IEEE, Compute Canada and WestGrid

IEEE SciVis Contests

- 2020 Transport mechanisms of eddies in the Red Sea
- 2019 Cosmological simulation
- 2018 Deep water asteroid impacts
- 2017 Clouds and atmospheric processes
- 2016 Particular ensembles
- 2015 Visualize the Universe
- 2014 Volcanic eruptions and their atmospheric aftermath
- 2013 Allen Developing Mouse Brain Atlas
- 2012 Computational material science
- 2011 Stability visualization in fluid dynamics
- 2010 Advanced visualization for neurosurgical planning
- 2008 3D astrophysical turbulence
- 2006 Earthquake simulation
- 2005 Deep turbine installation and wind data
- 2004 Atmospheric data

Compute Canada's *Visualize This!* competition

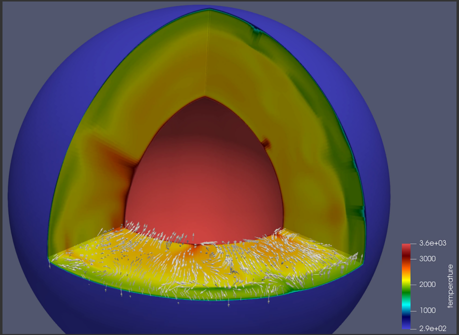
- 2019 Incompressible transitional air flow over a wind turbine section *or* bring your own data
- 2018 Interaction of a large protein structure with a cell's membrane *and* Linked humanities data
- 2017 Airflow around counter-rotating wind turbines
- 2016 Visualizing multiple variables in a global ocean model

Why SciVis contest?

1. Advertise and teach sci-vis tools and techniques to Canadian researchers
2. Help make research and scientific visualization accessible to a wider audience
3. Crowdsource innovative visualization ideas
   - with existing tools, participants come up with very original workflows that we have never thought of
   - particularly notable years: 2017 and 2021
4. Provide data for future sci-vis training and experimentation

2021 dataset: Earth's mantle convection dataset

- Dataset kindly provided by Hosein Shahnas and Russell Pysklywec (Pysklywec Lab, University of Toronto), download link `https://scivis2021.netlify.app/data`
- Numerical simulation performed on Compute Canada's Niagara cluster
  - 500 Myrs of geological evolution in 251 timesteps
  - $180 \times 201 \times 360$ spherical grid (intentionally small)
  - $3485\text{ km} \leq r \leq 6371\text{ km}$
- Included 3D fields:
  1. temperature [degrees K]
  2. three Cartesian velocity components [m/s]
  3. thermal conductivity anomaly [Watt/m/K]
  4. thermal expansivity anomaly [1/K]
  5. temperature anomaly [degrees K]
  6. spin transition-induced density anomaly [kg/m^3]
- NetCDF, Climate and Forecast (CF) convention, single precision $\Rightarrow$ 80.3GB compressed
- Recipes to read in ParaView, in Python with `xarray` or classic `netCDF4`

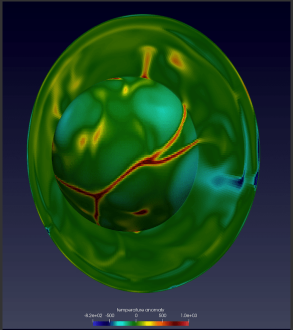


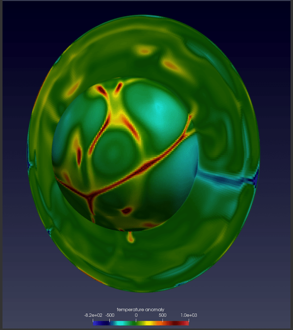
Complex dynamics of Earth’s mantle convection

`https://scivis2021.netlify.app`

1. Known for the past few decades: endothermic phase transition at 660 km
2. Suggested to play a major role in the mantle dynamics: iron spin transition (theoretically predicted in 1960) in two lower-mantle (depth > 1600 km) minerals, together accounting for $\sim 95\%$ volumetric contribution
   - $\Rightarrow$ change in density, thermal conductivity, thermal expansivity and resistance to compression

