AMRIC: A Novel In Situ Lossy Compression Framework for Adaptive Mesh Refinement Applications Use HDF5

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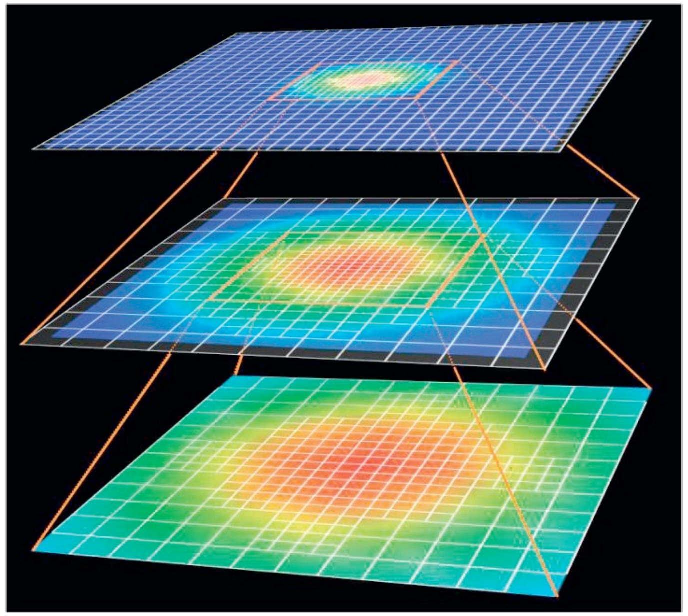
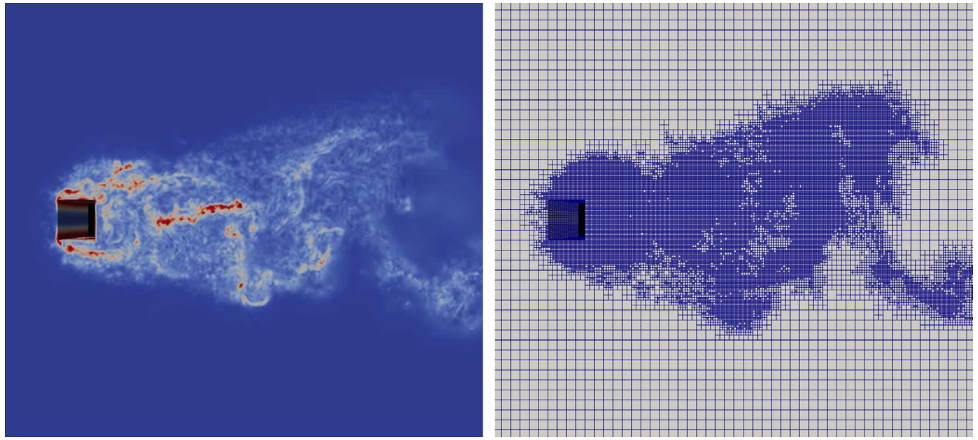
AMRIC, In situ AMR Compression: Background of AMR

Introduction to AMR

- Each mesh represents a value of an area.
  - Smaller mesh → higher resolution
- Change the mesh (**spatial resolution**) based on the level of refinement needed by the simulation, use **finer mesh** in "**more important**" region
  - Achieve the desired accuracy as well as increase computational and storage savings.
- Result in **hierarchical data** with **different resolutions**
- One of the most widely used frameworks for HPC apps





https://www.cttc.upc.edu/?q=node/165

Why HDF5?

Streamlined (de)compression

- Data can be (de)compressed using a (de)compression filter **during write/read** operations
  - For compression: set the filter and call H5Dwrite
  - For decompression: call H5Dread

Better usability, especially for the AMR data

- AMR data has a **hieratical** nature which aligns well with **H**DF5
  - Contains different lvl & dataset, which can be easily managed using H5
  - Contains lots of metadata which can be easily accessed & manage
    - **h5dump -A**

```
HDF5 "Ori.h5" {
GROUP "/" {
   ATTRIBUTE "dim" {...}
   ATTRIBUTE "num_levels" {...}
   ...
   GROUP "level_0" {
      ATTRIBUTE "prob_domain" {...}
      ATTRIBUTE "ref_ratio" {...}
      DATASET "boxes" {...}
      DATASET "data:datatype=0" {...}
      DATASET "data:offsets=0" {...}
      ...
   }
   GROUP "level_1" {
    ...
   }
}
}
```

AMRIC: HDF5 Compression Filter Modification

1. Compression-oriented **preprocessing** workflow for AMR data
2. Optimize the state-of-the-art SZ lossy **compressor's efficiency** for AMR data
3. **Overcome the gap between the HDF5 and AMR applications → bigger chunk**
   - Modifying the AMR data layout
   - Modifying the HDF5 compression filter mechanism

HDF5 need chunked data for compression filters → What is the best chunk size?

