NASA SDS Product Specification

Level-2 Geocoded Polarimetric Covariance

L2_GCOV

Rev B

JPL D-102274

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

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1 INTRODUCTION

1.1 Purpose of Description

This document provides a specification of the NASA-ISRO Synthetic Aperture Radar (NISAR) L-SAR Level-2 Geocoded Polarimetric Covariance (GCOV) product to be generated by the NASA Science Data System (SDS) and provided to the Distributed Active Archive Center (DAAC). This data product is usually referenced by the short name L2_GCOV.

1.2 Document Organization

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

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

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

Section 5 provides a detailed identification of the individual fields within the L2_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, Initial, Sep. 13, 2019

[AD2] NISAR NASA SDS Algorithm Development Plan, JPL D-95678, Initial, Sep. 12, 2019

[AD3] NISAR Science Data Management and Archive Plan, JPL D-80828, June 1, 2016

[AD4] NISAR Science Management Plan, JPL D-76340, Rev A, Aug. 14, 2018

[AD5] NISAR Calibration and Validation Plan, JPL D-102256, September. 2019

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

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

Reference Documents

[RD1] 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, Oct. 6, 2022.

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

[RD4] NISAR SDS File Naming Conventions, JPL D-102255, Initial, Nov. 4, 2020

[RD5] NISAR L1_RSLC Product Specification Document, JPL D-102268, R3.3, May 15, 2023

[RD6] HDF5 documentation at https://portal.hdfgroup.org/display/HDF5/HDF5

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

2 PRODUCT OVERVIEW

2.1 Product Background

Each NASA SDS L0-L2 L-band product (Figure 2-1 and 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 sub-groups within the granule in compliance with the HDF5 specification. The NISAR product level definitions are given in Table 2-2. These definitions differ somewhat from the NASA Earth Observing System and Data Information System (EOSDIS) definitions but are consistent with other SAR missions.

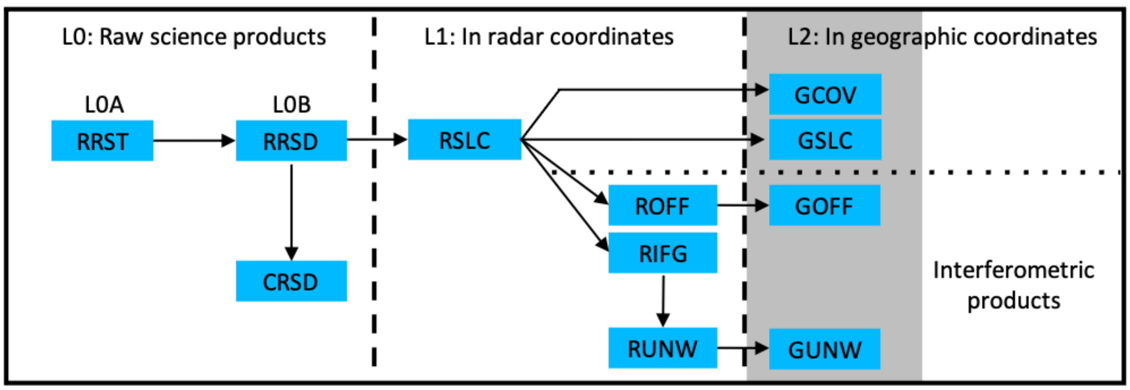

Figure 2-1 Product Dependency

Table 2-1. Key to Product Dependency Diagram

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

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

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

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

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

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

2.2 L2_GCOV Overview

The L2_GCOV product is a Level 2 Category 1 product derived from the Level-1 Range Doppler Single Look Complex (L1_RSLC) product providing terrain-corrected polarimetric covariance projected onto a predefined UTM or Polar stereographic system map grid (Appendix B: Geocoded Product Grids).

