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LANL Summer 2015, CCS-2, Mentor: Daniel Livescu

Survey and Analysis of Multiresolution Methods for Turbulence Data

Jesus Pulido[1,2], Daniel Livescu[2], Jonathan Woodring[2], James Ahrens[2], and Bernd Hamann[1]

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Submitted to Elsevier Computers & Fluids

Introduction

General

- Interest for multi-resolution representation of turbulence data
  - Feature discovery + tracking (coherent feature extraction)
  - Influence on simulation algorithms
- Downscaling of data (compression) for faster data analysis
  - For in-situ or post-processing applications
  - Faster post-processing of data for visualization

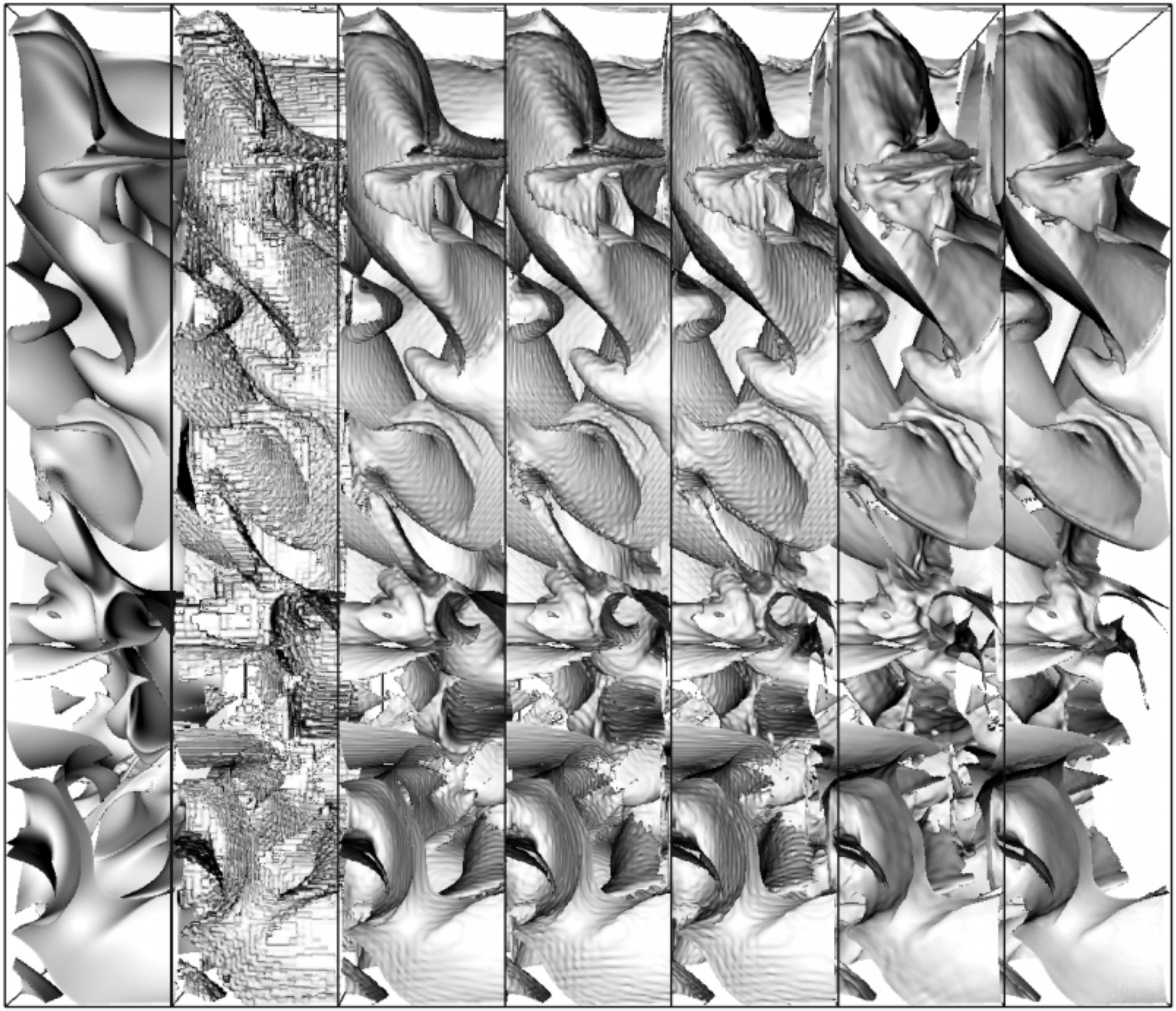
Contributions

- Analyzed and compared the effectiveness of Haar, Biorthogonal B-spline, and Daubechies wavelets, Coiflets, Surfacelets and Curvelets with respect to direct numerical simulation (DNS) data.
- Visualized and evaluated numerical accuracy of original data and derived quantities using limited amounts of coefficients on reconstruction
- Identified strengths and weaknesses of each technique and gave recommendations on the usage of these multi-resolution methods

