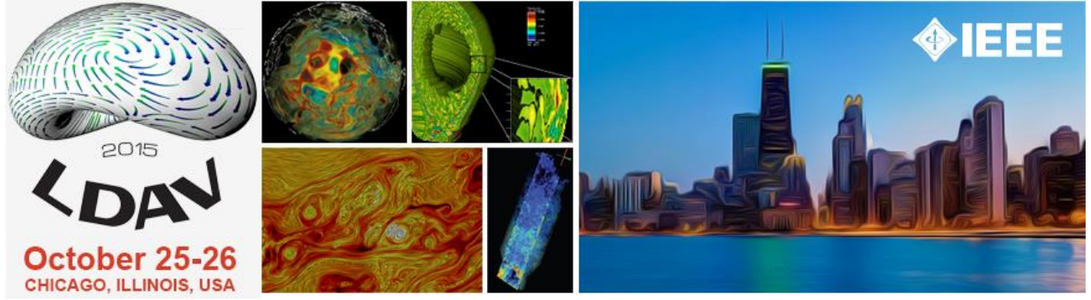


Fast Uncertainty-driven Large-scale Volume Feature Extraction on Desktop PCs

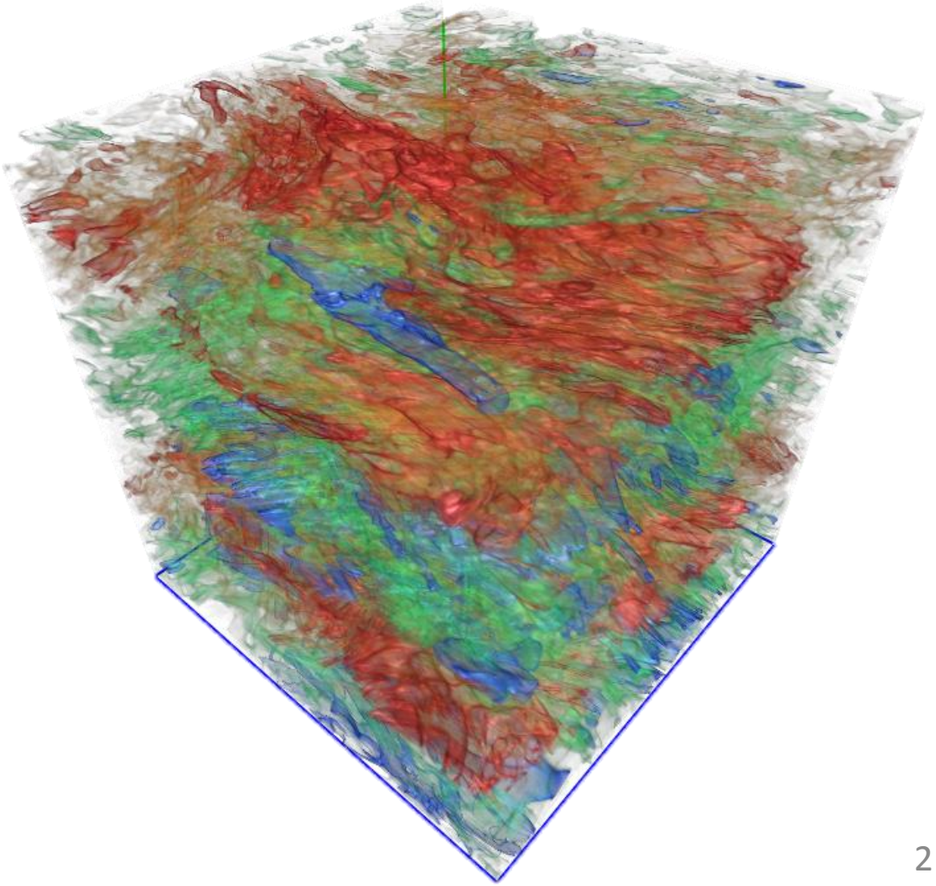
Jinrong Xie, Franz Sauer, Kwan-Liu Ma

ViDi
Visualization & Interface Design Innovation

UCDAVIS
UNIVERSITY OF CALIFORNIA

Introduction: Feature Extraction

- Extensively used in visualization and analysis
  - Explore physical quantities
  - Distinguish/isolate patterns
  - Data reduction
- Large-scale datasets?

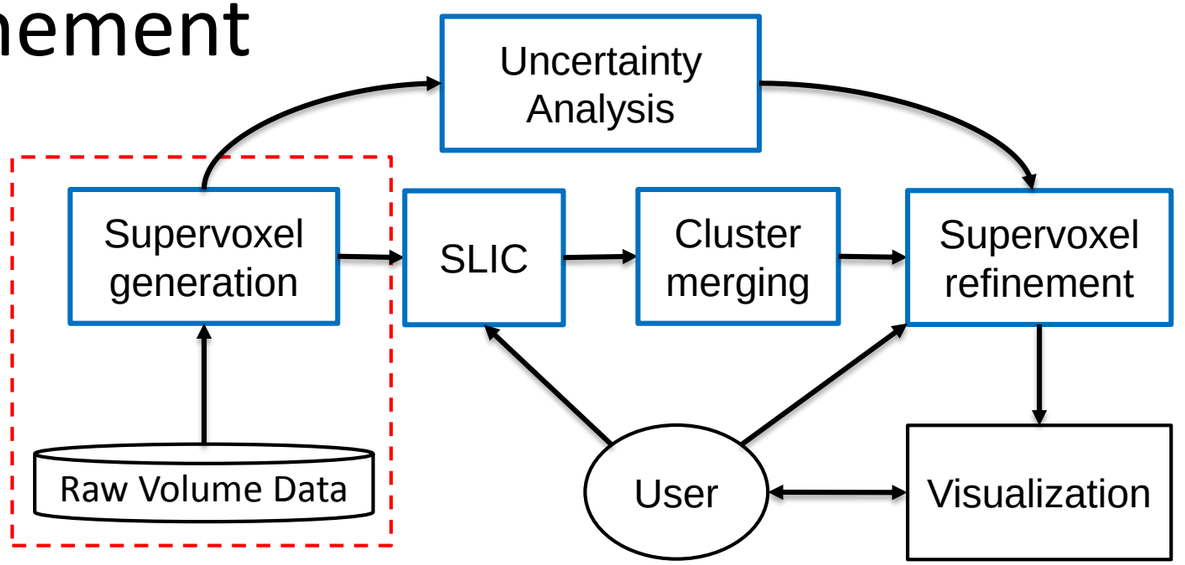


Introduction: Large-scale Data

- Drawbacks of distributed computing environments
  - Low interactivity
  - Compete over resources
  - Limited control over tools
- Can we leverage desktop PCs in new ways to handle large-scale data?

