VACET

MEET THE SciDAC VISUALIZATION AND ANALYTICS CENTER FOR ENABLING TECHNOLOGIES

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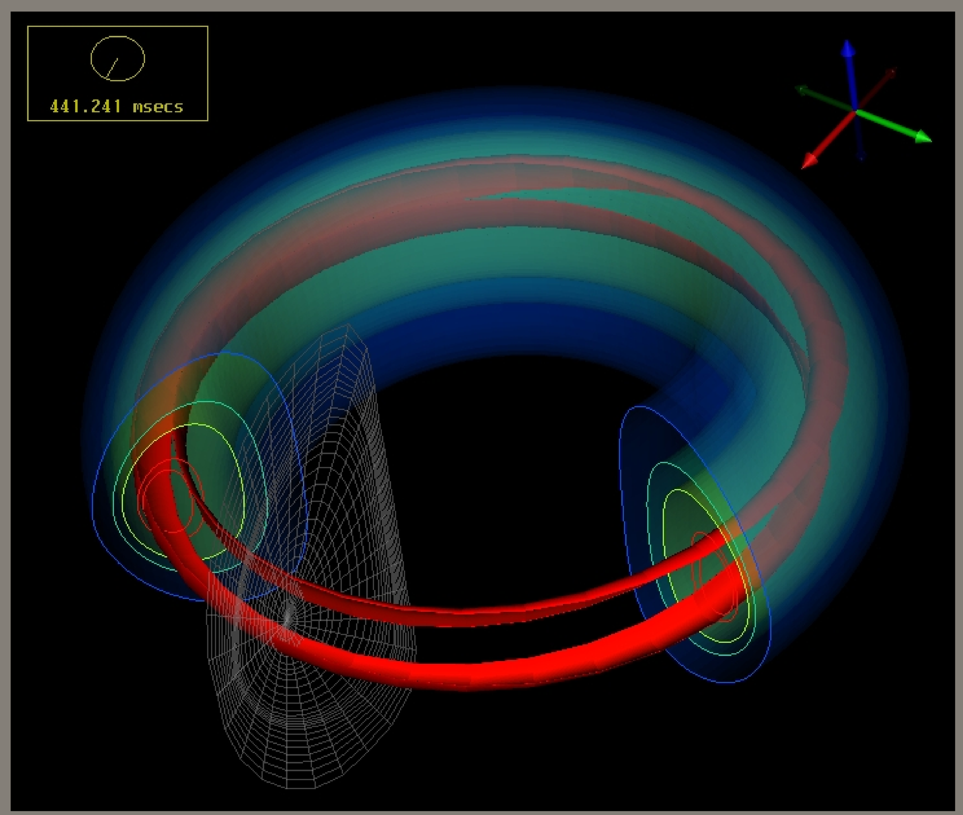
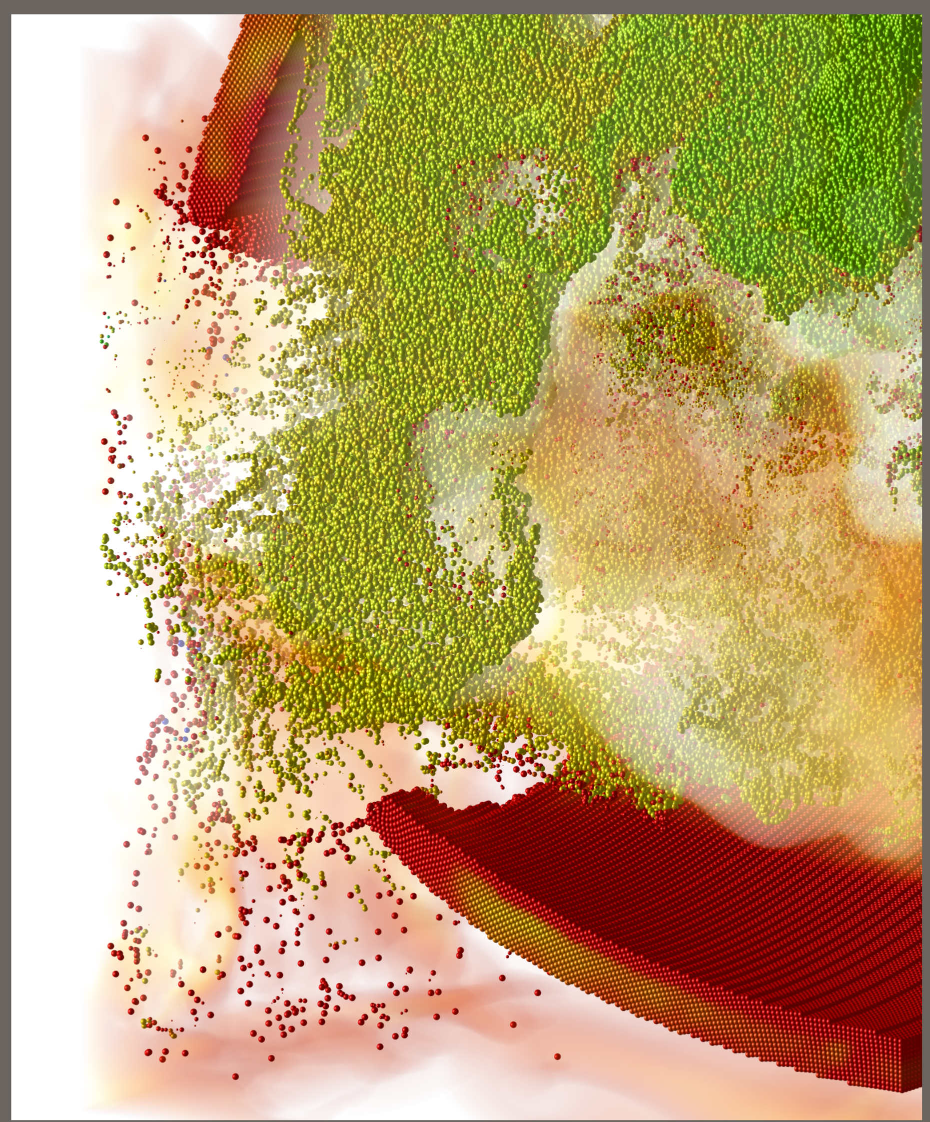
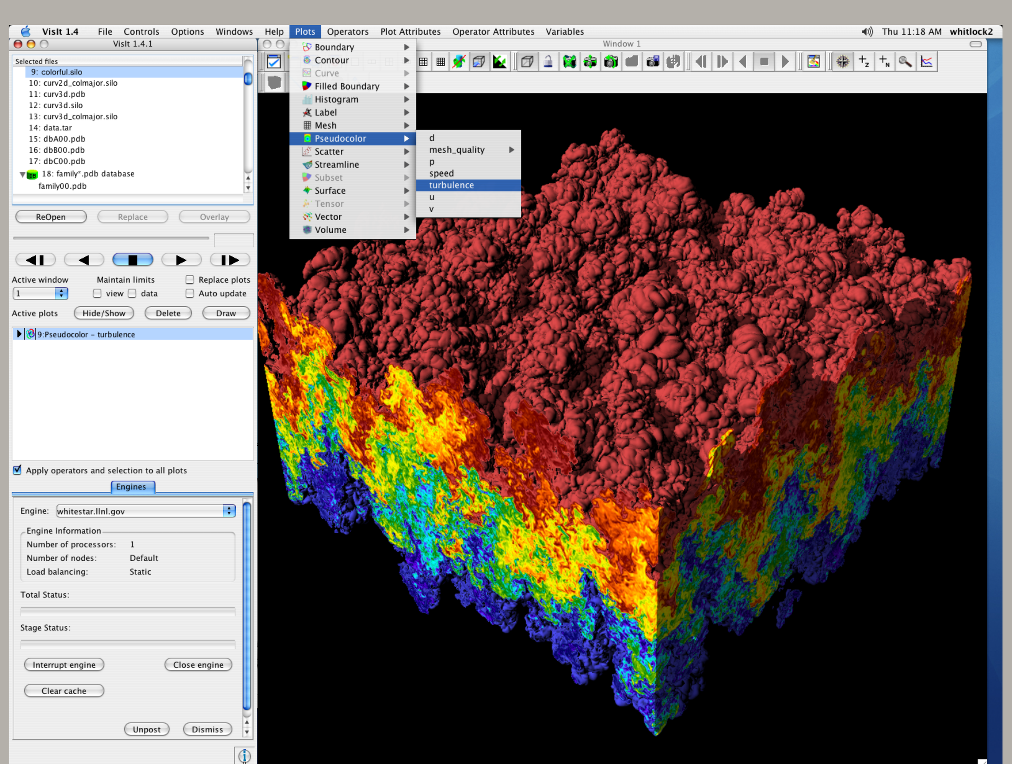