L1_RSLC radar samples, organized as a polarimetric vector, are cross-correlated originating the polarimetric covariance matrix expressed in the same grid as the L1_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, a process called radiometric terrain correction (RTC) is applied over the covariance terms, normalizing the backscatter coefficient beta0 to gamma0. The normalized covariance terms are then geocoded (map projected). Since radar samples at full resolution are strongly affected by SAR speckle, an averaging processing commonly known as multilooking is applied over the normalized covariance terms for geocoding. A recently-developed area-based projection algorithm is employed in the RTC and geocoding steps [RD1][RD2].

The area-based radiometric terrain correction delivers improved terrain normalization with a significantly shorter run time (up to 26.3 times faster) compared to state-of-the-art algorithms [RD1]. The shorter run time enables the correction of radar images at full single look complex (SLC) resolution resulting in RTC-S1 products with better terrain correction and finer details that can be processed at a large scale. The area-based geocoding performs the averaging of radar samples that intersect the output geographical grid with a window that varies with the topography and observation geometry. This approach substitutes the traditional multilooking with a constant-size window followed by geocoding with an interpolation algorithm (e.g, sinc interpolation). This process is carried out and full SLC resolution and it does not require interpolation, providing geocoded imagery with finer resolution, preserving more features from the scene, and free from interpolation errors such as overfitting caused by high-contrast targets or SAR speckle [RD1].

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 L2_GCOV processing mode.

The pixel spacing of the L2_GCOV terms vary with the input L1_RSLC range. L2_GCOV terms generated from SLCs with 5 MHz range bandwidth are sampled at 100 m pixel spacing, L2_GCOV products generated from 20 MHz and 80 MHz range bandwidth modes are sampled at 20 m pixel spacing, and L2_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 the L2_GCOV product based on the L1_RSLC range bandwidth

L1_RSLC Range Bandwidth (MHz)	Ground Range Resolution Mid-Swath (m)	Pixel Spacing in Northing (m)	Pixel Spacing in Easting (m)
5	~38.5	100	100
20	~9.6	20	20
40	~4.8	10	10
80	~2.4	20	20

The reference DEM for processing and radiometric terrain correcting L2_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.

The groups with their basic properties are given in Section 4. The details of the data elements are given in Section 5. Metadata cubes are discussed in Section 6.

3 PRODUCT ORGANIZATION

3.1 File Format

All NISAR standard products are in the Hierarchical Data Format version 5 (HDF5, [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 as groups with no actual data at the root(“/”) level. Table 3-3 shows the general layout of the HDF5 files that are generated by the NISAR Science Data System. All data are organized under “/science” with data from the L-SAR and S-SAR instruments separated into their own groups.

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

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

In the nominal baseline, L-SAR and S-SAR data will not appear in the same granule, even if they cover the same geographic area. 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 L2_GCOV

Attribute	Format	Description	Value
Conventions	string	NetCDF-4 conventions adopted in this product. This attribute should be set to CF-1.8 to indicate that the group is compliant with the Climate and Forecast NetCDF conventions	CF-1.8
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 L2_GCOV
contact	string	Contact information for producer of the product. (e.g., "ops@jpl.nasa.gov").	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. (Before applying add_offset and scale_factor).
add_offset	If present, this value should be added to each data element after it is read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
scale_factor	If present, the data are to be multiplied by the value after they are read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
comment	Miscellaneous information about the data or the methods to generate it.
coordinates	Coordinate variables associated with the variable. The basename of the coordinate variable is used in this representation and group scoping rules for CF conventions apply.
long_name	A descriptive variable name that indicates its content.
quality_flag	Names of variable quality flag(s) that are associated with this variable to indicate its quality.
units	Unit of data after applying offset (add_offset) and scale_factor.
valid_max	Maximum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as maximum value of actual data)
valid_min	Minimum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as minimum value of actual data)

Some HDF5 datasets are populated with statistical attributes. Table 3-6 and Table 3-7 describe statistical attributes added to real- and complex-valued HDF5 datasets, respectively. The list of real- and complex-valued HDF5 datasets for the standard L2_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_standard_deviation	Sample standard deviation of a real-valued HDF5 dataset

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

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

Table 3-8. L2_GCOV HDF5 datasets populated with statistical attributes.

