User Guide to the HDF5 NPOESS High-level Library for Handling Region References and Hyperslab Selections

Draft 2.0

1 Introduction

This document is a quick guide to the HDF5 NPOESS-HL[1] library for creating, manipulating, and querying data associated with a dataset region reference. The library[2] contains C and Fortran APIs designed to reduce a number of steps that a user has to traverse when working with the HDF5 region references. It also facilitates access to a raw data stored in an HDF5 file and pointed to by the region references.

[1] We may reconsider the name "NPOESS-HL" to reflect a general purpose of the library. I will use it for now as a placeholder.

[2] Current distribution works on Linux/Unix platforms only; library may be ported to the Windows platforms in the future.

It is assumed that the reader is familiar with the basic HDF5 concepts [1] and can write, compile, link and run a simple HDF5 C or Fortran program, and examine the content of an HDF5 file with h5dump or HDFView tools [2].

2 Installing the NPOESS-HL Library

The NPOESS-HL library is a standalone library built on top of the HDF5 C library. To install it, follow these steps:

1) Make sure you have the HDF5 library, version 1.8.5 or later, installed on your system. For updates and installation instructions, see http://www.hdfgroup.org/HDF5/.
2) To download the source code, go to http://www.hdfgroup.org/projects/npoess/.
3) Click the "Software" tab on the left to open the FTP page.
4) Click the "source" folder to open its contents.
5) Click the hdf5_HL_REGION-1.1.0.tar[3] file, which contains the source code, to fetch it. (Alternately, go directly to The HDF Group FTP server ftp://ftp.hdfgroup.uiuc.edu and then to the /pub/outgoing/NPOESS/source directory to access this source.)
6) Unpack the file and change directory to hdf5_HL_REGION-1.1.0.
7) Follow the installation instructions in the README.txt file to install the library under a directory `/dir` on your system.
8) Use `h5cc` or `h5fc` compiler scripts found in the `bin` directory of the HDF5 installation directory, to compile and link your application as shown

   h5cc –I/*dir*/include example.c –L/*dir*/lib –lhdf5_hl_region

   ```
   h5fc example.f90 -L/dir/lib -lhdf5_hl_region_fortran -lhdf5_hl_region
   ```

   If the library is installed with the HDF5 library (default), then the commands are simplified to

   ```
   h5cc  example.c -lhdf5_hl_region

   h5fc example.f90 -lhdf5_hl_region_fortran -lhdf5_hl_region
   ```

Note: The next section gives a quick overview of HDF5 references and provides examples of their usage. Readers familiar with this topic may skip Section 3 and proceed to Section 4 to learn about the library API.

3 What is an HDF5 Reference?

There are many different ways to organize data in an HDF5 file and to express relationships between different objects stored.

An HDF5 application may use a hierarchical structure to impose relationships between data objects stored in a file, allowing a user to navigate efficiently through the data. For example, measurements with the same time stamp can be stored in the datasets belonging to the same group in a file. The application just needs to know the path to the group to access all measurements with the same time stamp.

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[3] Version 1.1.0 has not been released yet. It will contain Fortran API and should be ready when this document goes out (March 31, 2010? – wishful thinking ;-)

While hierarchical structure and grouping mechanism work well for organizing objects of a "similar" nature, as in the time-stamp example above, they may not work well for organizing objects of a "dissimilar" nature: associating complex metadata with an object (such as an image and its possible palettes), locating objects with a particular property, or locating and accessing a particular subset of data elements stored in a dataset. To accomplish this task, HDF5 provides *references* to objects and *references* to dataset regions.

3.1 HDF5 Reference to an Object

An object reference points to an HDF5 object, such as a dataset or a group, stored in the same file. The application may use an array of object references to identify a set of related HDF5 objects.

Example: associating images with palettes. HDF5 Image uses an array of object references to associate different palettes with the same image. (For more information, see section 1.2 "Image Attributes" in *HDF5 Image and Palette Specification* [3].) Figure 1 shows an HDF5 file containing three images and four palettes. The image "image8bit" has four palettes associated with it.

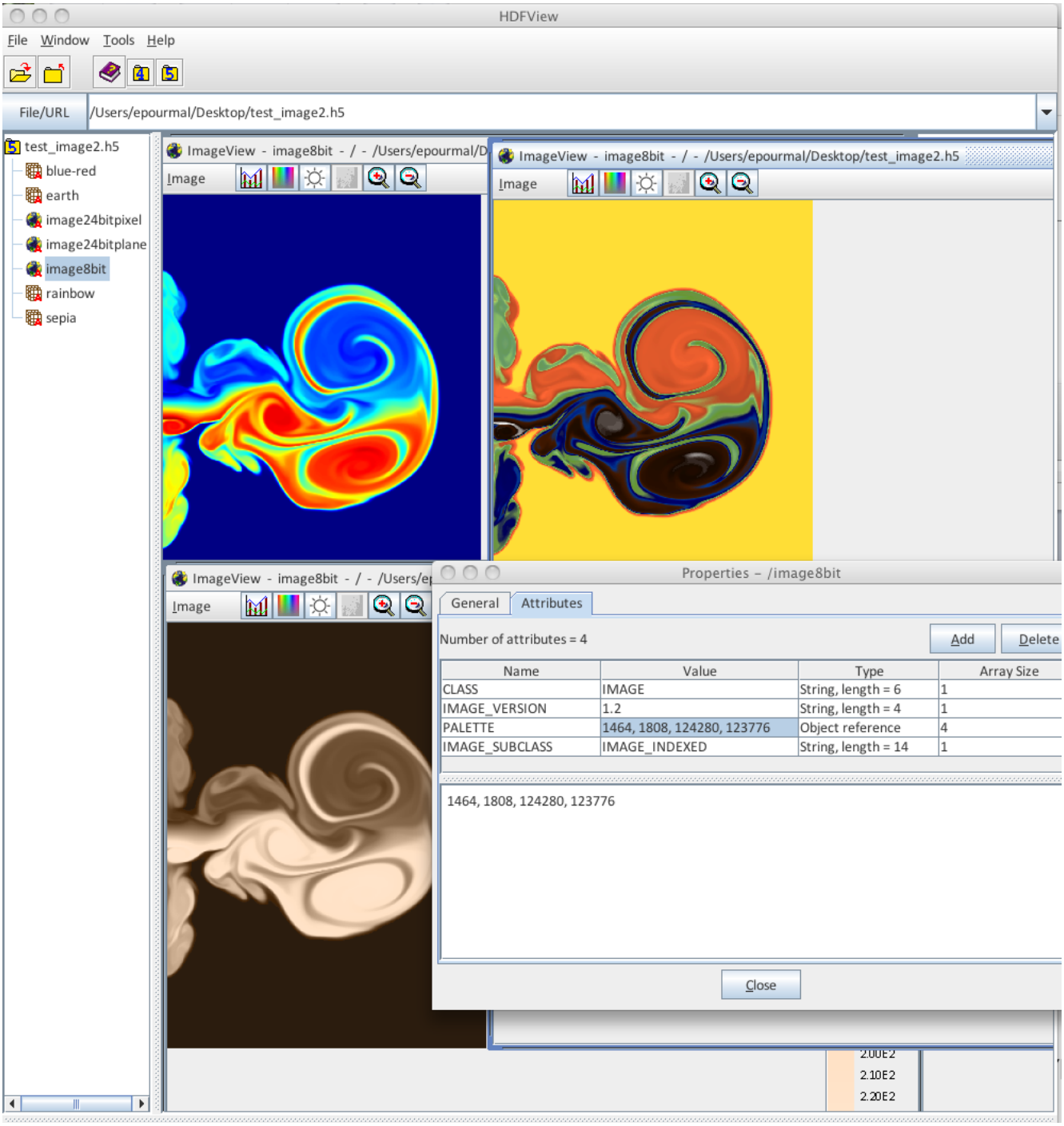


Figure 1. In HDFView, the image "image8bit" is shown using three different palettes. The Palette attribute of the image is an array of object references pointing to the palettes (datasets "rainbow", "sepia", "earth" and "blue-red" in the same file).

The image's attribute "PALETTE" (shown highlighted in the Properties Window) is an array of object references with the following numerical values: 1464, 1808, 124280, and 123776. Each number can be interpreted by the HDF5 library to access the datasets "rainbow", "sepia", "earth" and "blu-red", respectively, in the same file. HDFView uses palettes to display the dataset "image8bit".

Example: dimension scales. Internal implementation of dimension scales in HDF5 relies on object references to associate a dataset with its dimensions scales and to share them with other datasets in a file [4]. In the h5dump output example below, the two-dimensional dataset “Mydata” has a dimension scale associated with the each of the dimensions. The first dimension of size 4 has a dimension scale Xaxis with the values of the scale stored in the dataset Xaxis; the second dimension of size 3 has a dimension scale Yaxis with the values of the scale stored in the dataset Yaxis. The values of the corresponding object references are 1400 and 1672, respectively.

```
HDF5 "dimscale.h5" {
GROUP "/" {
   DATASET "Mydata" {
      DATATYPE  H5T_STD_I32LE
      DATASPACE  SIMPLE { ( 3, 4 ) / ( 3, 4 ) }
      DATA {…
            }
      ATTRIBUTE "DIMENSION_LIST" {
         DATATYPE  H5T_VLEN { H5T_REFERENCE}
         DATASPACE  SIMPLE { ( 2 ) / ( 2 ) }
         DATA {
         (0): (DATASET 1400 /Yaxis ), (DATASET 1672 /Xaxis )
         }
      }
   }
   DATASET "Xaxis" {
      …
      DATA {
      (0): 10, 20, 50, 100
      }
      …
   }
   DATASET "Yaxis" {
      …
      DATA {
      (0): 10, 20, 30
      }
      …
   }
}
}
```

3.2 HDF5 Reference to a Dataset Region

A region reference points to a dataset and a region within that dataset. When stored in a dataset, an array of region references can provide a unified view of the data stored in the different datasets in a file.

In general, region references are useful for directly accessing a portion of a dataset. Notably, region references play an important role in large datasets by providing a convenient and efficient way to point to data of interest.

Figure 2 illustrates the concept of region references. A user can create a file (*FileA.h5*) having a group (*Group_1D*) containing data values stored in a one-dimensional array (*DS1*), a group (*Group_2D*) containing data in a two-dimensional array (*DS2*), and a group (*Group_3D*) containing data in a three-dimensional array (*DS3*).

In order to quickly and efficiently access data within a dataset, an array of region references is created (*R1*). Each element in the region reference array points to a different selection of elements in the datasets. The first element in R1 points to a region in the dataset DS2, the second element in R1 points to a set of points in DS1, and so forth.

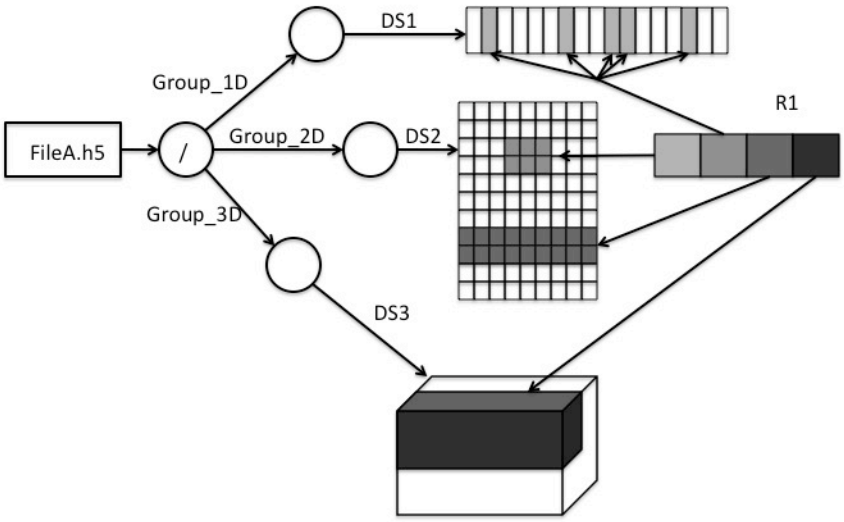


Figure 2. Elements of region reference array R1 point to regions in the datasets in an HDF5 file

The same file is shown in Figure 3 as displayed by HDFView. Dataset R1 has four elements of the region reference datatype. Each of the "TableView" windows on the right has one of the four elements selected. As one can see, an element of the region reference type contains two pieces of information: the first one, shown in the form 0:XXXX, indicates the dataset; the second one describes the selected region in that dataset. The region can be a set of points as is the case for the first element, described as a list of the points' coordinates. Or the region can be a rectangular subset, described as a pair of "lower-left"-"upper-right" coordinates as is the case for the second, third and forth elements.