This visualization shows the topological analysis of magnetic islands from a NIMROD simulation of tearing modes started from an equilibrium fit of laboratory data from the DIID-D Tokamak that produced a reversed-shear discharge. In this case a 2:1 magnetic island colored by the plasma temperature has been detected and visualized as a surface. The island is surrounded by five iso-temperature surfaces representing four different temperature values. The twisting and winding of the 2:1 magnetic island is visible throughout. This visualization was done using the SCIRun / Fusion PSE, which was developed as part of the SciDAC CEMM.



Visualized is a sectional view of the rupturing of a steel container that is filled with a plastic bonded explosive and heated by a fire. The explosion lasts several milliseconds. The simulation terminates when fragments of the cylinder escape the computational domain. The final result of the simulation, as depicted here, was calculated using 146 hours of computation time on 600 processors utilizing both the ALC and Thunder computers at Lawrence Livermore National Lab. The data from 450 time steps of this simulation, including the 2.8 million particles per time step, was visualized interactively using the Real Time Ray Tracer (RTRT) a single Linux machine running 8 dual core Opteron processors (16 cores). The particles are colored based on temperature; particle size corresponds to particle volume.



VisIt is an Open Source, scalable, extensible turnkey application for petascale visual data analysis that received an R&D100 award in 2005. VisIt originated at LLNL as a production visual analysis tool for hundreds of ASC users. It has gone on to serve a large and diverse community outside ASC, as evidenced by tens of thousands of external downloads. Its extensible and flexible architecture, capabilities and features make it well-suited for use as a visualization and analytics delivery platform for meeting the needs of the SciDAC2 program.

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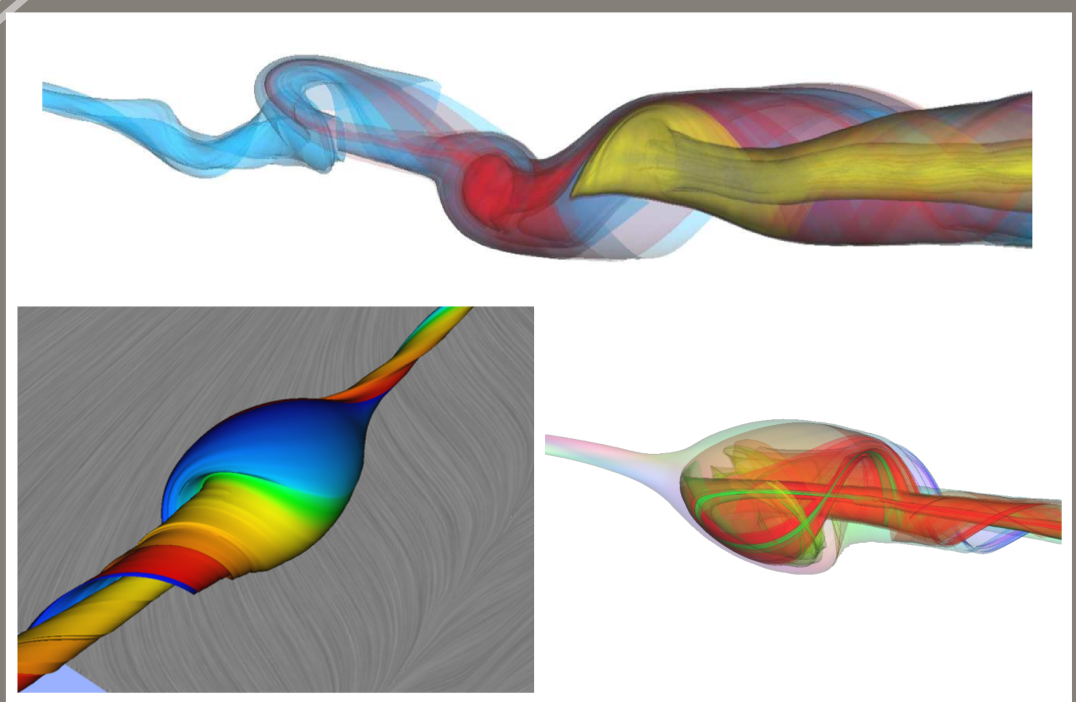
Launched in 2006 as one of nine centers under the Department of Energy's Scientific Discovery through Advanced Computing (SciDAC-2), VACET focuses on leveraging scientific visualization and analytics software technology as an enabling technology for increasing scientific productivity and insight. Advances in computational technology have resulted in an "information big bang," which in turn has created a significant data understanding challenge. This challenge is widely acknowledged to be one of the primary bottlenecks in contemporary science. The vision for our Center is to respond directly to that challenge by adapting, extending, creating when necessary and deploying visualization and data understanding technologies for our science stakeholders. Using an organizational model as a Visualization and Analytics Center for Enabling Technologies (VACET), we are well positioned to be responsive to the needs of a diverse set of scientific stakeholders, including other SciDAC projects, in a coordinated fashion using a range of visualization, mathematics, statistics, computer and computational science and data management technologies.