- We want a **large chunk** size in terms of **compression**
  - Small chunk→ too many of data blocks → low **compression ratio & I/O perf**
- HDF5 may not prefer too large chunk
  - I/O load imbalance
  - Cache size issue
  - Memory overhead
- **Compression perf vs HDF5 Perf?**

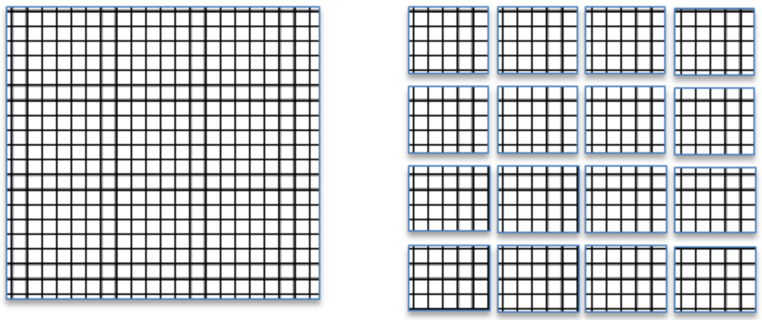
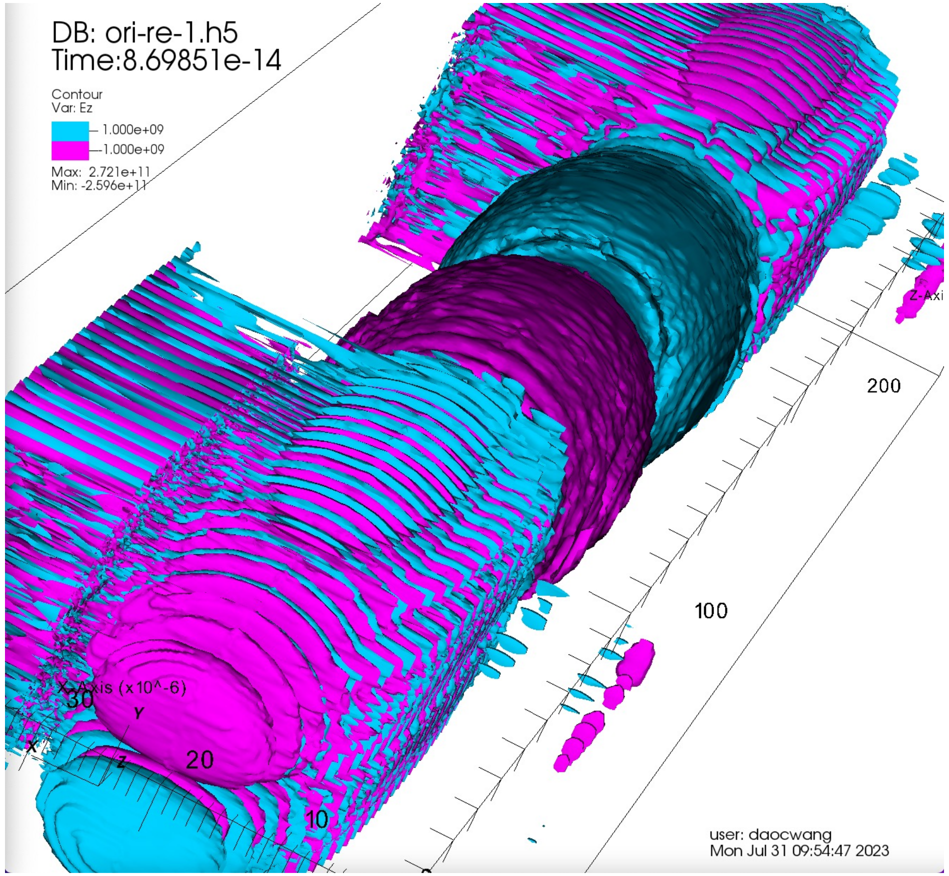


