Streaming Multi-Resolution Distance Visualization

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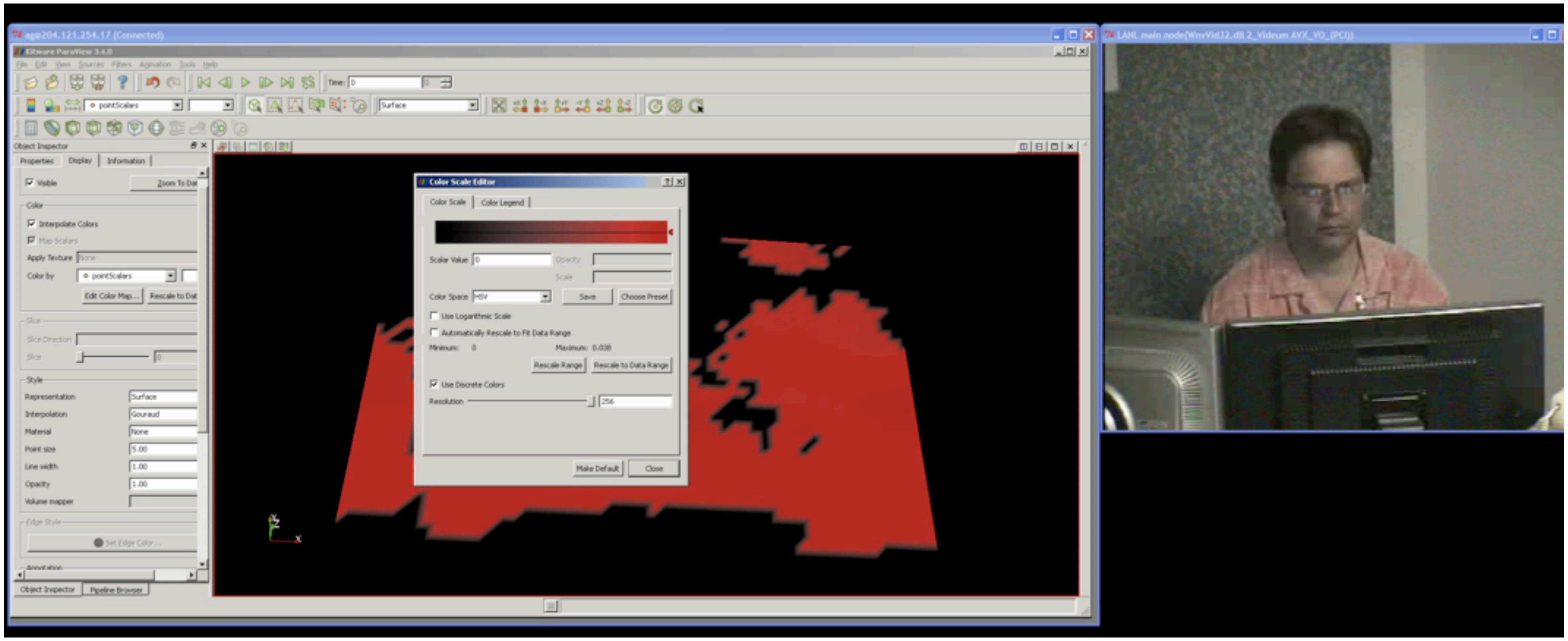
Executive Summary

- **Multi-resolution streaming visualization system for large scale data distance visualization**
  - Representation-based distance visualization (process data, send data, render client-side)
    - Alternative approach to image-based (process data, render data, send images)
  - Send low resolution data initially
    - Incrementally send (stream) increasing resolution data pieces over time and progressively render on the client side
    - Sends pieces in a prioritized manner, culling pieces that do not contribute
  - Implemented in ParaView/VTK and is publically available in the ParaView developer CVS archive
    - Works with most filters – the structural system changes only take place in the reader, renderer, and new pipeline meta-data messages

Remote Data

- **Mat Maltrud works at LANL on the Climate team and runs climate simulations at ORNL on Jaguar**
  - Mat is responsible for generating and analyzing the simulations
- **Other scientists we collaborate with use off-site resources as well**



ag@204.121.254.17 (Connected)

Kitware ParaView 3.4.0

Time: 0

Color by: pointScalars

Representation: Surface

Object Inspector – Display

☑ Visible

☑ Interpolate Colors

☑ Map Scalars

Apply Texture: None

Color by: pointScalars

Representation: Surface

Interpolation: Gouraud

Material: None

Point size: 5.00

Line width: 1.00

Opacity: 1.00

Color Scale Editor – Color Scale

Scalar Value: 0

Color Space: HSV

☐ Use Logarithmic Scale

☐ Automatically Rescale to Fit Data Range

Minimum: 0 Maximum: 0.038

☑ Use Discrete Colors

Resolution: 256

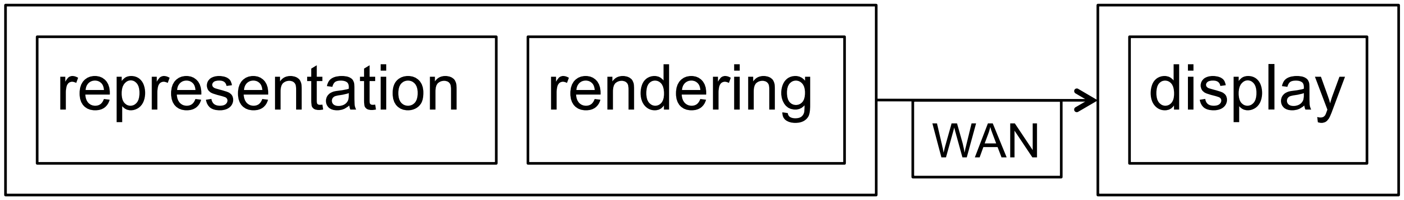
LANL main node(WnvVid32.dll 2_Videum AVX_VO_(PCI))

Remote LARGE Data

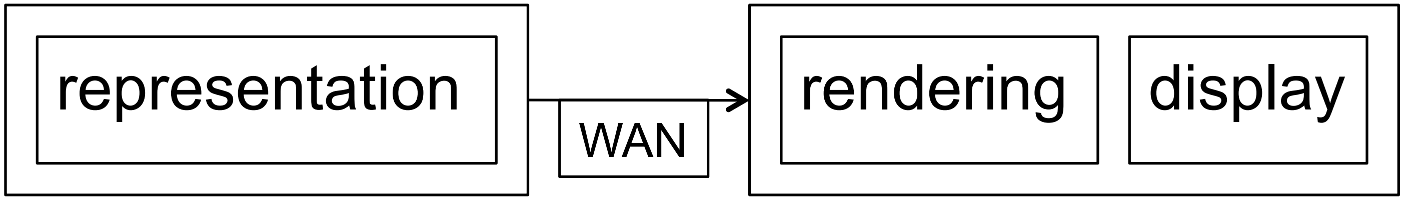
- **Using 100 TeraFLOPs of Jaguar (ORNL)**
  - 6 fields at 1.4GB each 20x a day
  - 3600 x 2400 x 42 floats
- **Transfer to LANL would take > 74 hours (~3 days)**
  - ~5 Mbps between LANL and ORNL (this was measured last year, it might have improved slightly since then; many software firewalls)
- **Transferring all of the data from ORNL to LANL will not work!**
  - 250 TeraFLOPs
    - 12 fields
  - 1 PetaFLOP
    - 24 fields and 40x a day = 740 hours (~1 month)

Two Remote Visualization Approaches

- **Server side rendering**
  - Run data server and render server on the supercomputer – send images



