Comparative Visualization and Transfer Functions for Time-Varying Data

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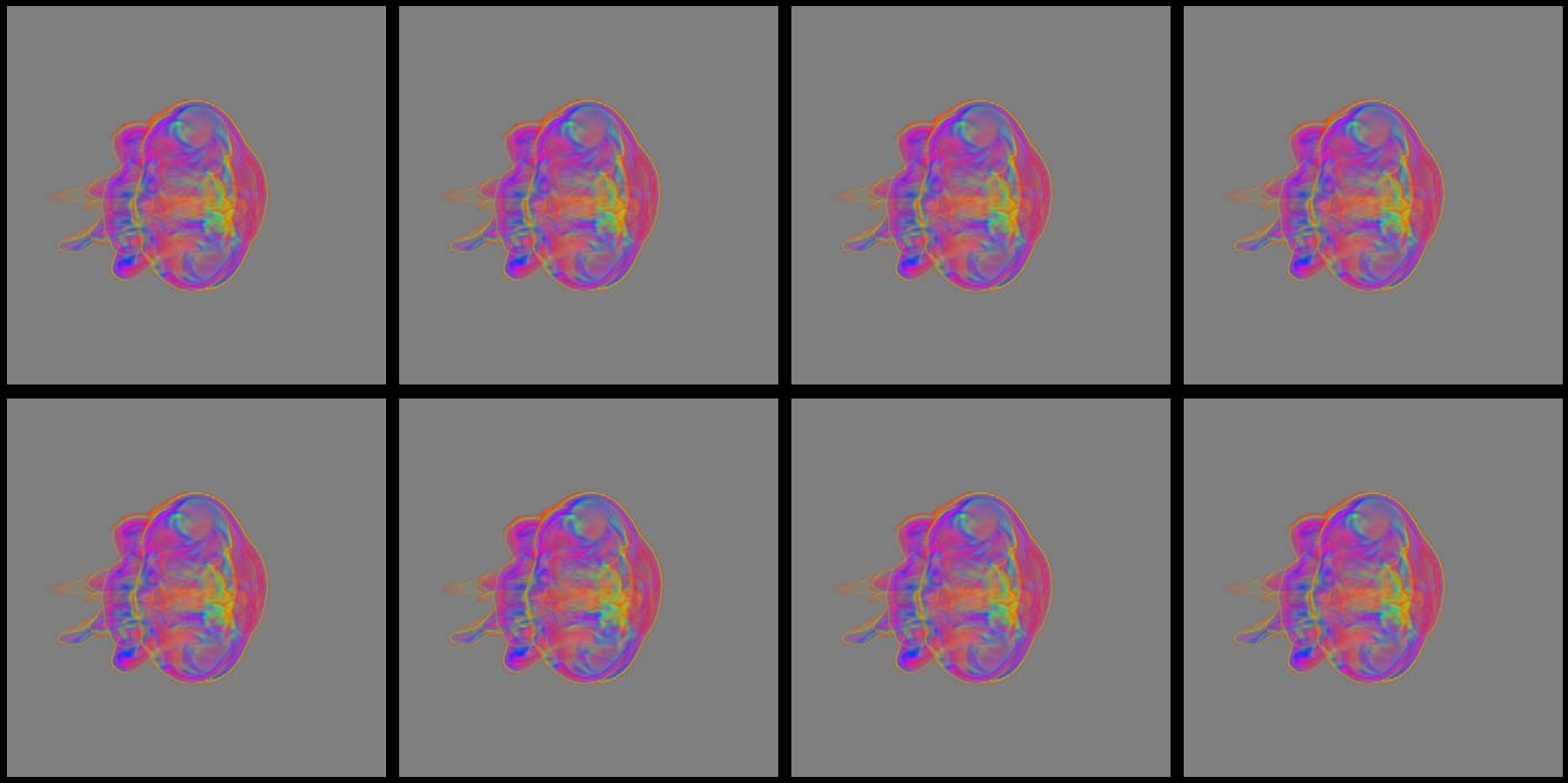
A Little Background

- My dissertation at The Ohio State University with Han-Wei Shen
- A caveat (the graduate student dilemma):
  - Most of the visualization techniques shown here aren't in an vis package ☹
  - Though I want them to be!
  - The last method has a downloadable tool, though!

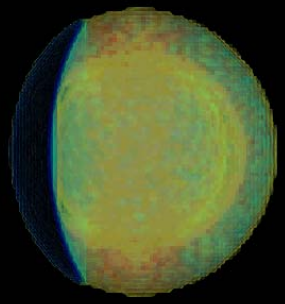
Problem Statement

- Time varying visualization for scientific or medical data has typically been done with animation and/or time step still renders
- Difficult to do precise visual analysis, to understand quantitative – actual value – differences over space, time, and trends
  - Perceptual issues
  - Lack of knowledge
  - Hard to make a transfer function

Differences – Worst Case



Animation – Memory



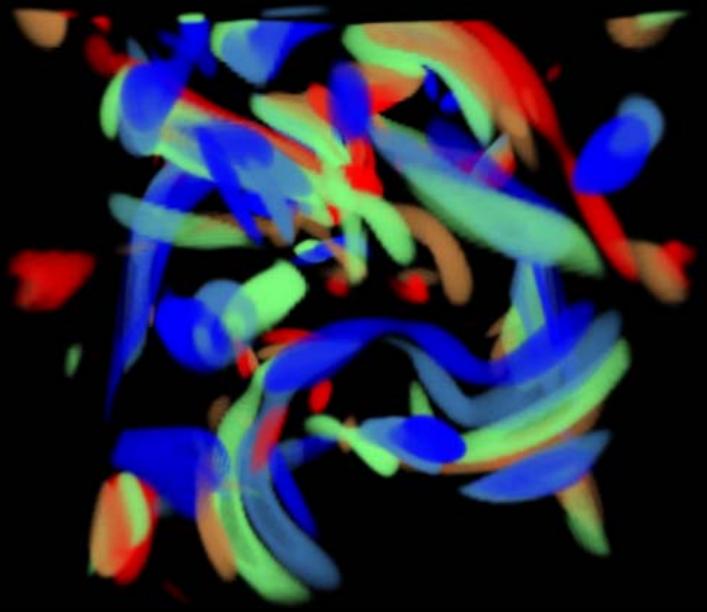
Count the Passes

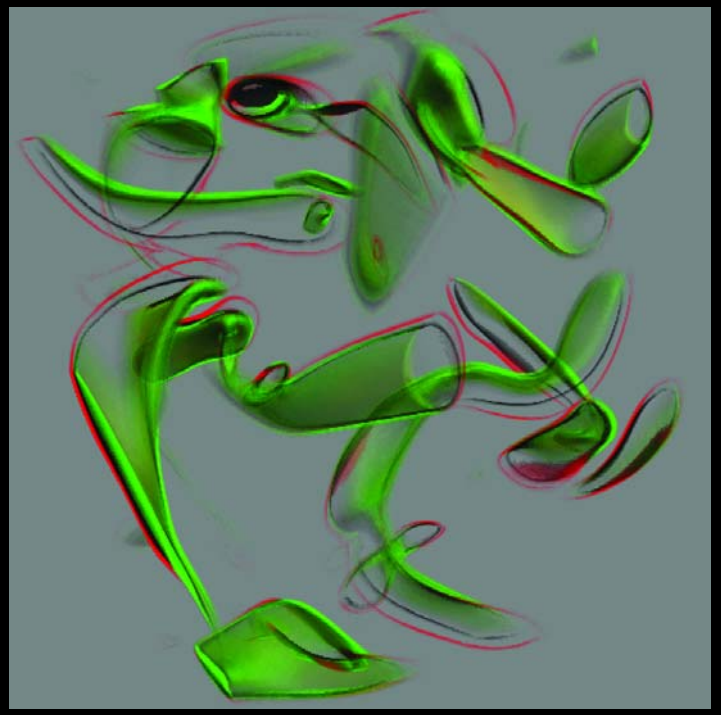
Classifying Time Data

- What values do the time series data have over time? (quantitative rather than qualitative)
  - What are the value ranges over a time period?
  - What other data points or features share the same value or have different?
  - What are the trends across time scales?
- Transfer functions for temporal data is hard
  - Which values and data points should we classify over time?
  - How to classify them over time? (changing ranges)

Comparative Fusion

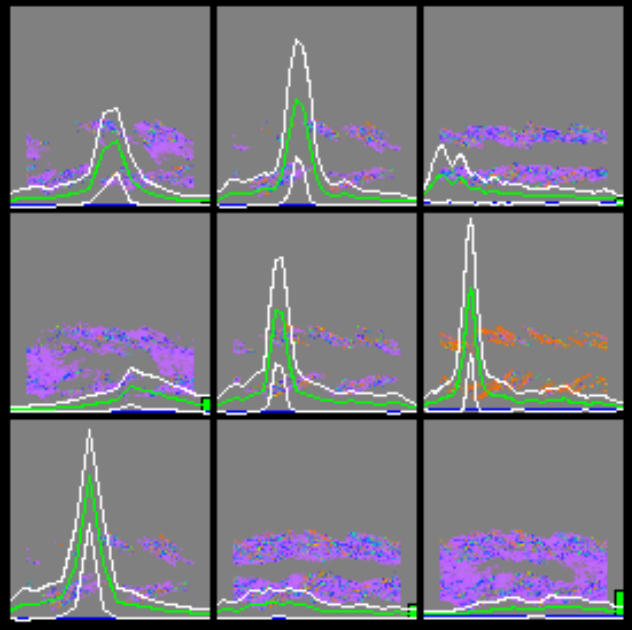
- Combine multiple time steps into a single static data set, provides context and the ability to make value and space comparisons