Method

Improvements made this summer

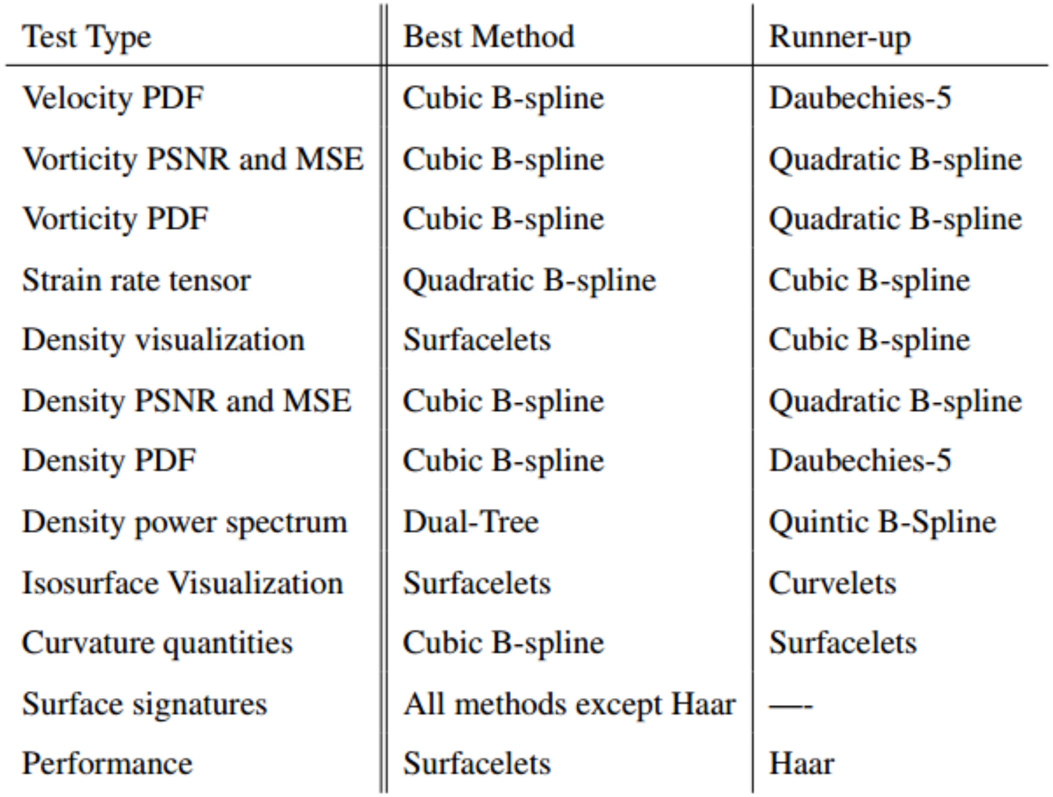
- Added parallel computation support for wavelet framework
  - Near linear-time speedup
- Implemented parallel sort for fast wavelet coefficient sorting (for N% coefficient thresholding)
- Added edge-case handling for wavelet decomposition and reconstruction
  - Can treat data as parabolic, mirror, zero-fill, etc.
- Re-implemented the Dual-Tree Complex wavelet transform in C++ and included it into our analysis pipeline



Original Haar Cubic Daub-5 Coif-12 Curvelet Surfacelet

Tests and Results

Summary



Test Type	Best Method	Runner-up
Velocity PDF	Cubic B-spline	Daubechies-5
Vorticity PSNR and MSE	Cubic B-spline	Quadratic B-spline
Vorticity PDF	Cubic B-spline	Quadratic B-spline
Strain rate tensor	Quadratic B-spline	Cubic B-spline
Density visualization	Surfacelets	Cubic B-spline
Density PSNR and MSE	Cubic B-spline	Quadratic B-spline
Density PDF	Cubic B-spline	Daubechies-5
Density power spectrum	Dual-Tree	Quintic B-Spline
Isosurface Visualization	Surfacelets	Curvelets
Curvature quantities	Cubic B-spline	Surfacelets
Surface signatures	All methods except Haar	—-
Performance	Surfacelets	Haar

Enabling Remote Visualization and Scale Analysis of Large Turbulence Databases

Jesus Pulido[1,2], Daniel Livescu[2], Randal Burns[3] ,Curtis Canada[2],
James Ahrens[2], and Bernd Hamann[1]

[1]Institute for Data Analysis and Visualization, University of California, Davis, CA, 95616-8562, U.S.A.
[2]Los Alamos National Laboratory, Los Alamos, NM 87544, USA
[3]Johns Hopkins University

Previously submitted to IEEE SciVis '15

Introduction

General

- Remote analysis and visualization of raw large turbulence data is challenging
- The Johns Hopkins Turbulence database (JHTDB) simplifies access to over 230 Terabytes of direct numerical simulation data through commodity hardware
- A demand exists for a visualization framework that adds high-speed remote visualization for large datasets

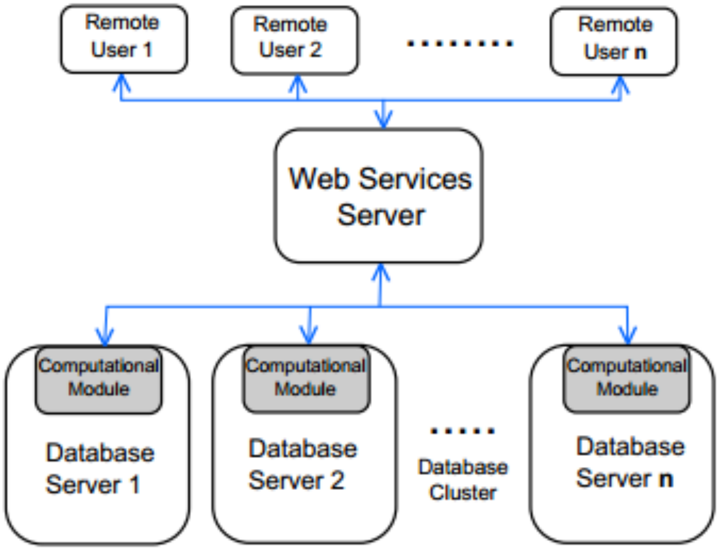
Contributions

- Remote visualization support and additional compute capabilities were added to the database cluster
- Wavelet compression was introduced at the data-level to reduce access cost, bandwidth, and improve visualization latency
- Wavelet compression used to reduce memory footprint of datasets for visualization

