NASA SDS Product Specification

Level-2 Geocoded Polarimetric Covariance

L2 GCOV

Rev D

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DOCUMENT CHANGE LOG

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Initial Release	Sep 15, 2019	All	N/A	New document LRR 044743 for NISAR ISRO LRR 044744 for NISAR JPL Sharma LRR 044745 for NISAR ADT Brancato & Shiroma
Rev A	June 15, 2020	Sec 1.3. Sec 2.1. Sec 4.4, Sec 5.3	 10	Release 1. Update document lists. Update product flow. Update product content.
Rev A ER R1.1	December 7, 2020	None	N/A	Minor wording cleanup. No product changes. For completeness for ER1.1
Rev A (R1.1) Working Version	February, 5, 2021	Sec 2.1, Sec 2.2, Sec 3.2, Sec 4.4	N/A	For Release R1.1. LRR-054214 for NISAR Science Team
Rev A (R2) 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. LRR056765 for NISAR Science Team LRR056772 for ISRO
Rev A (R2) Working Version 2	July 15, 2021	Sec 2.2, Sec 4.3.1, Sec 6	N/A	For Release R2.
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Rev A (R3) Working Version	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 products in Table 2-1. Updated product dependency Figure 2-1. Added missing and new acronyms in Appendix A. Removed incomplete LRR number in the footer.
Rev A (R3.1) Working Version	August 05, 2022	Signature page, Sec 1.3	N/A	Updated signature page; updated reference to the RSLC Product Specification Document; Added offset products to Figure 2-1.
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Rev B (R3.4)	November 9, 2023	Table 3.4, Table 3.8, Sec 4.3.1, Sec 4.4.2, Sec 5,	N/A	For Release R3.4. Table 3.4. Table 3.8. Sec 4.3.1. Substituted the RTC ANF layer with the RTC Gamma-To-

		Sec. 5.2, Sec 5.3, Sec. 5.4, Sec 5.5, Sec. 5.8, Sec. 5.6, and Sec 5.7		Sigma Factor layer. Sec 4.4.2. Added source data. Sec 5. Formatted the width of all tables. Sec. 5.2. Added granuleId, updated shape and description of fields isUrgentObservation and isGeocoded. Sec 5.3. Update description of fields xCoordinates and yCoordinates. Moved sourceData fields to a new section (Sec. 5.5). Sec 5.4 & 5.8 added projection information. Sec. 5.6 simplified paths to multilooking parameters, added outputBackscatterExpressionConvention, moved fields under processingInformation/inputs under metadata/sourceData. Sec 5.7 added referenceEpoch.
Rev C (R4.0)	February 7, 2024	Sec. 1.3, Table 2-1, Table 2-2, Sec. 2.2, Table 2-3, Table 3-4, Table 3-5, Table 3-8, Sec. 3.2.4, Sec. 4, Table 5-1 to Table 5.8, and Sec. 6	N/A	For Release 4.0. Removed prefix indicating the product level (e.g., L2_GCOV was renamed to GCOV). Sec. 1.3 Updated list of applicable and reference documents, Table 2-1. Added product level to the first column. Updated product descriptions. Table 2-2. Updated format and product level descriptions. Sec. 2.2 Improved text. Table 2-3. Added RSLC range spacing. Updated ground range spacing. Updated pixel spacing of 5 MHz products to 80m. Table 3-4. Updated the Description and Value of the field Conventions. Table 3-5. Removed unused Attributes and updated descriptions. Table 3-8. Removed polarization RVRH, Included Sec. 3.2.4. Georeferenced HDF5 Datasets. Sec. 4. Reviewed text of the entire section. Tables 5-1 to 5-8. Updated tables with latest product xml. Table 5-3 Removed polarization RVRH. Table 5.5. Added source data swaths HDF5 Group ".../metadata/sourceData/swaths". Sec. 6. Substituted perpendicular baseline with elevation angle
Rev D (R4.0.2)	May 30, 2024	Sec 4.3.3, Sec. 5	N/A	For Release 4.0.2. Added Sec. 3.8 Cloud Optimized HDF5 Files. Added Sec. 4.2.1 Composite Release Identifier. Added Sec. 4.3.3 Mask. Sec. 5.1: Added dopplerCentroidTimeLength, dopplerCentroidTimeLength, dopplerCentroidShape, numberOfInputTecFiles. 5.2: Added or updated boundingPolygon, compositeReleaseId. Sec. 5.4. Added parameter rfiLikelihood to all frequencies and polarizations; deleted crosstalk/projection; updated Crosspol. Sec. 5.5: Added or updated all fields under processingInformation/parameters; updated descriptions of all fields under processingInformation/algorithms through azimuthCompression. Sec. 5.6. Deleted rfiCorrection; added or updated referenceTerrainHeight, dopplerCentroid, tecFiles. Sec. 5.7: Updated interpMethod, orbitType, attitudeType. Cleared for public release. URS CL#24-3343.
* *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 Level-2 (L2) Geocoded Polarimetric Covariance (GCOV) product to be generated by the NASA Science Data System (SDS) and provided to the Distributed Active Archive Center (DAAC) at the Alaska Satellite Facility (ASF). This data product is usually referenced by the short name GCOV.

1.2 Document Organization

Section 2 provides an overview of the product.

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

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

Section 5 provides a detailed identification of the individual fields within the GCOV 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.

Appendix B provides a description of geolocation grids and projection systems used for the product.

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, Rev A, February 6, 2024

[AD2] NISAR NASA SDS Algorithm Development Plan, JPL D-95678, Initial, September 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, August 14, 2018

[AD5] NISAR SDS ADT Calibration and Validation Plan, JPL D-102256, Rev A, November 20, 2023

[AD6] NISAR NASA SDS L4 Software Management Plan (SMP), JPL D-95656, Rev A, September 19, 2019

[AD7] ISO-19115-2, https://www.iso.org/obp/ui/#iso:std:iso:19115:-2:ed-2:v1:en

Reference Documents

[RD1] G. H. X. Shiroma, M. Lavalle and S. M. Buckley, "An Area-Based Projection Algorithm for SAR Radiometric Terrain Correction and Geocoding," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, pp. 1-23, 2022, Art no. 5222723, doi: 10.1109/TGRS.2022.3147472. [link]

[RD2] NISAR NASA SDS Algorithm Theoretical Basis Document, JPL D-95677, Rev A, November 12, 2023

[RD3] EOSDIS Handbook, July 2016, retrieved from https://cdn.earthdata.nasa.gov/conduit/upload/5980/EOSDISHandbookWebFinaL2.pdf

[RD4] NISAR SDS L-SAR File Naming Conventions, JPL D-102255, Rev A, April 28, 2023

[RD5] NISAR L1 RSLC Product Specification Document, JPL D-102268, Rev D, May 30, 2024

[RD6] HDF5 documentation at https://portal.hdfgroup.org/documentation, Accessed May 30, 2024.

[RD7] 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.

[RD8] S. R. Cloude and E. Pottier, "A review of target decomposition theorems in radar polarimetry," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 34, no. 2, pp. 498-518, March 1996, doi: 10.1109/36.485127.

The NISAR Level-1 (L1) science requirements are translated into requirements on the various spacecraft and instrument systems, including the requirements related to the processing system producing the Level-0 (L0) to 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 Table 2-1 Product dependency) is distributed as a single Hierarchical Data Format version 5 (HDF5, [RD6]) granule. All metadata and imagery data are packaged in clearly defined subgroups within the granule in compliance with the HDF5 specification. The NISAR product level definitions are given in Table 2-2.

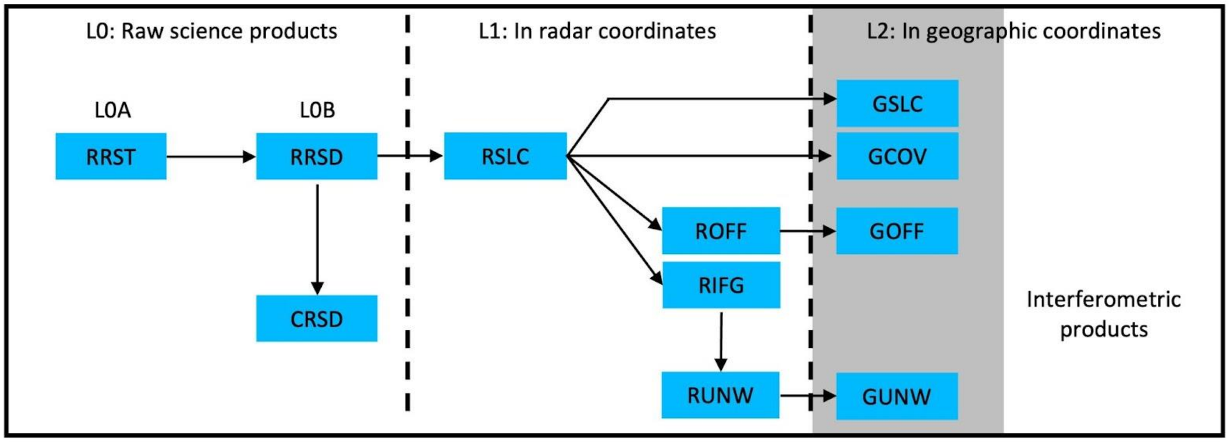

Figure 2-1 Product dependency.