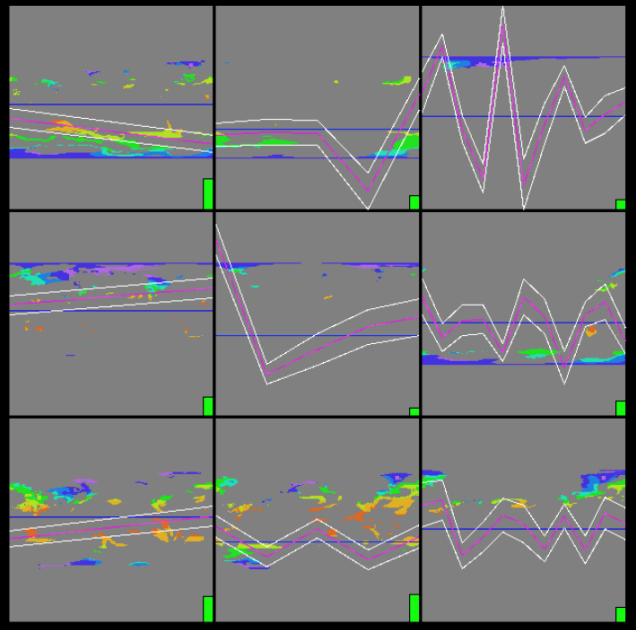




Comparative Trends

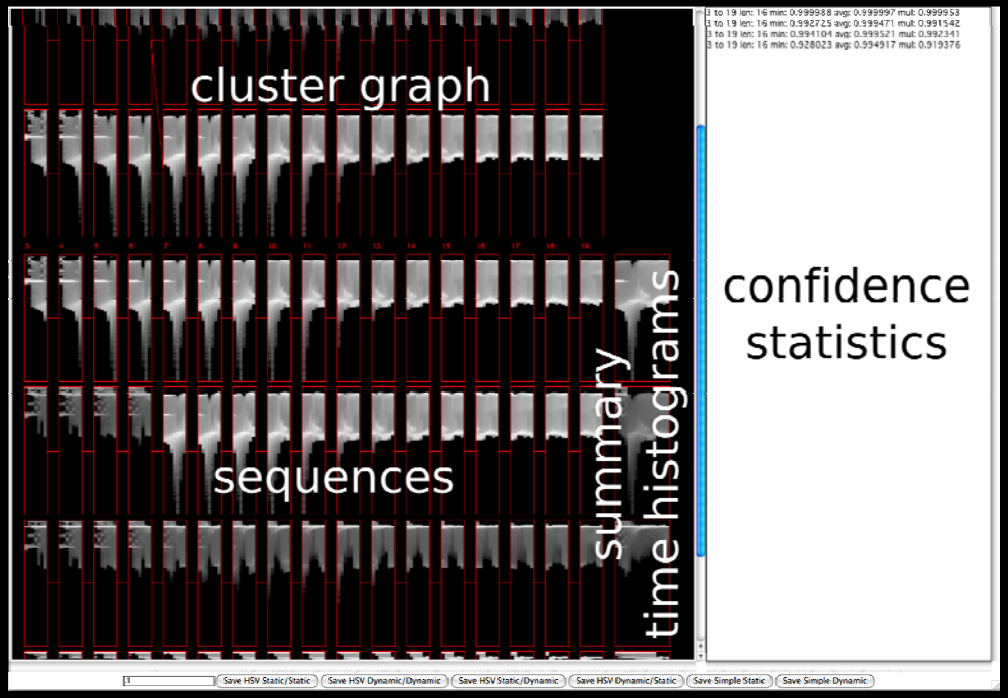
- Activity/curve/value representation allows for quantitative trend knowledge, similarity and differences of value over time

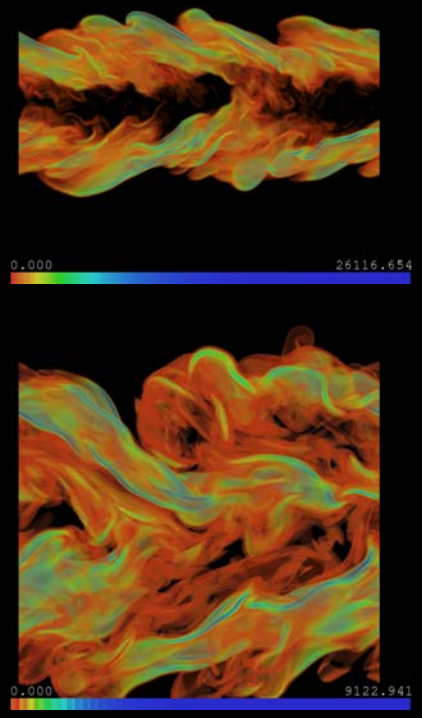




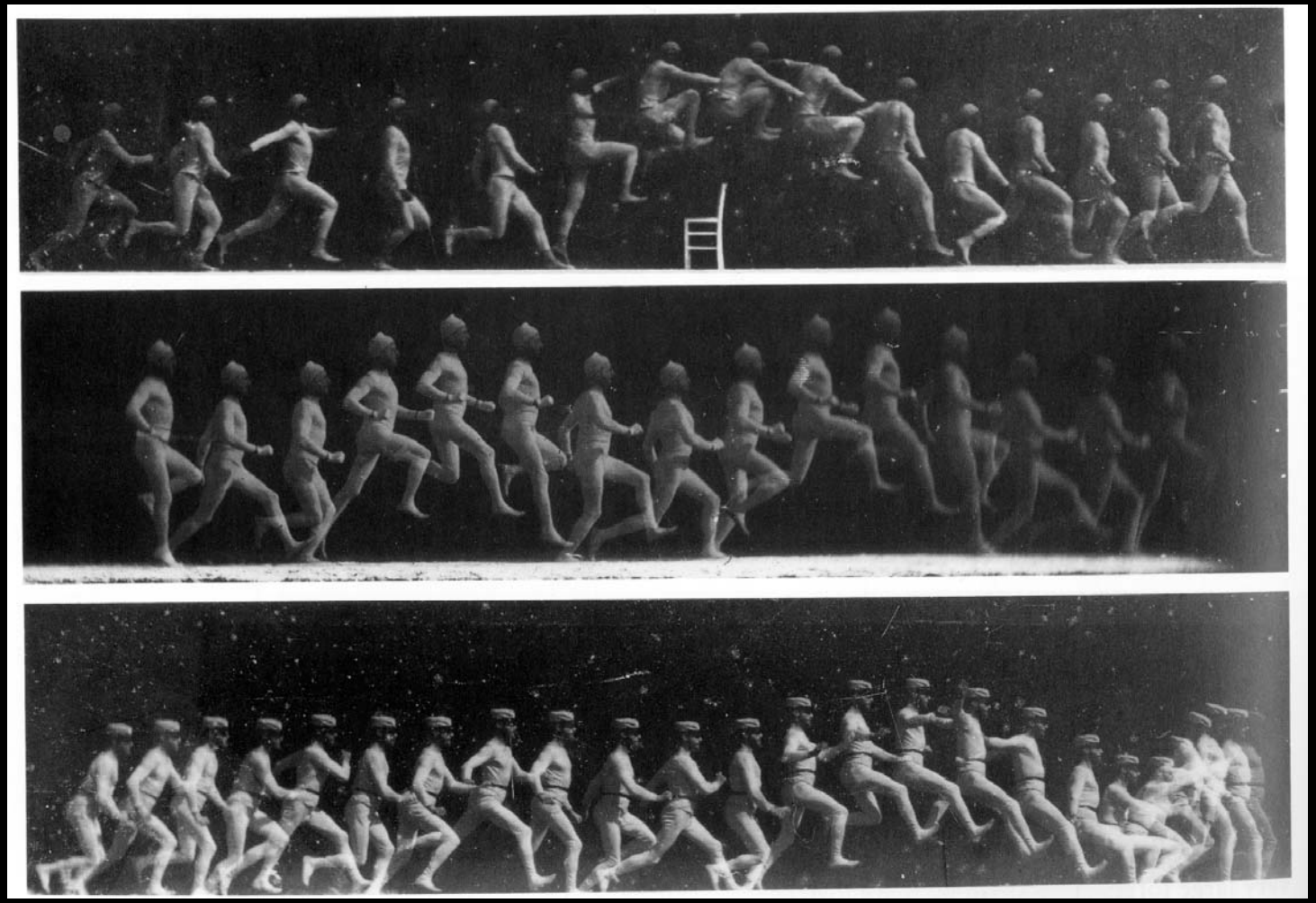
Using Trends for Transfer Functions

- Analyze the trends in a time-varying data set for automatic classification for transfer function generation



