HDF5 & Blosc2

Unleashing the full potential of Blosc2 from HDF5

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EUROPEAN HDF5 USER GROUP (HUG) meeting
May 31th 2022

The Blosc Development Team


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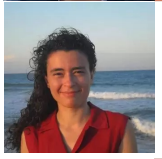
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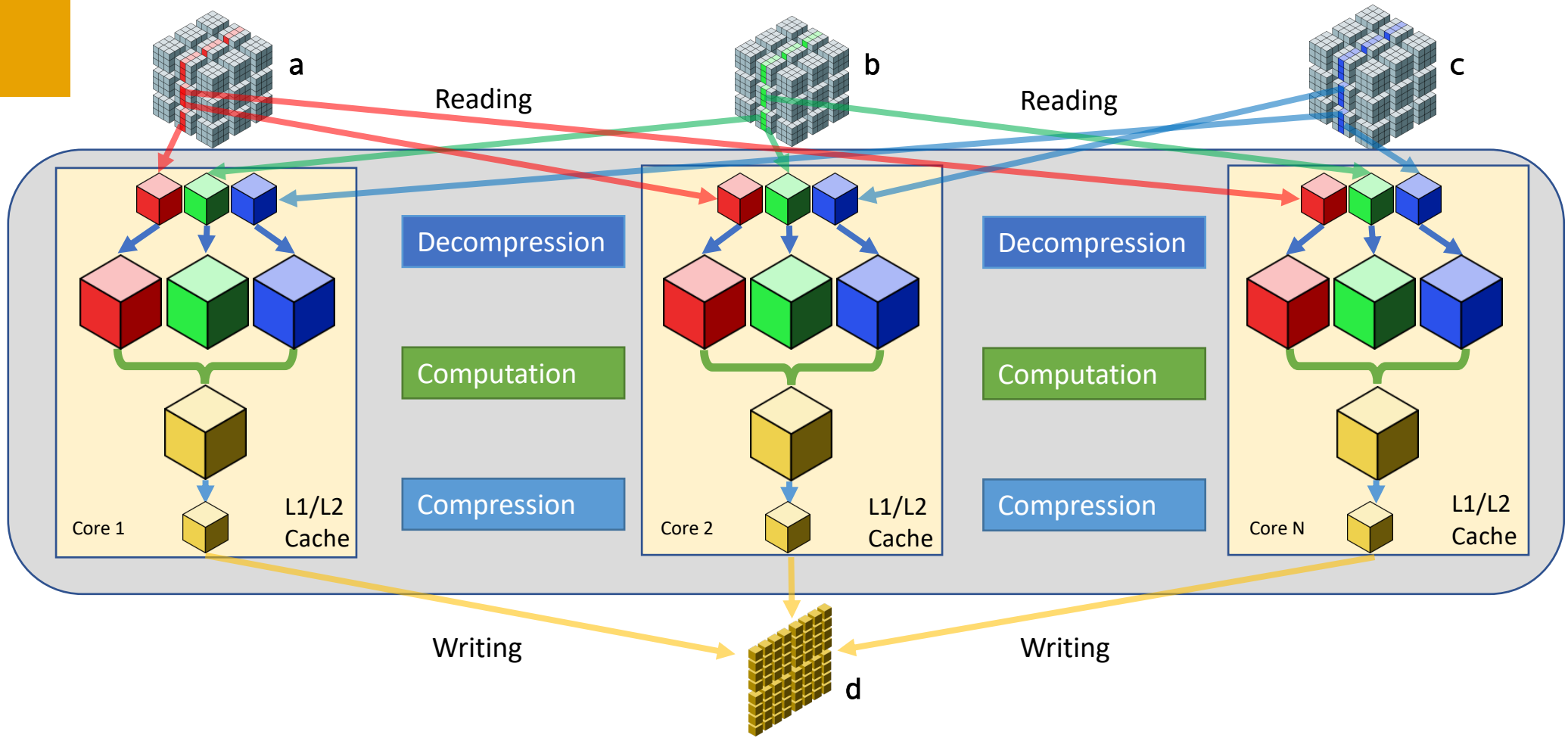
Francesc Alted (BDFL)

A few words about ironArray

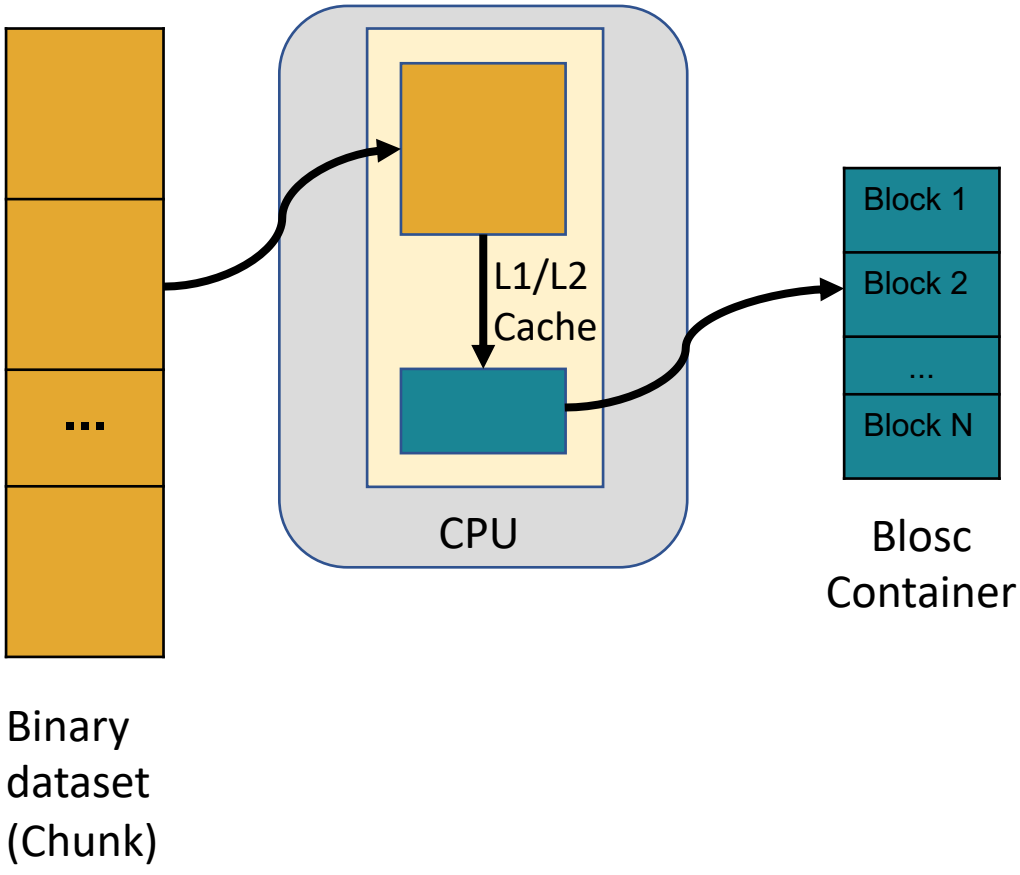
ironArray



Intertwining compression and computation for improving performance

What is Blosc?