Table 2-1. Key to product dependency diagram.

L0 Product	Scope	Description	Granule Size
Radar Raw Science Telemetry (RRST)	Global	This L0A product contains 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

L1 Product	Scope	Description	Granule Size
Range-Doppler Single Look Complex (RSLC)	Global	The L1 RSLC product contains focused SAR images in range-Doppler coordinates. The RSLC is an input to other L1 or L2 products.	On pre-defined track/frame.
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, ellipsoid and topographic phase flattened and formed with precise coregistration using geometrical offsets and high-resolution pixel offsets obtained from incoherent cross correlation.	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 cross correlation.	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, ellipsoid and topography flattened unwrapped interferogram in Range Doppler coordinates.	On pre-defined track/frame

L2 Product	Scope	Description	Granule Size
Geocoded SLC (GSLC)	Global and all channels.	Single Look Complex SAR image on geocoded map coordinate system.	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.	Unfiltered and unculled layers of pixel offsets in with different resolutions obtained from incoherent cross correlation and geocoded on map coordinate system.	On predefined track/frame
Geocoded Nearest-Time Unwrapped Interferogram (GUNW)	Global. Nearest pair in time and co-pol channels only.	Geocoded, multi-looked, ellipsoid and topography flattened unwrapped interferogram	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 product 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, time-ordered unprocessed instrument data at original resolution, time ordered, all communications artifacts removed.
Level 1	Processed instrument data, focused to full resolution complex images or derived radar parameters including interferometric phase and pixel offsets, in native radar coordinates system.
Level 2	Focused radar imagery or derived radar parameters projected to a map coordinate system.
Level 3	Derived geophysical parameters on geocoded grids with the same or coarser posting as Level 1 or Level 2 products.

2.2 GCOV Product Overview

The GCOV product is an L2 product derived from the L1 Range Doppler Single Look Complex (RSLC) product providing terrain-corrected polarimetric covariance projected onto a predefined Universal Transverse Mercator (UTM) or polar stereographic projection system grid (Appendix B: Geocoded Product Grids).

RSLC radar samples, organized as a polarimetric scattering vector, are cross-correlated with the scattering vector’s conjugate transpose, originating the polarimetric covariance matrix expressed in the same grid as the RSLC product grid (range-Doppler grid). The magnitude of the resulting polarimetric covariance terms is strongly affected by the topography, with areas facing the sensor becoming brighter and areas away from the sensor turning darker in the images, biasing covariance measurements. To reduce the effect of the topography, an area-based radiometric terrain correction (RTC) is applied over the covariance terms, normalizing the backscatter coefficient beta0 to gamma0 [RD1][RD2]. The normalized covariance terms are then geocoded (map projected) onto the output grid using an area-based adaptive multilooking [RD1][RD2].

Since the polarimetric covariance matrix is Hermitian, only the upper triangular covariance terms are provided. The diagonal terms of the polarimetric covariance matrix are real-valued, representing the radar backscatter associated with each polarimetric channel. The off-diagonal terms of the polarimetric covariance matrix are complex-valued and may or may not be present depending on the GCOV processing mode.

The L-SAR sensor operates at a range of frequencies varying from 1219 MHz to 1296 MHz, with the capability of dividing the acquired spectrum in two frequency bands, rereferred to as frequency A and frequency B. Four single frequency modes are available: 5, 20, 40, or 77 MHz, along with two dual-frequency modes 20 or 40 MHz on the lower part of the spectrum with 5 MHz on the upper part of the spectrum. In the dual-frequency mode, the sensor is capable of acquiring different polarizations on each side of the spectrum.

The pixel spacing of the GCOV terms vary with the input RSLC range bandwidth of the associated frequency band. GCOV terms generated from RSLC products with 5 MHz range bandwidth are sampled at 80 m pixel spacing, GCOV products generated from 20 MHz and 77 MHz range bandwidth modes are sampled at 20 m pixel spacing, and GCOV products generated from the 40 MHz mode are sampled at 10 m pixel spacing (see Table 2-3).

Table 2-3 Pixel spacing of GCOV imagery for a given frequency band based on the RSLC range bandwidth.

RSLC Range Bandwidth (MHz)	RSLC Azimuth Pixel Spacing (m)	RSLC Range Pixel Spacing (m)	RSLC Ground Range Pixel Spacing in Mid-Swath (m)	GCOV Pixel Spacing in Y/Northing (m)	GCOV Pixel Spacing in X/Easting (m)
5	~38.5	~25	~36.3	80	80
20	~5	~6.25	~9.1	20	20
40	~5	~3.12	~4.5	10	10
77	~5	~1.62	~2.4	20	20

The reference DEM for processing and radiometric terrain correcting GCOV products is based on the Copernicus DEM 30m (GLO-30) and Copernicus 90-m (GLO-90) with DEM heights referenced vertically over the World Geodetic System 1984 (WGS84) reference system.

3 PRODUCT ORGANIZATION

3.1 File Format

All NISAR standard products are in the Hierarchical Data Format version 5 (HDF5, [RD6]). 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 [RD6] 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 within a hierarchy of 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 Path	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. The rest of the document from this point on describes the layout of the product containing L-SAR data.

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 the “/science/LSAR/identification/” Group. These data are described further in Sec 4.2 and Sec 5.2.

Table 3-4 Global Attributes of a GCOV product.

Attribute	Format	Description	Value
Conventions	string	NetCDF-4 conventions adopted in this product	CF-1.7
title	string	Product title	NISAR L2 GCOV 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-102274 NISAR NASA SDS Product Specification Level-2 Geocoded Polarimetric Covariance GCOV
contact	string	Contact information for producer of the 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.

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
description	Miscellaneous information about the data or the methods to generate it
long_name	Long descriptive variable name that indicates its content
standard_name	Unique name used to identify the variable. A standard name contains no whitespace and is case sensitive
units	Units of the variable's data elements
valid_max	Maximum theoretical value of the variable (not necessarily the same as maximum value of actual data)
valid_min	Minimum theoretical value of the variable (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 GCOV 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_stddev	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_stddev_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_stddev_imag	Sample standard deviation of the imaginary part of a complex-valued HDF5 Dataset

Table 3-8. HDF5 Datasets populated with statistical attributes that may be present in the GCOV product.

Group Path	HDF5 Datasets	Dataset type
/science/LSAR/GCOV/grids/frequency[A|B]/	HHHH, HVHV, VHVH, VVVV, RHRH, RVRV	Real-valued
/science/LSAR/GCOV/grids/frequency[A|B]/	HHHV, HHVH, HHVV, HVVH, HVVV, VHVV, RHRV	Complex-valued
/science/LSAR/GCOV/grids/frequency[A|B]/	numberOfLooks, rtcGammaToSigmaFactor	Real-valued

3.2.4 Georeferenced HDF5 Datasets

NISAR L2 products contain georeferenced Datasets where the georeferencing information is provided in accordance with Climate and Forecast 1.7 (CF 1.7) conventions.

CF conventions require a "grid mapping" dataset which describes the coordinate system associated with the georeferenced Dataset. For NISAR L2 products, this grid mapping is represented by the Dataset "projection", which is included under the same Group as each georeferenced Dataset. Accordingly, each georeferenced Dataset contains an Attribute “grid_mapping”, whose value is always hard-coded to the string "projection" (Table 3-9).

The value of the "projection" Dataset is set to the European Petroleum Survey Group (EPSG) code of the associated georeferenced Dataset. The "projection" Dataset has Attributes with additional grid mapping information (see

Attribute	Description	Value
grid_mapping	Grid mapping Dataset name	Projection

Table 3-10). More information about the projections used to represent NISAR L2 products are provided in the Appendix B: Geocoded Product Grids.

In addition to a grid mapping dataset, CF conventions use HDF5 Dimension Scales [RD6] to associate coordinates to each georeferenced Dataset. The Dimension Scales employed in NISAR L2 products are the "xCoordinates", "yCoordinates", and "heightAboveEllipsoid" Datasets, which represent the horizontal X- and Y-coordinates, and elevation Z-coordinates, respectively, and are located within the same Group as the associated georeferenced Dataset. These are one dimensional (1-D) vectors with lengths matching the associated Dataset's dimensions; each vector element corresponds to the grid-mapping location at the center of the georeferenced array pixels. "heightAboveEllipsoid" is only included for three-dimensional (3-D) georeferenced Datasets.

The complete listing of all georeferenced HDF5 Datasets within the GCOV product is given in Table 3-11. . Note that the 3-D georeferenced Datasets are contained in the "radarGrid" Group; they are *metadata cubes* which represent the radar geometry in a compact form. Sec. 4.5 contains information about the “radarGrid” Group; Sec. 6 describes metadata cubes and their usage.

Table 3-9. Geolocation attributes for georeferenced HDF5 Datasets.