- **Client side rendering**
  - Run data server on the supercomputer – send geometry
  - Render client side



Evaluating Client Side Rendering

- **Image-based distance vis: it works, but…**
  - Completely server side based (dumb client)
  - Frame rate is network latency and bandwidth limited
- **Client side rendering?**
  - Higher potential frame
  - Can render without needing the server (caching)
  - Can still use a render server to deliver imagery if image-based distance visualization is still required
- **Though, this is large data – too big for the client, network, and display... Is it even practical?**

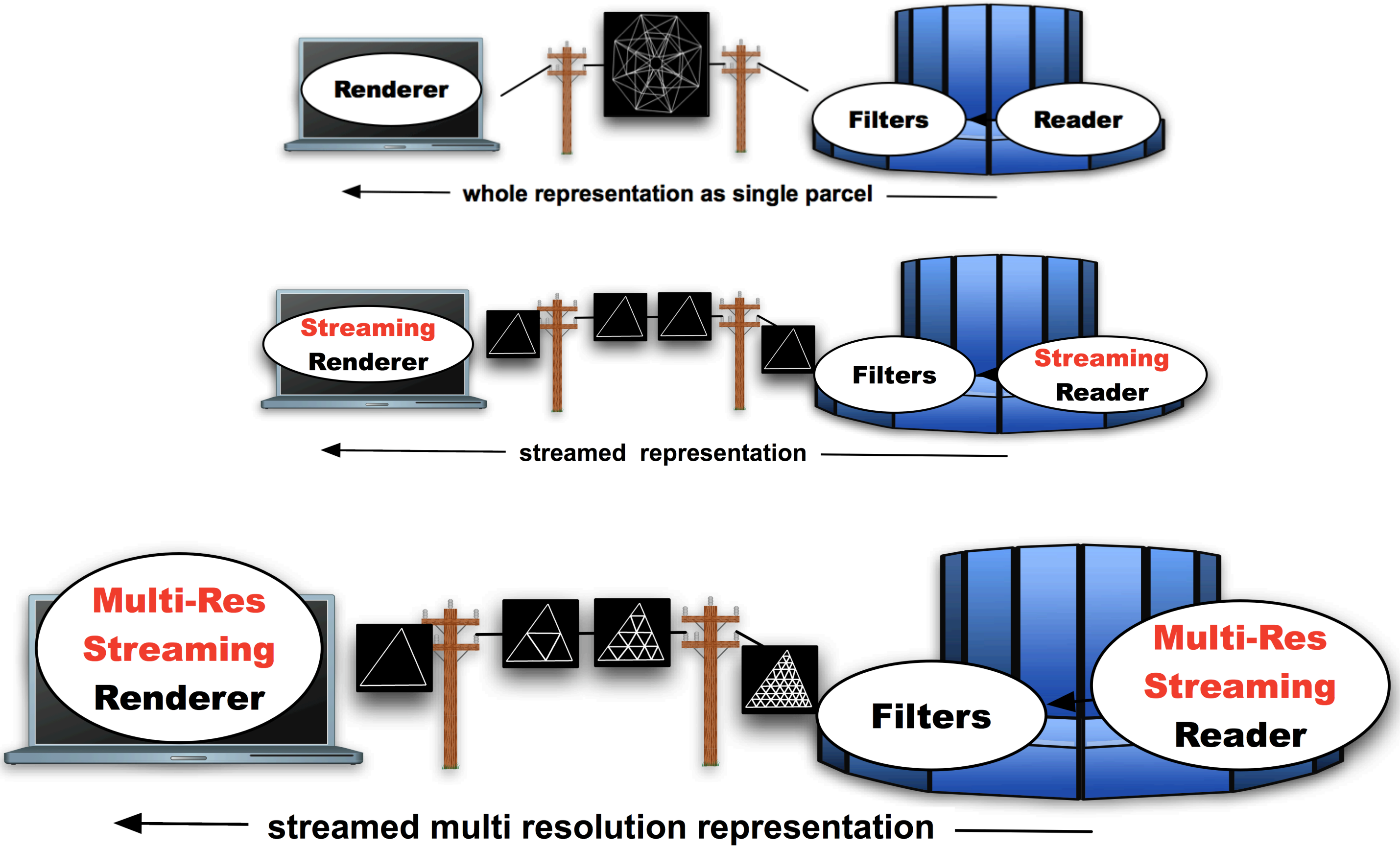
Subset and Downscale the Data to Fit Displays, Networks, and I/O

Prefix	Mega	Giga	Tera	Peta	Exa
10^n	10^6	10^9	10^{12}	10^{15}	10^{18}
Technology	Displays, networks, I/O		Data sizes and super-computing		

Downscaling
Sampling
Feature Extraction

The data has more points than available display pixels…
Post-sim I/O is expensive…
We need to reduce the data, anyways