Techniques

Applications	Technical Point of Contact	Visualization: Integration of Basic Tools for Visualization and Analysis	Visualization: Publication Quality Images, Illustrations, and Movies	Visualization: Project-Wide Visualization Tools	Visualization: Flow Techniques	Visualization: Scalable Tools	Visualization: Remote Data Access and Streaming Techniques	Visualization: Collaborative Tools	Analytics: Query Driven Visualization	Analytics: Statistical Displays	Analytics: Feature Detection (topological analysis, semantic range queries)	Analytics: Temporal specific issues (feature tracking, events, …)	Analytics: Multiple Fields	Analytics: Comparative Visualization and Analytics	Analytics: Uncertainty Visualization
Fusion	Utah ORNL LBNL	●●	●		●	●		●●	●●●	●●●	●●	●●●	●●●	●●●	●
Combustion	LBNL LLNL ORNL	●	●●●		●●●	●●●	●●●	●●●	●●●	●●	●●●	●●●	●●●	●●	●
Acclerator	LBNL	●	●	●	●	●	●●		●●●	●●	●●●	●●●	●●	●●	●
Astrophysics	ORNL LBNL	●	●●	●	●	●●	●●		●●●	●●	●●	●●	●●●	●●	●
Turbulence	LLNL	●	●●●		●	●●●	●●			●	●●●	●●●	●	●	
Climate	LLNL ORNL	●			●	●●	●●		●●●	●●	●●	●●	●●	●●	●●
Environmental Management	LBNL	●	●●	●●		●●●	●●●	●●							

Our main goal is to develop and deploy a variety of data analysis and visualization tools for our science stakeholders. They have diverse data understanding needs, use a variety of computing resources, and are geographically distributed. Additionally, we want to leverage solutions developed and deployed for one stakeholder to many other projects. We address these challenges by using a flexible approach to software development and project management that draws from the diverse strengths of our team. Based upon specific input from science stakeholders – which include the fields of climate modeling, fusion, combustion chemistry, astrophysics and environmental management – we group their needs into two main categories: (1) visualization techniques, ranging from classical rendering techniques to the most advanced data streaming and remote data access algorithms for managing extremely large datasets, and (2) analytics techniques, including data exploration, feature extraction, tracking and comparison that aid the scientist in the actual information discovery process.



Top: Topological structure of a vortex breakdown in a simulation of a delta wing with low speed and high angle of attack. Stream surfaces in red and yellow show the separating surfaces emanating from two stagnation points that bound a so-called recirculation bubble.

Bottom left: Stream surface visualization of a recirculation bubble.

Bottom right: Same visualization using transparency to reveal the intricacy of the flow patterns inside the recirculation bubble.

