

# BRIDGING ICESAT AND ICESAT-2 WITH STANDARD DATA PRODUCTS

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**ABSTRACT:** The ICESat-2 SIPS (Science Investigator-led Processing System) software development team is preparing to design and implement ICESat-2 standard data products. The team has initiated two distinct but related efforts to identify and prototype standards and conventions that are applicable to the ICESat-2 standard data products. The first effort consists of converting current ICESat GLAS binary data products into HDF5. This is a 7-month task restricted to adopting and implementing an initial snapshot of standards and conventions. The second effort is a longer-term activity using a prototype SIPS to design and create scientific data products for MABEL, an aircraft-based ICESat-2-like photon-counting instrument. The MABEL effort will extend past the end of the GLAS conversion effort and will prototype standards and conventions deemed too ambitious for the GLAS conversion. Both prototype efforts feed directly into the ICESat-2 standard data product design process. The overall goal is to design and create standard data products that will be standards-compliant, enable interoperability between ICESat and ICESat-2 data, and promote data interoperability with other present and future Earth Science missions.

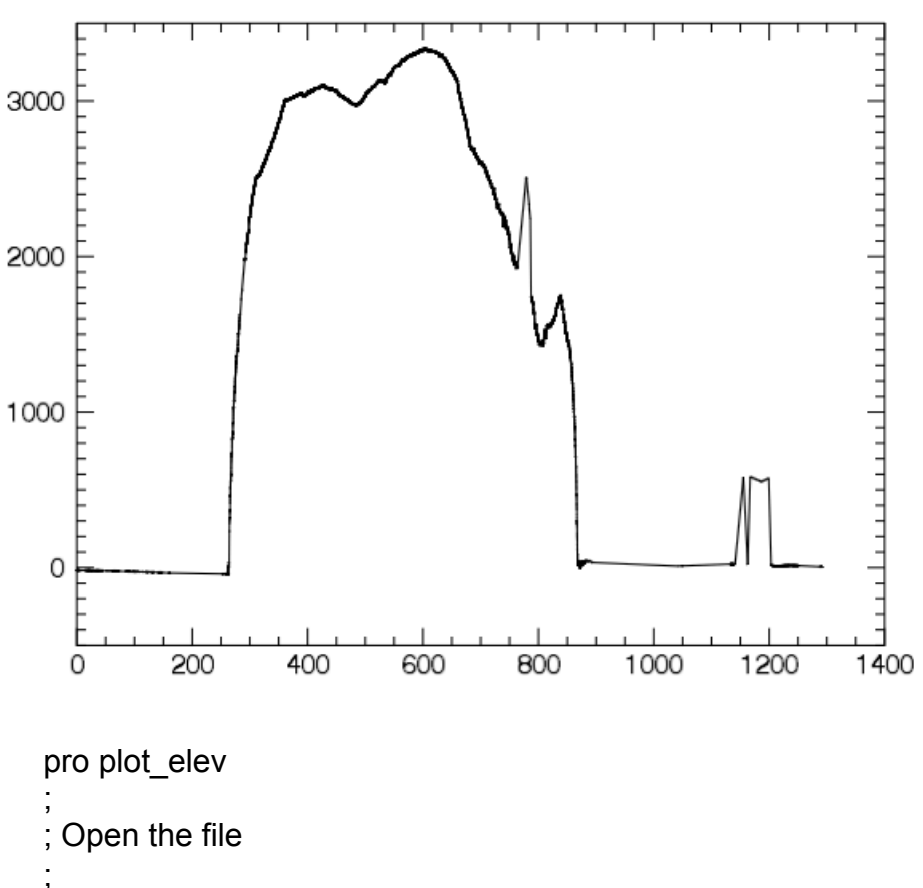
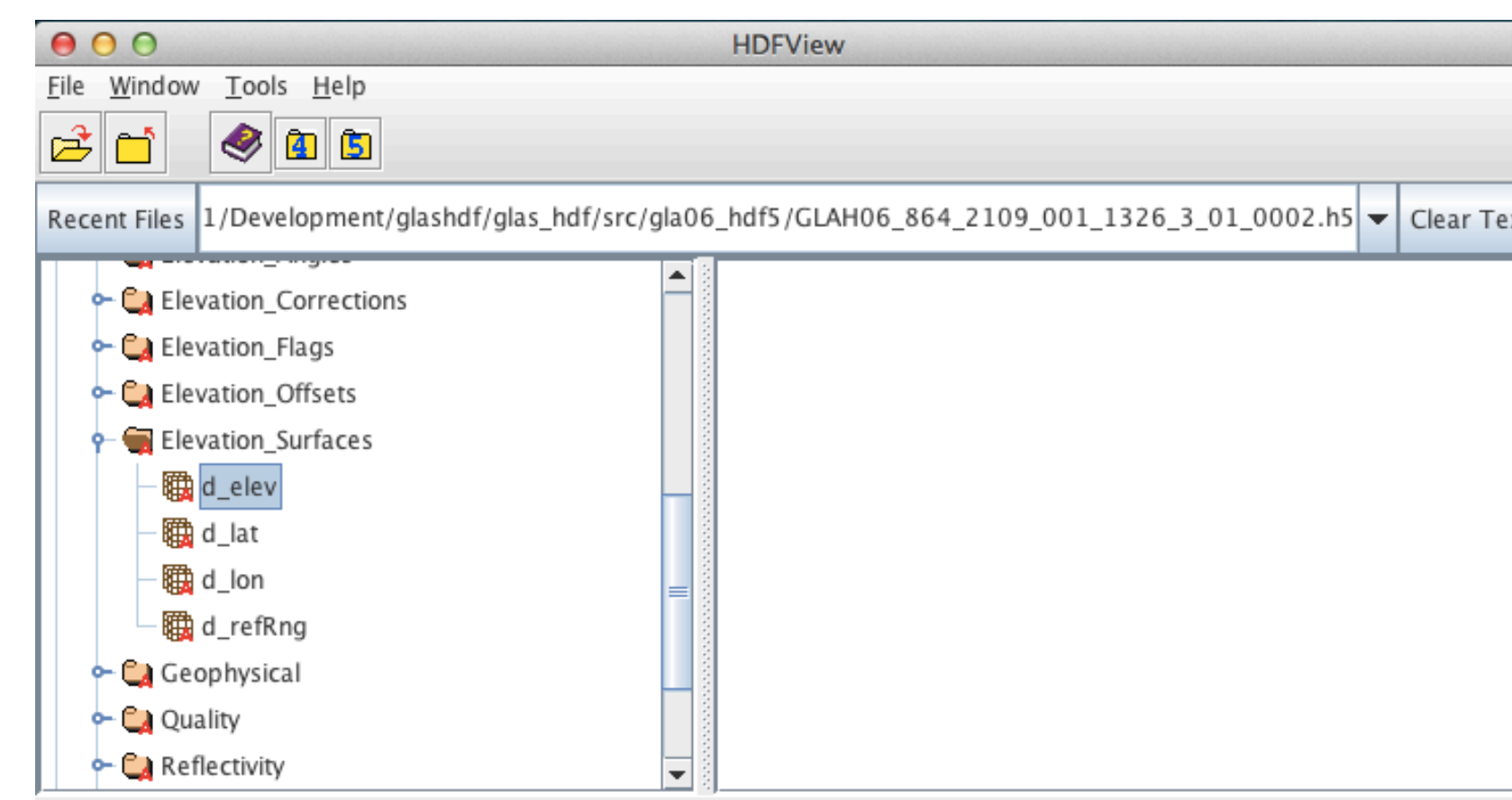
## GLAS Data Characteristics