Standard, Streaming, and Adaptive Streaming Pipelines



Renderer

Filters

Reader

whole representation as single parcel

Streaming Renderer

Filters

Streaming Reader

streamed representation

Multi-Res Streaming Renderer

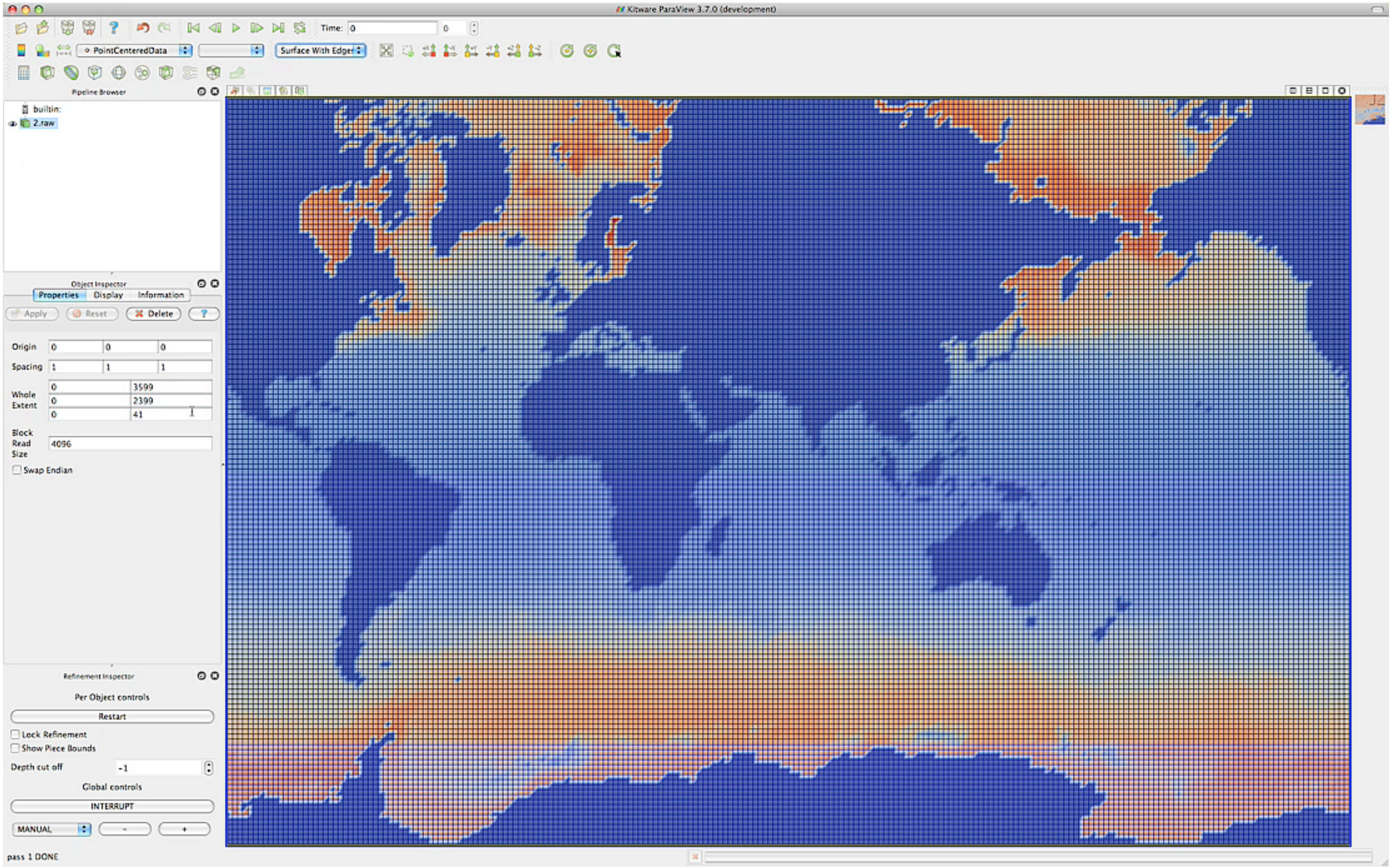
Filters

Multi-Res Streaming Reader

streamed multi resolution representation

Multi-resolution and Streaming Related Work

- Norton and Rockwood
- Clyne and Rast
- Pascucci and Frank
- Wang, Gao, Li, and Shen
- LaMar, Hamann, and Joy
- Prohaska, Hutanu, Kahler, and Hege
- Rusinkiewicz and Levoy
- Childs, Duchaineau, and Ma
- Ahrens, Desai, McCormick, Martin, and Woodring