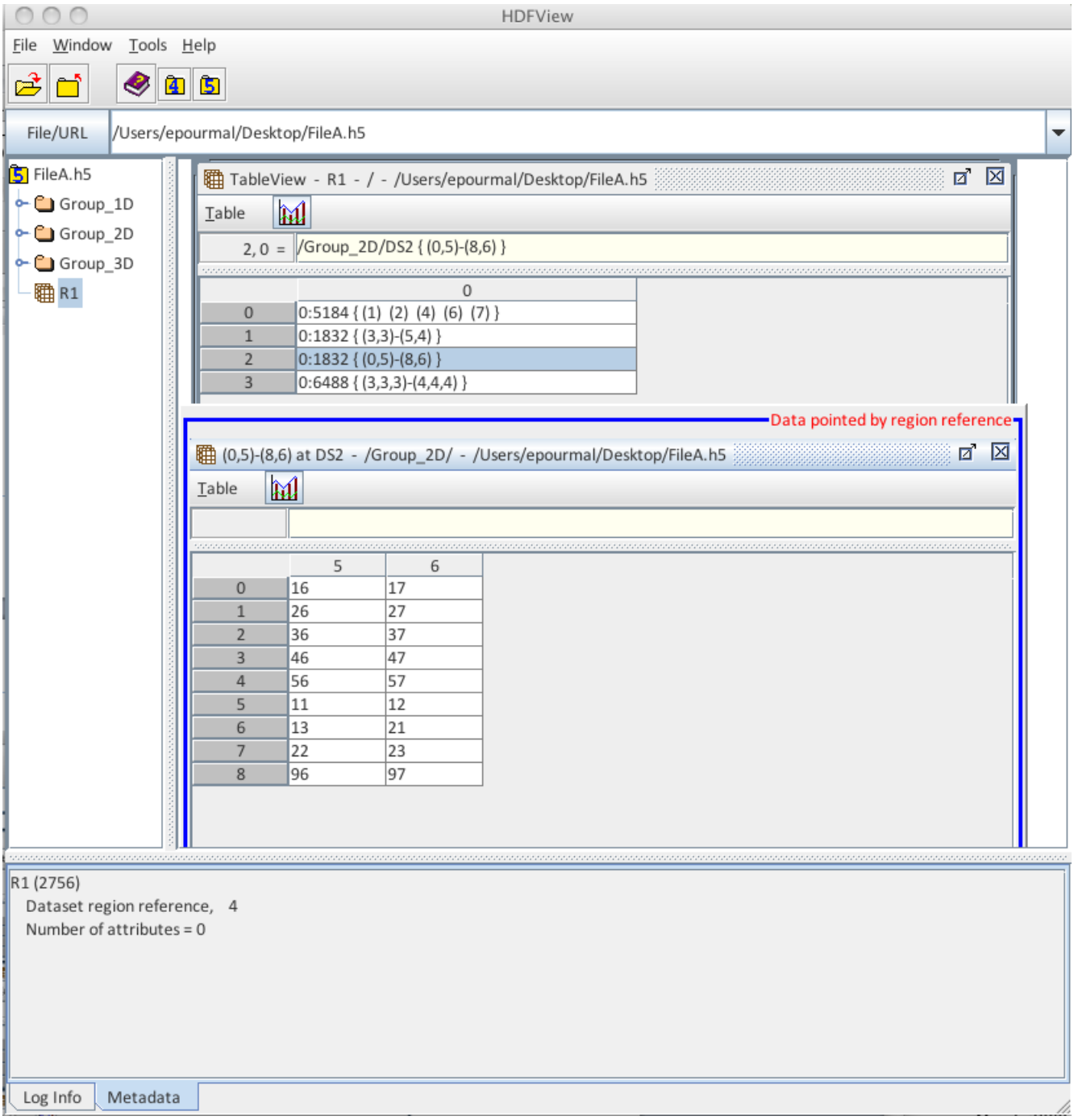


Figure 3. Each element of the dataset R1 is a region reference. Small pane window (in yellow) shows the full path to a dataset along with the selected elements within the dataset for each of the four elements of R1.

One can use the h5dump utility to see the content of the HDF5 file. Below is an output of the same file (for brevity's sake, the actual data in datasets DS1, DS2, DS2a are not included). For each element

of the dataset R1, h5dump prints the full path to the dataset within the file along with the coordinates of the selected region.

```
HDF5 "FileA.h5" {
GROUP "/" {
   GROUP "Group_1D" {
      DATASET "DS1" {…
}
   GROUP "Group_2D" {
      DATASET "DS2" {…
 }
GROUP "Group_3D" {
      DATASET "DS3" {…
}
DATASET "R1" {
      DATATYPE  H5T_REFERENCE
      DATASPACE  SIMPLE { ( 4 ) / ( 4 ) }
      DATA {
(0):          DATASET /Group_1D/DS1 {(1), (2), (4), (6), (7)},
(1):          DATASET /Group_2D/DS2 {(3,3)-(5,4)},
(2):          DATASET /Group_2D/DS2 {(0,5)-(8,6)},
(3):          DATASET /Group_3D/DS3 {(3,3,3)-(4,4,4)}
      }
   }
}
}
```

3.3 Example of the NPOESS File

Need a description here. Explain kind of data and how it is represented.

Figure 4 shows ….

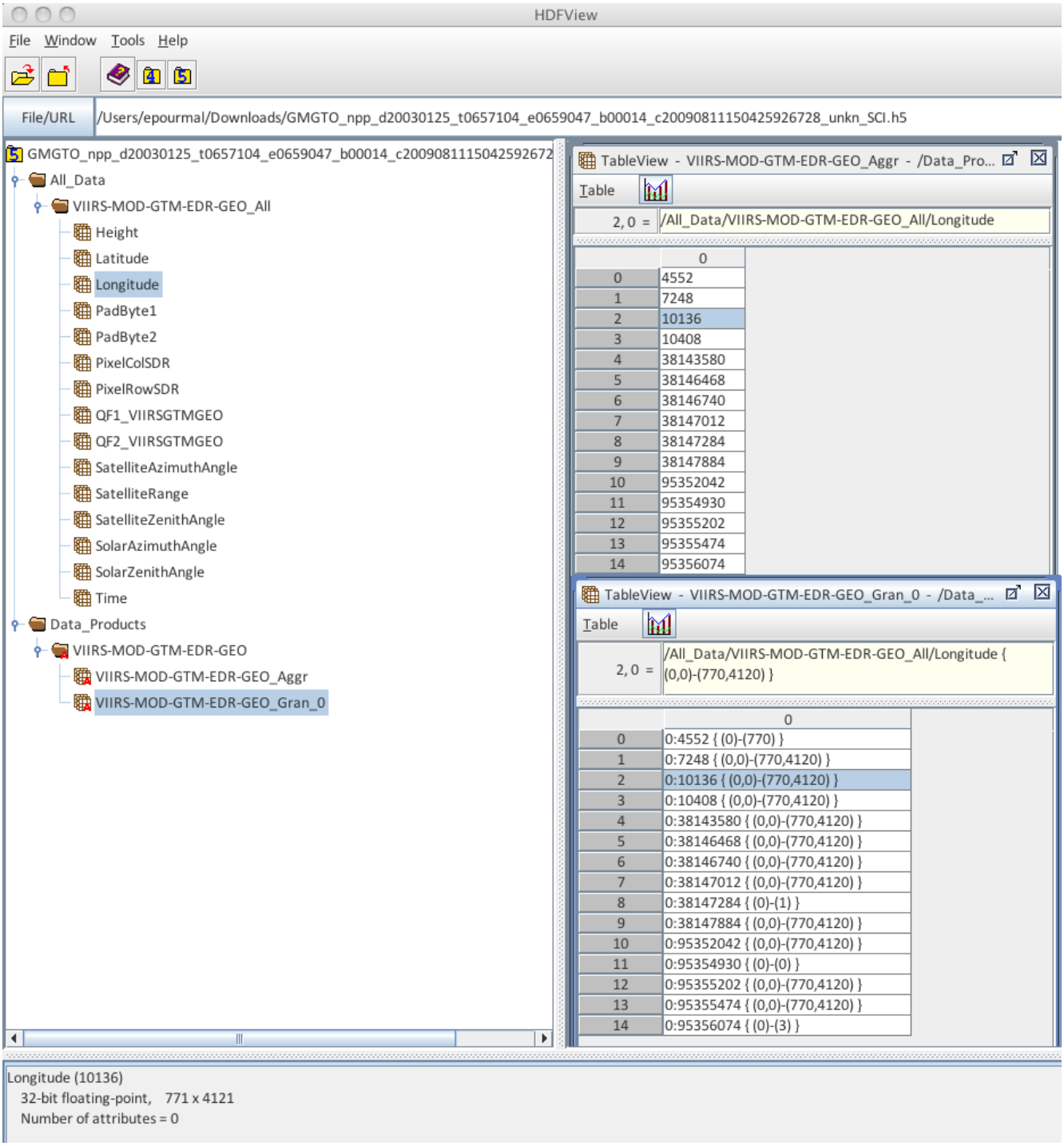


Figure 4. An example of the NPP file. Windows on the right show data for the datasets under "Data_Products" group. The highlighted element in the VIIRS-MOD-GTM-EDR-GEO_All dataset with the value 10136 is an object reference to the dataset "Longitude". The highlighted element in the VIIRS-MOD-GTM-EDR-GEO_Gran_0 dataset with the value 0:10136 {(0,0)-(770,4120)} is a region reference to the dataset "Longitude" and a selection within it.

4 Library APIs and Examples

This section summarizes C functions and Fortran subroutines in the NPOESS-HL library. Subsections below explain how to use the functions, h5dump and HDFView tools to get information about the data associated with the references and how to manipulate such data. For function signatures, see the NPOESS-HL library reference manual *HDF5 High-level Functions for Region References, Hyperslabs, and Bit-fields* [5]. Examples come with the source code and can be seen and downloaded from http://www.hdfgroup.org/projects/npoess/HL_NPOESS/doc/index.html.

Table 1. NPOESS-HL Library Functions

API Name (C/Fortran)	Description
H5LRget_region_info / h5lrget_region_info_f	Queries information about the data pointed to by a region reference, such as information about the dataset and a description of the referenced region within the dataset.
H5LRread_region / h5lrread_region_f	Reads data pointed to by the region reference.
H5LRcreate_region_references/ H5lrcreate_region_references_f	Creates an array of region references using an array of paths to datasets and an array of corresponding hyperslab descriptions.
H5LRmake_dataset / h5lrmake_dataset_f	Creates and writes a dataset containing a list of region references.
H5LRcopy_region / h5lrcopy_region_f	Copies data from a referenced region to a region in a destination dataset.
H5LRcopy_reference / h5lrcopy_reference_f	Copies data from the specified dataset to a new location and creates a reference to it.
H5LRcreate_ref_to_all/ h5lrcreate_ref_to_all_f	Creates a dataset with the region references to the data to all datasets located under a specified group in a file, or creates a dataset with object references to all objects (groups or datasets) located under a specified group in a file.
H5LTread_region / h5ltread_region_f	Reads selected data to an application buffer.
H5LTcopy_region / h5ltcopy_region_f	Copies data from a specified region in a source dataset to a specified region in a destination dataset.
H5LTread_bitfield_value	Retrieves the values of quality flags for each element to the application-provided buffer.

4.1 Programming with the High-level NPOESS Library

To use High-level NPOESS C functions, an application has to include the public header files NPOESS_H5LTpublic.h (for the H5LT* functions) and NPOESS_H5LRpublic.h (for the H5LR* functions). Since NPOESS functions are just the wrappers around the HDF5 C functions, they can be used along with the HDF5 C functions in the same application.

High-level NPOESS Fortran subroutines are the wrappers on top of the High-level NPOESS C functions. They use the Fortran2003 standardized mechanism for interoperating with C. Therefore, an application that uses High-level NPOESS Fortran subroutines is required to use the ISO_C_BINDING module. To use the h5lt* subroutines, an application would also need to include the NPOESS_H5LT module, and to use the h5lr* subroutines, an application would need to use the NPOESS_H5LR module. As with the C functions, High-level NPOESS Fortran subroutines can be used along with the HDF5 Fortran subroutines in the same application.

The sections below discuss how to access and manipulate data in HDF5 files using functions from the library.

4.2 Reading data that a region reference points to

This section explains how to get data that a region reference points to by using HDF5 tools and functions from the High-level NPOESS Library. In the first example, HDFView is used to display and export region-referenced data to a text file. In the second example, the h5dump utility is used to display and export data to a binary file. In the last example, the H5LRget_region_info and H5LRread_region functions are used to find information and read the data.

4.2.1 Using HDFView to read data that a region reference points to

Figure 4 in Section 3.3 shows the VIIRS-MOD-GTM-EDR-GEO_Gran_0 dataset with region references in the low TableView window. To see data that the third element with the value 0:10136 {(0,0)-(770,4120)} points to, click the highlighted element. HDView opens another window with the “Data pointed by region reference” label as shown in Figure 5. Only a specified selection is displayed, i.e., hyperslab with the coordinates (0,0) – (770,4120). To save data to a file, click “Table” and then the “Export Data from File” tab as shown in Figure 6; HDFview saves data in a text file with a specified name. Currently HDFView does not support exporting to a binary file; the feature may be added in the future.

HDFView does not show the dimensionality and the datatype of the data pointed to by a region reference. To find this information, one has to open the properties of a dataset; in our example, open the Longitude dataset in HDFView to see the information. As we will see in our next example, h5dump does provide this kind of information.

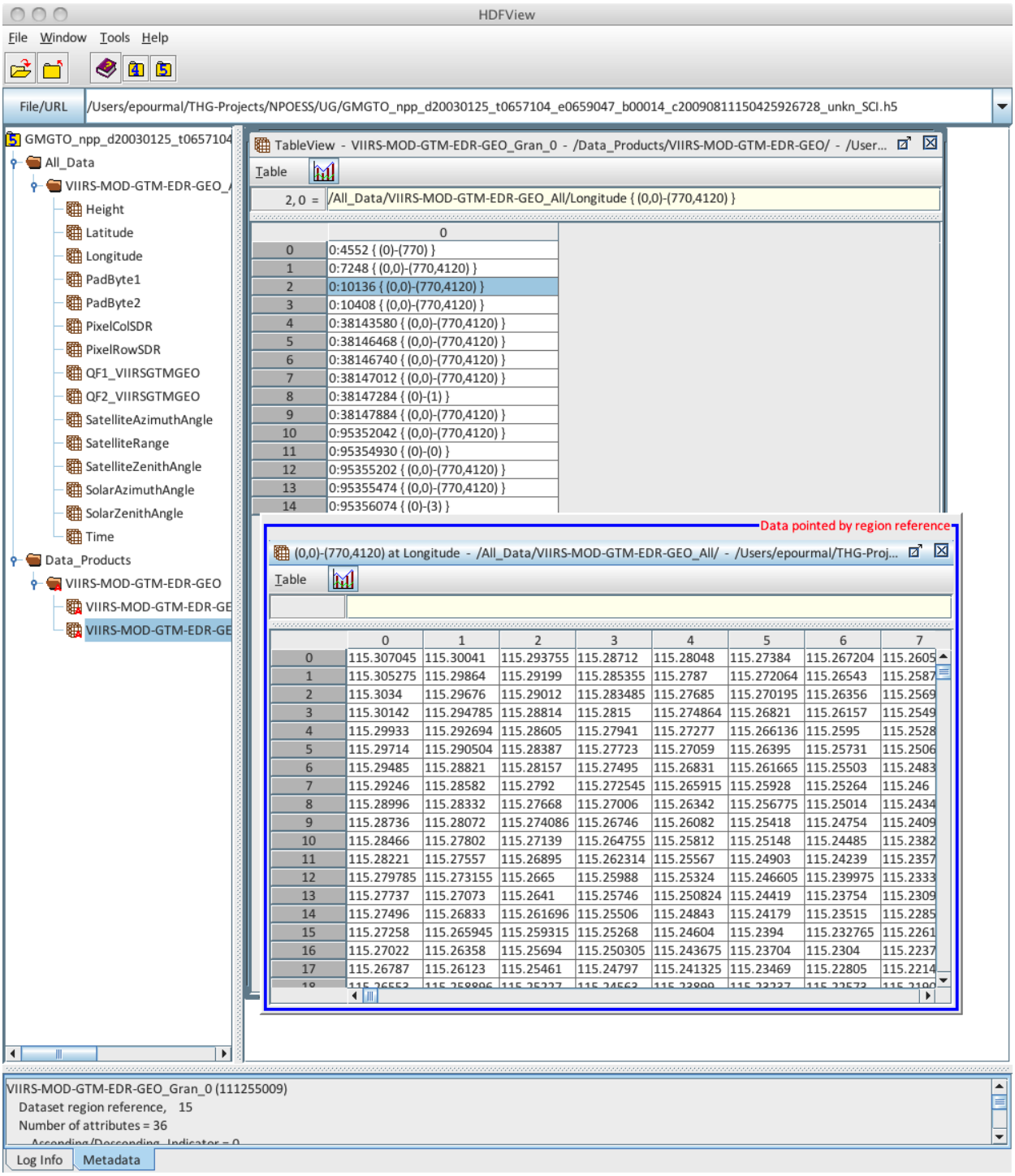


Figure 5. The top window displays data in the "Longitude" dataset, which is pointed to by a region reference stored in the third element of the VIIRS-MOD-GTM-EDR-GEO_Gran_0 dataset.