- Sparse Multi-rate Point Data
- Variable-length Waveforms (544 or 200 gates)
- Atmospheric Profiles
- Lots of Parameters!

## GLAS\_HDF Target Characteristics

- HDF5 (hdf5 1.8.8)
- Simple, self-describing datasets
- CF Conventions
- Rate & Logical Grouping + Dimension Scales
- ECHO+ (Collection+Inventory+Local) Metadata
- Collection-Level DOI
- Granule-Level UUIDs
- NetCDF "Friendly"

## Simple, Self-Describing Datasets with CF Attributes



```

pro plot_elev
  Open the file
  f_id=H5F_OPEN("GLAH06_864_2109_001_1326_3_01_0002.h5")
  Read Time
  time_id=H5D_OPEN(f_id, "Data_40Hz/Time/d_UTCTime")
  time=H5D_READ(time_id)
  H5D_CLOSE, time_id

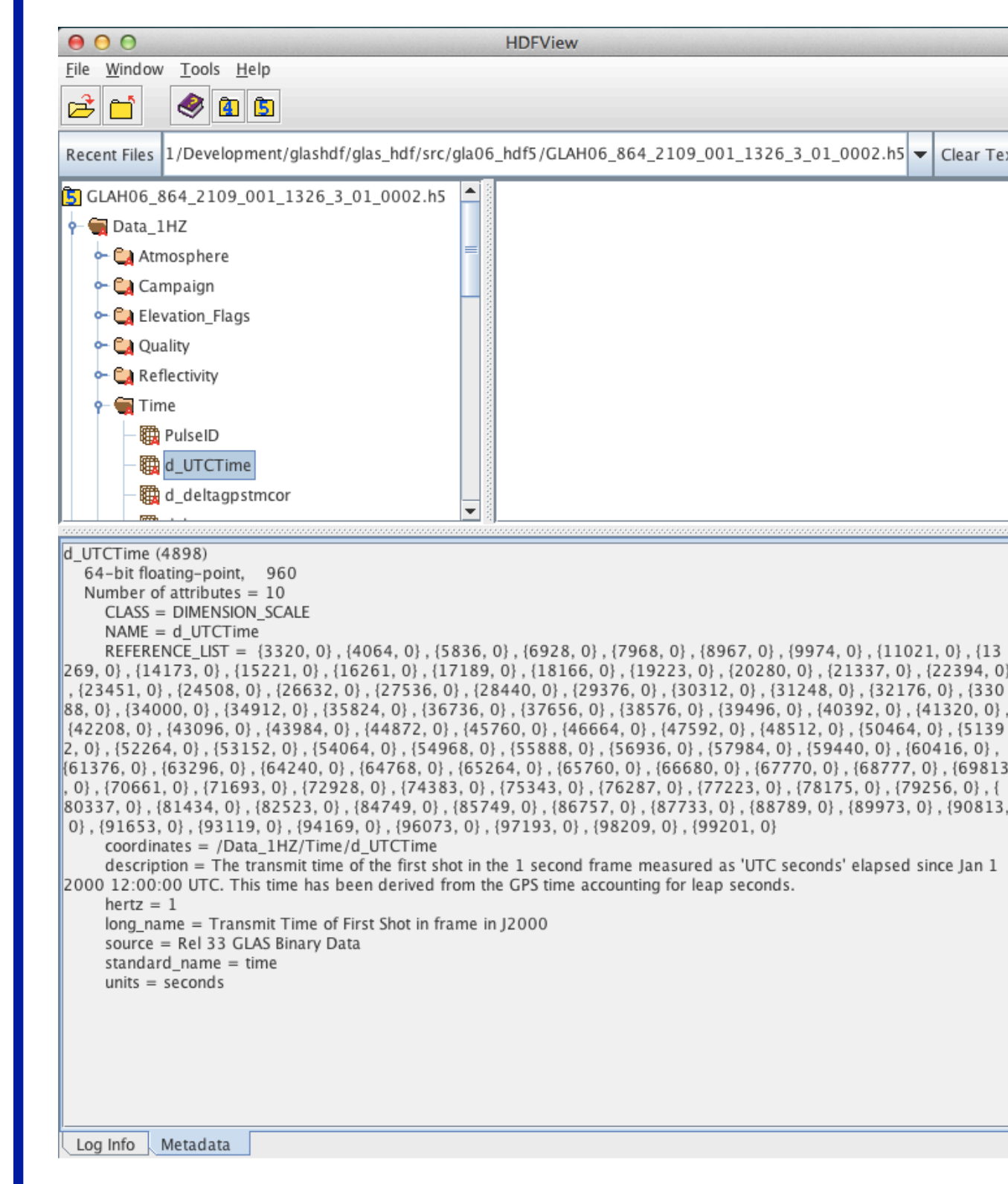
  Read Elevation values and the fill value attribute
  elev_id=H5D_OPEN(f_id, "Data_40Hz/Elevation_Surfaces/d_elev")
  elev=H5D_READ(elev_id)
  at_id=H5A_OPEN_NAME(elev_id, "_FillValue")
  bad_val=H5A_READ(at_id)
  H5A_CLOSE, at_id
  H5D_CLOSE, elev_id

  Plot the good data
  good=where(elev ne bad_val[0])
  a=plot(time[good], elev[good])
  H5F_CLOSE, f_id
end

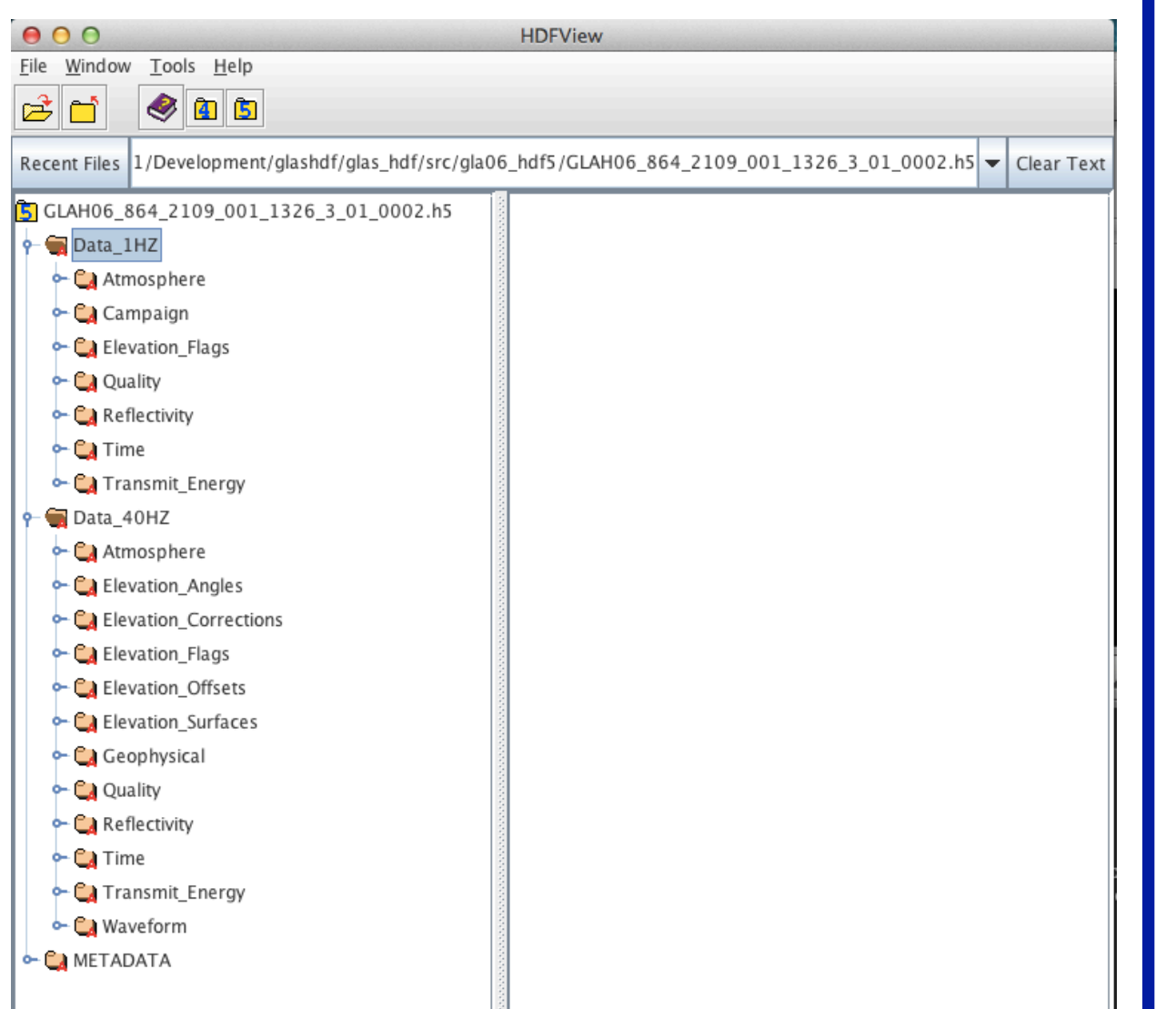
```