Attribute	Description	Value
grid_mapping	Grid mapping Dataset name	Projection

Table 3-10. Attributes of HDF5 Datasets “projection” that contains the grid mapping.

Attribute	Description
ellipsoid	Projection ellipsoid
epsg_code	Projection EPSG code
false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection
false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection
grid_mapping_name	Grid mapping variable name
inverse_flattening	Inverse flattening of the ellipsoidal figure
latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection
longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum
semi_major_axis	Semi-major axis
spatial_ref	Spatial reference
utm_zone_number	UTM zone number

Table 3-11. List of georeferenced HDF5 Datasets that may be present in the GCOV product.

Group Path	HDF5 Datasets	Array Dimensions
/science/LSAR/GCOV/grids/frequency[A|B]/	HHHH, HHHV, HHVH, HHVV, HVHV, HVVH, HVVV, VHVH, VHVV, VVVV, RHRH, RHRV, RVRV	2-D
/science/LSAR/GCOV/grids/frequency[A|B]/	numberOfLooks, rtcGammaToSigmaFactor	2-D
/science/LSAR/GCOV/metadata/radarGrid/	slantRange, zeroDopplerAzimuthTime, incidenceAngle, losUnitVectorX, losUnitVectorY, alongTrackUnitVectorX, alongTrackUnitVectorY, elevationAngle, groundTrackVelocity	3-D

3.3 Granule Definition

NISAR GCOV 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 GCOV Granule names will conform to the Standard Product File Naming Scheme [RD4].

3.5 Temporal Organization

Temporal organization is not specifically applicable to the GCOV product, although it is generally arranged in order of increasing azimuth time.

3.6 Spatial Organization

The L2 data are arranged on a uniformly spaced, North-up and West-left grid – i.e., decreasing North or Y coordinate in the row direction and increasing East or X coordinate in the column direction following the row-major order convention of representing 2D raster arrays. The L2 data georeferencing adheres to CF conventions, detailed in Sec. **Error! Reference source not found.**, with projection systems outlined in Appendix B: Geocoded Product Grids.

3.7 Spatial Sampling and Resolution

Some salient features of the output grid for the GCOV product are:

1. The top-left corner of the top-left pixel will correspond to the same geographic coordinate for all imagery layers in an L-SAR GCOV product – frequency A and frequency B.
2. The main (frequency A) and auxiliary (frequency B) bands of L-SAR data will have an exact integer scaling relationship to allow for easy inter-comparison (Table 2-3).

3.7.1 Mosaicking

The spatial sampling of the output grid has been designed to facilitate along-track mosaicking of contiguous GCOV product granules if the user desires. See Appendix B: Geocoded Product Grids for details on the common output grid used for all L2 products.

3.7.2 Partially compressed RSLC data

GCOV imagery samples will include partially and fully compressed RSLC data, identified through the mask layer

3.8 Cloud Optimized HDF5 Files

NISAR science data products utilize several special features of the HDF5 format to optimize file sizes and enable high-performance read access in a cloud environment. A key challenge of cloud data access is the latency associated with calls to the cloud storage API, so the following strategies are used to minimize the number of cloud API calls needed per byte of data read [RD6]:

- Chunks: Large datasets within the products use chunked storage. Every read operation thus fetches at least one entire chunk of data. The chunk size is nominally 512x512 pixels, though the precise chunk dimensions should be obtained using the H5Pget_chunk method of the HDF5 C API (or its equivalent in other language bindings).
- Compression: Data are written using a compression filter, minimizing the amount of data stored and hence transferred over the network. The HDF5 API handles decompression automatically.
- Paging: Files are created with the “paged” file space strategy (H5F_FSPACE_STRATEGY_PAGE in the HDF5 C API). These pages serve as the basic unit of allocation within the file. The page size is chosen larger than the chunk size so that both a chunk of data and its HDF5-internal metadata can be read in a single cloud API call. This parameter may be queried using the H5Pget_file_space_page_size method of the HDF5 C API.

Software that reads NISAR products stored on the cloud should take heed of the following recommendations:

- Set the page buffer size to a multiple of the file space page size using H5Pset_page_buffer_size in the HDF5 C API. This enables caching logic that reduces the number of cloud API calls in the file driver.
- Implement chunk-aligned data access patterns. Reads in multiples of the chunk size (and aligned with chunk boundaries) are most efficient.
- If other access patterns are desired, try setting the read cache large enough to hold all the chunks that may be re-read. For example, line-by-line access can still be efficient if the read cache is large enough to hold N lines, where N is the chunk dimension. That way lines can be read from the cache instead of fetching the same set of chunks N times over the network. The cache size may be set globally using the H5Pset_cache or locally with the H5Pset_chunk_cache methods of the HDF5 C API.

Note that, in general, these optimizations require knowledge of the file contents. Therefore, the most robust approach is to open the file, inspect the contents (e.g., chunk size, page size, and dataset dimensions) and then re-open the file with optimal parameters.

4 LEVEL 2 GEOCODED POLARIMETRIC COVARIANCE PRODUCT

In this section, we briefly describe the layout of GCOV data and associated metadata in the NISAR HDF5 file.

There are four products to support the NISAR NASA science disciplines. The GCOV product provides the geocoded polarimetric covariance in the UTM or a polar stereographic projection system (see Appendix B: Geocoded Product Grids) and it is derived from the Level-1 RSLC product using a DEM. The GCOV product can be directly overlaid on a map or combined with other similar GCOV products to create change maps, for example.

As explained in Section 2.2, the GCOV product is organized by the available frequency bands, i.e., frequency A or B, or both. For each frequency band, the GCOV product contains multiple images representing the real or complex covariance terms. These images are normalized to gamma0 in a processed called radiometric terrain correction, to reduce the dependence of the covariance terms with respect to the terrain. Conversion to the backscatter coefficient sigma0 can be accomplished by using the area normalization factor provided at the same posting as the imagery layers.

4.1 Dimensions and Shapes of Data

Information on the dimensions and shapes of the data items in various data tables is 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 the product is given under the Group "/science/LSAR/identification/" (Sec 5.2). This includes information such as orbit, cycle, track, and frame numbers, acquisition times, a polygon representing the bounding box of the included imagery in geographic coordinates, and product version, product version, and product specification version (i.e., the version number of this document).

4.2.1 Composite Release Identifier

The Composite Release Identifier (CRID) is a global version identifier documenting the algorithms and the overall status of the science data system used to generate the product. The CRID follows the format *EPMMmp* where:

- **E (Environment)**: a single character representing the environment or the venue where the product was generated. It can assume the values:
  - *A*: if the product was generated in the Algorithm Development environment
  - *D*: if the product was generated in the Development environment
  - *P*: if the product was generated in the Production environment
  - *T*: if the product was generated in the Integration and Test (I&T) environment
- **P (Mission Phase)**: a single numerical digit indicating the mission phase in which the product was generated. It can assume the following values:
  - *0*: for pre-launch (Phase D)
  - *1*: for primary science phase operations (Phase E)
  - *2*: extended mission (Phase E)
  - *3*: post-operations (Phase F), decommissioning, end of mission processing
- **MM (Major Release)**: two numeric digits monotonically increasing between 0 and 99. The Major Release resets to zero upon a change in the Mission Phase identifier. A change in the Major Release indicates a major change in the products i.e., a change to one or more algorithms or to the processing rules having a significant impact on the science content of the product. The Major Release stands as a composite of the versions of all the algorithms used in the science data production systems. Individual algorithm versions are allocated in the product metadata.
- **m (Minor Release):** a single numeric digit increasing monotonically between 0 and 1 indicating a minor update to the product and/or the data system. A change in the Minor Release identifier indicates minor algorithm changes (e.g., bug fixes, small functional updates) that do not have a significant impact on the product. The Minor Release identifier resets to zero upon every update to the Major Release identifier
- **p (Patch Release)**: a single numerical digit monotonically increasing between 0 and 1. A change in the Patch Release identifier indicates an update to the science data system software that has undergone the System Deployment Review to fix a critical bug. The Patch Release resets to zero upon updates to the Major Release or Minor Release identifiers.

4.3 Geocoded Polarimetric Covariance Terms

The primary data elements of the GCOV product are the images of the geocoded polarimetric covariance terms, stored under the HDF5 Group “/science/LSAR/GCOV/grids /frequency[A|B]”. The complete list of possible data fields is given in Sec 5.3.

GCOV terms are derived from the RSLC product single-look complex (SLC) data. For each polarimetric channel $P_1, \ldots P_n$, the SLCs can be arranged in the form of scattering vector k_n:

$$k_n = [s_{p1}, s_{p2}, \ldots, s_{pn}]^{\mathrm{T}}$$

where n is the number of polarimetric channels.

The polarimetric covariance matrix in the range-Doppler domain is then obtained by cross multiplying the scattering vector k_n with its conjugate transpose (Hermitian transpose) k_n^{*T} according to:

$$[C_n] = k_n\, k_n^{*T}$$

The diagonal terms of the covariance matrix $[C_n]$ are real-valued and represent the radar backscatter of the polarimetric channels of the scattering vector *k*. The off-diagonal terms are complex-valued and are only computed if the GCOV product was generated in the *full-covariance* mode, which can be verified by the flag "/science/LSAR/GCOV/metadata/processingInformation/parameters/isFullCovariance".