- Sending data from CPU to memory (and back) faster than *memcpy()*.
- Split in blocks for better cache use: divide and conquer.
- It can use different filters (e.g. shuffle, bitsuffle) and codecs (e.g. LZ4, Zlib, Zstd, BloscLZ).



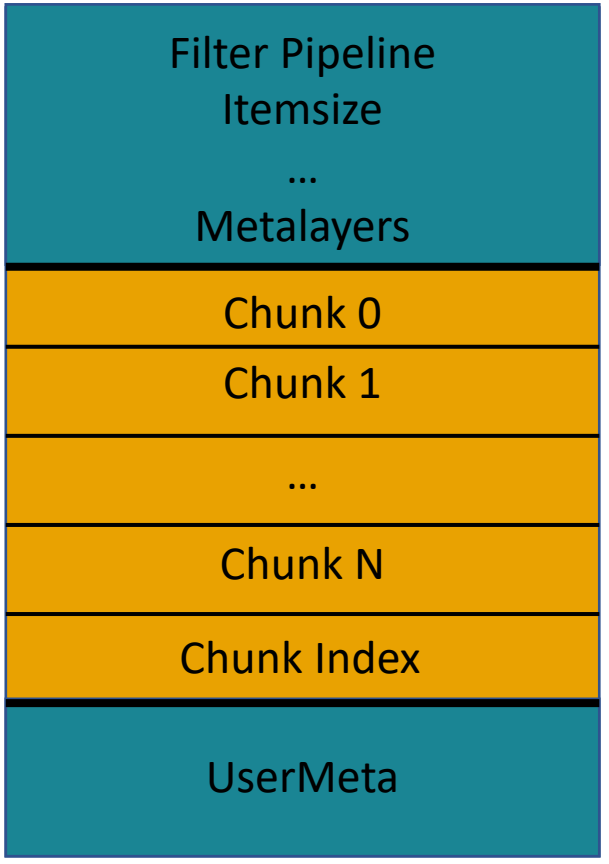
Origins of Blosc

- **2009**: it was very clear that compression was slowing down storage in PyTables/HDF5 a lot. Work began.
- **2010**: Blosc 1.0 was ready for production. Innovations:
    - Shuffle filter was optimized for SSE2 (*much* faster)
    - Multithreaded operation
- **2013**: Blosc gained multi-codec (LZ4, Snappy and Zlib where included)
- **2015**: hdf5-blosc plugin for HDF5 was released (hdf5plugin took over!)
- **2021**: Blosc2 appeared with **lots** of new features.

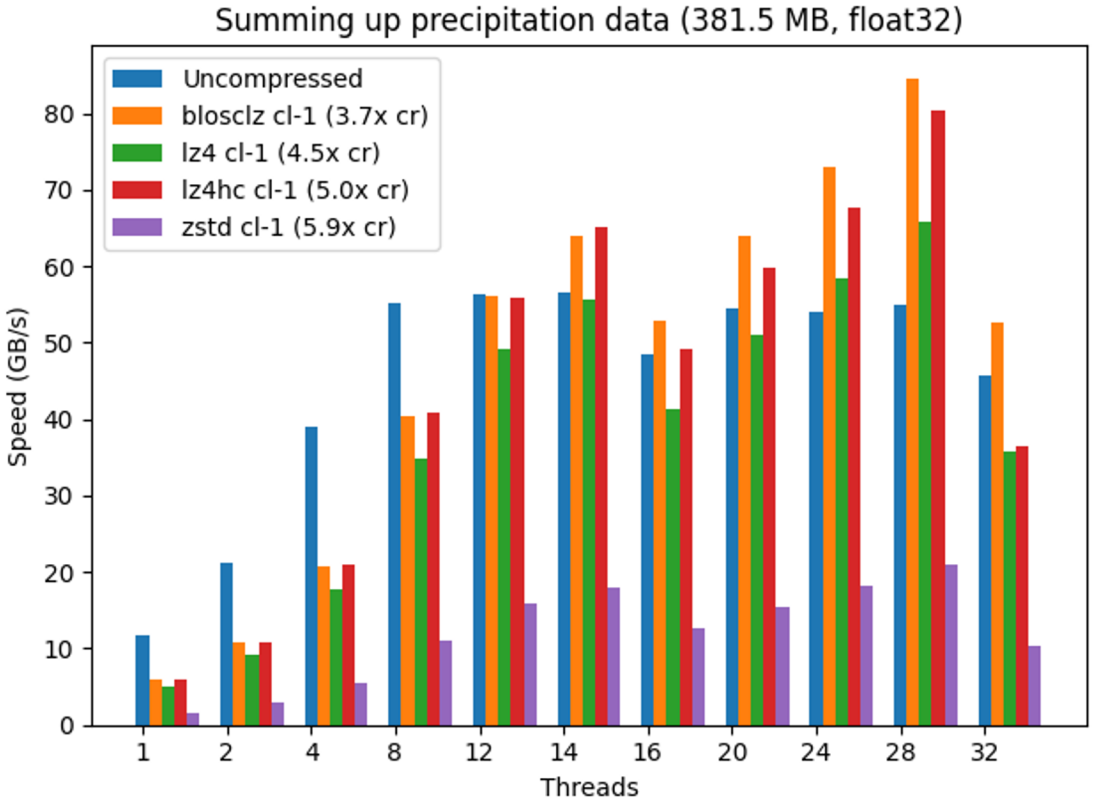
What is Blosc2?

- **Next generation of Blosc1**.
- New **63-bit frames** that expand over the existing 31-bit chunks in Blosc1.
- **Metalayers** for adding info for applications.
- Area for adding **metadata for users** (variable length).

Blosc2 Frame



Example of Decompression Speed



https://www.blosc.org/posts/breaking-memory-walls/

HDF5: Multidimensions and Chunking

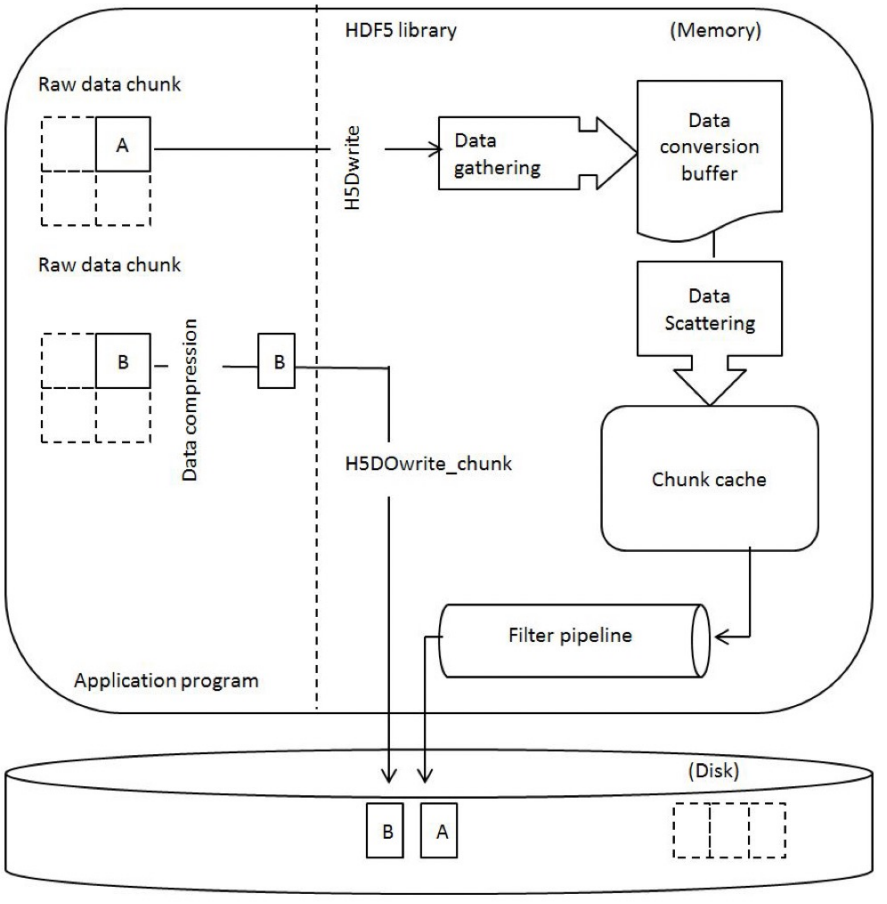
- Data can be stored in hypercubes, making retrieval very convenient.

