



HDF5: State of the Union

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The HDF Group



Data Challenges Addressed by HDF5

- Organize complex collections of data
- Efficient and scalable data storage and access
- Integrates a wide variety of types of data
- The evolution of data technologies
- Long term preservation of data



HDF5 Technology Platform

- **HDF5 Abstract Data Model**
 - Defines the “building blocks” for data organization and specification
 - Files, Groups, Links, Datasets, Attributes, Datatypes, Dataspaces

- **HDF5 Software**
 - Tools
 - Language Interfaces
 - HDF5 Library

- **HDF5 Binary File Format**
 - Bit-level organization of HDF5 file
 - Defined by HDF5 File Format Specification



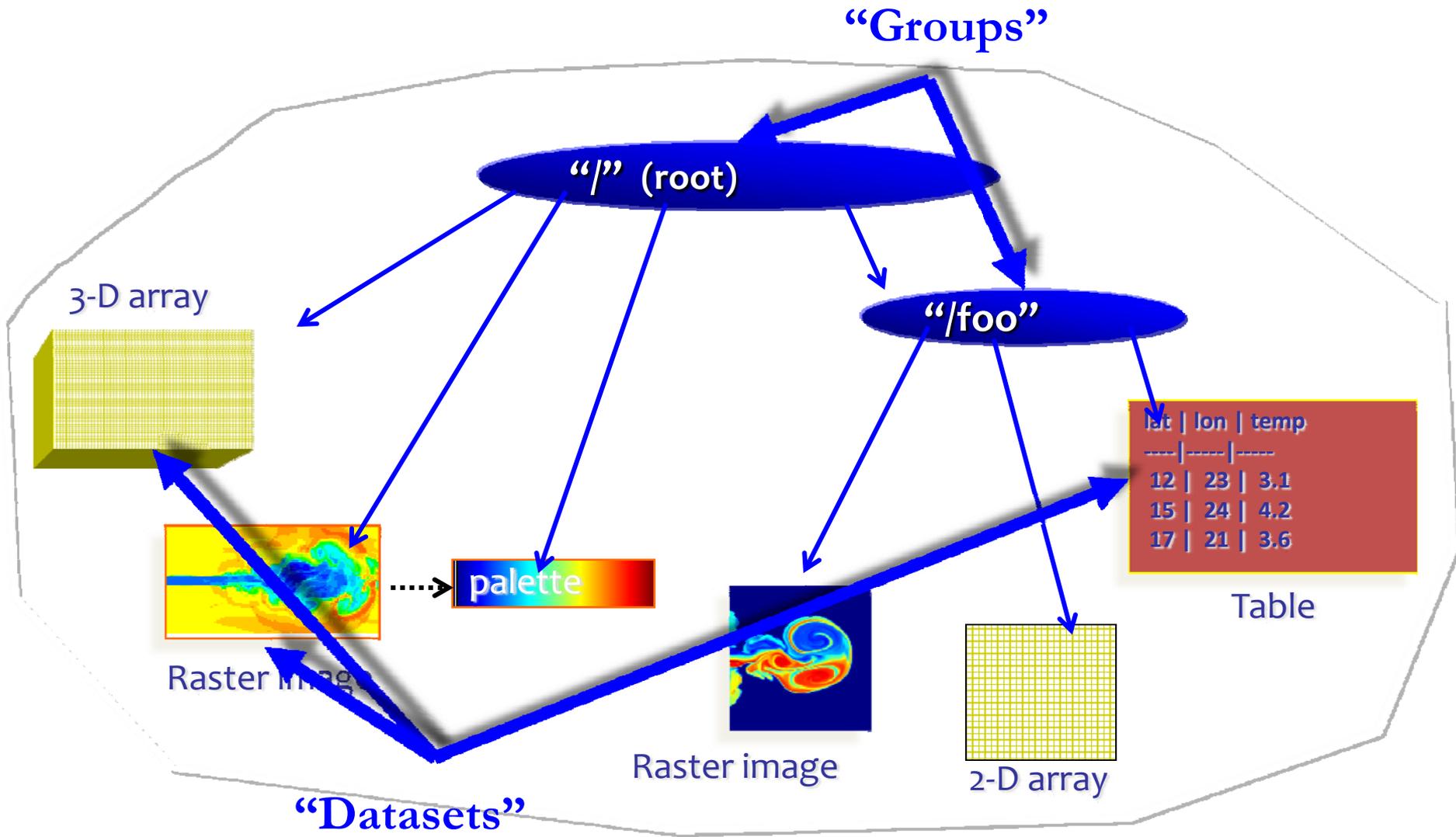
HDF5 Data Model

- Groups – provide structure among objects
- Datasets – where the primary data goes
 - Data arrays
 - Rich set of datatype options
 - Flexible, efficient storage and I/O
- Attributes, for metadata

Everything else is built essentially from these parts.



Structures to organize objects





Users of HDF5 Software



Tools & Applications

Most data consumers are here.
Scientific/engineering applications.
Domain-specific libraries/API, tools.

HDF5 Application Programming Interface

Applications, tools use this API to create, read, write, query, etc.
Power users (consumers)

“Virtual file layer” (VFL)

Modules to adapt I/O to specific features of system, or do I/O in some special way.