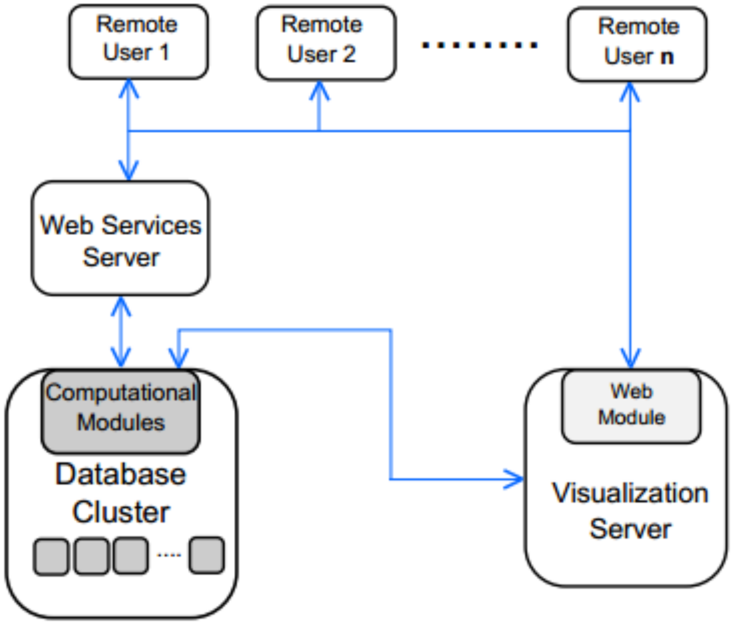
JHTDB: http://turbulence.pha.jhu.edu/

Johns Hopkins Turbulence Database

Original Pipeline

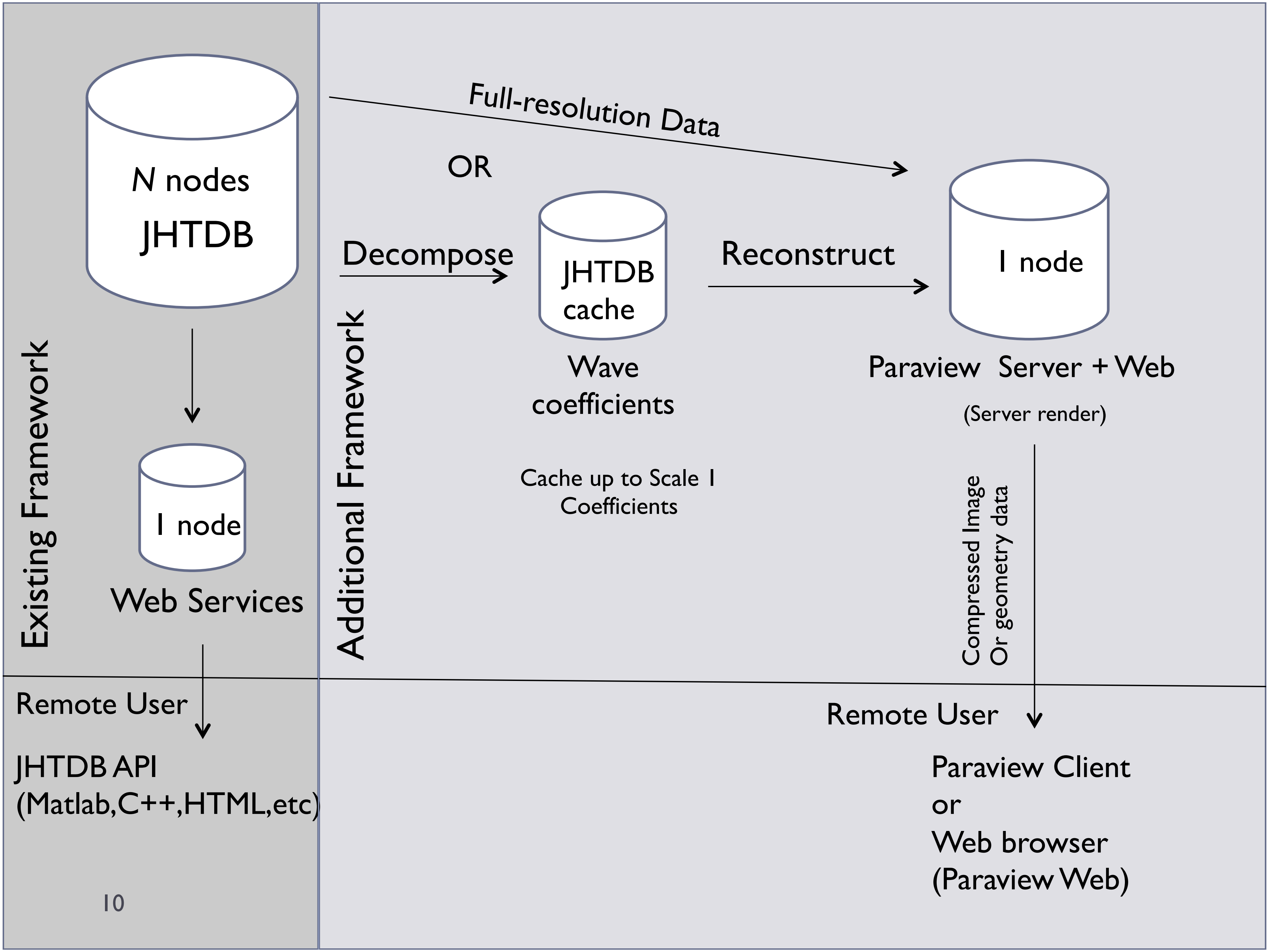

Remote User 1
Remote User 2
....
Remote User **n**
Web Services Server
Computational Module
Database Server 1
Computational Module
Database Server 2
.....
Database Cluster
Computational Module
Database Server **n**

