NASA SDS Product Specification

Level-1 Range Doppler UnWrapped Interferogram

L1_RUNW

Rev B

JPL D-102271

November 9, 2023

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EPDM ELECTRONIC SIGNATURES

User-Group/Role	...	Decision	Comments	Date
Cheng, Cecilia S (cecilia)-JPL Consumer/Project Con...	...	Approve		30-Nov-2023 17:14
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ACKNOWLEDGEMENT

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).

DOCUMENT CHANGE LOG

Revision	Cover Date	Sections Changed	ECR #	Reason, ECR Title, LRS #*
Preliminary		All	N/A	New document LRR044775 for ISRO LRR044776 for JPL Sharma LRR044777 for JPL Brancato and Shiroma
Draft for ER 1.1	December 7, 2020	None	N/A	Regenerated for R1.1 Engineering Release
Rev A (R1.1) Working Version	February 5, 2021	All	N/A	For Release 1.1. LRR054212 for NISAR Science Team
Rev A (ER2.0) Working Version 2	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. LRR056763 for NISAR Science team LRR056770 for ISRO
Rev A (R2) Working Version 2	July 15, 2021	Sec 6.1	N/A	Updated metadata cubes formula
Rev B (R2) Working Version 2	July 15, 2021	All	N/A	Removed LRR number in the footer. Updated list of TBD items table. Updated coordinate vector units in Table 5-7.
Rev A (ER 3.0) Working Version	December 10, 2021	Sec 3.2.3	N/A	For Engineering Release ER 3.0.
Rev A (R3) Working Version	March 04, 2022	Sec 1.3, Sec 2.1, Table 2.1, Figure 2.1, Appendix A, TBD table.	N/A	Updated Docushare link in Sec. 1.3. Added description of offset products in Table 2.1. Updated product dependency Figure 2.1. Update Sec 2.1 to include offset blending. Removed item from TBD table. Added missing and new acronyms in Appendix A.
Rev A (R3.1) Working Version	August 05, 2022	Front page, Sec. 2.1	N/A	Updated NISAR ADT Lead; Updated product dependency figure
Rev A (R3.1) Working Version	August 05, 2022	Cover. TBD, TBC tables, Acronym List	N/A	Requested fixes. LRR067549
Rev A (R3.2) Working Version	January 27, 2023	All	N/A	Revised for R3.2 release.
Rev A (R3.3)	June 6, 2023	All	N/A	Revised for R3.3 release. URS CL# 23-3140

Rev B (R3.4)	November 9, 2023	Cover page, Sec. 1.3, Sec. 2.2, Sec. 3.2.2, Sec 4.3; Sections 5.2, 5.3, 5.4, 5.5, 5.6	N/A	Modified date on cover page; Updated reference to RSLC product specification and NISAR products filename convention documents; Deleted link to EPDM; Added reference to SDS ATBD in text; Mentioned the ionosphere phase estimation uncertainty; Modified Table 3.4 to reflect information in product XML specifications; Corrected misspelling in Sec. 4.3; Resolved TBD in Table 5.7. Updated Sections 5.2, 5.3, 5.4, 5.5, 5.6.
* *Include the JPL Limited Release System (LRS) clearance number for each revision to be shared with foreign partners.*				

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1 INTRODUCTION

1.1 Purpose of Description

This document provides a specification of the NASA-ISRO Synthetic Aperture Radar (NISAR) L-SAR L1 Range Doppler Unwrapped Interferogram product to be generated by the NASA Science Data System (SDS) and provided to the Distributed Active Archive Center (DAAC). This data product is referenced by the short name L1_RUNW.

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_RUNW product, including for example their units, size, coordinates, etc.

Section 6 provides a description of the metadata cube representation.

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

1.3 Applicable and Reference Documents

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

Applicable Documents

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

Reference Documents

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

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

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

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

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

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

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

2 PRODUCT OVERVIEW

2.1 Product Background

Each NASA SDS L0-L2 L-band product (Figure 2-1 and **Error! Reference source not found.** Product Dependency) is distributed as a single HDF5 granule. All the metadata and imagery data are packaged in clearly defined sub-groups within the granule in compliance with the HDF5 specification. The NISAR product level definitions are given in **Error! Reference source not found.**.