Introduction: Overview

- Balance between **accuracy** and **performance**
- Hybrid technique
  - Multiresolution advantages of supervoxels
  - Uncertainty-based refinement
  - GPU accelerated SLIC



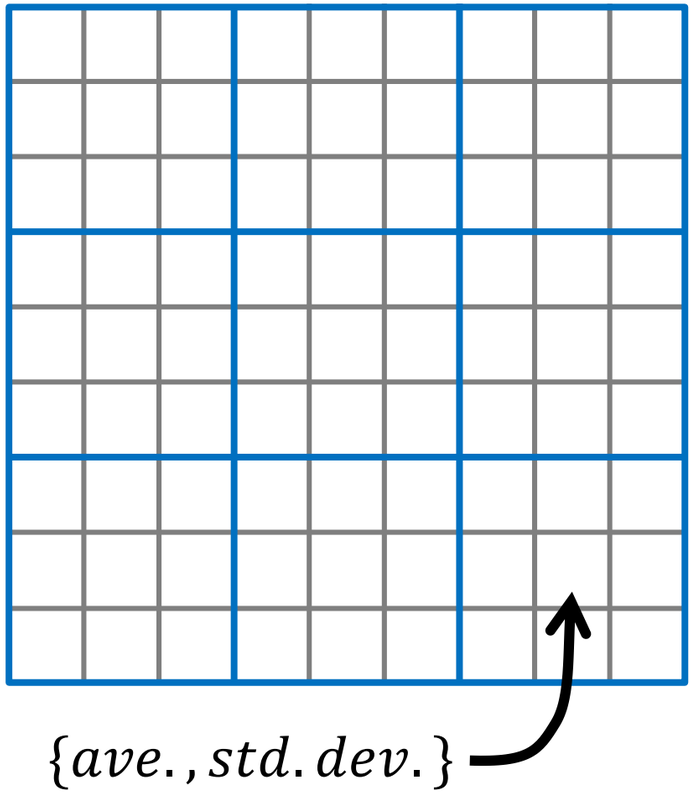
Background: SLIC

- Simple Linear Iterative Clustering (SLIC)*
- K-means based
- Limited search area
- Predefined cluster centers
  - Pixel values
  - Location to center

*Achanta et al. 2011

Methods: Supervoxel Generation

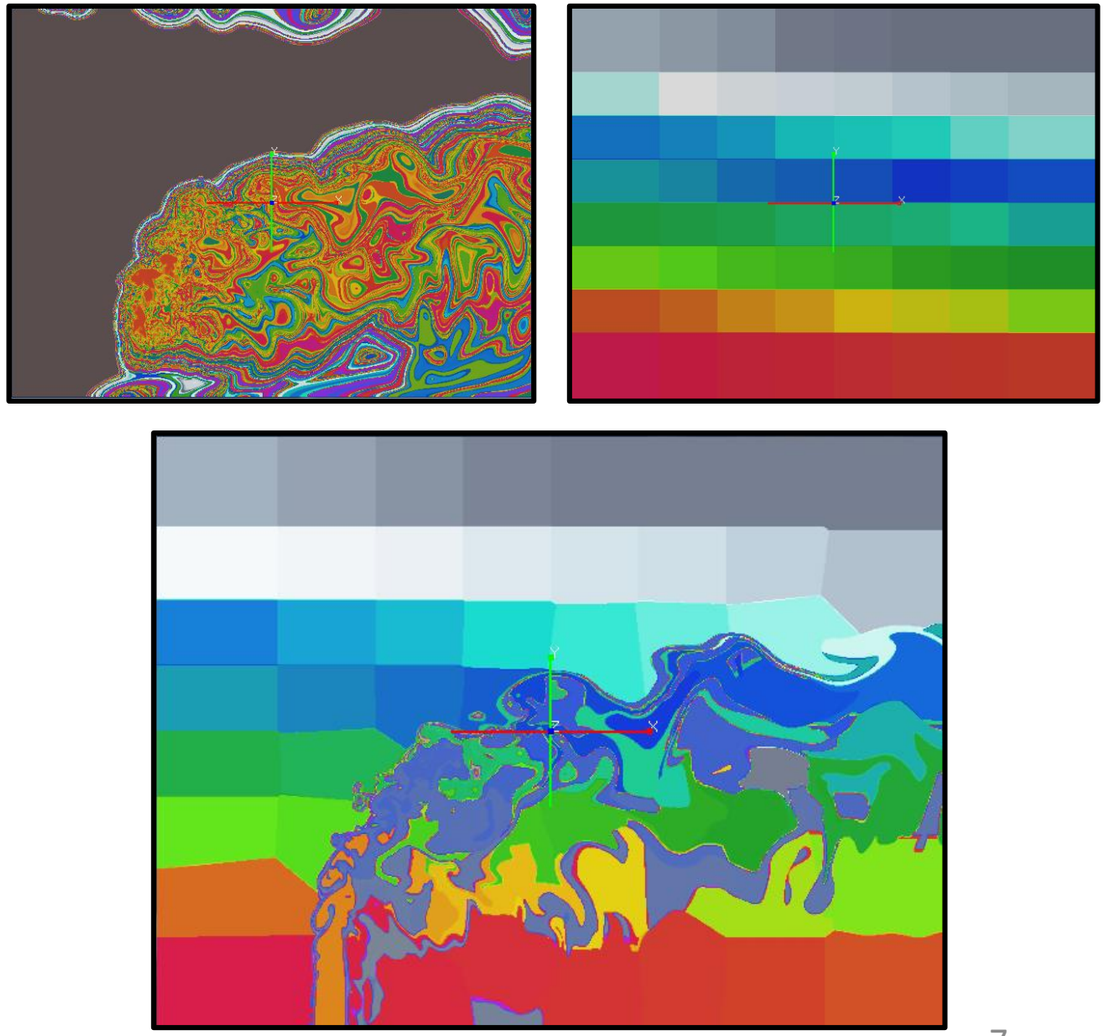
- Similar to down-sampling
- Compute relevant information
  - Average intensity
  - Standard deviation
- Use GPU acceleration
  - Supervoxel independence
  - Out-of-core if necessary



Methods: Supervoxel Clustering

- Extend SLIC to 3D volumes
- Seed initial cluster centers
- User controlled weights
  - Scalar data values
  - Euclidean distance
- Use GPU acceleration

$$d_{i,k} = w_1 \|c_k - v_i\|_2 + w_2 \|I_k - I_i\|_2$$

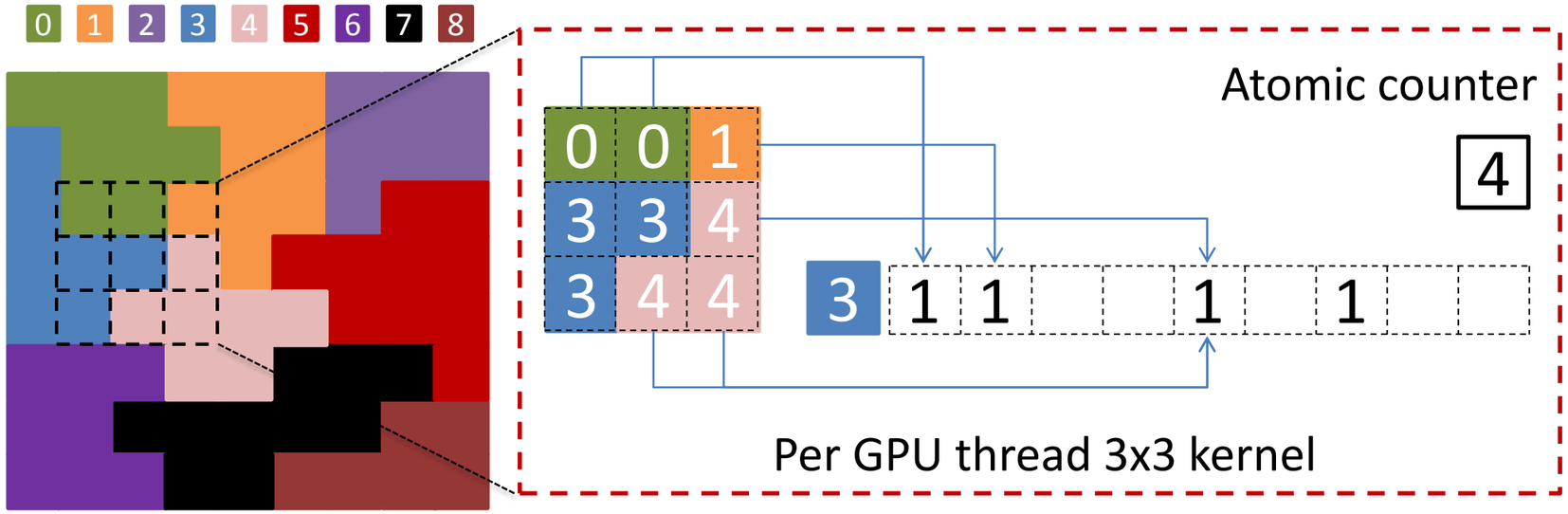


Methods: Hierarchical Merging

- SLIC tends to over segment the volume
  - Number of clusters is fixed
  - Redundant clusters in homogenous regions
- Need to merge clusters
- Need to determine topological connectivity