Query-driven visualization and analytics refers to the process of limiting visualization and analytics processing to data a user deems "interesting." This approach offers a promising alternative for high performance visualization and analysis by quickly finding, showing and analyzing "needles in haystacks." QDV is built upon a combination of technologies from scientific data management, visualization and analytics.

The example below illustrates how QDV technologies are applied to discovery and characterize a distributed network scanning attack hidden in a hero-sized data set consisting of 42 weeks' worth of network connection data.

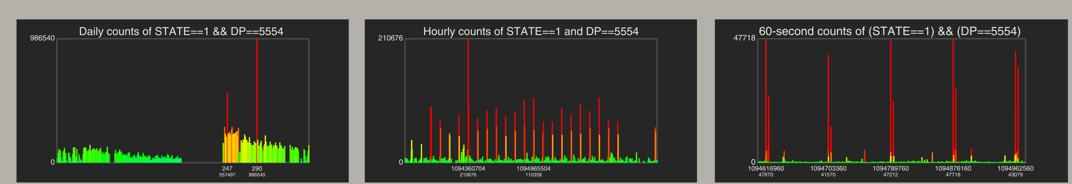


Figure 1: Histogram showing number of unsuccessful connection attempts over one year with daily temporal resolution. Red bars indicate three standard deviations or greater variance from mean values, which are shown as green bars.

Figure 2: Drilling in to a finer temporal resolution – four weeks with hourly resolution – we see regular, organized unsuccessful connection attempts.

Figure 3: Drilling in to an even finer temporal resolution – five days at one-minute resolution – we see suspicious activity occurring every day at precisely 21:15 local time.

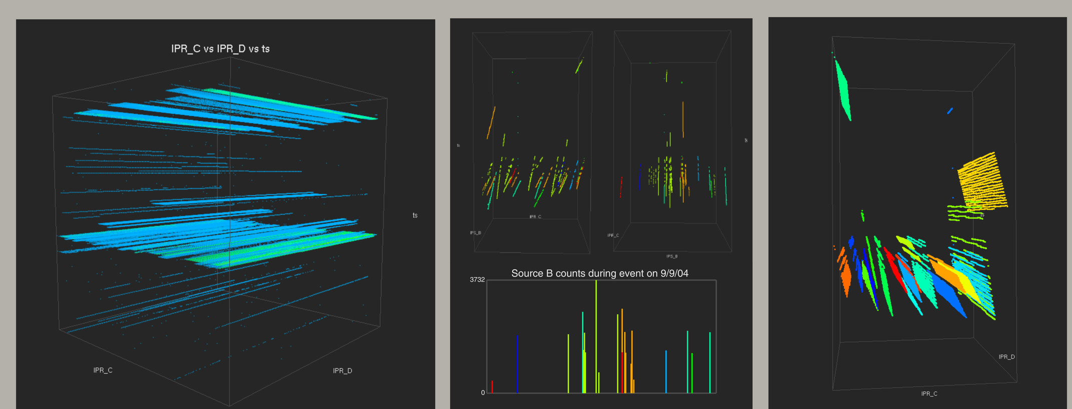
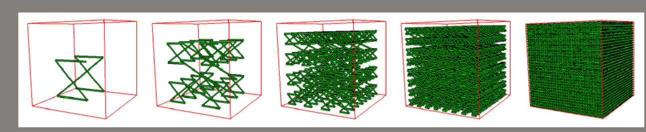


Figure 4: To confirm these events are indeed attacks, this 3D histogram shows organized coverage in the destination address space.

Figure 5: We use multiple views and visual display formats in conjunction with queries to identify the source addresses of the attacking hosts.

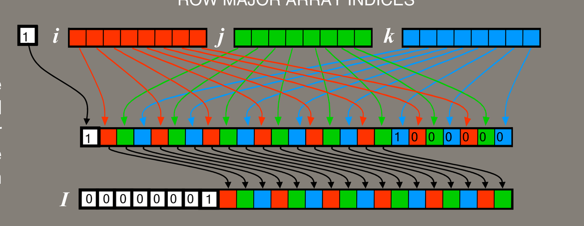
Figure 6: This histogram shows the destination address space being attacked by each of the twenty hosts participating in the distributed network scan.

