Los Alamos NATIONAL LABORATORY

Analytics Query Pushdown Using Object-Based Computational Storage

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Overview

Goal

- Rapid insight generation

Problem

- Scientific analysis often read more data than is necessary

Approach

- Execute queries closer to data using computational storage

OCS

Object-based Computational Storage

An effort in exploring an **open** object-based computational storage API for analysis query pushdown

A collaboration between SK hynix, Airmettle, Neuroblade, and Versity

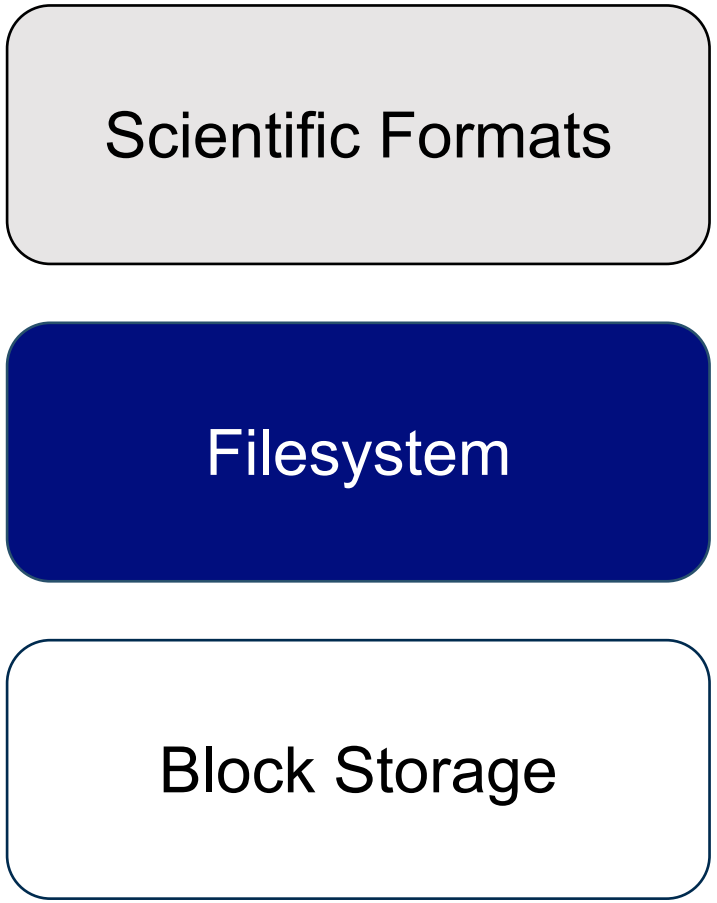
Background: Scientific Storage I/O Stack

Filesystem over blocks

Popular data formats: VTK, HDF5, NetCDF, …

- Self-describing
- Columnar (each column is a data array)
- Offset-based data access methods
- Geometry data (points, cells)

