

Ubiquitous Interactive Visualization of 3-D Mantel Convection Via Web Application Using Java and Ajax Framework



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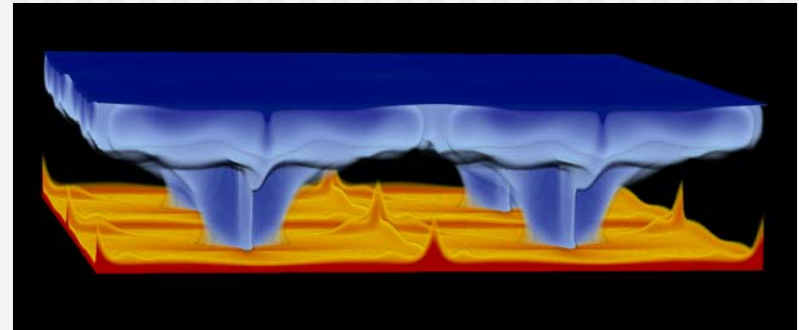
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Outline

1. Introduction: raison d'être, onslaught of petascale computing, the “data tsunami”
2. LCSE visualization system
3. 3-D numerical model ACuTEMan, by Charley Kameyama
4. Demands of interactive visualization
5. Examples
6. Emerging paradigm in numerical modeling and visualization

Petascale Computing

**It's sink or swim
as a tidal wave of
data approaches.**



The Devil Is in the Details

TERRAIN
Mountains and coasts, which can influence regional climate, are vaguely defined in even the best global models. Most models can evaluate natural features in blocks about 150 miles on a side.

Winds push against the ocean, creating waves and currents.

Low clouds block solar radiation and cool Earth.

Locally, mountains help clouds develop. Globally, they affect circulation.



OCEAN CIRCULATION
More precise models can represent specific phenomena clearly.

ICE SHEETS, GLACIERS

SEA ICE

WINDS
Clouds and waves

LAND LIFE

LAND COVER
Vegetation absorbs carbon dioxide, and it affects the land's reflectivity.

PLANTS
Microscopic plants pull carbon dioxide from the atmosphere through photosynthesis.

Deep currents help port heat globally. Eddies, or turbulence, mix warm and cold water locally.

GULF STREAM

The Hadley Center in Britain improved its simulation of the Gulf Stream after roughly doubling ocean resolution.

Computers would need hundreds of times more power to reach the resolution of the model at right, with blocks 20 miles on a side.

National Center for Atmospheric Research

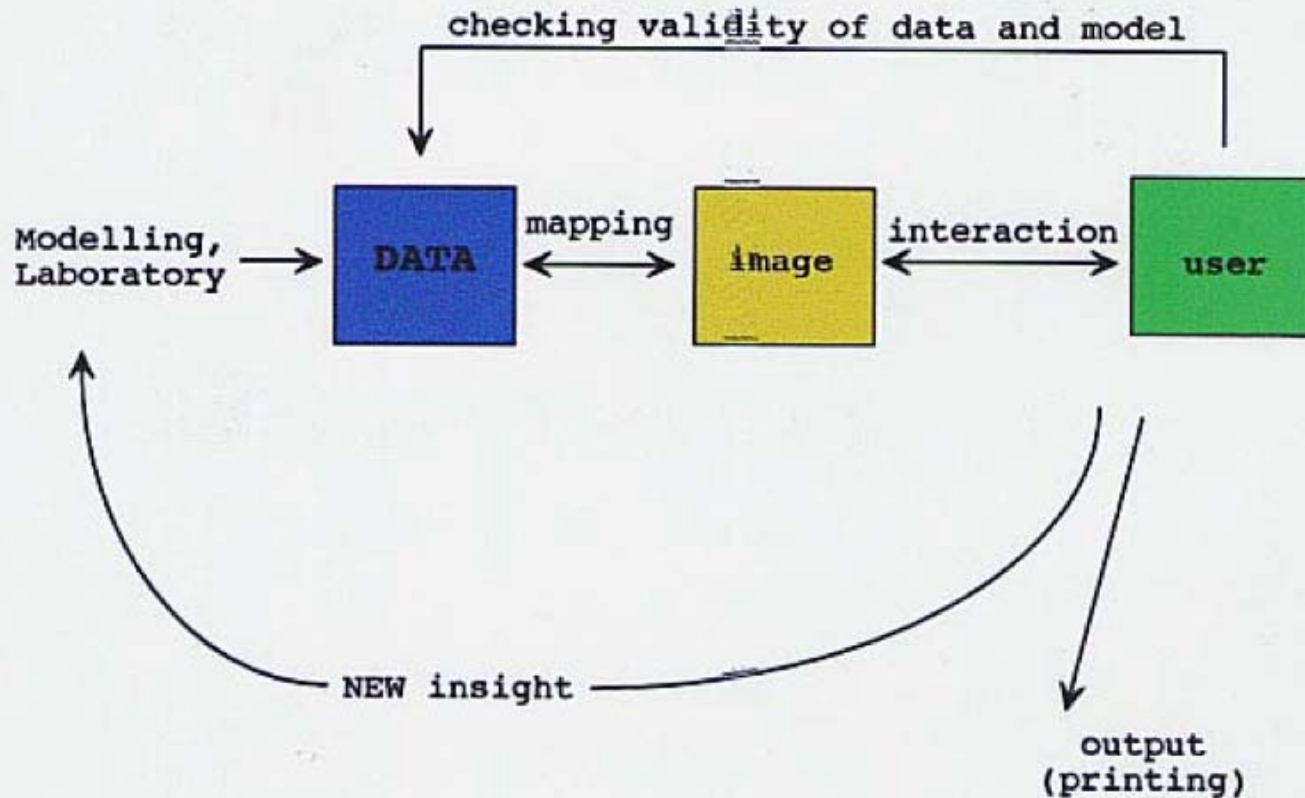
Image courtesy of the Sun, York, Canada

Source: NASA, Intergovernmental Panel on Climate Change; Dr. Geoff Jenkins, Hadley Center for Climate Prediction and Research; Dr. Curtis C. Covey, Lawrence Livermore National Laboratory; Dr. David Viner, Climate Impacts LINK Project, University of East Anglia (Britain)

Large 3-D Data Sets

- Can 3-D time dependent data sets be visualized on the fly?
- Seismology advancements: **2000x2000x2000** points from 500x500x1000 points!
- Wave patterns must be extracted from seismic calculations.
- This is more manageable using curvelets (De Hoop) for decomposition.

Challenges of Large Data Sets



Can we do this interactively and collaboratively?

Why Visualization?