Augmented Pipeline


Remote User 1
Remote User 2
....
Remote User **n**
Web Services Server
Computational Modules
Database Cluster
Web Module
Visualization Server

Remote visualization is achieved through Paraview and Paraview Web integration

JHTDB: http://turbulence.pha.jhu.edu/



Existing Framework

N nodes

JHTDB

1 node

Web Services

Remote User

JHTDB API
(Matlab,C++,HTML,etc)

Additional Framework

Full-resolution Data

OR

Decompose

JHTDB
cache

Wave
coefficients

Cache up to Scale 1
Coefficients

Reconstruct

1 node

Paraview Server + Web

(Server render)

Compressed Image
Or geometry data

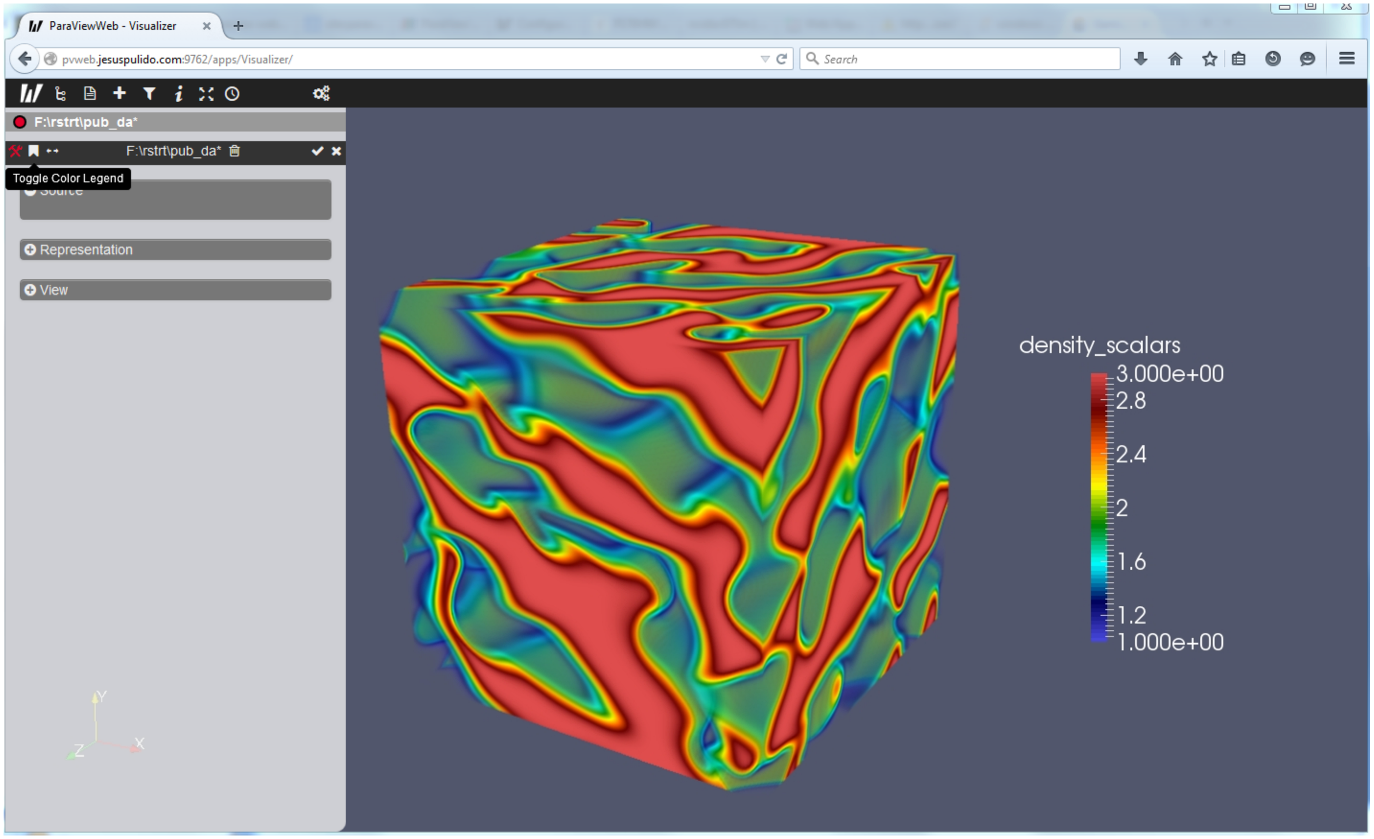
Remote User

Paraview Client
or
Web browser
(Paraview Web)