- At first, a descending cold slab approaching the mid-mantle (1600 km depth) can gain positive buoyancy (decrease in density relative to its surroundings) that can slow its descent rate or cause its stagnation
- A stagnated slab could turn into a sudden spin-transition induced mid-mantle avalanche and eventually penetrate into the lower mantle
- Similar spin-transition effects in hot plumes rising from the core-mantle boundary, leading to their acceleration or stagnation





Tasks

Participants were asked to visualize:

1. stagnated or diverted cold slabs (descending mantle material) at ∼660 km (upper and lower mantle boundary) depth
2. stagnated or diverted cold slabs at ∼1600 km (mid-mantle) depth
3. stagnated or diverted hot plumes (rising hot mantle material) at ∼1600 km depth and their rise to the upper regions of the lower mantle
4. stagnated or diverted hot plumes at ∼660 km depth
5. correlations between the state variables and the flow patterns

We asked participants to use only open-source tools so that the visualizations are (at least in theory) reproducible

Timeline

October 28, 2020	2021 SciVis Contest announced at IEEE Vis 2020
July 31, 2021	Deadline for Contest entry submissions
August 12, 2021	Accepted entries invited to participate in the Contest session
August 31, 2021	Winning team notification, following the review by 7 judges
October 28, 2021	Results announced at IEEE Vis 2021 conference

Results

We received 7 very interesting and very different submissions:

- 2 from Canada
- 2 from Germany
- 3 from the US

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- The Innovation Award went to Tim von Hahn and Chris K. Mechefske (Queen's University)

Tools

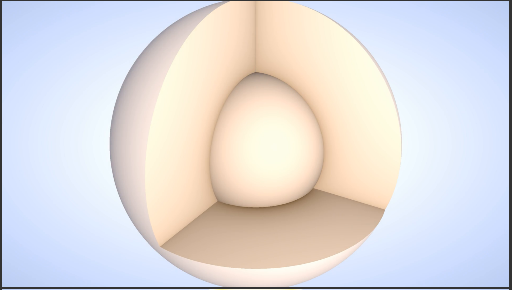
- C++ code with OpenGL
- ParaView
- CosmoScout VR (virtual Solar System in VR application written in C++ with OpenGL) + custom volume-rendering plugin (using Intel's OSPRay library)
- Generator adversarial network (GAN) to approximate results
- VisIt
- VTK-m – implementation of VTK for new processor architectures: multi-core CPUs and GPUs
- TTK to find critical points
- Voreen (`https://www.uni-muenster.de/Voreen`) – interactive (Qt-based) volume rendering and data analysis of volumetric datasets on GPUs
- JavaScript with D3.js (parallel coordinates) and Three.js (volume rendering)

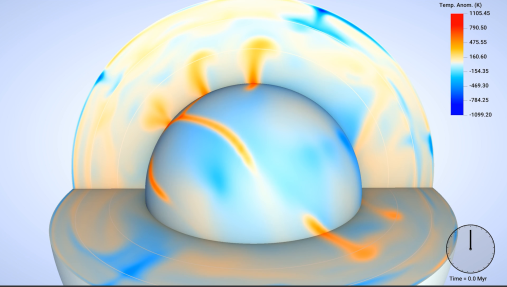
First Place Award: Tim McGraw and Michael Eddy

