



Cloud Optimized Data Formats

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How can data formats enable high-speed access?



1. Web Object Storage (e.g., Simple Storage Service)
 - a. Inexpensive storage, BUT...
 - b. ...access is via HTTP¹, not random disk reads
 - c. Does include HTTP “range-get” to retrieve a specific byte range
2. Approaches
 - a. Organize data as an aggregation of small, independently retrievable objects (e.g., zarr, HDF² in the Cloud)
 - b. Allow access to pieces of large objects (e.g., Cloud-Optimized GeoTIFF³, OPeNDAP⁴ in the Cloud)

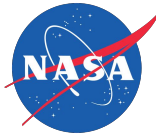
¹ HTTP = Hypertext Transport Protocol

² HDF = Hierarchical Data Format

³ TIFF = Tagged Image File Format

⁴ OPeNDAP = Open-source Project for a Network Data Access Protocol

Cloud Optimized Format Study



- Conducted a format study on common Earth Observation data structures
- Criteria:
 - Usability
 - Support for Fine-Grained Access
 - Support for a Variety of Data Types and Structures
 - Data Integrity
 - Self-describability
 - Tooling and Standards
 - Compatibility with Existing Tools
 - Open Specification
 - Independent Application Programming Interfaces
 - Programming Language Support
 - Standards-Body Approval
 - Ability to Comply with Metadata Conventions
 - Cost Factors