Tests and Results

Remote Visualization

- Web (HTML 5) interface


ParaViewWeb - Visualizer
pvweb.jesuspulido.com:9762/apps/Visualizer/
Search
F:\rstrt\pub_da*
F:\rstrt\pub_da*
Toggle Color Legend
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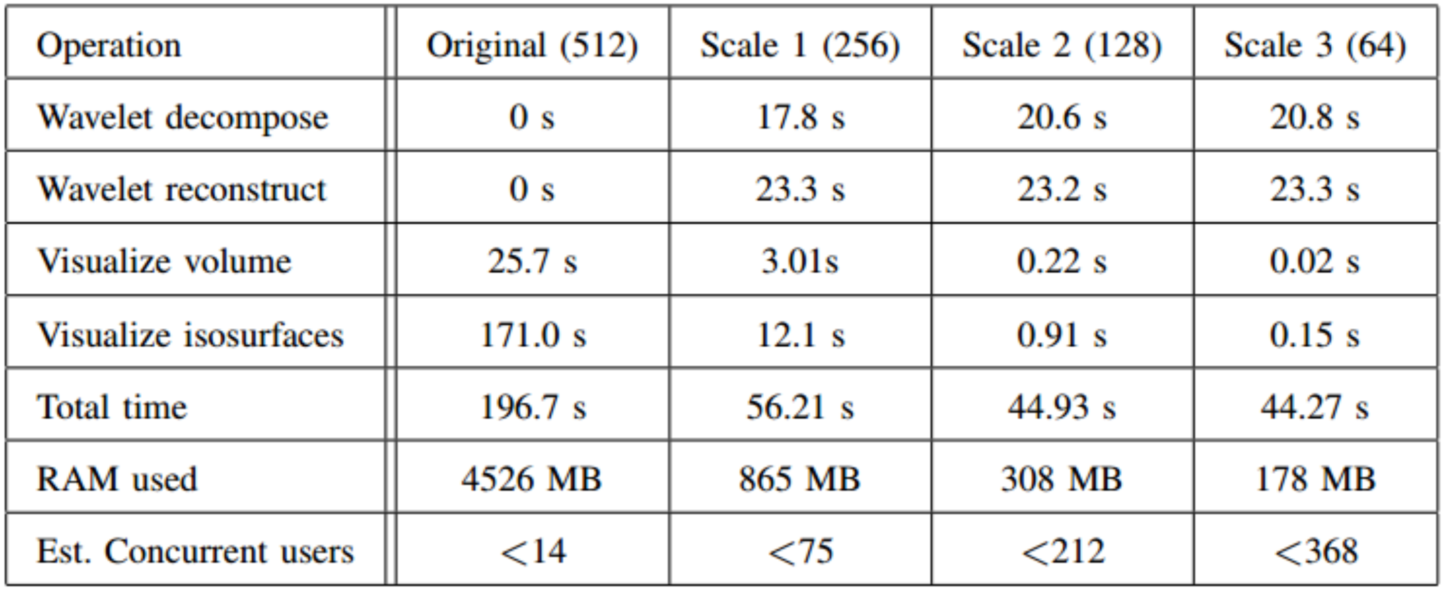
Representation
View
density_scalars
3.000e+00
2.8
2.4
2
1.6
1.2
1.000e+00
Y
Z
X

Tests and Results

Efficiency (Performance)

- Scenario: A single 512^3 grid size subset of a 1024^3 dataset is accessed and visualized by a single user.

TABLE I. PERFORMANCE RESULTS



Operation	Original (512)	Scale 1 (256)	Scale 2 (128)	Scale 3 (64)
Wavelet decompose	0 s	17.8 s	20.6 s	20.8 s
Wavelet reconstruct	0 s	23.3 s	23.2 s	23.3 s
Visualize volume	25.7 s	3.01s	0.22 s	0.02 s
Visualize isosurfaces	171.0 s	12.1 s	0.91 s	0.15 s
Total time	196.7 s	56.21 s	44.93 s	44.27 s
RAM used	4526 MB	865 MB	308 MB	178 MB
Est. Concurrent users	<14	<75	<212	<368