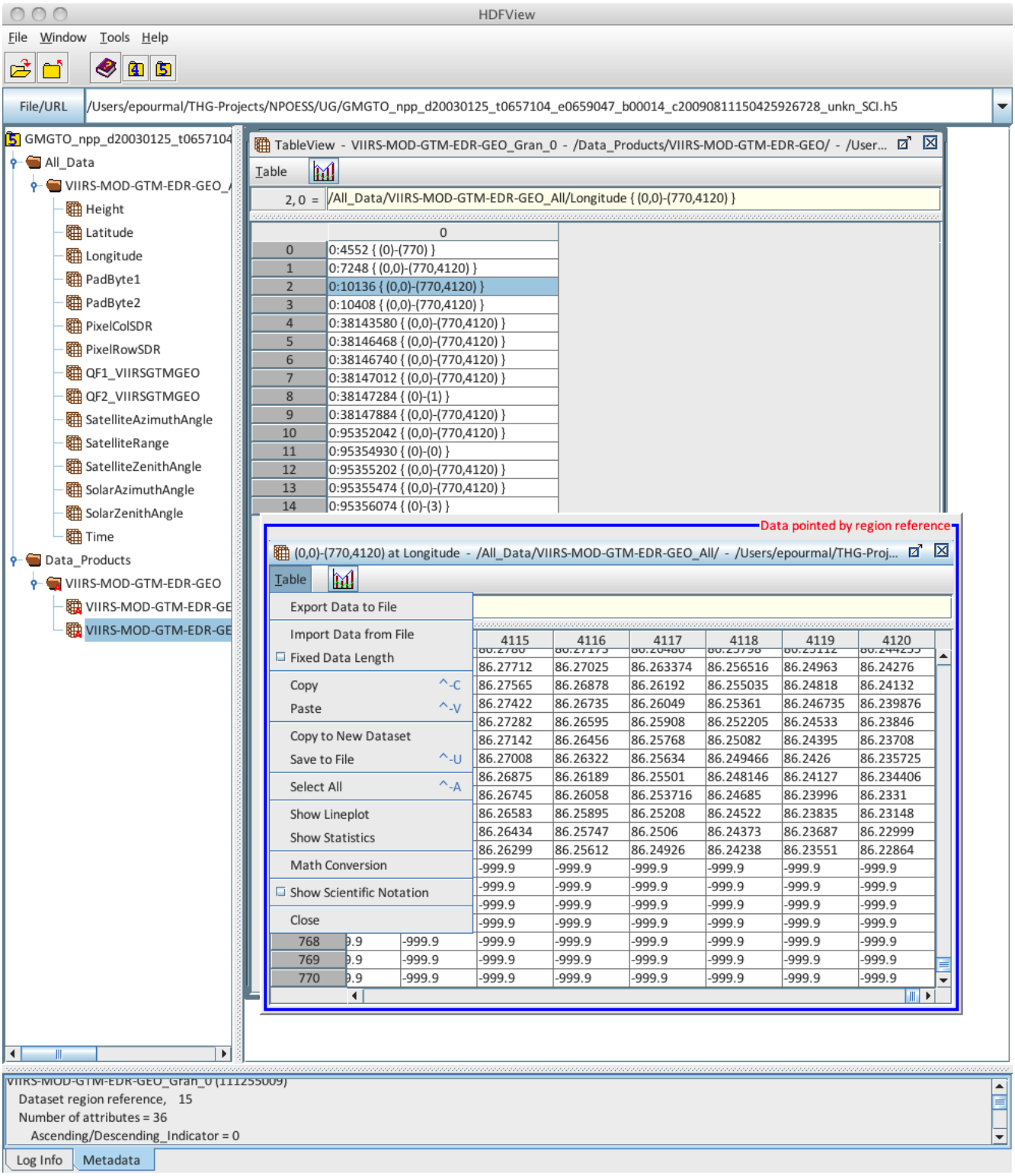

HDFView
File Window Tools Help
File/URL
/Users/epourmal/THG-Projects/NPOESS/UG/GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5
GMGTO_npp_d20030125_t0657104
All_Data
VIIRS-MOD-GTM-EDR-GEO_A
Height
Latitude
Longitude
PadByte1
PadByte2
PixelColSDR
PixelRowSDR
QF1_VIIRSGTMGEO
QF2_VIIRSGTMGEO
SatelliteAzimuthAngle
SatelliteRange
SatelliteZenithAngle
SolarAzimuthAngle
SolarZenithAngle
Time
Data_Products
VIIRS-MOD-GTM-EDR-GEO
VIIRS-MOD-GTM-EDR-GE
VIIRS-MOD-GTM-EDR-GE
TableView - VIIRS-MOD-GTM-EDR-GEO_Gran_0 - /Data_Products/VIIRS-MOD-GTM-EDR-GEO/ - /User...
Table
2, 0 = /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude { (0,0)-(770,4120) }
0
0 0:4552 { (0)-(770) }
1 0:7248 { (0,0)-(770,4120) }
2 0:10136 { (0,0)-(770,4120) }
3 0:10408 { (0,0)-(770,4120) }
4 0:38143580 { (0,0)-(770,4120) }
5 0:38146468 { (0,0)-(770,4120) }
6 0:38146740 { (0,0)-(770,4120) }
7 0:38147012 { (0,0)-(770,4120) }
8 0:38147284 { (0)-(1) }
9 0:38147884 { (0,0)-(770,4120) }
10 0:95352042 { (0,0)-(770,4120) }
11 0:95354930 { (0)-(0) }
12 0:95355202 { (0,0)-(770,4120) }
13 0:95355474 { (0,0)-(770,4120) }
14 0:95356074 { (0)-(3) }
Data pointed by region reference
(0,0)-(770,4120) at Longitude - /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/ - /Users/epourmal/THG-Proj...
Table
Export Data to File
Import Data from File
Fixed Data Length
Copy ^-C
Paste ^-V
Copy to New Dataset
Save to File ^-U
Select All ^-A
Show Lineplot
Show Statistics
Math Conversion
Show Scientific Notation
Close
4115 4116 4117 4118 4119 4120
86.27712 86.27025 86.263374 86.256516 86.24963 86.24276
86.27565 86.26878 86.26192 86.255035 86.24818 86.24132
86.27422 86.26735 86.26049 86.25361 86.246735 86.239876
86.27282 86.26595 86.25908 86.252205 86.24533 86.23846
86.27142 86.26456 86.25768 86.25082 86.24395 86.23708
86.27008 86.26322 86.25634 86.249466 86.2426 86.235725
86.26875 86.26189 86.25501 86.248146 86.24127 86.234406
86.26745 86.26058 86.253716 86.24685 86.23996 86.2331
86.26583 86.25895 86.25208 86.24522 86.23835 86.23148
86.26434 86.25747 86.2506 86.24373 86.23687 86.22999
86.26299 86.25612 86.24926 86.24238 86.23551 86.22864
-999.9
768 -999.9
769 -999.9
770 -999.9
Dataset region reference, 15
Number of attributes = 36
Ascending/Descending_Indicator = 0
Log Info
Metadata

Figure 6. Data shown in the "Data pointed by region references" window can be saved in a text file by using the "Table" and then the "Export Data to File" tabs.

4.2.2 Using h5dump to read data that a region reference points tp

As mentioned above, h5dump can display and export data pointed to by a region reference. Several flags such as "-d", "-s", "-R" and "-b" should be used as shown in the examples below.

4.2.2.1 Displaying a dataset with region references

The "-d" flag displays a specified dataset. When used on a dataset with region references, h5dump shows the full path to a dataset and a selection within that dataset that the region reference points to, as shown below for VIIRS-MOD-GTM-EDR-GEO_Gran_0.

```
h5dump -d /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0 <name>.h5[4]
HDF5 "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5" {
DATASET "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0" {
   DATATYPE  H5T_REFERENCE
   DATASPACE  SIMPLE { ( 15 ) / ( H5S_UNLIMITED ) }
   DATA {
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Time {(0)-(770)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Latitude {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SolarZenithAngle {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SolarAzimuthAngle {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteZenithAngle {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteAzimuthAngle {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Height {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/PadByte1 {(0)-(1)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/QF1_VIIRSGTMGEO {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/QF2_VIIRSGTMGEO {(0)-(0)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/PixelRowSDR {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/PixelColSDR {(0,0)-(770,4120)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/PadByte2 {(0)-(3)}
   }
```

[4] *<name>* is used for GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5 for readability purposes only

4.2.2.2 Displaying an element of a dataset with region references

To display just one element – for example, the third element of the dataset – one can use the "-s" flag as shown in the next example. The "-s" flag can be used to specify the coordinates of the element in a dataset array. The coordinates are 0-based; to specify the third element, use "-s" 2 as shown below.

```
h5dump -d /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0 -s 2 <name>.h5


HDF5 "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5" {
DATASET "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0" {
   DATATYPE  H5T_REFERENCE
   DATASPACE  SIMPLE { ( 15 ) / ( H5S_UNLIMITED ) }
   SUBSET {
      START ( 2 );
      STRIDE ( 1 );
      COUNT ( 1 );
      BLOCK ( 1 );
      DATA {
         DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude {(0,0)-(770,4120)}
      }
   }
 ….
```

4.2.2.3 Displaying data that a region reference points to

To display the data pointed to by the third element of the VIIRS-MOD-EDR-GEO_Gran_0 dataset and its datatype, use the "-R" flag.

The h5dump utility displays the description of the selection (`REGION_TYPE BLOCK (0,0)-(770,4120)`), its datatype (`H5T_IEEE_F32BE`) and the data values.

```
h5dump -d /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0 -s 2 -R <name>.h5
HDF5 "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5" {
DATASET "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0" {
   DATATYPE  H5T_REFERENCE { H5T_STD_REF_DSETREG }
   DATASPACE  SIMPLE { ( 15 ) / ( H5S_UNLIMITED ) }
   SUBSET {
      START ( 2 );
      STRIDE ( 1 );
      COUNT ( 1 );
      BLOCK ( 1 );
      DATA {
      (2): DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude {
         (2): REGION_TYPE BLOCK  (0,0)-(770,4120)
         (2): DATATYPE  H5T_IEEE_F32BE
         (2): DATASPACE  SIMPLE { ( 771, 4121 ) / ( H5S_UNLIMITED, H5S_UNLIMITED ) }
         (2): DATA {
```

```
(0,0): 115.307, 115.3, 115.294, 115.287, 115.28, 115.274,
(0,6): 115.267, 115.261, 115.254, 115.247, 115.241, 115.234,
(0,12): 115.227, 115.221, 115.214, 115.207, 115.201, 115.194,
(0,18): 115.188, 115.181, 115.174, 115.168, 115.161, 115.154,
…….
```

4.2.2.4 Saving data that a region reference points to[5]

To save data in a file, use "-y" to disable the printing of indices and "-o" to specify the output file:

```
h5dump -d /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0 -s 2 -R -y -o ref.txt
<name>.h5
```

The ref.txt file contains data values

```
115.307, 115.3, 115.294, 115.287, 115.28, 115.274, 115.267,
115.261, 115.254, 115.247, 115.241, 115.234, 115.227, 115.221,
115.214, 115.207, 115.201, 115.194, 115.188, 115.181, 115.174,
115.168, 115.161, 115.154, 115.148, 115.141, 115.134, 115.128,
115.121, 115.114, 115.108, 115.101, 115.095, 115.088, 115.081,
…..
```

To export data into a binary file, use the additional "-b" option followed by "LE" or "BE" to specify the binary format. The following command extracts data pointed to by the third element of the VIIRS-MOD-EDR-GEO_Gran_0 dataset, converts it to the little-endian format, and saves it into the ref.bin file.

```
h5dump -d /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0 -s 2 -R -b LE -o ref.bin
<name>.h5
```

4.2.3 Reading data with H5LRget_region_info and H5LRread_region

The NPOESS-HL library provides two functions, H5LRget_region_info and H5LRead_region, to facilitate access to the data that the region reference points to.