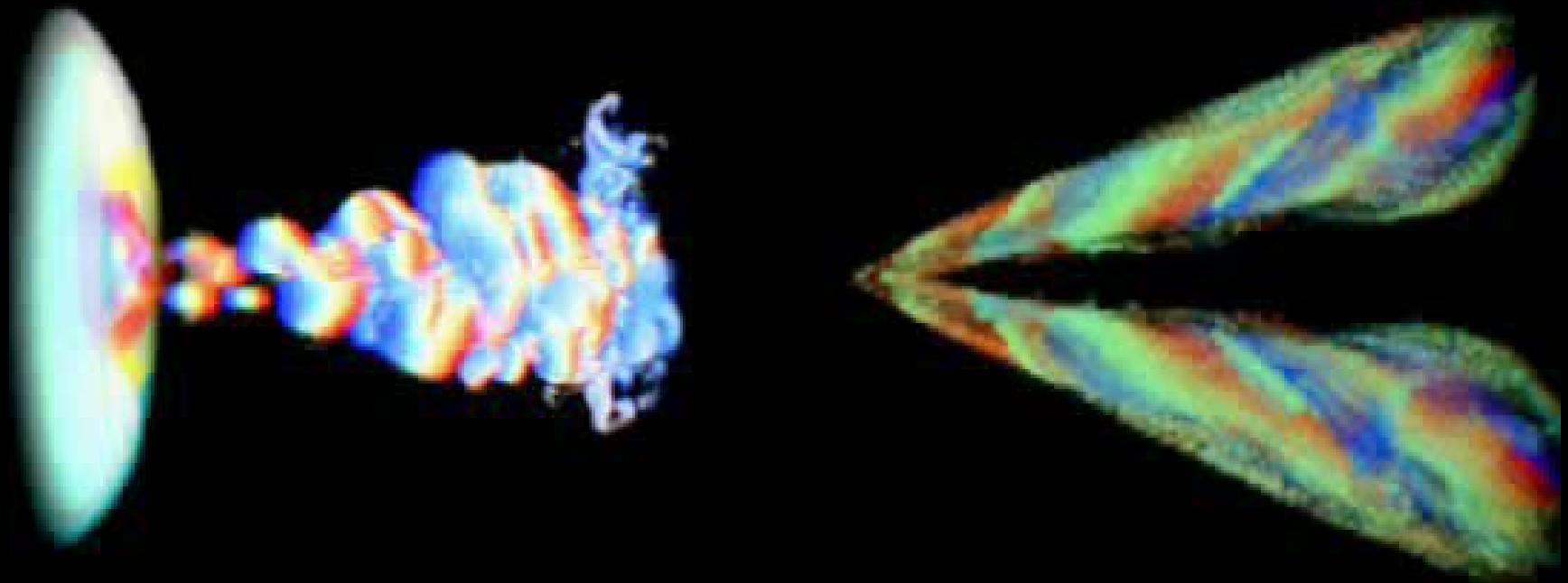


Chronophotography

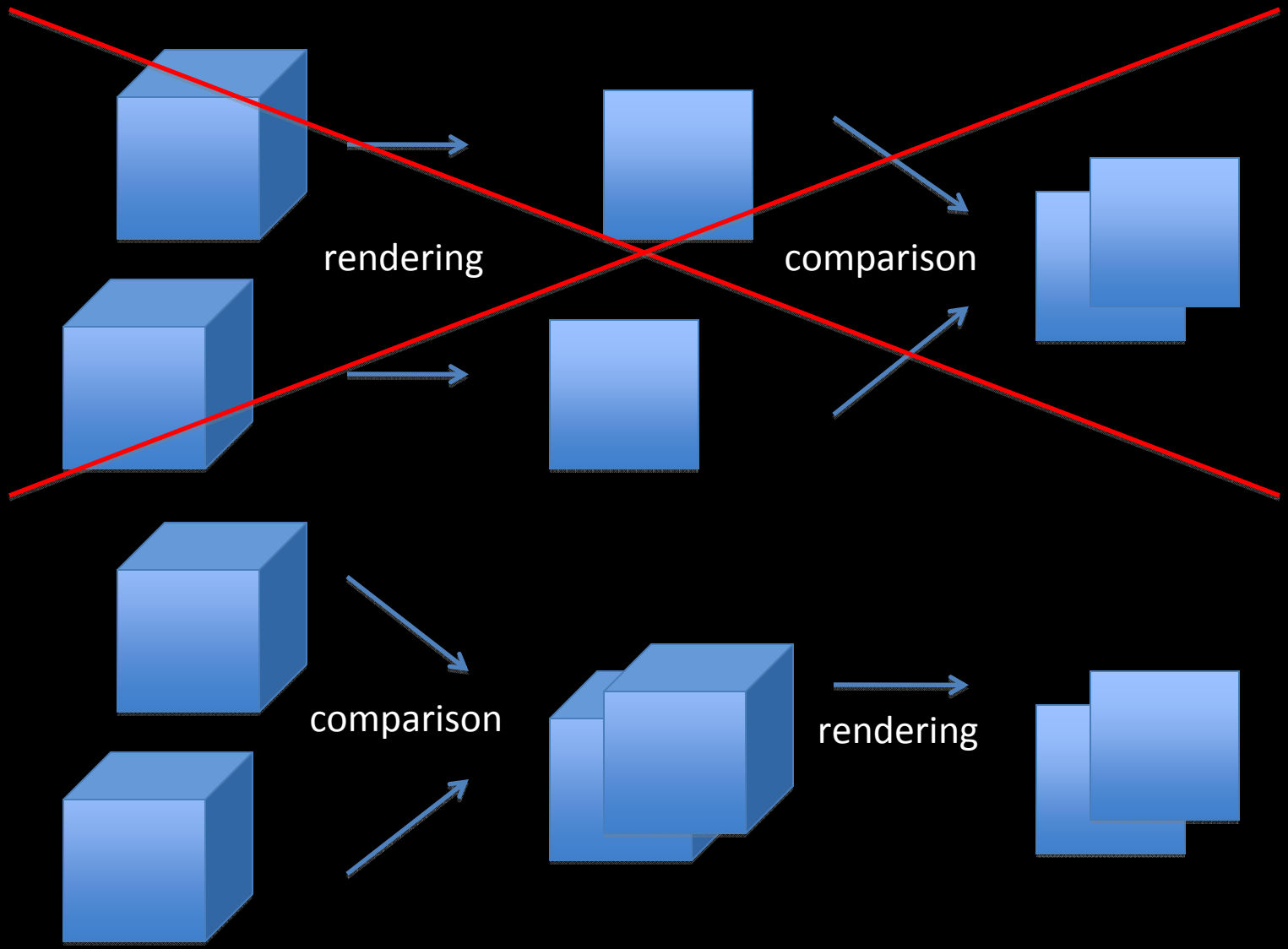


Chronovolumes

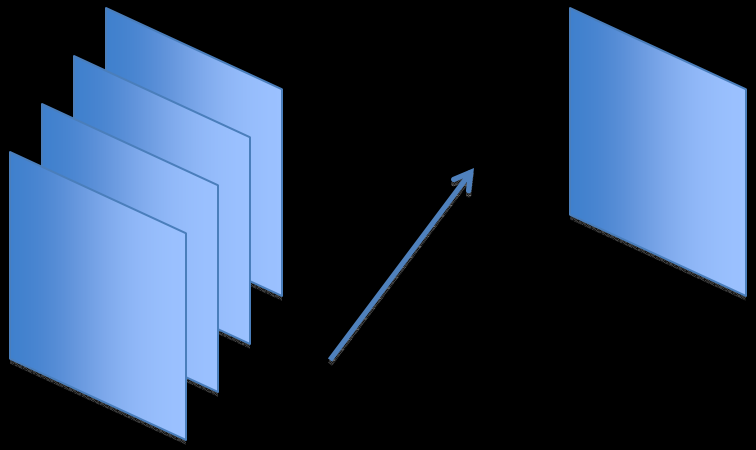
- Visually compare time steps by combining several time steps into one volume



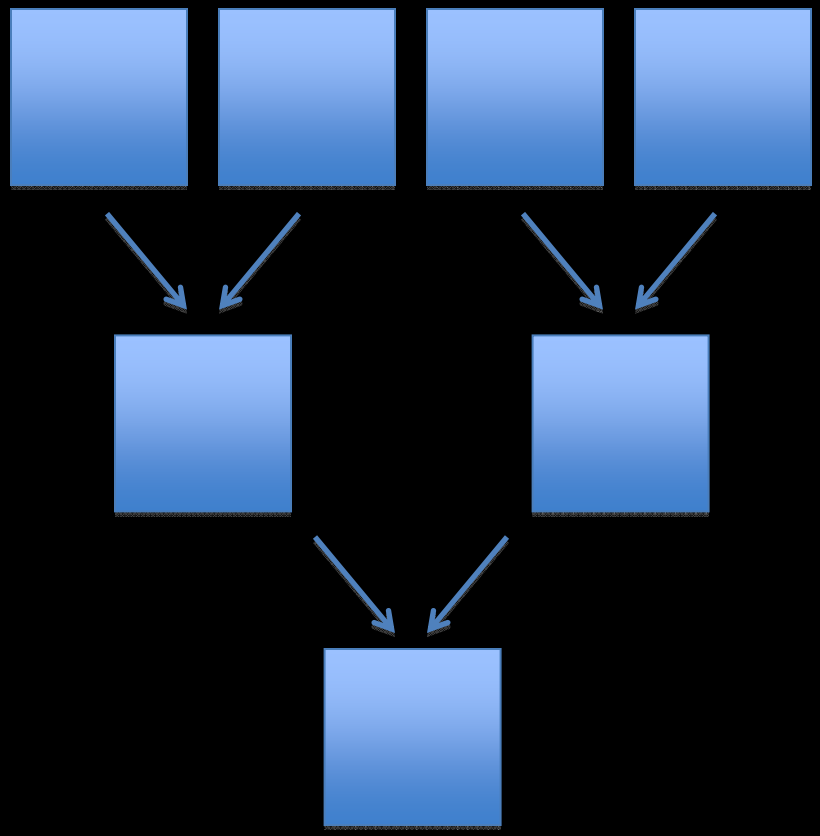
Comparative Fusion



2D Analogy



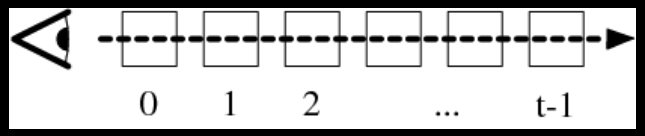
project through time
(reduction operator)

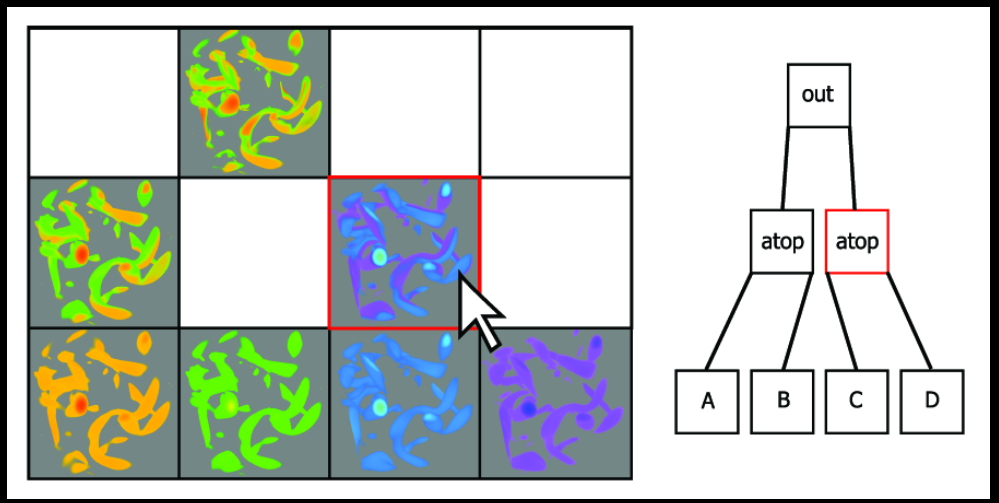


compose multiple time steps
(arbitrary operations)