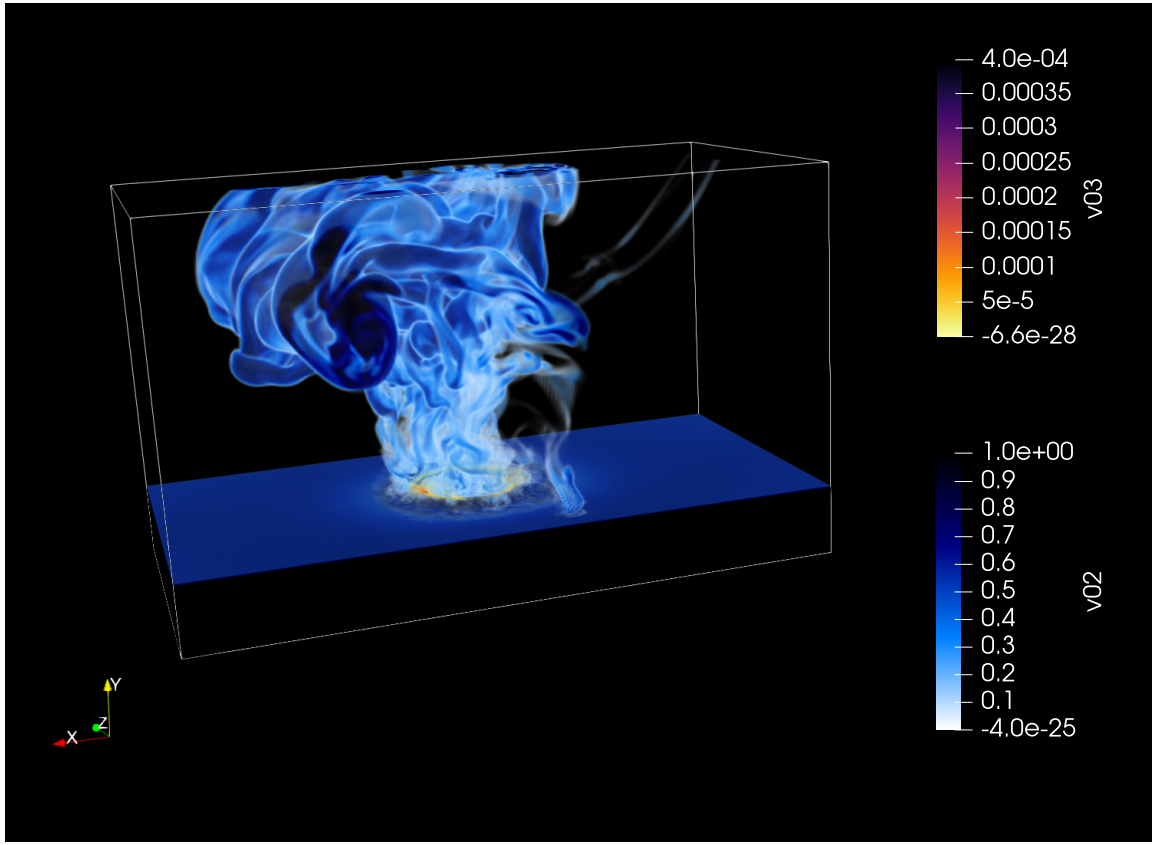
Data agnostic erasure protection at filesystem level



Example: Deep Water Asteroid Impact

Unstructured grid, 216M points, 182M cells, 11 data arrays (columns), 182M rows

	Column	Type	Description
1	rho	float	density in grams per cubic centimeter
2	prs	float	pressure in microbars
3	tev	float	temperature in electronvolt
4	xdt	float	x component vectors in centimeters per second
5	ydt	float	y component vectors in centimeters per second
6	zdt	float	z component vectors in centimeters per second
7	snd	float	sound speed in centimeters per second
8	grd	float	AMR grid refinement level
9	mat	float	material number id
10	v02	float	volume fraction of water
11	v03	float	volume fraction of asteroid



8GB/timestep

Analysis Rarely Uses All Columns

Existing scientific formats support efficient column skipping (by being columnar)