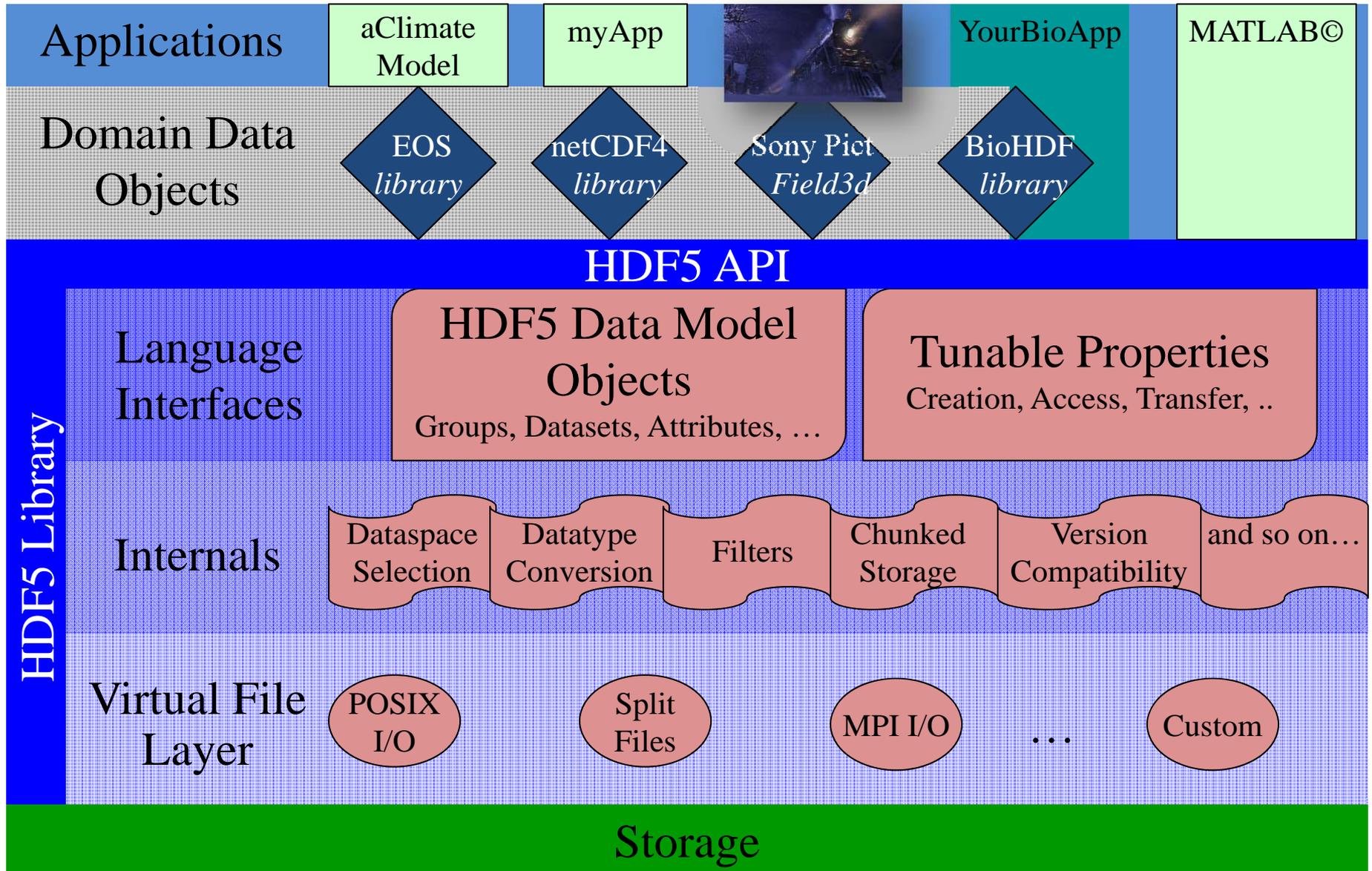
File system, MPI-IO, SAN, other layers

“HDF5 File”

“File” could be on parallel system, in memory, collection of files, etc.



HDF5 API and Applications





Topics

What's up with The HDF Group?

Library Update

Tools update

HDF Java Products

Library development in the works

Other activities



Brief History of HDF

1987 At NCSA (University of Illinois), a task force formed to create an architecture-independent format and library:
AEHOO (All Encompassing Hierarchical Object Oriented format)
Became HDF



Early 1990's NASA adopted HDF for Earth Observing System project

1996 DOE's ASC (Advanced Simulation and Computing) Project began collaborating with the HDF group (NCSA) to create "Big HDF"
(Increase in computing power of DOE systems at LLNL, LANL and Sandia National labs, required bigger, more complex data files).

"Big HDF" became HDF5.



HDF5 was released with support from DOE Labs, NASA, NCSA

2006 The HDF Group spun off from University of Illinois as non-profit corporation





The HDF Group

- Established in 1988
 - 18 years at University of Illinois' National Center for Supercomputing Applications
 - 5 years as independent non-profit company, "The HDF Group"
- The HDF Group owns HDF4 and HDF5
 - Basic HDF4 and HDF5 formats, libraries, and tools are open and free
- Currently employ 38 FTEs



The HDF Group Mission

To ensure long-term accessibility of HDF data through sustainable development and support of HDF technologies.



