I/O Performance with Compression Enabled

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NCAR/ASAP/IOWA
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CESM Data Volume Increasing

CMIP5 175TB
CMIP6 230TB (compressed)
Introduction

- CESM need compression with **good IO performance**
  - Enabled parallel compression
  - Enabled asynchronous read/write in PIO
  - Evaluate cloud-friendly data format
  - Compare IO alternatives with IOR benchmark results
  - Conclusion
Impact of Compression on IO Performance

- Compression performance analysis
  - Configuration:
    - Pecount = 288, ompthreads = 3 => 8 io processors
  - IO format:
    - Pnetcdf: parallel NetCDF in 64bit. ← default in CESM
    - NetCDF4c: NetCDF4 with serial compression
    - NetCDF4p: NetCDF4 with parallel
    - NetCDF4pc: NetCDF4 with parallel compression
    - Async NetCDF4pc: NetCDF4 with parallel compression in asynchronous mode

IO Performance with Compression Enabled
## Enabled Parallel Compression in CESM/PIO

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<tr>
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<td>f09_f09 (total/history io)(sec)</td>
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<tr>
<td>Total increased</td>
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<td></td>
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### Enabled Async Mode in CESM/PIO

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Evaluate Cloud-Friendly Data Format

• Zarr/Z5
  – Provides Python/C++ classes and functions for N-dimensional array
  – Writes out array data in chunks and each chunk is compressed
  – Convert to/from NetCDF files easily
  – Uses distributed storage systems: S3Map, HDFSMap, GCSMap

• Working on a SIParCS project with Weile to enable Z5 backend in PIO
IOR Benchmark

• IOR: Interleaved or Random
  – File system benchmarking tool
  – Well-suited for evaluating the performance of parallel system
  – Have several IO backend: POSIX, MPIIO, NCMPI, HDF5, S3

• Purpose
  – IOR has so many IO backend
  – Can compare performance among different IO backends

• Prepare for IOR benchmarking
  – Added c wrapper of Z5
  – Integrated in IOR benchmark tool
IOR Benchmark
Write 16 Segments of 256KB Blocks

• One processor per node
MPIIO Collective Write On Multiple Nodes

- Write throughput decreased to one tenth
- One processor per node

![Graph showing throughput vs number of nodes for different IO methods.]

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IO Performance with Compression Enabled
Conclusion on IO with Compression

- Write out from one node instead of multiple nodes
- Evaluate Z5 backend
  - Flexible chunking, compression and metadata management
  - Both pthread and MPI
  - Better with cloud storage
- Enable async mode with large buffers

- Potentially get a compression IO with good performance
Question?

• Contact me at haiyingx@ucar.edu
IOR Benchmark Scaling Study

Scaling study by multiple I/O Libraries

Throughput (MB/s)

- Z5
- HDF5
- NetCDF

Data points for:
- 64MB
- 128MB
- 256MB
- 512MB
- 1024MB
IOR Benchmark Aggregate Study on 1 Node

Aggregate study on one node by multiple I/O Libraries

Throughput (MB/s)

- Z5
- HDF5
- NetCDF

1 2 4 8 16
XIOS Server

• XML-IO-SERVER
  – Two ways: attached mode, and server mode
  – Accept one-to-one file mode and multiple-to-one file mode
  – Use double buffers on client side, and circular buffer on server side
  – Very good performance
    • 1.5% IO for daily mean output (4322x2882x31, 8160 cores, 32 XIOS)
    • 5% IO for 6 hours mean output
    • 15%-20% for hourly mean output (128 XIOS)

  – No API for inquiring dimension, variable id, etc.
  – Need to make sure all communications overlapped by computation
  – All writing overlapped by computation
  – Otherwise, blocking time will take longer
IOR Benchmark Conclusion

- Z5, NetCDF, HDF5 with compression
  - same performance when write once from multiple processors
  - Z5 and NetCDF need more memories
  - Z5 and HDF5 are better when write aggregately in one node
  - Z5 is five times better when write aggregately from multiple nodes
- IO processors of CESM/PIO now is distributed on processors on multiple nodes
- Z5 has the advantages on chunking, compression and metadata