cubic B-spline wavelets

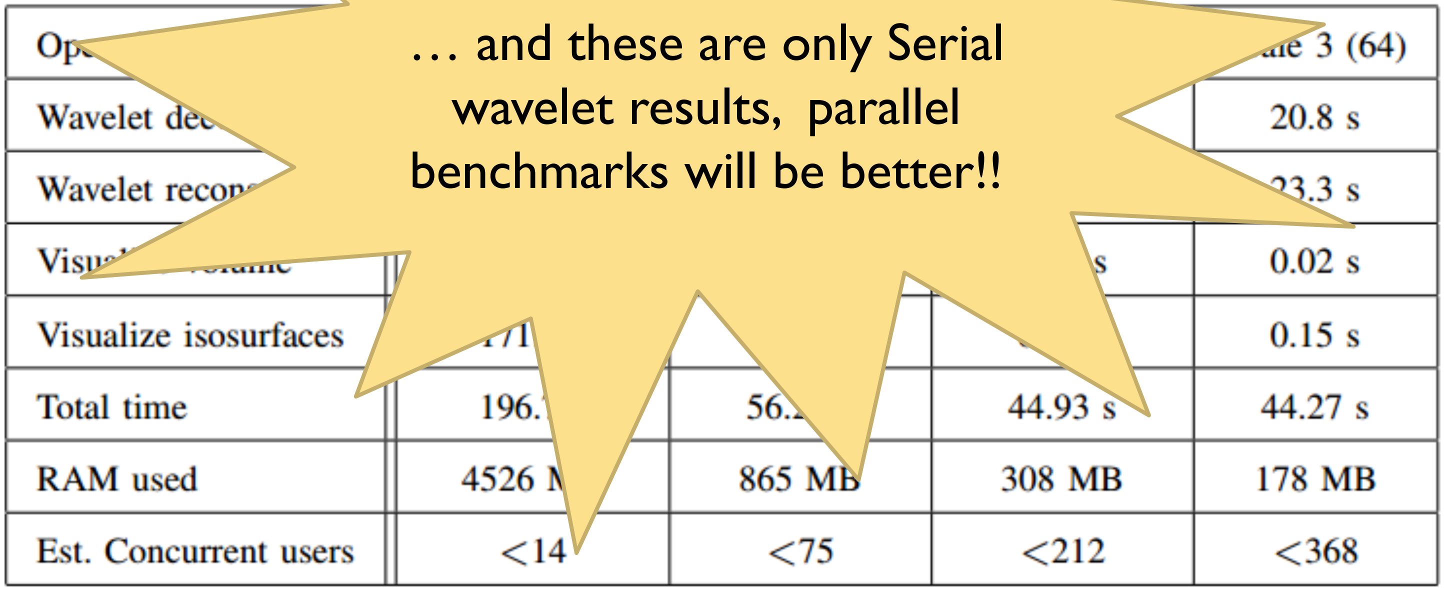
Intel Xeon E5440 @ 2.83 Ghz / 64GB RAM

Tests and Results

Efficiency (Performance)

- Scenario: A single 512^3 grid size su set of a 1024^3 dataset is accesse nd visualiz by a si user.

cubic B-spline wavelets



Op	[illegible]	[illegible]	[illegible]	le 3 (64)
Wavelet de	[illegible]	[illegible]	[illegible]	20.8 s
Wavelet recon	[illegible]	[illegible]	[illegible]	23.3 s
Visu	[illegible]	[illegible]	s	0.02 s
Visualize isosurfaces	171	[illegible]	[illegible]	0.15 s
Total time	196.	56.	44.93 s	44.27 s
RAM used	4526 M	865 MB	308 MB	178 MB
Est. Concurrent users	<14	<75	<212	<368

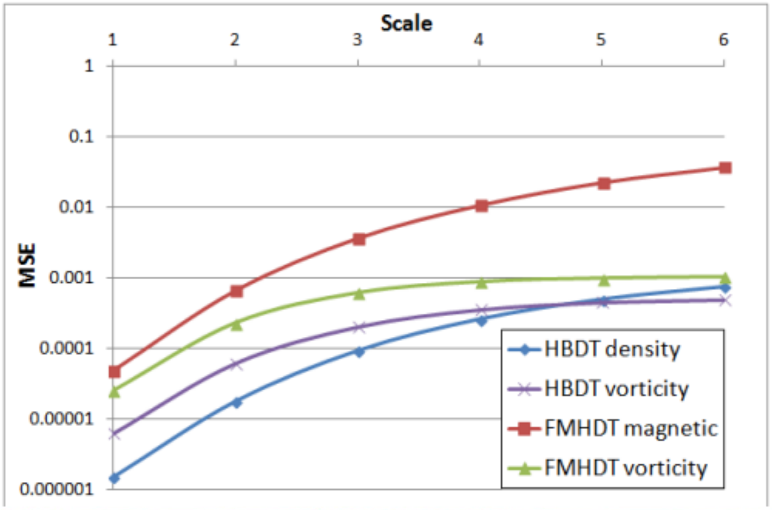
… and these are only Serial wavelet results, parallel benchmarks will be better!!

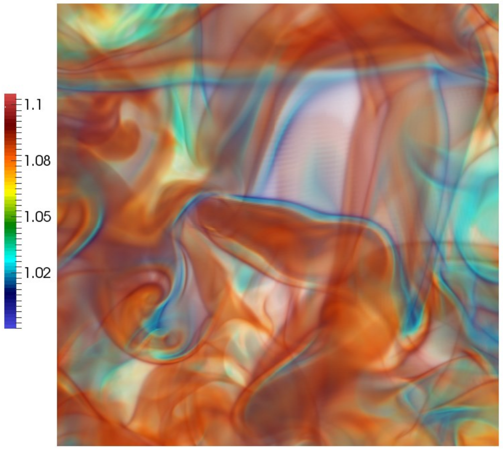
Intel Xeon E5440 @ 2.83 Ghz / 64GB RAM

Tests and Results

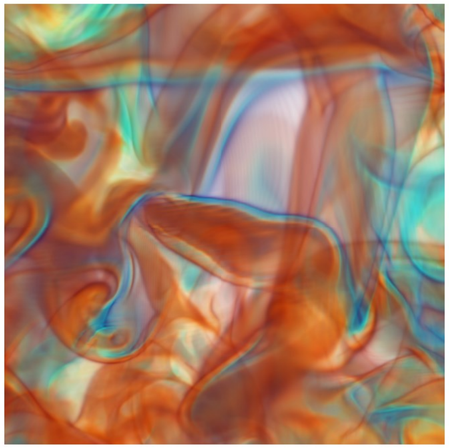
Quality

- Density component of a dataset is decomposed into 6 scales using cubic B-spline wavelets