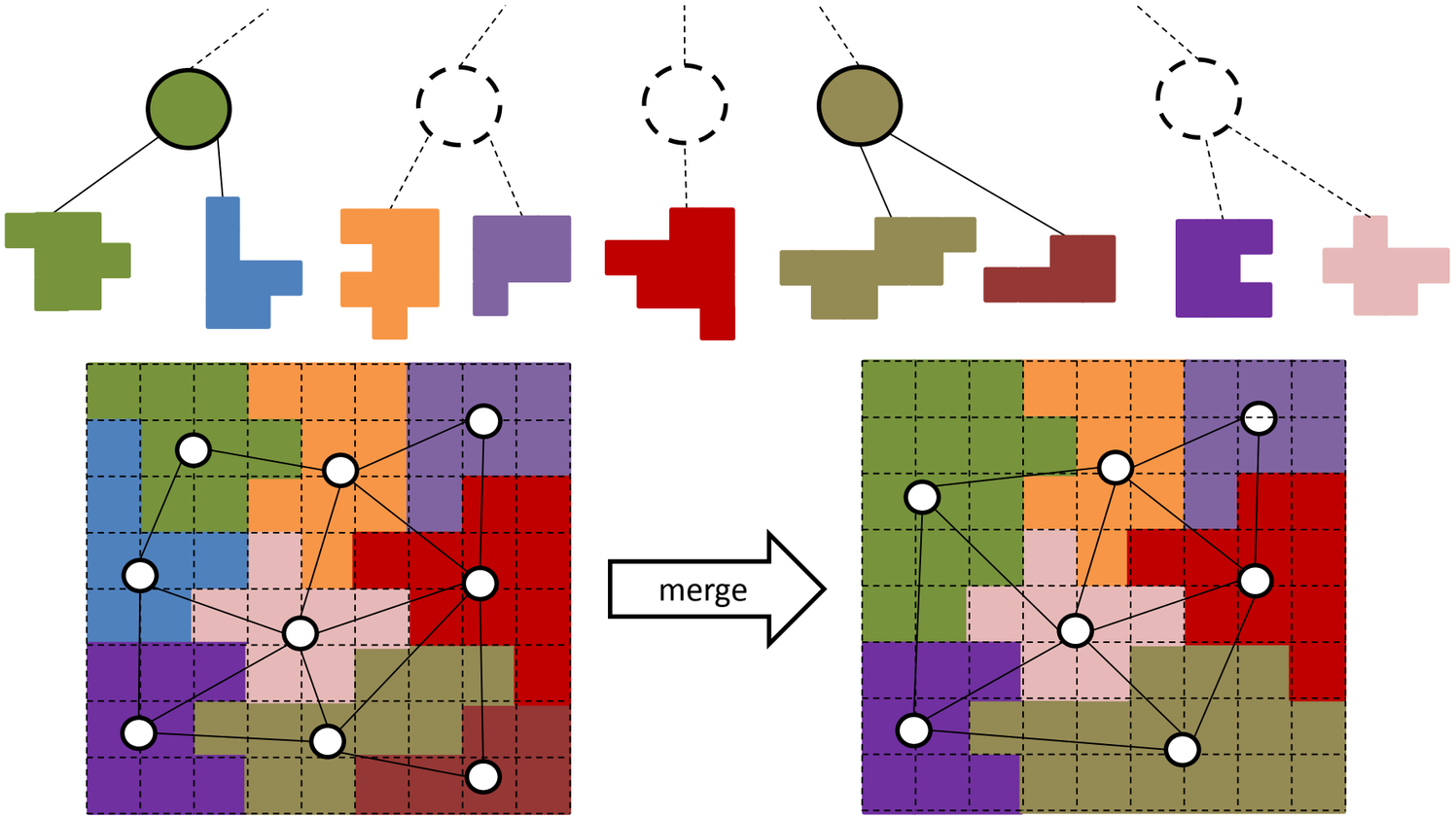
Methods: Hierarchical Merging

- Running template
- Construct a graph
  - Nodes → clusters; edges → neighbors
  - Adjacency matrix