Quad-polarimetric data are represented by the scattering vector k_4:

$$k_4 = [s_{HH}, s_{HV}, s_{VH}, s_{VV}]^T$$

Due to reciprocity between the HV and VH channels, the quad-polarimetric scattering vector k_4 is often reduced to a full-polarimetric scattering vector k_3 where the cross-polarimetric SLCs s_{HH} and s_{HV} are symmetrized into a single channel $\overline{s_{HV}}$. In the computation of the covariance matrix C_3 an additional factor $\sqrt{2}$ is commonly introduced to ensure that the total radar power (sum of the diagonal elements of the matrix) is preserved after polarimetric symmetrization [RD8]:

$$k_3' = [s_{HH}, \sqrt{2}\,\overline{s_{HV}}, s_{VV}]^T$$

However, this would result in GCOV terms with inconsistent power between different polarimetric modes, i.e., terms that include symmetrized cross-polarimetric channels (full-polarimetric data) would have a different power than terms that include non-symmetrized cross-polarimetric channels (e.g., dual polarimetric data). To avoid this, GCOV terms do not include the $\sqrt{2}$ factor due to the reduction of k_4 to k_3:

$$k_3 = [s_{HH}, \overline{s_{HV}}, s_{VV}]^T$$

The full-polarimetric covariance matrix $[C_3]$ is then computed as:

$$[C_3] = k_3\, k_3^{*T} = \begin{bmatrix} s_{hh}s_{hh}^* & s_{hh}\bar{s}_{vh}^* & s_{hh}s_{vv}^* \\ \bar{s}_{vh}s_{hh}^* & \bar{s}_{vh}\bar{s}_{vh}^* & \bar{s}_{vh}s_{vv}^* \\ s_{vv}s_{hh}^* & s_{vv}\bar{s}_{vh}^* & s_{vv}s_{vv}^* \end{bmatrix}$$

A flag in the GCOV product metadata indicates if the polarimetric symmetrization has been applied: "/science/LSAR/GCOV/metadata/processingInformation/parameters/polarimetricSymmetrizationApplied".

The polarimetric covariance matrix $[C_\mathrm{n}]$ is then radiometric terrain corrected and geocoded using an area-based projection algorithm [RD1][RD2] producing the GCOV matrix $[G_\mathrm{n}]$. The HDF5 Datasets containing the GCOV matrix terms are provided under the HDF5 Group "/science/LSAR/GCOV/grids /frequency[A|B]".

4.3.1 Radiometric Terrain Correction Gamma-to-Sigma Factor

The map projected RTC Gamma-To-Sigma factor η is provided as georeferenced HDF5 Dataset under "/science/LSAR/GCOV/grids/frequency[A|B]/rtcGammaToSigmaFactor". The Dataset provides factors to normalize the backscatter normalization convention of the GCOV matrix from gamma0 $[G_\mathrm{n}^{\gamma}]$ to sigma0 $[G_\mathrm{n}^{\sigma\prime}]$:

$$[G_\mathrm{n}^{\sigma\prime}] = \eta\ [G_\mathrm{n}^{\gamma}]$$

It is worth noting that the actual RTC normalization factors applied to the GCOV product are computed over the range Doppler domain using RSLC radar samples at full resolution (i.e., without multilooking) [RD1][RD2]. However, since GCOV terms are provided over map coordinates, the original RTC Gamma-To-Sigma factors are reprojected from the range-Doppler domain to the GCOV grid. This reprojection is performed using the same area-based projection algorithm, i.e., geocoding with adaptive multilooking, used to generate GCOV terms [RD1][RD2]. In this process, the original normalization factors are lost, and therefore, the map projected RTC Gamma-To-Sigma Factor layer provides only an approximation ($[G_\mathrm{n}^{\sigma\prime}]$) for the GCOV matrix normalized to sigma0 $[G_\mathrm{n}^{\sigma}]$ that would be obtained by applying normalization over the range-Doppler domain.

4.3.2 Number of Looks

The GCOV terms are obtained from the geocoding of the RSLC product polarimetric covariance terms using an adaptive area-based multi-looking algorithm [RD1][RD2]. The multilooking window and number of averaged looks vary with the topography and radar geometry. The HDF5 Dataset "/science/LSAR/GCOV/grids/frequency[A|B]/numberOfLooks" provide the number of looks used for computing each GCOV term sample and it is provided in the same geographic grid as the GCOV imagery.

4.3.3 Mask

The mask layer is provided as an unsigned byte (8 bits) HDF5 Dataset located at "/science/LSAR/GCOV/grids/frequency[A|B]/mask. It has the same geographic grid as the

GCOV imagery. Each pixel of the mask layer is associated with the GCOV terms of same indexes. The mask layer pixels provide information about the averaging ensemble of radar samples that originated the GCOV terms through adaptive multilooking [RD1][RD2]. Possible mask layer values are:

- “0”: Invalid or partially focused – the averaging ensemble contains at least one radar sample inside the RSLC image bounds, and at least one sample that is marked as “invalid” or “partially focused”;
- “1” to “5”: Valid – the averaging ensemble contains at least one radar sample inside the RSLC image bounds and all averaged samples are marked as “valid” (“fully focused”). The mask value indicates the sub-swath number from which the majority of radar samples originated, i.e., sub-swath 1 to 5. NISAR RSLC products formed from SweepSAR acquisitions with constant pulse repetition frequency (PRF) will contain 4 to 5 sub-swaths. The RSLC products focused from dithered PRF acquisitions, will contain only one sub-swath to cover the scene and accordingly the value of the valid portion of the mask layer in the GSLC metadata will be 1.;
- “255”: Fill Value - The geographical extents of the GCOV pixel are outside of the RSLC image bounds;

4.4 Radar Metadata

Radar metadata needed to interpret the product, including the calibration information, processing information, source data information, and processing parameters, are organized under the Group “/science/LSAR/GCOV/metadata/”.

4.4.1 Calibration Information

The Group “.../metadata/calibrationInformation/” contains calibration parameters including the complex two-way elevation antenna patterns, under the Group “.../metadata/calibrationInformation/frequency[A|B]/elevationAntennaPattern/”, and the noise-equivalent sigma0 (nes0 or NESZ), under the Group “.../metadata/calibrationInformation/frequency[A|B]/nes0/”, organized by frequency (“A” or “B”) and polarization channels (Dataset names). These variables 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). The complete list of calibration information fields is given in Section 5.4.

4.4.2 Source Data

The Group “.../metadata/sourceData/” (see Sec 5.5) contains relevant information about the input RSLC product that was used to generate the GCOV product. It includes the RSLC identification parameters provided at the Group top level (“.../metadata/sourceData/”); the RSLC processing information parameters provided under the Group “.../metadata/sourceData/processingInformation/parameters/”; the algorithm list that was utilized to generate the RSLC product, under the Group

"/metadata/sourceData/processingInformation/algorithms; and the RSLC swath (radar grid) parameters placed under the Group ".../metadata/sourceData/swaths/".

4.4.3 Processing Information

Metadata giving processing parameters, algorithms, and inputs used are given under the Group "…/metadata/processingInformation/" are detailed in Section 5.6.

4.4.3.1 Parameters

The Group ".../metadata/processingInformation/parameters/" describes product processing parameters obtained from the runconfig (file used to control processing) such as flags identifying corrections applied to the product, e.g., radiometric terrain correction (RTC) ("radiometricTerrainCorrectionApplied"), radio frequency interference (RFI) correction ("rfiCorrectionApplied"), and corrections applied to improve the geolocation accuracy of the product, such as geolocation correction to compensate for ionospheric range delay ("rangeIonosphericGeolocationCorrectionApplied" and "azimuthIonosphericGeolocationCorrectionApplied") and tropospheric range delay ("dryTroposphericGeolocationCorrectionApplied" and "wetTroposphericGeolocationCorrectionApplied"). The ionospheric delay is estimated using GNSS-based TEC data (if available) and corrected during the geocoding process. The tropospheric delay is computed using a static model [RD2] and corrected during focusing of the RSLC product.

This Group also includes processing parameters that vary spatially, such as the Doppler centroid ("dopplerCentroid") and reference terrain height ("referenceTerrainHeight"), organized on a geographic grid with the same coordinate system as the product imagery, but with coarser pixel spacing.

4.4.3.2 Algorithm Information

The processing algorithm information is provided under the Group "/metadata/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.

4.4.3.3 Input Files

All the mission inputs – the L1 RSLC granule, DEM source description, and configuration files are tracked and listed under the Group "/metadata/processingInformation/inputs/".

4.4.4 Other Radar Metadata

Section 5.7 includes the information about the orbit ephemeris used for generating the GCOV under a Group named “/metadata/orbit/”, and the attitude under a Group named “/metadata/attitude/”.