Goals of The HDF Group

- Maintain and evolve HDF for sponsors and communities that depend on it
- Provide support to the HDF communities through consulting, training, tuning, development, research
- Sustain the company for the long term to assure data access over time



The HDF Group Services

- [Helpdesk and Mailing Lists](#)
 - Available to all users as a first level of support: help@hdfgroup.org
- [Priority Support](#)
 - Rapid issue resolution and advice
- [Consulting](#)
 - Needs assessment, troubleshooting, design reviews, etc.
- [Training](#)
 - Tutorials and hands-on practical experience
- [Enterprise Support](#)
 - Coordinating HDF activities across departments
- [Special Projects](#)
 - Adapting customer applications to HDF
 - New features and tools
 - Research and Development

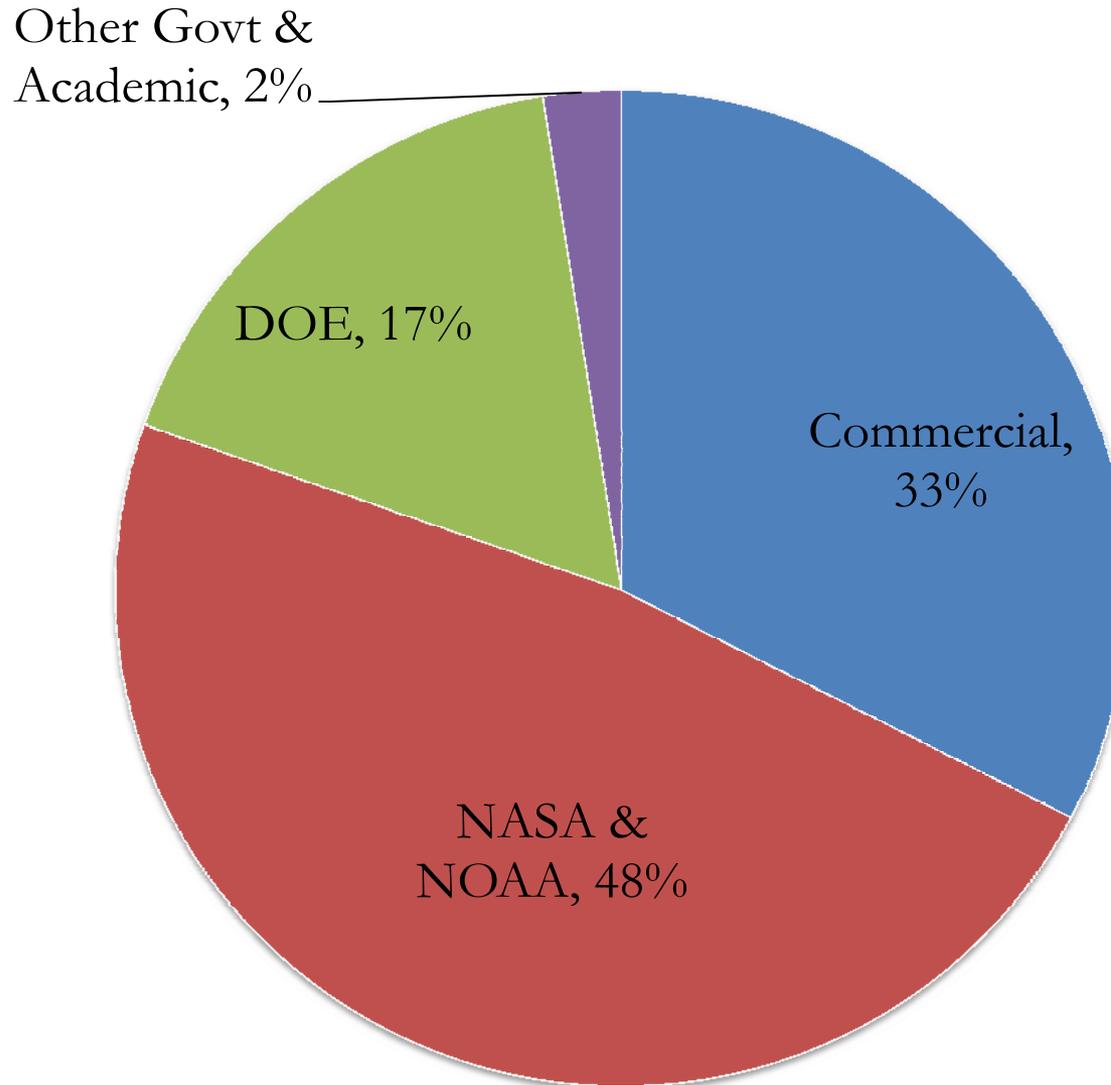


Members of the HDF support community

- NASA – Earth Observing System
- NOAA/NASA/Riverside Tech – NPOESS
- A large financial institution
- DOE – projects w/LBNL & PNNL, ANL & ORNL
- Lawrence Livermore National Lab
- Army Geospatial Center
- NIH/Geospiza (bio software company)
- Lawrence Berkeley National Lab
- University of Illinois/NCSA
- Sandia National Lab
- A leading U.S. aerospace company
- Projects for petroleum industry, vehicle testing, weapons research, others
- “In kind” support



Income Profile – 2012



Total income: ~\$3.7 million



New Directions We're Taking

- Expanding in Fusion Research data storage
 - Submitted proposal for ITER project's data management w/large industrial fusion partner
- Expanding applications of HDF5 in the Astronomy field
 - Submitted NSF SI2 grant w/NRAO
 - Working toward new standard for radioastronomy data storage
- Exploring synthesis of HDF5 and cloud storage w/Microsoft
 - Developing “RESTful” API for accessing HDF5 data in Azure cloud