HDF5

- But there is a price to pay for this flexibility: HDF5 is known to be **slow** when writing/retrieving (hyperslabs of) data.

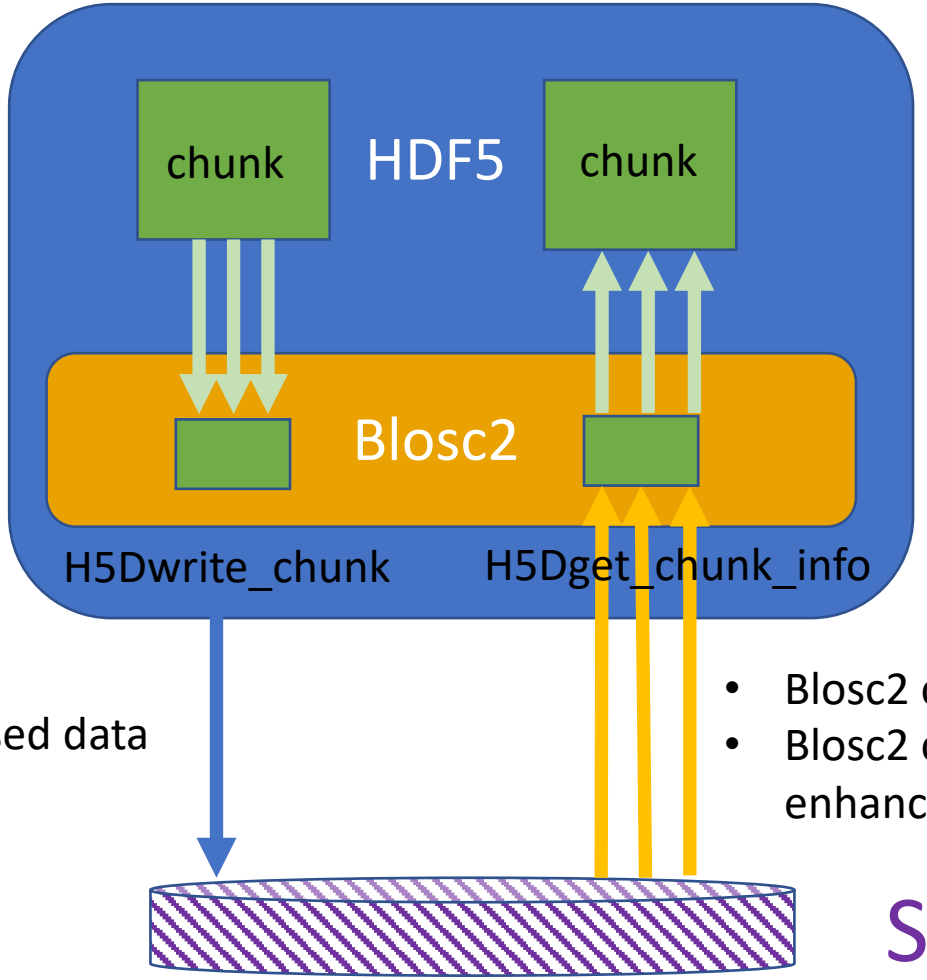
Direct Chunk Write/Read Feature

- Allow the aplication to handle the chunk I/O and bypass the powerful (but slow!) chunk handling machinery in HDF5.
- The result is that data can be handled up to about 10x faster (with efficient pre and post processing in the app).



Proposal 1: Use Blosc2 Inside Direct Chunk

All compression and decompression executed in parallel via Blosc2!



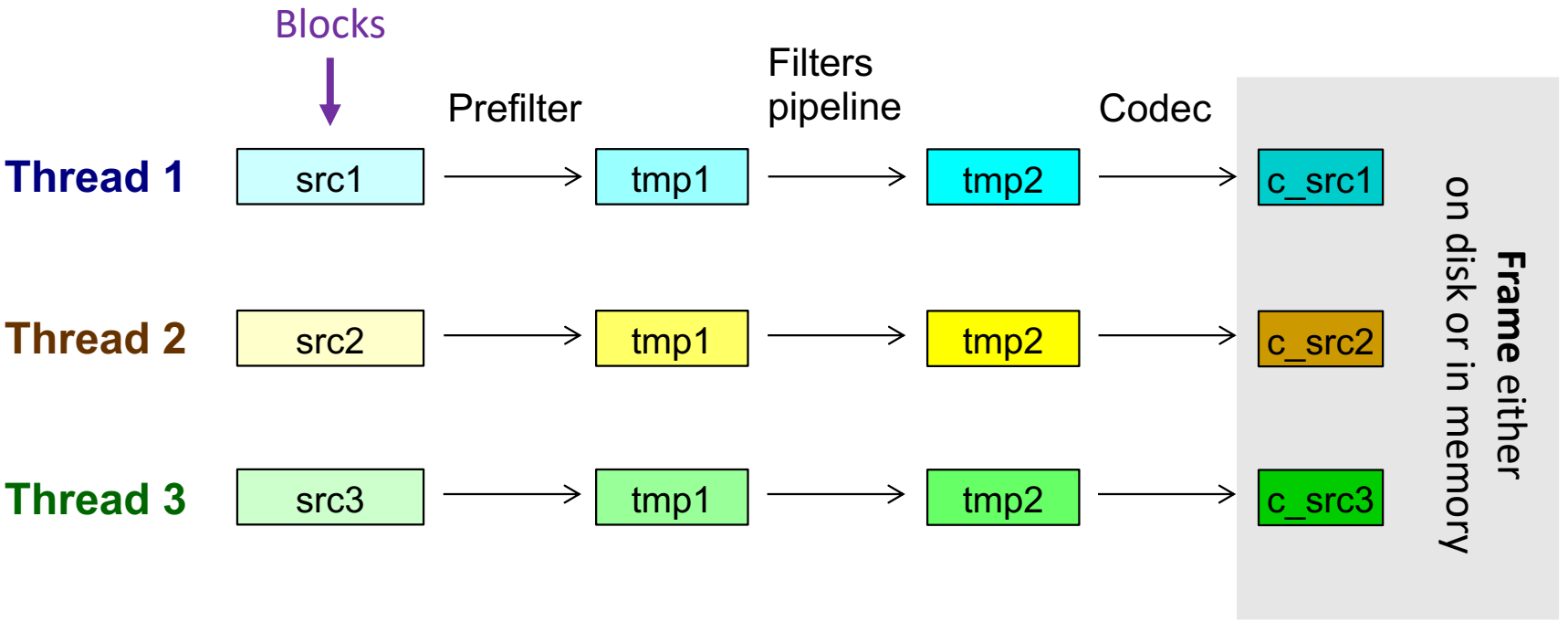
- HDF5 stores compressed data

- Blosc2 can do parallel I/O
- Blosc2 can do chunk reads with enhanced selectivity from disk