HDF5 Group	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, RVRH	Complex-valued
/science/LSAR/GCOV/grids/frequency[A|B]	numberOfLooks, rtcGammaToSigmaFactor	Real-valued

3.3 Granule Definition

NISAR L2_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 L2_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 L2_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. Pixel-is-area convention (see Appendix B: Geocoded Product Grids) is used to tag the raster layers with coordinate information.

3.7 Spatial Sampling and Resolution

Some salient features of the output grid for the L2_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 L2_GCOV product – frequency A and frequency B.
2. The main imaging band (frequencyA) is spatially averaged to the same posting, irrespective of the imaging mode. This allows for spatial mosaicking operations across instrument mode changes.
3. 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 L2_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

Partially compressed data in L1_RSLC files are not used to produce L2_GCOV products.

4 LEVEL 2 GEOCODED POLARIMETRIC COVARIANCE PRODUCT

There are three L2 polarimetric and interferometric SAR products to support the NISAR NASA science disciplines. The L2_GCOV product is the Geocoded Multi-looked Polarimetric Covariance product and is derived from the Level-1 RSLC (L1_RSLC) product using a DEM and the best available orbit information. It is output in the UTM/ Polar Stereographic system (see Appendix B: Geocoded Product Grids). The L2_GCOV product can be directly overlaid on a map or combined with other similar L2_GCOV products to create change maps, for example.

In this section, we briefly describe the layout of L2_GCOV data and associated metadata in the NISAR HDF5 file. The L2_GCOV product represents real or complex covariance in gamma0. Conversion to beta0 is accomplished using the area normalization factor provided at the same posting as the imagery layers. In this section, we focus on the organization of L-SAR instrument data under the Group name "/science/LSAR".

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 number, track-frame number, acquisition times, a polygon representing the bounding box of the included imagery in geographic coordinates, and product version.

4.3 Radar Imagery

The primary data elements of the L2_GCOV product, referred to as the L2_GCOV imagery, are the covariance terms of the geocoded polarimetric covariance matrix, that are stored within the Group "/science/LSAR/GCOV/grids /frequency[A|B]".

L2_GCOV terms are derived from the L1_RSLC product SLCs. For each polarimetric channel $P_1, \dots P_n$, the L1_RSLC product SLCs can be arranged in the form of scattering vector k_n:

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

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 polarimetric channels of the scattering vector k. The off-diagonal terms are complex-valued and are only computed if the L2_GCOV is product is *full-covariance*, which can be verified by the flag “/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 L2_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-simmetrized cross-polarimetric channels (e.g., dual polametric data). To avoid this, L2_GCOV terms do not include the $\sqrt{2}$ 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 L2_GCOV product metadata indicates if the polarimetric symmetrization has been applied: “/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 L2_GCOV matrix $[G_\mathrm{n}]$. The L2_GCOV matrix terms are provided within the HDF5 Group "…/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 under the group ".../grids/frequency[A|B]/rtcGammaToSigmaFactor". This layer provides factors to normalize the backscatter normalization convention of the L2_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 L2_GCOV product are computed over the range Doppler domain using L1_RSLC radar samples at full resolution (i.e., without multilooking) [RD1][RD2]. However, since L2_GCOV terms are provided over map coordinates, the original RTC Gamma-To-Sigma factors are reprojected from the range-Doppler domain to the L2_GCOV grid. This reprojection is performed using the same area-based projection algorithm, i.e., geocoding with adaptive multilooking, used to generate L2_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 ($[G_\mathrm{n}^{\sigma\prime}]$) of the L2_GCOV matrix normalized to sigma0 $[G_\mathrm{n}^{\sigma}]$ that would be obtained by applying RTC over the range-Doppler domain.