Time: 0 0

PointCenteredData

Surface With Edges

Origin	0	0	0
Spacing	1	1	1

Whole Extent	0	3599
	0	2399
	0	41

Block Read Size: 4096

□ Swap Endian

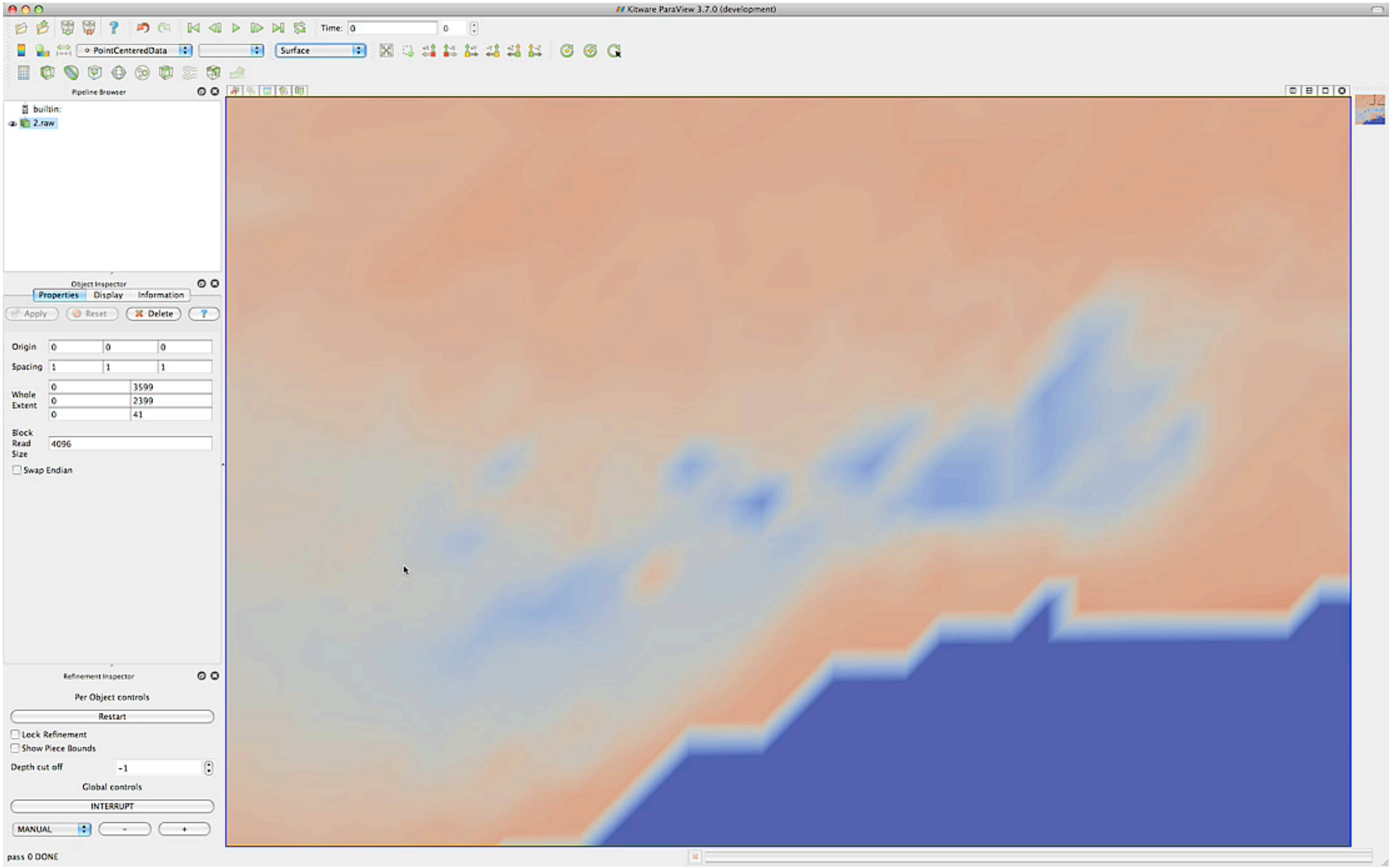
□ Lock Refinement

□ Show Piece Bounds

Depth cut off: -1

MANUAL

pass 1 DONE



Time: 0 0

PointCenteredData

Surface

Origin 0 0 0

Spacing 1 1 1

Whole Extent 0 3599
0 2399
0 41

Block Read Size 4096

□ Swap Endian

□ Lock Refinement

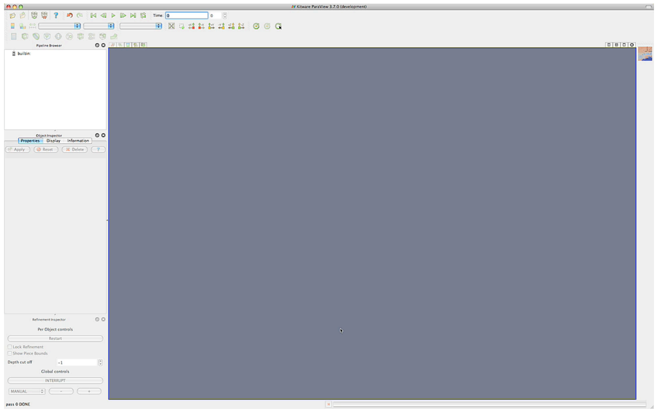
□ Show Piece Bounds

Depth cut off -1

MANUAL

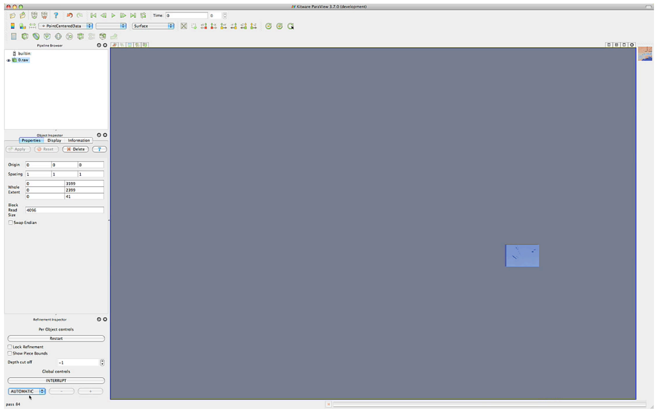
pass 0 DONE

Pipeline Approaches in ParaView



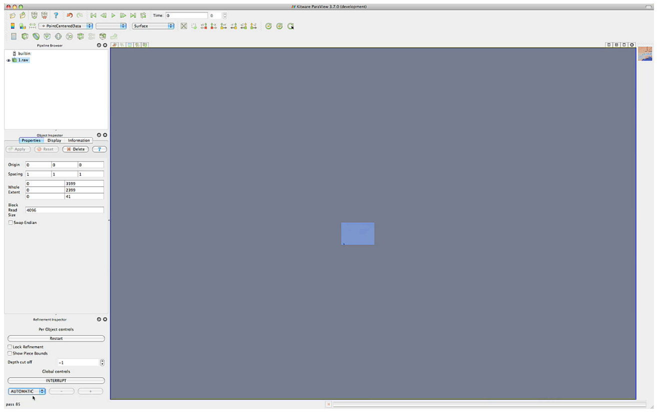
□ Lock Refinement
□ Show Piece Bounds
Depth cut off -1
MANUAL
pass 0 DONE

standard



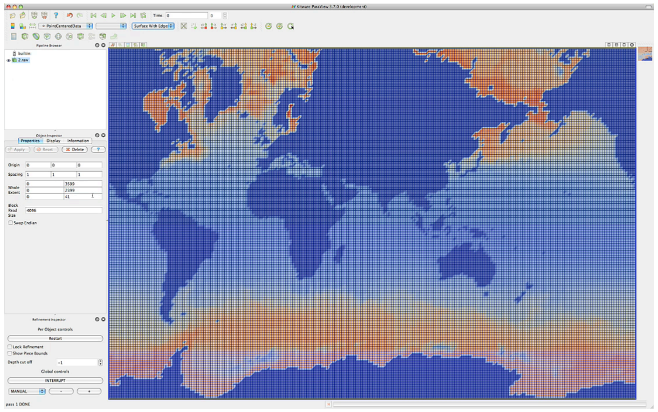
Origin 0 0 0
Spacing 1 1 1
Whole Extent 0 3599
0 2399
0 41
Block Read Size 4096
□ Swap Endian
□ Lock Refinement
□ Show Piece Bounds
Depth cut off -1
AUTOMATIC
pass 84

streaming



Origin 0 0 0
Spacing 1 1 1
Whole Extent 0 3599
0 2399
0 41
Block Read Size 4096
□ Swap Endian
□ Lock Refinement
□ Show Piece Bounds
Depth cut off -1
AUTOMATIC
pass 85

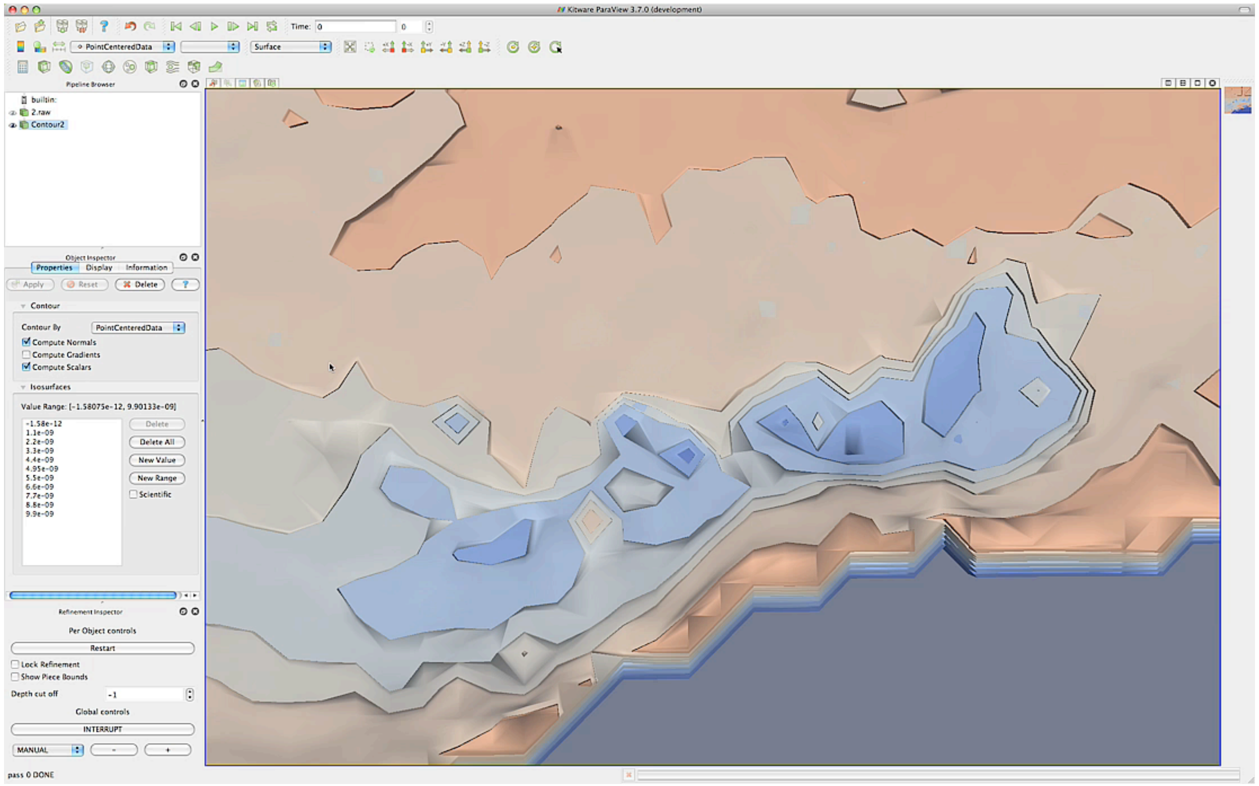
prioritized streaming



Origin 0 0 0
Spacing 1 1 1
Whole Extent 0 3599
0 2399
0 41
Block Read Size 4096
□ Swap Endian
□ Lock Refinement
□ Show Piece Bounds
Depth cut off -1
MANUAL
pass 1 DONE

multi-resolution prioritized streaming

Multi-resolution Visualization System



Time: 0 0

PointCenteredData

Surface

Contour

Contour By PointCenteredData

☑ Compute Normals

☐ Compute Gradients

☑ Compute Scalars

Isosurfaces

Value Range: [-1.58075e-12, 9.90133e-09]

```
-1.58e-12
1.1e-09
2.2e-09
3.3e-09
4.4e-09
4.95e-09
5.5e-09
6.6e-09
7.7e-09
8.8e-09
9.9e-09
```