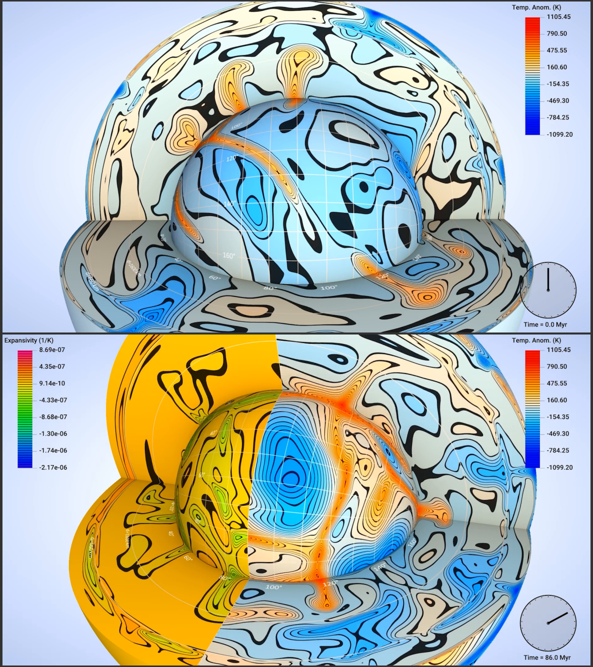
For best identification of the flow features, excellent comprehensive visualization and genuinely new ways to study the convective flow.

- "Best *traditional 3D view* visualization."
- "Using surface line integral convolution produces stunning results."

- Written in C++ and OpenGL
- Mixture of real-time ray tracing and conventional rasterization
- Everything is built on top of the ray-traced proxy geometry with ambient occlusion on the surfaces, can be modified by the user

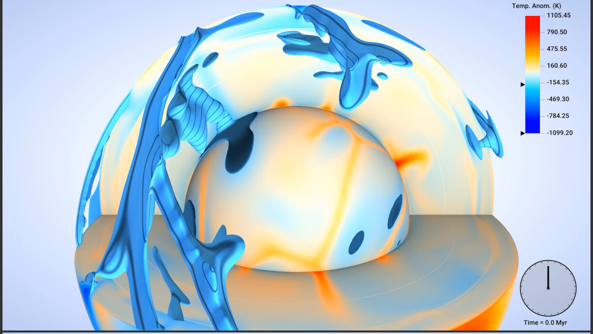


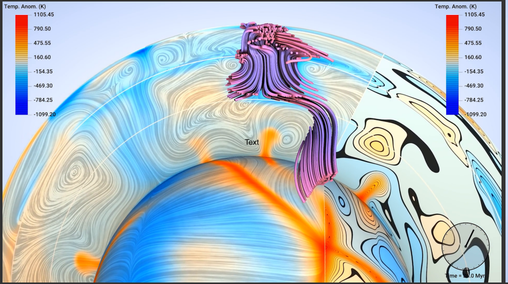


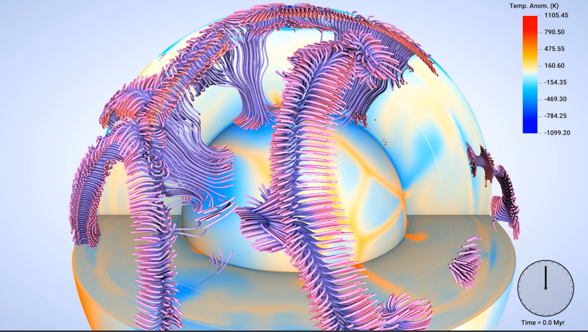


- Cubic texture interpolation for smoother contours on this low-res data
- Colourmap / contour design was inspired by Aldo Giorgini and the op-art movement of the 1960s
- Two variables can be displayed simultaneously on either side of a split line (drag with a mouse)

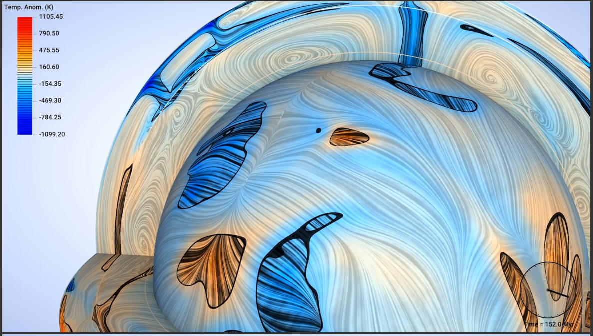
- Ray-cast isosurfaces or rasterized streamtubes can be displayed between the clip planes of the proxy geometry
- Heavy use of surface LIC coloured by different variables $\Rightarrow$ convection patterns
- Fixed-time rotation of the quarter-volume to explore 3D structure (short clip link)

