NASA SDS Product Specification

Level-1 Range Doppler Single Look Complex

L1_RSLC

Template R200

Rev B

JPL D-102268

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DOCUMENT CHANGE LOG

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Preliminary	Sep 5, 2019	All	N/A	New document LRR044772 for ISRO LRR044773 for JPL Sharma LRR044774 for JPL Brancato and Shiroma
Rev A	June 18, 2020	Sec 1.3. Sec 2.1.		Release 1. Update document lists. Update product flow.
Rev A (ER 1.1)	December 7, 2020	None	N/A	Regenerated for R1.1 Engineering Release
Rev A (R1.1) Working Version	February, 5, 2021	Sec 2.1, Sec 3.2	N/A	For Release R1.1. LRR054209 for NISAR Science Team
Rev A (R1.1) Working Version 2	March 4, 2021	Sec 2.1, Sec 3.2, Table 5.3 (image data type from CFloat32 to CFloat16. Group name from SLC to RSLC)	N/A	For Release R1.1. Make spec agree with code (xml also updated for doc gen, QA checking). RSLC parallel GSLC.
Rev A (R2.0) Working Version 3	May 13, 2021	Sec 1.2, Sec 2.1, Sec 2.2, Sec 6	N/A	Merged info from Product Description Document (PDD). Removed reference to PDD. Added Section 6 on metadata cubes. LRR056760 for NISAR Science Team LRR056767 for ISRO
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Rev A (R2) Working Version 5	January 20, 2022	All	N/A	Updated export marking and TBD items
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Rev A (R3)	March 04, 2022	Sec 1.3, Figure 2-1, Table 2-1, Appendix A	N/A	Updated Docushare link in Sec. 1.3. Added description of offset product in Table 2-1. Updated product dependency Figure 2-1. Added new and missing acronyms in Appendix A.
Rev A (R3.1)	August 5, 2022	Sec 1.3, Figure 2-1, Sec 4.4.1, Sec 4.4.3	N/A	Updated Docushare link in Sec. 1.3. Updated product dependency Figure 2-1. Clarified nominal orbit/attitude product levels. Clarified backscatter LUT usage.
Rev A (R3.2)	January 27, 2023	Sec 1.3, Sec 3.2.2, Sec 4.2, App A	N/A	Updated links. Changed diagnosticModeFlag from bool to int. Clarified file metadata. Updated acronyms. Removed TBD/TBC tables.
Rev A (R3.3)	May 15, 2023	Sec 3.7.2, Sec 4.4.1	N/A	Updated links. Clarified valid subswath definition. Harmonized calibration LUTs with S1 definition.
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Revision	Cover Date	Sections Changed	ECR #	Reason, ECR Title, LRS #*
Rev B (R3.4)	October 23, 2023	§5.2:	N/A	§5.2: Added granuleId, changed isUrgentObservation to scalar, clarify isGeocoded description

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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 Level-1 Range Doppler Single Look Complex (RSLC) product to be generated by the NASA Science Data System (SDS) and provided to the Distributed Active Archive Center (DAAC). This data product is usually referenced by the short name L1_RSLC.

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_RSLC 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, Sep. 19, 2019.

[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, Initial, Nov. 4, 2020

[RD4] HDF5 documentation at https://portal.hdfgroup.org/display/HDF5/HDF5

[RD5] 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.

[RD6] NASA SDS Radar Pointing Product Software Interface Specification, JPL D-102264, Apr. 15, 2021.

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) [RD4] 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 Table 2-2.

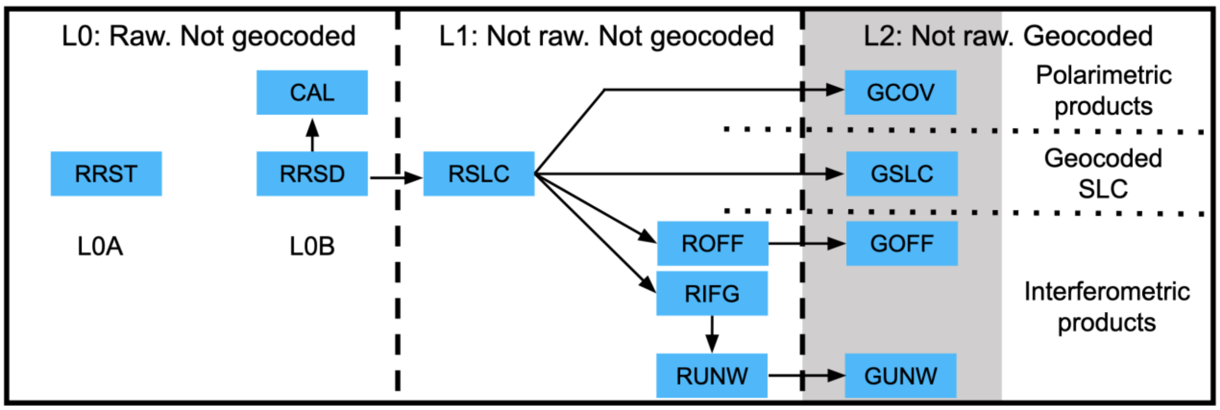

Figure 2-1 Product Dependency

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 datatake, 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 and obtained from coherent and incoherent speckle tracking.	On pre-defined track/frame
Range-Doppler Nearest-Time Unwrapped Interferogram (RUNW)	Antarctica, Greenland, and selected mountain glacers. 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 co-pol channels only	Geocoded version of ROFF product using 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 some communications artifacts removed, but without reconstruction of missing data and reordering 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_RSLC Overview

The L1_RSLC product is in the zero-Doppler radar geometry convention [RD1]. The output image is on a grid characterized by constant azimuth time interval and one-way slant range spacing. The output grid is also characterized by a fixed set of starting slant range, azimuth time interval, and slant range spacing values to allow for easy interpolation. All the primary image layers for a multi-polarization or multi-frequency product are generated on a common azimuth time-slant range grid.