Simple IDL code created the plot.

## Top-Level Rate Groups and Logical By-Discipline Subgrouping



All data of the same rate are contained within a top level "rate" group which provides a 1-to-1 corresponding time-based dimension scale.



A second level of grouping arranges parameters logically by discipline.

## Flavors of Metadata: What's YOUR Favorite?

For the TEST product, we did all 3!

*Must be simple: easily parsed, but human-readable*

We wrote code to parse ESDT MCF files then merged Collection-level metadata, GLAS metadata and local metadata.

## Provenance: DOIs, UUIDs, and Prior Processing

**Conventions = CF-1.6**  
**DOI = 10.5067/ICESAT/GLAS/GLAH06**  
**HDFVersion = HDF5 1 8 8**

UUID = 15955791-7A98-4839-834C-9C31D4616E2F  
 comment = Please direct comments to David.W.Hancock@nasa.gov  
 featureType = point  
 history = Described in Metadata group  
 institution = NASA Goddard Space Flight Center  
 references = http://icesat.gsfc.nasa.gov/icesat/icesat\_data.php  
 source = Satellite Observations  
 title = ICESAT HDF5 Data Granule

PROVENANCE.PreGranuleID = GLA06\_864\_2109\_001\_1326\_3\_01\_0001.DAT  
 PROVENANCE.PreProcPower = GLA05\_863\_2109\_001\_1326\_2\_01\_0001.DAT, GLA05\_863\_2109\_001\_1326\_3\_01\_0001.DAT, GLA05\_863\_2109\_001\_1327\_0\_01\_0001.DAT, GLA05\_863\_2109\_001\_1327\_1\_01\_0001.DAT, ANCO1\_006\_20041007\_060000\_01\_0000.DAT, ANCO1\_006\_20041007\_060000\_01\_0004.DAT, ANCO1\_006\_20041007\_060000\_01\_0007.DAT, ANCO1\_006\_20041007\_060000\_01\_0008.DAT, ANCO1\_006\_20041007\_060000\_01\_0009.DAT, ANCO1\_006\_20041007\_060000\_01\_0010.DAT, ANCO1\_006\_20041007\_060000\_01\_0011.DAT, ANCO1\_006\_20041007\_060000\_01\_0012.DAT, ANCO1\_006\_20041007\_060000\_01\_0013.DAT, ANCO1\_006\_20041007\_060000\_01\_0014.DAT, ANCO1\_006\_20041007\_060000\_01\_0015.DAT, ANCO1\_006\_20041007\_060000\_01\_0016.DAT, ANCO1\_006\_20041007\_060000\_01\_0017.DAT, ANCO1\_006\_20041007\_060000\_01\_0018.DAT, ANCO1\_006\_20041007\_060000\_01\_0019.DAT, ANCO1\_006\_20041007\_060000\_01\_0020.DAT, ANCO1\_006\_20041007\_060000\_01\_0021.DAT, 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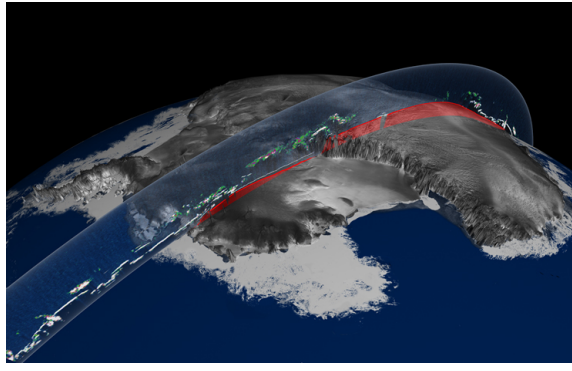


## ICESat/ICESat-2 SSDT Goals

- Design products and write software for ICESat-2.
- Create interoperable data products for the ICESat-2 demonstrator instrument (MABEL).
- Transform GLAS data products into something more interoperable and future-proof.

## ICESat (GLAS) Rewind

- Geoscience Laser Altimeter System (GLAS)
  - Traditional Laser Altimeter
  - 40 shots/sec
- 15 Data Product Types (GLAxx)
  - L1 – L2A
  - Fixed-record-length integer-binary
- Sparse Multi-rate Point Data
  - 40/sec, 1/sec, 1/4sec, 1/8sec, 1/16sec
  - Lat, Lon, Elev
- 33 Releases
  - Final completed this year
- 7 years of campaign-mode data collection
- Returned to Earth August 30, 2010



<http://icesat.gsfc.nasa.gov/icesat/>

## MABEL Review

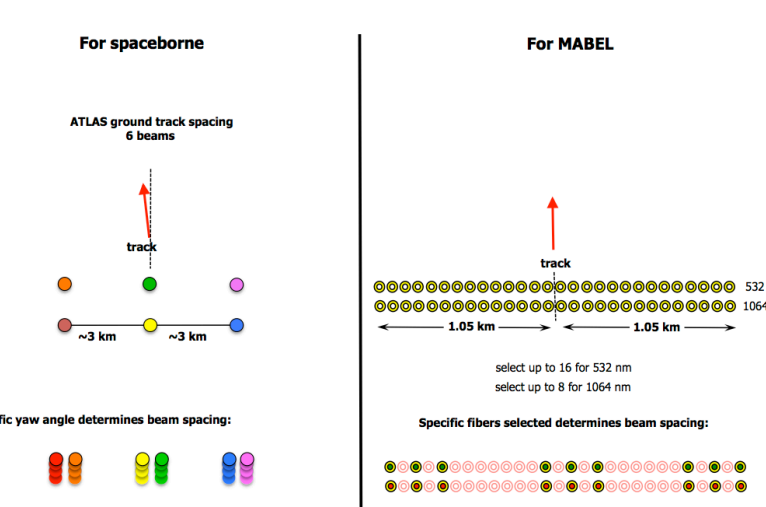
- Multiple Altimeter Beam Experimental Lidar (MABEL).
- Demonstrator instrument for ATLAS.
- Photon-counting LIDAR.
- 16 Beams/Tracks for 532nm
- 8 Beams/Tracks for 1064nm.
- Flies aboard ER-2 – Flying from Iceland NOW
- Average Size of 30 sec Granules
  - L1A = 503 MB
  - L1B = 272 MB
  - L2A = 234 MB



[http://icesat.gsfc.nasa.gov/icesat2/data/mabel/mabel\\_docs.php](http://icesat.gsfc.nasa.gov/icesat2/data/mabel/mabel_docs.php)