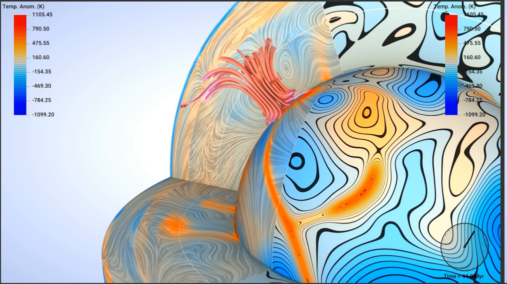


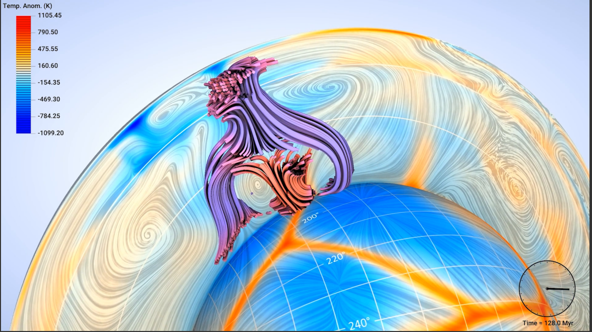




- Downward flow of cold slabs followed by stagnation or diversion at ∼660 km, other slabs are stagnated or diverted at ∼1600 km
- Same for hot rising plumes
- Plumes can be wrapped between deep convection cells, and some can rise close to the surface







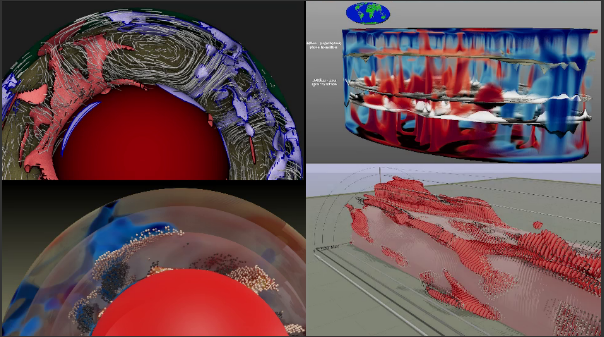
Best Cover Visualization: Lucas Temor, Peter Coppin, David Steinman

For using the 3D cartographic projection to provide a full and immersive view of the mantle processes that is not possible in the 3D spherical geometry, and for using warped planes in the same projection to show several variables side-by-side.

- "This submission presented the most complete approach, with very compelling visualizations and a very nice story."
- "The cartographic projection, 4D extruded view and textual glyphs all make this work stand out in the competition."

Four different visualization approaches:

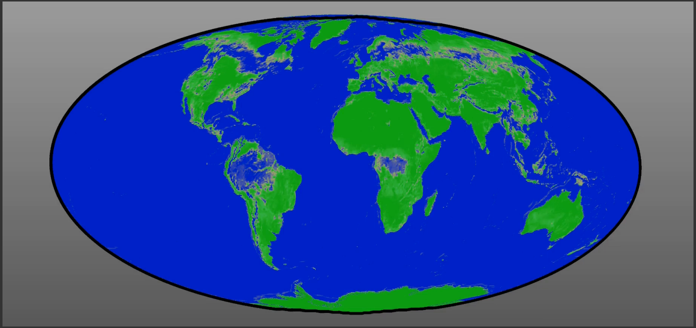
1. 2.5D view to reduce occlusion
2. Multi-variate glyphs to show correlations
3. Cartographic projection
4. Extruded 4D view to show time evolution