H5LRget_region_info takes as an input a region reference and retrieves information about the dataset it points to along with the information about the selection within that dataset. Information returned by this function includes:

- The full path to a dataset the region reference points to (e.g., the reference points to the dataset /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude)
- The description of the hyperslab selection the region reference points to (e.g., a list of corners (0,0) - (770,4120))
- The file datatype of the referenced data (e.g., H5T_IEEE_F32BE)
- The rank of the dataset (e.g., 2 if the dataset the reference points to is two dimensional)
- The type of selection (e.g., H5S_SEL_POINTS for the point selection and H5S_SEL_HYPERSLABS for the hyperslab selection)

[5] This feature will be available in HDF5 1.8.6

Using this information, one can find the number of elements in the selection within a dataset and allocate an appropriate buffer to read the data pointed to by a region reference using the H5LRread_region function (see Figure 7).

The second function H5LRread_region uses an element of a region reference to return the following:

- The number of elements in the selected region
- Data into a buffer allocated by the application

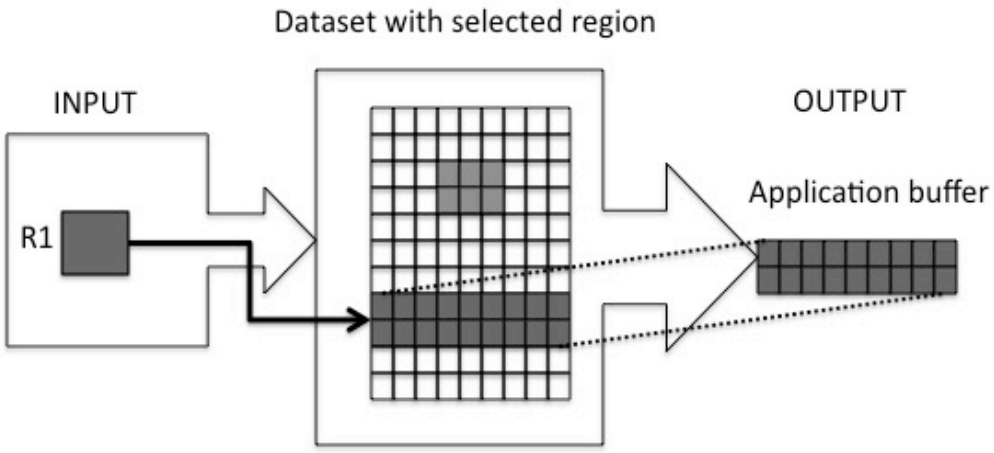


Figure 7. `H5LRread_region` retrieves data that a region reference points to and moves it to a buffer provided by an application.

The next two sections discuss both functions in greater detail.

4.2.3.1 Exploring properties of a dataset with H5LRget_region_info

The excerpt below from Program 1 in the Appendix shows, by using the `H5LRget_region_info` function, how to get information about the data that a region reference points to, data that is similar to the information displayed by h5dump in section 4.2.2.3 . The program opens the GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5 file and the dataset `/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0` with the region references. `H5Dread` reads region references stored in the dataset into the buffer `ref`. Then H5LRget_region_info retrieves the path to a dataset `ref[2]` points to, its datatype and coordinates of the hyperslabs that comprise the selection within the dataset.

```
#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"
#define dsetname "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0"
……
char name[1024];
…
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);
    /*
     * Open dataset and read the dataset with the region references.
     * We made an assumption that the size of the dataset is known.
```

```
     */
    dset_id = H5Dopen(file_id, dsetname, H5P_DEFAULT);
    status = H5Dread(dset_id, H5T_STD_REF_DSETREG, H5S_ALL, H5S_ALL, H5P_DEFAULT,ref);

    /*
     * Get region reference information such as a name of the dataset the region reference
     * point to, number of contiguous blocks in the selection (should be 1) and
     * the hyperslab coordinates (0,0) - (770,4120)
     */
    status = H5LRget_region_info(file_id,
                                 (const hdset_reg_ref_t*)ref[2],
                                 &name_length,
                                 name,
                                 NULL,
                                 &dtype,
                                 NULL,
                                 &numelem,
                                 buf);
```

The following information was retrieved by the H5LRget_region_info function:

```
 Third element of the array with the region references points to   /All_Data/VIIRS-MOD-GTM-EDR-
GEO_All/Longitude
 Length of the string above is 46
 Region's datatype is H5T_IEEE_F32BE
 Number of blocks in the region is 1
 Block's coordinates are (0,0) - (770,4120)
```

Since length of the dataset name, type of the selection and number of the coordinate blocks or selected elements are generally unknown, this information must be found before allocating the read buffers accordingly as shown below. Notice the difference for allocating buffers for hyperslab and point selections.

```
 status = H5LRget_region_info(file_id,
                                 (const hdset_reg_ref_t*)ref[2],
                                 &name_length,
                                 &rank,
                                 NULL,
                                 &dtype,
                                 &sel_type,
                                 &numelem,
                                 NULL);
/* Allocate name */
name = (char *) malloc (name_length);

/* If it is a hyperslab selection buffer is twice bigger */
if (sel_type == H5S_SEL_HYPESLAB)
buf = (hsize_t *) malloc ( numelem * rank * sizeof(hsize_t) * 2 );

if (sel_type == H5S_SEL_POINTS)
buf = (hsize_t *) malloc ( numelem * rank * sizeof(hsize_t));
```

4.2.3.2 Reading data that a region reference points to using H5LRread_region

Using datatype and block coordinates retrieved by the `H5LRget_region_info` function, we now can read data that a region reference points to. The excerpt from Program 1 in the Appendix allocates a

buffer of an appropriate size and type, and reads data that a region reference points to, which is stored in ref[2] using the call to H5LRread_region.

```
   float *rdata;
   ….
   /*
    *  We  will  read  data  to  the  floating-point  buffer;  using  information  provided  by
H5LRget_region_info
    * allocate the buffer to read data in.
    */
    rdims[0] = buf[2] - buf[0] + 1;
    rdims[1] = buf[3] - buf[1] + 1;
    rdata = (float *) malloc (rdims[0] * rdims[1] * sizeof(float));

    /*
     * Read data pointed by the third region reference into a buffer and display the first six
elements.
     */
    status  =  H5LRread_region(file_id,(const  hdset_reg_ref_t*)ref[2],  H5T_NATIVE_FLOAT,  &rnumelem,
rdata);
```

We used block coordinates to calculate the number of elements to be read and allocated a buffer for reading. We assumed that we read floating-point data and therefore specified H5T_NATIVE_FLOAT to describe the rdata buffer to the HDF5 library.

Very often the type of the data to read is not known and has to be discovered by the application. As shown in the example in section 4.2.3.1.1, the H5LRget_region_info function returns the datatype of the region data as it is stored in the file, via datatype handle dtype. The HDF5 library provides functions H5Tget_native_type and H5Tget_size to find the appropriate datatype and datatype size to be used to read data back by H5TLRread_region, as shown in a code snippet below. For the complete example, see Program 2 in the Appendix.

In this example, we used the number of elements rnumelem returned by the H5LRget_region_info function and the size of the datatype to allocate a buffer of the appropriate size.

```
    char *rdata;
    /*
    * Get datatype of the data the region reference points to.
    */
    status = H5LRget_region_info(file_id, (const hdset_reg_ref_t*)ref[2], NULL, NULL, NULL, &dtype,
                                 NULL, NULL, NULL);

    /*
     * Find the corresponding type in memory and its size.
     */
    mtype = H5Tget_native_type(dtype, H5T_DIR_ASCEND);
    msize = H5Tget_size(mtype);

    /*
     * Find number of elements in the region to read.
     */
    status = H5LRread_region(file_id,(const hdset_reg_ref_t*)ref[2], mtype, &rnumelem, NULL);

    /*
     * Allocate buffer to read data in.
```

```
     */
    rdata = (char *) malloc (rnumelem * msize);
    status = H5LRread_region(file_id,(const hdset_reg_ref_t*)ref[2], mtype, NULL, rdata);
```

4.3 Creating a dataset with region and object references

In this section we will explore the functions to create datasets with region and object references using high-level functions.

4.3.1 Creating a dataset with region references

The current process of creating a dataset with the region references is very tedious: a region reference element is created one at a time using HDF5 library information such as dataset and dataspace identifiers and then is stored in an application buffer. After all references are created, the buffer is written to the dataset. The `H5LRcreate_region_references` function allows the creation of arrays of references to be done in one step. It uses a list of paths to datasets and a list of the simple hyperslab description in the corresponding datasets to create an array of region references. The simple hyperslab description is a list of corner coordinates for each **simple** hyperslab in the corresponding dataset (i.e., this function does not support point selections and arbitrary hyperslab selections). Simple hyperslabs may have different dimensionality. The function discovers the rank of each of the listed datasets and uses this information to interpret the array of corner coordinates.

A snippet from Program 3 in the Appendix shows how the `H5LRcreate_region_references` and `H5LTmake_dataset` functions are used to create a dataset with the region references. This example takes hyperslabs with the coordinates (3,51) – (7, 53) in the datatsets `SatelliteZenithAngle`, `SatelliteAzimuthAngle` and `SatelliteRange` in the group `/All_Data/VIIRS-MOD-EDR-GEO_All` in the file, creates an array of references, and saves it in the dataset Satellite under the `/All_Products` group.

```
hsize_t block_coord[12] = {3, 51, 7, 53, 3, 51, 7, 53, 3, 51, 7, 53};

….

path[0]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteZenithAngle";
path[1]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteAzimuthAngle";
path[2]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange";

/*
 * Create three region references pointing to hyperslabs with block coordinates (3,51)-(7,53) in
 * SatelliteZenithAngle, SatelliteAzimuthAngle and SatelliteRange datasets.
 */
 status = H5LRcreate_region_references(file_id, 3, path, block_coord, ref);

 /*
  * Create a dataset with the region references.
  */
 status = H5LTmake_dataset(file_id, "/Data_Products/Satellite", 1, dims, H5T_STD_REF_DSETREG,
                           (const hdset_reg_ref_t *)ref);
```

The following output results from using the h5dump command on the newly created array of references:

```
h5dump -R -d /Data_Products/Satellite <name>.h5
```

```
HDF5 "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5" {
DATASET "/Data_Products/Satellite" {
   DATATYPE  H5T_REFERENCE
   DATASPACE  SIMPLE { ( 3 ) / ( 3 ) }
   DATA {
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteZenithAngle {(3,51)-(7,53)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteAzimuthAngle {(3,51)-(7,53)},
      DATASET /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange {(3,51)-(7,53)}
   }
}
```

To create a dataset with the region references to datasets located under a group, use the `H5LRcreate_ref_to_all` function. The function iterates over all datasets under a specified group; for each dataset found, it selects the whole dataset and creates a region reference; after all references are created it writes an array of region references to a specified dataset. The same function can be used to create an array of references to objects located under a group, as shown in the next section.

4.3.2 Creating a dataset with references to datasets region or objects found under a group

Using the `H5LRcreate_ref_to_all` function one can create a dataset with the region references or object references. An NPP example file <name>.h5 contains datasets under the group `/All_Data/VIIRS-MOD-EDR-GEO_All`. The following example shows how datasets with the dataset region or object references under the /Data_Products/VIIRS-MOD-GTM_EDR-GEOgroup can be created in one step.

```
/*
 * This example shows how to create datasets with region and object references to
 * datasets located under the group /Data_Products/VIIRS-MOD-GTM-EDR-GEO
 *   Main illustrative functions: H5LRcreate_ref_to_all
 */

#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "H5LTpublic.h"
#include "h5hl_region.h"

#define GROUP "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All"
#define Dataset_Aggr "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Aggr"
#define Dataset_Gran_0 "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0"

#define filename "GMGTO_npp_raw.h5"

int main(void)
{
    hid_t file_id;  /* file identifier */
    herr_t status;
    /*
     * Open the NPP file.
     */
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);

    /*
     * Create a dataset with region references to all the datasets located under
     * /All_Data/VIIRS-MOD-GTM-EDR-GEO_All
```

```
     * Store the region references in the /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-
GEO_Gan_0
     * dataset.
     */
    status = H5LRcreate_ref_to_all(file_id, GROUP, Dataset_Gran_0, H5_INDEX_NAME, H5_ITER_INC,
                                   H5R_DATASET_REGION);
    /*
     * Create a dataset with object references to all the datasets located under
     * /All_Data/VIIRS-MOD-GTM-EDR-GEO_All
     * Store the region references in the /Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-
GEO_Aggr
     * dataset.
     */
    status = H5LRcreate_ref_to_all(file_id, GROUP, Dataset_Aggr, H5_INDEX_NAME, H5_ITER_INC,
H5R_OBJECT);
    status = H5Fclose(file_id);

}
```

The first call to the `H5LRcreate_ref_to_all` function creates the dataset `Dataset_Gran_0` (specified by the third parameter) with the region references. Region references point to the selections in the datasets found under the group `GROUP` and sorted in alphabetical order (specified by `H5_INDEX_NAME` as a value of the fourth parameter). `H5_ITER_INC` was used to specify the increasing order of iteration. As a result, the first element of the dataset `Dataset_Gran_0` references the dataset `Height`, and the last references dataset `Time`. Using H5_ITER_DEC reverses the order of the references: the first element would reference the dataset `Time` and the last would reference dataset `Height`. If the group had a property set to track the order in which the datasets were created, we could use the `H5_INDEX_CRT_ORDER` parameter to iterate over the datasets in the order they were created. Then the references in the `Dataset_Gran_0` dataset would be created in the order corresponding to the creation order of the datasets instead of the alphabetical order.

The second call to the `H5LRcreate_ref_to_all` function creates the dataset `Dataset_Aggr` with the references to the datasets found under the group `GROUP`. Once again the datasets were iterated in alphabetical order since `H5_INDEX_NAME` was specified as a value of the fourth parameter.

The original file `GMGTO_npp_raw.h5` used in the program did not contain the group VIIRS-MOD-GTM-EDR-GEO under the group `/Data_Products`. The function checks the existence of the group VIIRS-MOD-GTM-EDR-GEO, creates it if necessary, and then proceeds with the creation of the dataset with region references or references to the objects.

4.4 Combining data that a region reference points to

The function `H5LRmake_dataset` is used to combine all data that a specified region reference points to into one dataset. For example, if region references point to the highlighted regions in the datasets shown on the right in Figure 8, `H5LRmake_dataset` dataset will read each referenced region and write it to the dataset indicated as OTPUT in Figure 8. It is assumed that all regions have the same datatype, rank and dimension sizes, except for the slowest changing one.

