NASA SDS Product Specification

Level-1 Range Doppler Pixel Offsets

L1_ROFF

Rev -

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Preliminary	March 04, 2022	All	N/A	New document
Working version (R3.1)	August 05, 2022	Front page, Sec. 2.1	N/A	Changed NISAR ADT Lead; Updated product dependency figure
Working version (R3.1)	August 05, 2022	Cover. TBD, TBC tables, Acronym List	N/A	Requested fixes. LRR067555
Working version (R3.2)	January 27, 2023	All	N/A	Revised for R3.2 release
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Initial (R3.4)	November 9, 2023	Cover page, Sec. 1.3, Sec. 2.2, Sec. 3.2.2, Sec 5.2, 5.3, 5.4, 5.6	N/A	Modified date on cover page and updated document revision; Updated reference to RSLC product specification and NISAR SDS filename convention document; Deleted reference and link to EPDM; Added reference to NISAR SDS ATBD; Modified Table 3.4 to reflect information in product XML specifications. Sec 5.2 Identification. Sec 5.3 FillValue. Sec 5.4 Processing Information. Sec 5.6 Geolocation Grid.

* *Include the JPL Limited Release System (LRS) clearance number for each revision to be shared with foreign partners.*

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1 INTRODUCTION

1.1 Purpose of Description

This document provides a specification of the NASA-ISRO Synthetic Aperture Radar (NISAR) L-SAR L1 Range Doppler Pixel Offsets product to be generated by the NASA Science Data System (SDS) and provided to the Distributed Active Archive Center (DAAC). This data product is referenced by the short name L1_ROFF.

1.2 Document Organization

Section 2 provides an overview of the product, including its purpose, and latency.

Section 3 provides the structure of the product, including granule definition, file organization, spatial resolution, temporal and spatial organization of the content, the size, and data volume.

Section 4 provides qualitative descriptions of the information provided in the product.

Section 5 provides a detailed identification of the individual fields within the L1_ROFF product, including for example their units, size, and coordinates.

Section 6 provides a description of the metadata cube representation.

Appendix A provides a listing of the acronyms used in this document.

1.3 Applicable and Reference Documents

Applicable documents levy requirements on areas addressed in this document. Reference documents are cited to provide additional information to readers. In case of conflict between the applicable documents and this document, the Project shall review the conflict to find the most effective resolution.

Applicable Documents

[AD1] NISAR NASA SDS Level 4 Requirements, JPL D-95655, Initial, Sep. 13, 2019
[AD2] NISAR NASA SDS Algorithm Development Plan, JPL D-95678, Initial, Sep. 12, 2019
[AD3] NISAR Science Data Management and Archive Plan, JPL D-80828, June 1, 2016
[AD4] NISAR Science Management Plan, JPL D-76340, Rev A, Aug. 14, 2018
[AD5] NISAR Calibration and Validation Plan, JPL D-102256, September. 2019
[AD6] NISAR NASA SDS L4 Software Management Plan (SMP), JPL D-95656, Rev A, Sep. 19, 2019
[AD7] ISO-19115-2, https://www.iso.org/obp/ui/#iso:std:iso:19115:-2:ed-2:v1:en

Reference Documents

[RD1] NISAR NASA SDS Algorithm Theoretical Basis Document, JPL D-95677, Initial, Feb. 06, 2022.

[RD2] EOSDIS Handbook, July 2016, retrieved from https://cdn.earthdata.nasa.gov/conduit/upload/5980/EOSDISHandbookWebFinaL2.pdf

[RD3] NISAR SDS File Naming Conventions, JPL D-102255, Rev A, Apr. 28, 2023.

[RD4] NISAR L1_RSLC Product Specification Document, JPL D-102268, R3.4, Oct. 23, 2023.

[RD5] HDF5 documentation at https://portal.hdfgroup.org/display/HDF5/HDF5

[RD6] Eineder, M. (2003), Efficient simulation of SAR interferograms of large areas and of rugged terrain, IEEE Transactions on Geoscience and Remote Sensing, 41(6), 1415-1427.

The NISAR Level 1 science requirements are translated into requirements on the various spacecraft and instrument systems, including the requirements related to the processing system producing the L0-L2 products. These SDS requirements [AD1] fall into three general categories: resolution requirements, radiometric and spatial location accuracy requirements, and latency and throughput requirements.

2 PRODUCT OVERVIEW

2.1 Product Background

Each NASA SDS L0B-L2 LSAR product (Figure 2-1 and Table 2-1 Product Dependency) is distributed as a single Hierarchical Data Format version 5 (HDF5) [RD5] granule. All the metadata and imagery data are packaged in clearly defined sub-groups within the granule in compliance with the HDF5 specification. The NISAR product level definitions are given in **Error! Reference source not found.**.

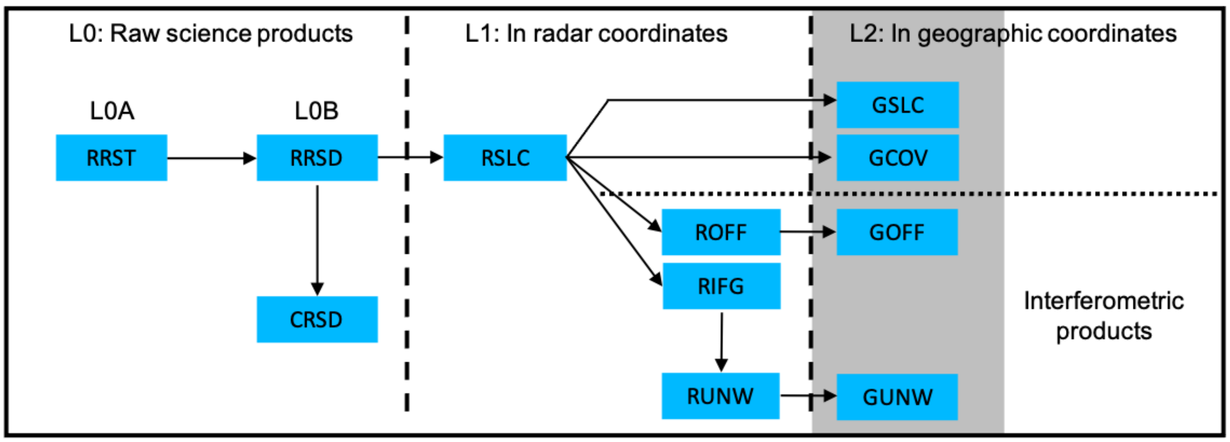

Figure 2-1 Product Dependency

Table 2-1. Key to Product Dependency Diagram

Product	Scope	Description	Granule Size
Radar Raw Science Telemetry (RRST)	Global	This L0A product is the raw downlinked data delivered to SDS	By downlinked files
Radar Raw Signal Data (RRSD)	Global	This L0B product is corrected, aligned radar pulse data derived from the RRST products and used for further processing	By radar observation, i.e., continuous data collected in a single radar mode
Calibration Raw Signal Data (CRSD)	Global	This L0B product contains instrument calibration data.	By radar data take, i.e., a sequence of observations for one radar-on period

Product	Scope	Description	Granule Size
Range-Doppler Single Look Complex (RSLC)	Global	Used to generate all higher-level products	On pre-defined track/frame. High-resolution modes will have a high-res RSLC product and a background resolution RSLC product
Range-Doppler Nearest-Time Interferogram (RIFG)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Multi-looked interferogram in Range Doppler coordinates with geometrical phase (including topographic phase) removed and formed using high-resolution dense pixel offsets.	On pre-defined track/frame
Range-Doppler Nearest-Time Pixel Offsets (ROFF)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Unfiltered and unculled layers of pixel offsets in Range Doppler coordinates with different resolutions obtained from incoherent speckle tracking.	On pre-defined track/frame
Range-Doppler Nearest-Time Unwrapped Interferogram (RUNW)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Multi-looked, unwrapped differential interferogram in Range Doppler coordinates with geometrical phase (including topographic phase) removed.	On pre-defined track/frame

Product	Scope	Description	Granule Size
Geocoded SLC (GSLC)	Global and all channels.	Geocoded version of RSLC product using the MOE state vectors and a DEM.	On pre-defined track/frame
Geocoded Nearest-Time Pixel Offsets (GOFF)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Geocoded version of ROFF product using the MOE state vectors and a DEM.	On pre-defined track/frame

Product	Scope	Description	Granule Size
Geocoded Nearest-Time Unwrapped Interferogram (GUNW)	Global. Nearest pair in time and co-pol channels only.	Geocoded, multi-looked unwrapped differential interferogram with geometrical phase (including topographic phase) removed. It contains a geocoded version of the wrapped interferogram and normalized interferometric correlation at a finer posting.	On pre-defined track/frame
Geocoded Polarimetric Covariance Matrix (GCOV)	Global and all channels. Single/Dual/Quad pol.	Geocoded, multi-looked polarimetric covariance matrix.	On pre-defined track/frame

Table 2-2 NISAR Data Level Descriptions defined by Science.