Blosc2 Advantages

Blosc2: Fine Tuned Cache Usage

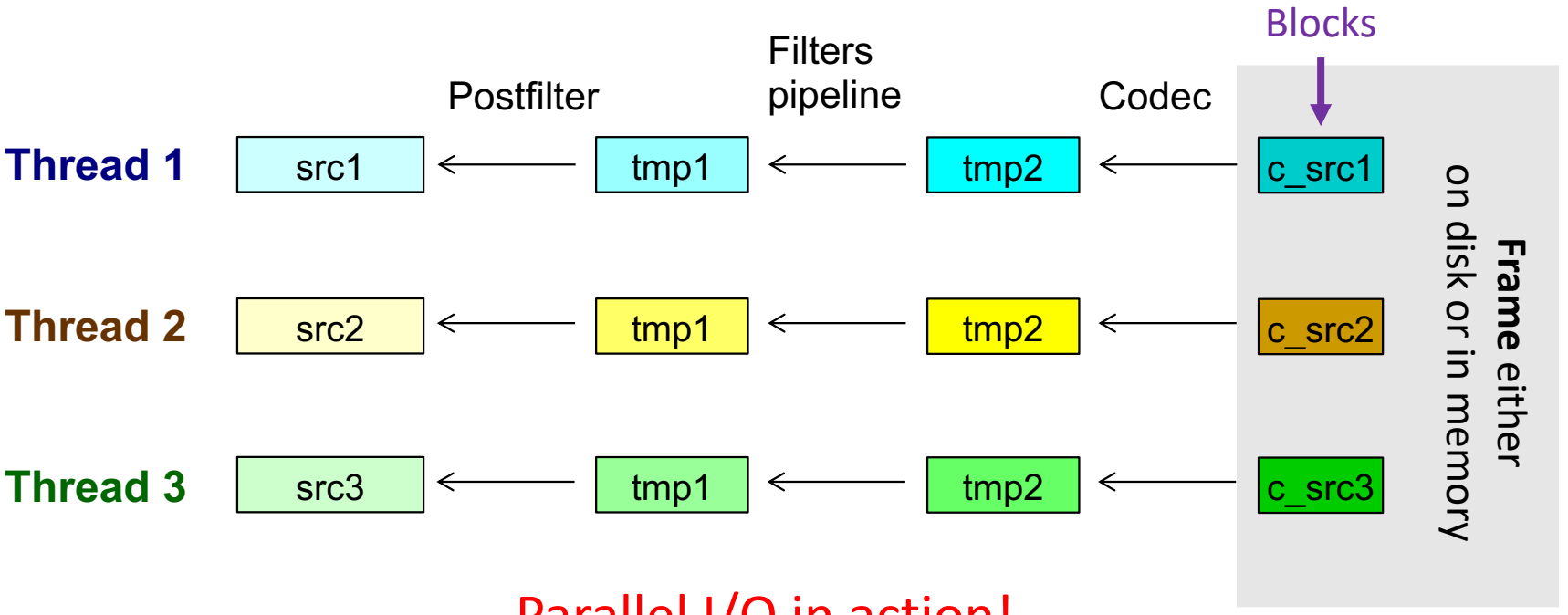
Compression: chunks are split in blocks for CPU cache sake



Buffers are reused **inside** CPU caches -> speed!

Blosc2: Leveraging I/O Parallelism

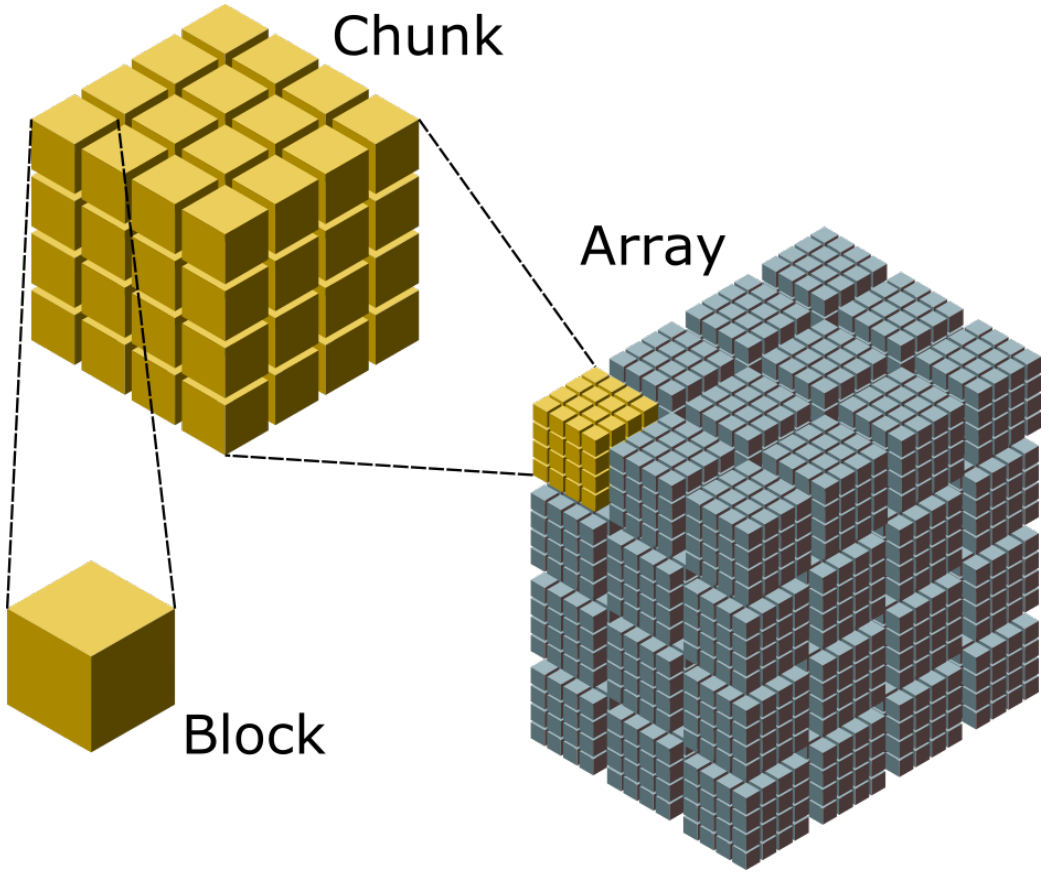
Decompression: blocks are read in parallel from storage



Parallel I/O in action!