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Where We've Been

- Release 1.0
 - First “prototype” release in Oct, 1997
 - Incorporated core data model: datatypes, dataspace & datasets and groups
 - Parallel support added in r1.0.1, in Jan, 1999
- Release 1.2.0 - Oct, 1999
 - Added support for bitfield, opaque, enumeration, variable-length and reference datatypes.
 - Added new ‘h5toh4’ tool
 - Lots of polishing
 - Performance optimizations



Where We've Been

- Release 1.4.0 - Feb, 2001
 - Added Virtual File Driver (VFD) API layer, with many drivers
 - Added 'h4toh5', h5cc tools, XML output to h5dump
 - Added array datatype
 - F90 & C++ API wrappers
 - Performance optimizations
- Release 1.6.0 - July, 2003
 - Generic Property API
 - Compact dataset storage
 - Added 'h5diff', 'h5repack', 'h5jam', 'h5import' tools
 - Performance optimizations

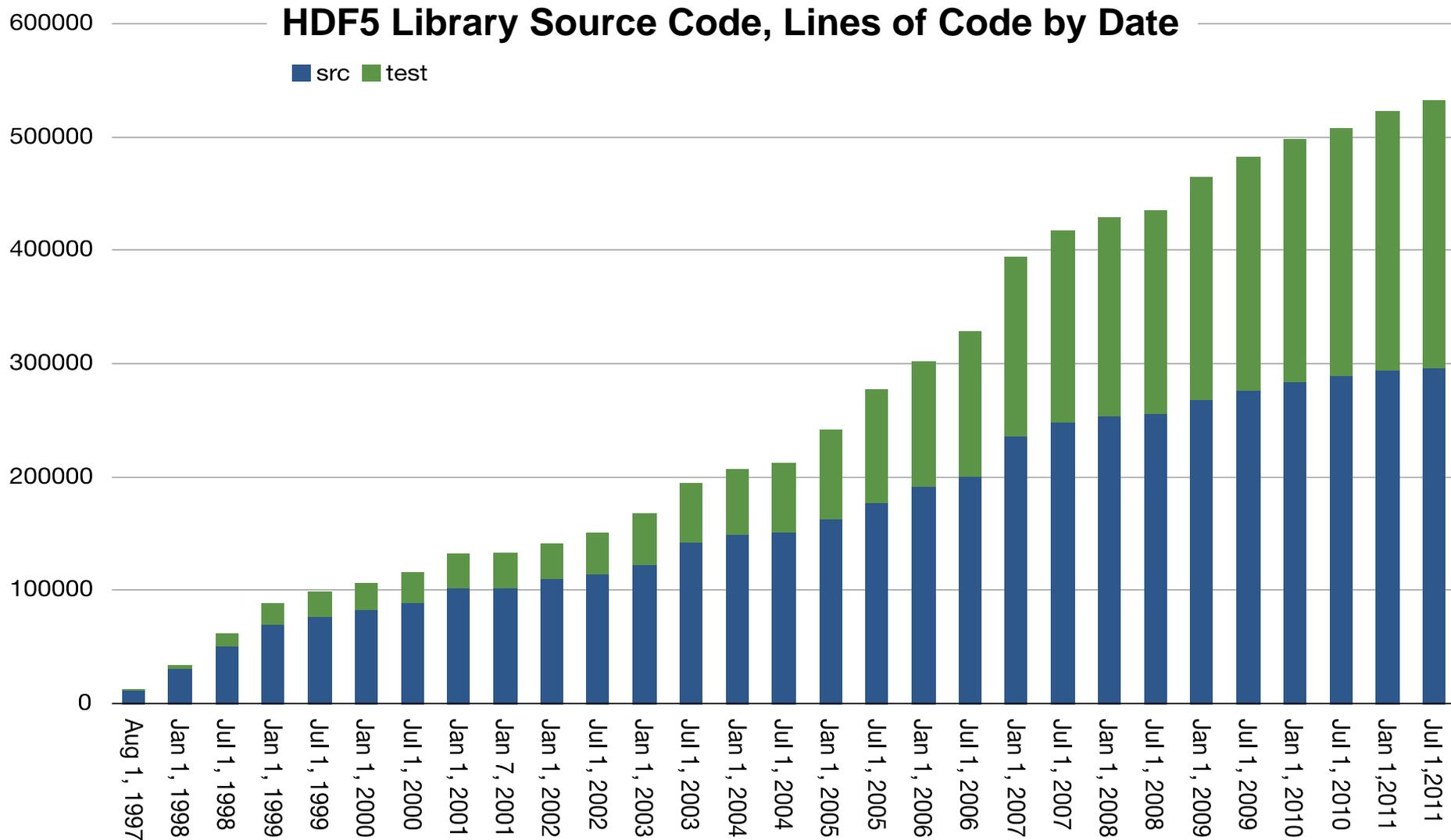


Where We're At Now

- Release 1.8.0 - Feb, 2008
 - Features to support netCDF-4
 - Creation order indexing on links and attributes
 - Integer-to-floating point conversion support
 - NULL dataspace
 - More efficient group storage
 - External Links
 - New H5L (links) and H5O (objects) APIs
 - Shared Object Header Messages
 - Unicode-8 Support
 - Anonymous object creation
 - New tools: 'h5mkgrp', 'h5stat', 'h5copy'
 - CMake build support
 - Performance optimizations