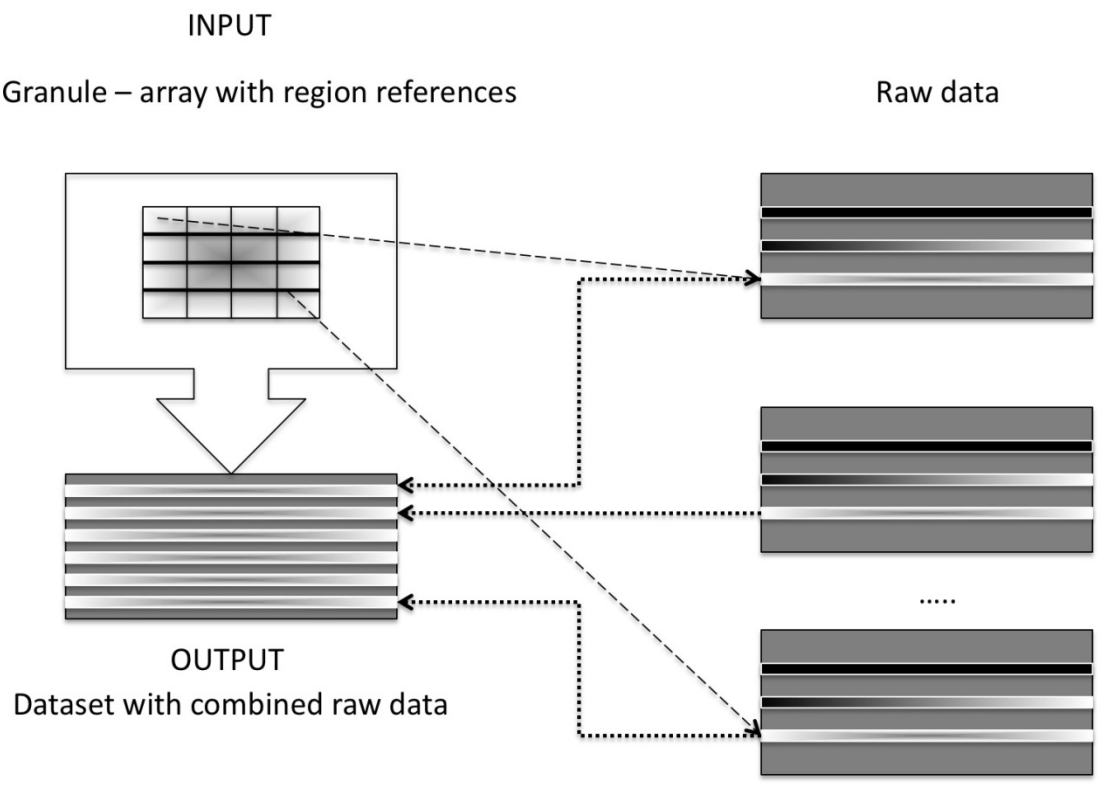


Figure 8: H5LRcreate_dataset finds data that a region reference points toand writes it to the new dataset.

The slightly artificial code shown in Program 4 in the Appendix created references to sub-arrays and then used the references to combine data in one dataset.

```
/*
 *   This example copies subregions of the satellite data SatelliteZenithAngle
 *   SatelliteAzimuthAngle and SatelliteRange under /All_Data/VIIRS-MOD-GTM-EDR-GEO_All
 *   to one dataset Satellite, located under /Data_Products/Subset of the NPP
 *   file.
 *   Main illustrative functions: H5LRcreate_region_references and H5LRmake_dataset
 */

#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "h5hl_region.h"

#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"

int main(void)
{
    hid_t file_id;  /* file identifier */
    hsize_t block_coord[12] = {3, 51, 7, 53, 3, 51, 7, 53, 3, 51, 7, 53};
    /* hyperslab coordinates, (3,51)-(7,53), for
                              SatelliteZenithAngle, SatelliteAzimuthAngle, SatelliteRange */
    hdset_reg_ref_t ref_subset[3];
    const char *path[3]; /* full paths to the satellite target datasets for the region references*/
```

```
    hid_t  file_id_array[3];  /* identifiers describing which HDF5 file the corresponding region
reference belongs to*/
    herr_t status;
    int i;

    path[0]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteZenithAngle";
    path[1]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteAzimuthAngle";
    path[2]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange";

    /*
     * Open the NPP file.
     */
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);

    /*
     * We are creating the data set in the same file, so fill the file_id path with the same file
id.
     */
    for (i = 0; i < 3; i++)
      file_id_array[i] = file_id;

    /*
     * Create three region references pointing to hyperslabs with block coordinates (3,51)-(7,53) in
     * SatelliteZenithAngle, SatelliteAzimuthAngle and SatelliteRange datasets.
     */
    status = H5LRcreate_region_references(file_id, 3, path, block_coord, ref_subset);

    /*
     * Combine the three datasets into one dataset, 'Satellite', under '/Data_Products/Subset',
     * resulting in a final dataset of size (0,0)-(14,2). Notice the group 'Subset' did not exist
     * so the function automatically created the necessary intermediate group.
     */

    status = H5LRmake_dataset(file_id, "/Data_Products/Subset/Satellite", H5T_NATIVE_FLOAT, 3,
                              file_id_array, ( const hdset_reg_ref_t *)ref_subset);

    status = H5Fclose(file_id);
}
```

Data from the datasets that belong to different files can be combined also. The fifth parameter to the function is an array of file or objects identifiers (`file_id_array`). Each element of this array describes to which HDF5 file the corresponding region reference in the array `ref_subsets` belongs. In our example, we created region references that point to the datasets in the same file, but we could create an array of the region references, as shown in the snippet below, that could point to the datasets in the different files. For example, if dataset `SatelliteRange` belongs to a file FOO.h5 with the identifier `file_id_foo`, the dataset Satellite will contain data from both files.

```
hsize_t block_coord[4] = {3, 51, 7, 53};
…..
status = H5LRcreate_region_references(file_id, 1, path[0], block_coord, ref_subset[0]);
status = H5LRcreate_region_references(file_id, 1, path[1], block_coord, ref_subset[1]);
status = H5LRcreate_region_references(file_id_foo, 1, path[2], block_coord, ref_subset[2]);
```

4.5 Reading and copying a subset of data (hyperslabs)

In section 4.2, we explored how to access data that a region reference points to by using HDFView, h5dump and H5LRread_region. In this section, we discuss how to read and copy a dataset region when its corner coordinates are known.

4.5.1 Accessing and copying a region in HDFView

When the name of the dataset and the region of interest are known, it is easy to display the data from the region using HDFView. Figure 9 (file UG-4.5.1) shows how to access hyperslab with the coordinates (3,51) – (7,53) in the dataset /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange in the file <name>.h5.

Open the file and find the dataset SatelliteRange. Then click the dataset to highlight it and right-click to display a dropdown menu. Choose the "Open As" option and enter coordinates of the hyperslab in the "Data Selection" window. The selected region appears in a TableView window. Data can be exported from HDFView and saved in a text file, as was discussed in section 4.2.1.

We can copy data in HDFView from one dataset to another. Figure 10 shows the dataset SatelliteRange_Subset under the Data_Products group. The dataset is a two-dimensional array 7x5 of floating-point numbers and was created by using HDFView with the follow steps:

1. Highlight the Data_Products group and right-click to display the dropdown menu.
2. Choose "New" and "Dataset".
3. Enter the dataset name "SateliteRange_Subset", choose the datatype class "FLOAT", and enter the current size "7x5".
4. Click OK and the newly created dataset appears under the group Data_Products.
5. Open the dataset by clicking an icon in the Tree View pane; data is all 0.
6. In the TableView window that displays the subset of the SatelliteRange dataset, select all data.
7. Go to Table in the TableView window and select "Copy".
8. Go to the StalliteRange_Subset TableView window and click the cell with the coordinates (1,1); then go to Table and choose "Paste". The data are copied to the new dataset.

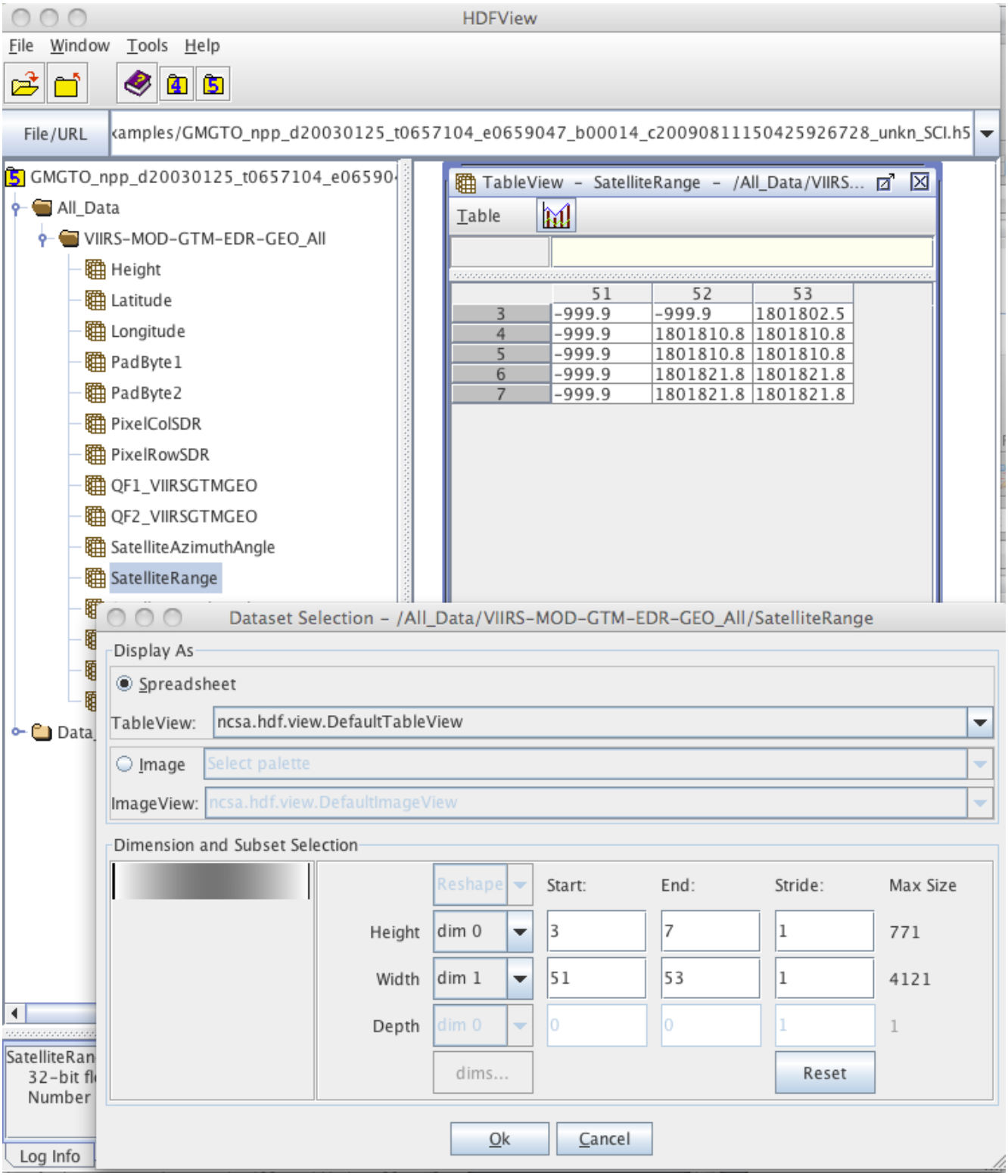


Figure 9. Selecting a region with the coordinates (3,51)-(7,53) in HDFView

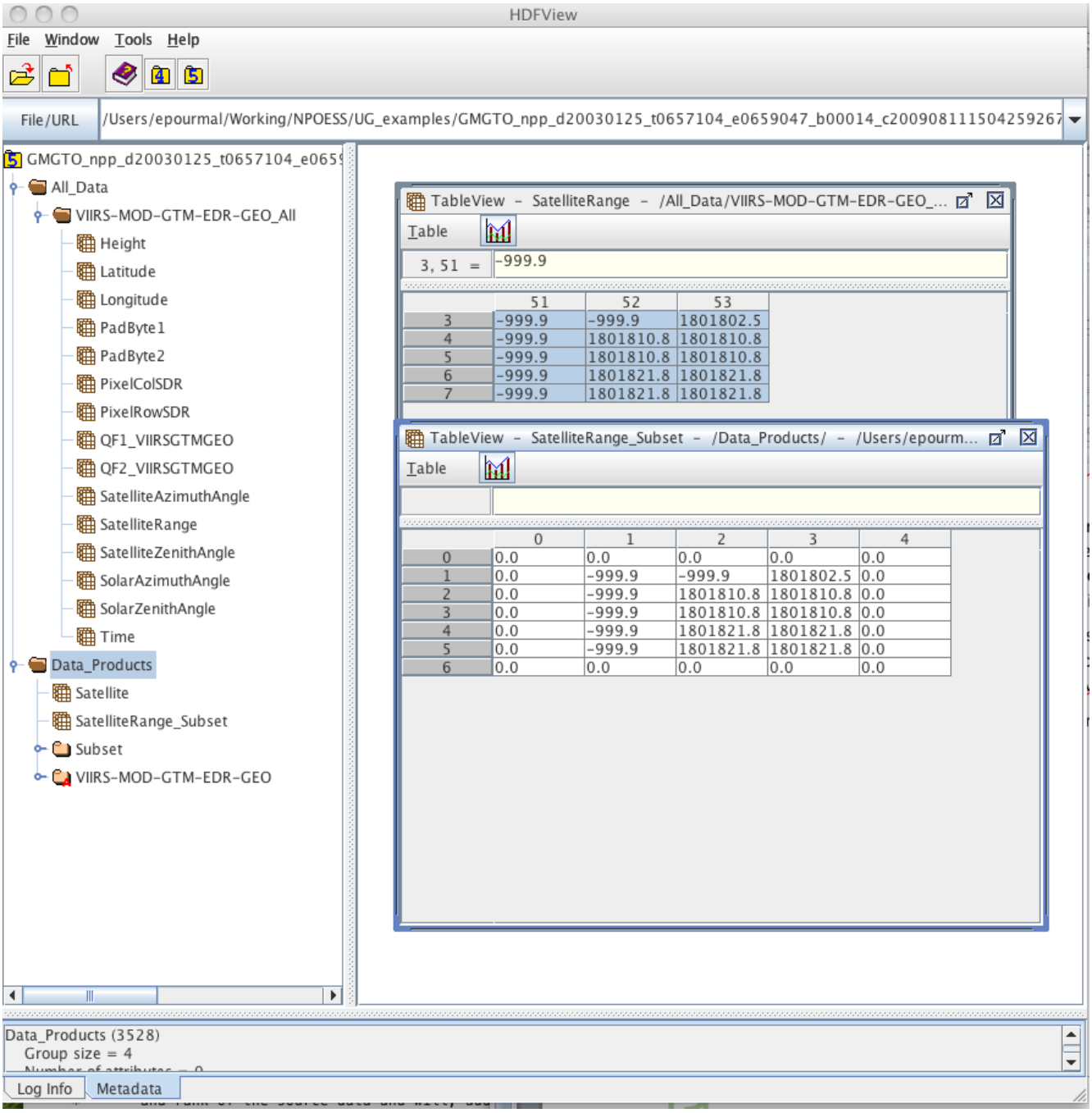


Figure 10. Copying data in HDFView

While displaying and copying small regions work well in HDFView, it is not practical for significant amounts of data. To accomplish this, it is better to export selected data to a file, and then import it to a new file starting at the specified location. Check the "Export Data to File" and "Import Data from File" options under Table in the TableView window.