4.4.4.1 Orbit

The orbit ephemeris used for generating the GCOV product can be found under a Group “/metadata/orbit/”. This Group includes time-tagged antenna phase center position and velocity vectors in Earth Centered Earth Fixed (ECEF) cartesian coordinates. The orbit fidelity, such as the Medium-precision Orbit Ephemeris (MOE) utilized in nominal operations, is indicated by the Dataset “orbitType”.

4.4.4.2 Attitude

The attitude state vectors used for generating the GCOV product can be found under a Group named “/metadata/attitude/”. This Group includes time-tagged quaternions and Euler Angles representing the slant range plane from the antenna phase center in ECEF cartesian system. In nominal operations, this would be the restituted attitude state vectors that were used by the L2 processor.

4.5 Radar Grid

The Group "/science/LSAR/GCOV/metadata/radarGrid/” contains information describing the radar geometry during data taking in the form of metadata cubes. The specifications of the metadata cubes provided in the GCOV product are given in Section 5.8.

The representation as data cubes, rather than two-dimensional rasters, is used to reduce the amount of space required to store radar geometry values within NISAR L2 products. This is possible because each radar grid cube contains slowly-varying values in space, that can be described by a low-resolution three-dimensional grid with sufficient accuracy. These values, however, are usually required at the terrain height, often characterized by a fast-varying surface representing the local topography. A higher-resolution DEM can then be used to interpolate radar grid cubes and generate high-resolution maps of the corresponding radar geometry variable. Further information about metadata cubes along with examples on how to interpolate them using a reference DEM is provided in Sec. 6.

The metadata cubes of NISAR L2 products, referred to as *radar grid cubes,* provide radar geometry and radar coordinates of the input RSLC product in the same coordinate system as the NISAR L2 product’s imagery with similar extents (bounding box) but coarser pixel spacing. The three-dimensional geographic grid is defined by the HDF5 Datasets “xCoordinates” (defining the X component), “yCoordinates” (Y component), and “heightAboveEllipsoid” (height above the

WGS84 ellipsoid), common to all radar grid cubes, and conforming to CF conventions 1.7. More details on the georeferencing of radar grid cubes can be found in Section 3.2.4.

The GCOV product includes the following list of radar grid cubes Datasets::

1. “slantRange” and “zeroDopplerAzimuthTime” describing the slant-range position in meters and the zero-Dopper azimuth time in seconds, respectively, with respect to the product’s geographical grid.
2. “losUnitVectorX” and “losUnitVectorY” identifying the X (e_x) and Y (e_y) components, respectively, of the line-of-sight (LOS) unit vector, i.e., the vector from the target to the sensor, in the east-north-up (ENU) coordinate system with respect to the geographic grid.

   Note that the third (“up”) component of the LOS unit vector $e_z$is not provided in the product as it can be derived from the other two components:

$$e_z = \sqrt{1 - e_x^2 - e_y^2}$$

3. “alongTrackUnitVectorX” and “alongTrackUnitVectorY” containing the X and Y components, respectively, of the along-track unit vector, i.e., the projection of the platform velocity vector at the ground height) in UTM or polar stereographic projection system coordinates.
4. “incidenceAngle containing the incidence angle, i.e., the angle between the LOS vector and the normal to the ellipsoid at the target height
5. “elevationAngle” containing the elevation angle i.e., the angle between the LOS vector and the normal to the ellipsoid at the sensor
6. “groundTrackVelocity” containing the ground track velocity i.e., the absolute value of the platform velocity scaled at the target height

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 file. 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 GCOV product.

Name	Shape	Description
scalar	scalar	scalar values
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
numberOfFrequencyACovarianceTerms	scalar	Number of covariance terms associated with L-SAR frequency A
frequencyAWidth	scalar	Number of pixels in all L-SAR frequency A imagery datasets
frequencyALength	scalar	Number of lines in all L-SAR frequency A imagery datasets
complexDataFrequencyAShape	(frequencyALength, frequencyAWidth)	Shape associated with L-SAR frequency A complex-valued imagery datasets
realDataFrequencyAShape	(frequencyALength, frequencyAWidth)	Shape associated with L-SAR frequency A real-valued imagery datasets
numberOfFrequencyBPolarizations	scalar	Number of polarization layers associated with L-SAR frequency B
numberOfFrequencyBCovarianceTerms	scalar	Number of covariance terms associated with L-SAR frequency B
frequencyBWidth	scalar	Number of pixels in all L-SAR frequency B imagery datasets
frequencyBLength	scalar	Number of lines in all L-SAR frequency B imagery datasets
complexDataFrequencyBShape	(frequencyBLength, frequencyBWidth)	Shape associated with L-SAR frequency B complex-valued imagery datasets
realDataFrequencyBShape	(frequencyBLength, frequencyBWidth)	Shape associated with L-SAR frequency B real-valued imagery datasets
radarGridShape	(radarCubeLength, radarCubeWidth)	Shape associated with 2D rasters on same grid as metadata cubes
radarCubeShape	(radarCubeHeight, radarCubeLength, radarCubeWidth)	Shape associated with metadata cubes
radarCubeHeight	scalar	Height dimension of the metadata cube
radarCubeLength	scalar	Length dimension of the metadata cube
radarCubeWidth	scalar	Width dimension of the metadata cube
dopplerCentroidLength	scalar	Length dimension of Doppler centroid grid
dopplerCentroidWidth	scalar	Length dimension of Doppler centroid grid

dopplerCentroidShape	(dopplerCentroidLength, dopplerCentroidWidth)	Shape of the Doppler centroid grid
calibrationLength	scalar	Length of calibration LUTs
calibrationWidth	scalar	Width of calibration LUTs
calibrationScaleShape	(calibrationLength, calibrationWidth)	Shape of calibration LUTs
antennaPatternComplexShape	(calibrationLength, calibrationWidth)	Shape of antenna pattern datasets
crosstalkComplexShape	scalar	Shape of crosstalk datasets
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
orbitListLength	scalar	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
numberOfInputL1Files	scalar	Number of input L1 granules
numberOfInputOrbitFiles	scalar	Number of input orbit files
numberOfInputTecFiles	scalar	Number of input total electon content (TEC) 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	1
/science/LSAR/identification/trackNumber		
Type: UByte	**Shape: scalar**	
Description: Track number		
	units	1
/science/LSAR/identification/frameNumber		
Type: UInt16	**Shape: scalar**	
Description: Frame number		
	units	1
/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, either "Left" or "Right"		
/science/LSAR/identification/orbitPassDirection		
Type: string	**Shape: scalar**	
Description: Orbit direction, either "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		
/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 representing the bounding polygon of the image. Horizontal coordinates are WGS84 longitude followed by latitude (both in degrees), and the vertical coordinate is the height above the WGS84 ellipsoid in meters. The first point corresponds to the start-time, near-range radar coordinate, and the perimeter is traversed in counterclockwise order on the map. This means the traversal order in radar coordinates differs for left-looking and right-looking sensors. The polygon includes the four corners of the radar grid, with equal numbers of points distributed evenly in radar coordinates along each edge		
	ogr_geometry	polygon
	epsg	4326
/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, either "L" or "S"		
/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.		
/science/LSAR/identification/compositeReleaseId		
Type: string	**Shape: scalar**	
Description: Unique version identifier of the science data production system		

5.3 Radar Imagery

Table 5-3 NISAR HDF5 variables related to SAR imagery.

Product Imagery Variables		
/science/LSAR/GCOV/grids/frequencyA/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyAPolarizations)**
Description: List of processed polarization layers with frequency A		
/science/LSAR/GCOV/grids/frequencyA/listOfCovarianceTerms		
Type: string		**Shape: (numberOfFrequencyACovarianceTerms)**
Description: List of processed covariance terms		
/science/LSAR/GCOV/grids/frequencyA/yCoordinateSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal spacing in meters between consecutive lines		
	units	meters
/science/LSAR/GCOV/grids/frequencyA/xCoordinateSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal spacing in meters between consecutive pixels		
	units	meters
/science/LSAR/GCOV/grids/frequencyA/numberOfLooks		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Number of averaged radar-grid pixels for covariance estimation		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/projection		
Type: UInt32		**Shape: scalar**
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/grids/frequencyA/xCoordinates		
Type: Float64		**Shape: (frequencyAWidth)**
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/grids/frequencyA/yCoordinates		
Type: Float64		**Shape: (frequencyALength)**
Description: Y coordinates in specified projection		

	units	meters
/science/LSAR/GCOV/grids/frequencyA/rtcGammaToSigmaFactor		
Type: Float32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Radiometric terrain correction factor to normalize GCOV terms from gamma0 to sigma0		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/mask		
Type: UByte	**Shape: (frequencyALength, frequencyAWidth)**	
Description: GCOV terms mask		
	valid_min	0
	_FillValue	255
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HHHH		
Type: Float32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance between HH and HH		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HHHV		
Type: CFloat32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance between HH and HV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HHVH		
Type: CFloat32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance betweeen HH and VH		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HHVV		
Type: CFloat32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance between HH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HVHV		
Type: Float32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance between HV and HV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/HVVH		
Type: CFloat32	**Shape: (frequencyALength, frequencyAWidth)**	
Description: Covariance between HV and VH		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1