Comparison Methods

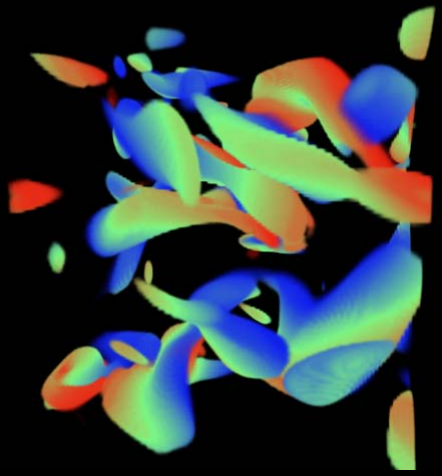
- High Dimensional Projection
  - 4D (space + time) reduction to 3D along a 4D ray
- Composition
  - Combination of operators and queries



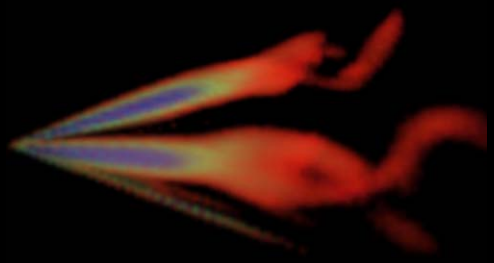


Example Operations

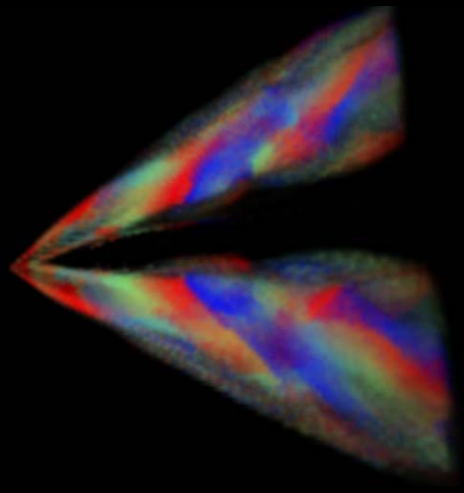
Alpha composition



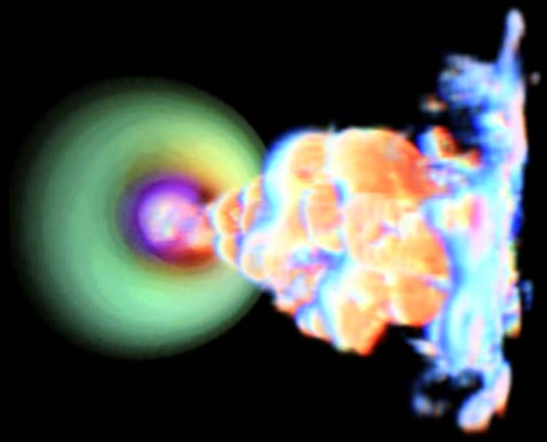
Average



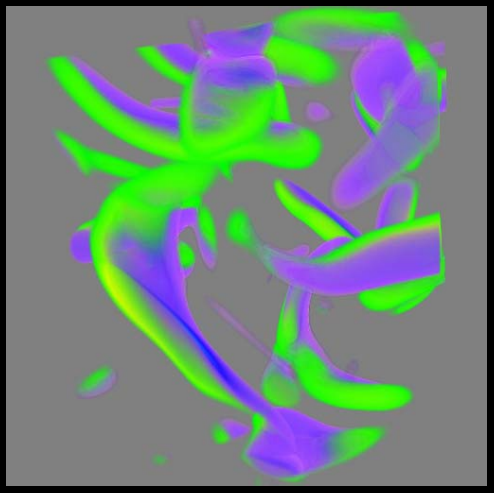
Min



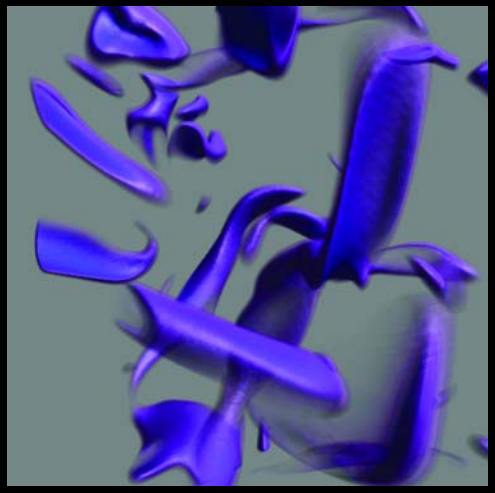
Additive color



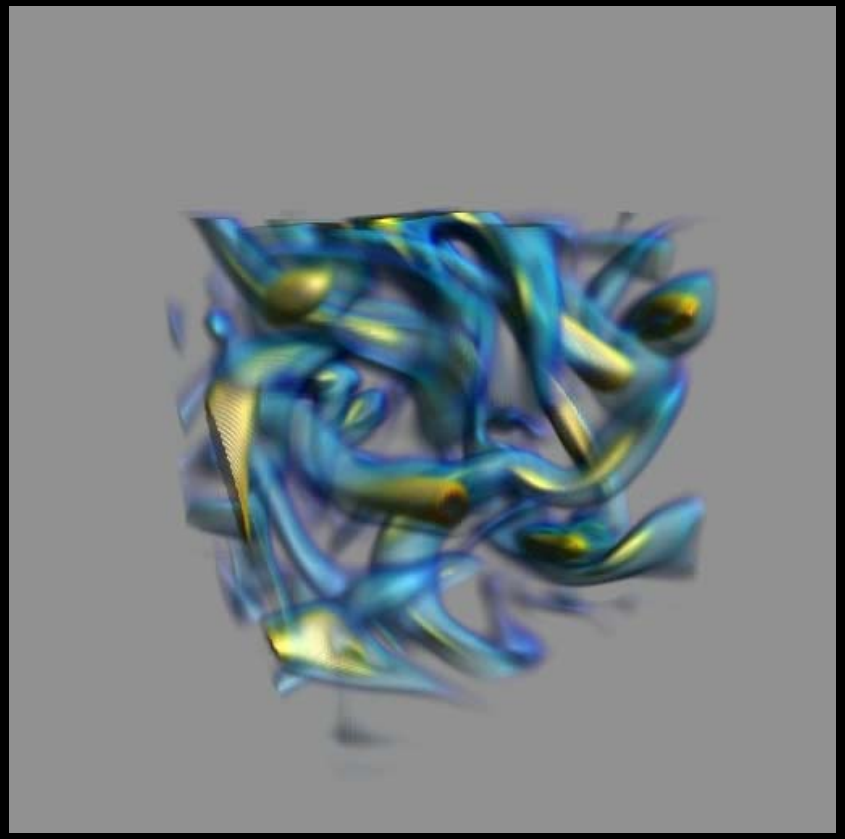
XOR

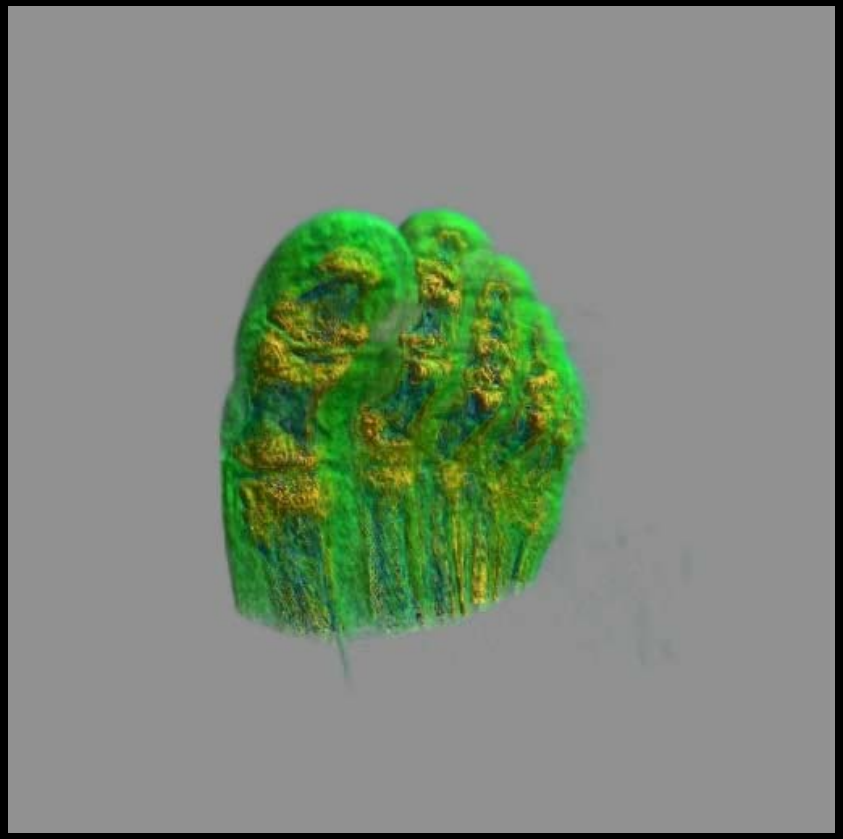


OUT



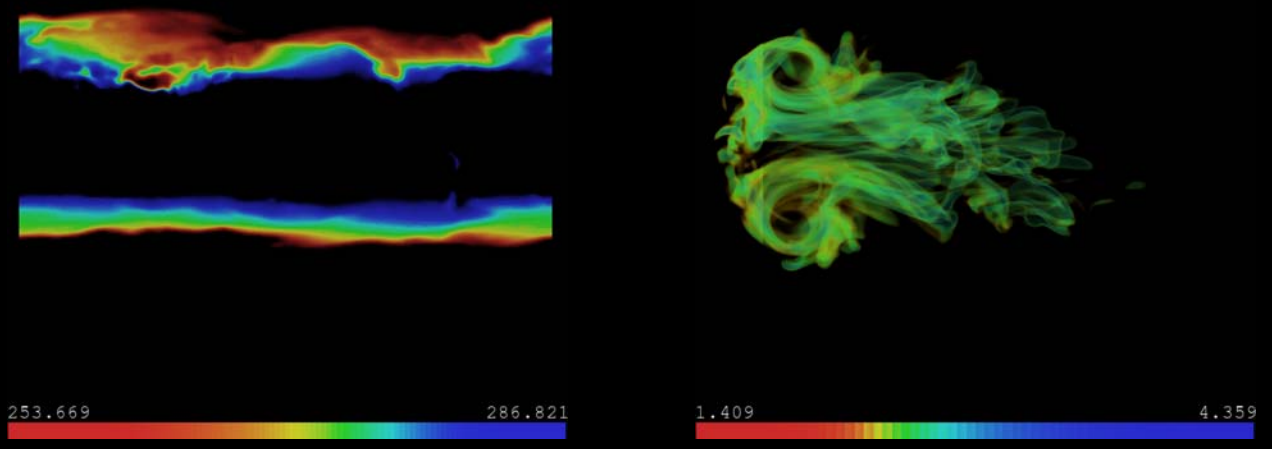
Intermission –
Motion (Animation) as a Focus





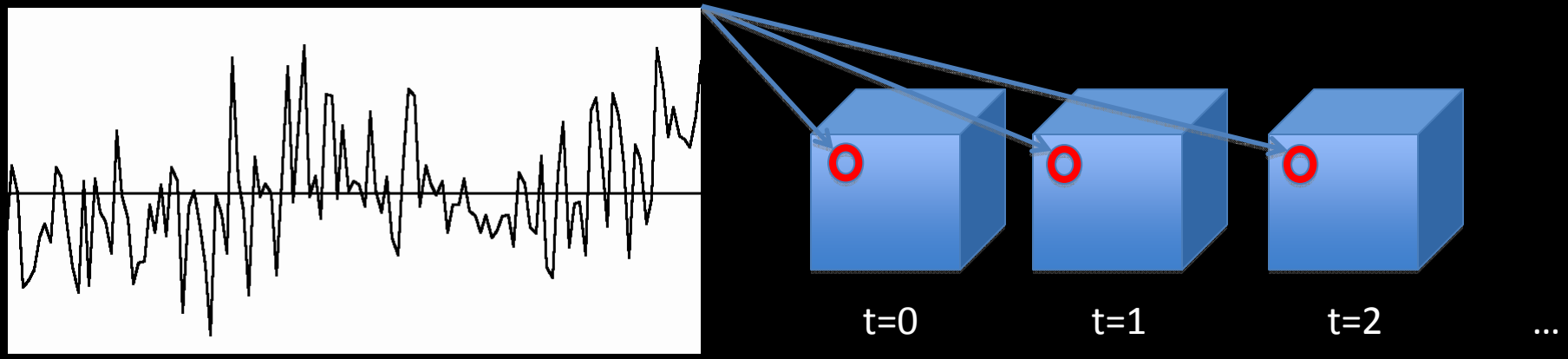
Comparative Trend Visualization

- Focus on exploration of trends and activity by analysis and more quantitative visualization
- The assumption is that data points that behave similarly (value coherence over time) belong to the same class of data