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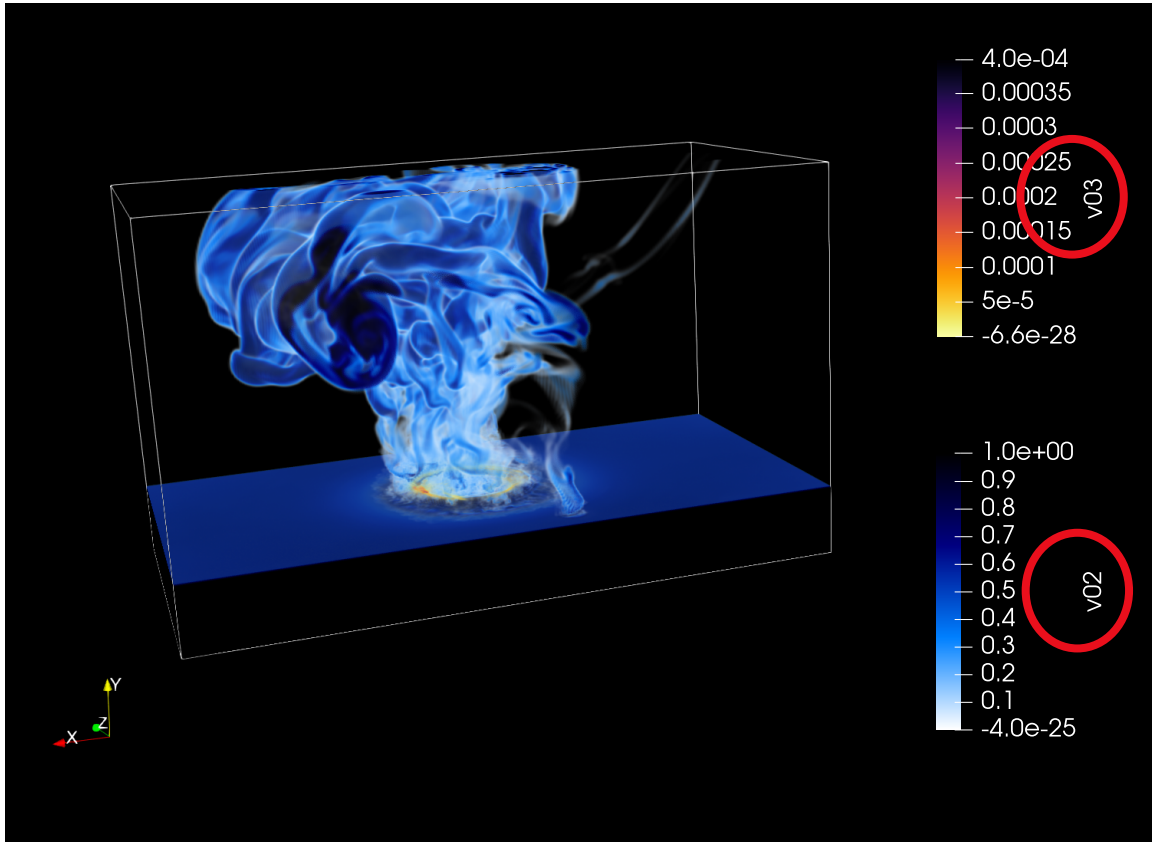

How About Row Skipping?