## ICESat-2 (ATLAS) Preview

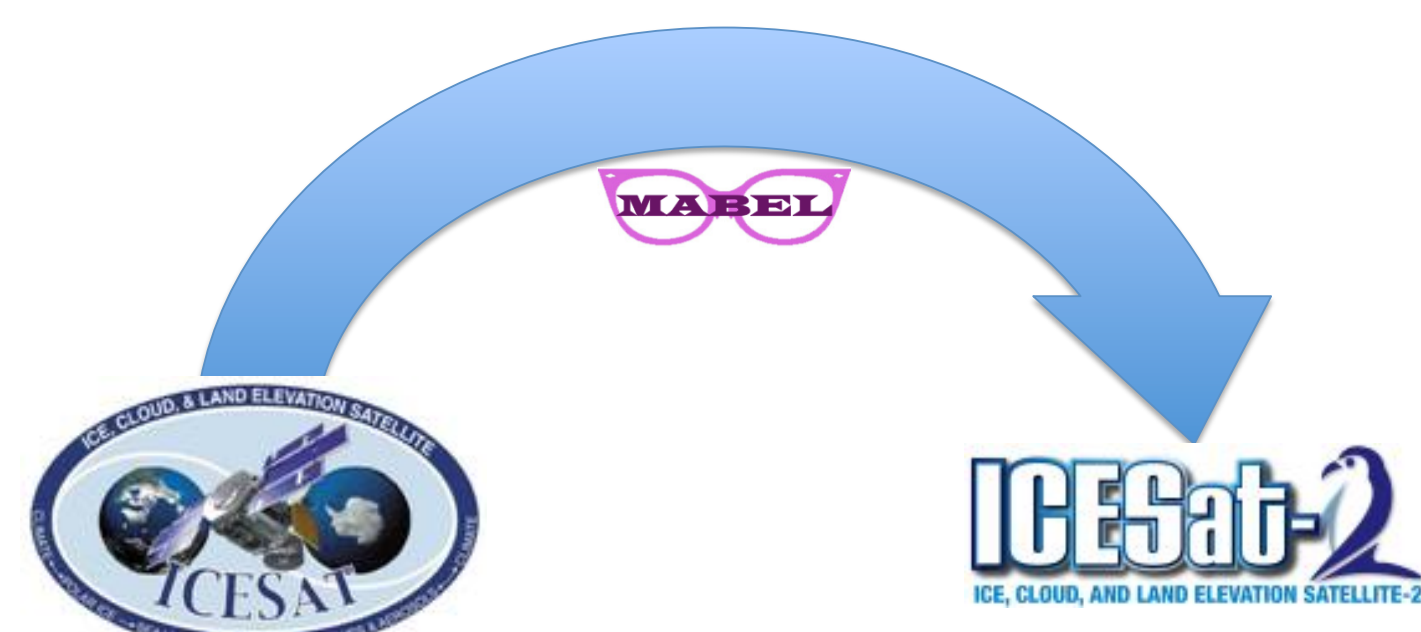
- Advanced Topographic Laser Altimeter System (ATLAS)
  - Photon Counting Lidar
  - 6 Beams/Tracks
  - 10,000 shot/sec; may average 3 surface photons/shot/beam
- 21 Suggested Product Types
  - L1A-L4
  - 13 Sparse Multi-Rate Point
  - 8 Gridded
- Big Data!
  - L0 : 80GB/Day
  - Total Granules : 860GB / Day
- Launch 2016



<http://icesat.gsfc.nasa.gov/icesat2/>



## Bridging ICESat and ICESat-2 with Standard Data Products



SGT/Jeffrey Lee  
Code 615, NASA GSFC/WFF  
HDF & HDF-EOS Workshop XV, April 17-19 2012  
jeffrey.e.lee@nasa.gov

## Contributors

- ICESat GLAS and ICESat-2 ATLAS Science Software Development Teams (GSAS SDT and ASAS SDT)
  - SGT/Jeffrey Lee, SGT/John Dimarzio, SGT/Peggy Jester, SGT/Suneel Bhardwaj, SSAI/Kristine Barbieri, SGT/LeeAnne Roberts, Sigma/David W Hancock
- ESDIS
  - 423/Jeanne Behnke, 432/Jeff Walter, 423/Hampapuram Ramapriyan
- Earth Science Data Systems Working Groups
  - Standards Process Group
  - Technical Infusion Working Group
- NSIDC (ICESat Data Center)
- SMAP Product Development Team