- 3D spherical view: lot of occlusion (multiple features blocking each other), especially when stagnated regions move out of sight

⇒ Idea 1: unwrap the spherical geometry using the 3D Mollweide projection - with `https://scitools.org.uk/cartopy/docs/latest` Python library

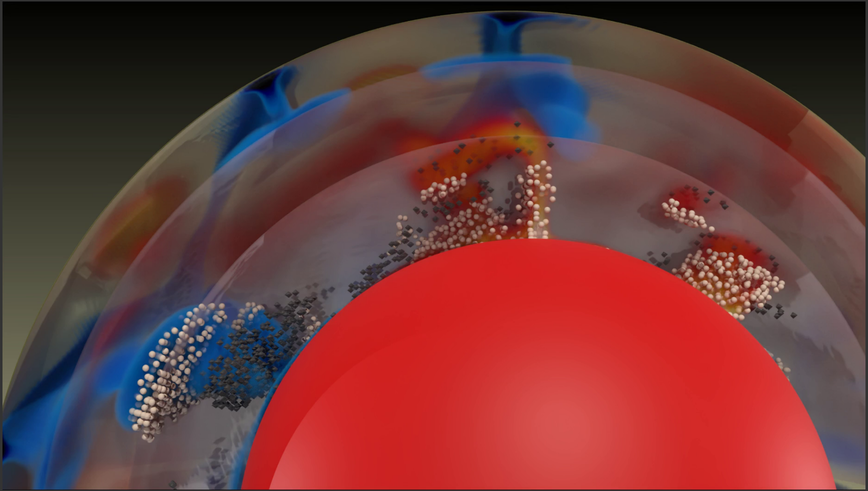
⇒ Idea 2: add cross-planes and warp them proportional to relevant thermodynamic variables



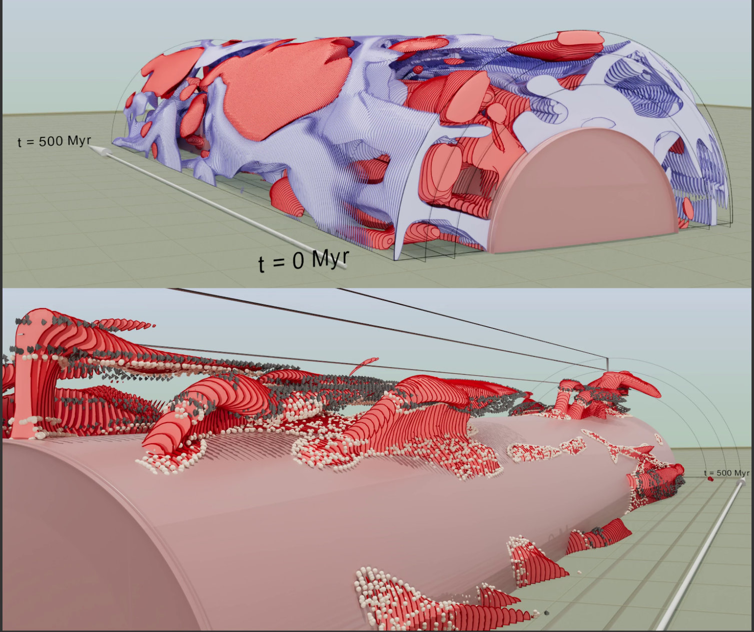
Click on the image to view the clip

Randomly sample the density field with glyphs:

- heavier / dark glyphs represent regions of low buoyancy (positive density anomaly)
- lighter glyphs represent regions of high buoyancy (negative density anomaly)



1. Project 3D isosurfaces on to a 2D plane
2. Stack a time sequence of these 2D planes in the 3rd dimension



Best Interactive Visualization System: Jonathan Fritsch and collaborators

For the ray tracer that emphasizes interactivity, with progressive volume rendering and image warping.