Data Level	Description
Level 0A	Unprocessed instrument data with communications artifacts removed, but without conditioning to reconstructed and reordered to represent the time-ordered sequence of samples from the instrument. May still contain bit errors and missing data that needs reconstruction.
Level 0B	Reconstructed, unprocessed instrument data at original resolution, time ordered, all communications artifacts removed.
Level 1	Processed instrument data, focused to full resolution complex images, time referenced and annotated with ancillary information, including radiometric and relevant geometric calibration coefficients and georeferencing parameters (i.e. platform ephemeris) computed and appended, in natural radar coordinates.
Level 2 Category 1	Derived radar-specific parameters at the same or reduced resolution as Level 1 imagery, but resampled and geocoded to a geographic or ellipsoidal grid.
Level 2 Category 2	Derived radar-specific parameters at reduced resolution, in original Level 1 coordinates.
Level 3	Geophysical parameters derived from Level 1 or 2 data that have been spatially and/or temporally re-sampled to a global grid.

2.2 L1_ROFF Overview

The L1_ROFF product contains a collection of dense pixel offsets layers obtained from applying incoherent speckle tracking on a pair of coarsely coregistered L1_RSLC products in the Range Doppler geometry of the earlier (i.e., “reference”) L1_RSLC product. The pair of L1_RSLC used to produce L1_ROFF is first coarsely aligned with geometrical coregistration using the best available orbit ephemeris and a Digital Elevation Model (DEM) [RD1].

The spacing, the window size, and the search radius used to generate L1_ROFF offsets layers for L-SAR data are summarized in Table 2-3 to Table 2-6 and organized by sensor mode (e.g., 40 MHz single-pol) and area of observation (i.e., ice sheets or mountain glaciers). It is assumed that pixel offsets layers within a L1_ROFF share the same spacing and the same starting pixel along slant range and azimuth directions. Each pixel offset layer is distributed without performing any conventional post-processing operation i.e., layers might contain offset outliers, and are not low pass filtered to reduce noise in the data [RD1].

The L1_ROFF product is primarily meant for cryosphere applications, and it is only generated for LSAR acquisitions over Antarctica, Greenland, and selected mountain glaciers.

Table 2-3. Pixel offset layers: 80 MHz, Antarctica, and Greenland.

Layer**	Range Bandwidth (MHz)	Sample spacing in slant range (pixels)	Sample spacing in along-track (pixels)	Window size in slant-range (pixels)	Window size in along-track (pixels)	Search radius in slant range (pixels)	Search radius in along-track (pixels)
IL1_80IS	80	30	15	64	32	64	33
IL2_80IS	80	30	15	96	64	64	33
IL3_80IS	80	30	15	196	128	8	8

IL stands for incoherent speckle tracking layer

Table 2-4. Pixel offset layers: 40 MHz, Antarctica, and Greenland.

Layer*	Range Bandwidth (MHz)	Sample spacing in slant range (pixels)	Sample spacing in along-track (pixels)	Window size in slant range(pixels)	Window size in along-track (pixels)	Search radius in slant range (pixels)	Search radius in along-track (pixels)
IL1_40IS	40	15	15	32	32	8	8
IL2_40IS	40	15	15	64	64	8	8
IL3_40IS	40	15	15	128	128	8	8

IL stands for incoherent speckle tracking layer

Table 2-5. Pixel offset layers: 20 MHz, mountain glaciers.

Layer**	Range Bandwidth (MHz)	Sample spacing in slant range (pixels)	Sample spacing along-track (pixels)	Window size in slant range (pixels)	Window size in along-track (pixels)	Search radius in slant range (pixels)	Search radius in along-track (pixels)
IL1_20MG	20	8	15	32	32	16	32
IL2_20MG	20	8	15	32	64	16	32
IL3_20MG	20	8	15	64	128	16	32

IL stands for incoherent speckle tracking layer

Table 2-6. Pixel offset layers: 40 MHz, mountain glaciers.

Layer**	Range Bandwidth (MHz)	Sample spacing in slant range (pixels)	Sample spacing along-track (pixels)	Window size in slant range (pixels)	Window size in along-track (pixels)	Search radius in slant range (pixels)	Search radius in along-track (pixels)
IL1_40MG	40	15	15	32	32	32	32
IL2_40MG	40	15	15	64	64	32	32
IL3_40MG	40	15	15	128	128	32	32

IL stands for incoherent speckle tracking layer

The structure of the L1_ROFF product is described in Section 4. The details of the data elements are given in Section 5. Metadata cubes are discussed in Section 6.

3 PRODUCT ORGANIZATION

3.1 File Format

All NISAR standard products are in the Hierarchical Data Format version 5 (HDF5 [RD5]). HDF5 is a general-purpose file format and programming library for storing scientific data. The National Center for Supercomputing Applications (NCSA) at the University of Illinois developed HDF to help scientists share data more easily. Use of the HDF library enables users to read HDF files regardless of the underlying computing environments. HDF files are equally accessible in Fortran, C/C++, and other high-level computation packages such as IDL, MATLAB or Python.

The HDF Group, a spin-off organization of the NCSA, is responsible for development and maintenance of HDF. Users should reference The HDF Group website at https://portal.hdfgroup.org/display/HDF5/HDF5 [RD5] to download HDF software and documentation.

HDF5 represents a significant departure from the conventions of previous versions of HDF. The changes that appear in HDF5 provide flexibility to overcome many of the limitations of previous releases. The basic building blocks have been largely redefined and are more powerful but less numerous. The key concepts of the HDF5 Abstract Data Model are Files, Groups, Datasets, Datatypes, Attributes and Property Lists. The following sections provide a brief description of each of these key HDF5 concepts.

3.1.1 HDF5 File

A File is the abstract representation of a physical data file. Files are containers for HDF5 Objects. These Objects include Groups, Datasets, and Datatypes.

3.1.2 HDF5 Group

Groups provide a means to organize the HDF5 Objects in HDF5 Files. Groups are containers for other Objects, including Datasets, named Datatypes and other Groups. In that sense, groups are analogous to directories that are used to categorize and classify files in standard operating systems.

The notation for files is identical to the notation used for Unix directories. The root Group is “/”. A Group contained in root might be called “/myGroup.” Like Unix directories, Objects appear in Groups through “links”. Thus, the same Object can simultaneously be in multiple Groups.

3.1.3 HDF5 Dataset

The Dataset is the HDF5 component that stores user data. Each Dataset associates with a Dataspace that describes the data dimensions, as well as a Datatype that describes the basic unit of storage element. A Dataset can also have Attributes.

3.1.4 HDF5 Datatype

A Datatype describes a unit of data storage for Datasets and Attributes. Datatypes are subdivided into Atomic and Composite Types.

Atomic Datatypes are analogous to simple basic types in most programming languages. HDF5 Atomic Datatypes include Time, Bitfield, String, Reference, Opaque, Integer, and Float. Each atomic type has a specific set of properties. Examples of the properties associated with Atomic Datatypes are:

- Integers are assigned size, precision, offset, pad byte order, and are designated as signed or unsigned.
- Strings can be fixed or variable length and may or may not be null-terminated.
- References are constructs within HDF5 Files that point to other HDF5 Objects in the same file.

HDF5 provides a large set of predefined Atomic Datatypes. Table 3-1 lists the Atomic Datatypes that are used in NISAR data products.