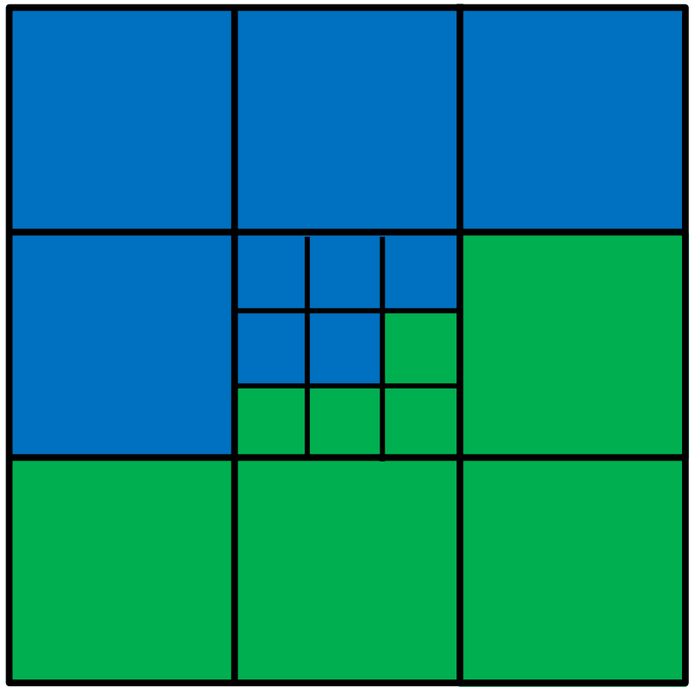
Methods: Hierarchical Merging

- Merge nodes in graph if they are too similar



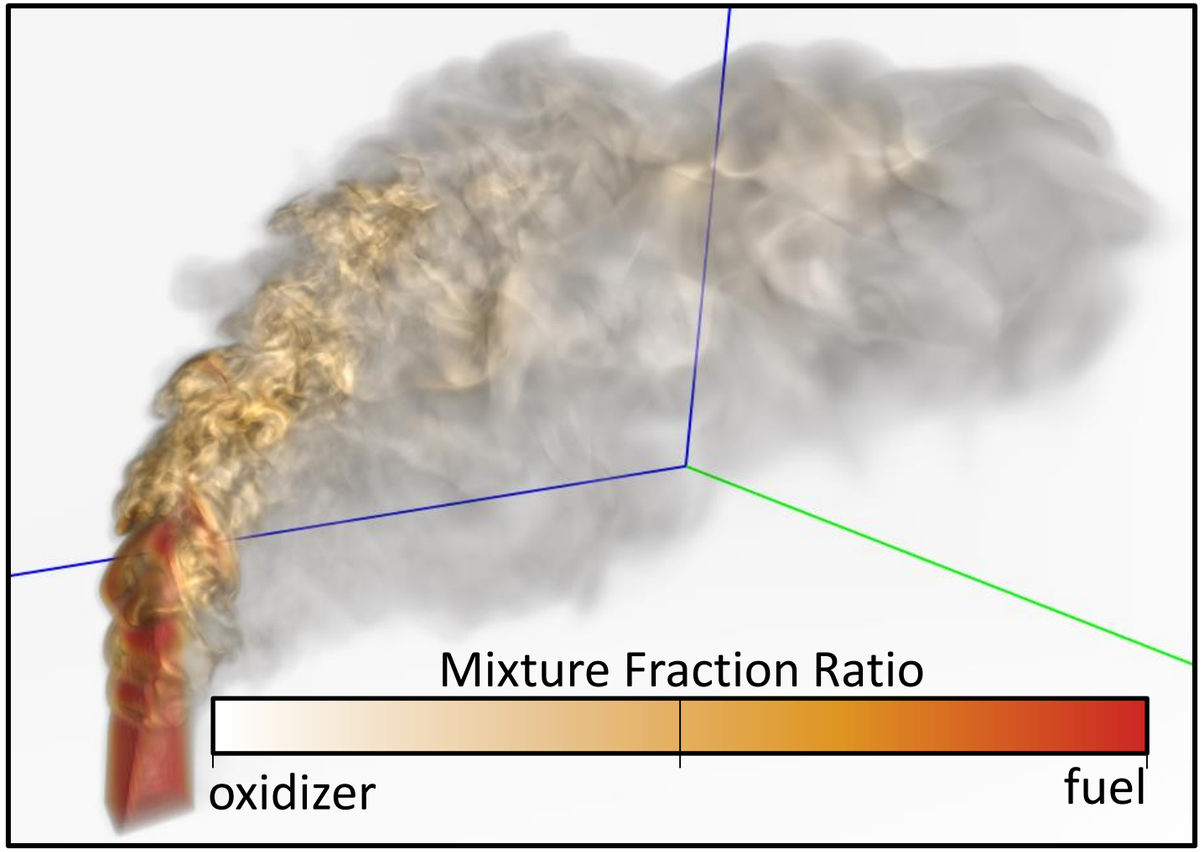
Methods: Uncertainty-based Refinement

- Only refine supervoxels with high uncertainty
- Fetch necessary raw data
- Re-cluster new voxels
- Performance vs. accuracy

