

Visual Analysis of Spatio-temporal Features in Multi-field Earth's Mantle Convection Simulations

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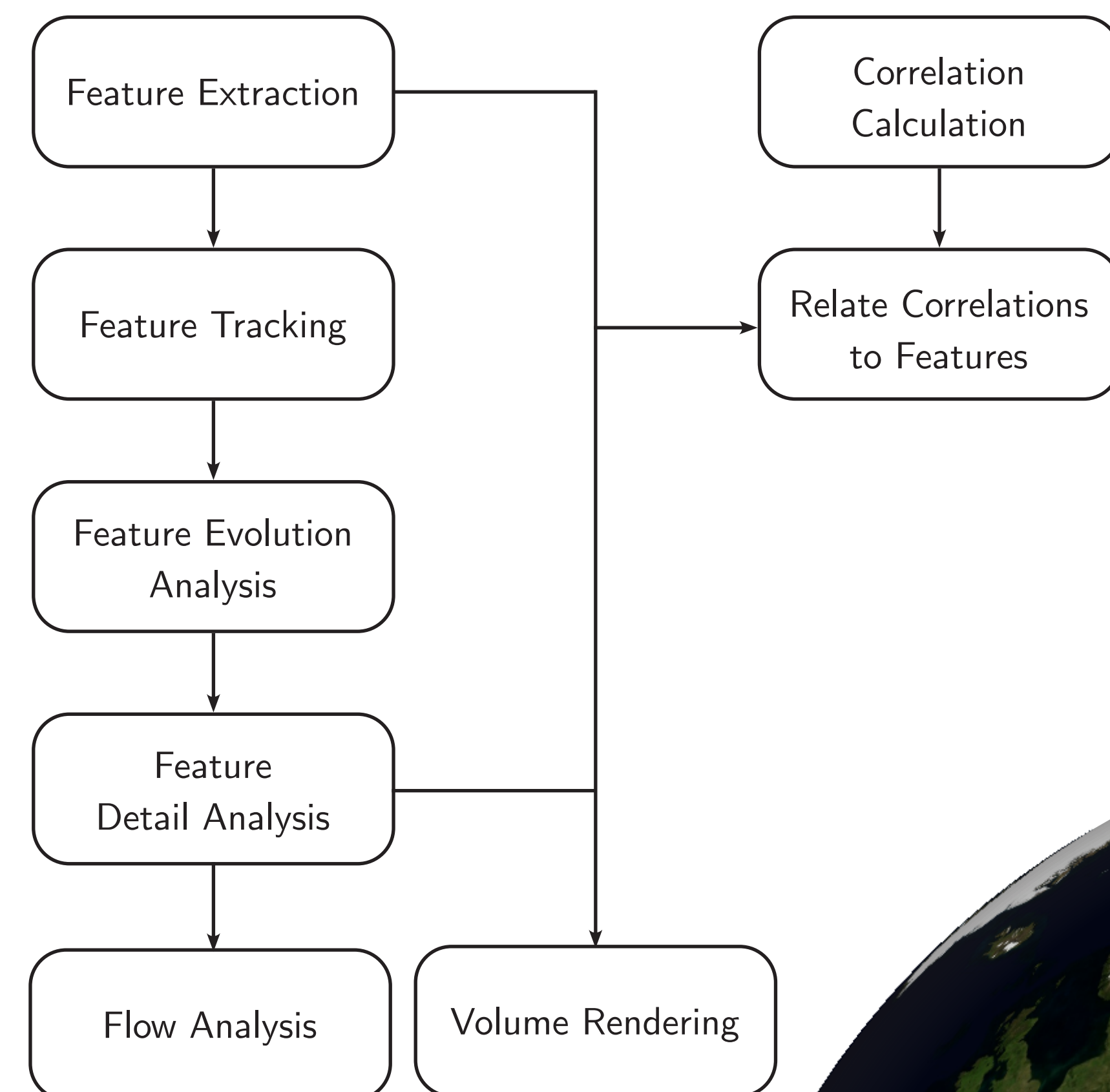
Abstract

To build an understanding of the formation and constant change of the Earth, it is crucial to gain an understanding of the convection processes in the Earth's mantle describing the distributions and paths of hot and cold material. We present an interactive visual analysis tool for the extraction and analysis of spatio-temporal features in multi-field Earth's mantle convection simulations.