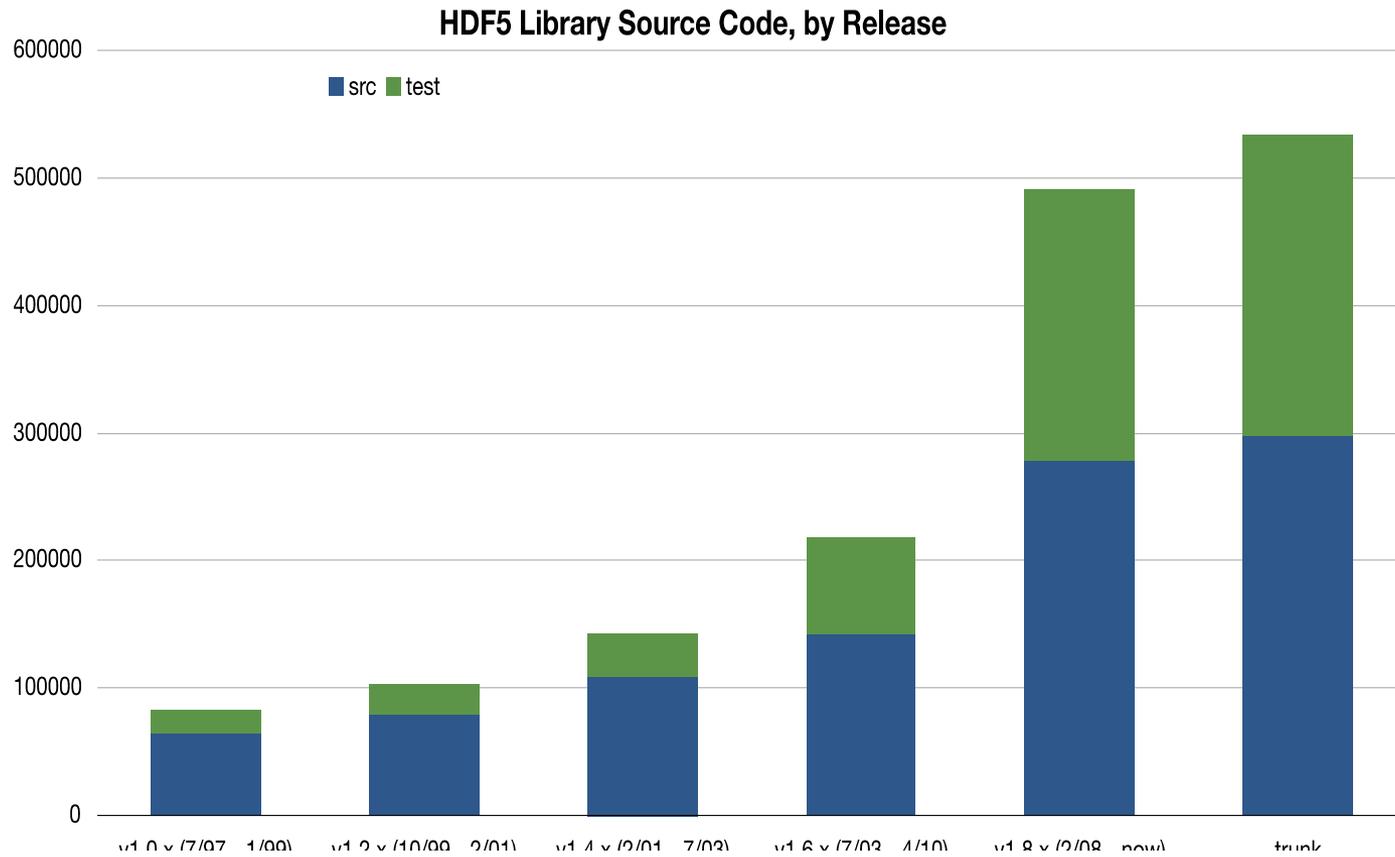
Repository Statistics





Repository Statistics

HDF5 Library Source Code, Lines of Code by Release



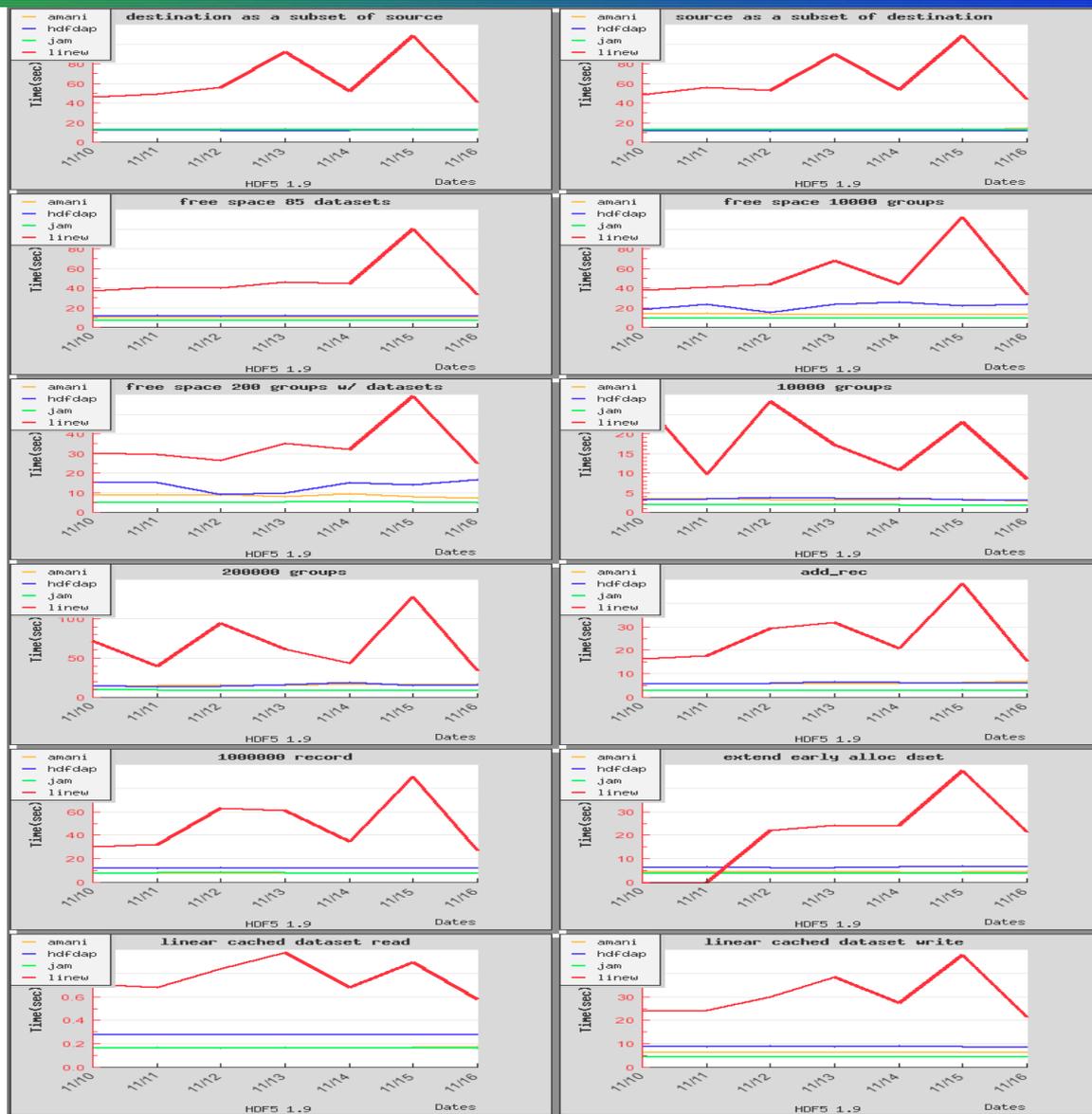


Software Engineering in HDF5

- We spend *considerable* effort in ensuring we produce very high quality code for HDF5.
- Current efforts:
 - Correctness regression testing
 - Nightly testing of >60 configurations on >20 machines
 - Performance regression testing
 - Applying static code analysis – Coverity, Klocwork
 - Memory leak detection – valgrind
 - Code coverage – *coming soon*



Performance Regression Test Suite





- New library features
 - Added ability to cache files opened through external links.
 - Added new macros to let users compare version numbers with the library being used.
- Tool features:
 - h5diff: Added new "verbose with levels" option.
 - h5dump: Added new option to display error stack information in the output stream.
- Bugs fixed:
 - Various minor performance improvements.
 - Many bugs fixed in tools.



HDF5 1.8.8 minor release (Nov '11)

- Library:
 - H5Tcreate now supports string type (fixed-length and variable-length).
 - New API routines to work with hyperslab selections.
- Parallel I/O:
 - New API routine to query whether independent or collective I/O was used for data I/O operation.
- Tools
 - Internal code refactoring and improvements.
- Bugs fixed:
 - Performance improvements to hyperslab selections.
 - Many bugs fixed in tools.



Where We'll Be Soon

- Release 1.10 - Overview
 - Beta release in November, 2011
 - Stopped adding major features, fleshing out our current efforts now
 - Major Efforts:
 - Improved scalability of chunked dataset access
 - Single-Writer/Multiple Reader (SWMR) Access
 - Improved fault tolerance