Other tools like h5dump and h5import may be useful for extracting and importing data. The next section shows how a region can be displayed and exported to a file by h5dump. For importing data, see the h5import utility at http://www.hdfgroup.org/HDF5/doc/RM/Tools.html.

4.5.2 Accessing a region via h5dump

To display a region of a dataset with h5dump, use sub-setting parameters to specify the region as it is shown below.

```
./h5dump -d "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange[3,51;;5,3;]" <name>.h5

HDF5 "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5" {
DATASET "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange" {
   DATATYPE  H5T_IEEE_F32BE
   DATASPACE  SIMPLE { ( 771, 4121 ) / ( H5S_UNLIMITED, H5S_UNLIMITED ) }
   SUBSET {
      START ( 3, 51 );
      STRIDE ( 1, 1 );
      COUNT ( 5, 3 );
      BLOCK ( 1, 1 );
      DATA {
      (3,51): -999.9, -999.9, 1.8018e+06,
      (4,51):  -999.9, 1.80181e+06, 1.80181e+06,
      (5,51):  -999.9, 1.80181e+06, 1.80181e+06,
      (6,51):  -999.9, 1.80182e+06, 1.80182e+06,
      (7,51):  -999.9, 1.80182e+06, 1.80182e+06
      }
   }
}
}
```

As you may notice, the first pair in the brackets that follow the dataset name `/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange` is the starting coordinate of the hyperslab (3,51). The next pair is omitted. The third pair indicates how many elements to display in each dimension (7-3+1= 5 in the first dimension, and 53-51+1=3 in the second dimension); the fourth pair is omitted. For more information on sub-setting and sub-setting parameters see the help page for h5dump [2], HDF5 Tutorial "Introductory Topics: Reading from or Writing to a Subset of a Dataset" [1], and Chapter 7 of the HDF5 User's Guide [6].

4.5.3 Accessing and copying a region with the high-level functions H5LTread_region and H5LTcopy_region

Reading a selected region with the HDF5 APIs library requires several function calls. (See Figure 11.) The high-level function `H5LTread_region` significantly reduces the overhead for reading a simple hyperslab. The function is similar to `H5LRread_region`, but it does not use a region reference as input. It uses a path to a dataset and hyperslab corner coordinates (for example, obtained by the `H5LRget_region_info` function) to return the following:

- The number of elements in the selected region
- Data into a buffer allocated by the application

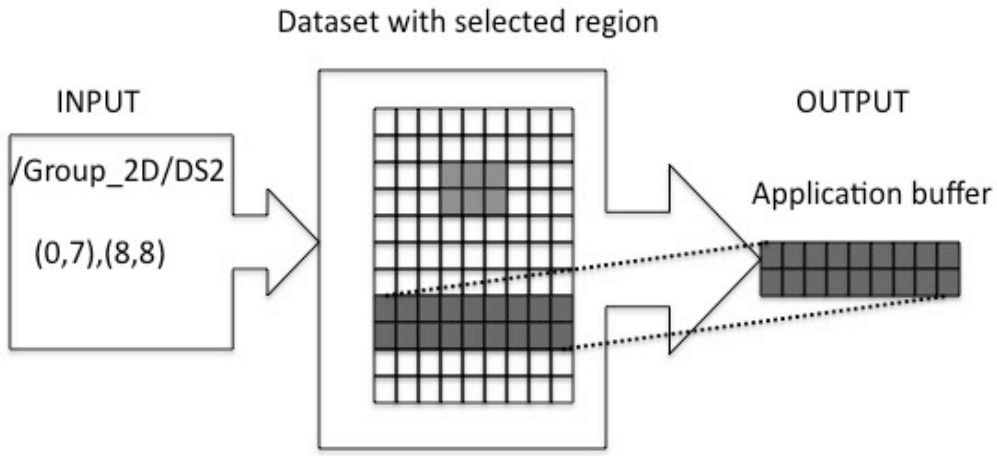


Figure 11. [Caption here.]

The snippet of code below, from Program 5 in the Appendix, shows how the function can be used to read the hyperslab selection discussed in the sub-sections 4.5.1 and 4.5.2.

```
#define PATH_DEST "/Data_Products/SatelliteRange_Subset"
….
hsize_t block_coord_dest[4] = {1, 1, 5, 3 };
….
/*
 *
 * Reads a subset region of "/Data_Products/SatelliteRange_Subset"
 * specified by coordinates (1,1)-(5,3).
 *
 */
 status = H5LTread_region(filename,PATH_DEST, block_coord_dest, H5T_NATIVE_FLOAT, rdata);
```

Output:

```
Subset of /Data_Products/SatelliteRange_Subset with coordinates (1,1)-(5,3):

  [ -999.900024 -999.900024 1801802.500000 ]
  [ -999.900024 1801810.750000 1801810.750000 ]
  [ -999.900024 1801810.750000 1801810.750000 ]
  [ -999.900024 1801821.750000 1801821.750000 ]
  [ -999.900024 1801821.750000 1801821.750000 ]
```

The function H5LTcopy_region copies data from a specified region in a source dataset to a specified region in a destination dataset. The destination dataset may be in another file, but if it does not exist, the function copies the source dataset and data from the specified region. (See Figure 12.)

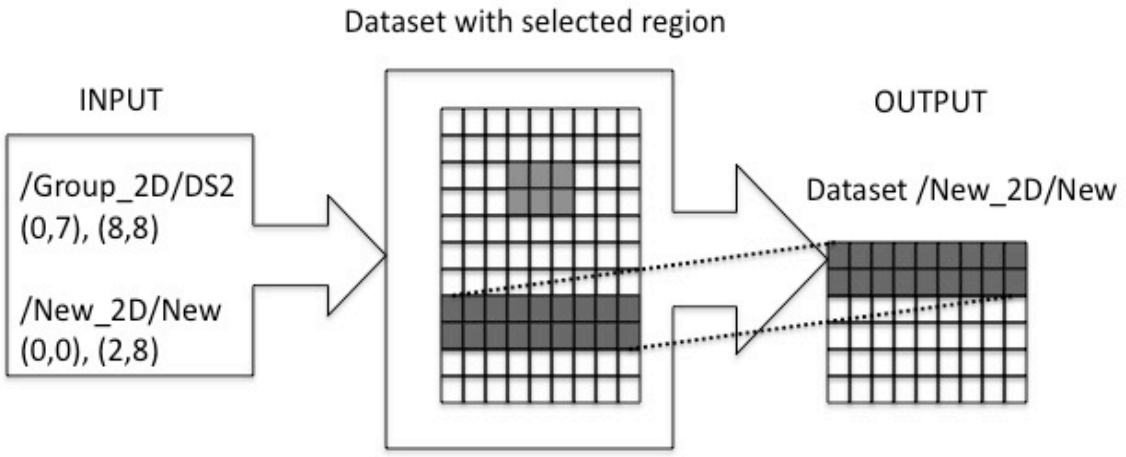


Figure 12. [Caption here.]

The code snippet below shows how the function can be used to copy region (3,51)-(7,53) in the dataset SatelliteRange to the new dataset SatelliteRange_Subset, as was done by using HDFView in section 4.5.1.

```
#define PATH_DEST "/Data_Products/SatelliteRange_Subset"
#define PATH_SRC "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange"
….
hsize_t block_coord_src[4] = {3, 51, 7, 53}; /* source's block coordinates (3,51)-(7,53) */
hsize_t block_coord_dest[4] = {1, 1, 5, 3 }; /* destination's block coordinates (1,1)-(5,3) */
….
/*
 * Copy a block of the "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange"
 * data with block corner coordinates of (3,51)-(7,53) to
 * a subset of the "/Data_Products/SatelliteRange_Subset" with hyperslab
 * coordinates (1,1)-(5,3).
 */
 status = H5LTcopy_region(filename, PATH_SRC, block_coord_src, filename, PATH_DEST,
                                                    block_coord_dest);
```

4.6 Reading data packed into integer (quality flags)

The purpose of NPOESS quality flags data is to provide quality information about data delivered on an element-by-element basis. Quality flags are stored in HDF5 datasets in an NPOESS product file. The rank and dimension sizes of a quality flags dataset are the same as the rank and dimension sizes of the product data to which quality flags are applied. The datatype of a quality flags dataset is an 8-bit unsigned integer (one byte).

To improve storage efficiency, several quality flags associated with a data product may be packed into one byte, and each quality flag may be comprised of one or more consecutive bits as shown in Figure 13 The IST quality flag takes two bits, while the “Active Fire” quality flag takes one bit. The description of the quality flags is stored in the user block of the NPOESS product file in XML form and is not interpreted by the HDF5 library.

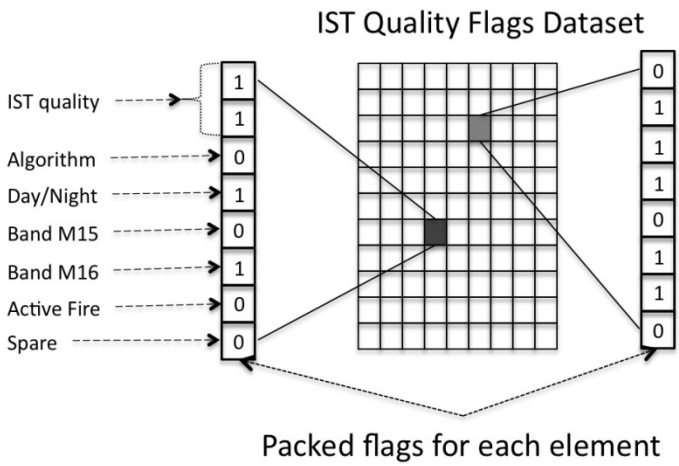


Figure 13. [Caption here.]

HDFView and h5dump were modified to display values packed in an 8-bit integer.

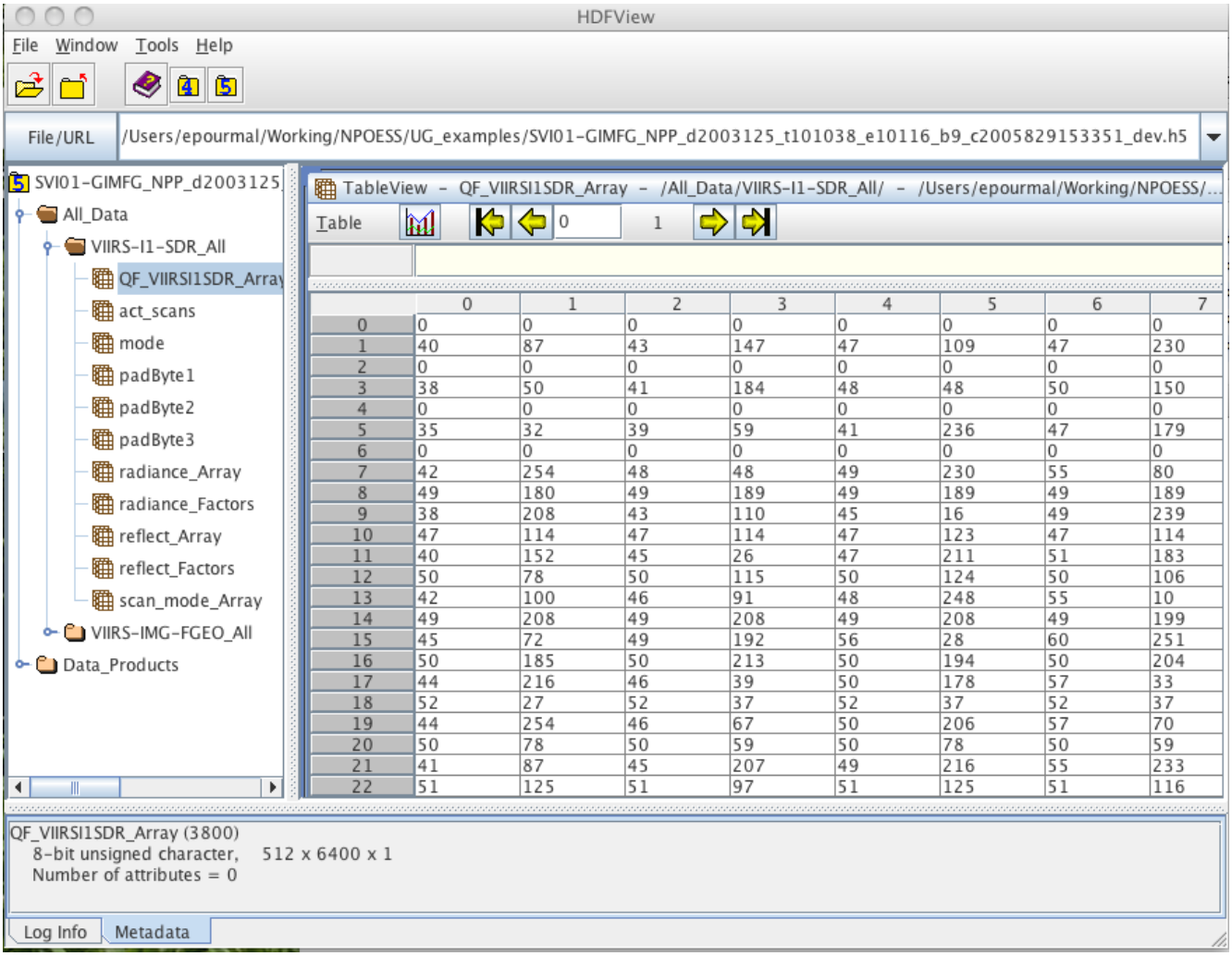
4.6.1 Displaying packed data with HDFView

Here is a section about HDFView and cross references for figures.