- Numerical simulations and field experiments produce extremely large datasets
- Petascale computing: in 2002 it was a dream, but by 2012 it is a reality, like Global Warming
- The size of these datasets are increasing exponentially fast, with resolution
- Numerical output (e.g. tables) does not lend itself to easy comprehension
- We need new dynamical display of fields for unraveling new physics

Post-Processing Visualization

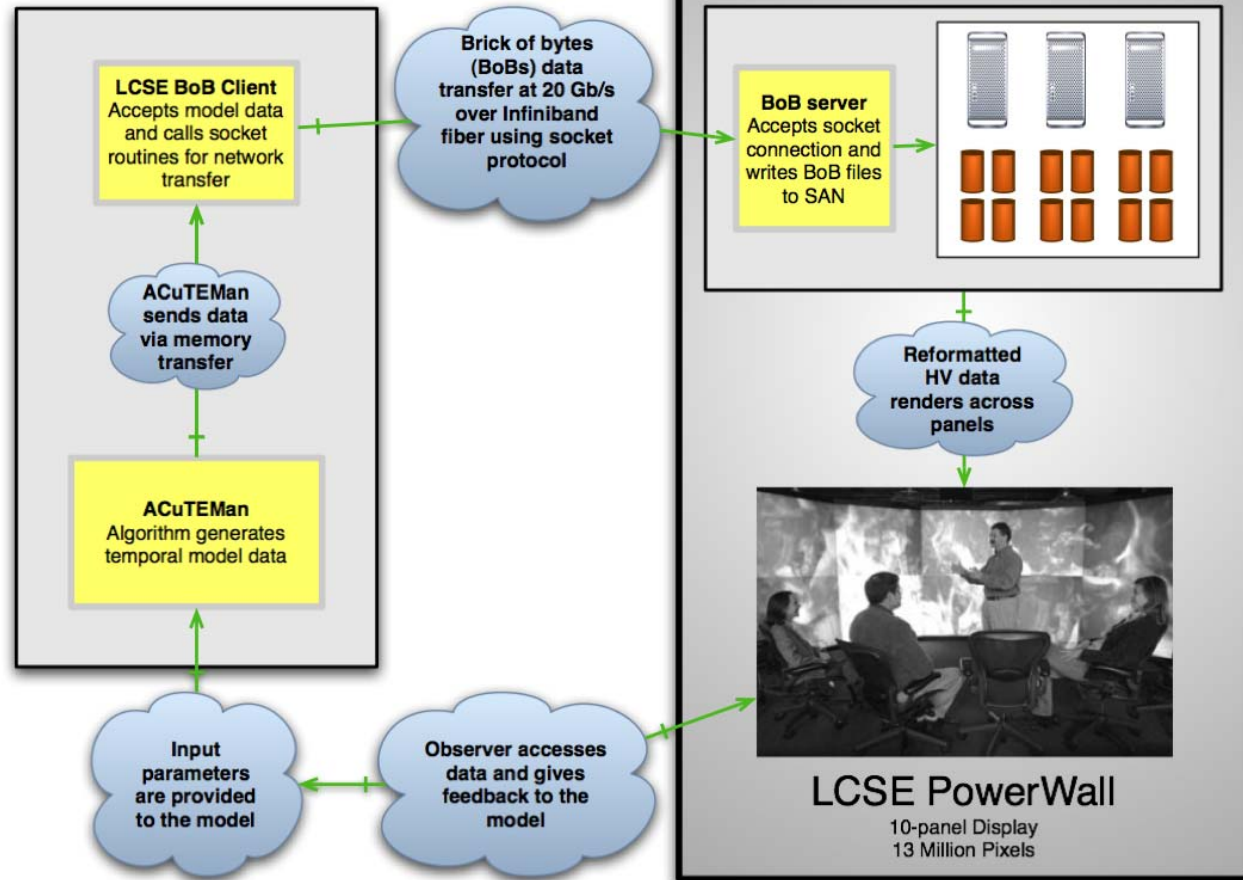
- Start with raw data files from HPC system
- Results are analyzed to determine the best visualization techniques
- Human spends a lot of time learning and using software packages
- **There is a need to automate these steps for a much faster turn around**

LCSE Visualization System

- Raw data from the BladeCenter is transferred over Infiniband using a client-server application
- 3-D results are rendered as a volume at LCSE
- Researchers use DSCVR software to interact with data
- Data can be displayed on high resolution Powerwall

MSI IBM BladeCenter Linux Cluster

1168 Cores Total
Dual-core 2.6 GHz
AMD Opteron Processors
8 GB RAM per Node



Closer look at LCSE system

LCSE PowerWall 13 Million Pixels



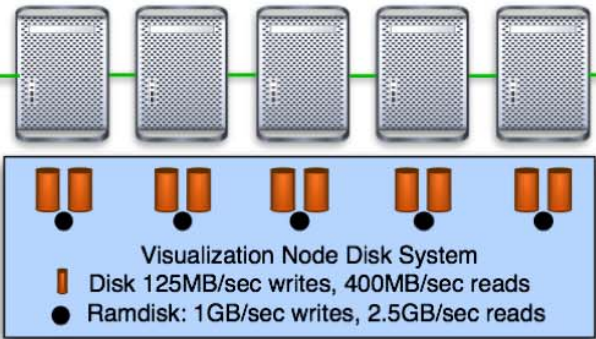
Users adjust visualization parameters

Visualization Control PC

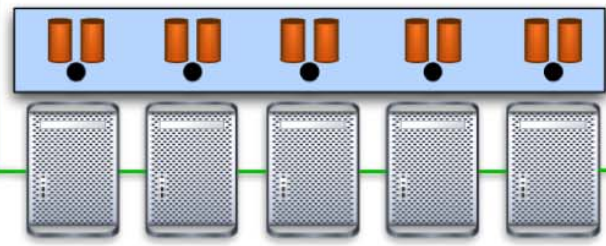


Images for rendering

Dell 670n Precision Visualization Nodes



Infiniband Interconnect
transfer rates > 630 MB/s

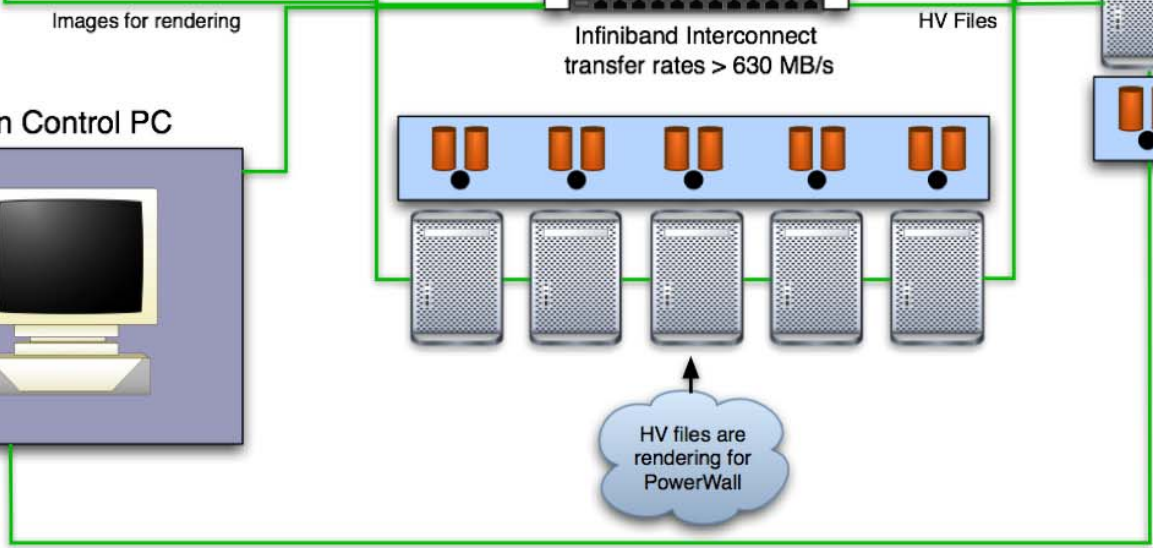
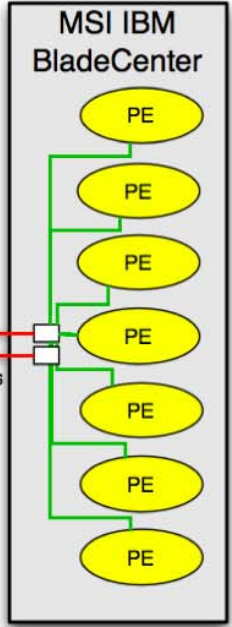