Caterva: Blosc2 Goes Multidimensional

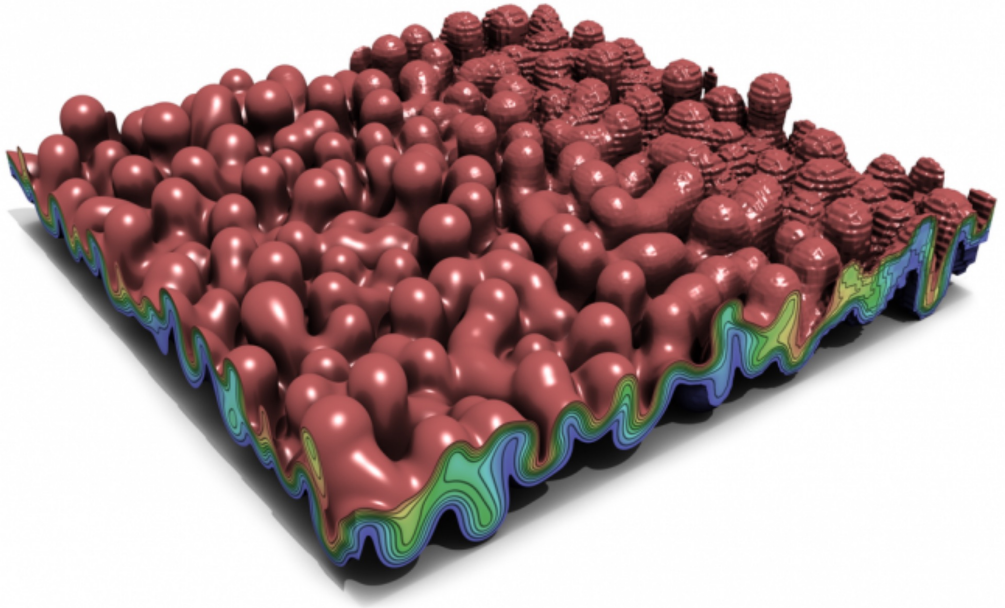
- Metalayer representing multidimensionality
- Each Caterva array is split in chunks
- Each chunk is split in blocks
- All the partitions are multidimensional!



Benefits of the Caterva Layer

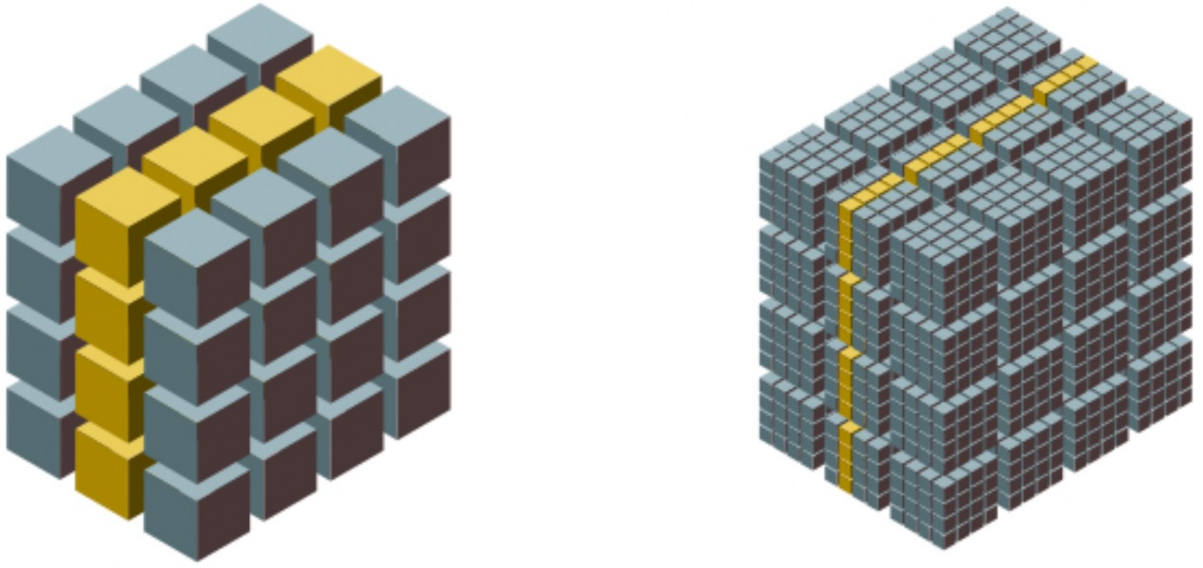
- Get **improved compression ratio** because data is packed in a way that can show higher spatial locality.

- Also, get **improved hyperslab query speed**, i.e. some blocks can be masked out so as to not read them.



ZFP: a new registered plugin

Masked & Paralel I/O in Multidim Datasets

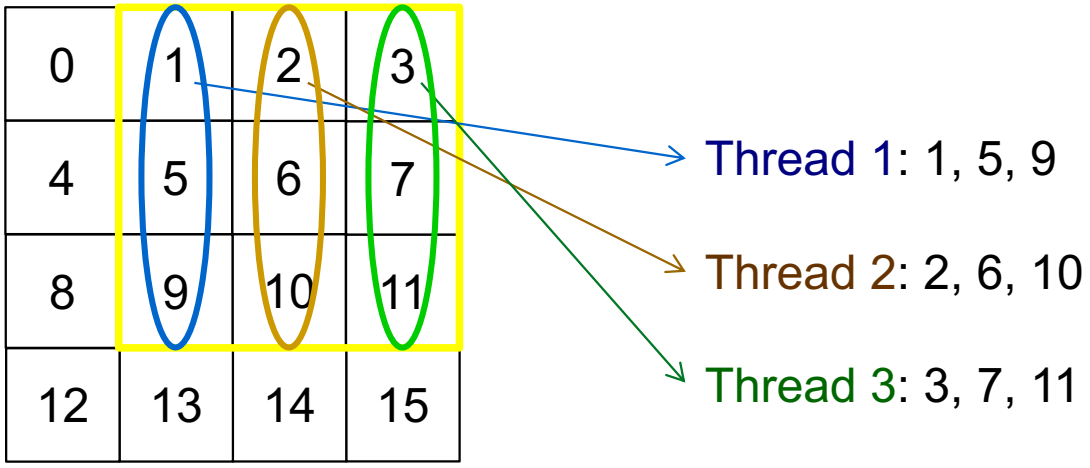


Much more selective and faster queries!