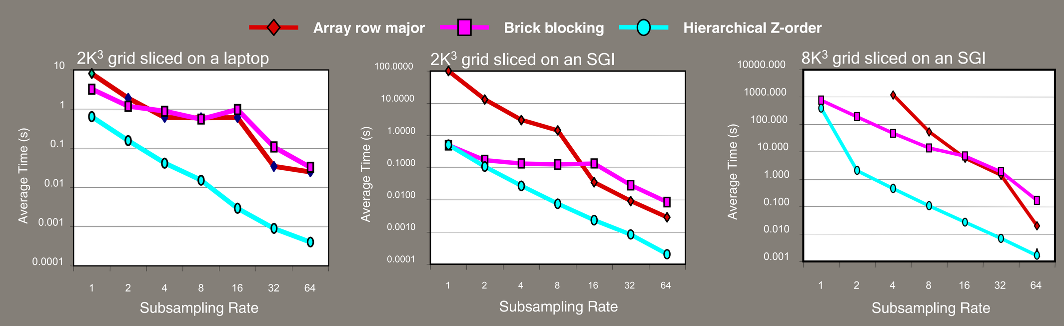
We achieve real time exploration of large regular grids via a novel hierarchical z-order data layout combined with progressive computation of output slices or volume rendering.



We use the 3D z-order space filling curves to define a hierarchical subsampling of a regular grid.

Simple bit manipulations allow to compute the address of a data sample in hierarchical z-order from the original (i,j,k) row major array index. This allows to combine the coarse-to-fine progressive traversal with fast direct data access.





Practical performance tests show order of magnitude improvement with respect to previous storage layouts and scalability with respect to both data size and computing resources available.

The VACET team has developed innovative data-level comparative visualization techniques. Our parallel-capable implementation provides the ability to perform quantitative "A vs. B" comparisons, which forms the basis for temporal, ensemble and experiment vs. simulation analyses. This important new capability is implemented in the Visit production visual analysis application (figure 1).

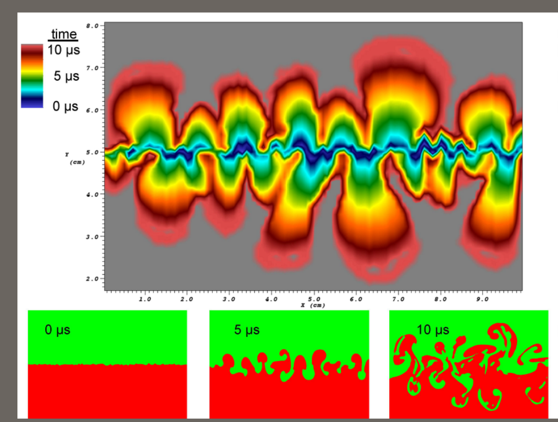


Figure 1: Comparative visual analysis of a time-varying 2D slice from a Rayleigh-Taylor instability simulation. The bottom three images show mixing at three different time steps – heavy fluids are green, light fluids are red. The top image shows mixing rates over all time steps. Blue areas mixed early in the simulation, while red areas mixed later. Gray areas did not mix during the simulation. This plot allows us to observe mixing rates as well. We can see that the mixing rate increased as the simulation went on since there is more red than blue in the picture.

Figure 2 shows visual and comparative analysis of results from an ensemble of Rayleigh-Taylor instability simulation runs. The objective is to understand the relationship between a subset of input parameters – turbulent viscosity and coefficient of buoyancy – and the resulting mixing rate.

The upper left image shows a 2D slice from a single simulation colored by velocity magnitude. The upper right image is colored by the ensemble simulation index having the greatest velocity magnitude at each grid point and shows that no one simulation dominates. The lower left image is colored by buoyancy coefficient at each grid point of the simulation having maximum velocity. It indicates the buoyancy coefficient parameter is not significantly related to maximum velocity. The lower right image is colored by turbulent viscosity value at each grid point of the simulation having maximum velocity. It suggests that high velocity values are strongly correlated to very low (blue) or very high (red) turbulent viscosity coefficients.