Table 3-1. HDF5 Atomic Datatypes

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	unsigned, 8-bit, little-endian integer
H5T_STD_U16LE	unsigned, 16-bit, little-endian integer
H5T_STD_U32LE	unsigned, 32-bit, little-endian integer
H5T_STD_U64LE	unsigned, 64-bit, little-endian integer
H5T_STD_I8LE	signed, 8-bit, little-endian integer
H5T_STD_I16LE	signed, 16-bit, little-endian integer
H5T_STD_I32LE	signed, 32-bit, little-endian integer
H5T_STD_I64LE	signed, 64-bit, little-endian integer
H5T_IEEE_F32LE	32-bit, little-endian, IEEE floating point
H5T_IEEE_F64LE	64-bit, little-endian, IEEE floating point
H5T_C_S1	character string made up of one or more bytes

Derived Datatypes are user-defined variants of predefined Atomic Datatypes where the data organization has been modified at the bit-level. Derived data types are particularly useful for representing custom N-bit integers and floating-point numbers.

Composite Datatypes incorporate sets of Atomic datatypes. Composite Datatypes include Array, Enumeration, Variable Length and Compound.

- The Array Datatype defines a multi-dimensional array that can be accessed atomically.

- Variable Length presents a 1-D array element of variable length. Variable Length Datatypes are useful as building blocks of ragged arrays.
- Compound Datatypes are composed of named fields, each of which may be dissimilar Datatypes. Compound Datatypes are conceptually equivalent to structures in the C programming language.

Named Datatypes are explicitly stored as Objects within an HDF5 File. Named Datatypes provide a means to share Datatypes among Objects. Datatypes that are not explicitly stored as Named Datatypes are stored implicitly. They are stored separately for each Dataset or Attribute they describe.

NISAR products employ the following Derived and Compound Datatypes.

Table 3-2 NISAR HDF5 Derived and Compound Datatypes

Description	Comments
16-bit little-endian floating point	“binary16” half precision type in IEEE 754-2008 standard. Matches numpy.float16 type in Python. We will refer to this type as H5T_IEEE_F16LE or Float16 in our documents.

H5T_COMPOUND
{
16-bit little-endian floating-point "r";
16-bit little-endian floating-point "i";
}
	Complex numbers made up of two half precision floating point numbers. We will refer to this type as H5T_CPX_F16LE or CFloat16 in our documents.

H5T_COMPOUND
{
32-bit little-endian floating-point "r";
32-bit little-endian floating-point "i";
}
	Complex numbers made of two single precision floating point numbers. We will refer to this type as H5T_CPX_F32LE or CFloat32 in our documents.

H5T_COMPOUND
{
64-bit little-endian floating-point "r";
64-bit little-endian floating-point "i";
}
	Complex numbers made of two double precision floating point numbers. We will refer to this type as H5T_CPX_F64LE or CFloat64 in our documents.

3.1.5 HDF5 Attribute

An Attribute is a small aggregate of data that describes Groups or Datasets. Like Datasets, Attributes are also associated with a particular Dataspace and Datatype. Attributes cannot be subsetted or extended. Attributes themselves cannot have Attributes.

3.2 NISAR File Organization

3.2.1 Groups

All NISAR HDF5 files are organized as groups with no actual data at the root("/") level. Table 3-3 shows the general layout of the HDF5 files that are generated by the NISAR Science Data System. All data are organized under "/science" with data from the L-SAR and S-SAR instruments separated into their own groups.

Table 3-3 Group organization at the top level of a NISAR HDF5 File

Group Name	Description
/science/LSAR	All science data from the L-SAR instrument is organized under this group
/science/SSAR	All science data from the S-SAR instrument is organized under this group
/science/LSAR/identification	File level metadata for cataloging, archiving the granule

In the nominal baseline, L-SAR and S-SAR data will not appear in the same granule, even if they cover the same geographic area. Data structure described below the primary groups ("/science/LSAR" for L-SAR and "/science/SSAR" for S-SAR) will be the same for L-SAR and S-SAR products. The rest of the document from this point on describes the layout of the product containing L-SAR data. The specification for equivalent S-SAR data products is expected to be the same except for the substitution of "LSAR" by "SSAR" in the dataset paths in the HDF5 granule.

3.2.2 File Level Metadata

Global metadata at the file level are currently given as Global Attributes shown in Table 3-4.

Metadata regarding the data in the particular granule are given in "/science/LSAR/identification" for L- or S-SAR. These data are described further in Sec 4.2 and Sec 5.2.

Table 3-4 Global attributes of L1_ROFF

Attribute	Format	Description	Value
Conventions	string	NetCDF-4 conventions adopted in this product. This attribute should be set to CF-1.8 to indicate that the group is compliant with the Climate and Forecast NetCDF conventions.	CF-1.7
title	string	Product title.	NISAR L1_ROFF Product
institution	string	Name of producing agency.	NASA JPL
mission_name	string	Mission name.	NISAR

reference_document	string	Name and version of Product Description Document to use as reference for product.	D-105009 NISAR NASA SDS Product Specification L1 Range Doppler Pixel Offsets
contact	string	Contact information for producer of product.	nisar-sds-ops@jpl.nasa.gov

3.2.3 Variable Metadata (HDF5 Attributes)

NISAR standards incorporate additional metadata that describe each HDF5 Dataset within the HDF5 file. Each of these metadata elements appear in an HDF5 Attribute that is directly associated with the HDF5 Dataset. Wherever possible, these HDF5 Attributes employ names that conform to the Climate and Forecast (CF) conventions.

Table 3-5 lists the CF names for the HDF5 Attributes that NISAR products typically employ.

Table 3-5 Common variable attributes in HDF5 file.

Attribute	Description
_FillValue	The value used to represent missing or undefined data. (Before applying add_offset and scale_factor).
add_offset	If present this value should be added to each data element after it is read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
scale_factor	If present, the data are to be multiplied by the value after they are read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
comment	Miscellaneous information about the data or the methods to generate it.
coordinates	Coordinate variables associated with the variable. The basename of the coordinate variable is used in this representation and group scoping rules for CF conventions apply.
long_name	A descriptive variable name that indicates its content.
quality_flag	Names of variable quality flag(s) that are associated with this variable to indicate its quality.
units	Unit of data after applying offset (add_offset) and scale_factor.
valid_max	Maximum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as maximum value of actual data)
valid_min	Minimum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as minimum value of actual data)

Some HDF5 datasets are populates with statistical attributes. Table 3-6 and Table 3-7 describe the statistical attributes added to real- and complex-valued HDF5 datasets, respectively. The list of real-valued HDF5 datasets for the standard L1_ROFF product is given in table 3-8.

Table 3-6 Statistical attributes for real-valued HDF5 datasets.

Attribute	Description
min_value	Minimum value of real-valued HDF5 dataset
mean_value	Mean value of real-valued HDF5 dataset
max_value	Maximum value of real-valued HDF5 dataset
sample_standard_deviation	Sample standard deviation of real-valued HDF5 dataset

Table 3-7 Statistical attributes for complex valued HDF5 datasets.

Attribute	Description
min_real_value	Minimum value of the real part of a complex-valued HDF5 dataset
mean_real_value	Mean value of the real part of a complex-valued dataset HDF5 dataset
max_real_value	Maximum value of the real part of a complex-valued HDF5 dataset
sample_standard_deviation_real	Sample standard deviation of the real part of a complex-valued HDF5 dataset
min_imag_value	Minimum value of the imaginary part of a complex-valued HDF5 dataset
mean_imag_value	Mean value of the imaginary part of a complex-valued HDF5 dataset
max_image_value	Max value of the imaginary part of a complex-valued HDF5 dataset
sample_standard_deviation_imag	Sample standard deviation of the imaginary part of a complex-valued HDF5 dataset

Table 3-8 L1_ROFF HDF5 datasets populated with statistical attributes.

Attribute	HDF5 Datasets	Dataset type
/science/LSAR/ROFF/ swaths/frequencyA/pixelOffsets/ HH/layer1/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued
/science/LSAR/ROFF/ swaths/frequencyA/pixelOffsets/ VV/layer1/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued

/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/	slantRangeOffset alongTrackOffset correlationSurfacePeak crossOffsetVariance alongTrackOffsetVariance slantRangeOffsetVariance snr	Real-valued

3.3 Granule Definition

NISAR L1_ROFF granules will conform to the Tiling Scheme being developed for the mission and are expected to have a ground footprint of 240 km x 240 km.