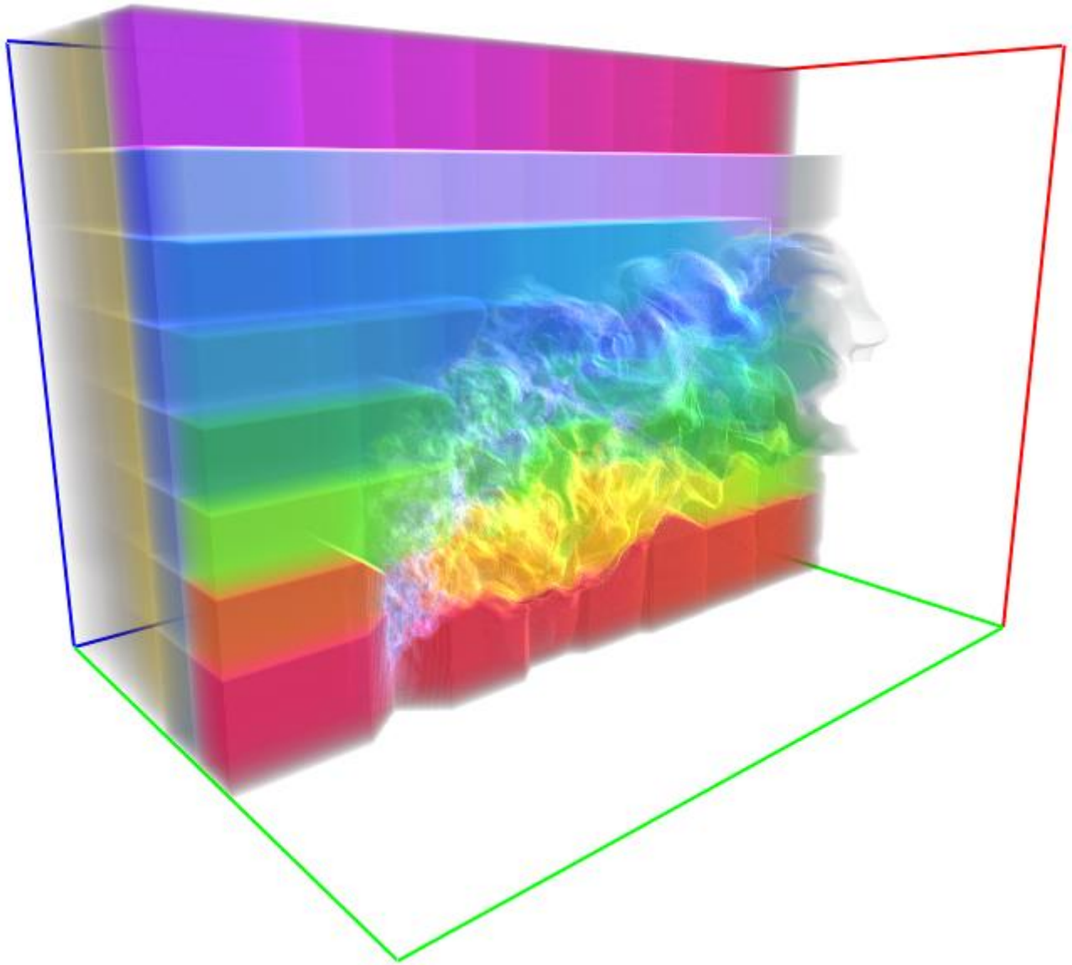


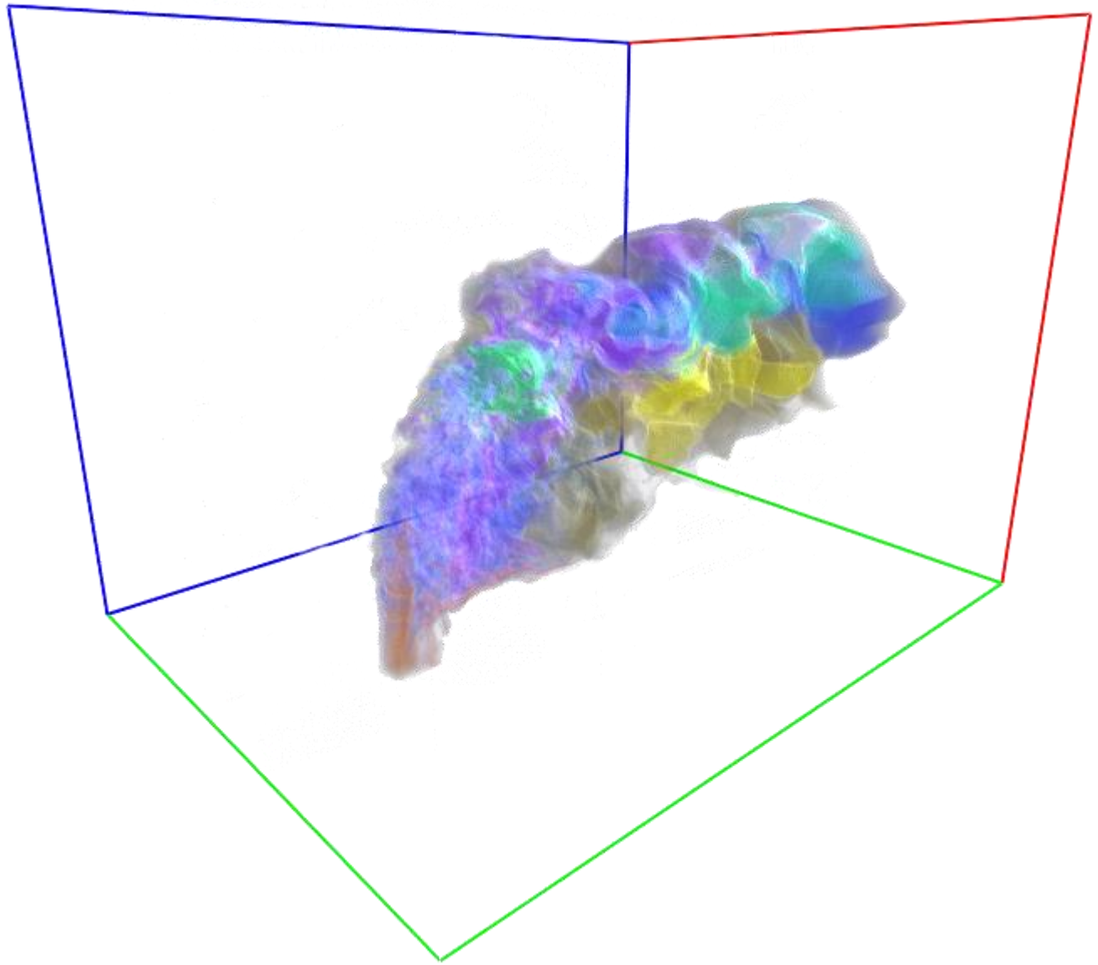
Results: Combustion Dataset

- S3D, Sandia National Labs
- Highly turbulent and complex features
- 704 x 540 x 550
- Mixture fraction variable