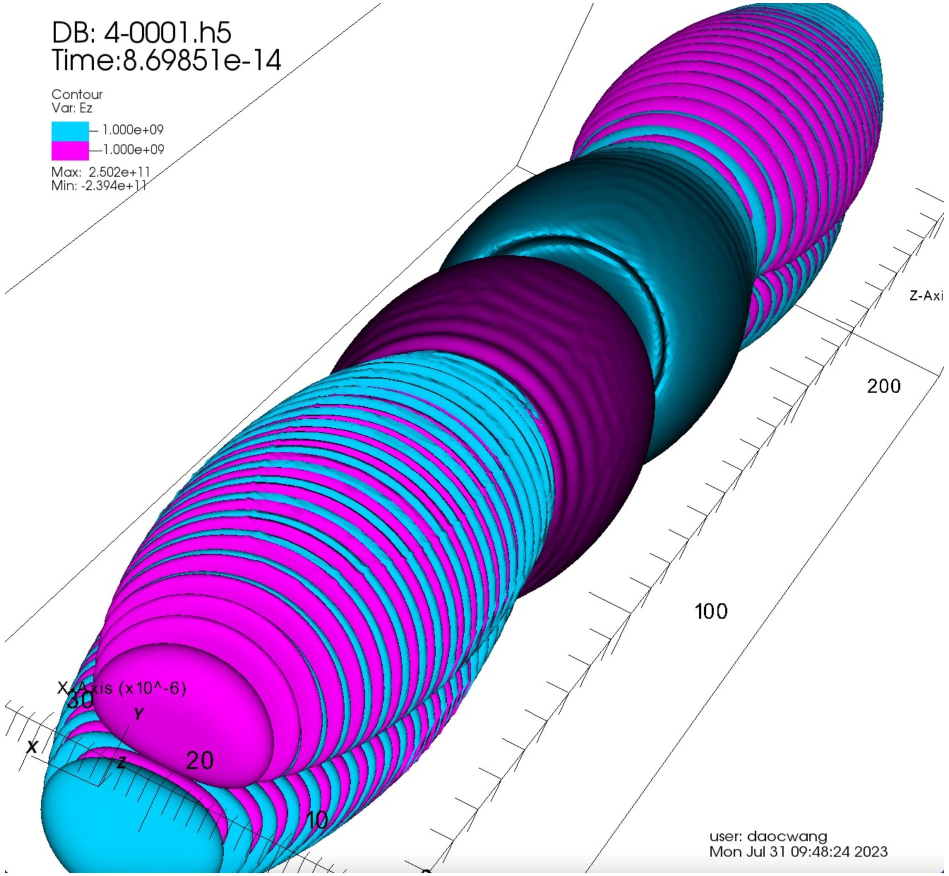
Figure 1: Data array is logically split into equally sized chunks each of which is stored separately in the file.

AMRIC: Evaluation on Compression perf

Boost compression perf for AMR applications



Original, CR = **19.0**
small chunk size



Our AMRIC, CR = **23.9**
Large chunk size

AMRIC: Evaluation on I/O Time

Up to **10.5×** I/O performance improvement over the non-compression solution.
Up to **39×** over the previous compression solution (w/ small chunk)

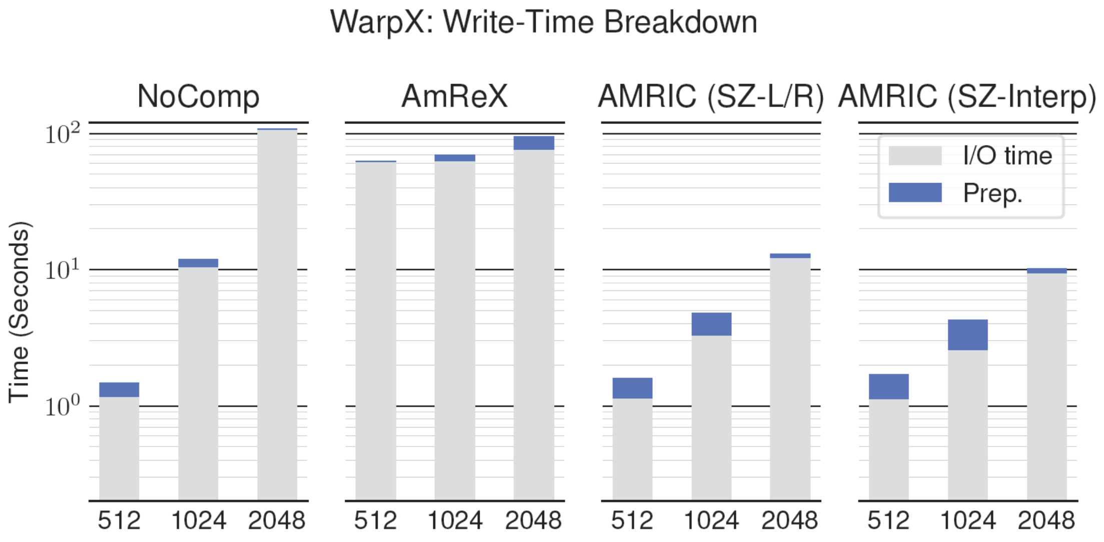


Figure 17: Writing time of WarpX runs with different scales (in a weak scaling study). Log scale is used here for better comparison.

Figure 18: Writing time of Nyx runs with different scales. Log scale is used for better comparison.