3.4 File Naming Convention

NISAR L1_ROFF Granule names will conform to the Standard Product File Naming Scheme [RD3].

3.5 Temporal Organization

The L1_ROFF data are arranged on a uniformly spaced, increasing zero-Doppler azimuth time grid. Using row-major order convention of representing 2D raster arrays, zero-Doppler azimuth time is represented by the row direction or the slowest changing dimension.

3.6 Spatial Organization

The L1_ROFF data are arranged on a uniformly spaced, increasing zero-Doppler azimuth time in the row direction and increasing slant range grid in the column direction following the row-major order convention of representing 2D raster arrays.

3.7 Spatial Sampling and Resolution

NISAR mission uses a non-uniformly spaced sequence of pulses in SweepSAR mode to collect radar data, to overcome the limitations imposed by transmit gaps affecting the wide imaging swath [RD1]**Error! Reference source not found.**. Processing software accounts for the non-uniform sampling to generate the final L1_ROFF product on a uniform grid. Some salient features of the output grid for the L1_ROFF product are:

1. The center of the top-left pixel will correspond to the same zero-Doppler azimuth time and slant range for all imagery layers in an L-SAR L1_ROFF product.
2. The main imaging band (frequencyA) is spatially averaged to the same posting, irrespective of the imaging mode (Table 2-3 to Table 2-6). This allows for spatial mosaicking operations across instrument mode changes.

3.7.1 Along Track Mosaicking

The spatial sampling of the output grid has also been designed to facilitate along-track mosaicking of contiguous L1_ROFF product granules if the user desires. The following features simplify the implementation of along-track mosaicking

1. The slow time sampling frequency (inverse of the zero Doppler time spacing between consecutive lines) will be chosen to be an integer, to allow synchronization between adjacent granules at integer second boundaries without the need for resampling in the azimuth time direction.
2. The slant range to the first pixel will be a multiple of the lowest sampling frequency (corresponding to 5MHz) to enable concatenation of adjacent granules with simple integer shifts of imagery in the slant range direction.

Currently, it is not possible to mosaic products generated using data acquired with different bandwidths (different wavelengths) in the along-track direction.

3.7.2 Partially compressed SLC data

Partially compressed data in L1_RSLC files will not be used to produce L1_ROFF products. Spatially averaged pixels with any partially compressed or missing data in SLCs will be set to the fill value (specified by _FillValue attribute).

4 LEVEL 1 RADAR PIXEL OFFSET PRODUCT

In this section, we briefly describe the layout of L1_ROFF data and associated metadata within the NISAR HDF5 file. Detailed description of Group and Dataset names can be found in Section 5. In this section, we focus on the organization of L-SAR instrument data within the file under the Group name “/science/LSAR”.

4.1 Shapes and Dimensions of Data

Information on the shapes and dimensions of the data items in various data tables are described as part of the metadata (Sec **Error! Reference source not found.**). This information is useful both as part of the product identification and for setting up further processing, i.e., dimensioning arrays.

4.2 Product Identification

Information needed to identify this product is given under the Group “/science/LSAR/identification” (Sec **Error! Reference source not found.**). This includes information such as orbit number, cycle number, track-frame number, acquisition times, a polygon representing the bounding box of the included imagery in geographic coordinates, and product version.

4.3 Radar Imagery

The imagery layers of the L1_ROFF product are organized by center frequency under the group “/science/LSAR/ROFF/swaths/frequencyA”. Pixel offset layers are generated only from the main imaging band (frequencyA). The “frequencyA” group is further organized by polarization (TxRx) and each polarization group (e.g., HH) is further organized in distinct groups for each offset layer. For example, the dataset “/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/slantRangeOffset” correspond to the first layer of slant range pixel offsets (i.e., IL1 in e.g., Table 2-3) obtained with the parameters described in Table 2-3 to Table 3-6 for polarization combination HH and center frequency frequencyA.

The details of the data elements are given in Section **Error! Reference source not found.**. The resolution of data elements is discussed in Section 2.2.

4.4 Radar Metadata

The *metadata* group under "/science/LSAR/ROFF/metadata" includes a list of miscellaneous metadata needed to interpret the geolocation and the imagery (e.g., layers of slant range and along-track pixel offsets) included in the L1_ROFF product.

4.4.1 Processing Information

The *processingInformation* includes the processing parameters used to generate the L1_ROFF product. This group also include a list of the used algorithms, and the inputs granules and files used to produce L1_ROFF. For a complete description of this group, refer to Section 5.4.

4.4.1.1 Parameters

The *parameters* subgroup ("/science/LSAR/ROFF/metadata/processingInformation/parameters") is further organized in four subgroups:

1. *common*: organized by frequency, and including the parameters derived by combining the information from the reference and secondary RSLC such as common Doppler Centroid and the common Doppler bandwidth
2. *reference*: including the effective velocity and the reference terrain height of the reference RSLC. This subgroup is further organized by frequency and includes some relevant parameters of the reference RSLC such as the slant range and zero Doppler time, the slant range and the azimuth bandwidth, the azimuth FM rate, and the Doppler centroid.
3. *secondary*: this subgroup follows the same organization of *reference* but includes the corresponding metadata for the secondary RSLC.
4. *pixelOffsets*: including the parameters used to generate the individual layers of dense pixel offsets in the radar geometry. This group is further organized by frequency. The subgroup *frequencyA* contains the offsets parameter common to each layer of offsets i.e., the offset spacings in slant range and along-track direction, the correlation surface oversampling factor. The offsets parameters specific for each offset layer are further organized in the *layer* subgroups. Each *layer* subgroup contains the along-track and slant range window and search window sizes used to generate the pixel offsets for that specific layer.

The *parameters* subgroup also contains a field called *runConfigurationContents* which included the content of the run configuration file with all the options and the input files used for processing.

4.4.1.2 Algorithms

The *algorithms* subgroup ("/science/LSAR/ROFF/metadata/processingInformation/algorithms") includes the name and the version of the software used to generate the product. The subgroup is further organized by the processing step used to generate the L1_ROFF product:

1. *coregistration*: including the algorithms used to perform the coarse and fine coregistration of the reference and secondary RSLCs (e.g., geometry coregistration, cross-correlation algorithm).

2. *crossCorrelation*: further organized by offset layer and including the cross-correlation algorithm used to generate each individual layer of pixel offset.

4.4.1.3 Input Files

The *inputs* subgroup ("/science/LSAR/ROFF/metadata/processingInformation/inputs") includes all the input files and granules used to generate the product i.e., L1_RSLC reference and secondary input granules, a description of the DEM used for processing, configuration files, and orbit files.

4.4.2 Other Radar Metadata

Section 5.5 includes the orbit ephemeris used for generating the L1_ROFF under a subgroup named "/science/LSAR/ROFF/metadata metadata/orbit".

4.4.2.1 Orbit

The orbit ephemeris used for generating the L1_ROFF product can be found under a subgroup named "orbit". This group includes time-tagged antenna phase center position and velocity vectors in Earth Centered Earth Fixed (ECEF) cartesian coordinates. In nominal operations, this would be the MOE state vectors that were used by the L2 processor.

4.4.3 Geolocation Grid

Section 5.6 contains information describing the radar geometry of the sensor during data taking in the group "/science/LSAR/ROFF/metadata/geolocationGrid". The geolocationGrid cubes include the coordinateX and coordinateY datasets to describe the geographical grid. They are referenced over the radar-grid which is defined by the coordinate vectors slantRange, zeroDopplerTime, and heightAboveEllipsoid. Normals are with respect to the WGS84 ellipsoid.

Geolocation grid cubes also provide the following list of radar geometry information in the associated HDF5 datasets:

1. The line-of-sight (LOS) unit vector, i.e., the vector from the target to the sensor, is defined by the datasets "losUnitVectorX" and "losUnitVectorY" which contain respectively the east and north components of the LOS unit vector in the east-north-up (ENU) coordinate system for each point of the geographic grid. Note that the third component of the LOS unit vector is not provided in the product as it can be simply derived from the other two components as:

$$losUnitVectorZ = \sqrt{1 - losUnitVectorX^2 - losUnitVectorY^2}$$

2. The along-track unit vector represents the projection of the along-track vector at the ground height. It is defined by the datasets "alongTrackUnitVectorX" and "alongTrackUnitVectorY" containing respectively the east and north components of the along-track unit vector in UTM coordinates.