HV files are rendering for PowerWall

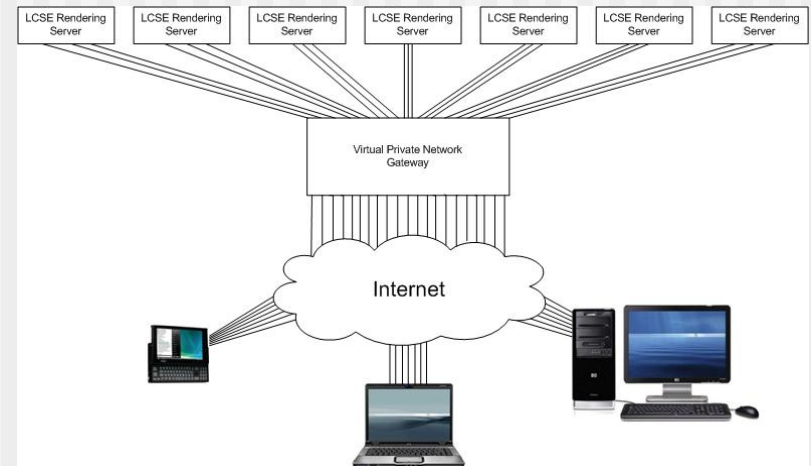
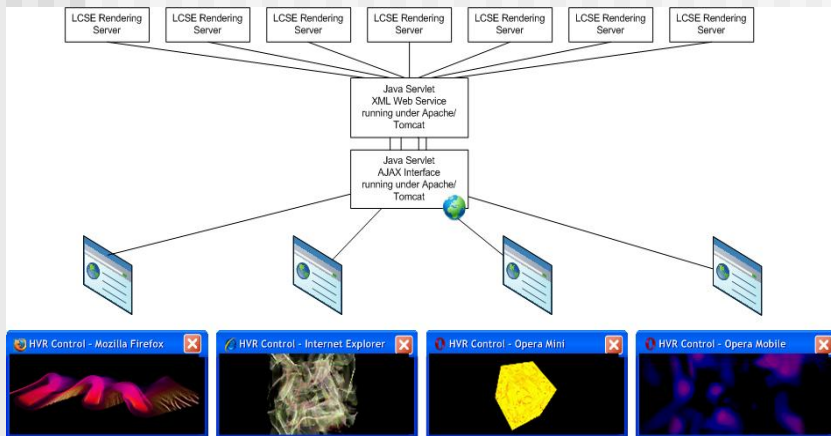
Performs BoB to HV conversion
LCSE Front Visualization Node



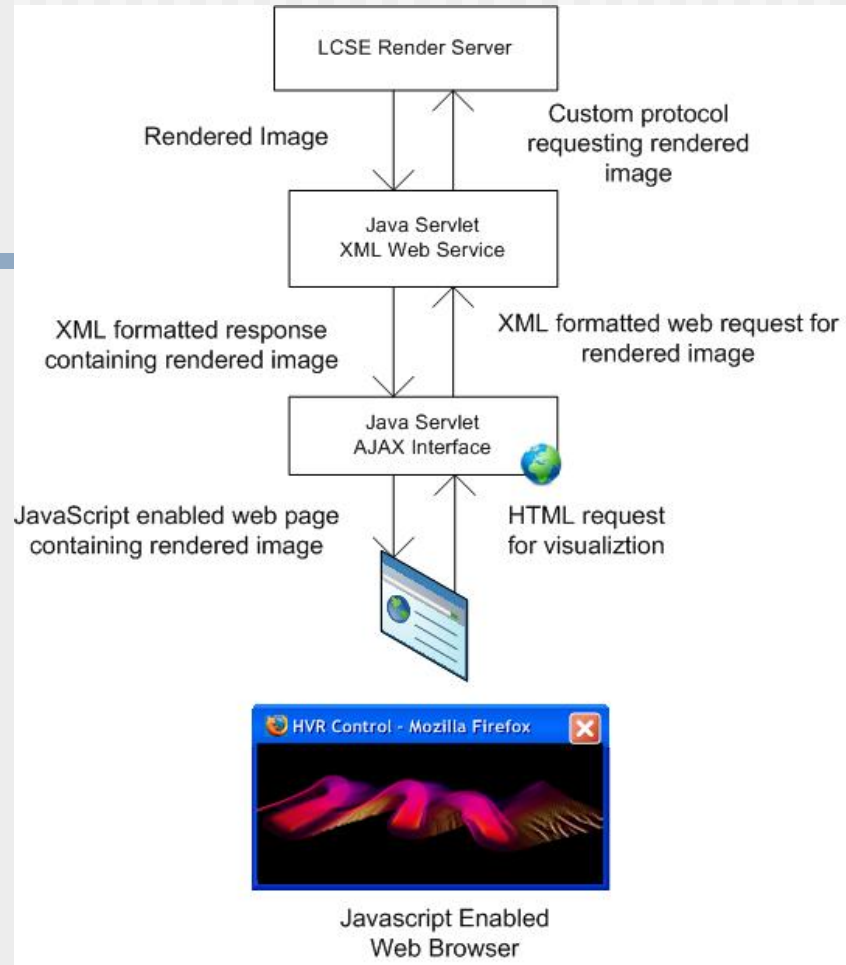
PEs send output data over dual Gigabit links



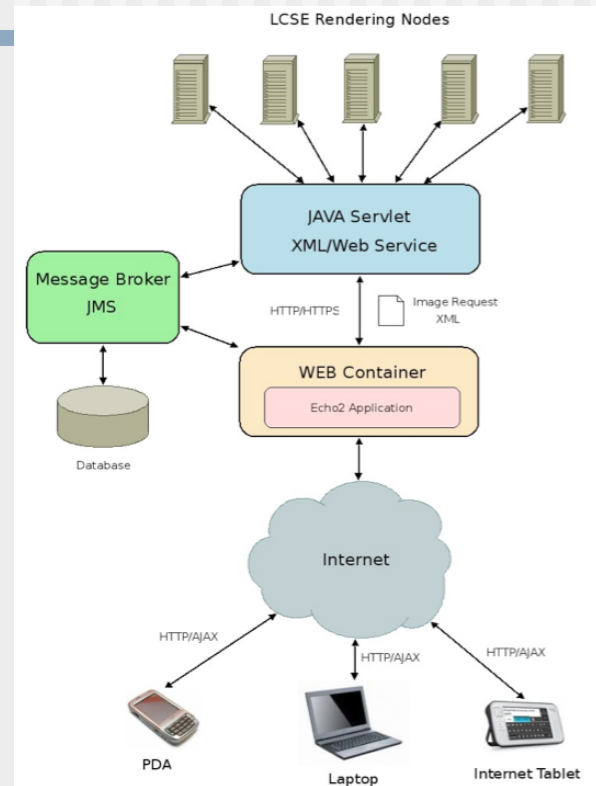
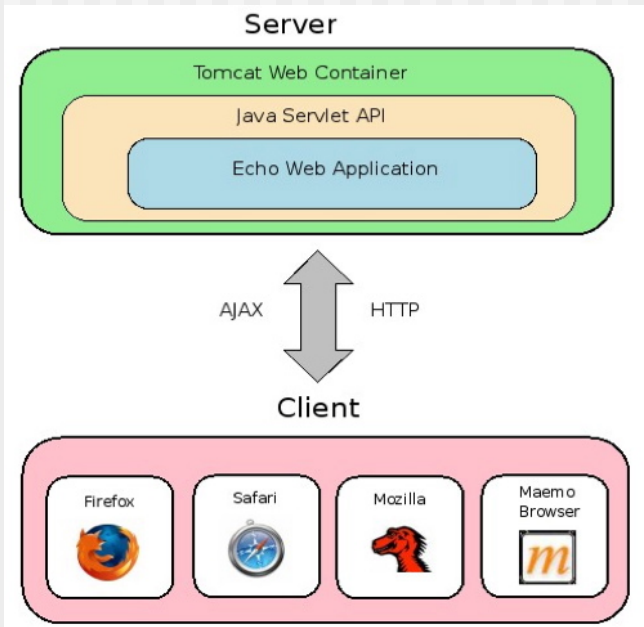
Software