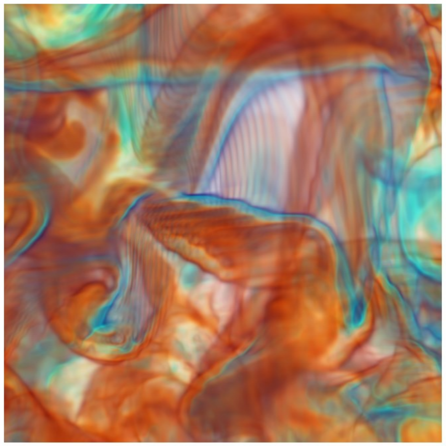




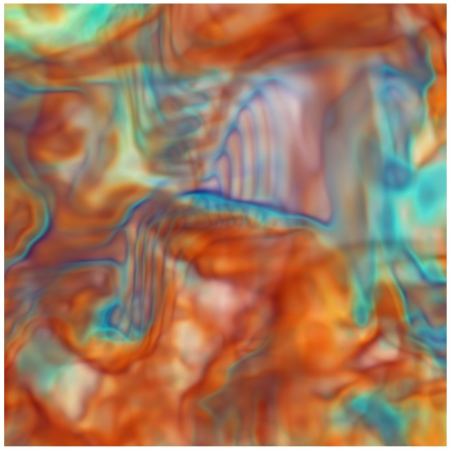
Original



Scale 1



Scale 2



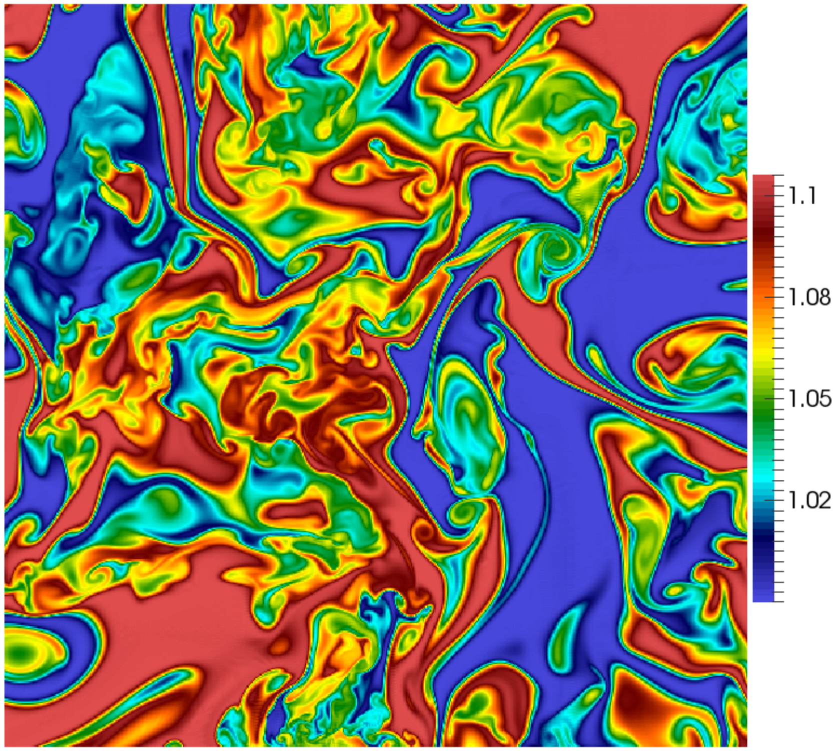
Scale 3

Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Original

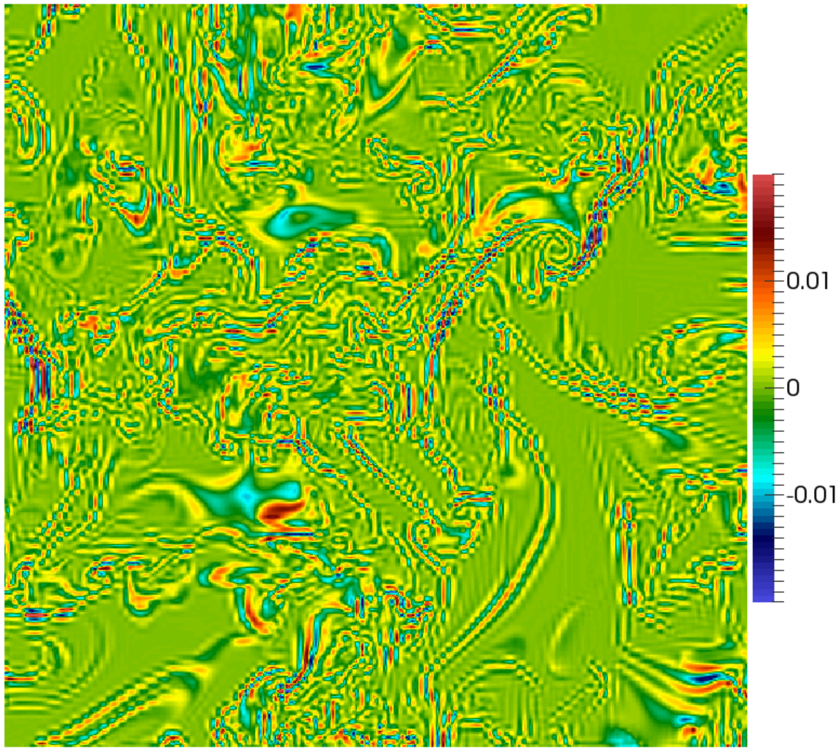


Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 2