/science/LSAR/GCOV/grids/frequencyA/HVVV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance betweeen HH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/VHVH		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between VH and VH		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/VHVV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance betweeen VH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/VVVV		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between VV and VV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/RHRH		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RH and RH		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/RHRV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RH and RV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/RVRV		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RV and RV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyA/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	1
/science/LSAR/GCOV/grids/frequencyB/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyBPolarizations)**
Description: List of processed polarization layers with frequency B		

/science/LSAR/GCOV/grids/frequencyB/listOfCovarianceTerms		
Type: string		**Shape: (numberOfFrequencyBCovarianceTerms)**
Description: List of processed covariance terms		
/science/LSAR/GCOV/grids/frequencyB/yCoordinateSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal spacing in meters between consecutive lines		
	units	meters
/science/LSAR/GCOV/grids/frequencyB/xCoordinateSpacing		
Type: Float64		**Shape: scalar**
Description: Nominal spacing in meters between consecutive pixels		
	units	meters
/science/LSAR/GCOV/grids/frequencyB/projection		
Type: UInt32		**Shape: scalar**
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/grids/frequencyB/xCoordinates		
Type: Float64		**Shape: (frequencyBWidth)**
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/grids/frequencyB/yCoordinates		
Type: Float64		**Shape: (frequencyBLength)**
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/grids/frequencyB/numberOfLooks		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Number of averaged radar-grid pixels for covariance estimation		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/rtcGammaToSigmaFactor		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Radiometric terrain correction factor to normalize GCOV terms from gamma0 to sigma0		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/mask		
Type: UByte		**Shape: (frequencyBLength, frequencyBWidth)**

Description: GCOV terms mask		
	valid_min	0
	_FillValue	255
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HHHH		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and HH		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HHHV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and HV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HHVH		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen HH and VH		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HHVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HVHV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HV and HV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HVVH		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HV and VH		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/HVVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen HH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/VHVH		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between VH and VH		
	valid_min	0

	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/VHVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen VH and VV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/VVVV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between VV and VV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/RHRH		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RH and RH		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/RHRV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RH and RV		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/RVRV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RV and RV		
	valid_min	0
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/grids/frequencyB/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	1

5.4 Calibration Information

Table 5-4 NISAR HDF5 variables related to calibration.

Calibration-related variables		
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/yCoordinates		
Type: Float64	**Shape: (calibrationLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	

Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RH		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RV		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/projection		
Type: UInt32		**Shape: scalar**
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/yCoordinates		
Type: Float64		**Shape: (calibrationLength)**
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/xCoordinates		
Type: Float64		**Shape: (calibrationWidth)**
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HH		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HV		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection

	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	_FillValue	(nan+nan*j)
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/yCoordinates		
Type: Float64	**Shape: (calibrationLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/HH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	

Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/HV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/VH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/VV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/RH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/RV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/HH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.

	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/yCoordinates		
Type: Float64	**Shape: (calibrationLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/HV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/VH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/VV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/RH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/RV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	_FillValue	nan
	grid_mapping	projection
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/txHorizontalCrosspol		
Type: CFloat32	**Shape: ()**	
Description: Crosstalk in H-transmit channel expressed as ratio txV / txH		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/txVerticalCrosspol		
Type: CFloat32	**Shape: ()**	
Description: Crosstalk in V-transmit channel expressed as ratio txH / txV		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/rxHorizontalCrosspol		
Type: CFloat32	**Shape: ()**	

Description: Crosstalk in H-receive channel expressed as ratio rxV / rxH		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/rxVerticalCrosspol		
Type: CFloat32	**Shape: ()**	
Description: Crosstalk in V-recieve channel expressed as ratio rxH / rxV		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/commonDelay		
Type: Float64	**Shape: scalar**	
Description: Range delay correction applied to all polarimetric channels		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/faradayRotation		
Type: Float64	**Shape: scalar**	
Description: Faraday rotation correction applied in processing		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HH/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HV/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VH/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VV/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RH/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RV/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HH/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HV/rfiLikelihood		
Type: Float64	**Shape: scalar**	
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		

	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VH/rfiLikelihood		
Type: Float64		**Shape: scalar**
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VV/rfiLikelihood		
Type: Float64		**Shape: scalar**
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RH/rfiLikelihood		
Type: Float64		**Shape: scalar**
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RV/rfiLikelihood		
Type: Float64		**Shape: scalar**
Description: Severity of radio frequency interference (RFI) contamination in the data. Value is in the interval [0,1], where 0: lowest severity, and 1: highest severity (or NaN if RFI detection was skipped)		
	units	1
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyA/HV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HV channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/HV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyA/VH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to VH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyA/VV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to VV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VV channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/VV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyA/RH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to RH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to RH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyA/RV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RV/differentialPhase		

Type: Float64		**Shape: scalar**
Description: Phase correction applied to RV channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/RV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to RV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/commonDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to all polarimetric channels		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/faradayRotation		
Type: Float64		**Shape: scalar**
Description: Faraday rotation correction applied in processing		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/HV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to HV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to HV channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/HV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to HV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/VH/differentialDelay		
Type: Float64		**Shape: scalar**

Description: Range delay correction applied to VH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/VV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to VV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to VV channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/VV/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to VV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/RH/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RH channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RH/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to RH channel		
	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RH/scaleFactor		
Type: Float64		**Shape: scalar**
Description: Scale factor applied to RH channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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/GCOV/metadata/calibrationInformation/frequencyB/RV/differentialDelay		
Type: Float64		**Shape: scalar**
Description: Range delay correction applied to RV channel		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RV/differentialPhase		
Type: Float64		**Shape: scalar**
Description: Phase correction applied to RV channel		

	units	radians
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/RV/scaleFactor		
Type: Float64	**Shape: scalar**	
Description: Scale factor applied to RV channel complex amplitude (at antenna boresite)		
	units	1
/science/LSAR/GCOV/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 Source Data Metadata

Table 5-5 NISAR HDF5 HDF5 variables related to the source data metadata.

Source data variables		
/science/LSAR/GCOV/metadata/sourceData/productVersion		
Type: string	**Shape: scalar**	
Description: Product version of the source data		
/science/LSAR/GCOV/metadata/sourceData/lookDirection		
Type: string	**Shape: scalar**	
Description: Look direction, either "Left" or "Right"		
/science/LSAR/GCOV/metadata/sourceData/productLevel		
Type: string	**Shape: scalar**	
Description: Source data product level. 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/GCOV/metadata/sourceData/processingDateTime		
Type: string	**Shape: scalar**	
Description: Source data processing UTC date and time in the format YYYY-mm-ddTHH:MM:SS		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/runConfigurationContents		
Type: string	**Shape: scalar**	
Description: Contents of the run configuration file associated with the processing of the source data		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/referenceTerrainHeight		
Type: Float32	**Shape: (dopplerCentroidTimeLength)**	
Description: Reference terrain height corresponding to the source data processing information records		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to source data processing information records		
	units	seconds since YYYY-mm-ddTHH:MM:SS
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	
Description: Slant range dimension corresponding to source data processing information records		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyA/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to source data processing information records		
	units	seconds since YYYY-mm-ddTHH:MM:SS
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyA/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	
Description: Slant range dimension corresponding to the source data processing information records		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler centroid for frequency A corresponding to the source data processing information records		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyB/zeroDopplerTime		
Type: Float64	**Shape: (dopplerCentroidTimeLength)**	
Description: Zero doppler time dimension corresponding to source data processing information records		
	units	seconds since YYYY-mm-ddTHH:MM:SS
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyB/slantRange		
Type: Float64	**Shape: (dopplerCentroidSlantRangeWidth)**	

Description: Slant range dimension corresponding to source data processing information records		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/processingInformation/parameters/frequencyB/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler centroid for frequency B corresponding to the source data processing information records		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rfiDetection		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) detection corresponding to the source data processing information records		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rfiMitigation		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) mitigation corresponding to the source data processing information records, either "ST-EVD" or "FDNF" (or "disabled" if no RFI mitigation was applied)		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rangeCompression		
Type: string	**Shape: scalar**	
Description: Algorithm for focusing the data in the range direction corresponding to the source data processing information records		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/elevationAntennaPatternCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating the antenna pattern corresponding to the source data processing information records		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rangeSpreadingLossCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating range fading corresponding to the source data processing information records		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/dopplerCentroidEstimation		
Type: string	**Shape: scalar**	
Description: Algorithm for calculating Doppler centroid corresponding to the source data processing information records		
	algorithm_type	doppler centroid estimation
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/azimuthPresumming		
Type: string	**Shape: scalar**	
Description: Algorithm for regridding and filling gaps in the raw data in azimuth corresponding to the source data processing information records		
	algorithm_type	azimuth regridding
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/azimuthCompression		
Type: string	**Shape: scalar**	
Description: Algorithm for focusing the data in the azimuth direction corresponding to the source data processing information records		
	algorithm_type	azimuth regridding
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/softwareVersion		
Type: string	**Shape: scalar**	
Description: Software version used for processing the source data		
/science/LSAR/GCOV/metadata/sourceData/swaths/zeroDopplerStartTime		
Type: string	**Shape: scalar**	
Description: Azimuth start time of the source data product		
	units	seconds
/science/LSAR/GCOV/metadata/sourceData/swaths/zeroDopplerTimeSpacing		
Type: Float64	**Shape: scalar**	
Description: Time interval in the along-track direction of the source data in seconds		
	units	seconds
/science/LSAR/GCOV/metadata/sourceData/swaths/numberOfAzimuthLines		