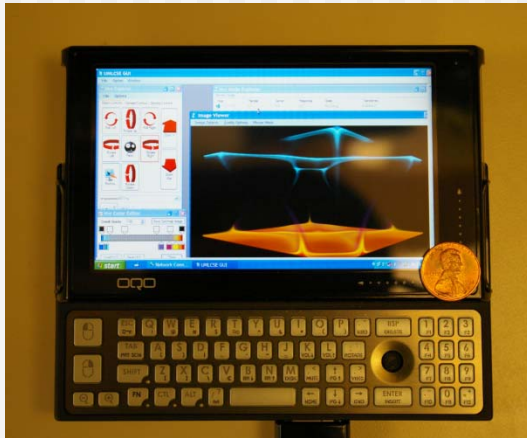
This is a schematic diagram showing the hierarchy of our visualization rendering web service under an Ajax interface using Java. We stress here the simplicity of the implementation, as compared to the use of VPN protocol shown in the figure on the right.



Detailed diagram showing the message passing and receiving scheme used in interactive visualization with javascript.

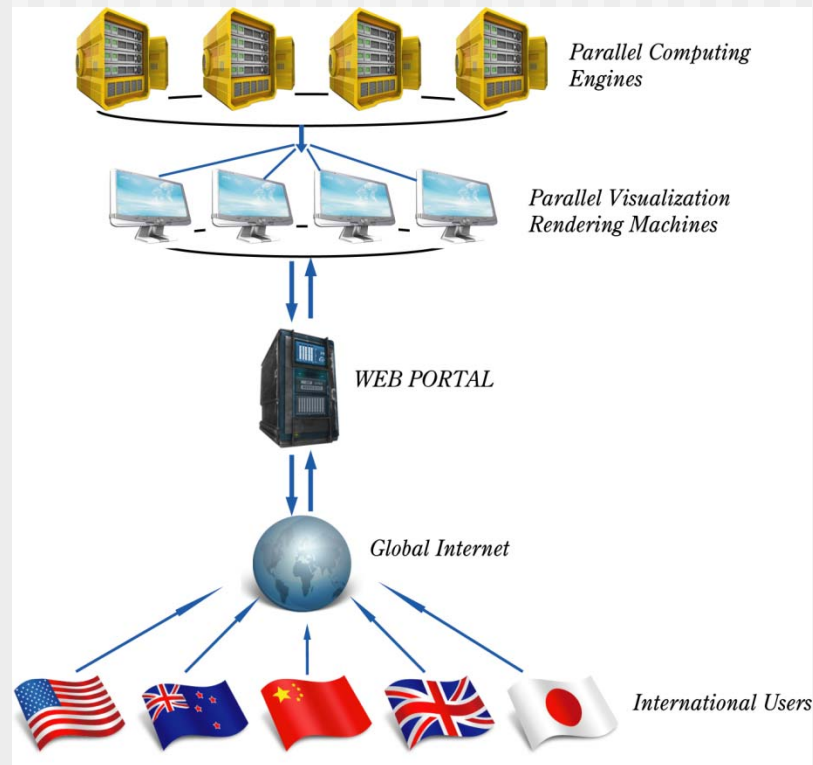


Client – Server message passing



Mantle convection data being interactively visualized on hand-held devices. The OQO on the left runs Windows XP while the Nokia on the right is running a version of Linux.

Summary of the ubiquitous interactive visualization concept via the Web-Portal paradigm.