The RSLC product, which is used to derive other L1/L2 products, contains individual binary raster layers representing complex signal return for each polarization layer. The RSLC data corresponding to the auxiliary sub-band is stored in a similar format but in a separate data group within the HDF5 product granule. The RSLC product is also packed with input, instrument and processing facility information; processing, calibration and noise parameters; geolocation grid; and data quality flags.

The L1_RSLC product complex backscatter is in Digital Numbers (DNs) with secondary layer look up tables (LUTs) provided to convert to beta-naught, sigma-naught, and gamma-naught.

The L1_RSLC product contains LUTs for radiometric ellipsoid correction. Many of the secondary layers are slowly varying quantities compactly stored in metadata cubes (see Sec 6).

All standard (i.e., non-urgent response) products are processed using the Medium-fidelity Orbit Ephemeris (MOE) product for forward processing and the Precise Orbit Ephemeris (POE) product for reprocessing campaigns.

The L1_RSLC product groups with their basic properties are given 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) [RD4]. 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 or MATLAB.

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 [RD4] 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/[L|S]SAR/identification	File level metadata for cataloging, archiving the particular 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/[L|S]SAR/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_RSLC

Attribute	Format	Description
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.
title	string	NISAR L1_RSLC Product
institution	string	Name of producing agency.
mission_name	string	"NISAR"

reference_document	string	Name and version of Product Description Document to use as reference for product.
contact	string	Contact information for producer of product. (e.g., "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 populated with statistical attributes. Table 3-6 and Table 3-7 describe statistical attributes added to real- and complex-valued HDF5 datasets, respectively. The list of real- and complex-valued HDF5 datasets for the standard RSLC product is given in Table 3-8.

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

Attribute	Description
min_value	Minimum value of a real-valued HDF5 dataset
mean_value	Mean value of a real-valued HDF5 dataset
max_value	Maximum value of a real-valued HDF5 dataset
sample_standard_deviation	Sample standard deviation of a 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 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_imag_value	Maximum 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_RSLC HDF5 datasets populated with statistical attributes.

HDF5 Group	HDF5 Datasets	Dataset type
/science/{L/S}SAR/RSLC/swaths/frequency{A/B}	HH, HV, VH, VV, RH, RV	Complex-valued

3.3 Granule Definition

NISAR L1_RSLC 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_RSLC Granule names will conform to the Standard Product File Naming Scheme [RD3].

3.5 Temporal Organization

The L1_RSLC 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_RSLC 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

The NISAR L-SAR 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]. Processing software accounts for the non-uniform sampling to generate the final L1_RSLC product on a uniform grid. Some salient features of the output grid for the L1_RSLC 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_RSLC product – frequency A and frequency B.
2. All imagery layers in an L-SAR L1_RSLC product – frequency A and frequency B, are generated on the same zero-Doppler azimuth time grid corresponding to a 1520 Hz PRF, which is approximately 1.2 times the processed azimuth bandwidth and results in roughly 5 m ground postings.
3. The slant range sampling is generally 1.2 times the range bandwidth. For example, 20 MHz data are sampled at 24 MHz. The only exceptions are 77 MHz data, which are sampled at 96 MHz.
4. The main (frequency A) and auxiliary (frequency B) bands of L-SAR data have an exact integer scaling relationship. All bands are sampled at an integer multiple of 6 MHz.

The L1_RSLC products are all processed to 6 m azimuth resolution. No windowing or whitening is applied in azimuth, so the antenna pattern determines the shape of the azimuth spectrum. A Kaiser window with shape parameter 1.6 is applied in range. A nominal impulse response is shown in Figure 3-1.

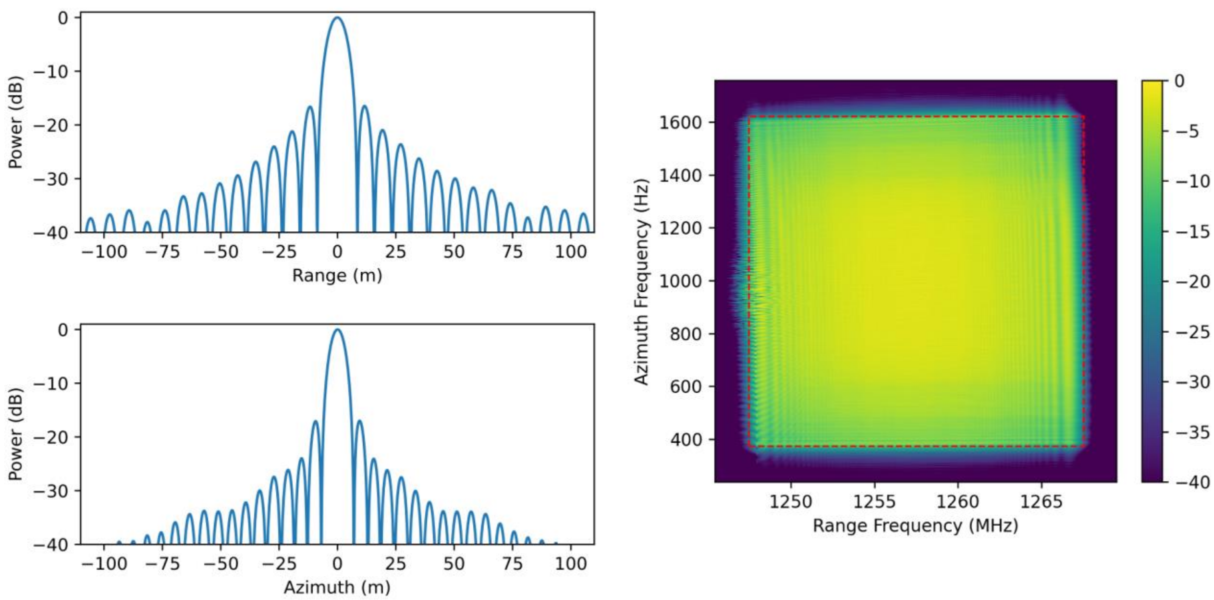

Figure 3-1 Impulse response and spectrum of simulated NISAR data
(20 MHz range bandwidth and 1910 Hz dithered PRF).