Data

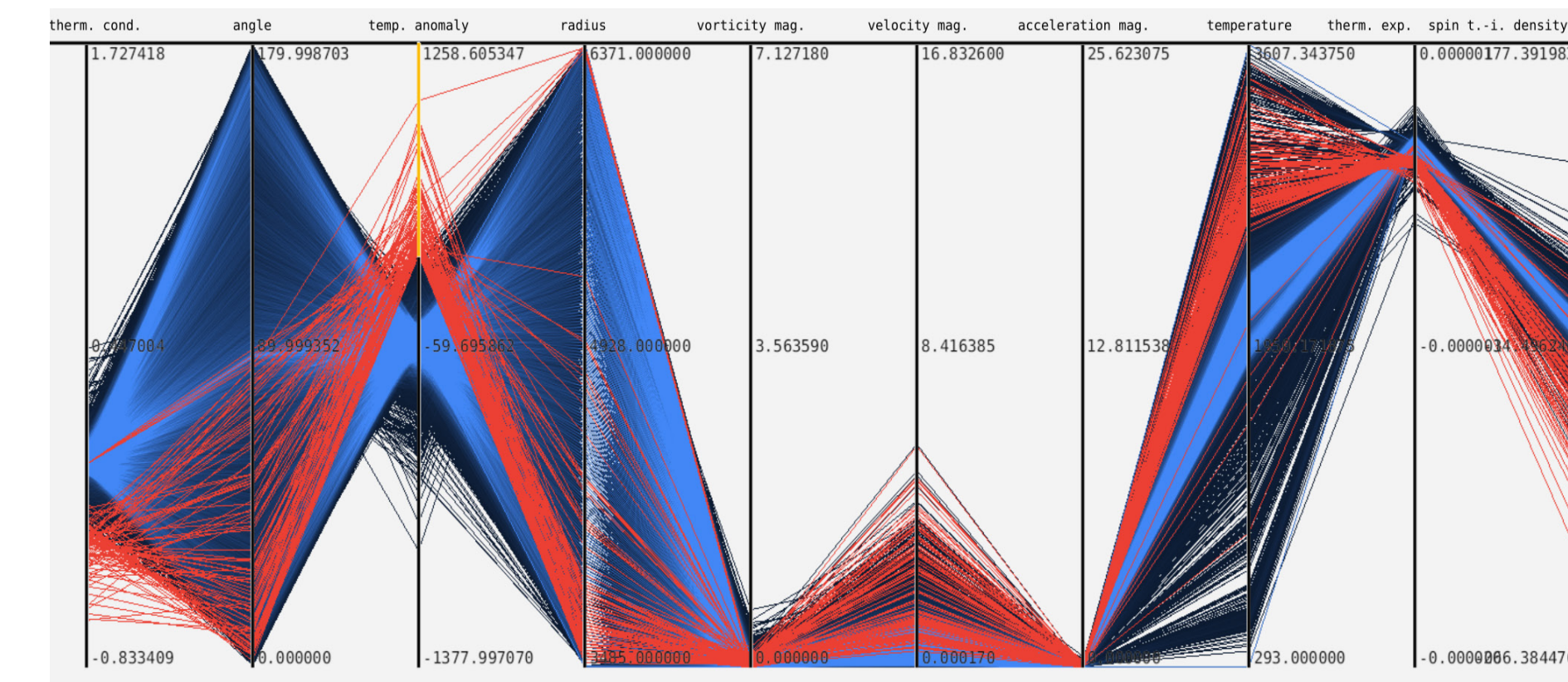
- 251 time steps
- Spatial resolution: 180 x 201 x 360
- 5 scalar fields:
 - temperature
 - thermal conductivity anomaly
 - thermal expansivity anomaly
 - temperature anomaly
 - spin transition-induced density anomaly
- 1 vector field (velocity)

Workflow



Feature Extraction

- Interactive feature definition based on brushing in a parallel coordinates plot
- Selected voxels shown in a volume visualization