Type: UInt64	**Shape: scalar**	
Description: Number of azimuth lines within the source data product		
	units	seconds
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/rangeBandwidth		
Type: Float64	**Shape: scalar**	
Description: Source data processed range bandwidth in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/azimuthBandwidth		
Type: Float64	**Shape: scalar**	
Description: Source data processed azimuth bandwidth in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/centerFrequency		
Type: Float64	**Shape: scalar**	
Description: Center frequency of the processed source data image in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/slantRangeStart		
Type: Float64	**Shape: scalar**	
Description: Source data slant range start distance		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/slantRangeSpacing		
Type: Float64	**Shape: scalar**	
Description: Slant range spacing of the source data in meters		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyA/numberOfRangeSamples		
Type: UInt64	**Shape: scalar**	
Description: Number of slant range samples for each azimuth line within the source data		
	units	1
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/rangeBandwidth		
Type: Float64	**Shape: scalar**	
Description: Source data processed range bandwidth in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/azimuthBandwidth		
Type: Float64	**Shape: scalar**	
Description: Source data processed azimuth bandwidth in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/centerFrequency		
Type: Float64	**Shape: scalar**	
Description: Center frequency of the processed source data image in hertz		
	units	hertz
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/slantRangeStart		
Type: Float64	**Shape: scalar**	
Description: Source data slant range start distance		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/slantRangeSpacing		
Type: Float64	**Shape: scalar**	
Description: Slant range spacing of the source data in meters		
	units	meters
/science/LSAR/GCOV/metadata/sourceData/swaths/frequencyB/numberOfRangeSamples		
Type: UInt64	**Shape: scalar**	
Description: Number of slant range samples for each azimuth line within the source data		
	units	1

5.6 Processing Information

Table 5-6 NISAR HDF5 variables related to processing parameters.

Processing information variables	
/science/LSAR/GCOV/metadata/processingInformation/parameters/noiseCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if noise correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessingMultilookingApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if a preprocessing multilooking has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/polarizationOrientationCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the polarization orientation correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/faradayRotationApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the Faraday rotation correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/radiometricTerrainCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the radiometric terrain correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/dryTroposphericGeolocationCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the dry tropospheric correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/wetTroposphericGeolocationCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the wet tropospheric correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/rangeIonosphericGeolocationCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the range ionospheric correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/azimuthIonosphericGeolocationCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the azimuth ionospheric correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/rfiCorrectionApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if an RFI correction has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/postProcessingFilteringApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the post-processing filtering has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/isFullCovariance	
Type: string	**Shape: scalar**
Description: Flag to indicate if the product is full-covariance	
/science/LSAR/GCOV/metadata/processingInformation/parameters/validSamplesSubSwathMaskingApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the valid samples subswath masking has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/shadowMaskingApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the shadow masking has been applied	
/science/LSAR/GCOV/metadata/processingInformation/parameters/polarimetricSymmetrizationApplied	
Type: string	**Shape: scalar**
Description: Flag to indicate if the polarimetric symmetrization has been applied	

/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyA/numberOfRangeLooks		
Type: UInt64	**Shape: scalar**	
Description: Number of range looks applied to the RSLC before geocoding		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyA/numberOfAzimuthLooks		
Type: UInt64	**Shape: scalar**	
Description: Number of azimuth looks applied to the RSLC before geocoding		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyB/numberOfRangeLooks		
Type: UInt64	**Shape: scalar**	
Description: Number of range looks applied to the RSLC before geocoding		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyB/numberOfAzimuthLooks		
Type: UInt64	**Shape: scalar**	
Description: Number of azimuth looks applied to the RSLC before geocoding		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/inputBackscatterNormalizationConvention		
Type: string	**Shape: scalar**	
Description: Backscatter normalization convention of the source data		
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/outputBackscatterNormalizationConvention		
Type: string	**Shape: scalar**	
Description: Backscatter normalization convention of the primary data associated with this product		
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/outputBackscatterExpressionConvention		
Type: string	**Shape: scalar**	
Description: Backscatter expression convention		
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/memoryMode		
Type: string	**Shape: scalar**	
Description: Radiometric terrain correction (RTC) memory mode		
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/minRtcAreaNormalizationFactorInDB		
Type: Float64	**Shape: scalar**	
Description: Radiometric terrain correction (RTC) minimum area normalization factor value in dB computed as `10 * log10(area_out / area_in)` where `area_in` and `area_out` are the reference surfaces associated with the source data (input) and GCOV terms (output) backscatter conventions, respectively		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/geogridUpsampling		
Type: Float64	**Shape: scalar**	
Description: Radiometric terrain correction (RTC) geogrid upsampling		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/memoryMode		
Type: string	**Shape: scalar**	
Description: Geocoding memory mode		
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/geogridUpsampling		
Type: Float64	**Shape: scalar**	
Description: Geocoding geogrid upsampling		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/minBlockSize		
Type: UInt64	**Shape: scalar**	
Description: Minimum block size in megabytes (MB) per thread		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/maxBlockSize		
Type: UInt64	**Shape: scalar**	

Description: Maximum block size in megabytes (MB) per thread		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/isSourceDataUpsampled		
Type: string	**Shape: scalar**	
Description: Flag to indicate if the source data is upsampled for geocoding		
/science/LSAR/GCOV/metadata/processingInformation/parameters/geo2rdr/convergenceThreshold		
Type: Float64	**Shape: scalar**	
Description: Slant range convergence threshold for geo2rdr transformation		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geo2rdr/maxNumberOfIterations		
Type: UInt64	**Shape: scalar**	
Description: Maximum number of iterations for geo2rdr transformation		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/geo2rdr/deltaRange		
Type: Float64	**Shape: scalar**	
Description: Step size for computing numerical gradient of Doppler in meters for geo2rdr transformation		
	units	1
/science/LSAR/GCOV/metadata/processingInformation/parameters/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/processingInformation/parameters/yCoordinates		
Type: Float64	**Shape: (dopplerCentroidLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/referenceTerrainHeight		
Type: Float32	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: Reference Terrain Height as a function of map coordinates		
	_FillValue	nan
	grid_mapping	projection
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid

	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/yCoordinates		
Type: Float64	**Shape: (dopplerCentroidLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler centroid for frequency A		
	_FillValue	nan
	grid_mapping	projection
	units	hertz
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/yCoordinates		
Type: Float64	**Shape: (dopplerCentroidLength)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinates in specified projection		

	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidTimeLength, dopplerCentroidSlantRangeWidth)**	
Description: 2D LUT of Doppler centroid for frequency B		
	_FillValue	nan
	grid_mapping	projection
	units	hertz
/science/LSAR/GCOV/metadata/processingInformation/parameters/runConfigurationContents		
Type: string	**Shape: scalar**	
Description: Contents of the run configuration file with parameters used for processing		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/demInterpolation		
Type: string	**Shape: scalar**	
Description: DEM interpolation method		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/geocoding		
Type: string	**Shape: scalar**	
Description: Geocoding algorithm		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/radiometricTerrainCorrection		
Type: string	**Shape: scalar**	
Description: Radiometric terrain correction (RTC) algorithm		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/polarimetricSymmetrization		
Type: string	**Shape: scalar**	
Description: Polarimetric symmetrization algorithm		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/radiometricTerrainCorrectionAlgorithmReference		
Type: string	**Shape: scalar**	
Description: Reference to the radiometric terrain correction (RTC) algorithm applied (if applicable)		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/geocodingAlgorithmReference		
Type: string	**Shape: scalar**	
Description: Reference to the geocoding algorithm applied (if applicable)		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/softwareVersion		
Type: string	**Shape: scalar**	
Description: Software version used for processing		
/science/LSAR/GCOV/metadata/processingInformation/inputs/l1SlcGranules		
Type: string	**Shape: (numberOfInputL1Files)**	
Description: List of input L1 RSLC products used		
/science/LSAR/GCOV/metadata/processingInformation/inputs/orbitFiles		
Type: string	**Shape: (numberOfInputOrbitFiles)**	
Description: List of input orbit files used		
/science/LSAR/GCOV/metadata/processingInformation/inputs/tecFiles		
Type: string	**Shape: (numberOfInputTecFiles)**	
Description: List of input total electron content (TEC) files used		
/science/LSAR/GCOV/metadata/processingInformation/inputs/configFiles		
Type: string	**Shape: (numberOfInputConfigFiles)**	
Description: List of input config files used		
/science/LSAR/GCOV/metadata/processingInformation/inputs/demSource		
Type: string	**Shape: scalar**	
Description: Description of the input digital elevation model (DEM)		

5.7 Other Radar Metadata

Table 5-7 NISAR HDF5 variables related to useful radar metadata.