3. The incidence angle, i.e., the angle between the LOS vector and the normal to the ellipsoid at the target height, is given by the dataset “incidenceAngle.
4. The elevation angle, defined as the angle between the LOS vector and the normal to the ellipsoid at the sensor, is provided as “elevationAngle”.
5. The ground track velocity which contains the absolute value of the platform velocity scaled at the target height is given as “groundTrackVelocity”.
6. The baseline between reference and secondary L1_RSLCs is given by the dataset “perpendicularBaseline” and “parallelBaseline”.

5 PRODUCT SPECIFICATION

5.1 Dimensions and Shapes

To simplify the description of the layout of data within the HDF5 file, we will use a table of dimensions and shapes to represent the relationship between similarly sized datasets. The entries in this table do not present actual datasets in the HDF5. This table is meant to be a guide to interpreting the shapes of the datasets in subsequent subsections.

Table 5-1 Table of dimensions and shapes in L1_ROFF product

Name	Shape	Description
scalar	scalar	None
numberOfDatatakes	scalar	number of datatakes in product
numberOfObservations	scalar	number of observations in product
numberOfFrequencies	scalar	Number of L-SAR frequencies in product
numberOfFrequencyAPolarizations	scalar	Number of polarization layers associated with L-SAR frequency A
frequencyASlantRangeWidth	scalar	Number of pixels in all L-SAR frequency A imagery datasets
frequencyAZeroDopplerTimeLength	scalar	Number of lines in all L-SAR frequency A imagery datasets
complexDataFrequencyAShape	(frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)	Shape associated with L-SAR frequency A imagery datasets
realDataFrequencyAShape	(frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)	Shape associated with L-SAR frequency A imagery interferometric dataset
offsetDataShape	(offsetZeroDopplerTimeLength, offsetSlantRangeWidth)	Shape associated with Pixel Offset layers
offsetSlantRangeWidth	scalar	Number of pixels in Pixel Offset layers
offsetZeroDopplerTimeLength	scalar	Number of lines in all L-SAR frequency A imagery datasets
validSamplesShapeFrequencyA	(frequencyAZeroDopplerTimeLength, 2)	Shape associated with L-SAR frequency A valid samples dataset
geolocationCubeShape	(geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)	Shape associated with metadata cubes

twoLayersCubeShape	(geolocationCubeWidth, geolocationCubeLength, twoLayersCubeHeight)	Shape associated with baseline metadata cubes
geolocationCubeHeight	scalar	Height dimension of the metadata cube
geolocationCubeLength	scalar	Length dimension of the metadata cube
geolocationCubeWidth	scalar	Width dimension of the metadata cube
twoLayersCubeHeight	scalar	Height dimension of the baseline metadata cube
dopplerCentroidTimeLength	scalar	Length dimension of Doppler centroid grid
dopplerCentroidSlantRangeWidth	scalar	Length dimension of Doppler centroid grid
dopplerCentroidShape	(dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)	Shape of the Doppler centroid grid
calibrationTimeLength	scalar	Length of calibration LUTs
calibrationSlantRangeWidth	scalar	Width of calibration LUTs
calibrationScaleShape	(calibrationTimeLength, calibrationSlantRangeWidth)	Shape of calibration LUTs
antennaPatternComplexShape	(calibrationTimeLength, calibrationSlantRangeWidth)	Shape of antenna pattern datasets
orbitListLength	scalar	description="Number of orbit state vectors
orbitShape	(orbitListLength, 3)	Shape of orbit state vector triplets dataset
attitudeListLength	scalar	Number of attitude state vectors
attitudeQuaternionShape	(attitudeListLength, 4)	Shape of attitude quaternion dataset
attitudeShape	(attitudeListLength, 3)	Shape of attitude Euler angle triplets dataset
chirpWeightingFrequencyLength	scalar	Shape associated with 1D filter representations in frequency domain
numberOfInputL1Files	scalar	Number of input L1 granules
numberOfInputConfigFiles	scalar	Number of input configuration files
numberOfInputOrbitFiles	scalar	Number of input orbit files

5.2 Product Identification

Table 5-2 NISAR HDF5 variables used for product identification

Product Identification Variables		
/science/LSAR/identification/absoluteOrbitNumber		
Type: UInt32	**Shape: scalar**	
Description: Absolute orbit number		
	units	unitless
/science/LSAR/identification/trackNumber		
Type: UByte	**Shape: scalar**	
Description: Track number		
	units	unitless
/science/LSAR/identification/frameNumber		
Type: UInt16	**Shape: scalar**	
Description: Frame number		
	units	unitless
/science/LSAR/identification/missionId		
Type: string	**Shape: scalar**	
Description: Mission identifier		
/science/LSAR/identification/processingCenter		
Type: string	**Shape: scalar**	
Description: Data processing center		
/science/LSAR/identification/productType		
Type: string	**Shape: scalar**	
Description: Product type		
/science/LSAR/identification/granuleId		
Type: string	**Shape: scalar**	
Description: Unique granule identification name		
/science/LSAR/identification/productVersion		
Type: string	**Shape: scalar**	
Description: Product version which represents the structure of the product and the science content governed by the algorithm, input data, and processing parameters		
/science/LSAR/identification/productSpecificationVersion		
Type: string	**Shape: scalar**	
Description: Product specification version which represents the schema of this product		
/science/LSAR/identification/lookDirection		
Type: string	**Shape: scalar**	
Description: Look direction can be left or right		
/science/LSAR/identification/orbitPassDirection		

Type: string	**Shape: scalar**
Description: Orbit direction can be ascending or descending	
/science/LSAR/identification/referenceZeroDopplerStartTime	
Type: string	**Shape: scalar**
Description: Azimuth start time of reference RSLC product	
/science/LSAR/identification/secondaryZeroDopplerStartTime	
Type: string	**Shape: scalar**
Description: Azimuth start time of secondary RSLC product	
/science/LSAR/identification/referenceZeroDopplerEndTime	
Type: string	**Shape: scalar**
Description: Azimuth stop time of reference RSLC product	
/science/LSAR/identification/secondaryZeroDopplerEndTime	
Type: string	**Shape: scalar**
Description: Azimuth stop time of secondary RSLC product	
/science/LSAR/identification/plannedDatatakeId	
Type: string	**Shape: (numberOfDatatakes)**
Description: List of planned datatakes included in the product	
/science/LSAR/identification/plannedObservationId	
Type: string	**Shape: (numberOfObservations)**
Description: List of planned observations included in the product	
/science/LSAR/identification/isUrgentObservation	
Type: string	**Shape: scalar**
Description: Boolean indicating if observation is nominal or urgent	
/science/LSAR/identification/listOfFrequencies	
Type: string	**Shape: (numberOfFrequencies)**
Description: List of frequency layers available in the product	
/science/LSAR/identification/diagnosticModeFlag	
Type: UByte	**Shape: scalar**
Description: Indicates if the radar operation mode is a diagnostic mode (1-2) or DBFed science (0): 0, 1, or 2	
units	unitless
/science/LSAR/identification/productLevel	
Type: string	**Shape: scalar**
Description: Product level. L0A: Unprocessed instrument data; L0B: Reformatted, unprocessed instrument data; L1: Processed instrument data in radar coordinates system; and L2: Processed instrument data in geocoded coordinates system	
/science/LSAR/identification/isGeocoded	
Type: string	**Shape: scalar**
Description: Flag to indicate if the product data is in the radar geometry ("False") or in the map geometry ("True")	
/science/LSAR/identification/boundingPolygon	
Type: string	**Shape: scalar**
Description: OGR compatible WKT representation of bounding polygon of the image	

/science/LSAR/identification/processingDateTime	
Type: string	**Shape: scalar**
Description: Processing UTC date and time in the format YYYY-MM-DDTHH:MM:SS	
/science/LSAR/identification/radarBand	
Type: string	**Shape: scalar**
Description: Acquired frequency band	
/science/LSAR/identification/instrumentName	
Type: string	**Shape: scalar**
Description: Name of the instrument used to collect the remote sensing data provided in this product	
/science/LSAR/identification/processingType	
Type: string	**Shape: scalar**
Description: NOMINAL (or) URGENT (or) CUSTOM (or) UNDEFINED	
/science/LSAR/identification/isDithered	
Type: string	**Shape: scalar**
Description: "True" if the pulse timing was varied (dithered) during acquisition, "False" otherwise.	
/science/LSAR/identification/isMixedMode	
Type: string	**Shape: scalar**
Description: "True" if this product is generated from reference and secondary RSLCs with different range bandwidths, "False" otherwise.	