(See Figure 14.)

(See Figure 15.)

(See Figure 16.)



	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	40	87	43	147	47	109	47	230
2	0	0	0	0	0	0	0	0
3	38	50	41	184	48	48	50	150
4	0	0	0	0	0	0	0	0
5	35	32	39	59	41	236	47	179
6	0	0	0	0	0	0	0	0
7	42	254	48	48	49	230	55	80
8	49	180	49	189	49	189	49	189
9	38	208	43	110	45	16	49	239
10	47	114	47	114	47	123	47	114
11	40	152	45	26	47	211	51	183
12	50	78	50	115	50	124	50	106
13	42	100	46	91	48	248	55	10
14	49	208	49	208	49	208	49	199
15	45	72	49	192	56	28	60	251
16	50	185	50	213	50	194	50	204
17	44	216	46	39	50	178	57	33
18	52	27	52	37	52	37	52	37
19	44	254	46	67	50	206	57	70
20	50	78	50	59	50	78	50	59
21	41	87	45	207	49	216	55	233
22	51	125	51	97	51	125	51	116

Figure 14. Vewing the "Quality Flags" dataset in HDFView – data is displayed as an 8-bit unsigned integer (character) (file UG-4.6.1.png)

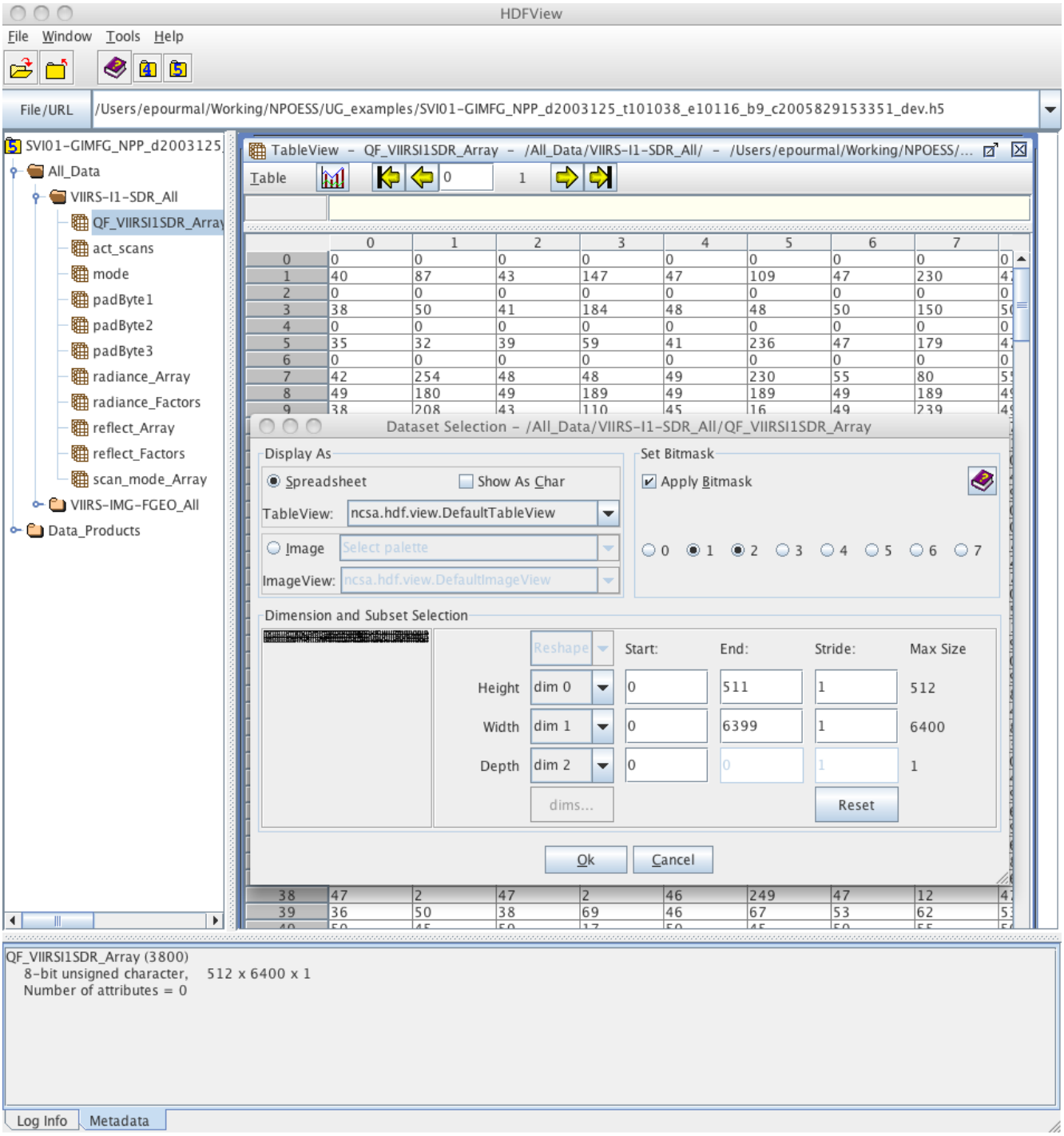


Figure 15. Extracting the second and third bits in HDFView (file UG_4.6.1.2.png)

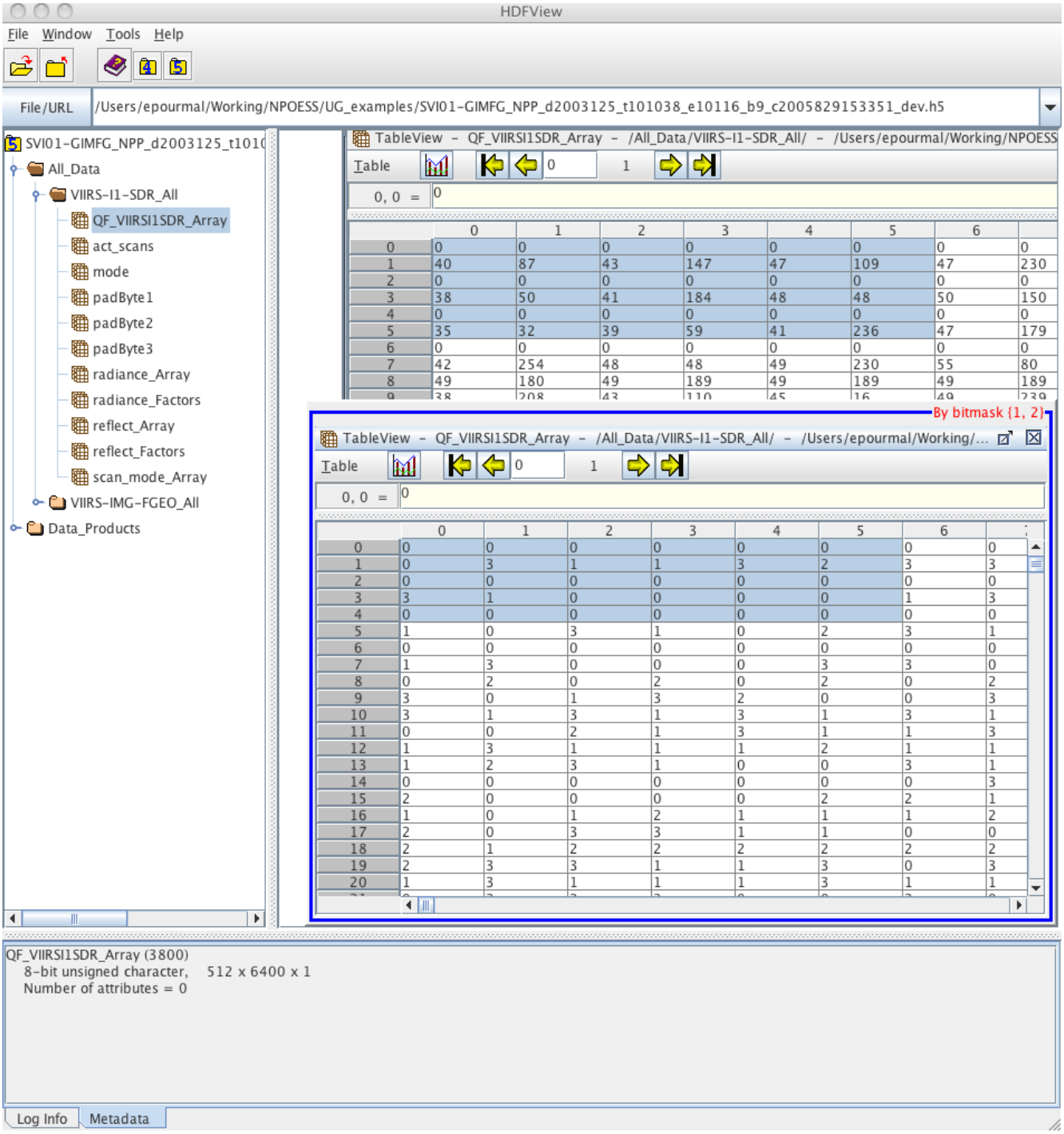


Figure 16. Displaying a number represented by the second and third bits (UG-4.6.1.3.png)

4.6.2 Displaying packed data with h5dump

The following is the output by h5dump of the highlighted data above:

```
./h5dump -d "/All_Data/VIIRS-I1-SDR_All/QF_VIIRSI1SDR_Array[0,0,0;;5,6,1;]" -M 1,2
SVI01-GIMFG_NPP_d2003125_t101038_e10116_b9_c2005829153351_dev.h5
HDF5 "SVI01-GIMFG_NPP_d2003125_t101038_e10116_b9_c2005829153351_dev.h5" {
DATASET "/All_Data/VIIRS-I1-SDR_All/QF_VIIRSI1SDR_Array" {
   DATATYPE  H5T_STD_U8LE
   DATASPACE  SIMPLE { ( 512, 6400, 1 ) / ( H5S_UNLIMITED, H5S_UNLIMITED, H5S_UNLIMITED ) }
   PACKED_BITS OFFSET=1 LENGTH=2
   SUBSET {
      START ( 0, 0, 0 );
      STRIDE ( 1, 1, 1 );
      COUNT ( 5, 6, 1 );
      BLOCK ( 1, 1, 1 );
      DATA {
      (0,0,0): 0,
      (0,1,0):  0,
      (0,2,0):  0,
      (0,3,0):  0,
      (0,4,0):  0,
      (0,5,0):  0
      (1,0,0):  0,
      (1,1,0):  3,
      (1,2,0):  1,
      (1,3,0):  1,
      (1,4,0):  3,
      (1,5,0):  2
      (2,0,0):  0,
      (2,1,0):  0,
      (2,2,0):  0,
      (2,3,0):  0,
      (2,4,0):  0,
      (2,5,0):  0
      (3,0,0):  3,
      (3,1,0):  1,
      (3,2,0):  0,
      (3,3,0):  0,
      (3,4,0):  0,
      (3,5,0):  0
      (4,0,0):  0,
      (4,1,0):  0,
      (4,2,0):  0,
      (4,3,0):  0,
      (4,4,0):  0,
      (4,5,0):  0
      }
   }
}
}
```

4.6.3 Extracting packed data with `H5LTread_bitfield_value`

The function `H5LTread_bitfield_value` extracts specified bit-field values for each element of the product dataset into a buffer provided by the application, which might be useful for any general application that extracts bit-field values from 8-bit unsigned integers (one byte) stored in HDF5 dataset.