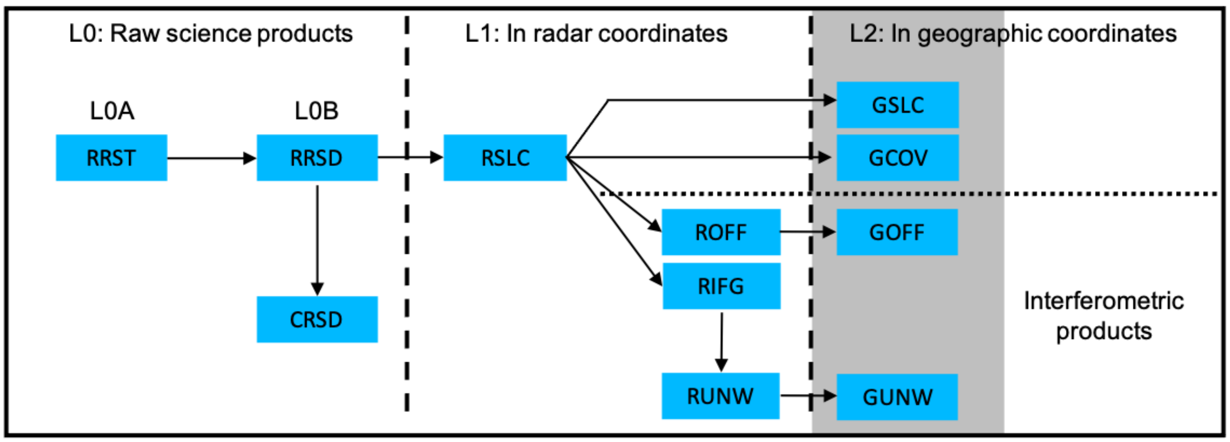

Figure 2-1 Product Dependency

Table 2-1. Key to Product Dependency Diagram

Product	Scope	Description	Granule Size
Radar Raw Science Telemetry (RRST)	Global	This L0A product is the raw downlinked data delivered to SDS	By downlinked files
Radar Raw Signal Data (RRSD)	Global	This L0B product is corrected, aligned radar pulse data derived from the RRST products and used for further processing	By radar observation, i.e., continuous data collected in a single radar mode
Calibration Raw Signal Data (CRSD)	Global	This L0B product contains instrument calibration data.	By radar 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 obtained from incoherent speckle tracking.	On pre-defined track/frame
Range-Doppler Nearest-Time Unwrapped Interferogram (RUNW)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Multi-looked, unwrapped differential interferogram in Range Doppler coordinates with geometrical phase (including topographic phase) removed.	On pre-defined track/frame

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

Product	Scope	Description	Granule Size
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_RUNW Overview

The L1_RUNW product represents the unwrapped, multi-looked interferogram generated from two L1_RSLCs in the Range Doppler geometry of the earlier (“reference”) acquisition. The L1_RUNW product is only generated between co-pol channels of the main imaging band (frequencyA) with a nominal posting of 80 meters (Table 2-3).

The L1_RUNW product contains individual binary raster layers representing single precision floating point unwrapped phase for each co-pol channel of the main imaging band. In addition, layers corresponding to normalized interferometric correlation, geometry masks (e.g., layover/shadow mask), connected component information, and the sub-pixel offsets obtained from incoherent speckle tracking are included in the HDF5 granule. Lookup tables for parallel and perpendicular baseline components are also included. An ionospheric phase screen is estimated from the two spectral bands (frequencyA and frequencyB) wherever possible. In the case of mode transitions where continuity of spectral bands is impacted, a split spectrum ionospheric phase estimate and an estimate of its standard deviation is derived from the main imaging band (frequencyA). Due to the variable quality of the estimated phase screens in different modes, which could significantly impact mosaicking, the estimated ionospheric phase screen is included as a layer in the product but not applied by default.