5.3 Radar Imagery

Table 5-3 NISAR HDF5 variables related to SAR imagery

Product Imagery Variables		
/science/LSAR/ROFF/swaths/frequencyA/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyAPolarizations)**
Description: List of processed polarization layers with frequencyA		
/science/LSAR/ROFF/swaths/frequencyA/sceneCenterAlongTrackSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal along-track spacing in meters between consecutive lines near mid-swath of the ROFF images		
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/sceneCenterGroundRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal ground range spacing in meters between consecutive pixels near mid-swath of the ROFF images		
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/centerFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the processed image in Hz		
	units	Hz
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/slantRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Slant range spacing of the pixel offsets grid		
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/zeroDopplerTimeSpacing		
Type: Float64		**Shape: scalar**
Description: Along-track spacing of the offset grid		
	units	seconds
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**

Description: Pixel offsets signal-to-noise ratio		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/slantRangeOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer1/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Pixel offsets signal-to-noise ratio		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/slantRangeOffsetVariance		

Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer2/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Pixel offsets signal-to-noise ratio		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/slantRangeOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offsets variance		
	_FillValue	nan
	units	unitless

/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/HH/layer3/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Pixel offsets signal-to-noise ratio		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/slantRangeOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer1/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan

	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Pixel offsets signal-to-noise ratio		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/slantRangeOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offset variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer2/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) slant range pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Raw (unculled, unfiltered) along-track pixel offsets		
	_FillValue	nan
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/snr		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Pixel offsets signal-to-noise ratio		

	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/slantRangeOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/alongTrackOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track pixel offsets variance		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/VV/layer3/crossOffsetVariance		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Off-diagonal term of the pixel offsets covariance matrix		
	_FillValue	nan
	units	unitless
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/slantRange		
Type: Float64		**Shape: (offsetSlantRangeWidth)**
Description: Slant range vector		
	units	meters
/science/LSAR/ROFF/swaths/frequencyA/pixelOffsets/zeroDopplerTime		
Type: Float64		**Shape: (offsetZeroDopplerTimeLength)**
Description: Zero Doppler azimuth time vector		
	units	seconds since YYYY-MM-DD HH:MM:SS

5.4 Processing Information

Table 5-4 NISAR HDF5 variables related to processing parameters

Processing-related variables		
/science/LSAR/ROFF/metadata/processingInformation/parameters/runConfigurationContents		
Type: string		**Shape: scalar**
Description: Contents of the run configuration file with parameters used for processing		
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/referenceTerrainHeight		
Type: Float32		**Shape: (dopplerCentroidTimeLength)**
Description: Reference Terrain Height as a function of time for reference RSLC		
	units	meters
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/isMixedMode		
Type: string		**Shape: scalar**
Description: "True" if reference RSLC is a composite of data collected in multiple radar modes, "False" otherwise		
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/rfiCorrectionApplied		
Type: string		**Shape: scalar**
Description: Flag to indicate if RFI correction has been applied to reference RSLC		
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/frequencyA/slantRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Slant range spacing of reference RSLC		
	units	meters
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/frequencyA/zeroDopplerTimeSpacing		
Type: Float64		**Shape: scalar**
Description: Time interval in the along-track direction for reference RSLC raster layers		
	units	seconds
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/frequencyA/rangeBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed slant range bandwidth for reference RSLC		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/frequencyA/azimuthBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed azimuth bandwidth for reference RSLC		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/reference/frequencyA/dopplerCentroid		
Type: Float64		**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**
Description: 2D LUT of Doppler Centroid for Frequency A		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/referenceTerrainHeight		
Type: Float32		**Shape: (dopplerCentroidTimeLength)**

Description: Reference Terrain Height as a function of time for secondary RSLC		
	units	meters
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/rfiCorrectionApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if RFI correction has been applied to secondary RSLC		
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/isMixedMode		
Type: string	**Shape: scalar**	
Description: "True" if secondary RSLC is a composite of data collected in multiple radar modes, "False" otherwise		
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/frequencyA/slantRangeSpacing		
Type: Float64	**Shape: scalar**	
Description: Slant range spacing of secondary RSLC		
	units	meters
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/frequencyA/zeroDopplerTimeSpacing		
Type: Float64	**Shape: scalar**	
Description: Time interval in the along-track direction for secondary RSLC raster layers		
	units	seconds
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/frequencyA/rangeBandwidth		
Type: Float64	**Shape: scalar**	
Description: Processed slant range bandwidth for secondary RSLC		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/frequencyA/azimuthBandwidth		
Type: Float64	**Shape: scalar**	
Description: Processed azimuth bandwidth for secondary RSLC		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/secondary/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler Centroid for Frequency A		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/common/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: Common Doppler Centroid used for processing interferogram		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/common/frequencyA/dopplerBandwidth		
Type: Float64	**Shape: scalar**	
Description: Common Doppler Bandwidth used for processing interferogram		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/rangeBandwidth		
Type: Float64	**Shape: scalar**	
Description: Processed slant range bandwidth for frequencyA pixel offsets layers		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/azimuthBandwidth		

Type: Float64	**Shape: scalar**	
Description: Processed azimuth bandwidth for frequencyA pixel offsets layers		
	units	Hz
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/correlationSurfaceOversampling		
Type: UInt32	**Shape: scalar**	
Description: Oversampling factor of the cross-correlation surface		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/margin		
Type: UInt32	**Shape: scalar**	
Description: Margin in pixels around reference RSLC edges excluded during cross-correlation computation		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/slantRangeStartPixel		
Type: UInt32	**Shape: scalar**	
Description: Reference RSLC start pixel in slant range		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/alongTrackStartPixel		
Type: UInt32	**Shape: scalar**	
Description: Reference RSLC start pixel in along-track		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/slantRangeSkipWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation skip window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/alongTrackSkipWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation skip window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer1/alongTrackWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer1/slantRangeWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer1/alongTrackSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation search window size in pixels		

	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer1/slantRangeSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer2/alongTrackWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along track cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer2/slantRangeWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer2/alongTrackSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along track cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer2/slantRangeSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer3/alongTrackWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer3/slantRangeWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer3/alongTrackSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along track cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/parameters/pixelOffsets/frequencyA/layer3/slantRangeSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation search window size in pixels		

	units	unitless
/science/LSAR/ROFF/metadata/processingInformation/algorithms/softwareVersion		
Type: string	**Shape: scalar**	
Description: Software version used for processing		
/science/LSAR/ROFF/metadata/processingInformation/algorithms/coregistration/coregistrationMethod		
Type: string	**Shape: scalar**	
Description: RSLC coregistration method		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/algorithms/coregistration/geometryCoregistration		
Type: string	**Shape: scalar**	
Description: Geometry coregistration algorithm		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/algorithms/coregistration/resampling		
Type: string	**Shape: scalar**	
Description: Secondary RSLC resampling algorithm		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/algorithms/crossCorrelation/layer1/crossCorrelationAlgorithm		
Type: string	**Shape: scalar**	
Description: Cross-correlation algorithm for layer 1		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/algorithms/crossCorrelation/layer2/crossCorrelationAlgorithm		
Type: string	**Shape: scalar**	
Description: Cross-correlation algorithm for layer 2		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/algorithms/crossCorrelation/layer3/crossCorrelationAlgorithm		
Type: string	**Shape: scalar**	
Description: Cross-correlation algorithm for layer 3		
	algorithm_type	RSLC coregistration
/science/LSAR/ROFF/metadata/processingInformation/inputs/l1ReferenceSlcGranules		
Type: string	**Shape: (numberOfInputL1Files)**	
Description: List of input reference L1 RSLC products used		
/science/LSAR/ROFF/metadata/processingInformation/inputs/l1SecondarySlcGranules		
Type: string	**Shape: (numberOfInputL1Files)**	
Description: List of input secondary L1 RSLC products used		
/science/LSAR/ROFF/metadata/processingInformation/inputs/configFiles		
Type: string	**Shape: (numberOfInputConfigFiles)**	
Description: List of input config files used		
/science/LSAR/ROFF/metadata/processingInformation/inputs/demSource		
Type: string	**Shape: scalar**	
Description: Description of the input digital elevation model (DEM)		
/science/LSAR/ROFF/metadata/processingInformation/inputs/orbitFiles		
Type: string	**Shape: (numberOfInputOrbitFiles)**	