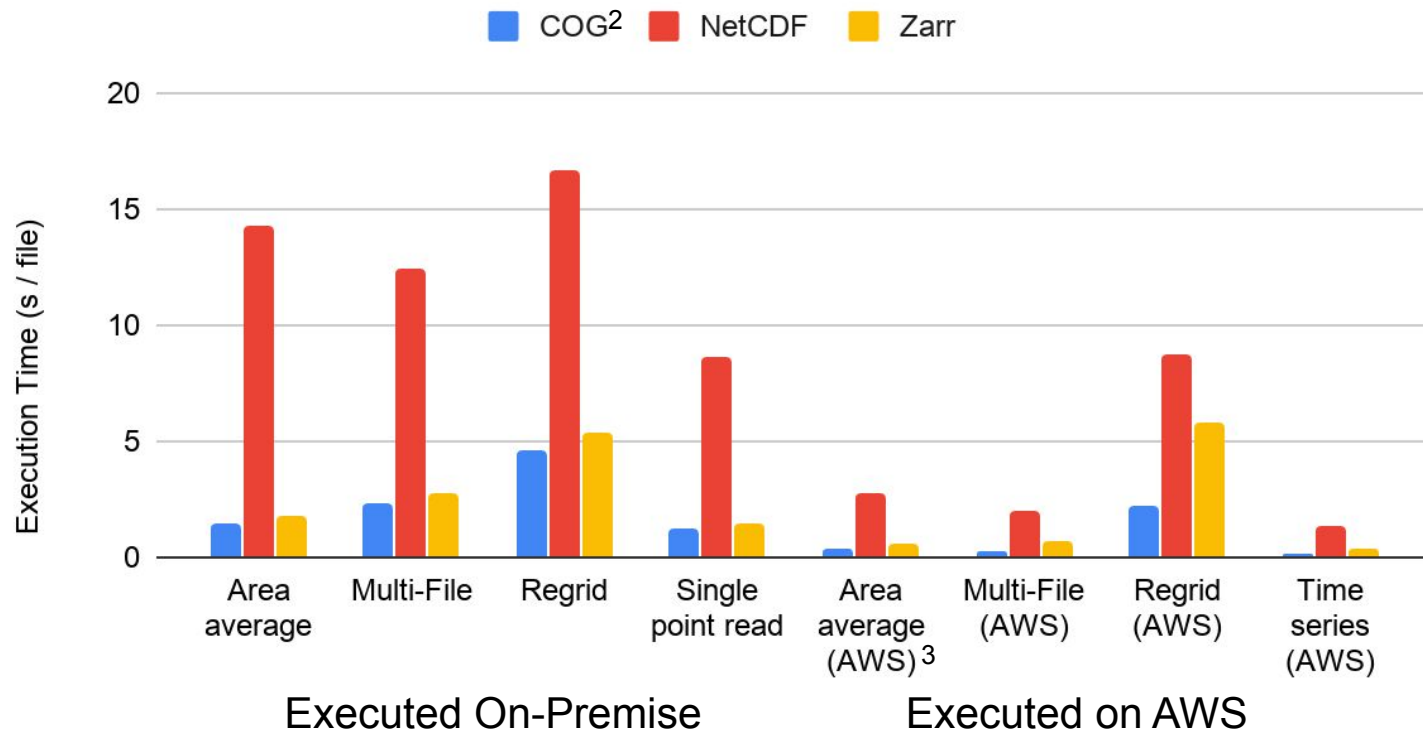
Formats Evaluated

- “Classic” Formats:
 - netCDF¹ (version 4)
 - GeoTIFF
- Network-Optimized Formats
 - Zarr
 - Cloud-Optimized GeoTIFF
 - Parquet
 - HDF in the Cloud

¹ netCDF = network Common Data Form

Benchmarking: regularly gridded global data

Benchmark Execution Time - 3IMERGHH¹ (Global Grid)