☐ Scientific

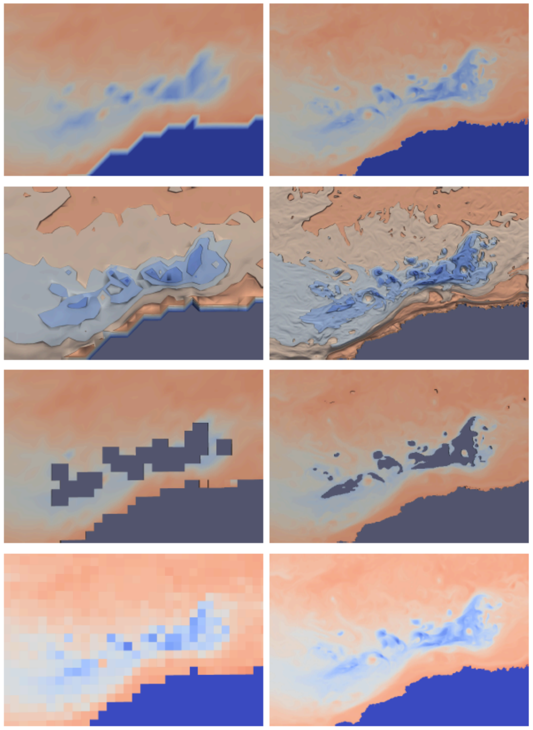
☐ Lock Refinement

☐ Show Piece Bounds

Depth cut off -1

MANUAL

pass 0 DONE



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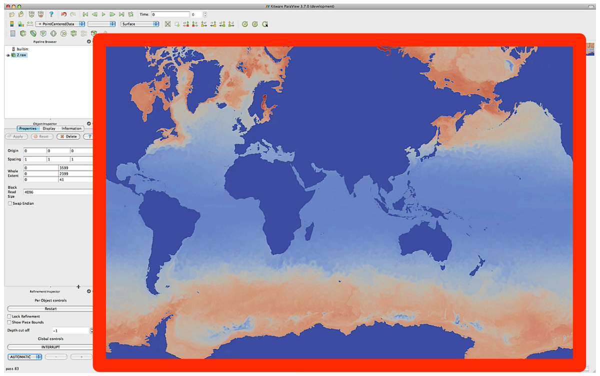
Multi-resolution Prioritized Streaming



Kitware ParaView 3.7.0 (development)

Time: 0

PointCenteredData

Surface

Pipeline Browser

builtin:

2.raw

Object Inspector

Properties | Display | Information

Apply | Reset | Delete

Origin	0	0	0
Spacing	1	1	1
Whole Extent	0	3599	
	0	2399	
	0	41	
Block Read Size	4096		

☐ Swap Endian

Refinement Inspector

Per Object controls

Restart

☐ Lock Refinement

☐ Show Piece Bounds

Depth cut off: -1

Global controls

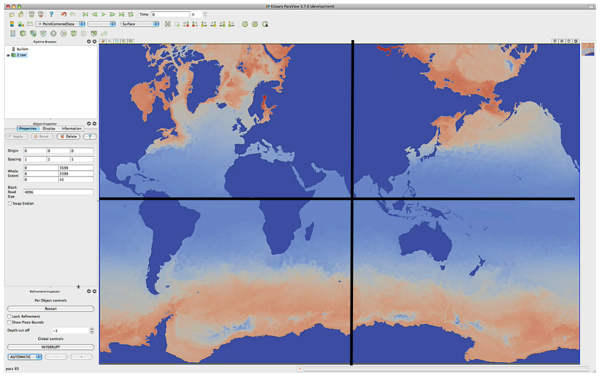
INTERRUPT

AUTOMATIC

pass 83

1) Send and render lowest resolution data

Multi-resolution Prioritized Streaming



Origin 0 0 0

Spacing 1 1 1

Whole Extent 0 3599
0 2399
0 41

Block Read Size 4096

□ Swap Endian

□ Lock Refinement

□ Show Piece Bounds

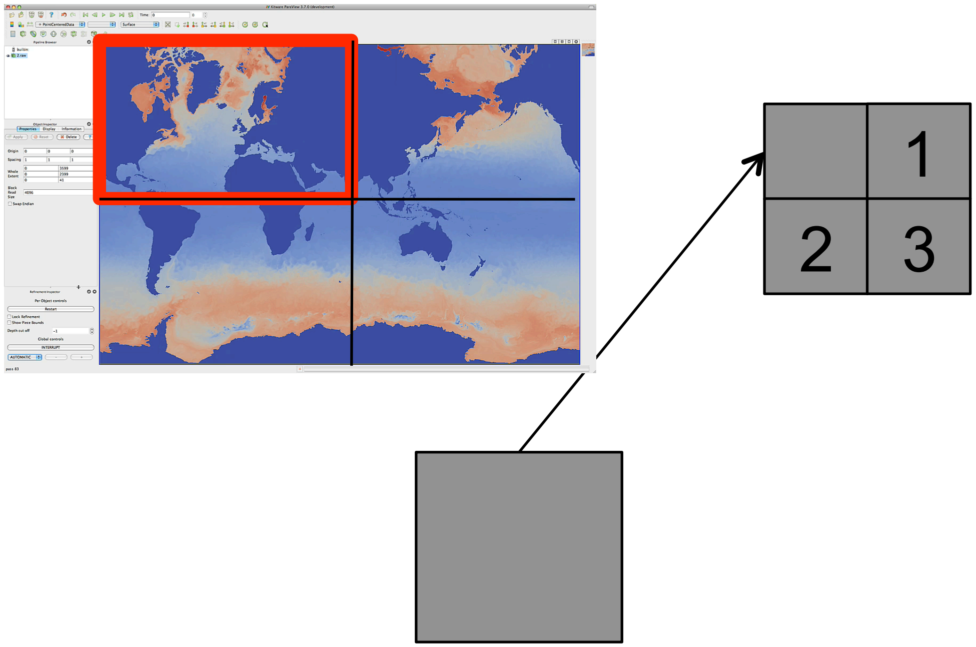
Depth cut off -1

1	2
3	4

1) Send and render lowest resolution data

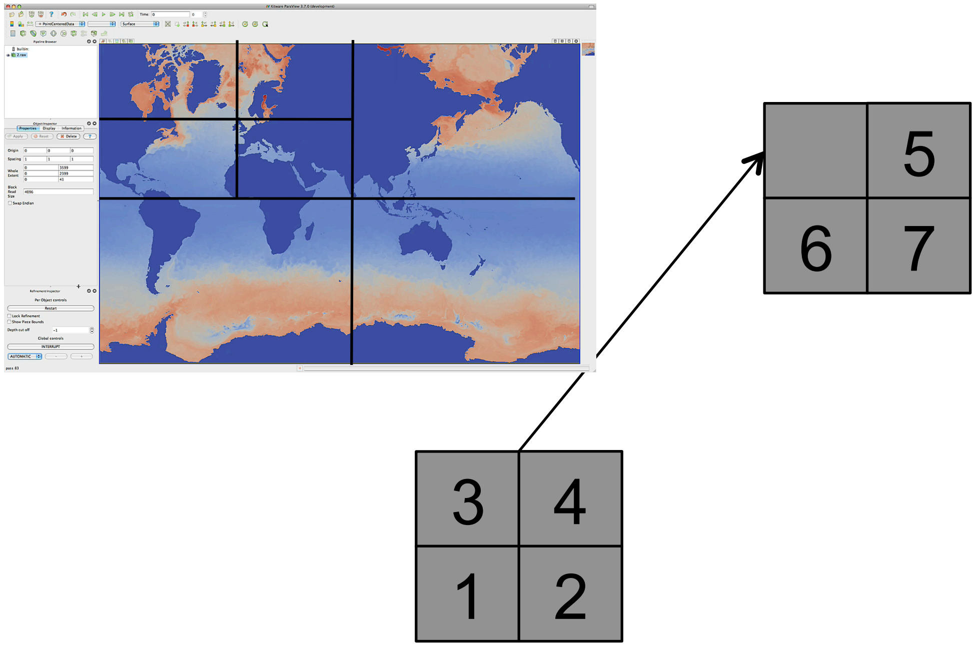
2) Virtually split into spatial pieces and prioritize pieces