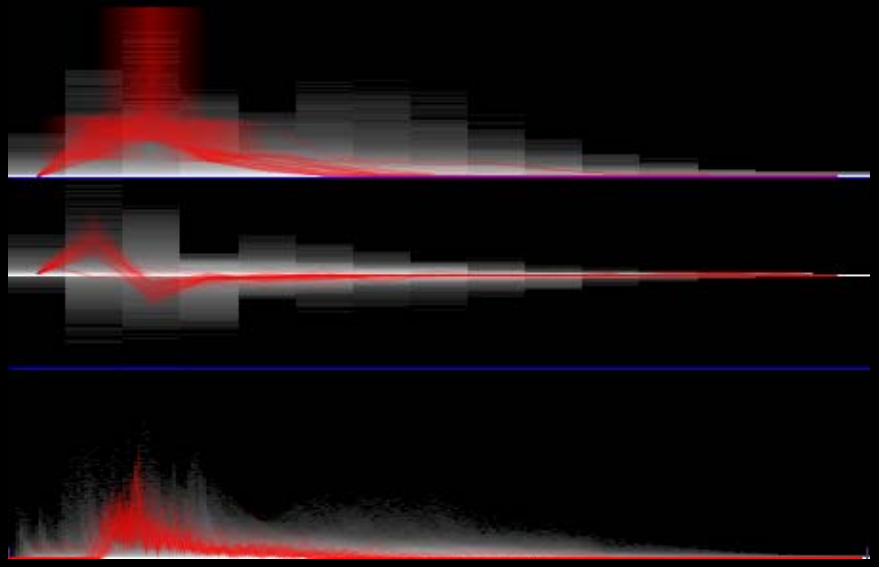
Time Activity Curve (TAC)

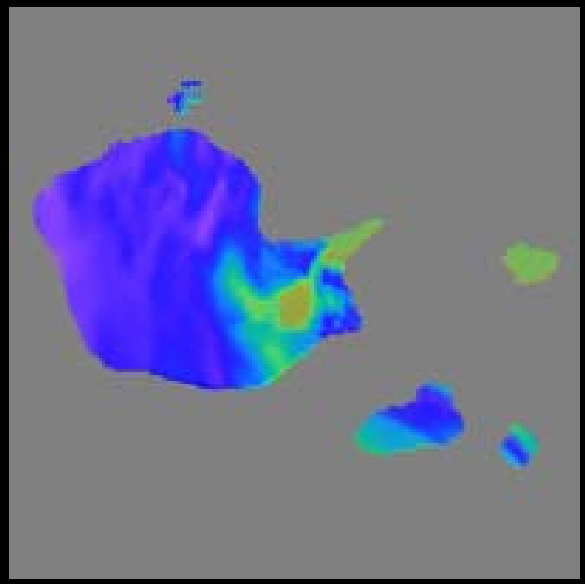
- Represent data points as time series curves
  - Also known as TAC vectors in sci vis literature
  - A TAC vector is a data point (point in space) representing data values over time at that point



Classifying Trends

- Treat data within a time window (or the entire series) as TAC vectors (time ordered series of values) and apply vector clustering (k-means, SOM, PCA, MDS, hierarchical, etc.) to classify





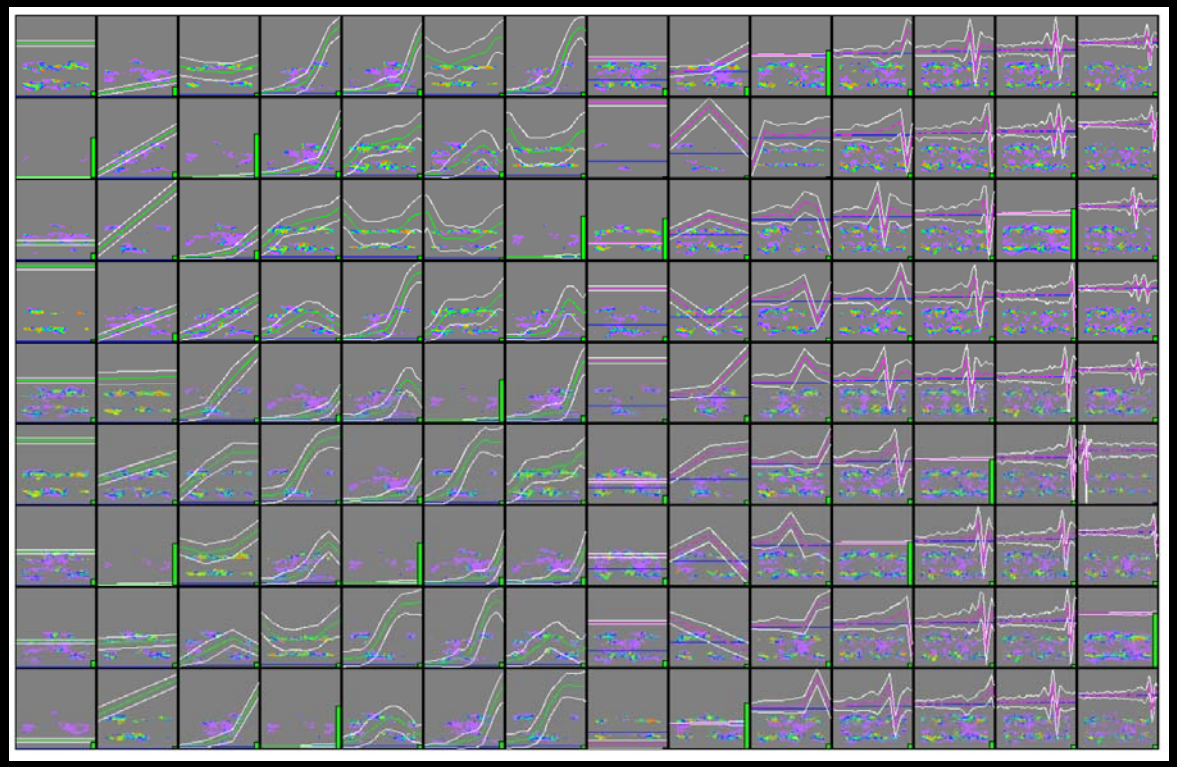
Classes across Different Time Scales

- Temporal activity can happen at different time scales
  - Short term scale: daily or monthly weather
  - Long term scale: yearly or decadal weather
- Activity classes are clustered by time scale
  - Use filter banks to pass-band filter the TACs into different time scales and then cluster by scale
  - Data points are separately classified in each time scale, thus different trends are identified