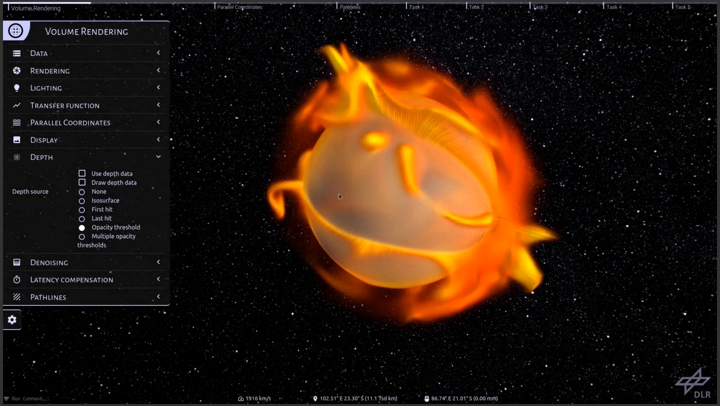
- RayPC: Interactive Ray Tracing Meets Parallel Coordinates
- Submission authors: Jonathan Fritsch, Simon Schneegans, Markus Flatken, Andreas Gerndt, Ana-Catalina Plesa, Christian Hüttig (German Aerospace Center)
- “Well-designed and developed virtual reality system”
- “How can we try this in person?”

- Based on CosmoScout VR `https://github.com/cosmoscout/cosmoscout-vr` – virtual reality system to explore planetary surfaces and identify landing sites for future missions
- Written for VR in C++ with OpenGL
- Custom volume-rendering plugin based on Intel’s OSPRay library, with quite a few tricks to achieve interactive volume visualization

Interactive volume rendering with ray tracing

https://github.com/cosmoscout/csp-volume-rendering

- You can switch between variables
- You can edit the volumetric transfer function with live updates
- Asynchronous rendering approach
  - renders at the interactive frame rate of the application
  - progressive rendering (multiple passes) refines the image once the camera is stationary
  - with fast interaction, uses image-based warping until the next frame is rendered



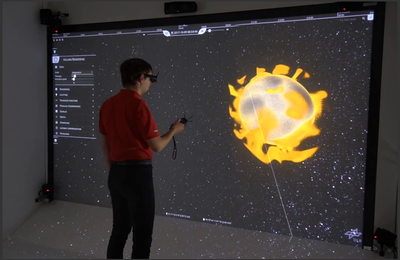
Click on the image to view the clip

Parallel coordinates

Cold sinking slabs:

non-positive radial velocity + negative temperature anomaly

- red shows positive density anomaly ⇒ sinking slabs
- blue shows negative density anomaly ⇒ stagnating slabs

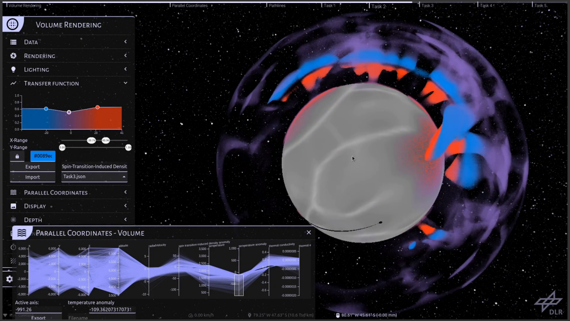


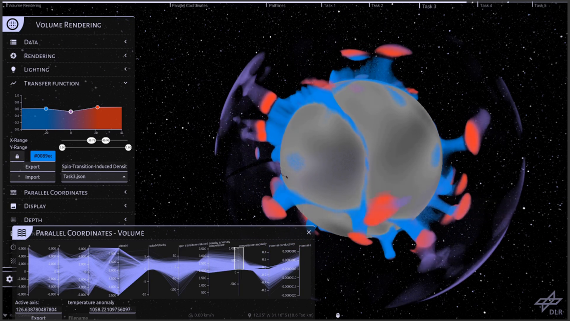
Click on the centre image to view the demo using parallel coordinates to identify flow features in VR