Multi-resolution Prioritized Streaming



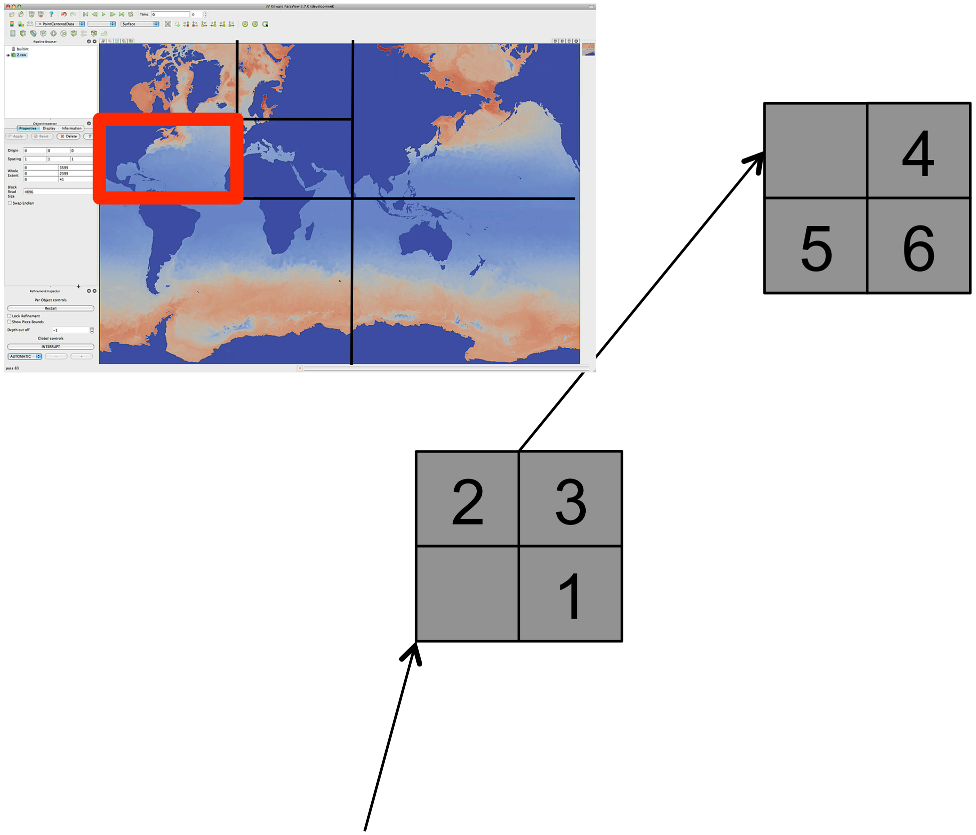
1) Send and render
lowest resolution data
2) Virtually split
into spatial pieces and
prioritize pieces
3) Send and render
highest priority piece
at higher resolution

Multi-resolution Prioritized Streaming



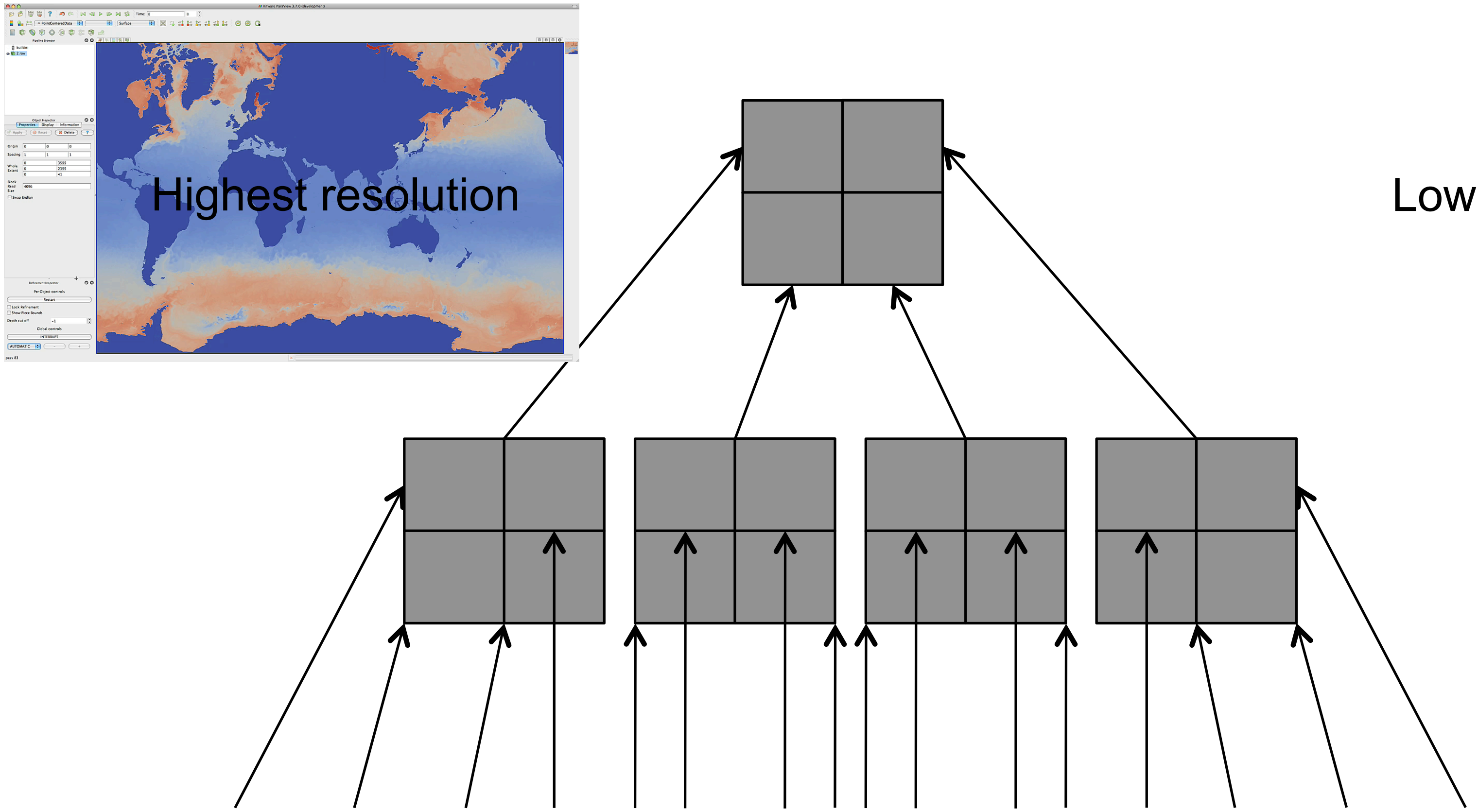
1) Send and render lowest resolution data
2) Virtually split into spatial pieces and prioritize pieces
3) Send and render highest priority piece at higher resolution
4) Goto step 2 until the data is at the highest resolution

Multi-resolution Prioritized Streaming



1) Send and render lowest resolution data
2) Virtually split into spatial pieces and prioritize pieces
3) Send and render highest priority piece at higher resolution
4) Goto step 2 until the data is at the highest resolution