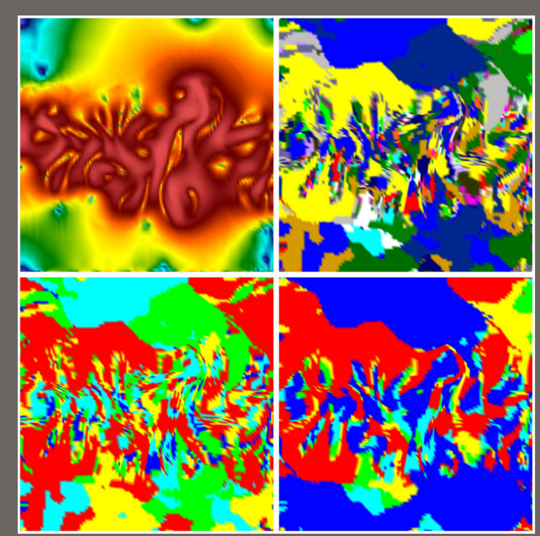
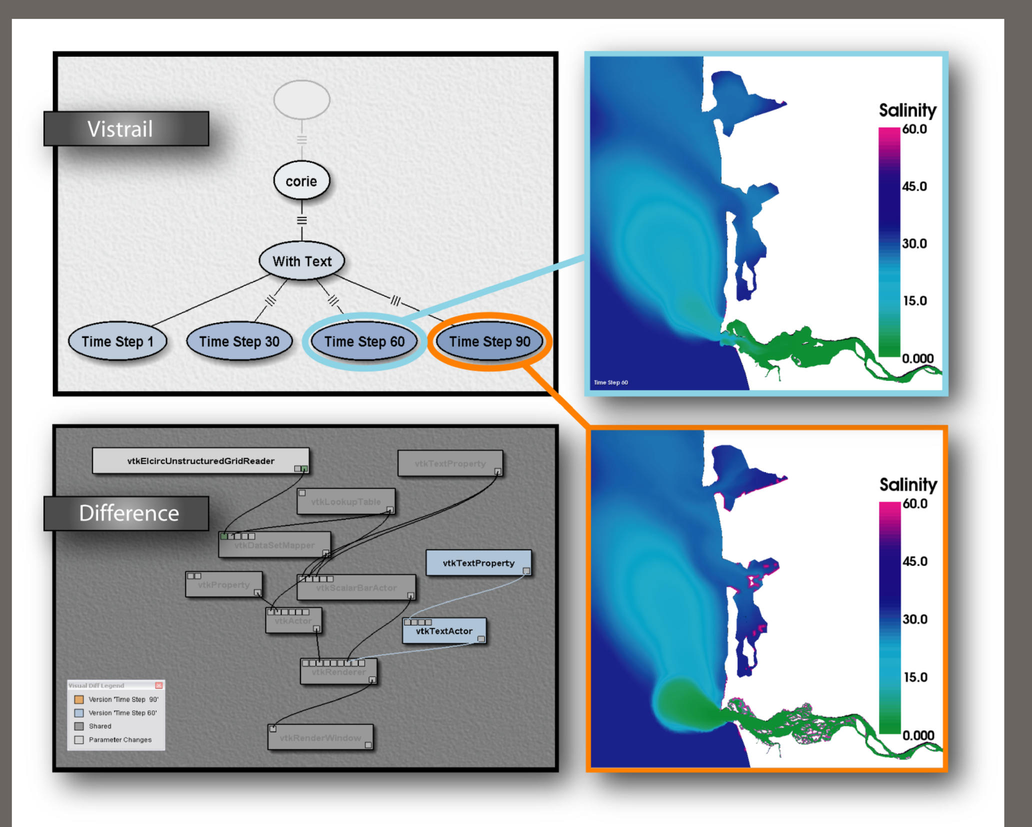


Figure 2

VisTrails



Another approach for comparative analysis is to quantify the differences in methodology used to produce visualizations, analysis, simulation or experimental results. VisTrails is a system for recording ordered actions for the purpose of later comparative analysis. The example shown here illustrates the difference in workflows used to produce two different visualizations.