Description: List of input orbit files used

5.5 Other Radar Metadata

Table 5-4 NISAR HDF5 variables related to useful radar metadata

Radar metadata-related variables		
/science/LSAR/ROFF/metadata/orbit/time		
Type: Float64	**Shape: (orbitListLength)**	
Description: Time vector record. This record contains the time corresponding to position, velocity, acceleration records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/ROFF/metadata/orbit/position		
Type: Float64	**Shape: (orbitListLength, tripletxyz)**	
Description: Position vector record. This record contains the platform position data with respect to WGS84 G1762 reference frame		
	units	meters
/science/LSAR/ROFF/metadata/orbit/velocity		
Type: Float64	**Shape: (orbitListLength, tripletxyz)**	
Description: Velocity vector record. This record contains the platform velocity data with respect to WGS84 G1762 reference frame		
	units	meters per second
/science/LSAR/ROFF/metadata/orbit/acceleration		
Type: Float64	**Shape: (orbitListLength, tripletxyz)**	
Description: Acceleration vector record. This record contains the platform acceleration data with respect to WGS84 G1762 reference frame		
	units	meters per second squared
/science/LSAR/ROFF/metadata/orbit/orbitType		
Type: string	**Shape: scalar**	
Description: PrOE (or) NOE (or) MOE (or) POE (or) Custom		
/science/LSAR/ROFF/metadata/attitude/time		
Type: Float64	**Shape: (orbitListLength)**	
Description: Time vector record. This record contains the time corresponding to attitude and quaternion records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/ROFF/metadata/attitude/quaternions		
Type: Float64	**Shape: (attitudeListLength, quaternions)**	
Description: Attitude quaternions (q0, q1, q2, q3)		
	units	unitless
/science/LSAR/ROFF/metadata/attitude/angularVelocity		
Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude angular velocity vectors (wx, wy, wz)		
	units	radians per second
/science/LSAR/ROFF/metadata/attitude/eulerAngles		

Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude Euler angles (roll, pitch, yaw)		
	units	degrees
/science/LSAR/ROFF/metadata/attitude/attitudeType		
Type: string	**Shape: scalar**	
Description: PrOE (or) NOE (or) MOE (or) POE (or) Custom		

5.6 Geolocation Grid

Table 5-5 NISAR HDF5 variables related to metadata cube

Metadata cube-related variables		
/science/LSAR/ROFF/metadata/geolocationGrid/epsg		
Type: Int32	**Shape: scalar**	
Description: EPSG code corresponding to the coordinate system used for representing the geolocation grid		
	long_name	EPSG code
	units	unitless
/science/LSAR/ROFF/metadata/geolocationGrid/coordinateY		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Y coordinate in specified EPSG code		
	_FillValue	nan
	grid_mapping	projection
	long_name	Coordinate Y
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/coordinateX		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: X coordinate in specified EPSG code		
	_FillValue	nan
	grid_mapping	projection
	long_name	Coordinate X
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/incidenceAngle		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Incidence angle is defined as the angle between the LOS vector and the normal to the ellipsoid at the target height		
	max	90.0
	min	0.0
	_FillValue	nan
	grid_mapping	projection
	long_name	incidence angle
	units	degrees
/science/LSAR/ROFF/metadata/geolocationGrid/losUnitVectorX		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: East component of unit vector of LOS from target to sensor		
	max	-1.0
	min	1.0
	_FillValue	nan
	grid_mapping	projection

	long_name	LOS unit vector X
	units	unitless
/science/LSAR/ROFF/metadata/geolocationGrid/losUnitVectorY		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: North component of unit vector of LOS from target to sensor		
	max	-1.0
	min	1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	LOS unit vector Y
	units	unitless
/science/LSAR/ROFF/metadata/geolocationGrid/alongTrackUnitVectorX		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: East component of unit vector along ground track		
	max	-1.0
	min	1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Along-track unit vector X
	units	unitless
/science/LSAR/ROFF/metadata/geolocationGrid/alongTrackUnitVectorY		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: North component of unit vector along ground track		
	max	-1.0
	min	1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Along-track unit vector Y
	units	unitless
/science/LSAR/ROFF/metadata/geolocationGrid/elevationAngle		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Elevation angle is defined as the angle between the LOS vector and the normal to the ellipsoid at the sensor		
	max	90.0
	min	0.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Elevation angle
	units	degrees
/science/LSAR/ROFF/metadata/geolocationGrid/secondaryZeroDopplerTime		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Zero Doppler azimuth time of corresponding pixel in secondary image		

	units	seconds since yyyy-mm-dd
/science/LSAR/ROFF/metadata/geolocationGrid/secondarySlantRange		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Slant range of corresponding pixel in secondary image		
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/parallelBaseline		
Type: Float64	**Shape: (geolocationCubeWidth, geolocationCubeLength, twoLayersCubeHeight)**	
Description: Parallel component of the InSAR baseline		
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/perpendicularBaseline		
Type: Float64	**Shape: (geolocationCubeWidth, geolocationCubeLength, twoLayersCubeHeight)**	
Description: Perpendicular component of the InSAR baseline		
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/slantRange		
Type: Float64	**Shape: (geolocationCubeWidth)**	
Description: Slant range values corresponding to the geolocation grid		
	units	meters
/science/LSAR/ROFF/metadata/geolocationGrid/zeroDopplerTime		
Type: Float64	**Shape: (geolocationCubeWidth)**	
Description: Zero Doppler time values corresponding to the geolocation grid		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/ROFF/metadata/geolocationGrid/groundTrackVelocity		
Type: Float64	**Shape: (geolocationCubeWidth)**	
Description: Absolute value of the platform velocity scaled at the target height		
	_FillValue	nan
	grid_mapping	projection
	long_name	Ground-track velocity
	units	meters per second
/science/LSAR/ROFF/metadata/geolocationGrid/heightAboveEllipsoid		
Type: Float64	**Shape: (geolocationCubeHeight)**	
Description: Height values above WGS84 Ellipsoid corresponding to the location grid		
	standard_name	height_above_reference_ellipsoid
	units	meters

6 METADATA CUBE

In this section, we provide an overview of the metadata cubes used to store spatially-varying ancillary data in the secondary layers of the NISAR L-SAR product HDF5 granules. Note that this sparse representation is to assist users in ingesting and analyzing NISAR products within existing GIS software and is not meant to replace traditional representations of SAR data within the product granules or traditional processing approaches with radar geometry-aware software.

Metadata cubes are represented as three-dimensional arrays in the NISAR product HDF5 modules (Figure 6-1). The axes of the array are interpreted as (height, increasing azimuth time, and increasing slant range) in case of radar geometry products and as (height, decreasing northing, and increasing easting) in case of geocoded products. The data is organized with height as the first axis, as this allows one to directly ingest data as GCPs or rasters into existing GIS software. Each height layer is the same size. Metadata cubes will have fixed grid spacing (3 km in azimuth/northing x 1 km in slant range/easting x 1.5 km in height and will allow for easy merging when multiple products along the same imaging track are to be concatenated. The metadata fields on this coarse resolution grid will be evaluated using traditional radar processing approaches without approximations. The metadata cube will also span a field slightly larger than the original image product to allow users to interpolate data without introducing edge effects. Such low-resolution representation of slowly varying parameters has been demonstrated for InSAR products and processing **Error! Reference source not found.**.