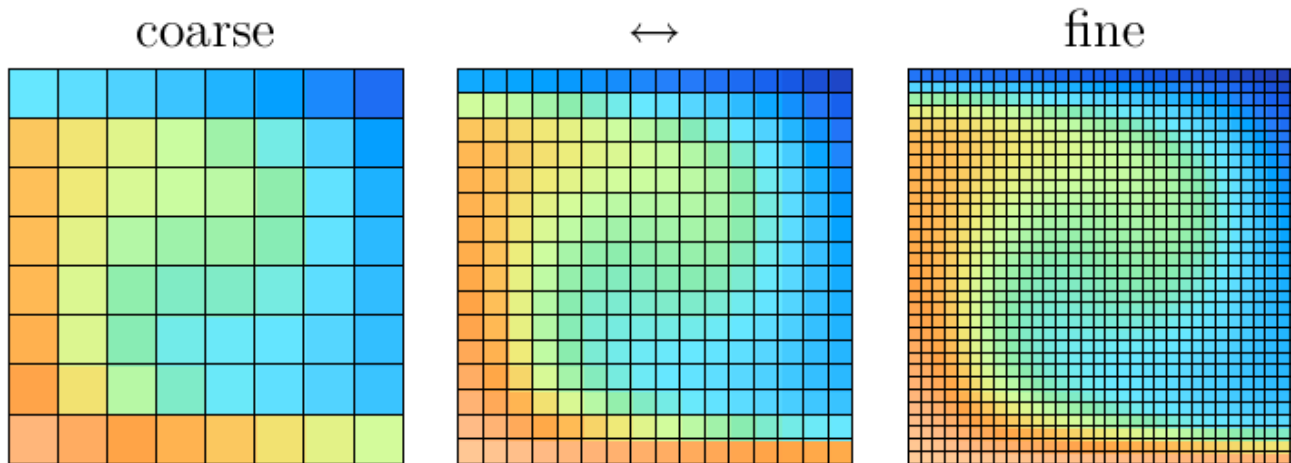


ACuTEMan

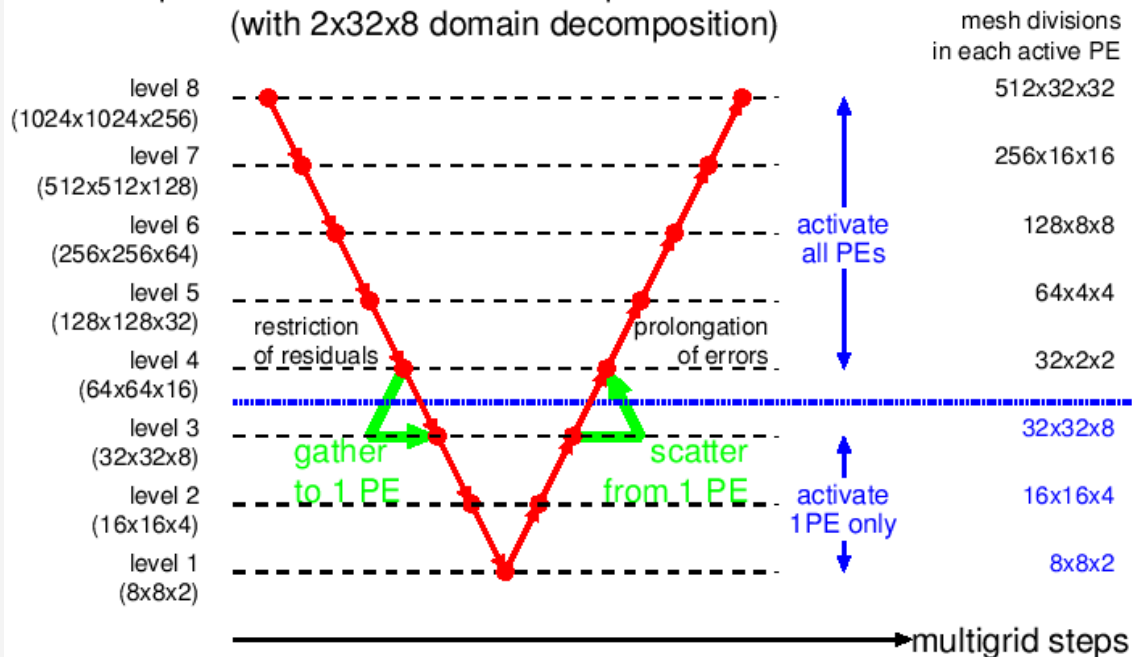
- Written by Charley Kameyama, who is moving to Ehime University in September 2007
- Parallel, multigrid cartesian, finite volume code, written for vector parallel computing using MPI-2
- Benchmarked at 3.4 Teraflops a Supercomputing 2005 in Pittsburgh
- Generalized to Yin-Yang grid for 3-D spherical geometry and recently executed on the Earth Simulator. Variable viscosity contrast up to ten thousand across adjacent grid points

*Kameyama, Kageyama, Sato, J. Computational Physics, 2005 Kameyama, J. Earth Simulator, 2006.

Multigrid Method



example for 1024x1024x256 mesh problem with 512 PEs
(with 2x32x8 domain decomposition)



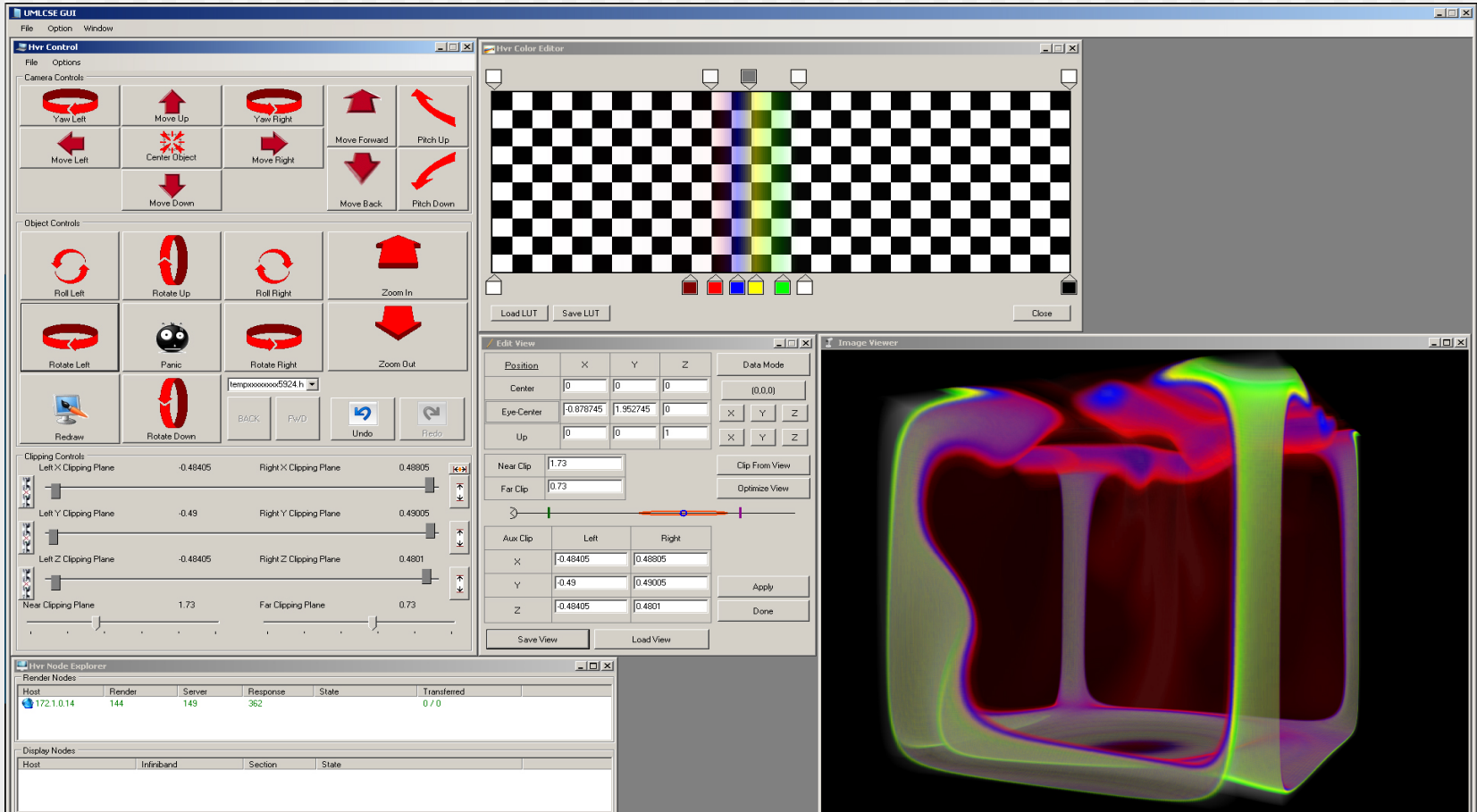
Demands of Petascale Computing

- 5 hours on 3-D grid with 2000x2000x2000 grid points
- 5 grid fields x 4 bytes storage every 5 minutes (or thousand time steps) on a linear scale with 5,000 cores
- $2000 \times 2000 \times 2000 \times 5 \times 4 \times 60 = 9.6$ TB
- 40 runs -> **384 TB of raw data** - AND we are only storing every 1,000 time steps (stingy)!
- Solutions:
 - Stream raw output data to visualization system in real time to generate movies - data compression
 - Interactive visualization with real-time simulation - avoid saving most of the data