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_RSLC 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.

3.7.2 Partially Compressed L1_RSLC Data

Some applications can benefit from using partially compressed data in near and far ranges, as well as in transmit gaps during operation in constant Pulse Repetition Frequency (PRF) mode (see Figure 3-2). The number of contiguous image swaths is given by a variable named “numberOfSubSwaths”. The slant range extent for each of these contiguous, fully focused regions is captured in an array named “validSamplesSubSwathN” where “N” is the index of the contiguous regions in [1,5]. Each of these extent arrays are as long as the raster imagery themselves and each line contains two numbers indicating the starting index and last index in pixels (using Python convention).

Partially compressed (processed) data should be explicitly discarded for radiometric studies and for generation of polarimetric products.

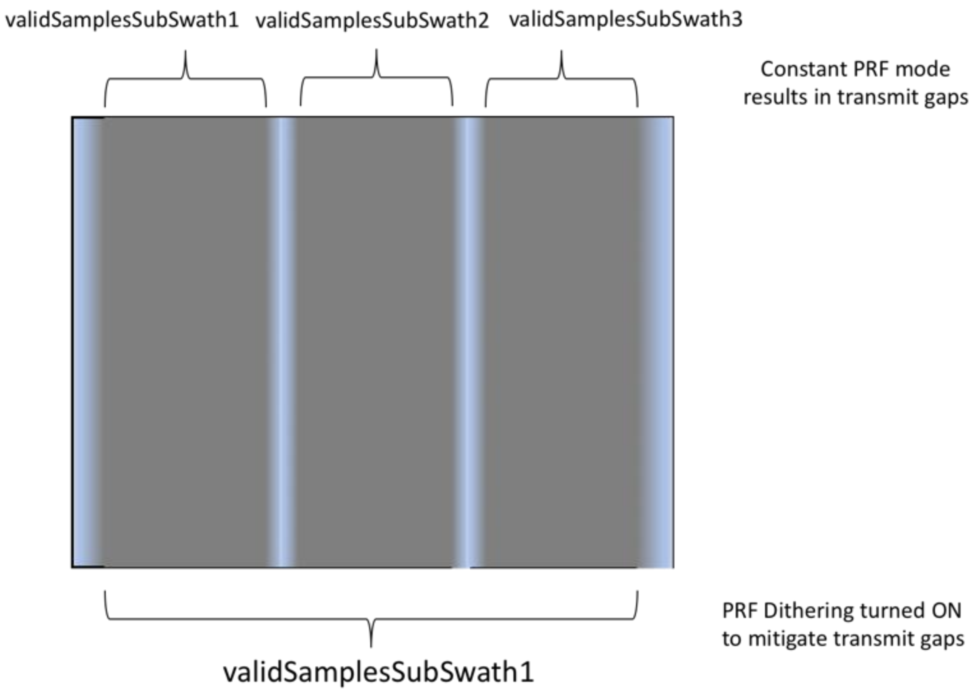

Figure 3-2 Representation of valid and partially compressed samples in constant PRF and dithered PRF modes

4 LEVEL 1 SINGLE LOOK COMPLEX PRODUCT

In this section, we briefly describe the layout of L1_RSLC data and associated metadata in 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 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 5.1). 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 particular product is given under the Group "/science/LSAR/identification" (Sec 5.2). This includes information such as orbit 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

All the imagery layers corresponding to the L1_RSLC product are organized by center frequency under the Group "/science/LSAR/RSLC/swaths". For L-SAR imaging modes with split imaging bands, the data is further organized into individual groups labeled "frequencyA" and "frequencyB". Imagery layers are further organized as individual 2D datasets by polarization (TxRx) within the frequency sub-groups, i.e., dataset "/science/LSAR/RSLC/swaths/frequencyA/HH" corresponds to the SLC imagery layer for polarization combination HH processed with center frequency corresponding to frequencyA.

The details of the data elements are given in Section 5.3.

4.4 Radar Metadata

Radar metadata needed to interpret the amplitude and phase information, as well as the geolocation of the imagery are organized under the Group "/science/LSAR/RSLC/metadata".

4.4.1 Calibration Information

The subgroup "calibrationInformation" contains two major types of information as shown in Section 5.4.

4.4.1.1 Radiometric Calibration

Secondary lookup tables (LUT), common to all frequencies and polarizations as these are purely a function of imaging geometry, are organized under the subgroup "calibrationInformation/geometry". The radar imagery themselves are provided as Digital Numbers (DNs), and LUTs are provided to transform the DNs to beta0, sigma0, and gamma0 (with respect to the reference ellipsoid) according to the following

```
beta0 = abs(RSLC)^2 / beta0_LUT^2
sigma0 = abs(RSLC)^2 / sigma0_LUT^2
gamma0 = abs(RSLC)^2 / gamma0_LUT^2
```

These LUTs are provided as a sparse grid in radar coordinates, and values at any location can be obtained using simple 2D interpolation (bilinear or higher order). After the above LUTs are applied, the resulting values have units of m^2/m^2 corresponding to radar cross section (m^2) normalized by a reference area.