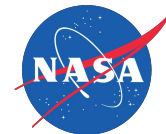


¹ 3IMERGHH = Half-hourly Merged Rainfall

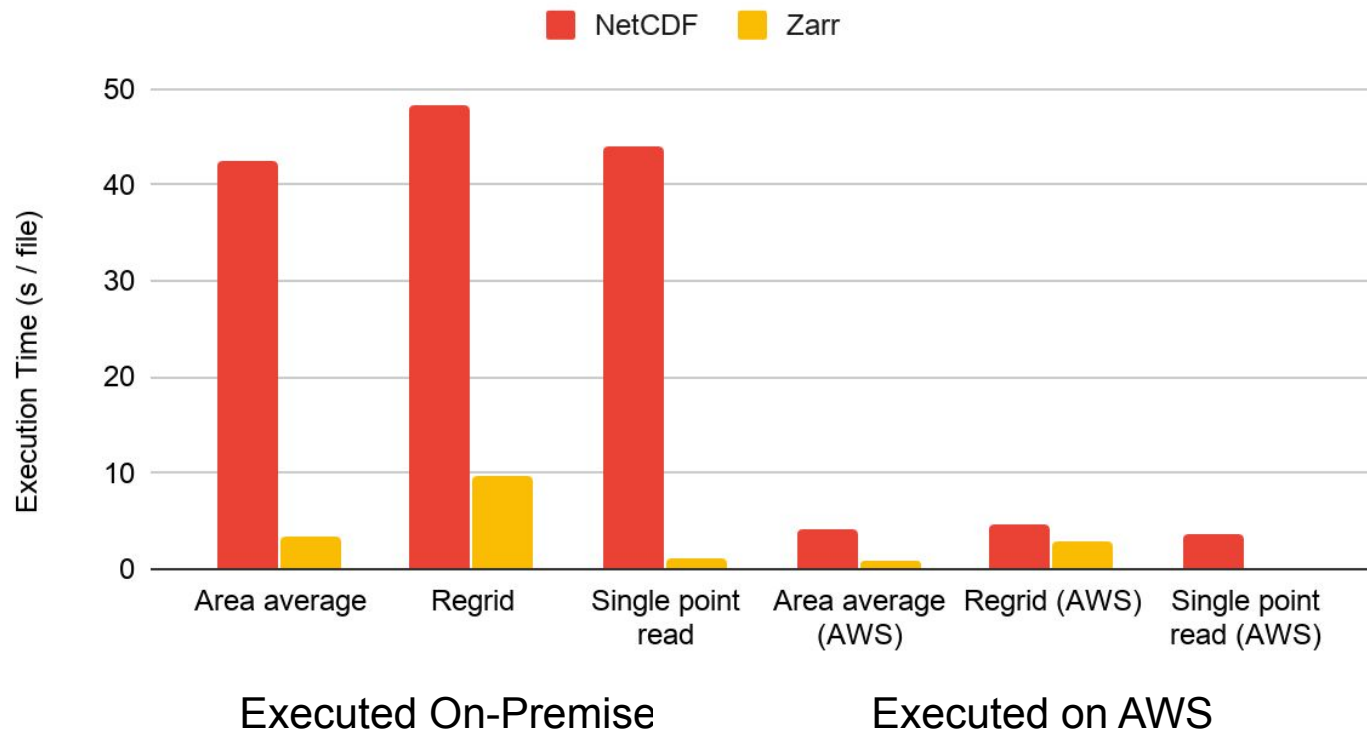
² COG = Cloud-optimized GeoTIFF

³ AWS = Amazon Web Services

Benchmarking: satellite swath



Benchmark Execution Time - AVHRR_G-NAVO (Swath)



Unweighted evaluation (see [doc](#) for details)



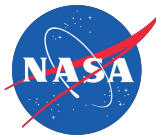
		Current Formats		Cloud-Optimized Formats			
Criteria	Criteria Weight	netCDF	GeoTIFF	Zarr	Parquet	Cloud - Optimized GeoTIFF	HDF in the Cloud
Support for Fine-Grained Access	1	3	3	6	9	9	6
Support for a Variety of Data Types and Structures	1	9	3	6	0	3	9
Data Integrity	1	9	3	3	0	3	6
Self-describability	1	9	6	9	9	6	9
Compatibility with Existing Tools	1	3	6	1	1	6	0
Programming Language Support	1	9	9	3	6	9	0
Open Specification	1	6	6	6	9	9	6
Independent APIs*	1	3	6	3	9	6	0
Standards-Body Approval	1	6	9	0	3	9	3
Ability to Comply with Metadata Conventions	1	9	3	9	6	3	9

*API = Application Programming Interface

Overall Results (see [doc](#) for details)



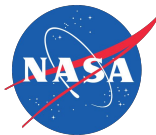
	netCDF	GeoTIFF	Zarr	Parquet	Cloud-Optimized GeoTIFF	HDF in the Cloud
Imagery	Moderate	High	Moderate	Poor	High	Moderate
Swath	Moderate	Low	Moderate	Low	Low	Moderate
Trajectory	Moderate	Poor	Moderate	Moderate	Poor	Moderate
Point Cloud	Low	Poor	Low	Moderate	Poor	Low
Projected Grids	High	High	High	Low	High	High
In Situ Data	Moderate	Poor	Moderate	High	Poor	Moderate
Airborne Data	Moderate	Low	Moderate	Low	Low	Moderate
Vector + values	Poor	Poor	Poor	High	Poor	Poor



Summary of Recommendations

1. Optimize files for partial access over HTTP using the Range header
2. No one-size-fits-all
 - a. Long-term archive: stable, self-describing, standard, integrity checks, portability -> self-contained formats
 - b. Multispectral Imagery: Cloud-Optimized GeoTIFF
 - c. Multidimensional Arrays: Zarr for analysis
 - d. Specialized Formats: Parquet for tabular data, SQL* access

*SQL = Structured Query Language



Ongoing Efforts

- **ESIP¹ Cloud Computing Cluster:** ESIP + AWS effort to look at best practices for cloud-optimized formats
- **Multi-dimensional Data**
 - **USGS² + The HDF Group:** [zarr access to HDF5 using sidecar zarr metadata files](#)
 - **OPeNDAP in the cloud:** server-based access to HDF5 using sidecar metadata
- **Point Cloud Data**
 - **Pangeo:** ICESat-2³ data in Zarr
 - **EOSDIS⁴ Standards Office:** survey of point cloud formats
 - **Open Geospatial Consortium:** Point Cloud Domain Working Group

¹ ESIP = Earth Science Information Partners

² USGS = United States Geological Survey

³ ICESat = Ice, Cloud and land Elevation Satellite

⁴ EOSDIS = Earth Observing System Data and Information System