Need for Software & Hardware Solutions

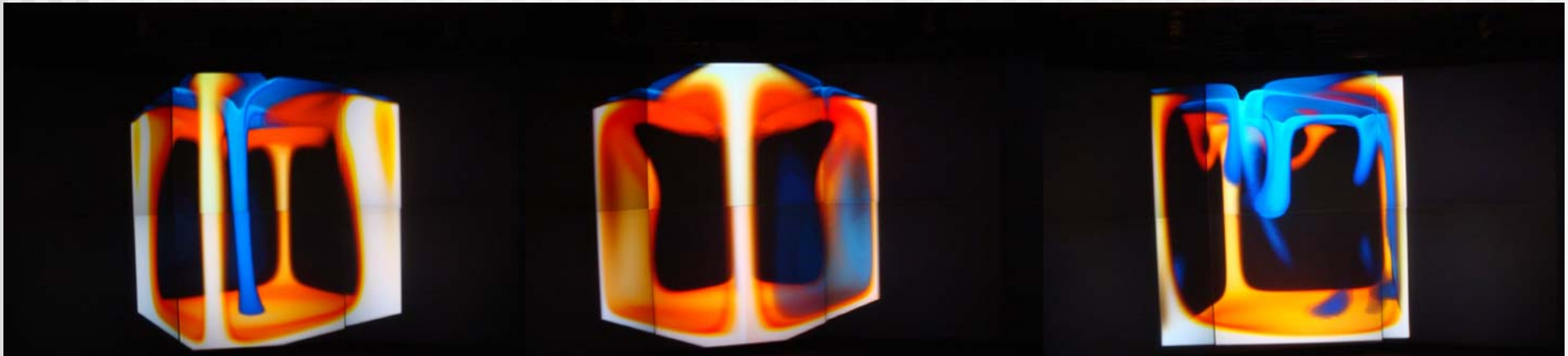
1. Collaborative mode of visualization whereby we can communicate readily upon viewing a common image
2. Storage capabilities at a central site on demand
3. Web-portal services for controlling our desires

Results - Real-time Interactive Visualization with LCSE DSCVR



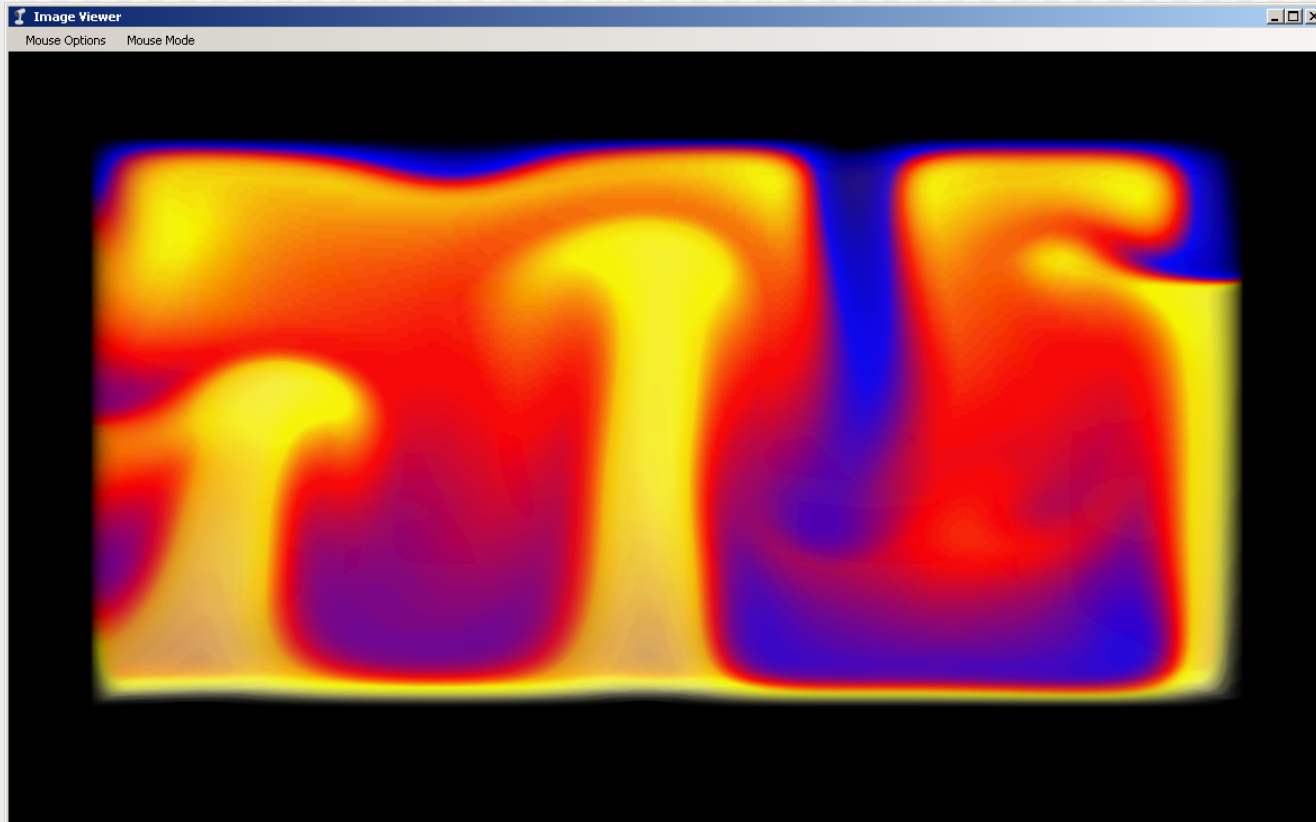
128x128x128 grid points rendering in real time across 128 PUs