Hot rising plumes:

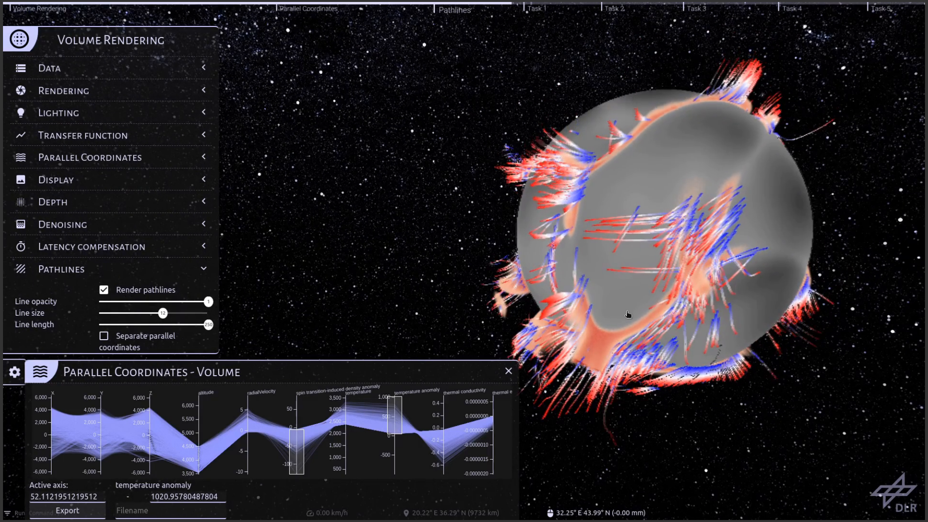
non-negative radial velocity + positive temperature anomaly

- blue shows negative density anomaly ⇒ rising plumes
- red shows positive density anomaly ⇒ stagnating plumes

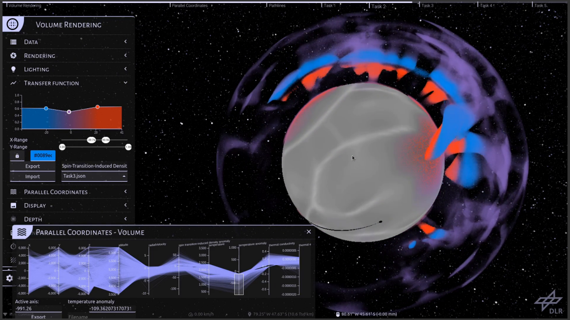




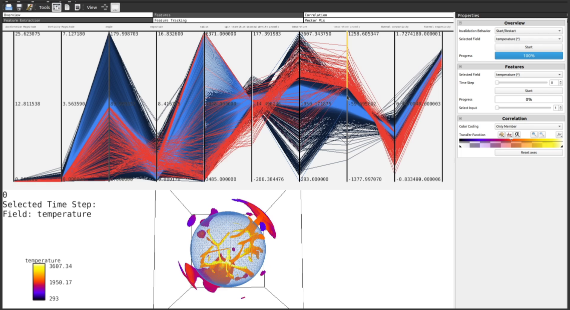
Pathlines spawned at (topologically) critical points of the temperature anomaly field, propagated 20 Myrs into the future, and colour-coded by time from blue to red $\Rightarrow$ temporal evolution in a single image



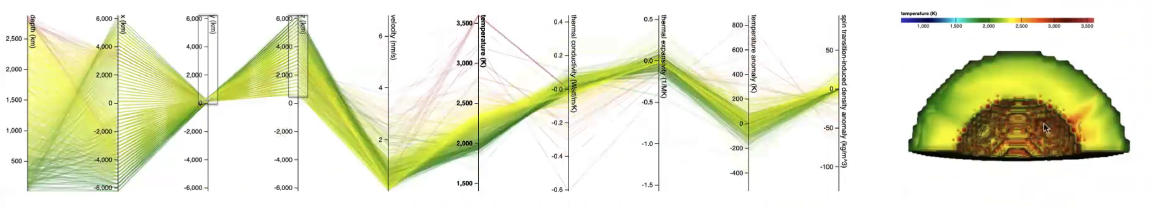
Speaking of parallel coordinates ...