 - Initial support for asynchronous I/O



Where We'll Be Soon

- Release 1.10 - Details
 - New chunked dataset indexing methods
 - Single-Writer/Multiple-Reader (SWMR) Access
 - Improved Fault Tolerance
 - Journalled Metadata Writing
 - Ordered Updates
 - Persistent file free space tracking
 - Basic support for asynchronous I/O
 - Expanded Virtual File Driver (VFD) interface
 - Lazy metadata writes (in serial)
 - F2003 Support
 - Compressed group information
 - Performance optimizations



Where We Might Get To

- Release 1.10 - Maybe?
 - Full C99 type support (long double, complex, boolean types, etc)
 - High-level “HPC” API
 - Support for runtime file format limits
 - Improved variable-length datatype storage



Where We're Not Going

- We're *not* changing multi-threaded concurrency support
 - Keep “global lock” on library
 - *Will* use asynchronous I/O heavily
 - *Will* be using threads internally though

What's up with The HDF Group?

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Tools update



HDF Java Products

Library development in the works

Other activities



Tool activities in the works

- New tool – h5watch
 - Display changes to a dataset, metadata and raw data
- New tool – h5compare
 - Rewritten and improved version of h5diff
- Improved code quality and testing
- Tools library: general purpose APIs for tools
 - Tools library currently only for our developers
 - Want to make it public so that people can use it in their products



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HDF-Java 2.7 (Feb, '11)

- Full support for [most] features in 1.8.x C library
- Many bug fixes and much better regression tests
- Performance improvements

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What Next?