The L1_RUNW product includes the slant range and along-track sub-pixel offsets obtained from speckle tracking and used to generate the complex wrapped interferogram. If an offset product in Range Doppler coordinates (e.g., L1_ROFF) is available for the processed frame, the sub-pixel offset layers included in L1_RUNW are obtained by optimally blending the multiresolution offset layers included in L1_ROFF [RD1]. On the contrary, when no L1_ROFF is available for the processed frame, the sub-pixel offset layers included in L1_RUNW are obtained by running speckle tracking once with a pre-defined set of parameters. The pixel offset layers in L1_RUNW may be subject to several post-processing operations (e.g., outlier removal, no-data filling, noise reduction) [RD1].

The variables with their basic properties are given in Section 4**Error! Reference source not found.**. The details of the data elements are given in Section 5. Metadata cubes are discussed in Section 6.

Table 2-3 L1_RUNW Averaging Window Size

Range Bandwidth (MHz)	Ground Range Resolution Mid-Swath (m)	Nominal Posting (m)	Averaging Window Size in Range (pixels)	Averaging Window Size in Azimuth (pixels)
20	~11.8	80	7	16
40	~5.9	80	14	16
80	~3.1	80	26	16

3 PRODUCT ORGANIZATION

3.1 File Format

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

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

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

3.1.1 HDF5 File

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

3.1.2 HDF5 Group

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

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

3.1.3 HDF5 Dataset

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

3.1.4 HDF5 Datatype

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

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

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

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

Table 3-1. HDF5 Atomic Datatypes

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

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

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

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

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

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

NISAR products employ the following Derived and Compound Datatypes.

Table 3-2 NISAR HDF5 Derived and Compound Datatypes

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

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

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

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

3.1.5 HDF5 Attribute

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

3.2 NISAR File Organization

3.2.1 Groups

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

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

Group Name	Description
/science/LSAR	All science data from the L-SAR instrument is organized under this group
/science/SSAR	All science data from the S-SAR instrument is organized under this group
/science/LSAR/identification	File level metadata for cataloging, archiving the 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/LSAR/identification" for L- or S-SAR. These data are described further in Sec 4.2 and Sec **Error! Reference source not found.**.

Table 3-4 Global attributes of L1_RUNW

Attribute	Format	Description	Value
Conventions	string	NetCDF-4 conventions adopted in this product. This attribute should be set to CF-1.8 to indicate that the group is compliant with the Climate and Forecast NetCDF conventions.	CF-1.7

title	string	Product title	NISAR L1 RUNW product
institution	string	Name of producing agency.	NASA JPL
mission_name	string	Mission name	NISAR
reference_document	string	Name and version of Product Description Document to use as reference for product.	D-102271 NISAR NASA SDS Product Specification L1 Range Doppler UnWrapped Interferogram
contact	string	Contact information for producer of product.	nisar-sds-ops@jpl.nasa.gov

3.2.3 Variable Metadata (HDF5 Attributes)

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

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

Table 3-5. Common variable attributes in HDF5 file.

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

Some HDF5 datasets are populated with statistical attributes. Table 3-5 and Table 3-6 describe statistical attributes added to real- and complex-valued HDF5 datasets, respectively. The list of real- and complex-valued HDF5 datasets for the standard RUNW product is given in Table 3-7.

Table 3-5. 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 3-6. 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 3-7. L1_RUNW HDF5 datasets populated with statistical attributes.

HDF5 Group	HDF5 Datasets	Dataset type
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH	unwrappedPhase, coherenceMagnitude, ionospherePhaseScreen	Real-valued
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV	unwrappedPhase, coherenceMagnitude, ionospherePhaseScreen	Real-valued
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/HH	alongTrackOffset, slantRangeOffset	Real-valued
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/VV	alongTrackOffset, slantRangeOffset	Real-valued
/science/LSAR/RUNW/metadata/geolocationGrid	parallelBaseline, perpendicularBaseline	Real-valued

3.3 Granule Definition

NISAR L1_RUNW 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_RUNW Granule names will conform to the Standard Product File Naming Scheme [RD3].

3.5 Temporal Organization

The L1_RUNW 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_RUNW data are arranged on a uniformly spaced, increasing zero-Doppler azimuth time in the row direction and increasing slant range grid in the column direction following the row-major order convention of representing 2D raster arrays.