4.4.1.2 Radar Information

Complex two-way antenna patterns and noise-equivalent sigma0 (nes0) are provided organized by frequency and polarization. Noise-equivalent-sigma0 could be used to apply noise correction during radiometric calibration. These datasets are provided on a sparse grid in map coordinates and values of interest at any geographical location can be estimated using simple 2D interpolation (bilinear or higher order).

4.4.2 Processing Information

Metadata giving processing parameters, algorithms, and inputs used are given in Section 5.5.

4.4.2.1 Parameters

Common parameters such as reference terrain height and chirp weighting parameters are included in the group "processingInformation/parameters". All processing parameters that vary spatially are organized on low resolution grids, to allow for easy lookup based on radar coordinates.

4.4.2.2 Algorithm Information

The processing algorithm information is provided in the subgroup "processingInformation/algorithms/". It includes the software version ("softwareVersion"), which is the version of the ISCE3 software that was used to generate the product, and the list of algorithms employed in the product processing.

4.4.2.3 Inputs

The key input files – L1_SLC granules, orbit, attitude, auxiliary, DEM source description, and configuration files are tracked and listed under the subgroup "processingInformation/inputs".

4.4.3 Other Radar Metadata

Section 5.6 includes the orbit ephemeris used for generating the L1_RSLC under a subgroup named "metadata/orbit" and the attitude under a subgroup named "metadata/attitude".

4.4.3.1 Orbit

The orbit ephemeris used for generating the L1_RSLC 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 Medium Orbit Ephemeris (MOE) state vectors that were used by the L1[BH2] processor.

4.4.3.2 Attitude

The attitude state vectors used for generating the L1_RSLC product can be found under a subgroup named "attitude". This group includes time-tagged quaternions and Euler Angles representing the orientation of the radar antenna in the Earth Centered Earth Fixed (ECEF) cartesian system. In nominal operations, this would be the Precise Radar Pointing (PRP) state vectors that were used by the L1 processor [RD6].

4.4.4 Geolocation Grid

Section 5.7 contains information describing the radar geometry of the sensor during data taking in the group "/science/LSAR/GCOV/metadata/geolocationGrid". The geolocationGrid cubes 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 mapping of the zero-Doppler grid to the geographic grid is described by the cubes datasets “coordinateX” and “coordinateY”, expressed in units defined by the EPSG code in “geolocationGrid/epsg”.
2. 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. 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:

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

3. 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.
4. 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”.
5. The elevation angle, defined as the angle between the LOS vector and the normal to the ellipsoid at the sensor, is provided as “elevationAngle”.
6. The ground track velocity which contains the absolute value of the platform velocity scaled at the target height is given as “groundTrackVelocity”.

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_RSLC 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
zeroDopplerTimeLength	scalar	Number of lines in all L-SAR imagery datasets
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
complexDataFrequencyAShape	(zeroDopplerTimeLength, frequencyASlantRangeWidth)	Shape associated with L-SAR frequency A imagery datasets
numberOfFrequencyBPolarizations	scalar	Number of polarization layers associated with L-SAR frequency B
frequencyBSlantRangeWidth	scalar	Number of pixels in all L-SAR frequency B imagery datasets
complexDataFrequencyBShape	(zeroDopplerTimeLength, frequencyBSlantRangeWidth)	Shape associated with L-SAR frequency B imagery datasets
validSamplesShape	(zeroDopplerTimeLength, 2)	Shape associated with L-SAR valid samples dataset
geolocationCubeShape	(geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)	Shape associated with 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
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
crosstalkComplexShape	scalar	Shape of crosstalk 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
numberOfInputL0BFiles	scalar	Number of input L0B granules
numberOfInputOrbitFiles	scalar	Number of input orbit files
numberOfInputAttitudeFiles	scalar	Number of input attitude files
numberOfInputAuxcalFiles	scalar	Number of input calibration files
numberOfInputConfigFiles	scalar	Number of input configuration 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/zeroDopplerStartTime		
Type: string	**Shape: scalar**	
Description: Azimuth start time of the product		
/science/LSAR/identification/zeroDopplerEndTime		
Type: string	**Shape: scalar**	
Description: Azimuth stop time of the 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: Flag indicating if observation is nominal ("False") or urgent ("True")		
/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 a composite of data collected in multiple radar modes, "False" otherwise.		

5.3 Radar Imagery

Table 5-3 NISAR HDF5 variables related to SAR imagery

Product Imagery Variables		
/science/LSAR/RSLC/swaths/zeroDopplerTime		
Type: Float64		**Shape: (zeroDopplerTimeLength)**
Description: CF compliant dimension associated with azimuth time		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/swaths/zeroDopplerTimeSpacing		
Type: Float64		**Shape: scalar**
Description: Time interval in the along track direction for raster layers. This is same as the spacing between consecutive entries in the zeroDopplerTime array		
	units	seconds
/science/LSAR/RSLC/swaths/frequencyA/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyAPolarizations)**
Description: List of processed polarization layers with frequencyA		
/science/LSAR/RSLC/swaths/frequencyA/sceneCenterAlongTrackSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal along track spacing in meters between consecutive lines near mid swath of the RSLC image		
	units	meters
/science/LSAR/RSLC/swaths/frequencyA/sceneCenterGroundRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal ground range spacing in meters between consecutive pixels near mid swath of the RSLC image		
	units	meters
/science/LSAR/RSLC/swaths/frequencyA/processedRangeBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed range bandwidth in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/acquiredRangeBandwidth		
Type: Float64		**Shape: scalar**
Description: Acquisition range bandwidth in Hz. In case of mode combination, this corresponds to mode with lowest bandwidth.		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/processedAzimuthBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed azimuth bandwidth in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/nominalAcquisitionPRF		
Type: Float64		**Shape: scalar**
Description: Nominal PRF of acquisition. In case of mode combination, this corresponds to mode with least nominal PRF.		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/processedCenterFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the processed image in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/acquiredCenterFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the acquisition in Hz. In case of mode combination, this corresponds to the mode with lowest Center Frequency.		