- Release 1.12 - Overview
 - Special focus on HPC features & performance
 - Improvements to data model
 - “Virtual Object Layer”

- Release 1.12 - Details
 - Special focus on HPC features & performance
 - Remove “all collective” metadata operation requirement
 - Use “staging area” to buffer and analyze data
 - Ordered updates in parallel
 - “Append-only” optimizations
 - “Embarrassingly parallel” optimizations
 - Asynchronous metadata and raw data I/O in parallel
 - Indexing on both raw data and metadata, along with query language
 - New parallel I/O benchmarking tool
 - Autotune to parallel file system
 - Support MPI fault tolerance



What Next?

- Release 1.12 - Details
 - Improvements to data model:
 - Shared dataspace
 - Attributes on dataspace and datatypes
 - “Virtual Object Layer”
 - HDF5 without a file?
 - Introduce new layer in library focused on abstract data model
 - Working with DOE Labs & Microsoft



What Next?

- Release 1.12 – Details
 - Other ideas:
 - Add feature to “re-sparsify” chunked datasets
 - Allow component values of datasets with composite datatypes to be stored in non-interleaved form
 - Port HDF5 to the NMI Build and Test facility
 - More, certainly...

What's up with The HDF Group?

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GES DISC

Goddard Earth Sciences Data and Information Services Center



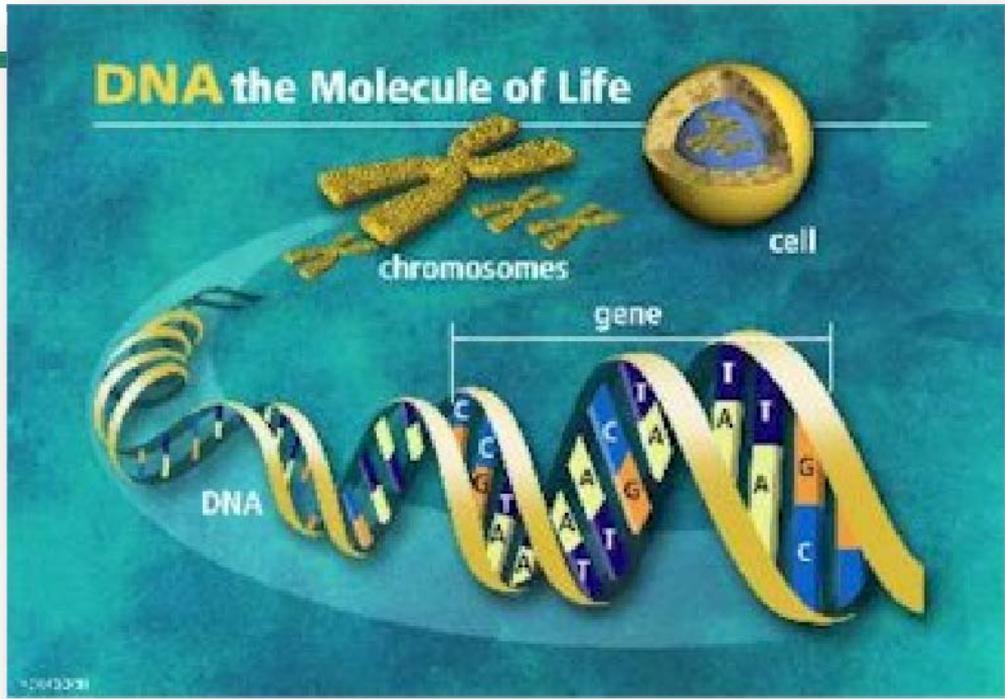
geospiza





Thank You!

Questions & Comments?



NIH STTR with Geospiza, Seattle WA

BIOHDF : TOWARD SCALABLE BIOINFORMATICS INFRASTRUCTURES



Next Generation DNA Sequencing

“Transforms today’s biology”

“Democratizing genomics”

“Changing the landscape”

“Genome center in a mail room”

“The beginning of the end for microarrays”

NGS is Powerful





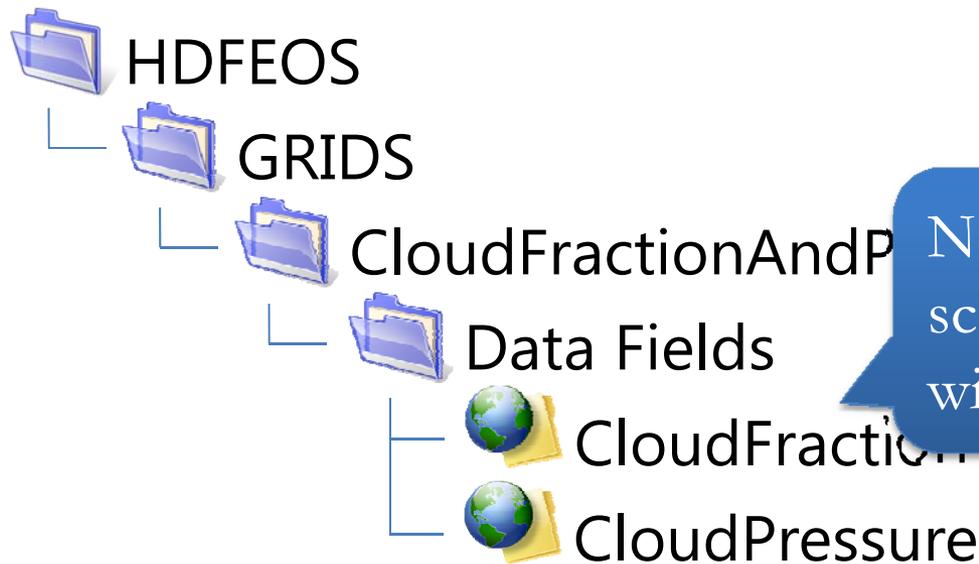
- ***Goal: Move bioinformatics problems from organizing and structuring data to asking questions and visualizing data***
 - Develop data models and tools to work with NGS data in HDF5
 - Create HDF5 domain-specific extensions and library modules to support the unique aspects of NGS data → BioHDF
 - Integrate BioHDF technologies into Geospiza products
- **Deliver core BioHDF technologies to the community as open-source software**