Today, all rows are read even when only a few are needed

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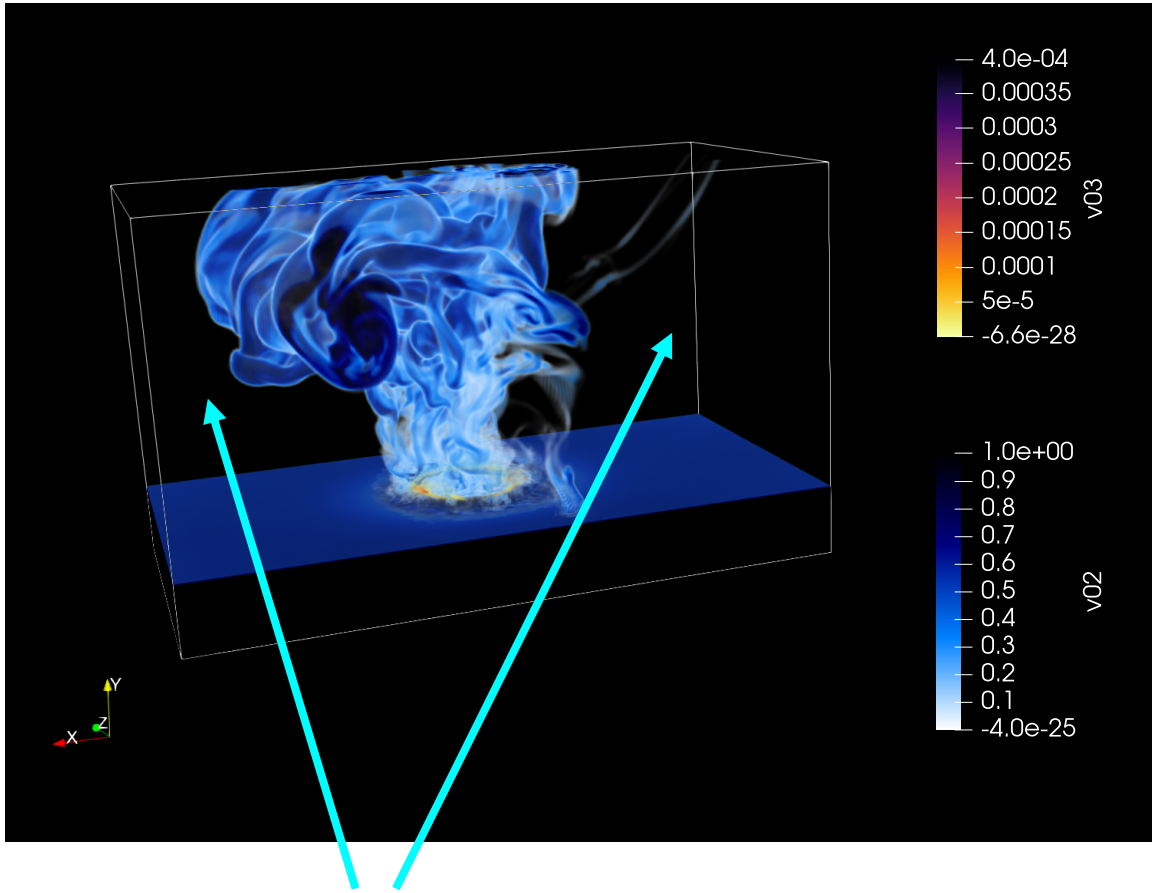
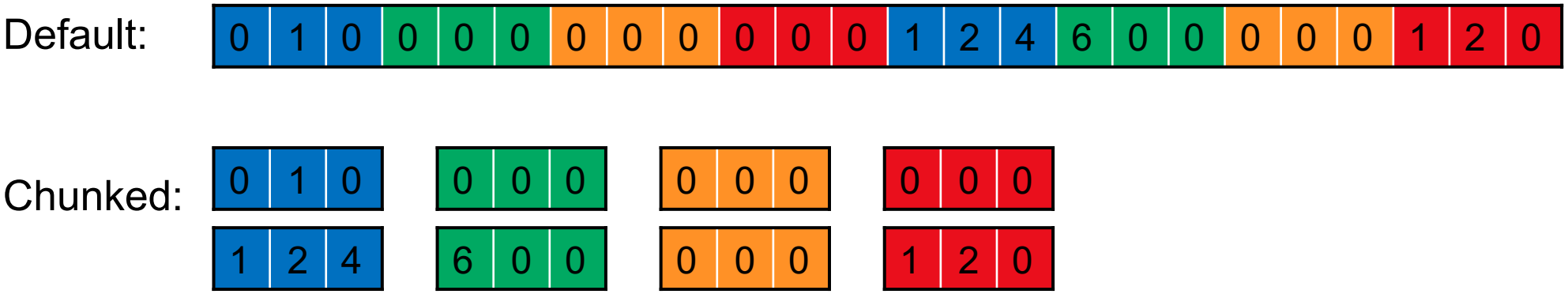


For example: it'd be nice if we could skip reading those "empty" cells

Mimicking Row Skipping With Chunking & Compression



The hope is for compression to reduce "0 0 0" chunks to almost nothing

- So that we don't pay much reading them

Purpose of chunking is to allow efficient subarray access (arr[n:m])

- Each chunk can be independently de/compressed

Current state-of-the-art in scientific world

Real World Predicates Are Often More Complex Than Skipping 0's

Challenges and opportunities: Complex queries tend to have higher selectivity

- Leaving opportunity for **more aggressive data reduction**
- And demand for **more advanced readers** to maximize reduction ratio