Jonathan Fritsch et al.



Marina Evers et al.



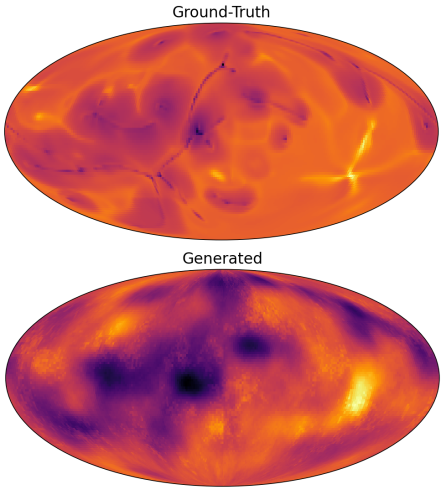
Jansen Wong et al.

The Innovation Award: Tim von Hahn and Chris Mechefske

For a novel approach that does not compete directly in regular visualization categories.

- EarthGAN: Can we visualize the Earth's mantle convection using a surrogate (approximate) model?
- "Innovative concept for future directions in sci-vis"
- "The goal is to provide an easier way to explore the data"
- "In the surrogate models, can you identify various flow features that you see in the original 3D model, e.g. tell that a certain feature comes from rising or descending material?"
- "Any comment on self-organization outcomes of the applied ML technique, and how does it help identify 3D flow features?"

- Self-described "free-style category"; work in progress
- Idea: use a generator adversarial network (GAN) to emulate simulation results, source code at `http://earthgan.com`
- On one hand, not really geared at the Contest dataset (it is small ⇒ easy to visualize directly on a low-end PC)
- On the other hand, quite expensive to train the model, even after significant downsampling

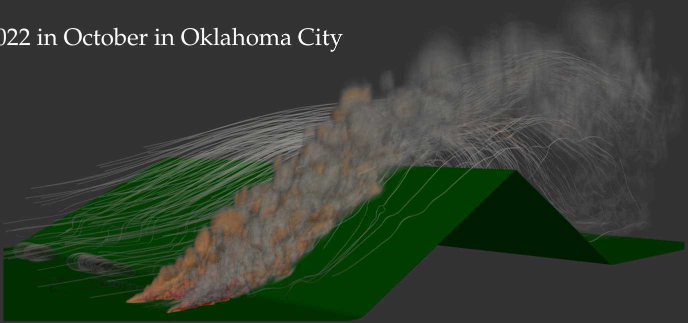


Preview of 2022 SciVis Contest

https://www.lanl.gov/projects/sciviscontest2022

Vorticity-driven Lateral Spread Ensemble Data Set

- Contest co-hosted by LLNL; focuses on wind-terrain-fire interaction in forest fires, esp. fire propagation behind ridge lines and in steep canyons
- The dataset comes from a simulation of a fire vortex on the leeward slope of an idealized ridge
  - includes a variety of physical processes and chemical reactions
  - data available for downloading now
  - join the Google Group to see all discussions
- Will be co-located with IEEE Vis 2022 in October in Oklahoma City



- Big thanks to Hosein Shahnas and Russell Pysklywec for providing the dataset and explaining the science behind it, all participants in the Contest, and the judges for taking time to review all submissions!
- You can find the Contest results at `https://scivis2021.netlify.app/results`
- 2021 SciVis Contest website `https://scivis2021.netlify.app` and dataset will be available for a long time $\Rightarrow$ dataset can be used for training and practice

Questions?