Results - Real-time Interactive Visualization with LCSE Powerwall



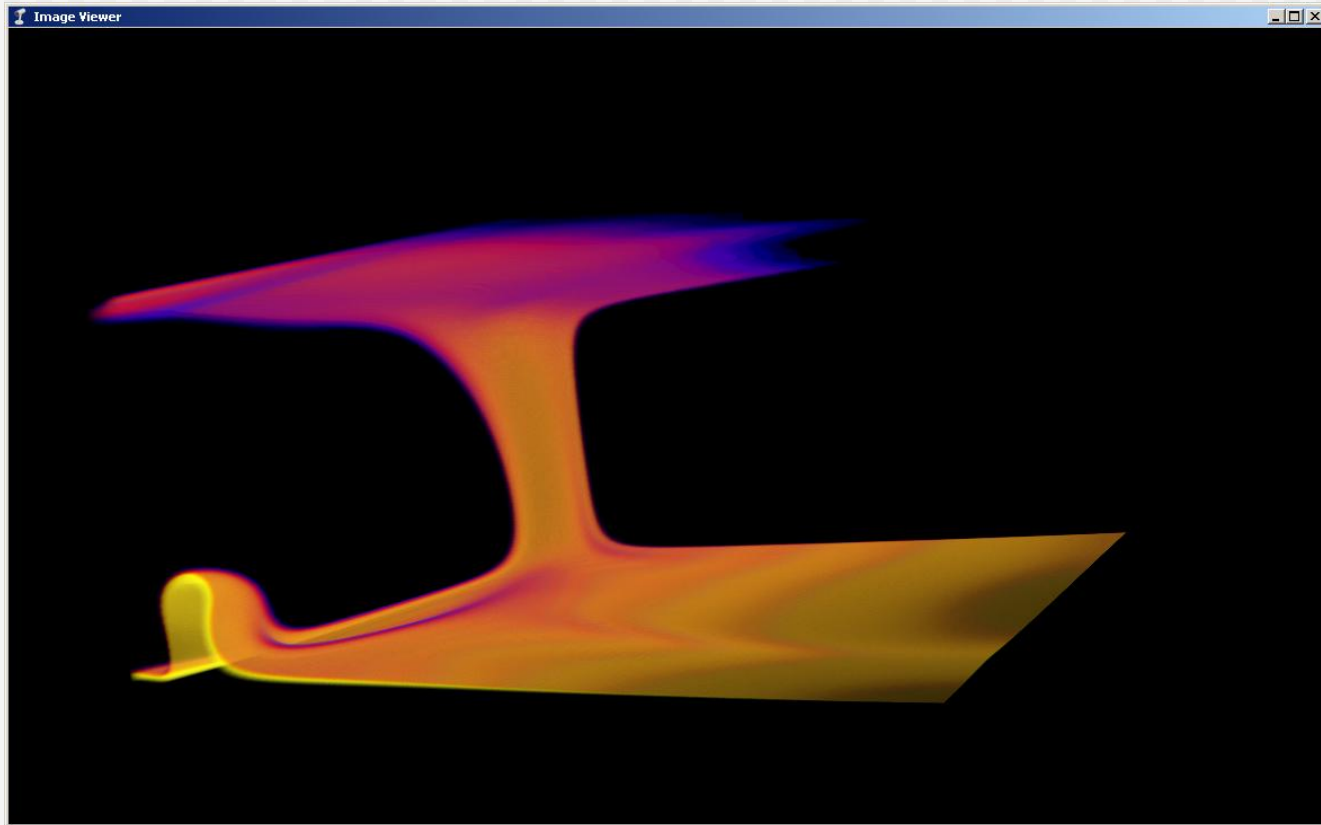
128x128x128 grid points rendered in real time across 128 PUs
Displayed on 13 megapixel Powerwall
Rayleigh number = 10^6

Results - Larger Grid, More Processors, Higher Rayleigh Number



128x256x256 grid points rendered in real time across 256 PUs
Time step 2,700
Rayleigh number = 4×10^6

16,000 time steps later...

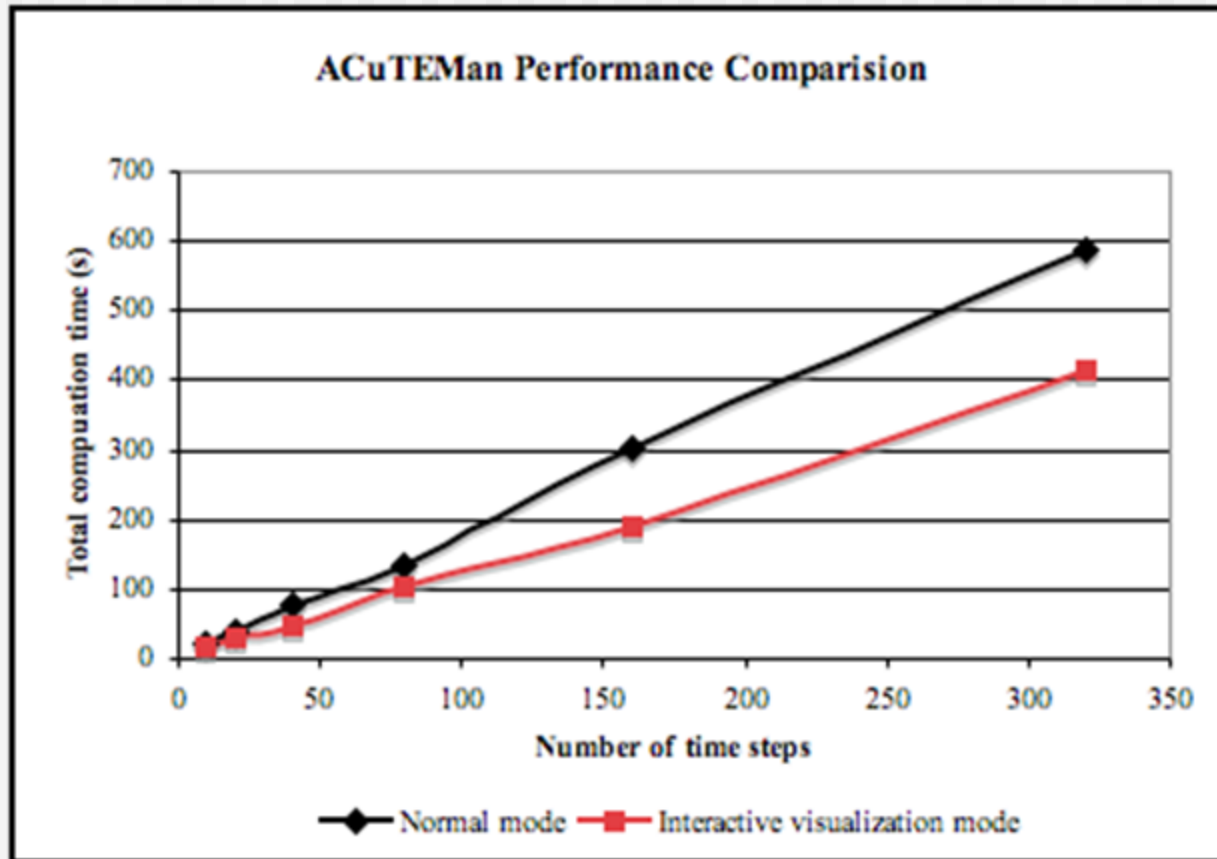


128x256x256 grid points rendering in real time across 256 PUs

Time step 19,000

Rayleigh number = 4×10^6

Results - Performance gains



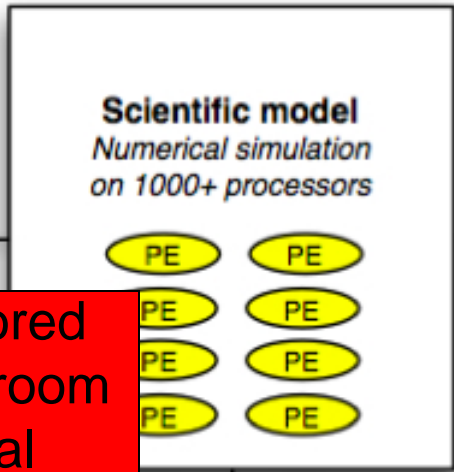
**Total compute time reduced on average by 30 %
Local disk space on Supercomputer also reduced**