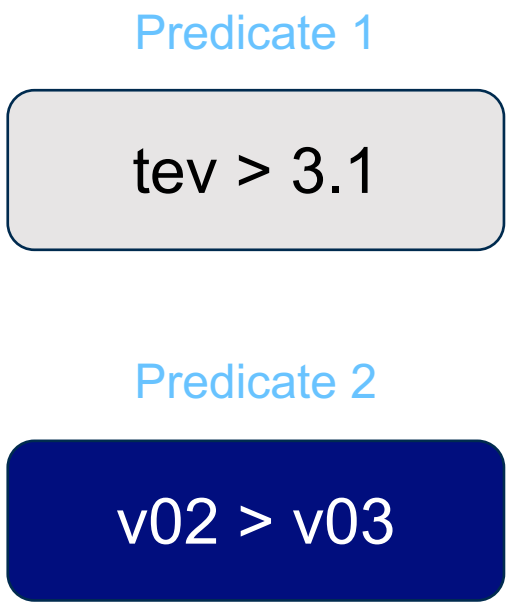
For example: SELECT v03 WHERE v03 > 9

- A reader can leverage per-chunk statistics (min/max values) to skip as many chunks as possible
- Existing scientific codes don't always perform this optimization

Real World Predicates Are Often More Complex Than Skipping 0's

Another example: SELECT v03 WHERE tev > 3.1 AND v02 > v03

- A reader may leverage per-column statistics to **estimate the selectivity of each predicate** and decide which one to serve as the primary filter
  - Use the primary filter to skip as many chunks as possible
- If user-supplied per-column indexes are available, also use them