4.3.2 Number of Looks

The L2_GCOV terms are obtained from the geocoding of the L1_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 ".../grids/frequency[A|B]/numberOfLooks" provide the number of looks used for computing each L2_GCOV term sample and it is provided in the same geographic grid as the L2_GCOV imagery.

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 subgroup "/calibrationInformation" contains two major types of information. Datasets for the complex two-way antenna patterns and noise-equivalent sigma0 (nes0 or NESZ) are organized by frequency and polarization. These datasets are provided on a sparse grid in map coordinates and values of interest at any geographical location can be estimated using simple 2D interpolation (bilinear or higher order). The complete list of calibration information fields is given in Section 5.4.

4.4.2 Source Data

The subgroup "/sourceData" includes relevant information about the input L1 RSLC product that was used to generate the L2_GCOV product. It includes the L1_RSLC identification parameters provided at the subgroup "/sourceData" level, the L1_RSLC processing information parameters provided under the subgroup "/sourceData/processingInformation", and swath (radar grid) parameters provided under the subgroup "/sourceData/swaths".

4.4.3 Processing Information

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

4.4.3.1 Parameters

The subgroup "/metadata/processingInformation/parameters" describes product processing parameters 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 and corrected during the geocoding process. The dry tropospheric delay is computed using a static model [RD2] and corrected during focusing the RSLC product. This subgroup 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 in the subgroup "/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 granules, DEM source description, and configuration files are tracked and listed under the subgroup "/metadata /processingInformation/inputs".

4.4.4 Other Radar Metadata

Section 5.6 includes the information about the orbit ephemeris used for generating the L2_GCOV under a subgroup named "/metadata/orbit", and the attitude under a subgroup named "/metadata/attitude".

4.4.4.1 Orbit

The orbit ephemeris used for generating the L2_GCOV product can be found under a subgroup named "/metadata/orbit". This group includes time-tagged antenna phase center position and velocity vectors in Earth Centered Earth Fixed (ECEF) cartesian coordinates. In nominal operations, this would be the MOE state vectors that were used by the L2 processor.

4.4.4.2 Attitude

The attitude state vectors used for generating the L2_GCOV product can be found under a subgroup named "/metadata/attitude". This group includes time-tagged quaternions and Euler Angles representing the slant range plane from the antenna phase center in Earth Centered Earth Fixed (ECEF) cartesian system. In nominal operations, this would be the restituted attitude state vectors that were used by the L2 processor.

4.4.5 Radar Grid

Section 5.7 contains information describing the radar geometry of the sensor during data taking in the group "/metadata/radarGrid/". This information is given in the form of data cubes, referred to as *radar grid cubes*, that are organized over a three-dimensional geographical grid. 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.

Radar grid cubes (for geocoded products) are provided in the same coordinate system as the product imagery with similar extents (bounding box) but coarser pixel spacing. The three-dimensional geographic grid is defined by the HDF5 datasets "xCoordinates" (defining the east component), "yCoordinates" (north component), and "heightAboveEllipsoid" (height above the WGS84 ellipsoid), common to all radar grid cubes, and conforming to CF conventions 1.8.

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

1. The zero-Doppler radar grid is defined through the datasets "slantRange" and "zeroDopplerAzimuthTime", which contain respectively the range position in meters and the zero-Dopper azimuth time in seconds for each point of the geographical grid.
2. The line-of-sight (LOS) unit vector, i.e., the vector from the target to the sensor, is defined by the datasets "losUnitVectorX" and "losUnitVectorY" which contain respectively the east e_x and north e_y components of the LOS unit vector in the east-north-up (ENU) coordinate system for each point of the geographic grid.
   Note that the third ("up") component of the LOS unit vector $e_z$is not provided along with the product as it can be derived from the other two components:

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

3. The along-track unit vector represents the projection of the along-track vector at the ground height. It is defined by the datasets "alongTrackUnitVectorX" and "alongTrackUnitVectorY" containing respectively the east and north components of the along-track unit vector in UTM coordinates.
4. The incidence angle, i.e., the angle between the LOS vector and the normal to the ellipsoid at the target height, is given by the dataset "incidenceAngle".
5. The elevation angle, defined as the angle between the LOS vector and the normal to the ellipsoid at the sensor, is provided as "elevationAngle".
6. The ground track velocity which contains the absolute value of the platform velocity scaled at the target height is given as "groundTrackVelocity".

5 PRODUCT SPECIFICATION

5.1 Dimensions and Shapes

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

Table 5-1 Table of dimensions and shapes in L2_GCOV product

Name	Shape	Description
scalar	scalar	None
numberOfDatatakes	scalar	number of datatakes in product
numberOfObservations	scalar	number of observations in product
numberOfFrequencies	scalar	Number of L-SAR frequencies in product
numberOfFrequencyAPolarizations	scalar	Number of polarization layers associated with L-SAR frequency A
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 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 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	(calibrationLength, calibrationWidth)	Shape of crosstalk datasets
orbitListLength	scalar	description="Number of orbit state vectors
orbitShape	(orbitListLength, 3)	Shape of orbit state vector triplets dataset
attitudeListLength	scalar	Number of attitude state vectors
attitudeQuaternionShape	(attitudeListLength, 4)	Shape of attitude quaternion dataset
attitudeShape	(attitudeListLength, 3)	Shape of attitude Euler angle triplets dataset
numberOfInputL1Files	scalar	Number of input L1 granules
numberOfInputOrbitFiles	scalar	Number of input orbit files
numberOfInputConfigFiles	scalar	Number of input configuration files

5.2 Product Identification

Table 5-2 NISAR HDF5 variables used for product identification

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

Description: List of planned datatakes included in the product		
/science/LSAR/identification/plannedObservationId		
Type: string	**Shape: (numberOfObservations)**	
Description: List of planned observations included in the product		
/science/LSAR/identification/isUrgentObservation		
Type: string	**Shape: scalar**	
Description: Flag indicating if observation is nominal ("False") or urgent ("True")		
/science/LSAR/identification/listOfFrequencies		
Type: string	**Shape: (numberOfFrequencies)**	
Description: List of frequency layers available in the product		
/science/LSAR/identification/diagnosticModeFlag		
Type: UByte	**Shape: scalar**	
Description: Indicates if the radar operation mode is a diagnostic mode (1-2) or DBFed science (0): 0, 1, or 2		
	units	unitless
/science/LSAR/identification/productLevel		
Type: string	**Shape: scalar**	
Description: Product level. L0A: Unprocessed instrument data; L0B: Reformatted, unprocessed instrument data; L1: Processed instrument data in radar coordinates system; and L2: Processed instrument data in geocoded coordinates system		
/science/LSAR/identification/isGeocoded		
Type: string	**Shape: scalar**	
Description: Flag to indicate if the product data is in the radar geometry ("False") or in the map geometry ("True")		
/science/LSAR/identification/boundingPolygon		
Type: string	**Shape: scalar**	
Description: OGR compatible WKT representation of bounding polygon of the image		
/science/LSAR/identification/processingDateTime		
Type: string	**Shape: scalar**	
Description: Processing UTC date and time in the format YYYY-MM-DDTHH:MM:SS		
/science/LSAR/identification/radarBand		
Type: string	**Shape: scalar**	
Description: Acquired frequency band		
/science/LSAR/identification/instrumentName		
Type: string	**Shape: scalar**	
Description: Name of the instrument used to collect the remote sensing data provided in this product		
/science/LSAR/identification/processingType		
Type: string	**Shape: scalar**	
Description: NOMINAL (or) URGENT (or) CUSTOM (or) UNDEFINED		
/science/LSAR/identification/isDithered		
Type: string	**Shape: scalar**	
Description: "True" if the pulse timing was varied (dithered) during acquisition, "False" otherwise.		
/science/LSAR/identification/isMixedMode		
Type: string	**Shape: scalar**	
Description: "True" if this product is a composite of data collected in multiple radar modes, "False" otherwise.		