	units	Hz
/science/LSAR/RSLC/swaths/frequencyA/slantRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Slant range spacing of grid. Same as difference between consecutive samples in slantRange array		
	units	meters
/science/LSAR/RSLC/swaths/frequencyA/slantRange		
Type: Float64		**Shape: (frequencyASlantRangeWidth)**
Description: CF compliant dimension associated with slant range		
	units	meters
/science/LSAR/RSLC/swaths/frequencyA/HH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (HH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/HV		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (HV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/VH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (VH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/VV		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (VV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/RH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (RH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/RV		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Focused RSLC image (RV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyA/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyA/validSamplesSubSwath1		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 1st subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyA/validSamplesSubSwath2		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 2nd subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyA/validSamplesSubSwath3		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 3rd subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyA/validSamplesSubSwath4		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 4th subswath		
	units	unitless

/science/LSAR/RSLC/swaths/frequencyA/validSamplesSubSwath5		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 5th subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyBPolarizations)**
Description: List of processed polarization layers with frequencyB		
/science/LSAR/RSLC/swaths/frequencyB/sceneCenterAlongTrackSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal along track spacing in meters between consecutive lines near mid swath of the RSLC image		
	units	meters
/science/LSAR/RSLC/swaths/frequencyB/sceneCenterGroundRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal ground range spacing in meters between consecutive pixels near mid swath of the RSLC image		
	units	meters
/science/LSAR/RSLC/swaths/frequencyB/processedRangeBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed range bandwidth in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/acquiredRangeBandwidth		
Type: Float64		**Shape: scalar**
Description: Acquisition range bandwidth in Hz. In case of mode combination, this corresponds to mode with lowest bandwidth.		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/processedAzimuthBandwidth		
Type: Float64		**Shape: scalar**
Description: Processed azimuth bandwidth in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/nominalAcquisitionPRF		
Type: Float64		**Shape: scalar**
Description: Nominal PRF of acquisition. In case of mode combination, this corresponds to mode with least nominal PRF.		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/processedCenterFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the processed image in Hz		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/acquiredCenterFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the acquisition in Hz. In case of mode combination, this corresponds to the mode with lowest Center Frequency.		
	units	Hz
/science/LSAR/RSLC/swaths/frequencyB/slantRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Slant range spacing of grid. Same as difference between consecutive samples in slantRange array		
	units	meters
/science/LSAR/RSLC/swaths/frequencyB/slantRange		
Type: Float64		**Shape: (frequencyBSlantRangeWidth)**
Description: CF compliant dimension associated with slant range		
	units	meters
/science/LSAR/RSLC/swaths/frequencyB/HH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (HH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/HV		

Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (HV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/VH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (VH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/VV		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (VV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/RH		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (RH)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/RV		
Type: CFloat16		**Shape: (zeroDopplerTimeLength, frequencyBSlantRangeWidth)**
Description: Focused RSLC image (RV)		
	units	DN
/science/LSAR/RSLC/swaths/frequencyB/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/validSamplesSubSwath1		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 1st subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/validSamplesSubSwath2		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 2nd subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/validSamplesSubSwath3		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 3rd subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/validSamplesSubSwath4		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 4th subswath		
	units	unitless
/science/LSAR/RSLC/swaths/frequencyB/validSamplesSubSwath5		
Type: UInt32		**Shape: (zeroDopplerTimeLength, firstLastPair)**
Description: First and last valid sample in each line of 5th subswath		
	units	unitless

5.4 Calibration Information

Table 5-4 NISAR HDF5 variables related to calibration

Calibration-related variables		
/science/LSAR/RSLC/metadata/calibrationInformation/geometry/zeroDopplerTime		
Type: Float64		**Shape: (calibrationTimeLength)**
Description: Zero doppler time dimension corresponding to calibration records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/calibrationInformation/geometry/slantRange		
Type: Float64		**Shape: (calibrationSlantRangeWidth)**
Description: Slant range dimension corresponding to calibration records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/geometry/beta0		
Type: Float32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: 2D LUT to convert DN to beta 0 assuming as a function of zero doppler time and slant range		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/geometry/sigma0		
Type: Float32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: 2D LUT to convert DN to sigma 0 assuming as a function of zero doppler time and slant range		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/geometry/gamma0		
Type: Float32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: 2D LUT to convert DN to gamma 0 as a function of zero doppler time and slant range		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/zeroDopplerTime		
Type: Float64		**Shape: (calibrationTimeLength)**
Description: Zero doppler time dimension corresponding to calibration elevationAntennaPattern records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/slantRange		
Type: Float64		**Shape: (calibrationSlantRangeWidth)**
Description: Slant range dimension corresponding to calibration elevationAntennaPattern records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HH		
Type: CFloat32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HV		
Type: CFloat32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VH		
Type: CFloat32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VV		
Type: CFloat32		**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**
Description: Complex two-way elevation antenna pattern		
	units	unitless

/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RH		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RV		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/zeroDopplerTime		
Type: Float64	**Shape: (calibrationTimeLength)**	
Description: Zero doppler time dimension corresponding to calibration elevationAntennaPattern records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/slantRange		
Type: Float64	**Shape: (calibrationSlantRangeWidth)**	
Description: Slant range dimension corresponding to calibration elevationAntennaPattern records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HH		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HV		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VH		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VV		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RH		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RV		
Type: CFloat32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/zeroDopplerTime		
Type: Float64	**Shape: (calibrationTimeLength)**	
Description: Zero doppler time dimension corresponding to calibration nes0 records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/slantRange		
Type: Float64	**Shape: (calibrationSlantRangeWidth)**	
Description: Slant range dimension corresponding to calibration nes0 records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/HH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/HV		

Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/VH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/VV		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/RH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/nes0/RV		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/HH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/zeroDopplerTime		
Type: Float64	**Shape: (calibrationTimeLength)**	
Description: Zero doppler time dimension corresponding to calibration nes0 records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/slantRange		
Type: Float64	**Shape: (calibrationSlantRangeWidth)**	
Description: Slant range dimension corresponding to calibration nes0 records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/HV		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/VH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/VV		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/RH		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/nes0/RV		
Type: Float32	**Shape: (calibrationTimeLength, calibrationSlantRangeWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/crosstalk/slantRange		
Type: Float64	**Shape: (calibrationSlantRangeWidth)**	

Description: Slant range dimension corresponding to crosstalk records		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/crosstalk/txHorizontalCrosspol		
Type: CFloat32	**Shape: (calibrationSlantRangeWidth)**	
Description: Crosstalk in H-transmit channel expressed as ratio txV / txH		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/crosstalk/txVerticalCrosspol		
Type: CFloat32	**Shape: (calibrationSlantRangeWidth)**	
Description: Crosstalk in V-transmit channel expressed as ratio txH / txV		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/crosstalk/rxHorizontalCrosspol		
Type: CFloat32	**Shape: (calibrationSlantRangeWidth)**	
Description: Crosstalk in H-receive channel expressed as ratio rxV / rxH		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/crosstalk/rxVerticalCrosspol		
Type: CFloat32	**Shape: (calibrationSlantRangeWidth)**	
Description: Crosstalk in V-recieve channel expressed as ratio rxH / rxV		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/commonDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to all polarimetric channels		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/faradayRotation		
Type: Float64	**Shape: scalar**	
Description: Faraday rotation correction applied in processing		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HH/differentialDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to HH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HH/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to HH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HH/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to HH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HH/scaleFactorSlope		
Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to HH channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HV/differentialDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to HV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HV/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to HV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HV/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to HV channel complex amplitude (at antenna boresite)		

	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/HV/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to HV channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to VH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VH/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to VH channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to VV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VV channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/VV/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to VV channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to RH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to RH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RH/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to RH channel complex amplitude with respect to elevation angle		
	units	radians^-1

/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to RV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to RV channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyA/RV/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to RV channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/commonDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to all polarimetric channels		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/faradayRotation		
Type: Float64		**Shape: scalar**
Description: Faraday rotation correction applied in processing		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HH/scaleFactorSlope		
Type: Float64		**Shape: scalar**
Description: Slope of scale factor applied to HH channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HV channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/HV/scaleFactorSlope		

Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to HV channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VH/differentialDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to VH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VH/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to VH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VH/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to VH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VH/scaleFactorSlope		
Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to VH channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VV/differentialDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to VV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VV/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to VV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VV/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to VV channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/VV/scaleFactorSlope		
Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to VV channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RH/differentialDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to RH channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RH/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to RH channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RH/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to RH channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RH/scaleFactorSlope		
Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to RH channel complex amplitude with respect to elevation angle		
	units	radians^-1
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RV/differentialDelay		
Type: Float64	**Shape: scalar**	

Description: Range delay correction applied to RV channel		
	units	meters
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RV/differentialPhase		
Type: Float64	**Shape: scalar**	
Description: Phase correction applied to RV channel		
	units	radians
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RV/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to RV channel complex amplitude (at antenna boresite)		
	units	unitless
/science/LSAR/RSLC/metadata/calibrationInformation/frequencyB/RV/scaleFactorSlope		
Type: Float64	**Shape: scalar**	
Description: Slope of scale factor applied to RV channel complex amplitude with respect to elevation angle		
	units	radians^-1

5.5 Processing Information

Table 5-5 NISAR HDF5 variables related to processing parameters

Processing-related variables		
/science/LSAR/RSLC/metadata/processingInformation/parameters/azimuthChirpWeighting		
Type: Float32	**Shape: (chirpFFTFrequency)**	
Description: 1-D array in frequency domain for azimuth processing. This is used for processing L0b to L1. FFT length=256 (assumed)		
	spacing	
/science/LSAR/RSLC/metadata/processingInformation/parameters/rangeChirpWeighting		
Type: Float32	**Shape: (chirpFFTFrequency)**	
Description: 1-D array in frequency domain for range processing. This is used for processing L0b to L1. FFT length=256 (assumed)		
	spacing	
/science/LSAR/RSLC/metadata/processingInformation/parameters/referenceTerrainHeight		
Type: Float32	**Shape: (dopplerCentroidTimeLength)**	
Description: Reference Terrain Height as a function of time		
	units	meters
/science/LSAR/RSLC/metadata/processingInformation/parameters/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to processing information records"		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/processingInformation/parameters/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	
Description: Slant range dimension corresponding to processing information records"		
	units	meters
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyA/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to processing information records"		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyA/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	
Description: Slant range dimension corresponding to processing information records"		
	units	meters
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler Centroid for Frequency A		
	units	Hz
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyB/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to processing information records"		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyB/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	
Description: Slant range dimension corresponding to processing information records"		
	units	meters
/science/LSAR/RSLC/metadata/processingInformation/parameters/frequencyB/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	