3.7 Spatial Sampling and Resolution

NISAR mission uses a non-uniformly spaced sequence of pulses in SweepSAR mode to collect radar data, to overcome the limitations imposed by transmit gaps affecting the wide imaging swath [RD1]. Processing software accounts for the non-uniform sampling to generate the final L1_RUNW product on a uniform grid. Some salient features of the output grid for the L1_RUNW 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_RUNW product.
2. The main imaging band (frequencyA) is spatially averaged to the same posting, irrespective of the imaging mode (Table 2-3). This allows for spatial mosaicking operations across instrument mode changes.

3.7.1 Along Track Mosaicking

The spatial sampling of the output grid has also been designed to facilitate along-track mosaicking of contiguous L1_RUNW 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.

Since the L1_RUNW product represents unwrapped phase in radians, these quantities need to be transformed to two-way displacement using the wavelength information to mosaic products in the along-track direction.

3.7.2 Partially compressed SLC data

Partially compressed data in L1_RSLC files will not be used to produce L1_RUNW products. Spatially averaged pixels with any partially compressed or missing data in SLCs will be set to the fill value (specified by _FillValue attribute).

4 LEVEL 1 UNWRAPPED INTERFEROGRAM PRODUCT

In this section, we will describe the layout of L1_RUNW data and associated metadata within the NISAR HDF5 file. Detailed description of Group and Dataset names can be found in Section 5. In this section, we focus on the organization of L-SAR instrument data within the file under the Group name “/science/LSAR”.

4.1 Shapes and Dimensions of Data

Information on the shapes and dimensions of the data items in various data tables are described as part of the metadata (Sec 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 product is given under the Group “/science/LSAR/identification” (Sec **Error! Reference source not found.**). 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

The imagery layers of the L1_RUNW product are organized by center frequency under the group “/science/LSAR/RUNW/swaths/frequencyA”. Unwrapped interferogram layers are generated only from the main imaging band (frequencyA). Imagery layers are further organized as individual 2D datasets by polarization (TxRx) under “science/LSAR/RUNW/swaths/frequencyA/interferogram”. For example, dataset “/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/unwrappedPhase” corresponds to the unwrapped interferogram for polarization combination HH and for center frequency "frequencyA”. The other main datasets under the “frequencyA” group are the speckle tracking offsets. The latter are contained in “/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets”. Similarly, to the “interferogram” group, the “pixelOffsets” group is further organized by polarization. The “frequencyA” level includes also the “valid validSamplesSubSwath<n>” map.

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

4.4 Radar Metadata

The *metadata* group under “/science/LSAR/RUNW/metadata” includes a list of miscellaneous metadata needed to interpret the geolocation and the imagery (e.g., unwrapped interferometric phase, normalized interferometric correlation, slant range and along-track pixel offsets) included in the L1_RUNW product.

4.4.1 Processing Information

The *processingInformation* includes the processing parameters used to generate the L1_RUNW product. This group also include a list of the used algorithms, and the inputs granules and files used to produce L1_RUNW. For a complete description of this group, refer to Section 5.4.

4.4.1.1 Parameters

The *parameters* subgroup (“/science/LSAR/RUNW/metadata/processingInformation/parameters”) is further organized in six subgroups:

1. *common*: organized by frequency, and including the parameters derived by combining the information from the reference and secondary RSLC e.g., Doppler centroid and the Doppler bandwidth
2. *reference*: including the reference terrain height of the reference RSLC and flags to indicate if the reference RSLC is the result of mixed mode processing or if it has been corrected for RFI. This subgroup is further organized by frequency and includes some relevant parameters of the reference RSLC such as the slant range and zero Doppler time spacings, the slant range and the azimuth bandwidth, and the Doppler centroid.
3. *secondary*: this subgroup follows the same organization of *reference* but includes the corresponding metadata for the secondary RSLC.
4. *interferogram*: including the parameters used to generate the complex wrapped interferogram and the normalized interferometric correlation e.g., the common slant range and azimuth bandwidth and the slant range and azimuth number of looks.
5. *pixelOffsets*: including the parameters (e.g., window size, search windows) used to generate the along-track and slant range dense pixel offsets layers used during the fine coregistration of the reference and secondary RSLCs.
6. *ionosphere*: including the parameters used to generate the ionosphere phase screen e.g., the bandwidth of the low and high sub-images used in the ionosphere phase estimation with the range split spectrum technique.