Multi-resolution Prioritized Streaming



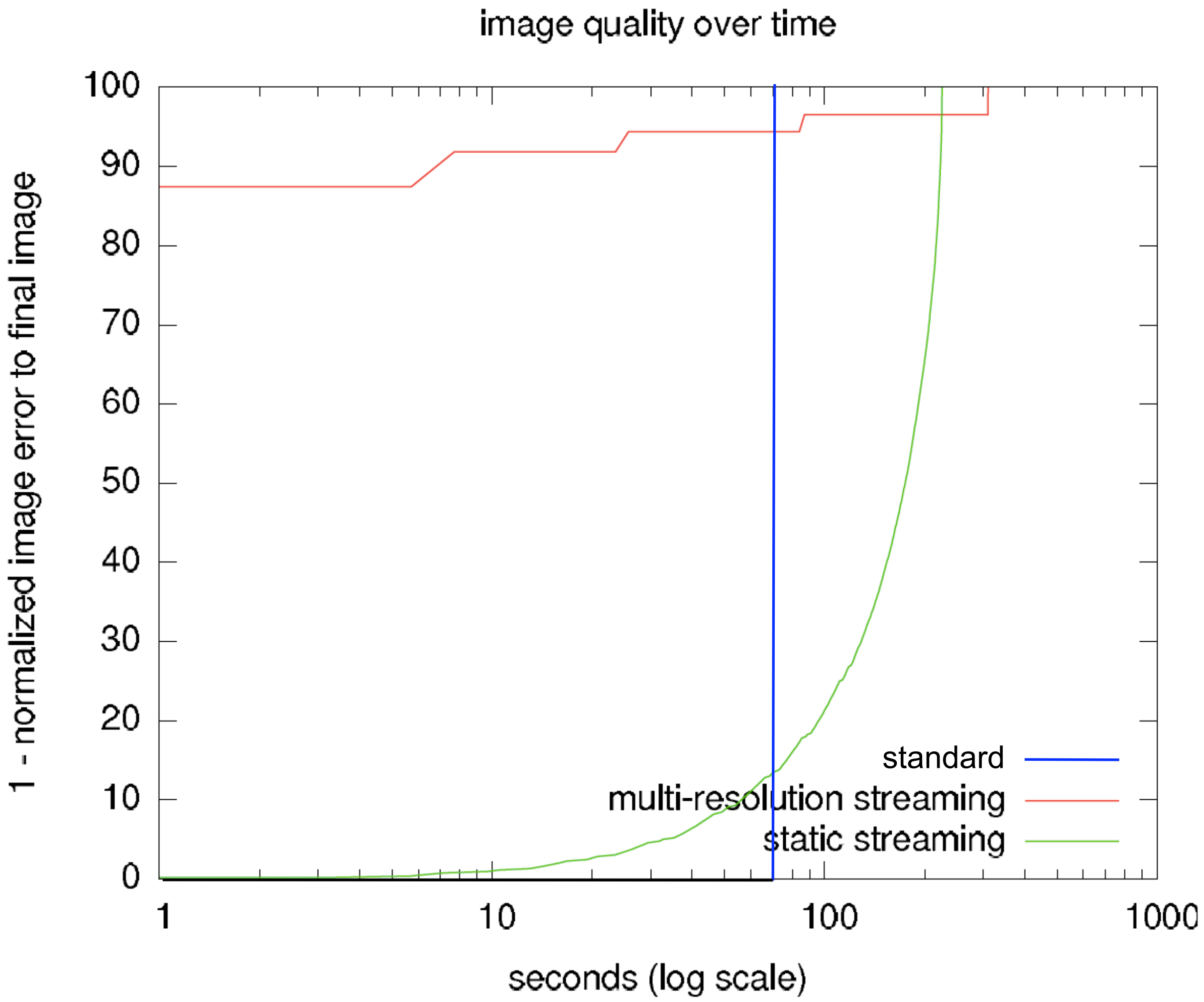
Lowest resolution

Highest resolution

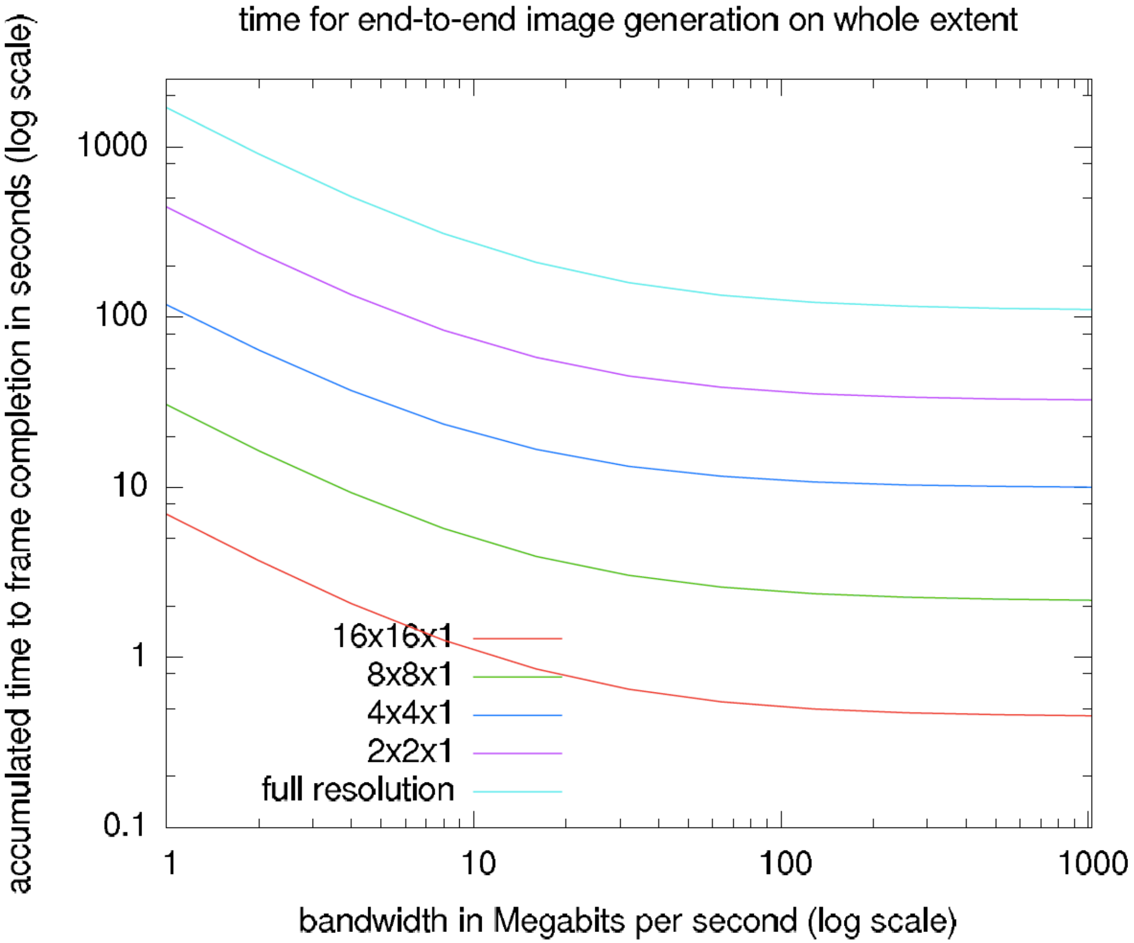
ParaView Implementation

- **Progressive multi-resolution renderer (sink)**
  - Implements the high level algorithm on the previous slides
- **Multi-resolution preprocessor (generating multi-resolution tree)**
  - Our implementation for structured data uses strided sampling – fast
  - Doesn't modify the original data – left as-is (highest resolution); worst case uses x1 additional space, realistic cases use 1/3rd or 1/7th additional space
- **Multi-resolution reader (source)**
  - The reader provides data pieces based on resolution request and piece request
  - Uses the preprocessed multi-resolution data for fast linear reads
- **Meta-information keys**
  - RESOLUTION request (what resolution is needed)
  - UPDATE_EXTENT request (what is the spatial extent of the piece needed)
  - PRIORITY keys (for prioritization sorting and culling)