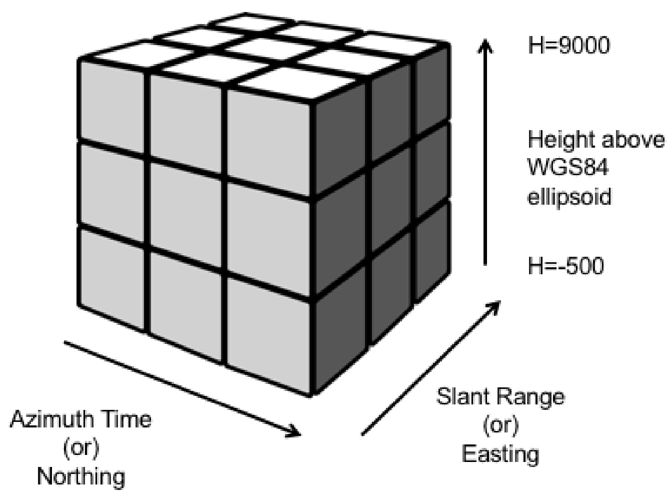

Figure 6-1. Metadata cube layer schematic

6.1 Metadata Cube Interpolation Example

We provide here a conceptual example of how these metadata cubes can be used within an existing GIS framework. Let us consider a L2_GUNW product on a UTM Zone 10 grid (Table

6-1). We use a geocoded product for the demonstration but the presented approach can be easily extended to radar coordinate products by replacing northing axis by azimuth time and easting axis by slant range.

Table 6-1. Example metadata cube properties

Name	Value	Description
Primary layer properties		
xmin	100000.0	Easting of the first column (m)
xmax	340000.0	Easting of the last column (m)
dx	30.0	Column spacing in Easting (m)
Nx	8001	Number of columns
ymax	570000.0	Northing of first row (m)
ymin	330000.0	Northing of last row (m)
dy	-30.0	Row spacing in Northing (m). Negative to emphasize North-up imagery in geocoded products
Ny	8001	Number of rows
Metadata cube properties		
Cxmin	97000.0	Easting of first column (m)
Cxmax	343000.0	Easting of last column (m)
Cdx	1000.0	Column spacing in Easting (m)
CNx	247	Number of columns
Cymax	579000.0	Northing of first row (m)
Cymin	321000.0	Northing of last row(m)
Cdy	-3000.0	Row spacing in Northing (m). Negative to emphasize North-up imagery in geocoded products
CNy	87	Number of rows
Czmin	-1500	Height of the first layer (m)
Czmax	9000	Height of the last layer (m)
Cdz	1500	Layer spacing in height (m)
CNz	8	Number of height layers

Suppose we are interested in computing the Perpendicular Baseline (Bperp) at a pixel of interest located at UTM coordinates point (Px,Py). Since these are coordinates on a map domain, we can look up a DEM to get the height at this point. The three-dimensional point of interest then becomes (Px, Py, h(Px,Py)).

The metadata cube for Perpendicular baseline can be thought of as a three-dimensional field Bperp(x,y,z) – even though it is oriented as (Nz,Ny,Nx) in the HDF5 file for ease of use with a GIS. The user can use standard built-in regular grid three-dimensional interpolation routines in languages like MATLAB (e.g, interp3), IDL or Python (e.g, RegularGridInterpolator) to interpolate the Bperp array. We recommend cubic interpolation for best results. If a three-dimensional interpolator is not available, one could use two-dimensional cubic interpolation for each height layer followed by a one-dimensional cubic interpolation in the following manner:

1. Populate f(i), i=0,…Nz-1 by two-dimensional cubic interpolation of each height layer:

$$f(i) = Bperp\left[i, \frac{Py - Cymax}{Cdy}, \frac{Px - Cxmax}{Cdx}\right]$$

   where the numbers in the square brackets indicate indices into the three-dimensional cube. For example, if we are interested in the point (107590.0 East, 555870.0 North, 300.0 Height), we would interpolate at Row 7.71 and Column 10.59 for each height layer.

2. Interpolate f(i) using one-dimensional cubic interpolation:

$$Bperp\big(Px, Py, h(Px, Py)\big) = f\left[\frac{h(Px, Py) - Czmin}{Cdz}\right]$$

   where the number in the square bracket indicates an index into a one-dimensional array. For example, for a height value of 200.0, we would interpolate at an index of 1.2.

6.2 Metadata Cube Usage Note

Note that the metadata cubes are designed to accommodate one double-precision cube within 1 MB of memory, allowing for information to be easily stored in memory for on-the-fly computation within GIS frameworks or software without much overhead. The metadata cubes are not a replacement for traditional SAR processing approaches or very high-resolution analyses. They are meant to facilitate rapid processing and analysis by non-experts and will serve the needs for most SAR applications. Analyses show that the geolocation error is on the order of 1.5 cm due to interpolation which is significantly smaller than errors from sources such as DEM, orbits, and atmospheric path delay. Interpolation errors for each of the metadata layers will be reported after additional study.

APPENDIX A: ACRONYMS

ADT	Algorithm Development Team
AT	Along Track
AWS	Amazon Web Services
BFPQ	Block adaptive Floating-Point Quantization
Cal/Val	Calibration and Validation (also sometimes cal/val)
CDR	Critical Design Review
CF	Climate and Forecast
CPU	Central Processing Unit
CRSD	Calibration Raw Signal Data
CSV	Comma-separated values
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DN	Digital Number
EAR	Export Administration Regulations
ECMWF	European Centre for Medium-Range Weather Forecasts
ECEF	Earth Centered Earth Fixed
EPSG	European Petroleum Survey Group
ESA	European Space Agency
FM	Frequency Modulation
FOP	Forecast Orbit Ephemeris
FOV	Field of View
GCOV	Geocoded Polarimetric Covariance (L2_GCOV)
GCP	Ground Control Point
GDAL	Geospatial Data Abstraction Library
GDS	Ground Data System
GIS	Geographic Information System
GMTED	Global Multi-resolution Terrain Elevation Data
GOFF	Geocoded Pixel Offsets (L2_GOFF)
GPU	Graphics Processing Unit
GSLC	Geocoded Single Look Complex (L2_GSLC)
GUNW	Geocoded Unwrapped Interferogram (L2_GUNW)
HDF5	Hierarchical Data Format version 5
HK, HKTM	Housekeeping Telemetry
InSAR	Interferometric Synthetic Aperture Radar
ISCE	InSAR Scientific Computing Environment
ISCE3	InSAR Scientific Computing Environment Enhanced Edition (for NISAR)
ISO	International Organization for Standardization

ISRO	Indian Space Research Organisation (British spelling)
L0B	Level-0B (data)
L1	Level-1 (data)
L2	Level-2 (data)
LOS	Line-Of-Sight
LUT	Lookup Table
Mbps	Megabits per second
MHz	Megahertz
MOE	Medium-precision Orbit Ephemeris
NCSA	National Center for Supercomputing Applications
NetCDF4	Network Common Data Form version 4
NISAR	NASA-ISRO Synthetic Aperture Radar
NOE	Near-Realtime Orbit Ephemeris
PDR	Preliminary Design Review
POD	Precision Orbit Determination
POE	Precision Orbit Ephemeris
PRF	Pulse Repetition Frequency
QA	Quality Assurance
REE	Radar Echo Emulator
RFI	Radio Frequency Interference
RIFG	Range-Doppler Interferogram (L1_RIFG)
ROFF	Range-Doppler Pixel Offsets (L1_ROFF)
RRSD	Radar Raw Signal Data
RRST	Radar Raw Science Telemetry
RSLC	Range-Doppler Single Look Complex (L1_RSLC)
RUNW	Range-Doppler UnWrapped Interferogram (L1_RUNW)
SAR	Synthetic Aperture Radar
SAS	Science Algorithm Software
SDS	Science Data System
SDT	Science Definition Team
SIS	Software Interface Specification
SLC	Single Look Complex
SNAPHU	Statistical-cost, Network-flow Algorithm for Phase Unwrapping
SRTM	Shuttle Radar Topography Mission
ST	Science Team
TAI	International Atomic Time (Temps Atomique International)
TCF	Terrain Correction Factor
TEC	Total Electron Content
TFdb	Track-frame Database
SWST	Sampling Window Start Time
UR	Urgent Response

UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 84
XML	eXtensible Markup Language (xml in code)
YAML	YAML Ain't Markup Language