Caterva (https://github.com/Blosc/caterva) and ironArray (https://ironarray.io)

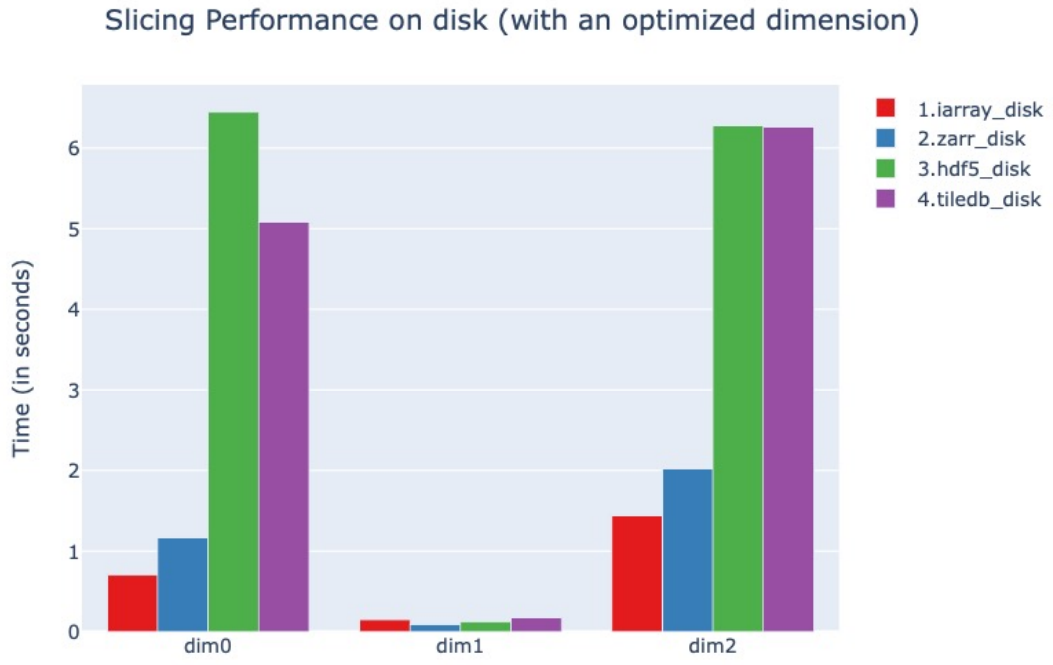
Block Masks and Parallel I/O

Block maskout	F	T	T	T	F	T	T	T	F	T	T	T	F	T	T	T
Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15



Specially effective when retrieving slices of multidim datasets.

Masked & Paralel I/O in Multidim Datasets



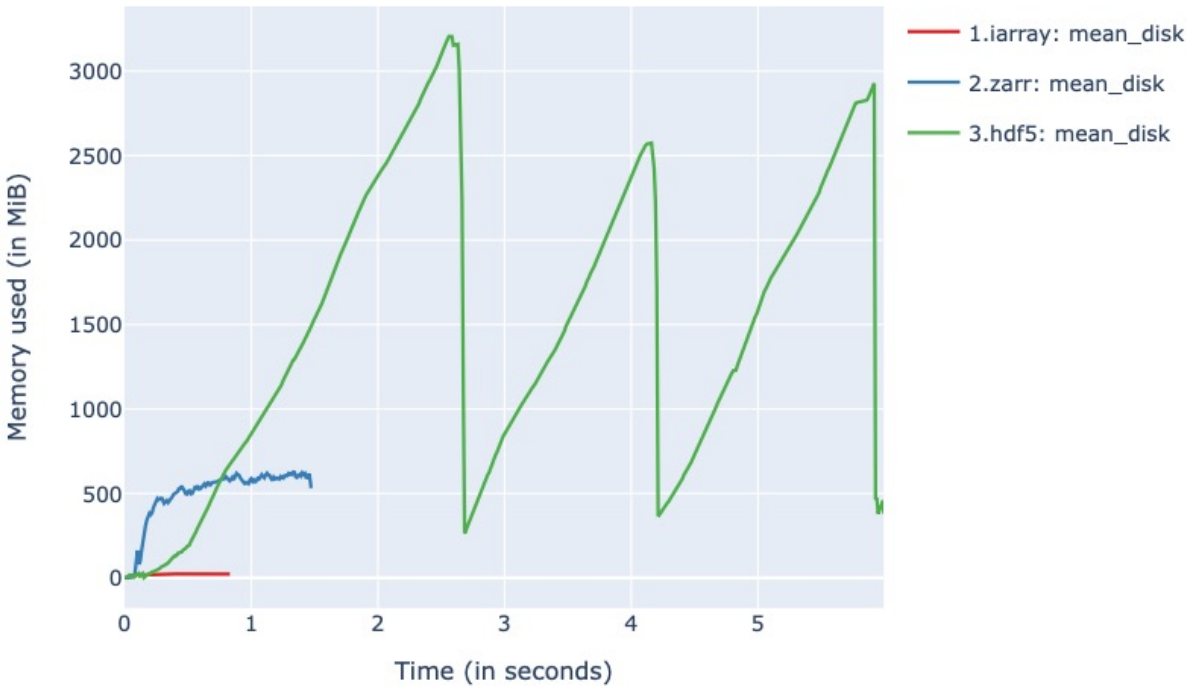
Better performance in general
(except for dimensions where retrieving a chunk is already optimal)

https://ironarray.io/docs/html/bench/03.Slicing_Datasets_and_Creating_Views.html

Blosc2: Paralellism and Efficiency

- In the plot: 3 compressed arrays are decompressed, operated with, and the result is compressed again.
- ironArray is using Blosc2.
- When handled correctly, parallelism can buy not only speed, but also less memory resources!

Mean of 3 arrays of 3 GB each (on disk)



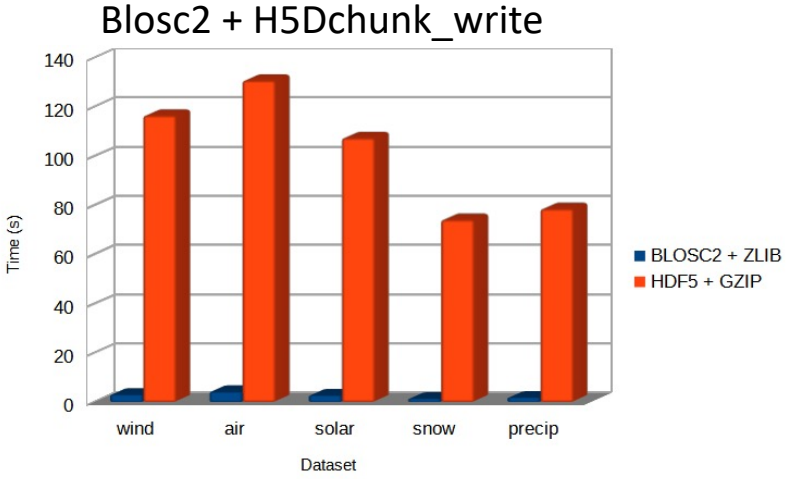
https://ironarray.io/docs/html/bench/05.Reductions_OnDisk.html

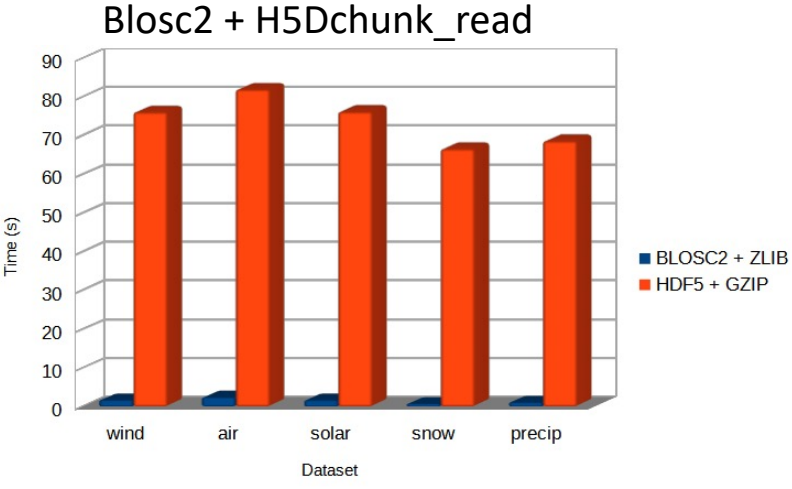
Blosc2 + HDF5 Direct Chunk Quick Benchmark

Quick test on data from ERA5 dataset, using different measurements (wind, temp, precip...). The datasets are about ~3 GB (uncompressed) each.