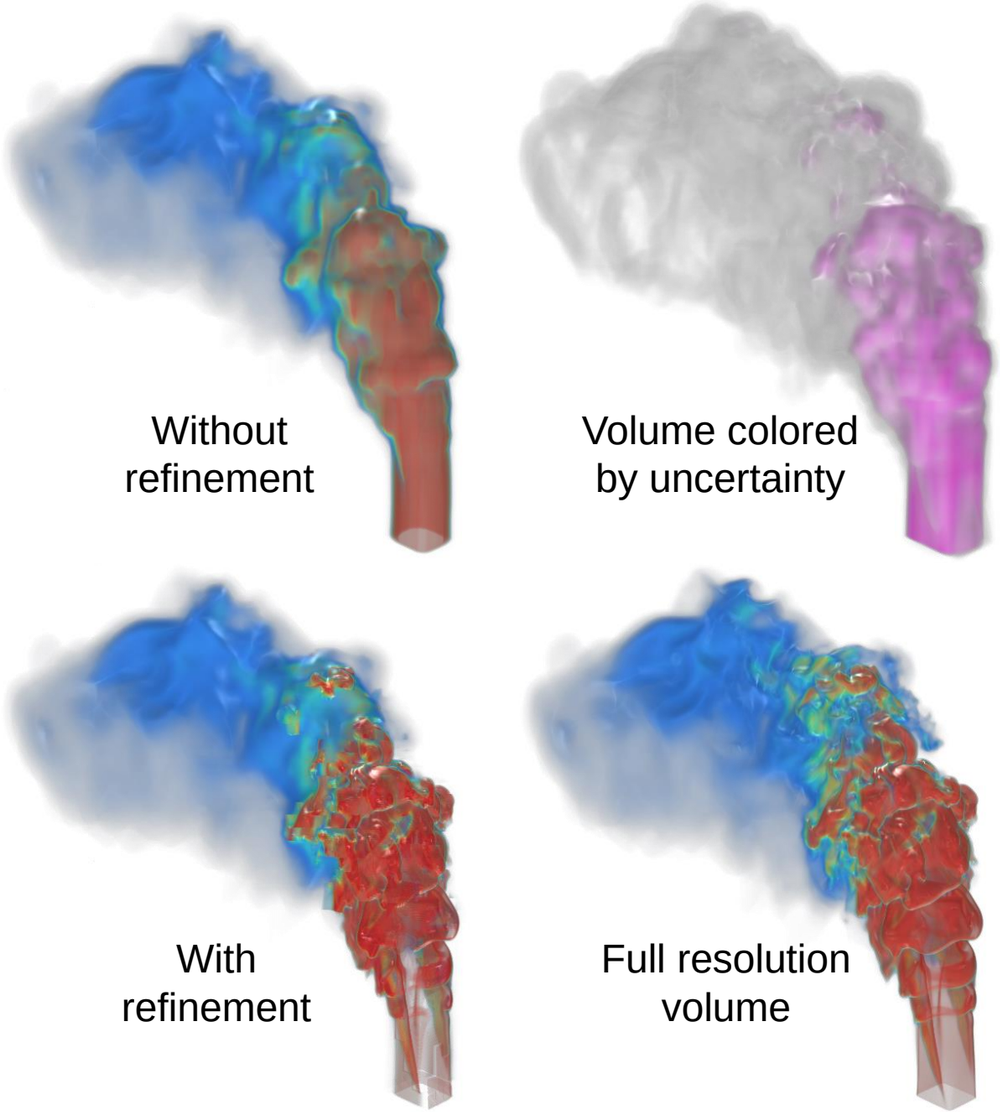
Results: Combustion Dataset





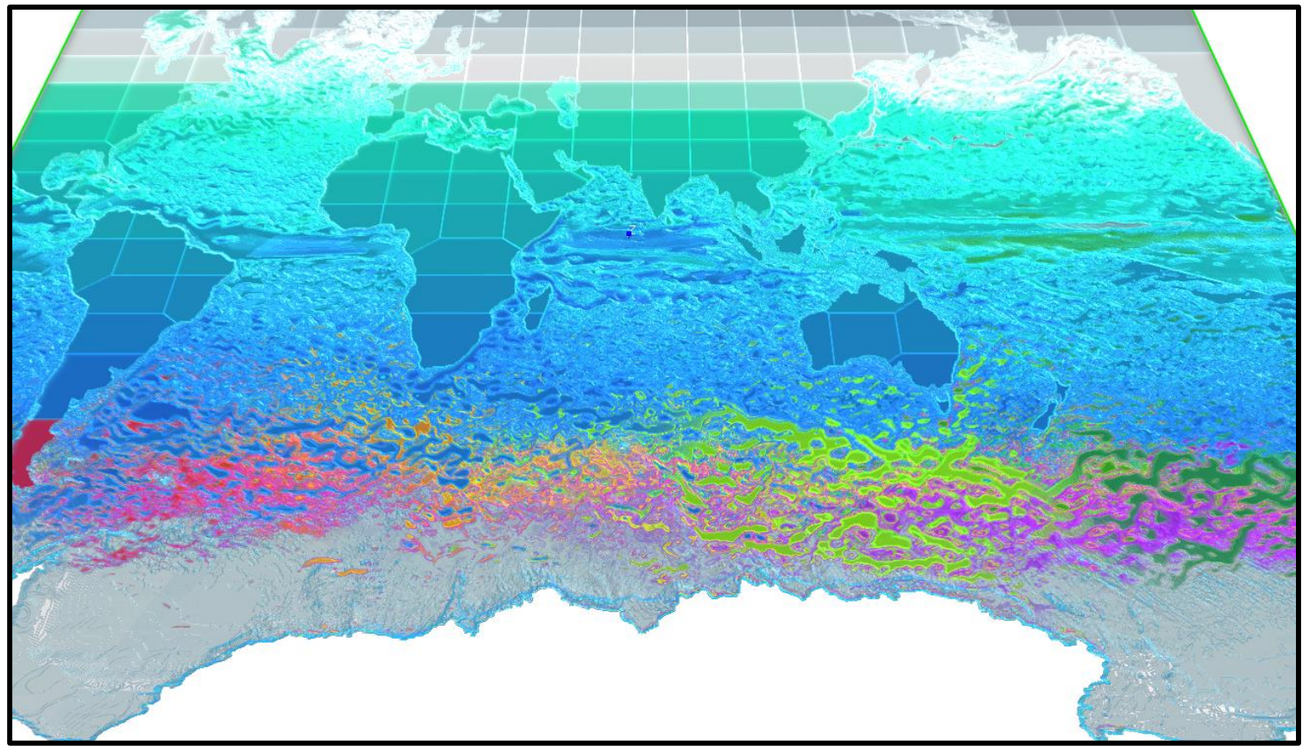
Results: Combustion Dataset

- Investigate uncertainty-based refinement
- Achieve results that closely match full resolution volume



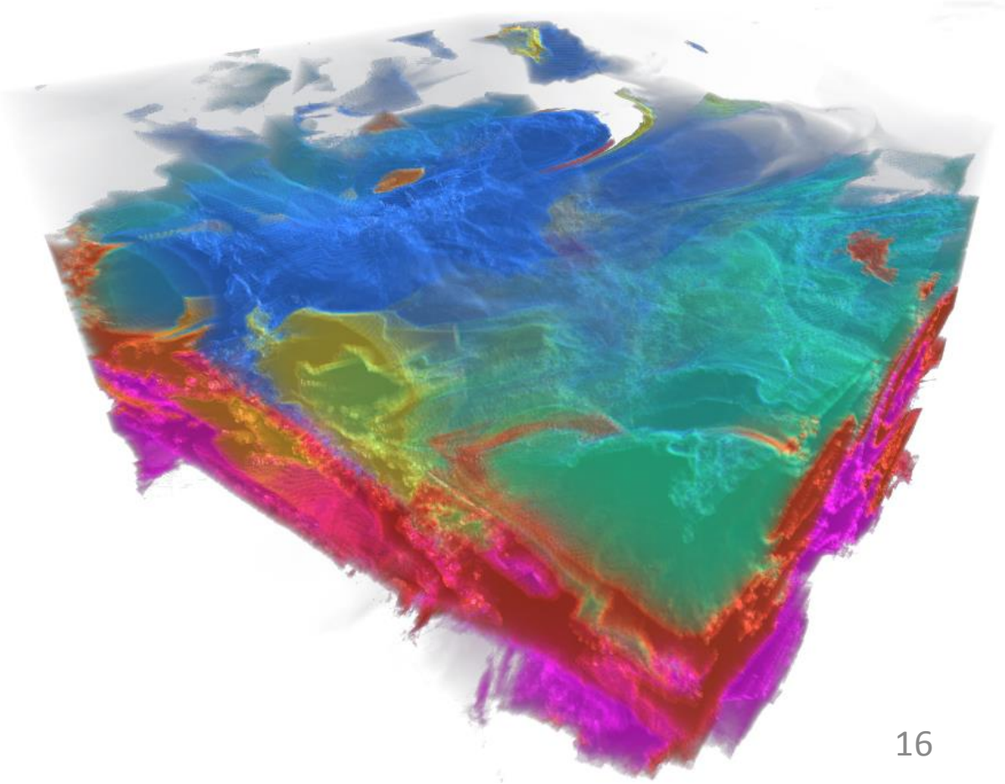
Results: Ocean Dataset

- POP model, NOAA Geophysical Fluid Dynamics Lab
- Turbulent mixing
- 3600 x 2400 x 42
- Flow velocity mag.



Results: Flow Dataset

- Flow simulation, Argonne National Laboratory
- Columnar and stratified structures of Boussinesq flows
- 4096 x 4096 x 4096
- Vorticity variable



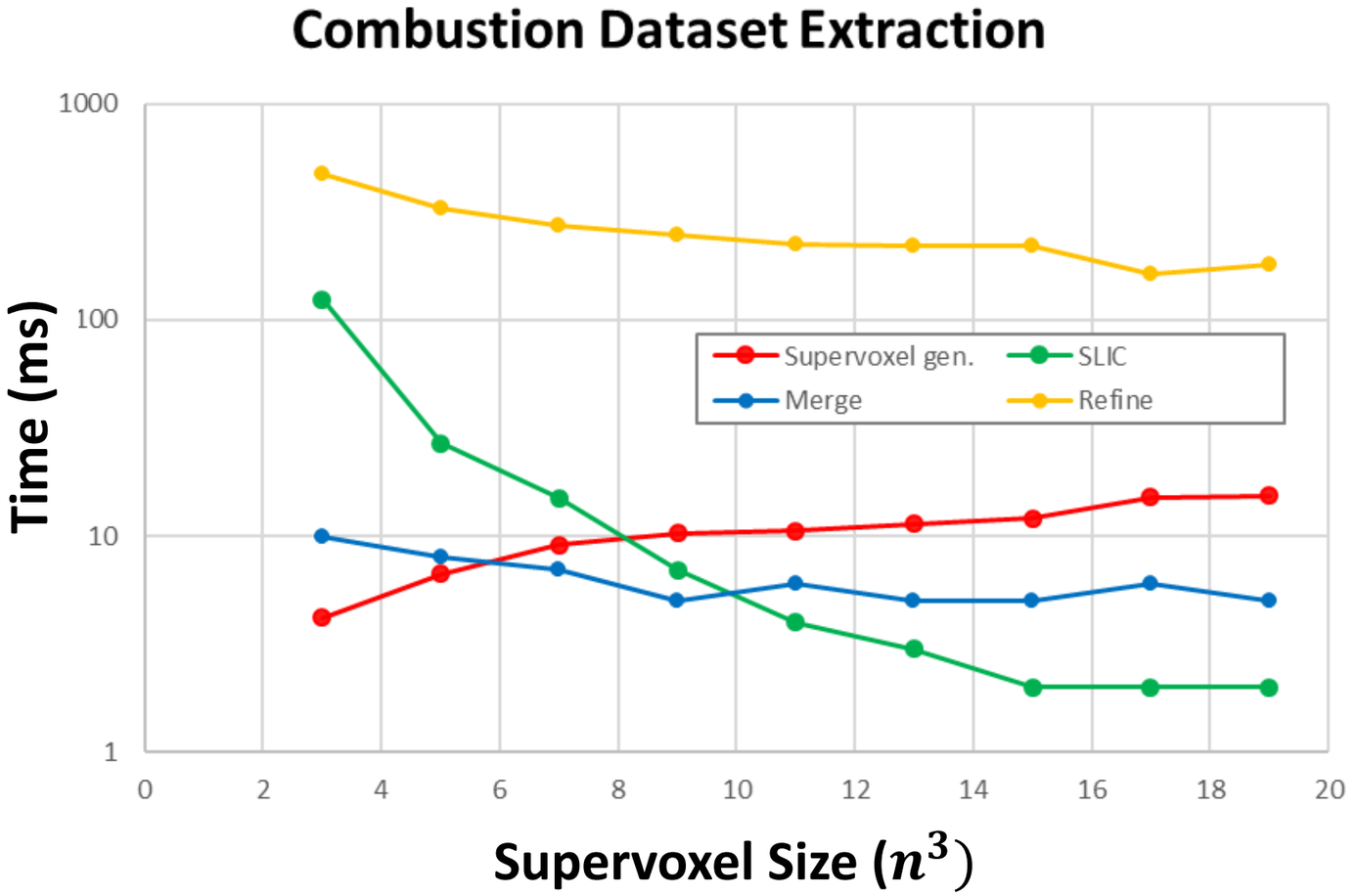
Results: Performance Tests

- Combustion Dataset (512 clusters)