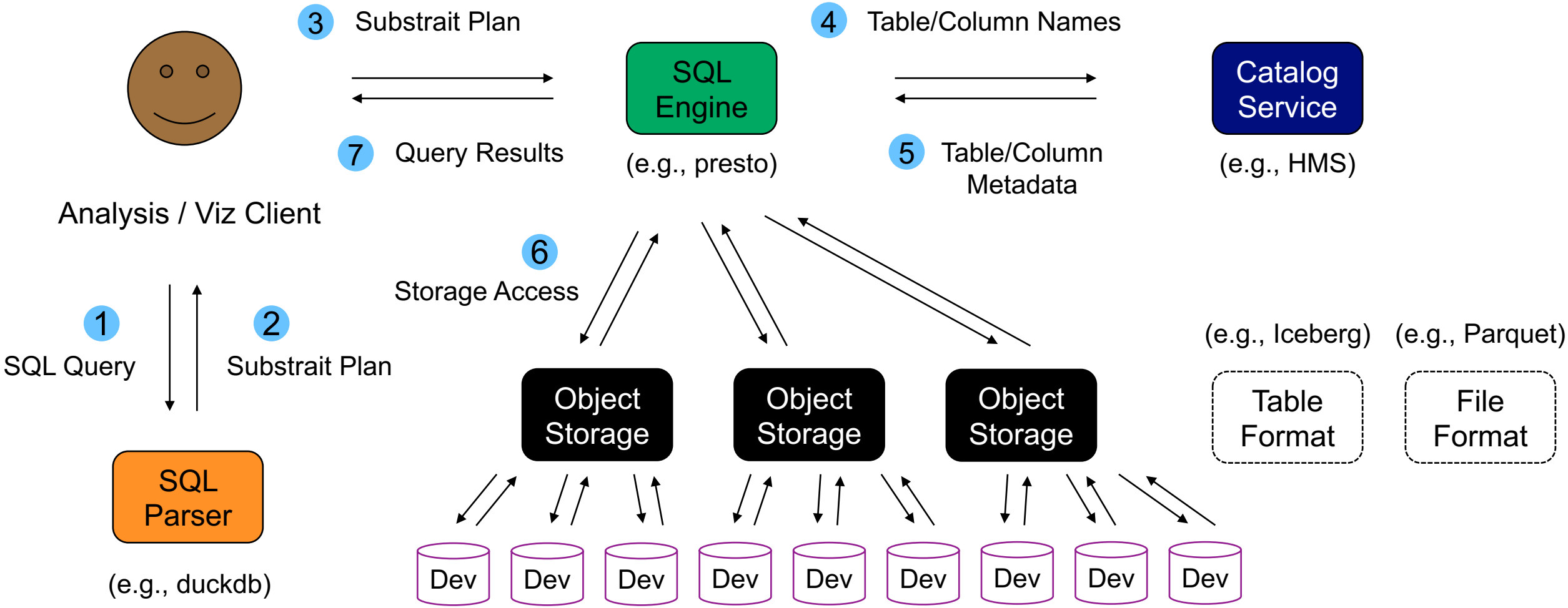
Not Reinventing the Wheel

Databases know how to best execute a SQL query

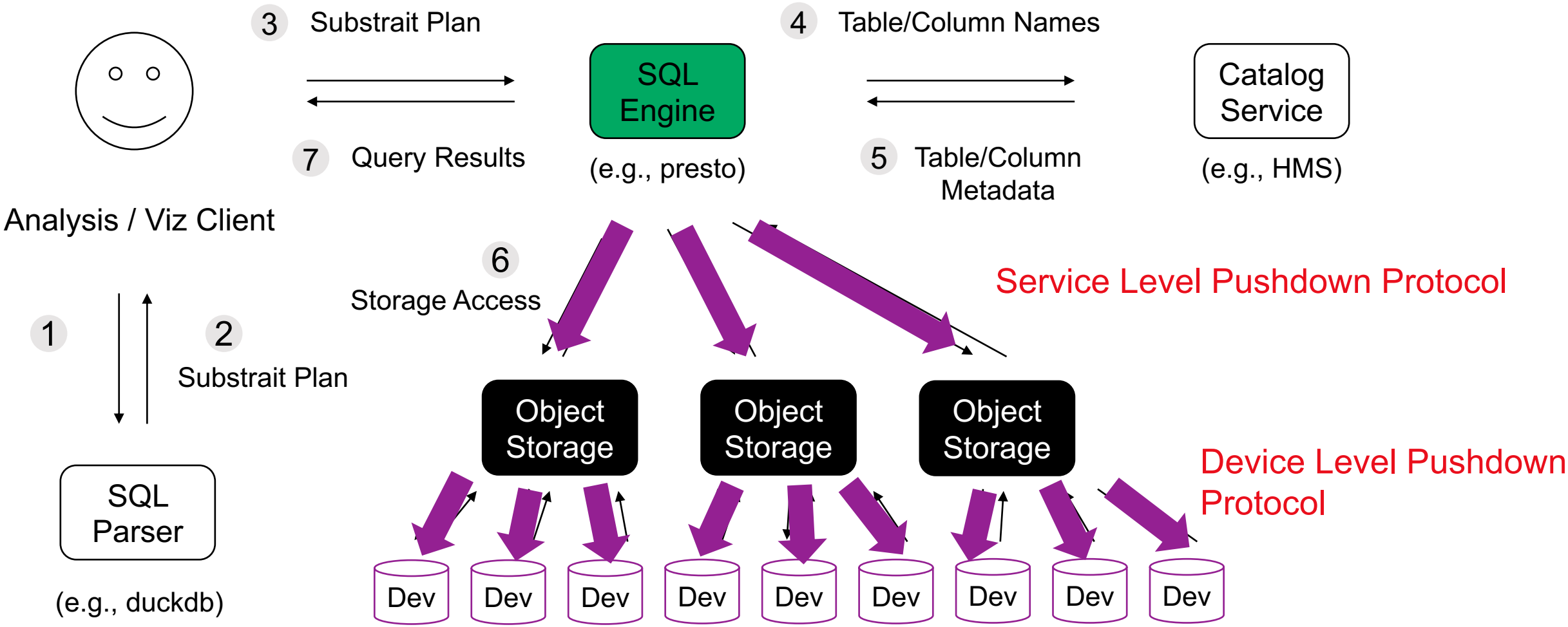
Composable databases are increasingly a thing

- SQL parser: Calcite
- Vendor neutral SQL query representation: Substrait
- Open-source SQL engines: Presto, Drill, Spark, Impala, Hive, DuckDB
- Catalog services: HMS (hive metastore)
- Open table formats: Iceberg, Hudi, Delta
- Columnar data formats: Parquet, Arrow, ORC
- Storage: S3 API
- Open query pushdown API for computational storage: ?