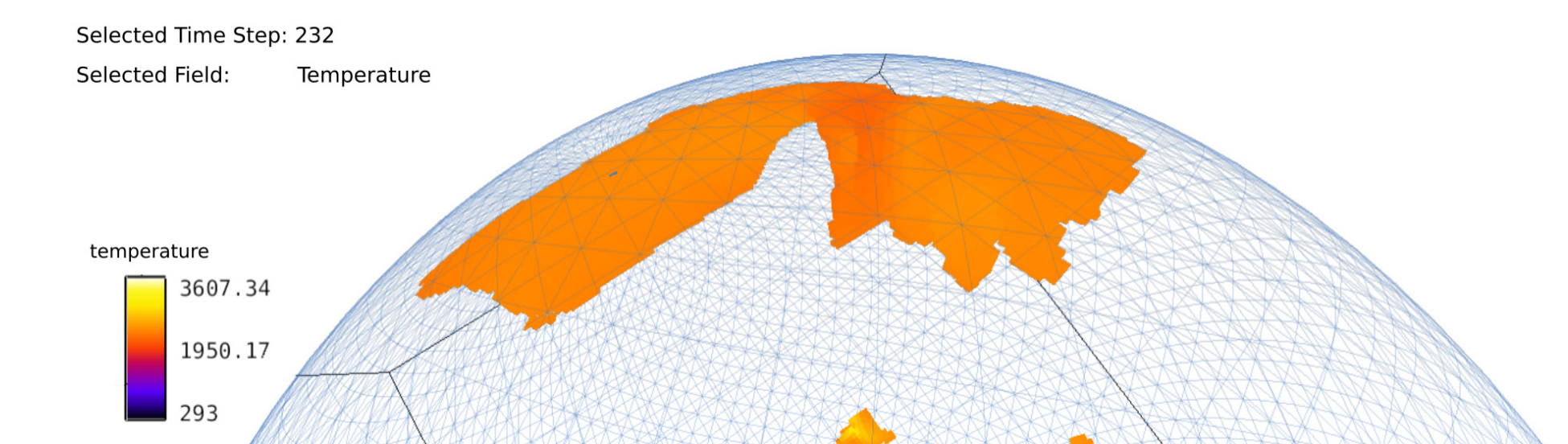
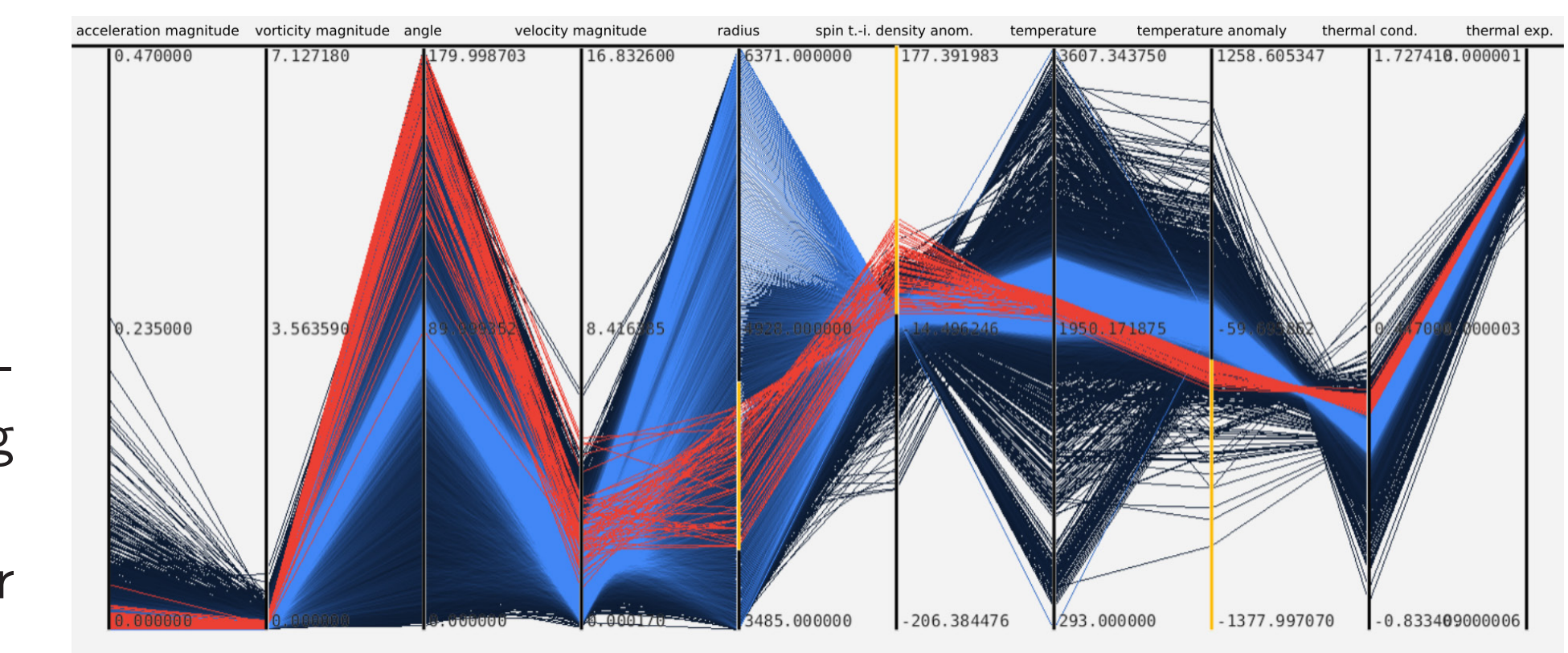