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

4.4.1.2 Algorithms

The *algorithms* subgroup ("/science/LSAR/RUNW/metadata/processingInformation/algorithms") includes the name and the version of the software used to generate the product. The subgroup is further organized by the processing step used to generate the L1_RUNW product:

1. *coregistration*: including the algorithms used to perform the coarse and fine coregistration of the reference and secondary RSLCs (e.g., geometry coregistration, cross-correlation algorithm).
2. *interferogramFormation*: including the algorithms used to form the complex wrapped interferogram and the normalized interferometric correlation (e.g., flattening method)
3. *unwrapping*: including the algorithms used to perform phase unwrapping (e.g., unwrapping algorithm, unwrapping initializer, type of performed preprocessing of the wrapped interferometric phase).
4. *ionosphereEstimation*: including the algorithm used to perform the estimation of the ionosphere phase screen (e.g., outlier estimation and filling, unwrapping error correction).

4.4.1.3 Input Files

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

4.4.2 Other Radar Metadata

Section 5.5 includes the orbit ephemeris used for generating the L1_RUNW under a subgroup named "/science/LSAR/RUNW/metadata metadata/orbit".

4.4.2.1 Orbit

The orbit ephemeris used for generating the L1_RUNW product can be found under a subgroup named "orbit". This group includes time-tagged antenna phase center position and velocity vectors in Earth Centered Earth Fixed (ECEF) cartesian coordinates. In nominal operations, this would be the MOE state vectors that were used by the L2 processor.

4.4.3 Geolocation Grid

Section 5.6 contains information describing the radar geometry of the sensor during data taking in the group "/science/LSAR/RUNW/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 vofr 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 for each point of the geographic grid. Note that the third component of the LOS unit vector is not provided in the product as it can be simply derived from the other two components as:

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

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".
7. The baseline between reference and secondary L1_RSLCs is given by the dataset "perpendicularBaseline" and "parallelBaseline".

5 PRODUCT SPECIFICATION

5.1 Dimensions and Shapes

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

Table 5-1 Table of dimensions and shapes in L1_RUNW product

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

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

5.2 Product Identification

Table 5-2 NISAR HDF5 variables used for product identification

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

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

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

5.3 Radar Imagery

Table 5-3 NISAR HDF5 variables related to SAR imagery

Product Imagery Variables		
/science/LSAR/RUNW/swaths/frequencyA/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyAPolarizations)**
Description: List of processed polarization layers with frequencyA		
/science/LSAR/RUNW/swaths/frequencyA/sceneCenterAlongTrackSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal along-track spacing in meters between consecutive lines near mid-swath of the RUNW images		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/sceneCenterGroundRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal ground range spacing in meters between consecutive pixels near mid-swath of the RUNW images		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/centerFrequency		
Type: Float64		**Shape: scalar**
Description: Center frequency of the processed image in Hz		
	units	Hz
/science/LSAR/RUNW/swaths/frequencyA/interferogram/slantRangeSpacing		
Type: Float64		**Shape: scalar**
Description: Slant range spacing of grid. Same as difference between consecutive samples in slantRange array		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/interferogram/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/RUNW/swaths/frequencyA/interferogram/slantRange		
Type: Float64		**Shape: (frequencyASlantRangeWidth)**
Description: Slant range vector		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/interferogram/zeroDopplerTime		
Type: Float64		**Shape: (frequencyAZeroDopplerTimeLength)**
Description: Zero Doppler azimuth time vector		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/unwrappedPhase		

Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Unwrapped interferogram between HH layers		
	_FillValue	nan
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/coherenceMagnitude		
Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Coherence magnitude for HH layers		
	_FillValue	nan
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/connectedComponents		
Type: Int16		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Connected components layer		
	_FillValue	255
	units	DN
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/ionospherePhaseScreen		
Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Ionosphere phase screen		
	_FillValue	nan
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/interferogram/HH/ionospherePhaseScreenUncertainty		
Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Uncertainty of the ionosphere phase screen		
	_FillValue	nan
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV/unwrappedPhase		
Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Unwrapped interferogram between VV layers		
	_FillValue	nan
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV/coherenceMagnitude		
Type: Float32		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Coherence magnitude for VV layers		
	_FillValue	nan
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV/connectedComponents		
Type: Int16		**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**
Description: Connected components layer		
	_FillValue	255

	units	DN
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV/ionospherePhaseScreen		
Type: Float32	**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**	
Description: Ionosphere phase screen		
	_FillValue	255
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/interferogram/VV/ionospherePhaseScreenUncertainty		
Type: Float32	**Shape: (frequencyAZeroDopplerTimeLength, frequencyASlantRangeWidth)**	
Description: Uncertainty of the ionosphere phase screen		
	_FillValue	nan
	units	radians
/science/LSAR/RUNW/swaths/frequencyA/numberOfSubSwaths		
Type: UByte	**Shape: scalar**	
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/validSamplesSubSwath1		
Type: UInt32	**Shape: (frequencyAZeroDopplerTimeLength, firstLastPair)**	
Description: First and last valid sample in each line of 1st subswath		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/validSamplesSubSwath2		
Type: UInt32	**Shape: (frequencyAZeroDopplerTimeLength, firstLastPair)**	
Description: First and last valid sample in each line of 2nd subswath		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/validSamplesSubSwath3		
Type: UInt32	**Shape: (frequencyAZeroDopplerTimeLength, firstLastPair)**	
Description: First and last valid sample in each line of 3rd subswath		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/validSamplesSubSwath4		
Type: UInt32	**Shape: (frequencyAZeroDopplerTimeLength, firstLastPair)**	
Description: First and last valid sample in each line of 4th subswath		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/validSamplesSubSwath5		
Type: UInt32	**Shape: (frequencyAZeroDopplerTimeLength, firstLastPair)**	
Description: First and last valid sample in each line of 5th subswath		
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/slantRangeSpacing		
Type: Float64	**Shape: scalar**	
Description: Slant range spacing of offset grid.		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/zeroDopplerTimeSpacing		
Type: Float64	**Shape: scalar**	

Description: Along-track spacing of the offset grid		
	units	seconds
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/HH/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range offset		
	_FillValue	nan
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/HH/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track offset		
	_FillValue	nan
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/HH/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/VV/slantRangeOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Slant range offset		
	_FillValue	nan
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/VV/alongTrackOffset		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Along-track offset		
	_FillValue	nan
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/VV/correlationSurfacePeak		
Type: Float32		**Shape: (offsetZeroDopplerTimeLength, offsetSlantRangeWidth)**
Description: Normalized correlation surface peak		
	_FillValue	nan
	units	unitless
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/slantRange		
Type: Float64		**Shape: (offsetSlantRangeWidth)**
Description: Slant range vector		
	units	meters
/science/LSAR/RUNW/swaths/frequencyA/pixelOffsets/zeroDopplerTime		
Type: Float64		**Shape: (offsetZeroDopplerTimeLength)**
Description: Zero Doppler azimuth time vector		