## ICESat (GLAS) Rewind

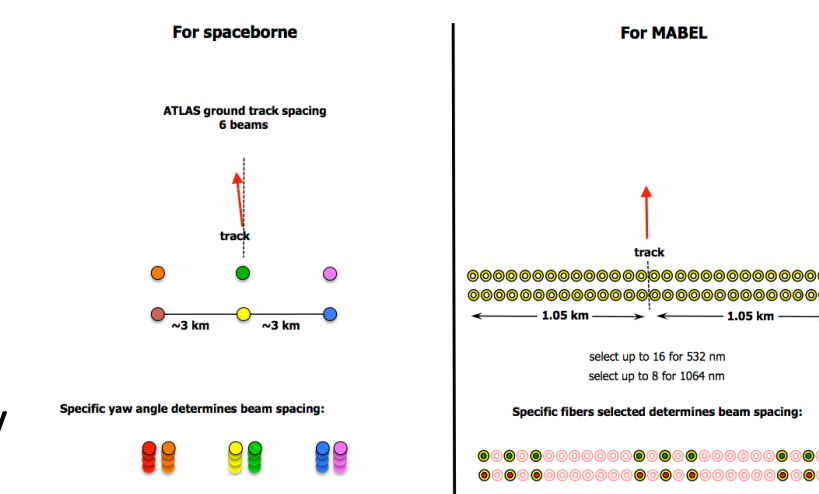
- Geoscience Laser Altimeter System (GLAS)
  - Traditional Laser Altimeter
  - 40 shots/sec
- 15 Data Product Types (GLAxx)
  - L1 – L2A
  - Fixed-record-length integer-binary
- Sparse Multi-rate Point Data
  - 40/sec, 1/sec, 1/4sec, 1/8sec, 1/16sec
  - Lat, Lon, Elev
- 33 Releases
  - Final completed this year
- 7 years of campaign-mode data collection
- Returned to Earth August 30, 2010



<http://icesat.gsfc.nasa.gov/icesat/>

## ICESat-2 (ATLAS) Preview

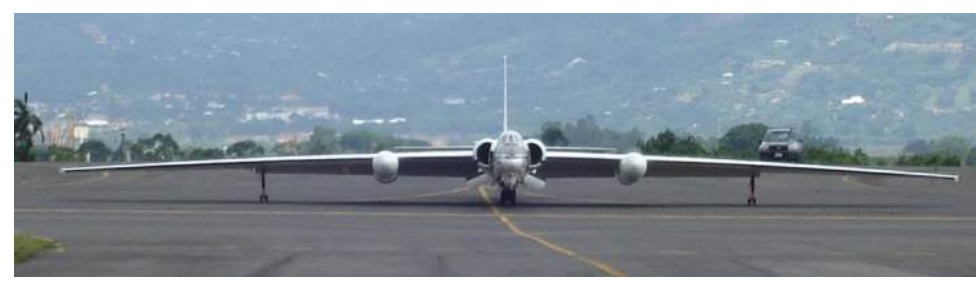
- Advanced Topographic Laser Altimeter System (ATLAS)
  - Photon Counting Lidar
  - 6 Beams/Tracks
  - 10,000 shot/sec; may average 3 surface photons/shot/beam
- 21 Suggested Product Types
  - L1A-L4
  - 13 Sparse Multi-Rate Point
  - 8 Gridded
- Big Data!
  - L0 : 80GB/Day
  - Total Granules : 860GB / Day
- Launch 2016



<http://icesat.gsfc.nasa.gov/icesat2/>

## MABEL Review

- Multiple Altimeter Beam Experimental Lidar (MABEL).
- Demonstrator instrument for ATLAS.
- Photon-counting LIDAR.
- 16 Beams/Tracks for 532nm
- 8 Beams/Tracks for 1064nm.
- Flies aboard ER-2 – Flying from Iceland NOW
- Average Size of 30 sec Granules
  - L1A = 503 MB
  - L1B = 272 MB
  - L2A = 234 MB



[http://icesat.gsfc.nasa.gov/icesat2/data/mabel/mabel\\_docs.php](http://icesat.gsfc.nasa.gov/icesat2/data/mabel/mabel_docs.php)

## ICESat/ICESat-2 SSDT Goals

- Design products and write software for ICESat-2.
- Create interoperable data products for the ICESat-2 demonstrator instrument (MABEL).
- Transform GLAS data products into something more interoperable and future-proof.

## Hmm...

- All three datasets are fairly similar in type:
  - Sparse, irregular, multi-rate point data.
- So, let's make the products of similar design!
- Benefits:
  - Promotes interoperability.
  - Enables natural progression of development experience.
  - Enhances code reuse/enables common codebase.