Avalanches:

- Low temperature values, high spin transition-induced density anomaly and a radius beginning at 1600km depth
- Material quickly moves towards the center
- Animation confirms acceleration of mantle material

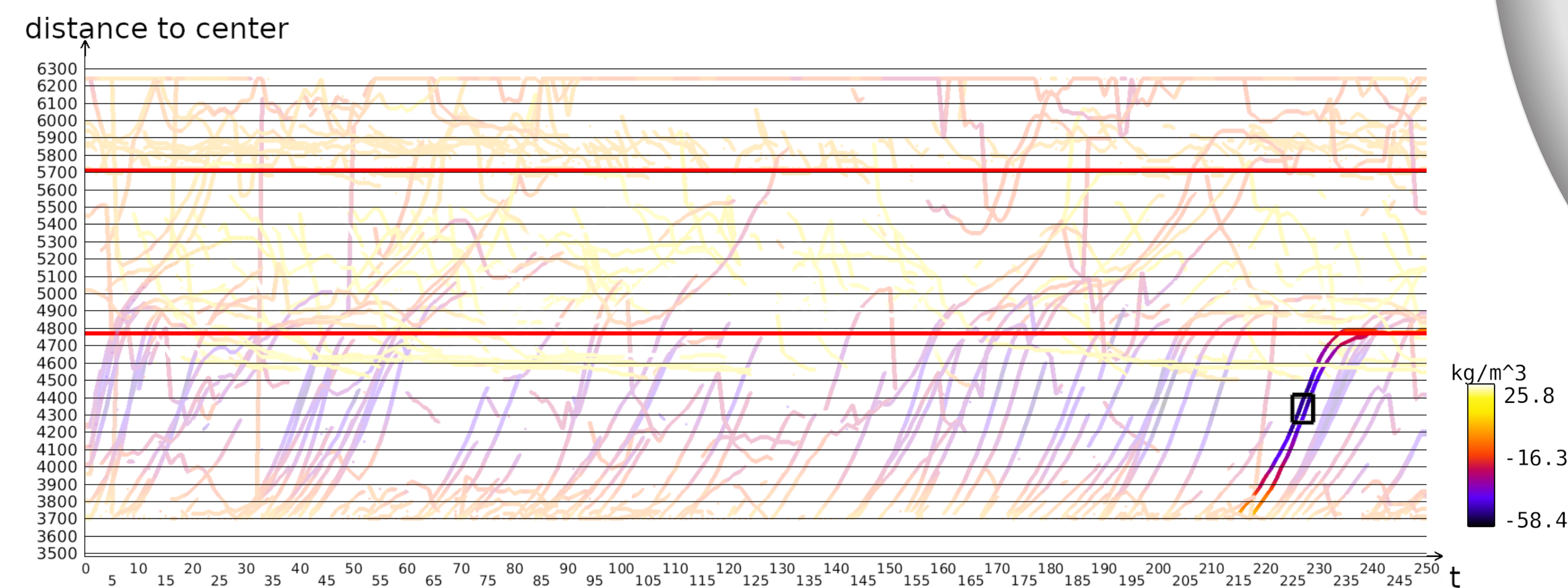
Analysis of plumes:

- Temperature anomaly above 200K
- Parallel coordinates show correlation to low angles and low thermal conductivity
- Volume rendering: horizontally extended material directly below the Earth's surface



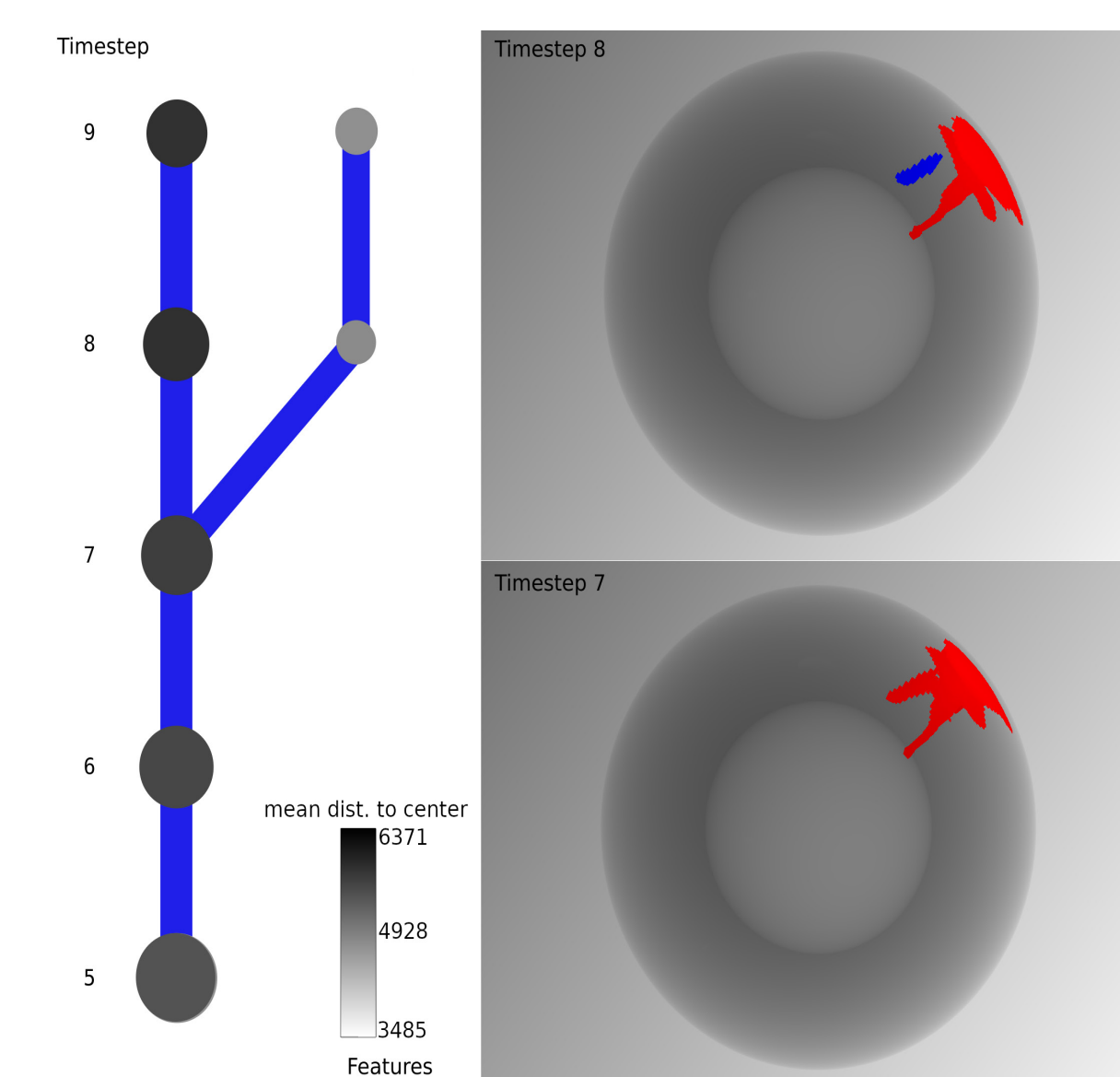
Feature Tracking

Track features over time by matching overlapping spatial regions of subsequent time steps