	units	seconds since YYYY-MM-DD HH:MM:SS

5.4 Processing Information

Table 5-4 NISAR HDF5 variables related to processing parameters

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

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

	units	Hz
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/azimuthBandwidth		
Type: Float64	**Shape: scalar**	
Description: Processed azimuth bandwidth for frequencyA interferometric layers		
	units	Hz
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/numberOfRangeLooks		
Type: UInt32	**Shape: scalar**	
Description: Number of looks applied in the slant range direction to form the wrapped interferogram		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/numberOfAzimuthLooks		
Type: UInt32	**Shape: scalar**	
Description: Number of looks applied in the along-track direction to form the wrapped interferogram		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/commonBandRangeFilterApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if common band range filter has been applied		
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/commonBandAzimuthFilterApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if common band azimuth filter has been applied		
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/ellipsoidalFlatteningApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if the interferometric phase has been flattened with respect to a zero height ellipsoid		
/science/LSAR/RUNW/metadata/processingInformation/parameters/interferogram/frequencyA/topographicFlatteningApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if the interferometric phase has been flattened with respect to topographic height using a DEM		
/science/LSAR/RUNW/metadata/processingInformation/parameters/ionosphere/lowBandBandwidth		
Type: Float64	**Shape: scalar**	
Description: Slant range bandwidth of the low sub-band image		
	units	Hz
/science/LSAR/RUNW/metadata/processingInformation/parameters/ionosphere/highBandBandwidth		
Type: Float64	**Shape: scalar**	
Description: Slant range bandwidth of the high sub-band image		
	units	Hz
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/alongTrackWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/slantRangeWindowSize		
Type: UInt32	**Shape: scalar**	

Description: Slant range cross-correlation window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/alongTrackSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/slantRangeSearchWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation search window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/alongTrackSkipWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Along-track cross-correlation skip window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/slantRangeSkipWindowSize		
Type: UInt32	**Shape: scalar**	
Description: Slant range cross-correlation skip window size in pixels		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/correlationSurfaceOversampling		
Type: UInt32	**Shape: scalar**	
Description: Oversampling factor of the cross-correlation surface		
	units	unitless
/science/LSAR/RUNW/metadata/processingInformation/parameters/pixelOffsets/frequencyA/isOffsetsBlendingApplied		
Type: string	**Shape: scalar**	
Description: Flag to indicate if pixel offsets are the results of blending multi-resolution layers of pixel offsets		
/science/LSAR/RUNW/metadata/processingInformation/algorithms/softwareVersion		
Type: string	**Shape: scalar**	
Description: Software version used for processing		
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/coregistrationMethod		
Type: string	**Shape: scalar**	
Description: RSLC coregistration method		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/geometryCoregistration		
Type: string	**Shape: scalar**	
Description: Geometry coregistration algorithm		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/crossCorrelation		
Type: string	**Shape: scalar**	

Description: Cross-correlation algorithm for sub-pixel offsets computation		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/resampling		
Type: string	**Shape: scalar**	
Description: Secondary RSLC resampling algorithm		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/crossCorrelationOutliers		
Type: string	**Shape: scalar**	
Description: Outliers identification algorithm		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/crossCorrelationFilling		
Type: string	**Shape: scalar**	
Description: Outliers data filling algorithm for cross-correlation offsets		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/coregistration/crossCorrelationFilterKernel		
Type: string	**Shape: scalar**	
Description: Filtering algorithm for cross-correlation offsets		
	algorithm_type	RSLC coregistration
/science/LSAR/RUNW/metadata/processingInformation/algorithms/interferogramFormation/multilooking		
Type: string	**Shape: scalar**	
Description: Multilooking algorithm		
	algorithm_type	Interferogram formation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/interferogramFormation/wrappedInterferogramFiltering		
Type: string	**Shape: scalar**	
Description: Algorithm to filter wrapped interferogram prior to phase unwrapping		
	algorithm_type	Interferogram formation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/interferogramFormation/flatteningMethod		
Type: string	**Shape: scalar**	
Description: Algorithm to used to flatten the wrapped interferogram		
	algorithm_type	Interferogram formation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/unwrapping/unwrappingAlgorithm		
Type: string	**Shape: scalar**	
Description: Algorithm used for phase unwrapping		
	algorithm_type	Unwrapping
/science/LSAR/RUNW/metadata/processingInformation/algorithms/unwrapping/unwrappingInitializer		
Type: string	**Shape: scalar**	
Description: Algorithm used to initialize phase unwrapping		
	algorithm_type	Unwrapping
/science/LSAR/RUNW/metadata/processingInformation/algorithms/unwrapping/costMode		
Type: string	**Shape: scalar**	
Description: Cost mode algorithm for phase unwrapping		