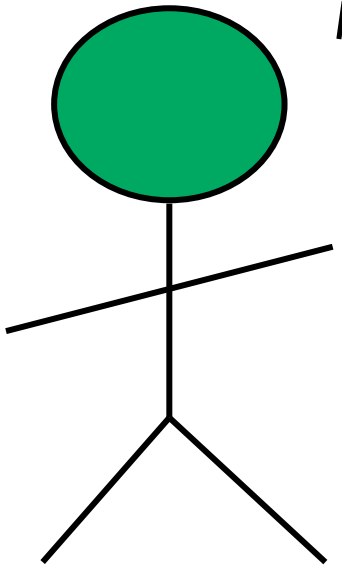
Converged, Open Analytics Stack for HPC and Non-HPC



Open Query Pushdown API for Computational Storage



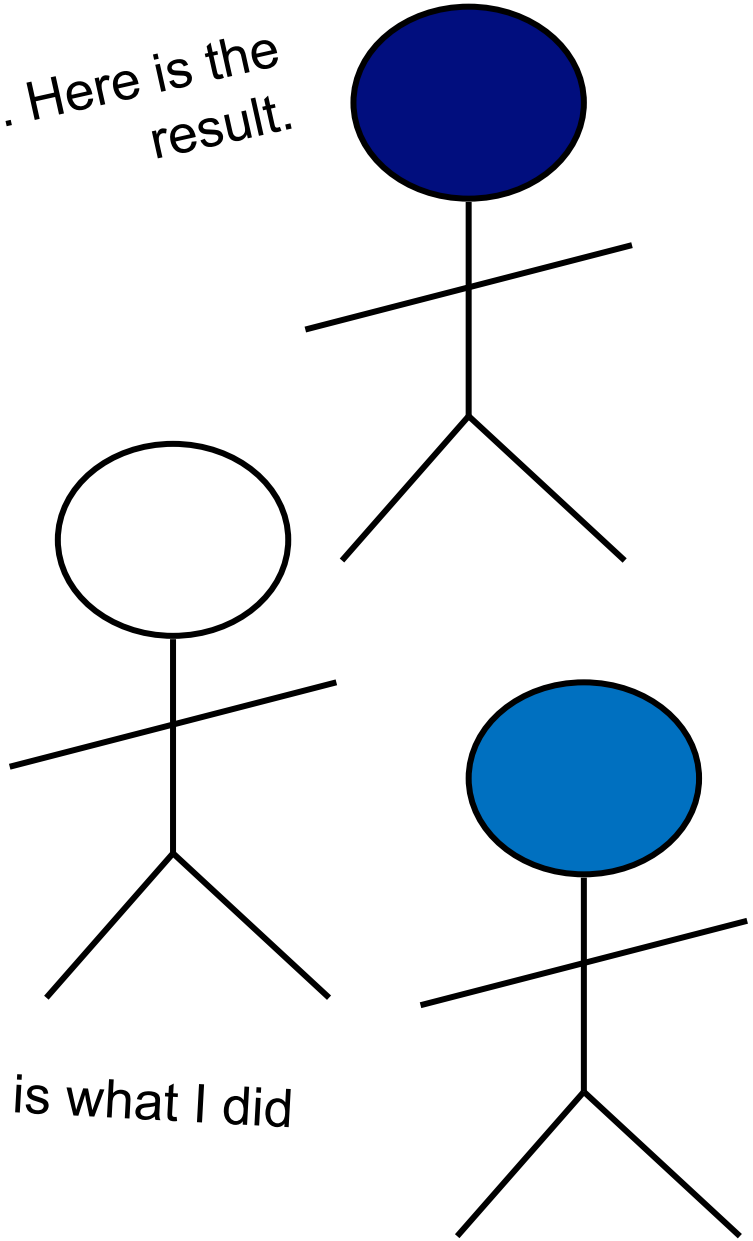
Division of Labor



Here is my substrait plan. Please run it.

I did nothing. Here is all the data that you might need.

I did everything. Here is the result.