Interactive Computing

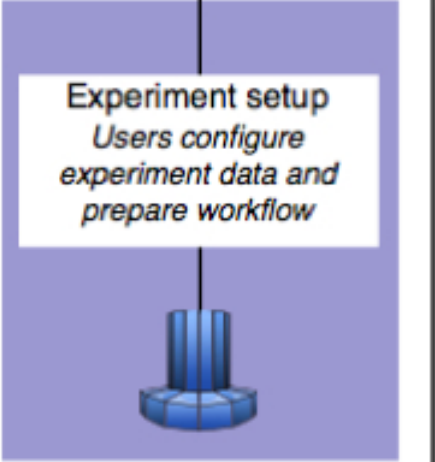
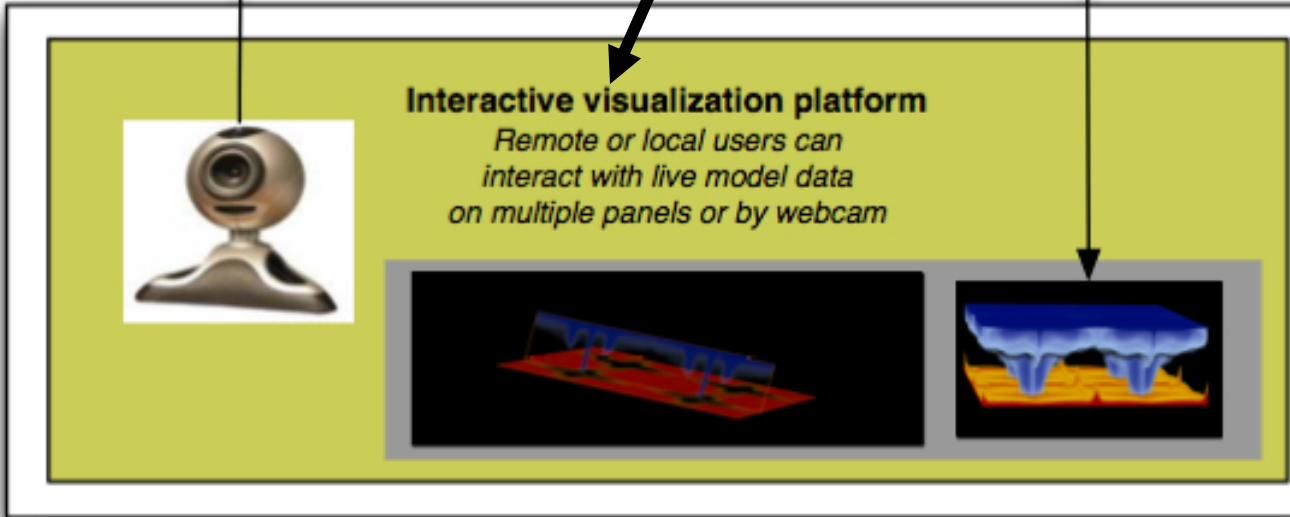
- Limited time duration, perhaps 1 or 2 hours
- Balance between grid resolution and number of processors
- Few frames to one frame per second
- Runs can be monitored from remote locations



Runs can be monitored from home or hotel room using a web portal



Restart files for experiments are loaded and stored from disk

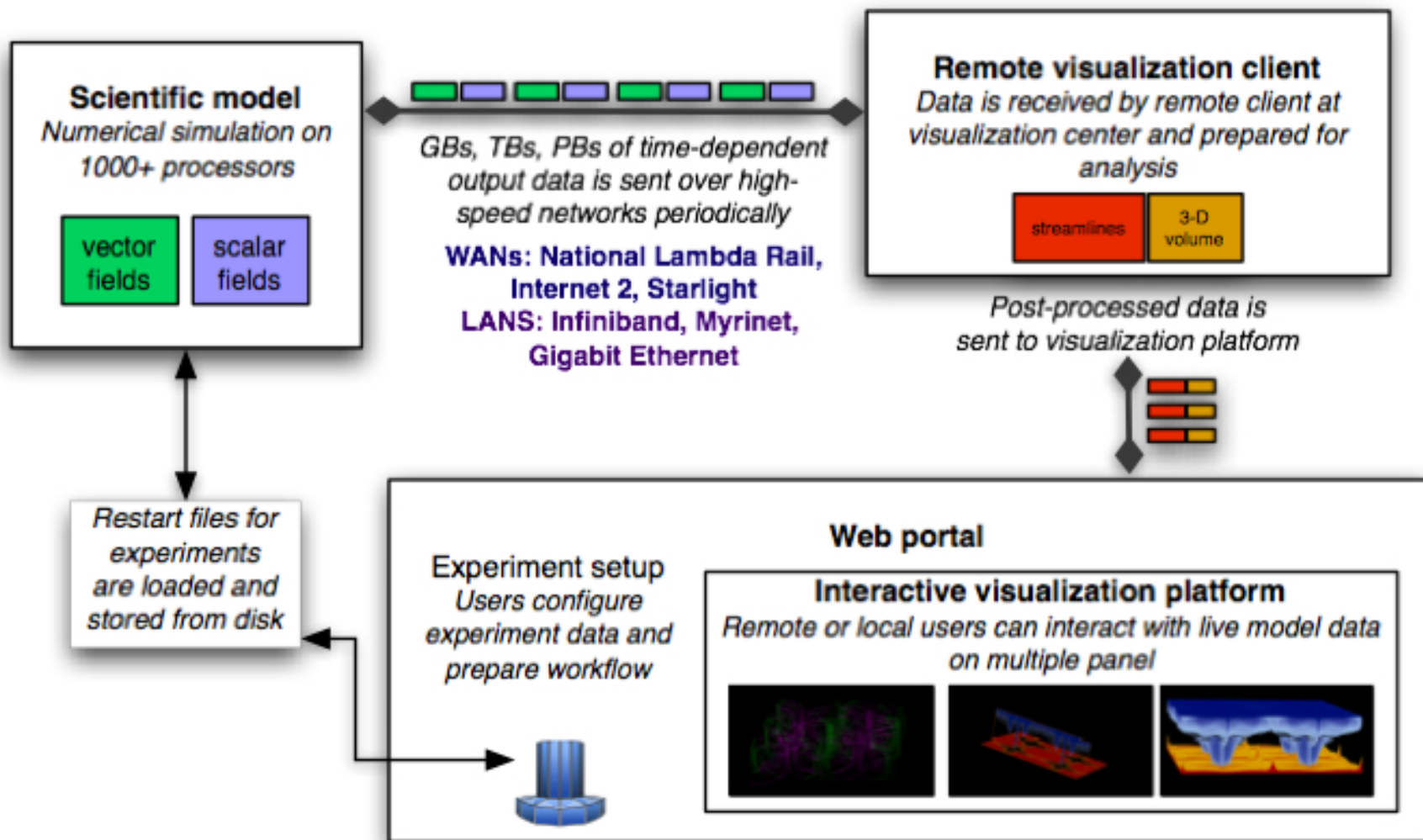


Interactive Visualization with Nokia N800

- Small-display system
- Anti-glare screen
- Currently investigating N800 as a stand-alone visualization system for Geophysical applications
- Pervasive visualization - visualize anywhere, anytime on mobile devices

New Paradigm in Numerical Modeling

- Disks are a well-known bottlenecks that slow research
- We need real-time computing combined with interactive visualization for fast feedback and results
- We can leverage high speed networks instead of disks to reduce storage requirements
- Web services for remote collaborations
- Streamlined visualization techniques
- This will drastically reduce storage requirements and save compute time
- We can run a model to analyze results instead of pulling results from an archive
- Short interactive periods



Summary

1. The imminent arrival (2011) of petascale computing makes it imperative that we develop some strategy for visualizing the flood of time-dependent 3-D data and simulations.
2. Interactive visualization of 3-D convection is feasible now with the deployment of hundreds of processors together with a fast network, multi-Terabyte storage at each visualization node. Large-display devices (CAVE, PowerWall) and web-portal services will allow for collaborative research.
3. This mode of operation (via a client-server application) will eventually be used by many parties around the world. A new paradigm in large-scale numerical modeling is now at hand.