	algorithm_type	Unwrapping
/science/LSAR/RUNW/metadata/processingInformation/algorithms/unwrapping/preprocessing/wrappedPhaseOutliers		
Type: string	**Shape: scalar**	
Description: Algorithm identifying outliers in the wrapped interferogram		
	algorithm_type	Unwrapping
/science/LSAR/RUNW/metadata/processingInformation/algorithms/unwrapping/preprocessing/wrappedPhaseFilling		
Type: string	**Shape: scalar**	
Description: Outliers data filling algorithm for phase unwrapping preprocessing		
	algorithm_type	Unwrapping
/science/LSAR/RUNW/metadata/processingInformation/algorithms/ionosphereEstimation/ionosphereAlgorithm		
Type: string	**Shape: scalar**	
Description: Algorithm used to estimate ionosphere phase screen		
	algorithm_type	Ionosphere estimation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/ionosphereEstimation/ionosphereOutliers		
Type: string	**Shape: scalar**	
Description: Algorithm identifying outliers in unfiltered ionosphere phase screen		
	algorithm_type	Ionosphere estimation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/ionosphereEstimation/ionosphereFilling		
Type: string	**Shape: scalar**	
Description: Outliers data filling algorithm for ionosphere phase estimation		
	algorithm_type	Ionosphere estimation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/ionosphereEstimation/ionosphereFiltering		
Type: string	**Shape: scalar**	
Description: Filtering algorithm for ionosphere phase screen computation		
	algorithm_type	Ionosphere estimation
/science/LSAR/RUNW/metadata/processingInformation/algorithms/ionosphereEstimation/unwrappingErrorCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm correcting unwrapping errors in sub-band unwrapped interferograms		
	algorithm_type	Ionosphere estimation
/science/LSAR/RUNW/metadata/processingInformation/inputs/l1ReferenceSlcGranules		
Type: string	**Shape: (numberOfInputL1Files)**	
Description: List of input reference L1 RSLC products used		
/science/LSAR/RUNW/metadata/processingInformation/inputs/l1SecondarySlcGranules		
Type: string	**Shape: (numberOfInputL1Files)**	
Description: List of input secondary L1 RSLC products used		
/science/LSAR/RUNW/metadata/processingInformation/inputs/configFiles		
Type: string	**Shape: (numberOfInputConfigFiles)**	
Description: List of input config files used		
/science/LSAR/RUNW/metadata/processingInformation/inputs/demSource		
Type: string	**Shape: scalar**	
Description: Description of the input digital elevation model (DEM)		

/science/LSAR/RUNW/metadata/processingInformation/inputs/orbitFiles	
Type: string	**Shape: (numberOfInputOrbitFiles)**
Description: List of input orbit files used	

5.5 Other Radar Metadata

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

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

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

5.6 Geolocation Grid

Table 5-6 NISAR HDF5 variables related to metadata cube

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

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

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

6 METADATA CUBE

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

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

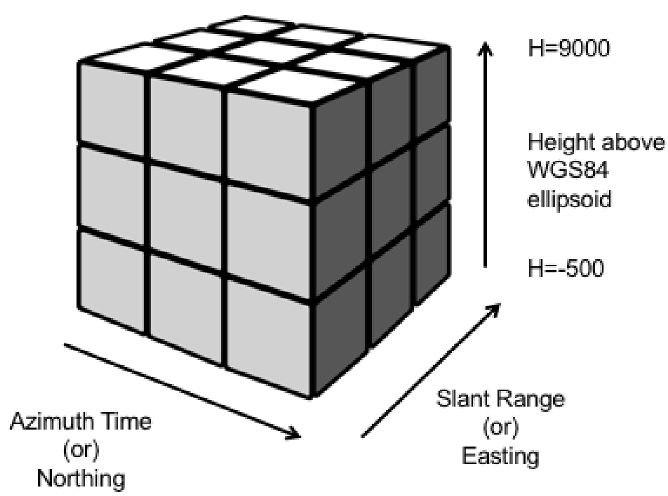

Figure 6-1. Metadata cube layer schematic

6.1 Metadata Cube Interpolation Example

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

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

Table 6-1. Example metadata cube properties

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

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

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

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

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

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

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

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

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

6.2 Metadata Cube Usage Note

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

APPENDIX A: ACRONYMS

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

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

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