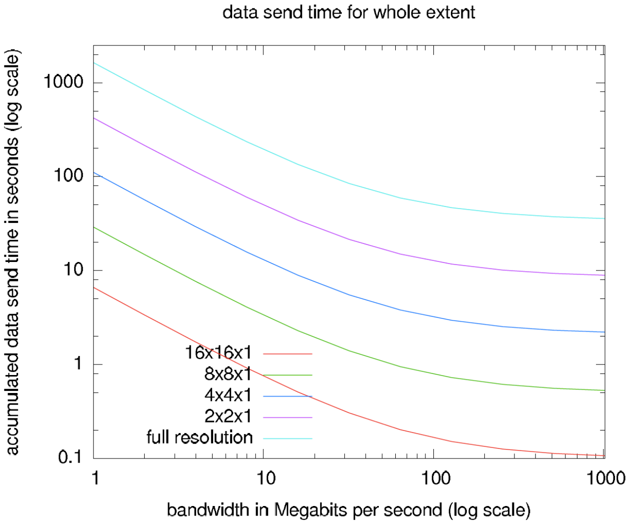
Image Quality over Time for Whole Extent (Single Node) (POP 3600 x 2400 x 42 floats, 10 MBps, 100 ms latency)



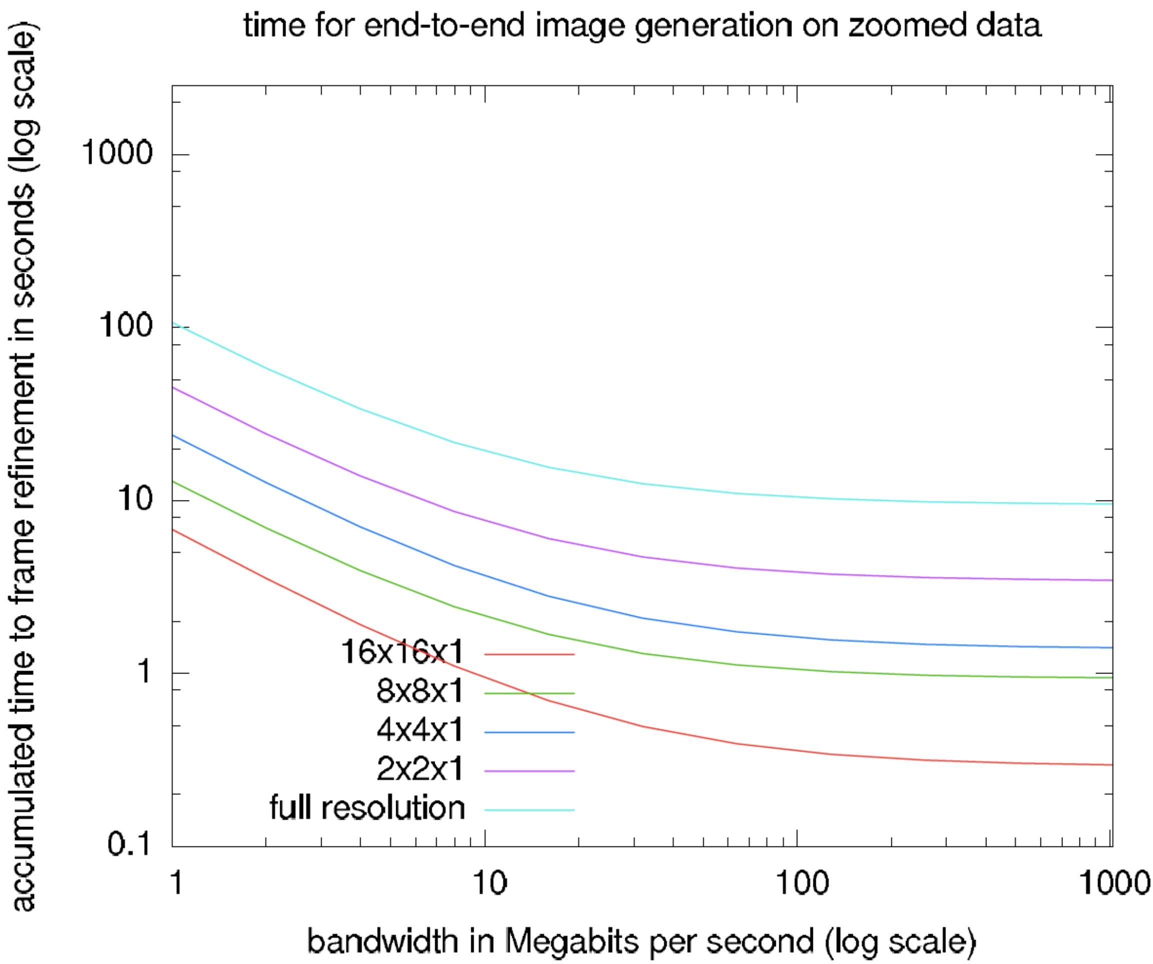
Whole Extent (POP data, 100 ms latency) (Single Node)
Total Rendering, Client Rendering, and Send Time



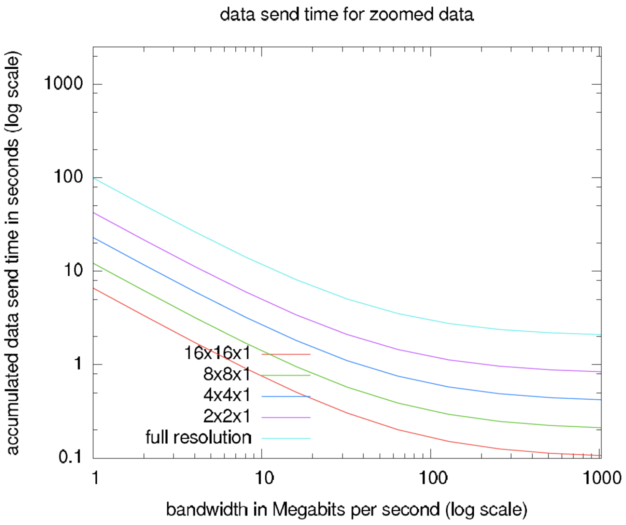
Full Extent	16x16x1	8x8x1	4x4x1	2x2x1	Full
Render	0.03 s	0.10 s	0.38 s	1.4 s	5.6 s



Zoomed In (Culling and Prioritization) (same params) Total Rendering, Client Rendering, and Send Time



Zoomed	16x16x1	8x8x1	4x4x1	2x2x1	Full
Render	0.03 s	0.03 s	0.05 s	0.09 s	0.27 s



Single Node
Cold Start Read and Write Timings (POP data)

Time to Read Whole File	Time to Read and Create 4 levels	Time to Read and Create 20 levels
30.0 s	46.5 s	150.6 s

Full Extent	16x16x1	8x8x1	4x4x1	2x2x1	Full
Read	0.18 s	0.92 s	5.0 s	11.8 s	35.6 s
Accum. Read	0.18 s	1.1 s	6.1 s	17.9 s	53.5 s

Zoomed	16x16x1	8x8x1	4x4x1	2x2x1	Full
Read	0.18 s	0.47 s	1.4 s	2.8 s	6.1 s
Accum. Read	0.18 s	0.64 s	2.0 s	4.8 s	11.0 s

Contact

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- John Patchett: patchett@lanl.gov
- Mat Maltrud: maltrud@lanl.gov

- Research is funded by Office of Science ASCR