Description: 2D LUT of Doppler Centroid for Frequency B		
	units	Hz
/science/LSAR/RSLC/metadata/processingInformation/parameters/runConfigurationContents		
Type: string	**Shape: scalar**	
Description: Contents of the run configuration file with parameters used for processing		
/science/LSAR/RSLC/metadata/processingInformation/algorithms/demInterpolation		
Type: string	**Shape: scalar**	
Description: DEM interpolation method		
/science/LSAR/RSLC/metadata/processingInformation/algorithms/rfiDetection		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) detection		
	algorithm_type	range processing
/science/LSAR/RSLC/metadata/processingInformation/algorithms/rfiMitigation		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) mitigation		
	algorithm_type	range processing
/science/LSAR/RSLC/metadata/processingInformation/algorithms/rangeCompression		
Type: string	**Shape: scalar**	
Description: Algorithm for focusing the data in the range direction		
	algorithm_type	range processing
/science/LSAR/RSLC/metadata/processingInformation/algorithms/elevationAntennaPatternCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating the antenna pattern		
	algorithm_type	range processing
/science/LSAR/RSLC/metadata/processingInformation/algorithms/rangeSpreadingLossCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating range fading		
	algorithm_type	range processing
/science/LSAR/RSLC/metadata/processingInformation/algorithms/dopplerCentroidEstimation		
Type: string	**Shape: scalar**	
Description: Algorithm for calculating Doppler centroid		
	algorithm_type	doppler centroid estimation
/science/LSAR/RSLC/metadata/processingInformation/algorithms/azimuthPresumming		
Type: string	**Shape: scalar**	
Description: Algorithm for regridding and filling gaps in the raw data in azimuth		
	algorithm_type	azimuth regridding
/science/LSAR/RSLC/metadata/processingInformation/algorithms/azimuthCompression		
Type: string	**Shape: scalar**	
Description: Algorithm for focusing the data in the azimuth direction		
	algorithm_type	azimuth regridding
/science/LSAR/RSLC/metadata/processingInformation/algorithms/softwareVersion		
Type: string	**Shape: scalar**	
Description: Software version used for processing		
/science/LSAR/RSLC/metadata/processingInformation/inputs/l0bGranules		
Type: string	**Shape: (numberOfInputL0BFiles)**	
Description: List of input L0B products used		
/science/LSAR/RSLC/metadata/processingInformation/inputs/orbitFiles		
Type: string	**Shape: (numberOfInputOrbitFiles)**	
Description: List of input orbit files used		
/science/LSAR/RSLC/metadata/processingInformation/inputs/attitudeFiles		
Type: string	**Shape: (numberOfInputAttitudeFiles)**	
Description: List of input attitude files used		
/science/LSAR/RSLC/metadata/processingInformation/inputs/auxcalFiles		

Type: string	**Shape: (numberOfInputAuxcalFiles)**
Description: List of input calibration files used	
/science/LSAR/RSLC/metadata/processingInformation/inputs/configFiles	
Type: string	**Shape: (numberOfInputConfigFiles)**
Description: List of input config files used	
/science/LSAR/RSLC/metadata/processingInformation/inputs/demSource	
Type: string	**Shape: scalar**
Description: Description of the input digital elevation model (DEM)	

5.6 Other Radar Metadata

Table 5-6 NISAR HDF5 variables related to useful radar metadata

Calibration-related variables		
/science/LSAR/RSLC/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/RSLC/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/RSLC/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/RSLC/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/RSLC/metadata/orbit/orbitType		
Type: string	**Shape: scalar**	
Description: PrOE (or) NOE (or) MOE (or) POE (or) Custom		
/science/LSAR/RSLC/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/RSLC/metadata/attitude/quaternions		
Type: Float64	**Shape: (attitudeListLength, quaternions)**	
Description: Attitude quaternions (q0, q1, q2, q3)		
	units	unitless
/science/LSAR/RSLC/metadata/attitude/angularVelocity		
Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude angular velocity vectors (wx, wy, wz)		
	units	radians per second
/science/LSAR/RSLC/metadata/attitude/eulerAngles		
Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude Euler angles (roll, pitch, yaw)		
	units	degrees
/science/LSAR/RSLC/metadata/attitude/attitudeType		
Type: string	**Shape: scalar**	
Description: PrOE (or) NOE (or) MOE (or) POE (or) Custom		

5.7 Geolocation Grid

Table 5-7 NISAR HDF5 variables related to metadata cube

Metadata cube-related variables		
/science/LSAR/RSLC/metadata/geolocationGrid/epsg		
Type: Int32	**Shape: scalar**	
Description: EPSG code corresponding to coordinate system used for representing geolocation grid		
/science/LSAR/RSLC/metadata/geolocationGrid/coordinateY		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: Y coordinate in specified EPSG code		
	units	meters
/science/LSAR/RSLC/metadata/geolocationGrid/coordinateX		
Type: Float64	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: X coordinate in specified EPSG code		
	units	meters
/science/LSAR/RSLC/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
	units	degrees
/science/LSAR/RSLC/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
	units	unitless
/science/LSAR/RSLC/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
	units	unitless
/science/LSAR/RSLC/metadata/geolocationGrid/alongTrackUnitVectorX		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: East component of unit vector along ground track		
	max	-1.0
	min	1.0
	units	unitless
/science/LSAR/RSLC/metadata/geolocationGrid/alongTrackUnitVectorY		
Type: Float32	**Shape: (geolocationCubeHeight, geolocationCubeLength, geolocationCubeWidth)**	
Description: North component of unit vector along ground track		
	max	-1.0
	min	1.0
	units	unitless
/science/LSAR/RSLC/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
	units	degrees
/science/LSAR/RSLC/metadata/geolocationGrid/slantRange		
Type: Float64		**Shape: (geolocationCubeWidth)**
Description: Slant range values corresponding to the geolocation grid		
	units	meters
/science/LSAR/RSLC/metadata/geolocationGrid/zeroDopplerTime		
Type: Float64		**Shape: (geolocationCubeWidth)**
Description: Zero Doppler time values corresponding to the geolocation grid		
	units	seconds since 1970.1.1
/science/LSAR/RSLC/metadata/geolocationGrid/groundTrackVelocity		
Type: Float64		**Shape: (geolocationCubeWidth)**
Description: Absolute value of the platform velocity scaled at the target height		
	units	meters per second
/science/LSAR/RSLC/metadata/geolocationGrid/heightAboveEllipsoid		
Type: Float64		**Shape: (geolocationCubeHeight)**
Description: Height values above WGS84 Ellipsoid corresponding to the location grid		
	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 [RD5].