- Blosc2 + HDF5 speed-up is typically between 30x and 40x for writing.
- Blosc2 + HDF5 speed-up is typically between 40x and 60x for reading.

Note: this is using a laptop with 6 cores, but the measuments make sense, specially when using a fast storage (in this case OS FS cache).





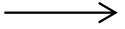
Adaptability: Plugins in Local Registry

User defined filter:

```
int urfilter2(
    blosc2_filter *filter) {
    …
}
```

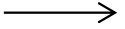
To register locally:

```
blosc2_register_filter(
    urfilter2)
```



Filters registry

BLOSC_SHUFFLE	1
BLOSC_BITSHUFFLE	2
BLOSC_DELTA	3
. . .	
BLOSC_NDCELL	32
BLOSC_NDMEAN	33
. . .	
urfilter1	160
urfilter2	161
. . .	



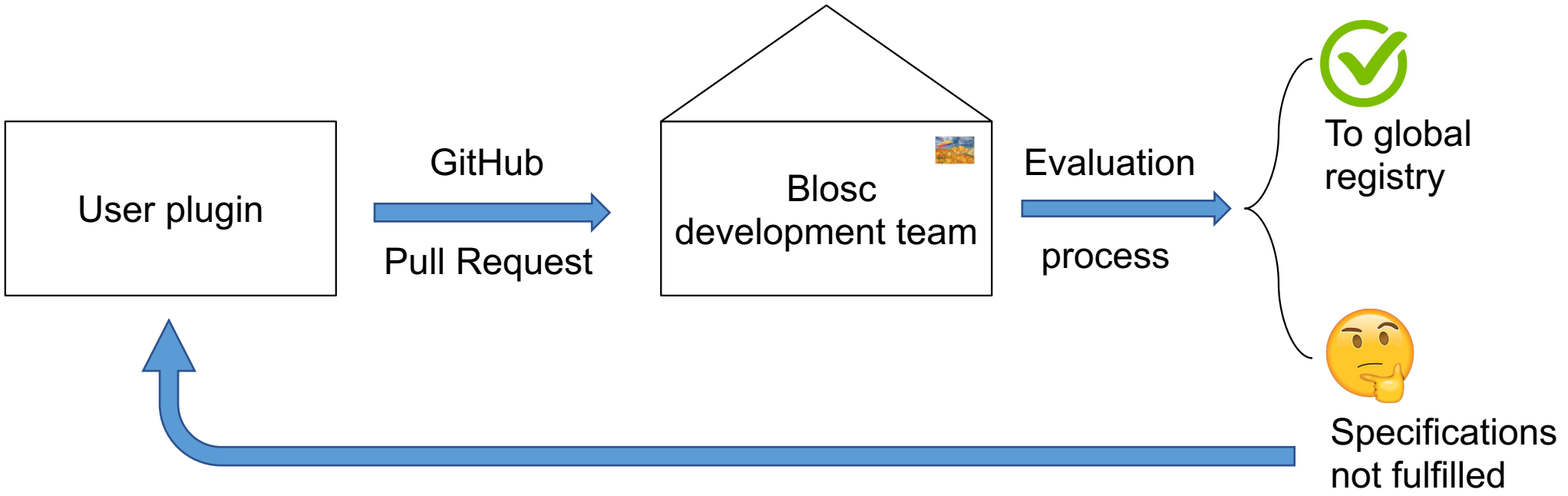
Can be used now:

```
cparams.filters[4] = 161;
```

- Blosc official registered filters
- User local filters

(Similar functionality to the plugin interface in HDF5)

Registering Global Plugins in Blosc2



Specs: https://github.com/Blosc/c-blosc2/blob/main/plugins/README.md

Proposal 2: Help in Determing Optimal Compression Pipelines

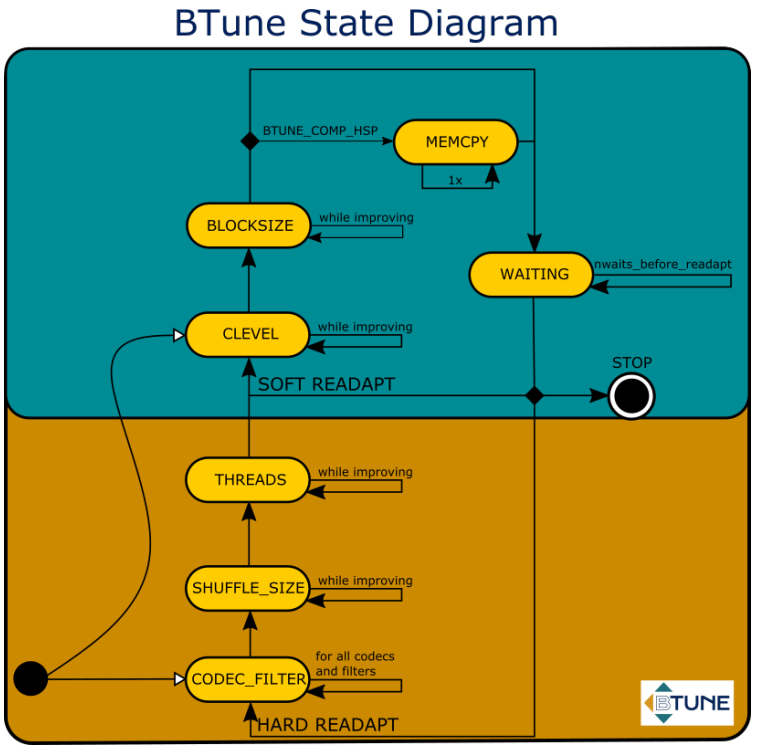
We are offering a service for adapting to the user data, and determining:

- Set of most useful codecs to be used
- Set of most useful filters to be used

We produce **specific versions** of **BTune**, a machine learning tool for selecting the best pipeline candidate on a **chunk by chunk** basis, that adapts to the needs of the user.

Fine Tuning Performance with BTune

- BTune can fine tune the different parameters of the underlying Blosc2 storage to perform as best as possible.
- Active during the compression pipeline. **Automatically learns the best parameters on the go**.