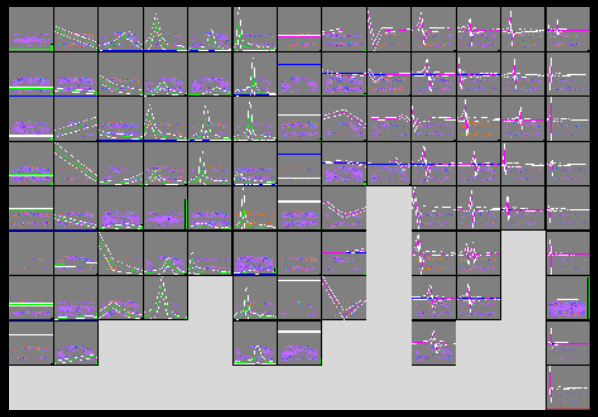
Comparative Trend Visualization

time scale

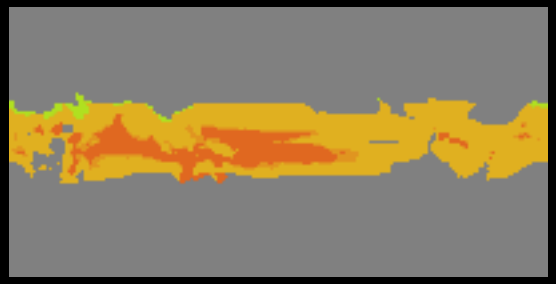
clusters

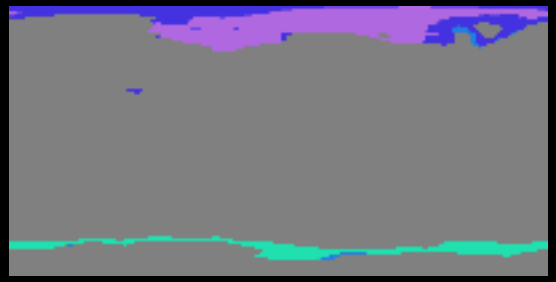


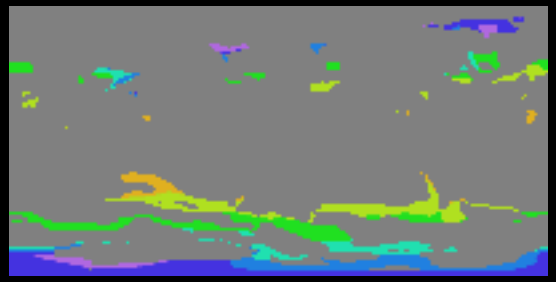
similarity culled

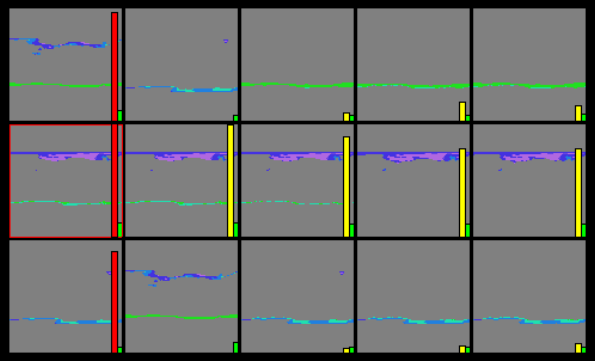


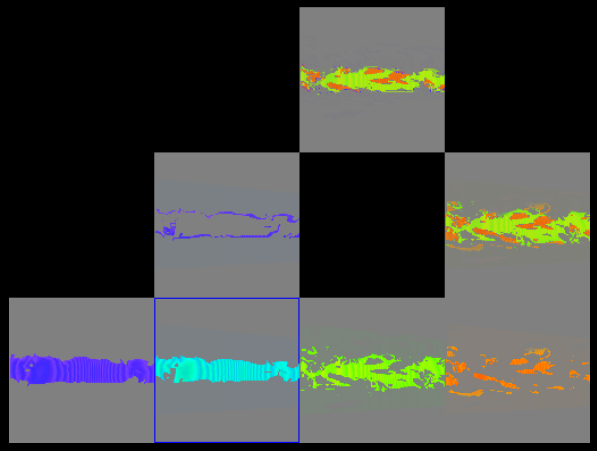
Showing Some Trends

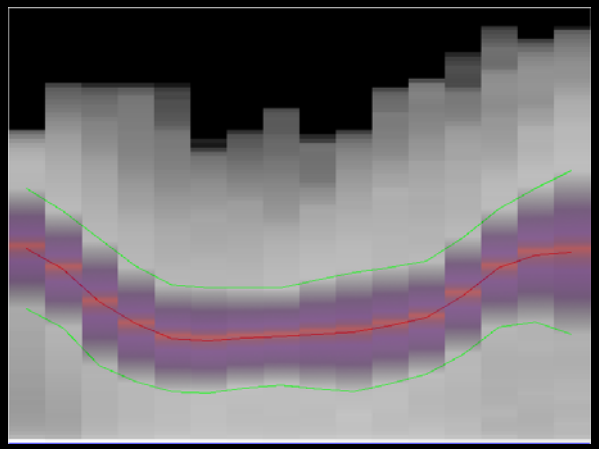


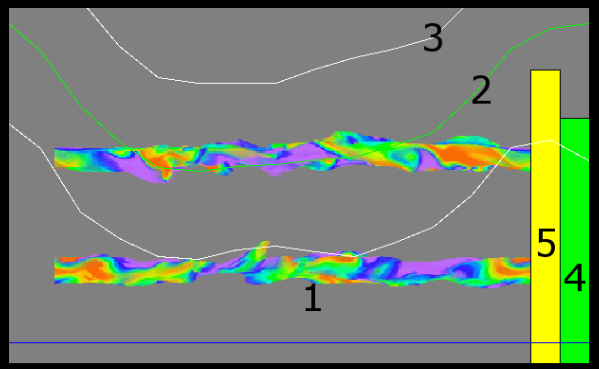




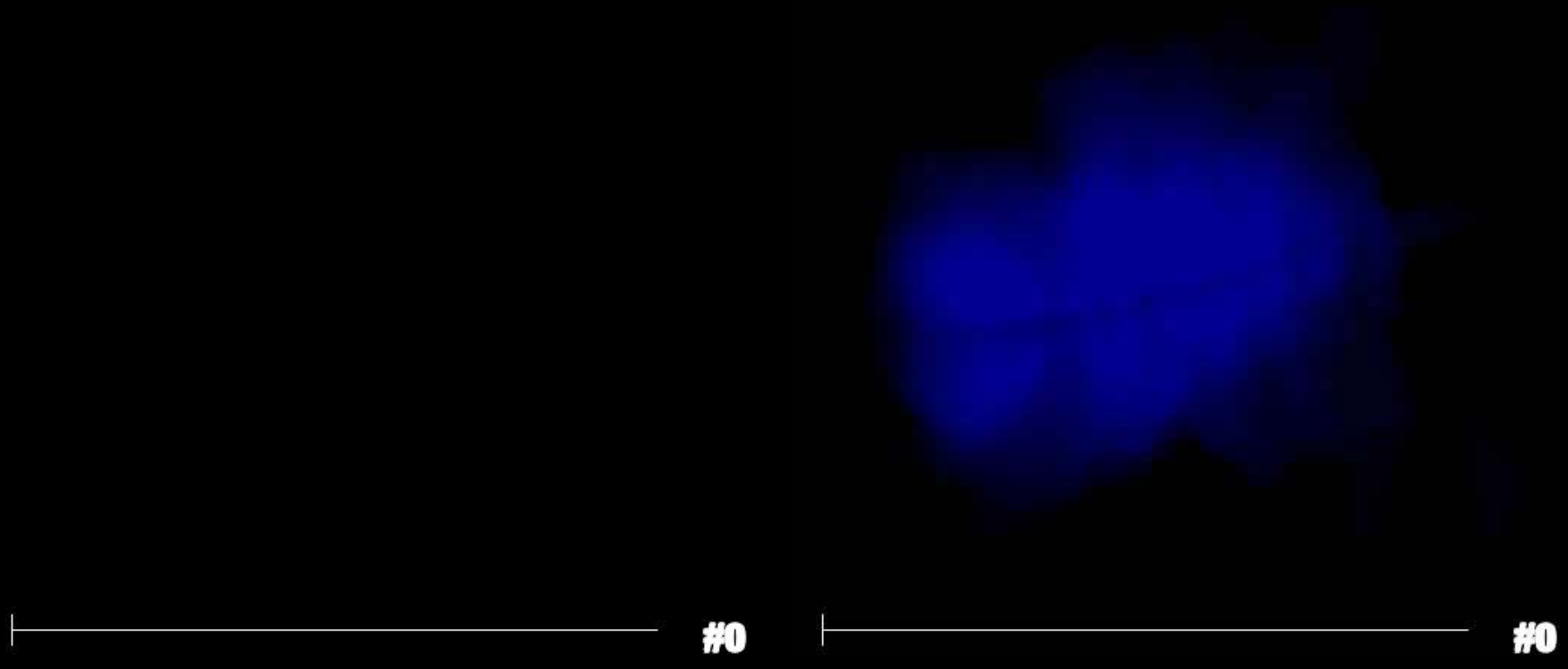






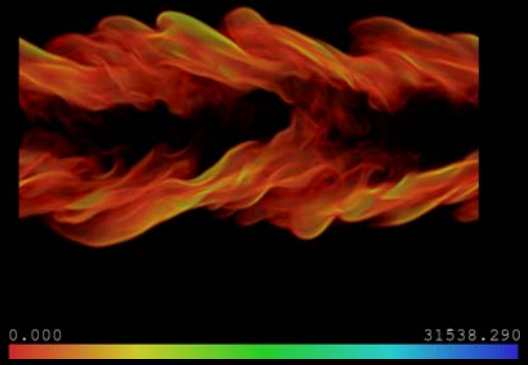


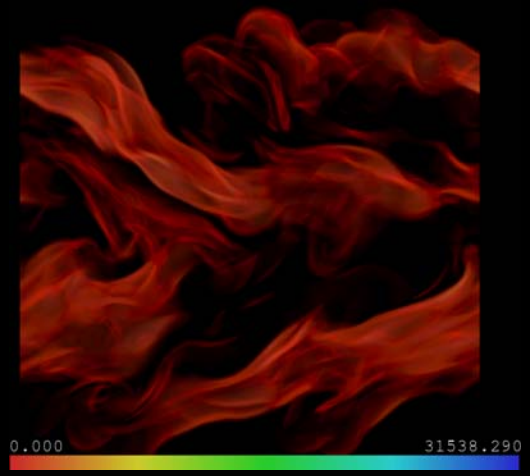
Animation Rescaling via TAC Centroid



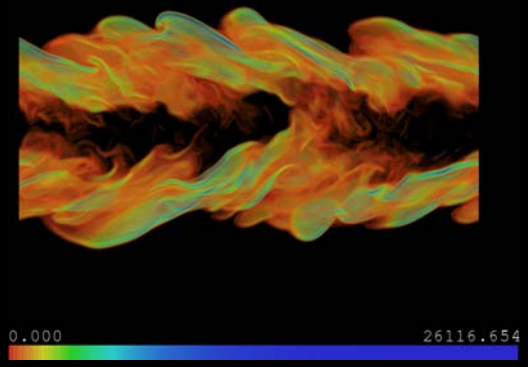
Using Trends for Semi-Automatic Transfer Function Generation

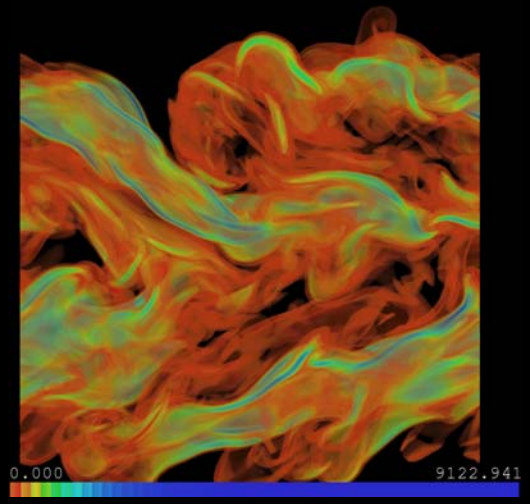
Static transfer function





Automatic method

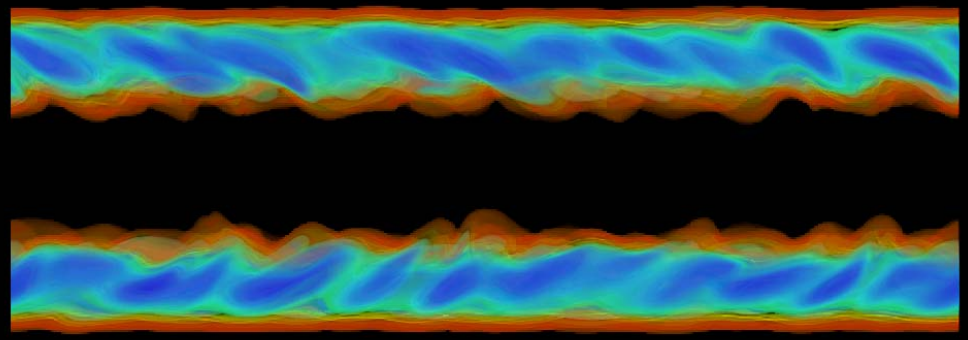




Early time step

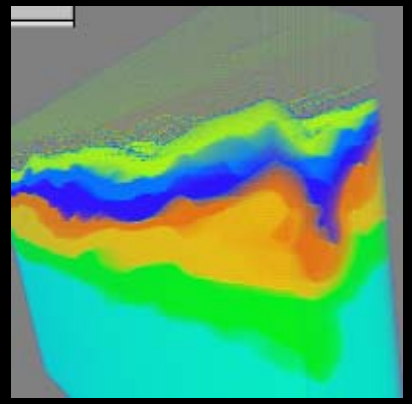
Late time step

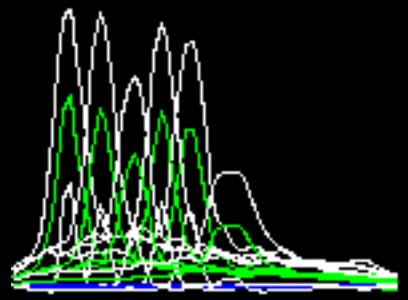