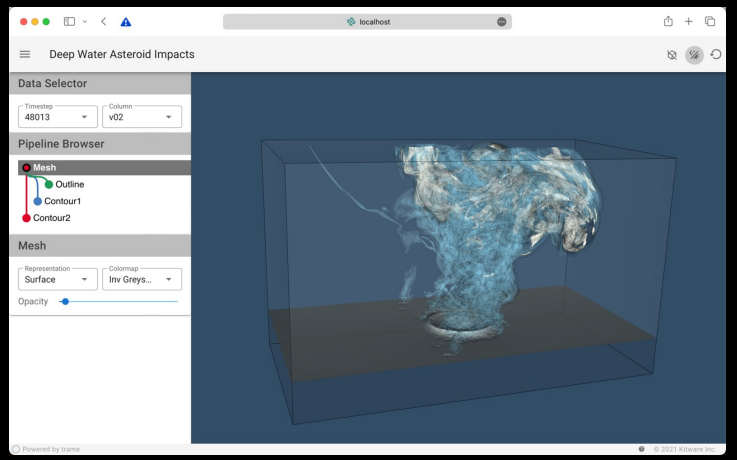


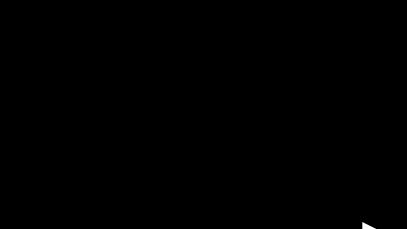
I did something. Here is what I did and my partial result.

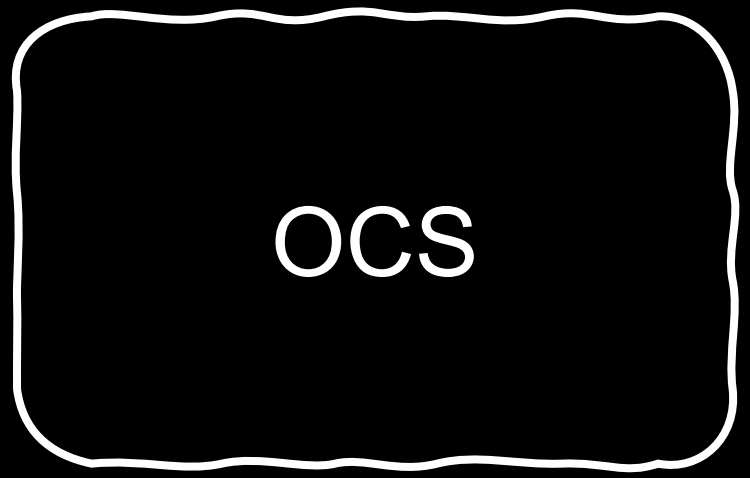
Upper Layer

Lower Layer

LANL/SK hynix FMS 2024 Live Demo @ Santa Clara Convention Center

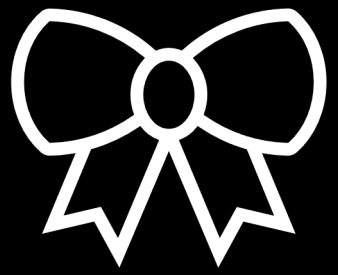




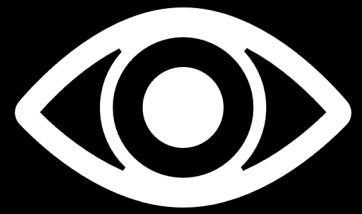


Real-world viz pipeline modified to leverage OCS open analytics stack to coordinate, plan, and run queries

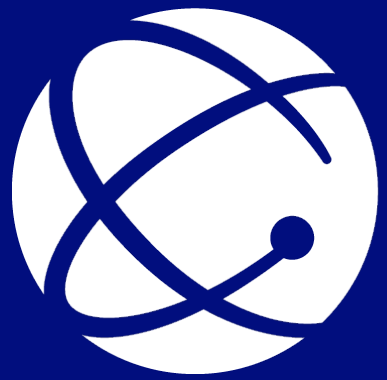
SK hynix's prototype OCS system implementing OCS pushdown APIs



Thank our collaborators: SK hynix, Airmettle, Neuroblade, and Versity



Look forward to seeing you all at FMS 24



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