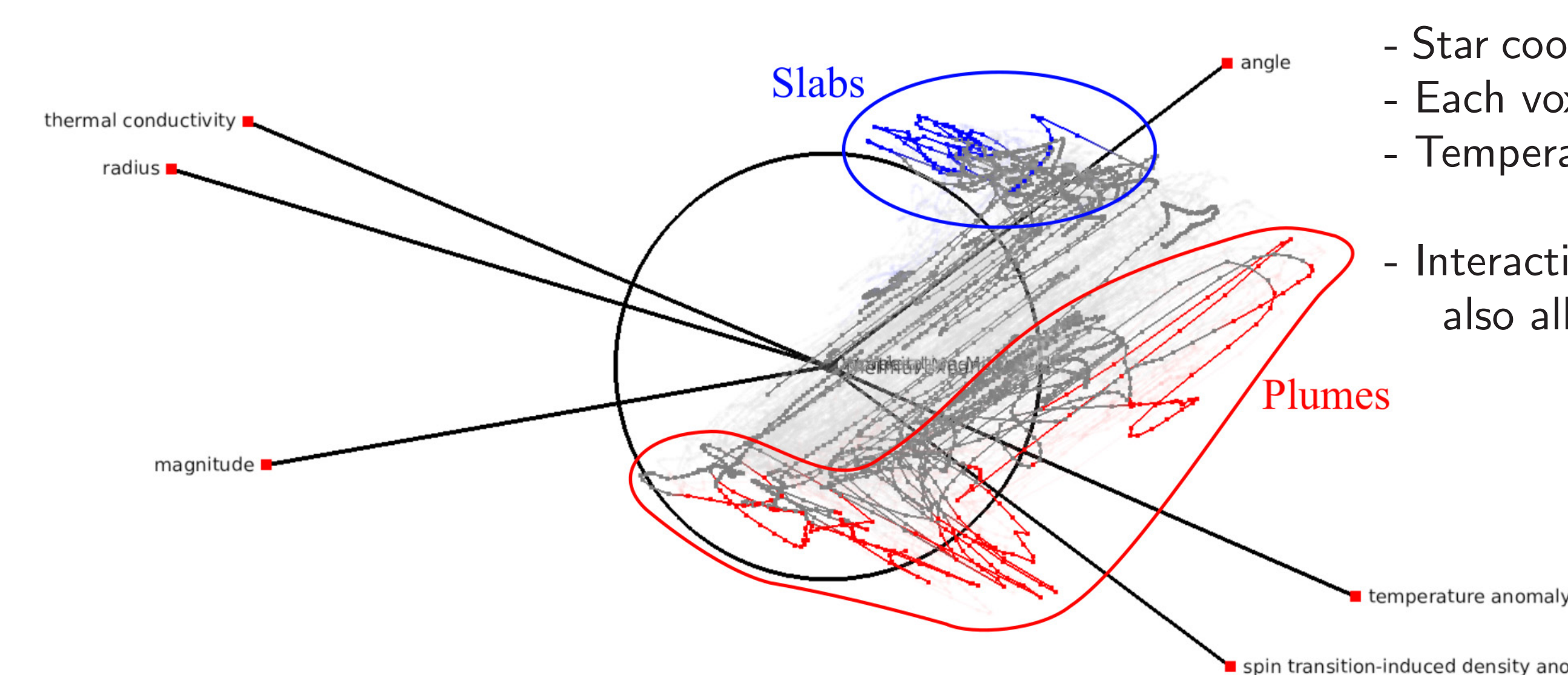
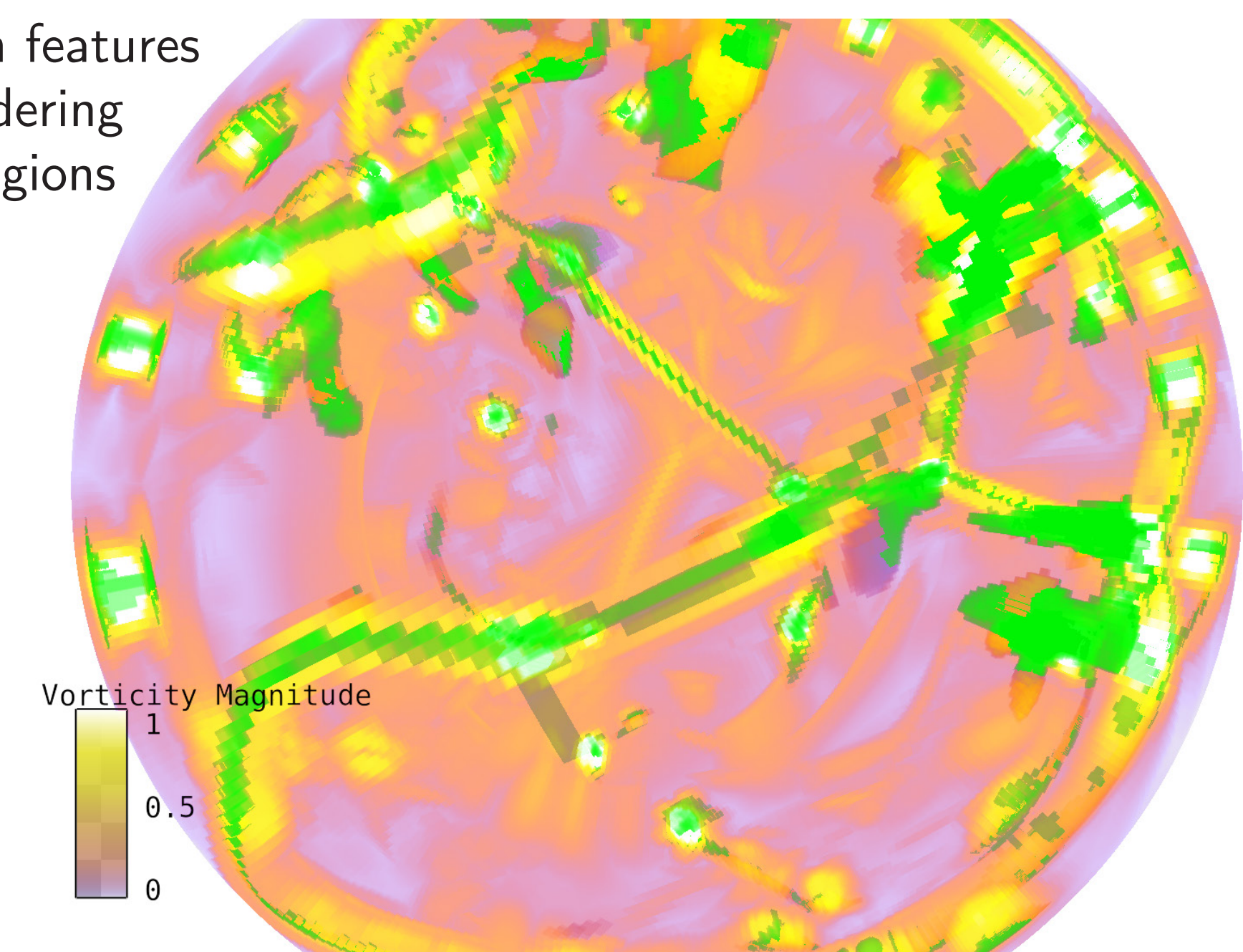
- Feature distance plot: minimum or maximum feature distance to Earth's center
- Color-coding: mean quantities of the features
- Select features and observe them in volume rendering (with animations)
- Here: higher density anomaly for plumes that pass the 1600km depth layer

- Merge-split events: graph representation
- Nodes represent a feature, radius encodes size, color encodes mean height
- Edges: blue if the overlap was greater in the subsequent time step, red if the overlap was greater in the preceding time step



Correlation Analysis

- Analyze spatial correlations between features and (derived) fields in a volume rendering
- Slabs (green) in upper layers lie in regions with a high vorticity magnitude



- Star coordinates: analysis of single voxels over time in feature space
- Each voxel is represented by a trajectory
- Temperature anomaly < -200K (slab): blue
- > 200K (plume): red
- Interacting with the star coordinate axes reveals that the angle also allows for a separation of the features