In Animation



Using Trend Classification for Moving Wavefronts

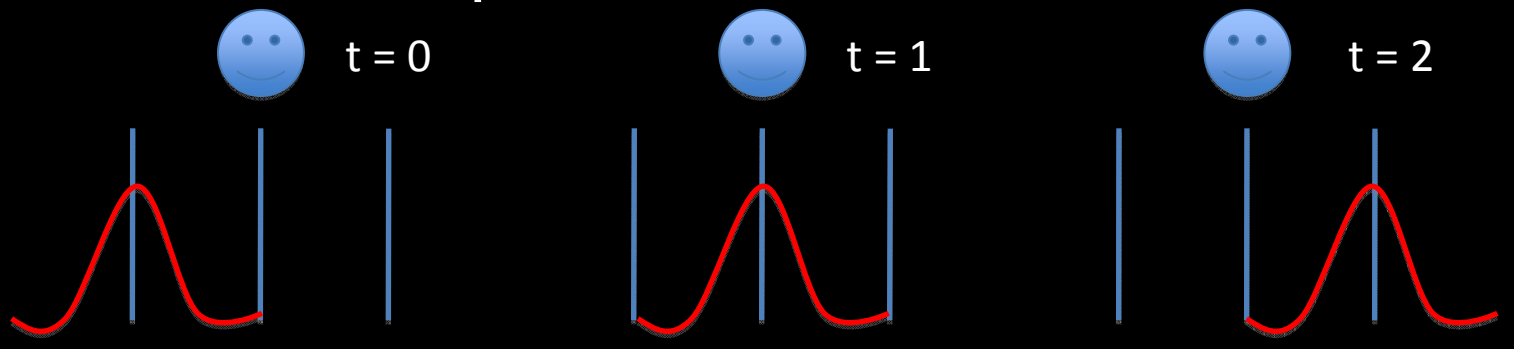
- The trend clustering method works well for classifying stationary features (climate regions, an earthquake basin), but not very well for moving data, like a wave
  - Using the trend clustering for a moving wave (if it has such a feature) segments the data into into subspaces the wave passes through over time
  - Each spatial region represents a wave front entering and exiting a region of space at a particular point in time





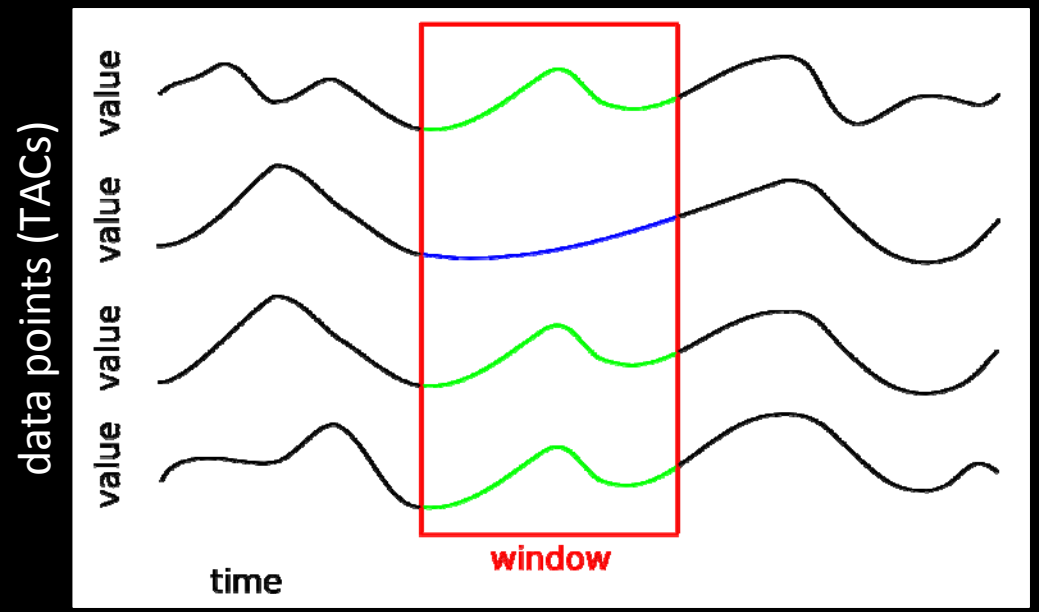
Identifying Wave Values

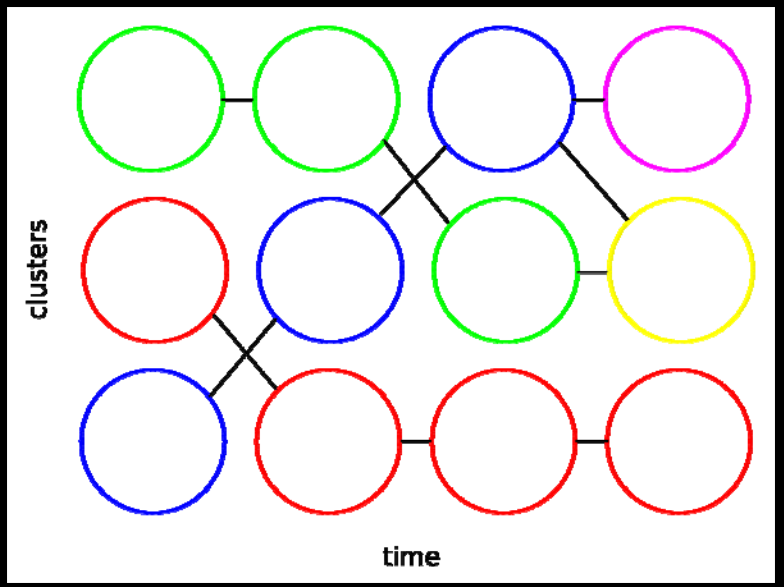
- The data points (spatial area) that comprise the wavefront have similar value behavior for a short period as the wave moves through a region of space
- As a wave moves in space, data points that contain the wave at a point in time, will have a similar trend to a set of data points, in near future and near past