The following snippet of code is taken from Program 6 in the Appendix:

```
qf_dset = H5Dopen (file, DATASET, H5P_DEFAULT);
  /*
   * Get dataspace and allocate memory for read buffer. Quality flags dataset
   * has the same dimensionality as corresponding product dataset;
   * we are using its dimensions for illustration purposes only.
   */
  space = H5Dget_space (qf_dset);
  status = H5Sselect_hyperslab(space, H5S_SELECT_SET, start, NULL, count, NULL);
  /*
   * For each element read the value that takes first two bits and
   * store it in a char buffer. This selects all the elements (H5S_ALL)
   */
  status = H5LTread_bitfield_value(qf_dset, num_flags, offset, length, space, (int *)qf_data);


Bit Field:
 [ 0  0  0  0  0  0 ]
 [ 0  3  1  1  3  2 ]
 [ 0  0  0  0  0  0 ]
 [ 3  1  0  0  0  0 ]
 [ 0  0  0  0  0  0 ]
```

Appendix

Program 1 (section 4.2.3)

```
/*
 *  This example opens an NPP file and reads a dataset with region references
 *  VIIRS-MOD_GTM-EDR-GEO_Gran_0 under the /Data_Products/VIIRS-MOD-GTM-EDR-GEO group.
 *  Then it finds information about the selected elements pointed by the third reference
 *  and reads the data in.
 *  Main illustrative functions: H5LRget_region_info, H5LRread_region
 */
#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "H5LTpublic.h"
#include "h5hl_region.h"

#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"
#define dsetname "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0"


int main(void)
{
    hid_t file_id; /* file identifier */
    hid_t dset_id; /* region reference dataset identifier */
    hsize_t dims[1] =  {15}; /* size of the VIIRS-MOD_GTM-EDR-GEO_Gran_0 dataset */
    hdset_reg_ref_t ref[15]; /* array to read region references */
    hsize_t buf[4]; /* buffer to read hyperslab coordinates defining region references */
    herr_t status;
    size_t name_length = {1024};
    char name[1024];
    hid_t dtype;
    size_t numelem;
    char type_string[15];
    size_t type_string_length = {15};
    hsize_t rdims[2];
    float *rdata;
    size_t rnumelem;
    int i;


    /*
     * Open the NPP file.
     */
```

```
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);
    /*
     * Open dataset and read the dataset with the region references.
     * We made an assumption that the size of the dataset is known.
     */
    dset_id = H5Dopen(file_id, dsetname, H5P_DEFAULT);
    status = H5Dread(dset_id, H5T_STD_REF_DSETREG, H5S_ALL, H5S_ALL, H5P_DEFAULT,ref);

    /*
     * Get region reference information such as a name of the dataset the region reference point to,
     *  number of contiguous blocks in the selection (should be 1) and the hyperslab coordinates (0,0) -
(770,4120)
     */
    status = H5LRget_region_info(file_id, (const hdset_reg_ref_t*)ref[2], &name_length, name, NULL, &dtype,
                                 NULL, &numelem, buf);

    /*
     * Display the info
     */
    H5LTdtype_to_text(dtype, type_string, H5LT_DDL, &type_string_length);
    printf(" Information retrieved by H5LRget_region_info: \n");
    printf(" Third element of the array with the region references points to  %s \n", name);
    printf(" Length of the string above is %d \n", (int)name_length);
    printf(" Region's datatype is %s \n", type_string);
    printf(" Number of blocks in the region is %d \n", (int)numelem);
    printf(" Block's coordinates are (%d,%d) - (%d,%d) \n", (int)buf[0],(int)buf[1],(int)buf[2],(int)buf[3]);
    printf("\n");

    /*
     * We will read data to the floating-point buffer; using information provided by H5LRget_region_info
     * allocate the buffer to read data in.
     */
    rdims[0] = buf[2] - buf[0] + 1;
    rdims[1] = buf[3] - buf[1] + 1;
    rdata = (float *) malloc (rdims[0] * rdims[1] * sizeof(int));

    /*
     * Read data pointed by the third region reference into a buffer and display the first six elements.
     */
    status = H5LRread_region(file_id,(const hdset_reg_ref_t*)ref[2], H5T_NATIVE_FLOAT, &rnumelem, rdata);
    printf(" Information retrieved by H5LRread_region: \n");
    printf(" Number of elements pointed by a region reference is %ld \n", rnumelem);
    printf(" The first six elements are: \n");
    for (i=0; i<6; i++) printf(" %7.3f ", rdata[i]);
    printf("\n");
    free(rdata);

    /*
     * Close dataset with region references and file.
     */
    status = H5Dclose(dset_id);
    status = H5Fclose(file_id);

    return 0;
}
Output:
 Information retrieved by H5LRget_region_info:
 Third element of the array with the region references points to  /All_Data/VIIRS-MOD-GTM-EDR-GEO_All/Longitude
 Length of the string above is 46
 Region's datatype is H5T_IEEE_F32BE
 Number of blocks in the region is 1
 Block's coordinates are (0,0) - (770,4120)

 Information retrieved by H5LRread_region:
 Number of elements pointed by a region reference is 3177291
 The first six elements are:
 115.307  115.300  115.294  115.287  115.280  115.274
```

Program 2 (section 4.2.3)

```
/*
 *   This example opens an NPP example file and reads a dataset with region references
 *   VIIRS-MOD_GTM-EDR-GEO_Gran_0 under the /Data_Products/VIIRS-MOD-GTM-EDR-GEO group.
 *   Then it finds information about the selected elements pointed by the third reference
 *   and reads the data in.
 *   Main illustrative functions: H5LRget_region_info, H5LRread_region
 */
#include <stdlib.h>
#include <string.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "H5LTpublic.h"
#include "h5hl_region.h"

#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"
#define dsetname "/Data_Products/VIIRS-MOD-GTM-EDR-GEO/VIIRS-MOD-GTM-EDR-GEO_Gran_0"

int main(void)
{
    hid_t file_id; /* file identifier */
    hid_t dset_id; /* region reference dataset identifier */
    hdset_reg_ref_t ref[15]; /* array to read region references */
    herr_t status;
    hid_t dtype; /* file datatype handle */
    hid_t mtype; /* mempry datatype handle */
    size_t msize; /* size of memory datatype */
    size_t rnumelem; /* number of elements to read */
    char *rdata; /* pointer to read buffer */
    int i;

    /*
     * Open the NPP file.
     */
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);
    /*
     * Open dataset and read the dataset with the region references.
     * We made an assumption that the size of the dataset is known.
     */
    dset_id = H5Dopen(file_id, dsetname, H5P_DEFAULT);
    status = H5Dread(dset_id, H5T_STD_REF_DSETREG, H5S_ALL, H5S_ALL, H5P_DEFAULT,ref);

    /*
     * Get datatype of the data the region reference points to.
     */
    status = H5LRget_region_info(file_id, (const hdset_reg_ref_t*)ref[2], NULL, NULL, NULL, &dtype,
                                 NULL, NULL, NULL);

    /*
     * Find the corresponding type in memory and its size.
     */
    mtype = H5Tget_native_type(dtype, H5T_DIR_ASCEND);
    msize = H5Tget_size(mtype);

    /*
     * Find number of elements in the region to read.
     */
    status = H5LRread_region(file_id,(const hdset_reg_ref_t*)ref[2], mtype, &rnumelem, NULL);

    /*
     * Allocate buffer to read data in.
     */
    rdata = (char *) malloc (rnumelem * msize);
    status = H5LRread_region(file_id,(const hdset_reg_ref_t*)ref[2], mtype, NULL, rdata);

    /*
     * We need to discover an appropriate C type to print data
     */
    if ((H5T_FLOAT == H5Tget_class(mtype)) & (sizeof(float) == msize)) {
        float tmp; /* temporary variables */
        char *tmp_p;
```

```
        printf(" Number of elements pointed by a region reference is %ld \n", rnumelem);
        printf(" The first six elements are: \n");
        tmp_p = rdata;
        for (i=0; i<6; i++) {
           memcpy (&tmp, tmp_p, msize);
           printf(" %7.3f ", tmp);
           tmp_p = tmp_p + msize;
        }
        printf("\n");
    }
    free(rdata);

    /*
     * Close dataset with region references and file.
     */
    status = H5Dclose(dset_id);
    status = H5Fclose(file_id);

    return 0;
}
Output:
 Number of elements pointed by a region reference is 3177291
 The first six elements are:
 115.307  115.300  115.294  115.287  115.280  115.274
```

Program 3 (section 4.3.1)

```
/*
 *   This example creates region refernces to the selections in the 'SatelliteZenithAngle'
 *   'SatelliteAzimuthAngle' and 'SatelliteRange' datsets under '/All_Data/VIIRS-MOD-GTM-EDR-GEO_All'
 *   and writes it to the 'Satellite' dataset located in the  '/Data_Products' group.
 *   Main illustrative functions: H5LRcreate_region_references
 */

#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "H5LTpublic.h"
#include "h5hl_region.h"

#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"

int main(void)
{
    hid_t file_id;  /* file identifier */
    /* hyperslab coordinates, (3,51)-(7,53) in each of the 'SatelliteZenithAngle', 'SatelliteAzimuthAngle',
      'SatelliteRange' datsets */
    hsize_t block_coord[12] = {3, 51, 7, 53, 3, 51, 7, 53, 3, 51, 7, 53};
    hdset_reg_ref_t ref[3];
    const char *path[3]; /* full paths to the satellite target datasets for the region references*/
    hsize_t dims[1] = {3};
    herr_t status;

    path[0]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteZenithAngle";
    path[1]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteAzimuthAngle";
    path[2]= "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange";

    /*
     * Open the NPP file.
     */
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);


    /*
     * Create three region references pointing to hyperslabs with block coordinates (3,51)-(7,53) in
     * 'SatelliteZenithAngle', 'SatelliteAzimuthAngle' and 'SatelliteRange' datasets.
     */
    status = H5LRcreate_region_references(file_id, 3, path, block_coord, ref);
```

```
    /*
     * Create a dataset with the region references.
     */

    status  =  H5LTmake_dataset(file_id,  "/Data_Products/Satellite",  1,  dims,  H5T_STD_REF_DSETREG,  (  const
hdset_reg_ref_t *)ref);

    status = H5Fclose(file_id);

}
```

Program 5 (section 4.5.3)

```
/*
 *   This example copies a hyperslab region of 'SatelliteRange' under
 *   '/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/' to another hyperslab region
 *   '/SatelliteRange_Subset' under '/All_Data'. It then reads back
 *   the newly created hyperslab region.
 *    Main illustrative functions: H5LTread_region, H5LTcopy_region
*/
#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "h5hl_region.h"

#define filename "GMGTO_npp_d20030125_t0657104_e0659047_b00014_c20090811150425926728_unkn_SCI.h5"

#define PATH_DEST "/Data_Products/SatelliteRange_Subset" /* Full path of the source dataset */
#define PATH_SRC "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange" /* Full path to the destination dataset */

#define NRANK 2 /* rank of source and destination dataset */

int main(void)
{
    hid_t file_id;                              /* file identifier */
    hid_t dset_id;                              /* dataset identifier */
    hid_t space_id;                             /* dataspace identifier */
    hsize_t block_coord_src[4] = {3, 51, 7, 53}; /* source's block coordinates (3,51)-(7,53) */
    hsize_t block_coord_dest[4] = {1, 1, 5, 3 }; /* destination's block coordinates (1,1)-(5,3) */
    hsize_t dims[NRANK] = {7,5};                /* receiving dataset dimensions */
    float rdata[5][3];                          /* buffer to read destination data into */
    int i,j;
    herr_t status;
    /*
     * Open the NPP file.
     */
    file_id = H5Fopen(filename, H5F_ACC_RDWR, H5P_DEFAULT);

    /*
     * First create the destination dataset "SatelliteRange_Subset" since it does not exist.
     *
     * NOTE: If the destination dataset does not already exist then H5LTcopy_region
     *       will automatically create a destination dataset that is the same size
     *       and rank of the source data and will, additionally, fill the destination
     *       block starting at (0,0); thus ignoring the destination's block coordinates.
     */
    space_id = H5Screate_simple(NRANK, dims, NULL);
    dset_id = H5Dcreate2(file_id, PATH_DEST, H5T_NATIVE_FLOAT, space_id, H5P_DEFAULT, H5P_DEFAULT, H5P_DEFAULT);
    status = H5Sclose(space_id);
    status = H5Fclose(file_id);

    /*
     * Copy a block of the "/All_Data/VIIRS-MOD-GTM-EDR-GEO_All/SatelliteRange"
     * data with block corner coordinates of (3,51)-(7,53) to
     * a subset of the "/Data_Products/SatelliteRange_Subset" with hyperslab
     * coordinates (1,1)-(5,3).
     *
     */
    status = H5LTcopy_region(filename, PATH_SRC, block_coord_src, filename, PATH_DEST,
```

```
                            block_coord_dest);

    /*
     *
     * Reads a subset region of "/Data_Products/SatelliteRange_Subset"
     * specified by coordinates (1,1)-(5,3).
     *
     */
    status = H5LTread_region(filename, PATH_DEST, block_coord_dest, H5T_NATIVE_FLOAT,
                            rdata);

    printf("Subset of /Data_Products/SatelliteRange_Subset with coordinates ");
    printf("(%d,%d)-(%d,%d):\n",(int)block_coord_dest[0],(int)block_coord_dest[1],
           (int)block_coord_dest[2],(int)block_coord_dest[3]);

    for (i=0; i< 5; i++)
      {
        printf("\n  [ ");
        for (j=0; j< 3; j++) {
          printf("%f ", rdata[i][j]);
        }
        printf("]");
      }
    printf("\n");

    return 0;
}
```

Program 6 (section 4.6.3)

```
/*
 * This example opens a file, and extracts
 * the bit field from a subset of a dataset.
 * The values are returned as a base-10 integer.
 * Main illustrative function: H5LTread_bitfield_value
 */

#include <stdlib.h>
#include "hdf5.h"
#include "hdf5_hl.h"
#include "h5hl_region.h"

#define FILENAME "SVI01-GIMFG_NPP_d2003125_t101038_e10116_b9_c2005829153351_dev.h5"
#define DATASET "/All_Data/VIIRS-I1-SDR_All/QF_VIIRSI1SDR_Array"
#define num_flags 1

int main(void)
{
  int qf_data[5][6][1];  /* Read buffer */
  unsigned int offset[1] = {1};  /* Starting bits to be extracted from element */
  unsigned int length[1] = {2};  /* Number of bits to be extracted for each value */
  hid_t file, space; /* Handles */
  hid_t qf_dset;
  herr_t status;
  hsize_t start[3] =  {0,0,0};
  hsize_t count[3] =  {5,6,1};
  int i, j;

  /*
   * Open file.
   */
  file = H5Fopen (FILENAME, H5F_ACC_RDONLY, H5P_DEFAULT);
  /*
   * Open the data set
   */
  qf_dset = H5Dopen (file, DATASET, H5P_DEFAULT);
  /*
   * Get dataspace and allocate memory for read buffer. Quality flags dataset
   * has the same dimensionality as corresponding product dataset;
```

```
   * we are using its dimensions for illustration purposes only.
   */
  space = H5Dget_space (qf_dset);
  status = H5Sselect_hyperslab(space, H5S_SELECT_SET, start, NULL, count, NULL);
  /*
   * For each element read the value that takes first two bits and
   * store it in a char buffer. This selects all the elements (H5S_ALL)
   */
  status = H5LTread_bitfield_value(qf_dset, num_flags, offset, length, space, (int *)qf_data);
  status = H5Sclose (space);

  /* Print out the bit field */
  printf("Bit Field:\n");
  for (i = 0; i<5; i++) {
    printf (" [");
    for (j = 0; j<6; j++) {
        printf(" %d ", qf_data[i][j][0]);
    }
    printf("]\n");
  }

  return 0;

}
```

References

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