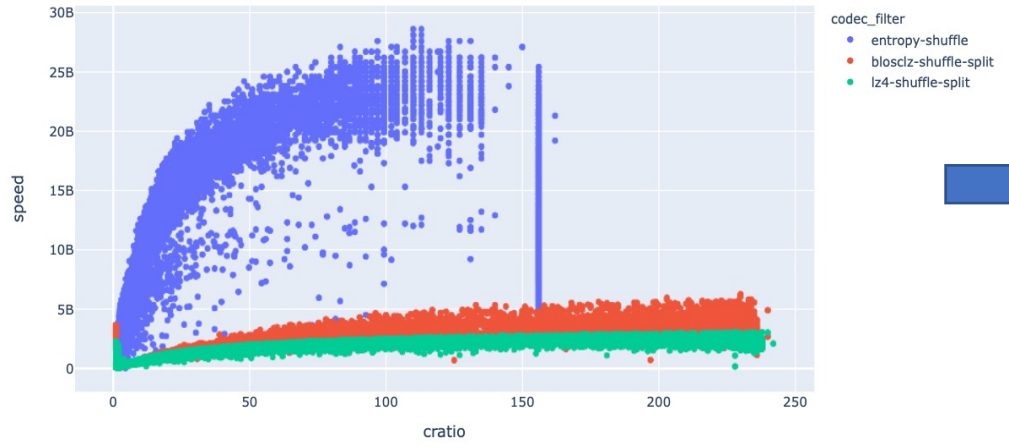
Demo time

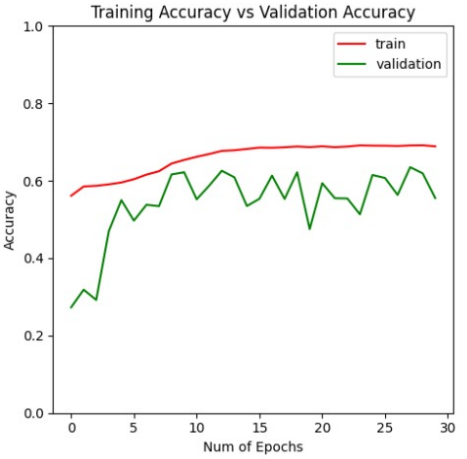
https://btune.blosc.org

Work in Improving BTune

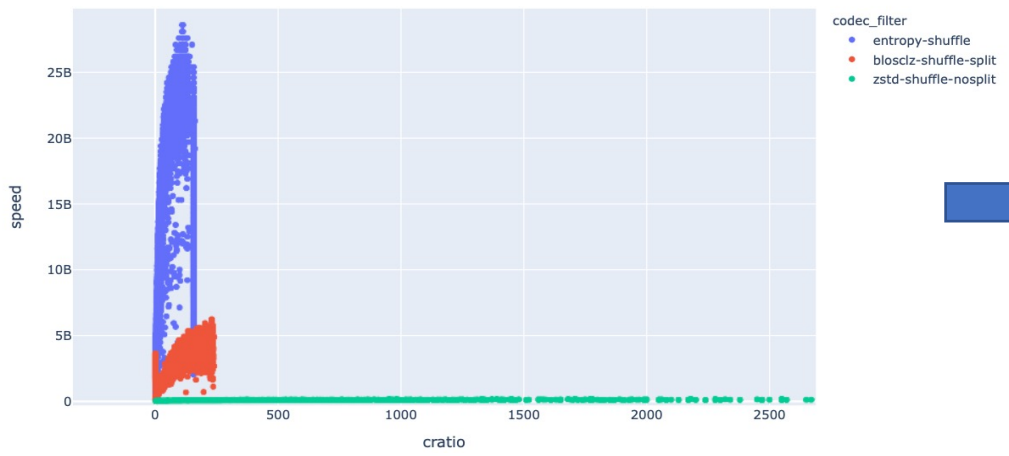
- Currently BTune needs some warm-up tests (hard and soft readapts) so as to come with a sensible guess.
- We are planning to shorten this warm-up period by using deep learning techiques.
- The idea is to come with some **predictor for the entropy** for every chunk and train a neural network. This will be used for reaching the **sensible guess faster**.

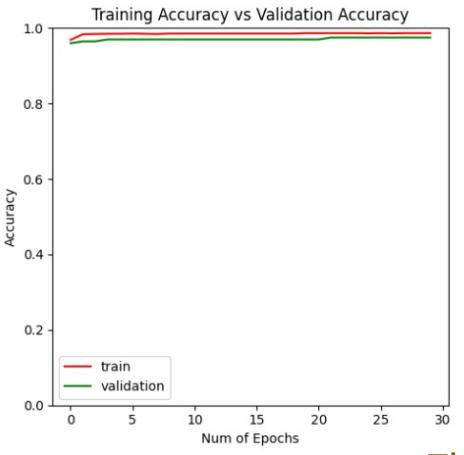
Current Investigation (Preliminary Results)





Codecs with similar features: Not good predictions





Codecs with different features: Much better predictions!

Thanks to Marta Aicart

Conclusion

Blosc2 Helps Saving Resources

Blosc2 orchestrates a **rich set of codecs and filters** for:

- **CPU parallelization** via multithreading
- Reuse and sharing internal buffers for **optimal memory consumption**
- **Parallel I/O**
- **More selective** hyperslabs

The result is a highly efficient tool for
compressing and accessing your data your way

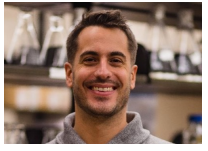
Summary of Proposals

1. Use Blosc2 in combination with HDF5 direct chunking mechanism for efficient compression and parallel I/O.

2. Help in determing optimal compression pipelines by adapting to user data and using machine learning techniques.

The Blosc team would be glad to be involved in efforts towards these goals

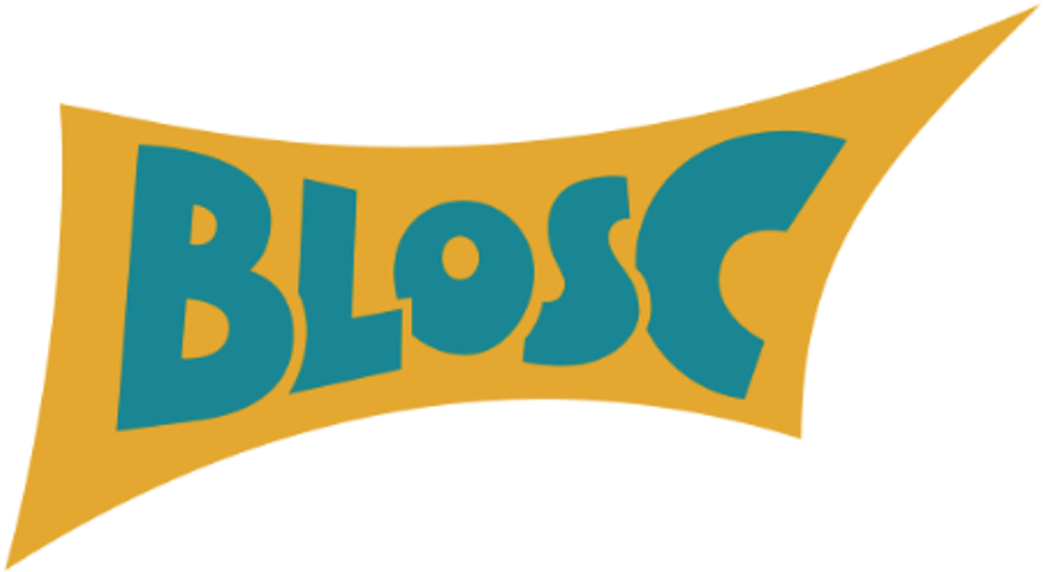
Thanks to donors & contracts & contractors!



Jeff Hammerbacher

Without them, we could not have possibly put Blosc2 into production status: Blosc2 2.0.0 came out in June 2021; now at 2.1.1.

Enjoy data!



https://blosc.org/