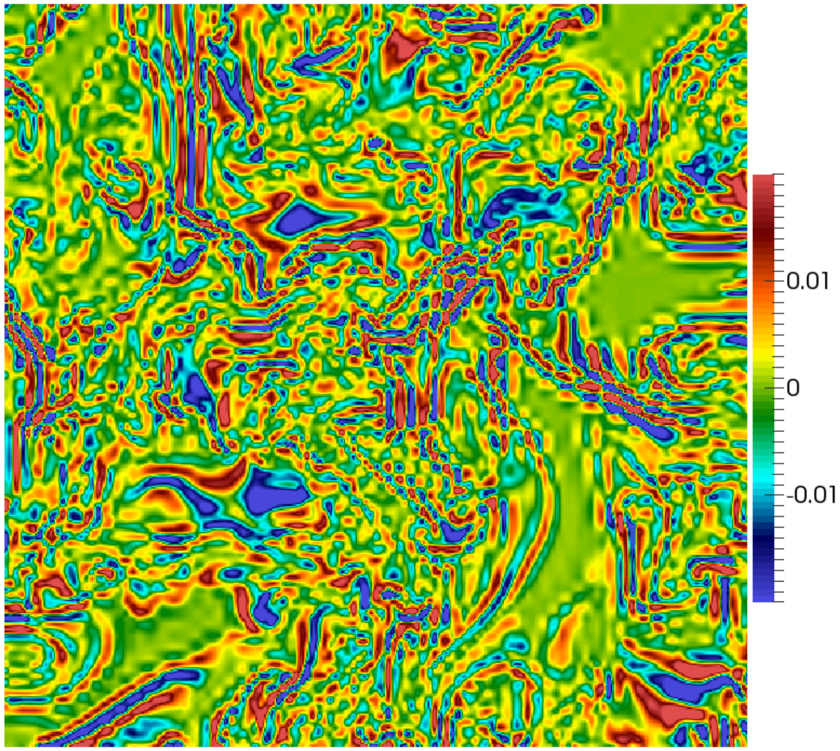


Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 3

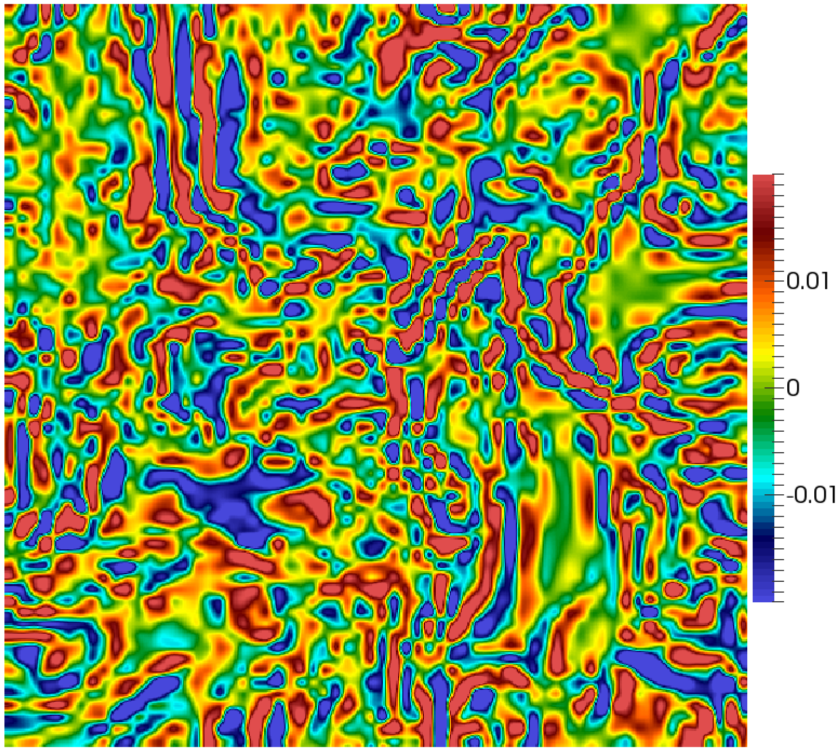


Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 4

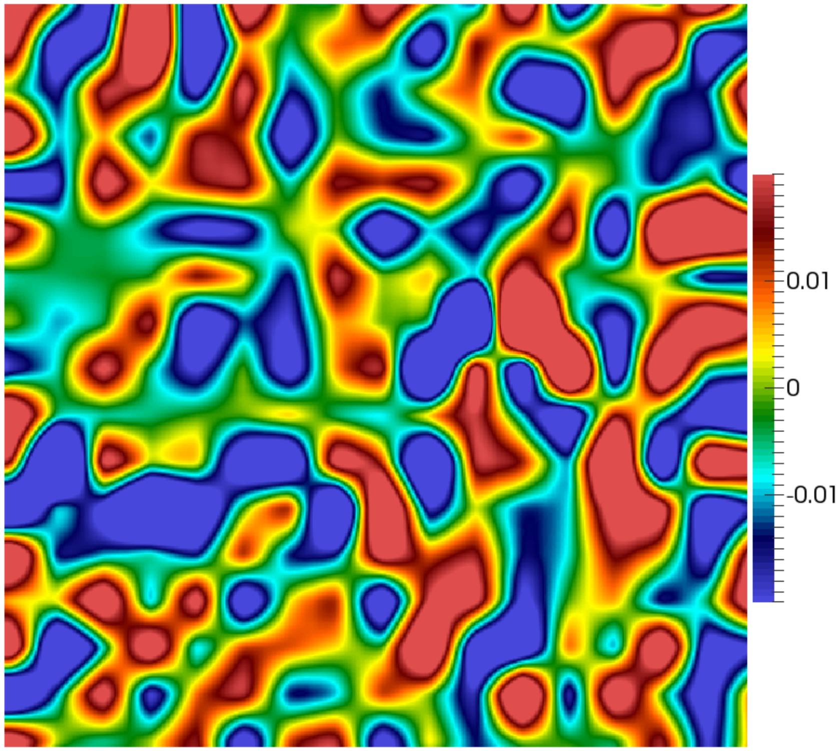


Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 6



Questions? Thank you!