## Development Plan

- Use MABEL for initial prototype. Design products in HDF5, write software, create initial products.
  - STATUS : 5 Releases of Data Products to Date.
- Write transformation software and design products for ICESat data (GLAS\_HDF) using MABEL as a basis.
  - STATUS : Draft Products Released.
- Integrate lessons learned in GLAS\_HDF to improve future releases of MABEL products.
- Apply all lessons-learned to ICESat-2.

## Relevant Satellite Data System Requirements

- Defined
  - ISO 19115 Metadata.
  - NASA-approved file format.
- In Study Phase
  - DOI (Digital Object Identifiers).
- Implied
  - CF conventions.

<http://science.nasa.gov/earth-science/earth-science-data/satellite-mission-data-system-requirements/>

## SDT Desires

- SIMPLICITY : `a=plot(time,elev)`
- Product should be self-describing.
- Product should be NetCDF4-friendly.
- Product should include UUIDs for granule-level unique identifiers.
- Development should leverage existing GLAS codebase.
- 3<sup>rd</sup> Party Libraries should be stable and well-tested.
- Software stack should be kept to a minimum.

## Low Hanging Fruit?

- Is there anything else we could do (that will not severely impact our schedule) with the GLAS\_HDF or MABEL products to help the community evaluate or develop future standards ?
- Example : UUID=Low Hanging Fruit

## Implementation Strategy

Feature	GLAS_HDF	MABEL	ICESat-2
File Format	HDF5	HDF5	HDF5
Granule-level Metadata	ECHO+	ECHO+ (Initial) ISO-19115 (Planned)	ISO 19115
Collection DOIs	YES	YES	YES
CF Conventions	YES	YES	YES
Self-Describing	YES	YES	YES
NetCDF4-friendly	YES	YES	TBD
Granule UUIDs	YES	YES	TBD
Development End Date	May 2012	TBD	TBD

## Technical Design

- HDF5 (1.8.8)
- Each parameter is a dataset.
  - Simple & NetCDF4-friendly.
  - Allows attached parameter attributes.
  - Allows user to easily read parameters they want.
- Parameters will be chunked/gzipped.
  - This is a –must– given future data sizes.
- Parameters will have attached CF attributes.
  - <http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.6/cf-conventions.html>

## Logical Design

- Rate Group – A solution for multi-rate data.
  - All Data of a particular rate are bundled into a top-level “rate” group. Each rate group has an associated time parameter with a 1-to-1 array index correspondence.
  - Yes, time is repeated, but is simpler than indexing and allows for “`a=plot(x,y)`”.
- Data are further grouped logically per discipline.

## Design Review

- ESDSWG Technical Infusion Working Group
  - Technical review of standards and implementation.
- NSIDC (ICESat Data Center)
  - Content review of data and organization.
- SMAP
  - Agreed to collaborate on interoperability at the start.
  - Walking in their footsteps.

## Development Challenge

- GLAS data consists of 15 products with a total of over 2000 parameters.
- That's a lot of code to write!
- We can read the integer-binary with existing routines. But...that's STILL a lot of code to write.
- MABEL development revealed that product shares a significant amount of coding constructs.

## Product\_Spec -> Compiled Code

- Prep Work
  - Export cf-style parameter metadata from existing data dictionary into text-based product\_spec.
  - Massage the product\_spec to add rate/logical grouping.
- Code Generation
  - Feed the product\_spec into gla\_codegen to generate Fortran90 product code.
  - Make minor fixes to generated code.

## gla\_codegen

- Internal-quality “evolutionary” code generator.
- Written in Fortran90; writes Fortran90 code.
- Calls SDT library routines & HDF5 library.
- Writes modular API code based on input product\_spec.
- Is Rate & Logical Group oriented.
- Handles:
  - Limited datatypes
  - Up to rank=2 arrays
  - CF attributes
  - Basic granule-level metadata
  - Chunking, gzip compression
  - HTML data dictionary generation

## Generated Product API

Module	Functionality
init_	Initializes the data structure for the group
allocate_	Allocates the data buffer
deallocate_	Deallocates the data buffer
h5_create_	Creates group and initializes for writing
h5_init_	Initializes the HDF5 data structures
h5_open_	Opens group and reads parameter attributes
h5_close_	Closes group and any open spaces
h5_read_chunk_	Reads a chunk of data from file to memory
h5_write_chunk_	Writes a chunk of data from memory to HDF file
print_attr_	Prints parameter attributes
print_data_	Prints parameter data
print_head_	Prints parameter headings
print_data_dict_	Prints structure for DD
sync_	Synchronizes group with time
h5_set_dims_	Sets parameter dimensional scales

## Generated Code

- GLAH06 Example:
  - Read 193 lines of product description
  - Wrote 21K lines of code to instantiate the API.
  - Using pre-existing code to read original GLAS data, the code generator provides over 90% of the code required for the transformation process.