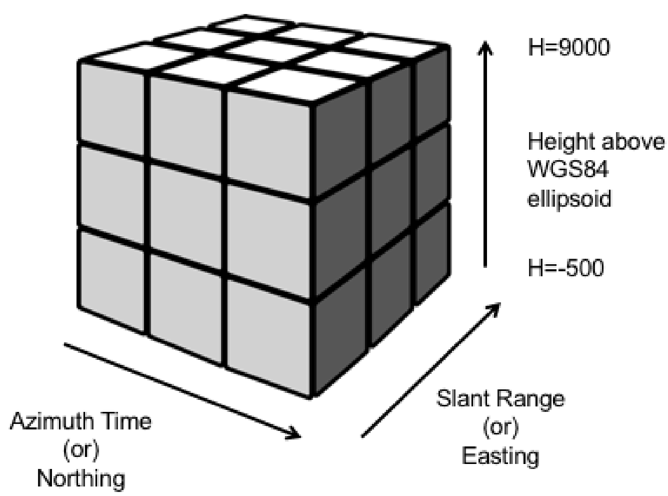

Figure 6-1. Metadata cube layer schematic

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 GUNW product on a UTM Zone 10 grid. 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:

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

   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
ANF	Area Normalization Factor
AT	Along Track
ATBD	Algorithm Theoretical Basis Document
AWS	Amazon Web Services
BFPQ	Block (adaptive) Floating-Point Quantization (adaptive may indicate implementation options)
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
DBF	Digital Beam Forming
DEM	Digital Elevation Model
DM	Diagnostic Mode
DN	Digital Number
EAR	Export Administration Regulations
EASE	Equal-Area Scalable Earth
ECMWF	European Centre for Medium-Range Weather Forecasts
ECEF	Earth Centered Earth Fixed
EOSDIS	Earth Observing System and Data Information System
EPSG	European Petroleum Survey Group
ER#.#	Engineering Release #.#
ERA5	ECMWF Reanalysis 5th generation
FFT	Fast Fourier Transform
FM	Frequency Modulation
FOE	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
GeoTIFF	Geographic Tagged Image File Format
GIS	Geographic Information System
GMTED	Global Multi-resolution Terrain Elevation Data
GNSS	Global Navigation Satellite System
GOFF	Geocoded Pixel Offsets (L2_GOFF)
GPU	Graphics Processing Unit

GSLC	Geocoded Single Look Complex (L2_GSLC)
GUNW	Geocoded Unwrapped Interferogram (L2_GUNW)
HH	Horizontal-transmit, Horizontal-receive polarization
HK, HKTM	Housekeeping Telemetry
HDF5	Hierarchical Data Format version 5
HV	Horizontal-transmit, Vertical-receive polarization
ICU	Integrated Correlation Unit
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)
JPL	Jet Propulsion Laboratory
JSON	JavaScript Notation
L0B	Level-0B (data)
L1	Level-1 (data)
L2	Level-2 (data)
L3	Level-3 (data)
LRR	[JPL] Limited Release Request
LRS	[JPL] Limited Release System
LUT	Lookup Table
Mbps	Megabits per second
MHz	Megahertz
MOE	Medium-precision Orbit Ephemeris
NASA	National Aeronautics and Space Administration
NETCDF4	Network Common Data Format 4 (also netCDF4)
NISAR	NASA-ISRO Synthetic Aperture Radar
NOE	Near-Realtime Orbit Ephemeris
OpenMP	Open Multi-Processing
PCM	Process Control Management
PDF	Portable Document Format (often pdf)
PDR	Preliminary Design Review
POD	Precision Orbit Determination
POE	Precision Orbit Ephemeris
PRF	Pulse Repetition Frequency
QA	Quality Assurance
R#.#	Release #.# (.0 often not used)
REE	Radar Echo Emulator
RFI	Radio Frequency Interference
RIFG	Range-Doppler Interferogram (L1_RIFG)
ROFF	Range-Doppler Pixel Offsets (L1_ROFF)
RRSD	Raw Radar Signal Data
RRST	Raw Radar Signal Telemetry

RSLC	Range-Doppler Single Look Complex (L1_RSLC)
RTC	Radiometric Terrain Correction
RUNW	Range-Doppler UnWrapped Interferogram (L1_RUNW)
RV	Right-circular, V-receive compact polarization
SAR	Synthetic Aperture Radar (L-SAR: L-band. S-SAR: S-band)
SAS	Science Algorithm Software
SDS	Science Data System
SDT	Science Definition Team
SIS	Software Interface Specification
SLC	Single Look Complex
SME2	Soil Moisture product based on a 200-meter global EASE Grid projection
SMAP	Soil Moisture Active Passive (Mission)
SNAPHU	Statistical-cost, Network-flow Algorithm for Phase Unwrapping
SRTM	Shuttle Radar Topography Mission
ST	Science Team
SWST	Sampling Window Start Time
TAI	International Atomic Time (Temps Atomique International)
TCF	Terrain Correction Factor
TEC	Total Electron Content
TFdb	Trackframe Database
SWST	Sampling Window Start Time
UR	Urgent Response
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VH	Vertical-transmit, Horizontal-receive polarization
VV	Vertical-transmit, Vertical-receive polarization
WGS84	World Geodetic System 84
XML	eXtensible Markup Language (xml in code)
YAML	YAML Ain’t Markup Language