Radar metadata-related variables		
/science/LSAR/GCOV/metadata/orbit/referenceEpoch		
Type: string	**Shape: scalar**	
Description: Reference epoch in the format YYYY-mm-ddTHH:MM:SS.SSS		
/science/LSAR/GCOV/metadata/orbit/interpMethod		
Type: string	**Shape: scalar**	
Description: Orbit interpolation method, either "Hermite" or "Legendre"		
/science/LSAR/GCOV/metadata/orbit/time		
Type: Float64	**Shape: (orbitListLength)**	
Description: Time vector record. This record contains the time corresponding to position and velocity records		
	units	seconds since YYYY-mm-ddTHH:MM:SS
/science/LSAR/GCOV/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/GCOV/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 / second
/science/LSAR/GCOV/metadata/orbit/orbitType		
Type: string	**Shape: scalar**	
Description: Orbit product type, either "FOE", "NOE", "MOE", "POE", or "Custom", where "FOE" stands for Forecast Orbit Ephemeris, "NOE" is Near real-time Orbit Ephemeris, "MOE" is Medium precision Orbit Ephemeris, and "POE" is Precise Orbit Ephemeris		
/science/LSAR/GCOV/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-ddTHH:MM:SS
/science/LSAR/GCOV/metadata/attitude/quaternions		
Type: Float64	**Shape: (attitudeListLength, quaternions)**	
Description: Attitude quaternions (q0, q1, q2, q3)		
	units	1
/science/LSAR/GCOV/metadata/attitude/eulerAngles		
Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude Euler angles (roll, pitch, yaw)		
	units	degrees
/science/LSAR/GCOV/metadata/attitude/attitudeType		
Type: string	**Shape: scalar**	
Description: Attitude type, either "FRP", "NRP", "PRP, or "Custom", where "FRP" stands for Forecast Radar Pointing, "NRP" is Near Real-time Pointing, and "PRP" is Precise Radar Pointing		

5.8 Radar Grid

Table 5-8 NISAR HDF5 variables related to metadata cube.

Metadata cube-related variables		
/science/LSAR/GCOV/metadata/radarGrid/slantRange		
Type: Float64	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: Slant range in meters		
	units	meters
/science/LSAR/GCOV/metadata/radarGrid/zeroDopplerAzimuthTime		
Type: Float64	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: Zero Doppler azimuth time in seconds		
	units	seconds since YYYY-mm-ddTHH:MM:SS
/science/LSAR/GCOV/metadata/radarGrid/incidenceAngle		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: Incidence angle is defined as the angle between the LOS vector and the normal to the ellipsoid at the target height		
	valid_max	90.0
	valid_min	0.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Incidence angle
	units	degrees
/science/LSAR/GCOV/metadata/radarGrid/losUnitVectorX		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: East component of unit vector of LOS from target to sensor		
	valid_max	1.0
	valid_min	-1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	LOS unit vector X
	units	1
/science/LSAR/GCOV/metadata/radarGrid/losUnitVectorY		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: North component of unit vector of LOS from target to sensor		
	valid_max	1.0
	valid_min	-1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	LOS unit vector Y
	units	1
/science/LSAR/GCOV/metadata/radarGrid/alongTrackUnitVectorX		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: East component of unit vector along ground track		
	valid_max	1.0
	valid_min	-1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Along-track unit vector X
	units	1
/science/LSAR/GCOV/metadata/radarGrid/alongTrackUnitVectorY		

Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: North component of unit vector along ground track		
	valid_max	1.0
	valid_min	-1.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Along-track unit vector Y
	units	1
/science/LSAR/GCOV/metadata/radarGrid/elevationAngle		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: Elevation angle is defined as the angle between the LOS vector and the normal to the ellipsoid at the sensor		
	valid_max	90.0
	valid_min	0.0
	_FillValue	nan
	grid_mapping	projection
	long_name	Elevation angle
	units	degrees
/science/LSAR/GCOV/metadata/radarGrid/groundTrackVelocity		
Type: Float64	**Shape: (radarCubeLength, radarCubeWidth)**	
Description: Absolute value of the platform velocity scaled at the target height		
	_FillValue	nan
	grid_mapping	projection
	long_name	Ground-track velocity
	units	meters / second
/science/LSAR/GCOV/metadata/radarGrid/projection		
Type: UInt32	**Shape: scalar**	
Description: Product map grid projection: EPSG code, with additional projection information as HDF5 Attributes		
	ellipsoid	Projection ellipsoid
	epsg_code	Projection EPSG code
	false_easting	The value added to all abscissa values in the rectangular coordinates for a map projection.
	false_northing	The value added to all ordinate values in the rectangular coordinates for a map projection.
	grid_mapping_name	Grid mapping variable name
	inverse_flattening	Inverse flattening of the ellipsoidal figure
	latitude_of_projection_origin	The latitude chosen as the origin of rectangular coordinates for a map projection.
	longitude_of_projection_origin	The longitude, with respect to Greenwich, of the prime meridian associated with the geodetic datum.
	semi_major_axis	Semi-major axis
	spatial_ref	Spatial reference
	utm_zone_number	UTM zone number
/science/LSAR/GCOV/metadata/radarGrid/xCoordinates		
Type: Float64	**Shape: (radarCubeWidth)**	
Description: X coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/radarGrid/yCoordinates		
Type: Float64	**Shape: (radarCubeWidth)**	
Description: Y coordinates in specified projection		
	units	meters
/science/LSAR/GCOV/metadata/radarGrid/heightAboveEllipsoid		
Type: Float64	**Shape: (radarCubeHeight)**	
Description: Height values above WGS84 Ellipsoid corresponding to the radar grid		

	units	meters

6 METADATA CUBES

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. 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. 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 [RD7].

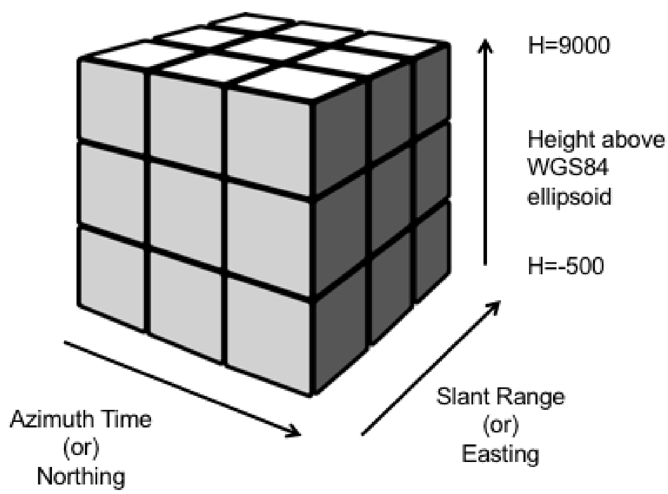

Figure 6-1. Metadata cube layer schematic.

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 GCOV 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 elevation angle ($\hat{\varepsilon}$) 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 elevation angle metadata cube E (HDF5 Dataset "elevationAngle") can be thought of as a three-dimensional field E(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 elevation angle array. We recommend cubic or a higher order 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:

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

   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:

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

   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
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
GPU	Graphics Processing Unit
GSLC	Geocoded Single Look Complex
GUNW	Geocoded Unwrapped Interferogram

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
ROFF	Range-Doppler Pixel Offsets
RRSD	Raw Radar Signal Data
RRST	Raw Radar Signal Telemetry
RSLC	Range-Doppler Single Look Complex
RTC	Radiometric Terrain Correction

RUNW	Range-Doppler UnWrapped Interferogram
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

APPENDIX B: GEOCODED PRODUCT GRIDS

NISAR L2 products will be generated on a pre-defined Track/Frame system. The projection system for a particular frame will be available to the users as a predefined map and will be held constant through the life of the system. Each L2 HDF5 granule itself will include information indicating the projection used for the product.

Map Projections

NISAR's SDS is able to ingest any Digital Elevation Model whose vertical datum represents height above the WGS84 Ellipsoid and the horizontal datum can be represented by a European Petroleum Standards Group (EPSG) code for generating geocoded product. Table 7-1 lists the various projection systems used to output L2 geocoded products.

Table B-00-1. Projection Systems for NISAR L2 Products.

EPSG code	PROJ.4 string	Common Name	Geographical scope
3031	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	Antarctic Polar Stereographic	Antarctica and Southern Hemisphere Sea Ice
3413	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	NSIDC Sea Ice Polar Stereographic North	Greenland and Northern Hemisphere Sea Ice
32601-32660	+proj=utm +zone=X-32600 +datum=WGS84 +units=m +no_defs	UTM Zone North	Northern Hemisphere Land except Greenland
32701-32760	+proj=utm +zone=X-32700 +south +datum=WGS84 +units=m +no_defs	UTM Zone South	Southern Hemisphere Land except Antarctica