Optimum:

SV Size: 17^3

Total Time: 187 ms



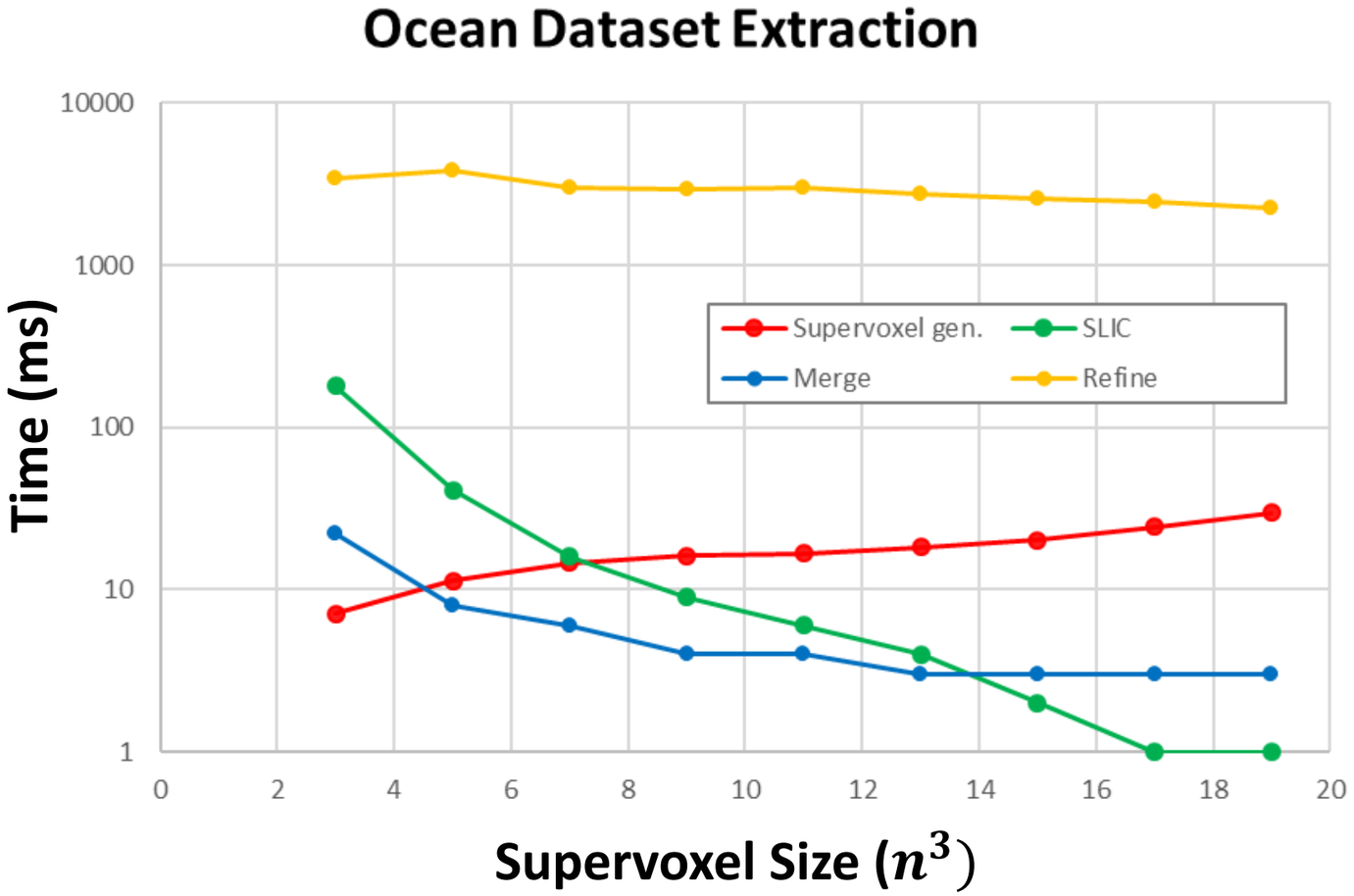
Results: Performance Tests

- Ocean Dataset (400 clusters)

Optimum:

SV Size: 19^3

Total Time: $2299\ ms$



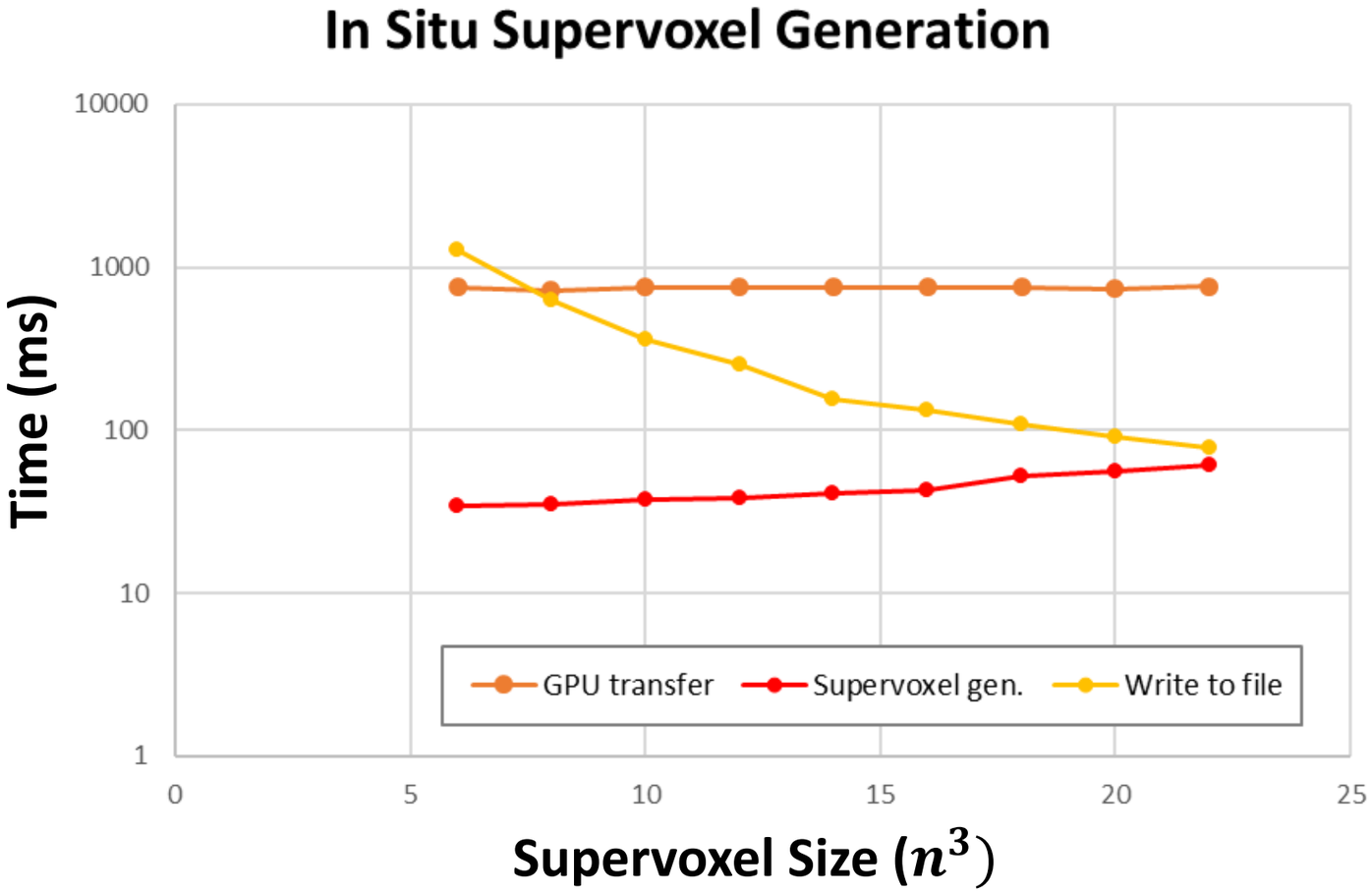
Results: Performance Tests

- Combustion and ocean easily manageable
- Flow dataset?
  - Hundreds of GB per timestep
  - Large I/O cost
- In situ supervoxel generation

Results: Performance Tests

- Emulate in situ case (Titan)

Constant number of nodes (256)



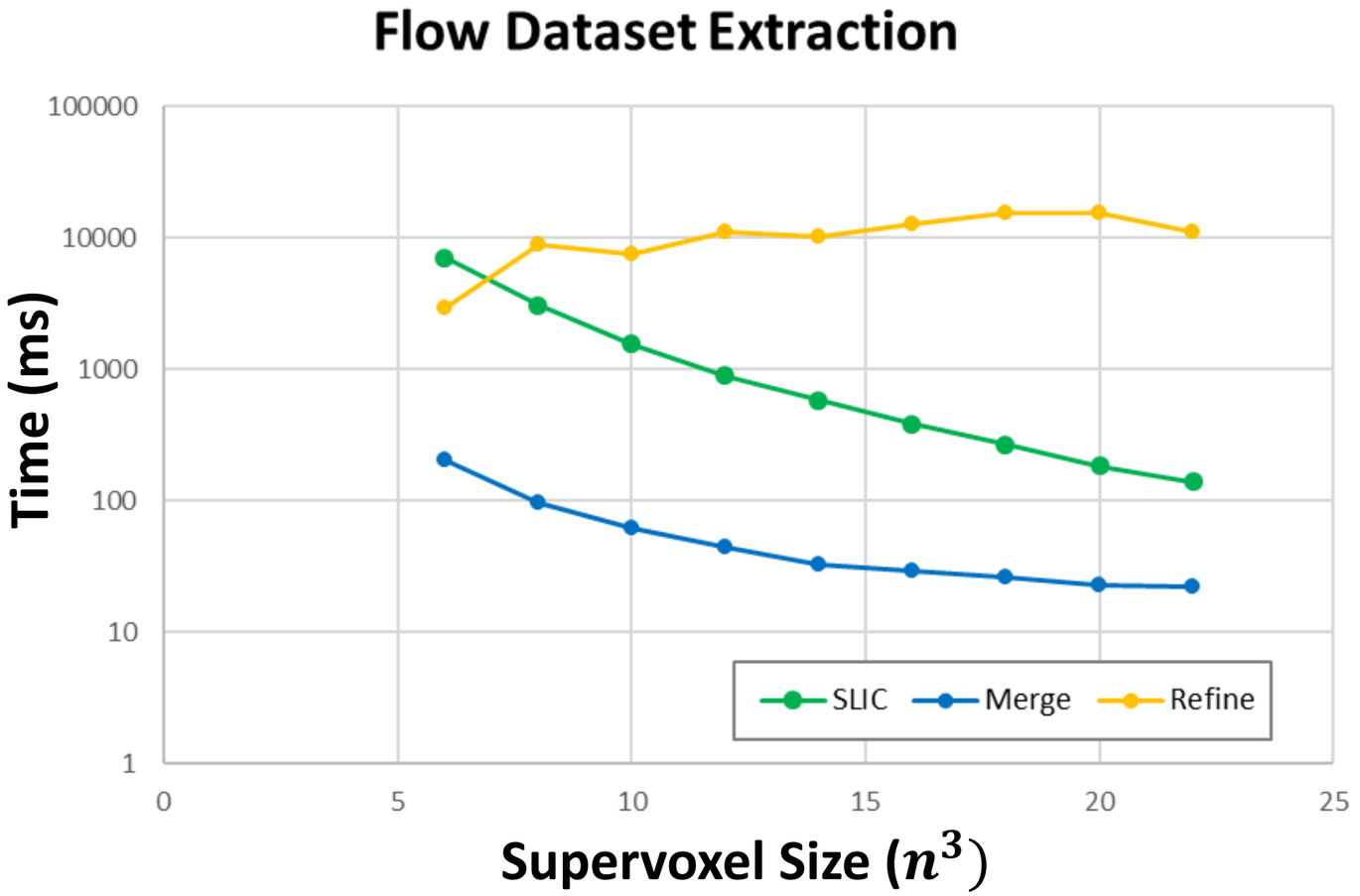
Results: Performance Tests

- Flow Dataset (1000 clusters)

Optimum:

SV Size: 10^3

Total Time: $9159\ ms$



Conclusion

- Develop a hybrid feature extraction technique
  - Multiresolution advantages of supervoxels
  - Uncertainty-based refinement
  - GPU accelerated SLIC
- Control over **performance** and **accuracy**
- Can interactively handle large datasets on a desktop PC

Acknowledgements

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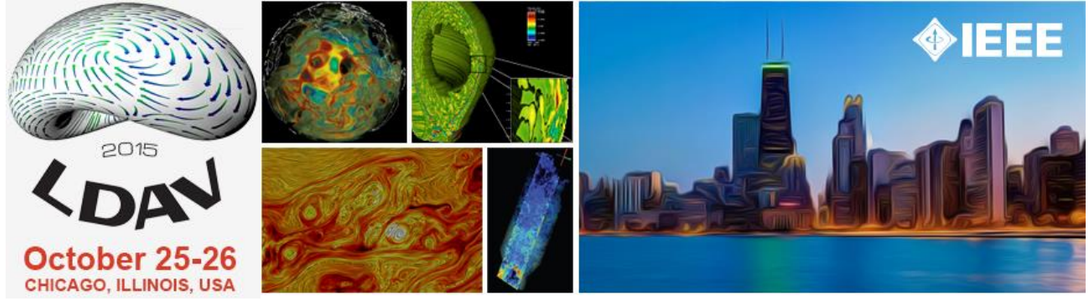
  - U.S. Department of Energy via grants DE-SC0005334, DE-FC02-12ER26072, and DE-SC0012610



Thank You

Questions?