HDF-EOS5/netCDF-4 Augmentation Tool

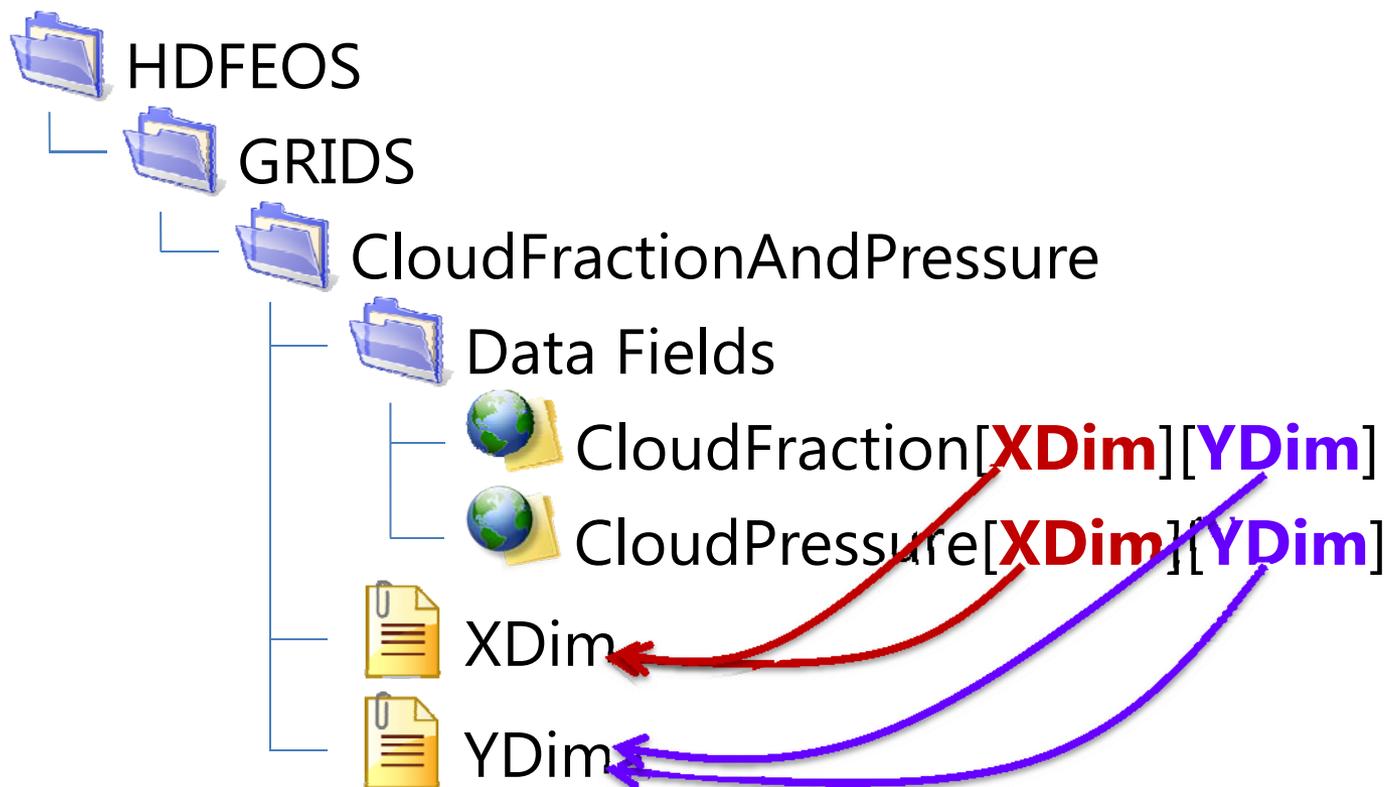
Accessing HDF-EOS5 files via netCDF-4 API

- NetCDF-4 model follows the HDF5 dimension scale model but HDF-EOS5 does not.



No HDF5 dimension scales are associated with this variable

- Provide dimensions required by netCDF-4



A decorative banner at the top of the slide features a collage of space-related images: a satellite in orbit, a space station, and a rocket launch. A horizontal line of binary code (0s and 1s) is overlaid on the left side of the banner.

OPeNDAP



- HDF5-OPeNDAP handler
 - Served OMI Swath data
- HDF4-OPeNDAP handler
 - Tested with some AIRS data and some MODIS data