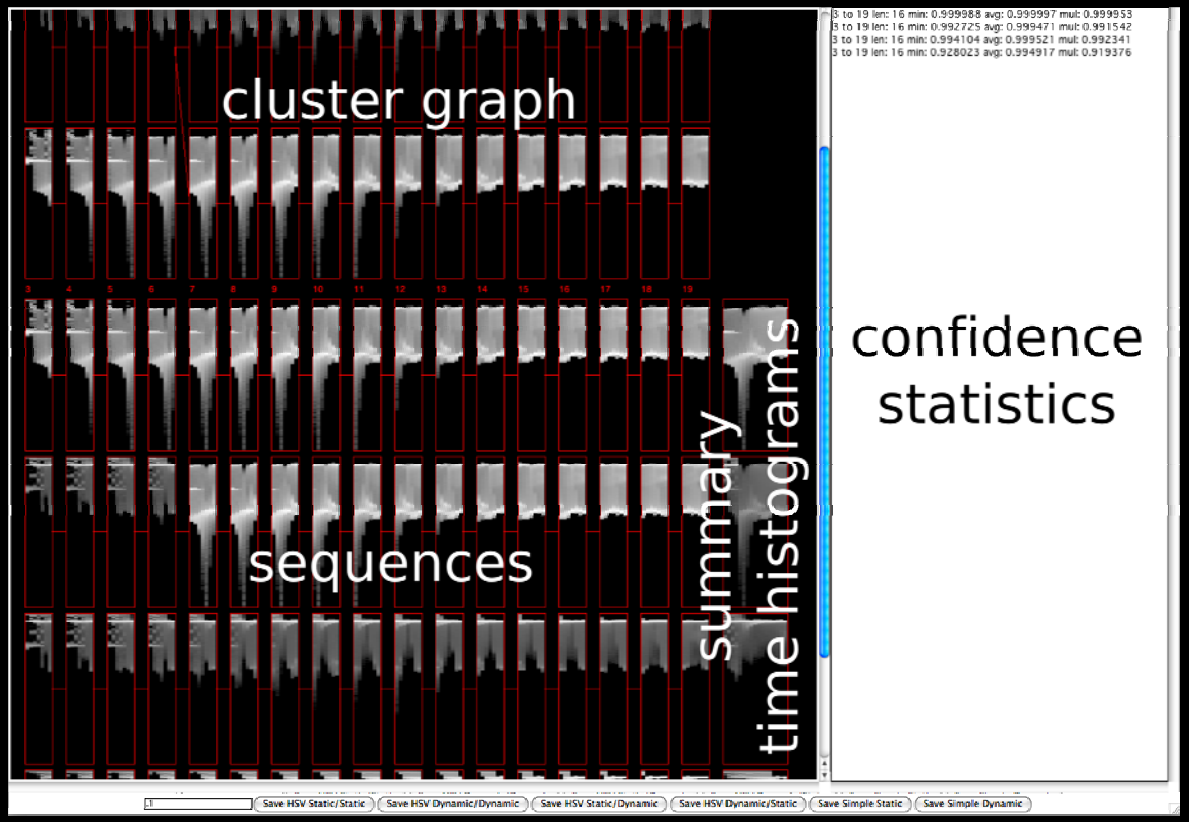
Formulating the Classification

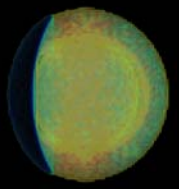
- Identify the trends that occur over a short period for a time step for every time step
- Match temporal trend clusters into a sequence of similar trends over time





Cluster and Sequence UI

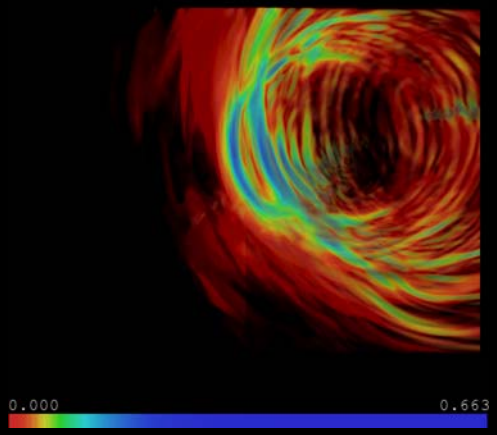


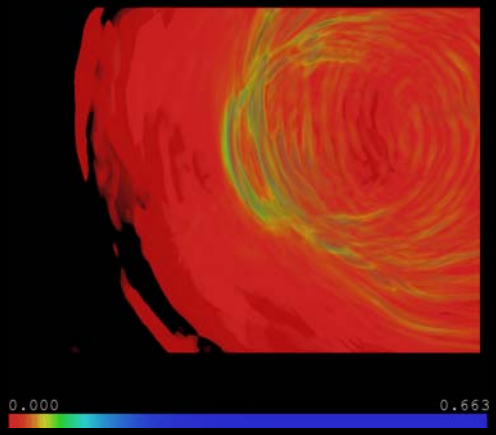


An animation using a selected sequence turned into a transfer function

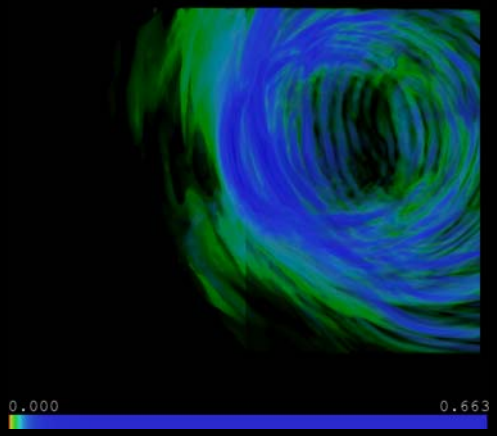
Different Types of Transfer Functions

Dynamic Color

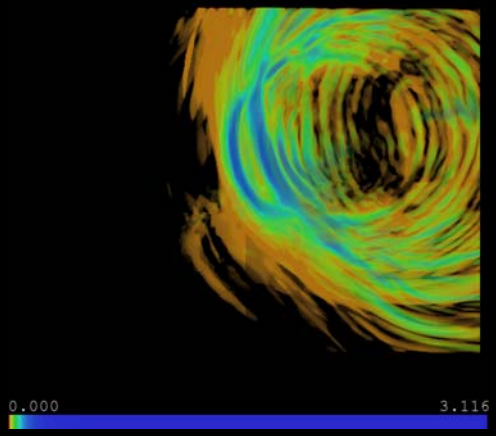




Static color

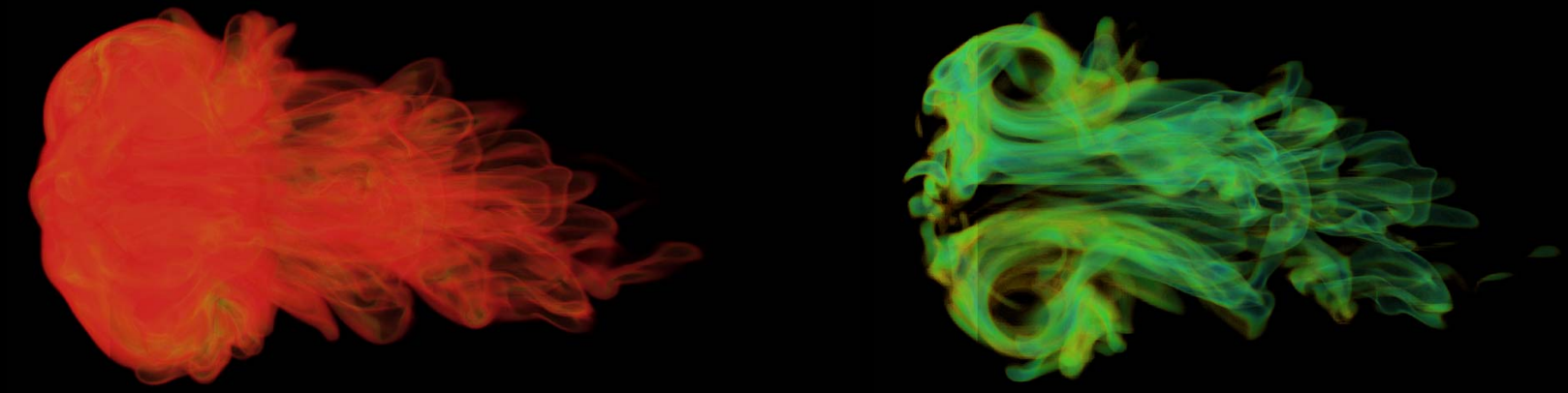


Dynamic Opacity



Static Opacity

Spatial Masking



value to color map without mask

with mask

Downloadable Implementation

- http://www.cse.ohio-state.edu/~hwshen/Research/Gravity/Download.html
  - Cluster data
  - Sequence clusters
  - Visualize sequences and clusters
  - Output a text color table/map(s)
  - Parallel (MPI) and serial implementation

Current Work

- Distance visualization issues (simulation data at ORNL, scientist at LANL)
- Biology (AIDS phylogeny tree visualization)
- Petascale/exascale (extreme? ultra?) scale visualization
- Cyber security visualization (infovis)
- Personal future wishlist
  - Put my time-varying visualization methods into VTK and/or ParaView
  - More research into extending time-varying visualization and analysis