5.3 Radar Imagery

Table 5-3 NISAR HDF5 variables related to SAR imagery

Product Imagery Variables		
/science/LSAR/GCOV/grids/frequencyA/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyAPolarizations)**
Description: List of processed polarization layers with frequencyA		
/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		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/projection		
Type: Int32		**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: CF compliant dimension associated with the X coordinates		
	units	meters
/science/LSAR/GCOV/grids/frequencyA/yCoordinates		
Type: Float64		**Shape: (frequencyALength)**
Description: CF compliant dimension associated with the Y coordinates		
	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		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/mask		
Type: Byte		**Shape: (frequencyALength, frequencyAWidth)**
Description: GCOV terms mask		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HHHH		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between HH and HH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HHHV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between HH and HV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HHVH		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance betweeen HH and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HHVV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between HH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HVHV		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between HV and HV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HVVH		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between HV and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/HVVV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance betweeen HH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/VHVH		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between VH and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/VHVV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance betweeen VH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/VVVV		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between VV and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/RHRH		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RH and RH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/RHRV		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RH and RV		

	units	unitless
/science/LSAR/GCOV/grids/frequencyA/RVRH		
Type: CFloat32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RV and RH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/RVRV		
Type: Float32		**Shape: (frequencyALength, frequencyAWidth)**
Description: Covariance between RV and RV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyA/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/listOfPolarizations		
Type: string		**Shape: (numberOfFrequencyBPolarizations)**
Description: List of processed polarization layers with frequencyB		
/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: Int32		**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: CF compliant dimension associated with the X coordinates		
	units	meters
/science/LSAR/GCOV/grids/frequencyB/yCoordinates		
Type: Float64		**Shape: (frequencyBLength)**
Description: CF compliant dimension associated with the Y coordinates		
	units	meters

/science/LSAR/GCOV/grids/frequencyB/numberOfLooks		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Number of averaged radar-grid pixels for covariance estimation		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/rtcGammaToSigmaFactor		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Radiometric terrain correction factor to normalize GCOV terms from gamma0 to sigma0		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/mask		
Type: Byte		**Shape: (frequencyBLength, frequencyBWidth)**
Description: GCOV terms mask		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HHHH		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and HH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HHHV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and HV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HHVH		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen HH and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HHVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HVHV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HV and HV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HVVH		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between HV and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/HVVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen HH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/VHVH		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between VH and VH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/VHVV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance betweeen VH and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/VVVV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between VV and VV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/RHRH		

Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RH and RH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/RHRV		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RH and RV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/RVRH		
Type: CFloat32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RV and RH		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/RVRV		
Type: Float32		**Shape: (frequencyBLength, frequencyBWidth)**
Description: Covariance between RV and RV		
	units	unitless
/science/LSAR/GCOV/grids/frequencyB/numberOfSubSwaths		
Type: UByte		**Shape: scalar**
Description: Number of swaths of continuous imagery, due to transmit gaps		
	units	unitless

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: Int32	**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 dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/HV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/VV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless

/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/elevationAntennaPattern/RV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/projection		
Type: Int32	**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 dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/HV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/VV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RH		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/elevationAntennaPattern/RV		
Type: CFloat32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Complex two-way elevation antenna pattern		

	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/projection		
Type: Int32	**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 dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/HH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/HV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/VH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/VV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/RH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyA/nes0/RV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/HH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	

Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/projection		
Type: Int32	**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 dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/xCoordinates		
Type: Float64	**Shape: (calibrationWidth)**	
Description: X coordinates dimension corresponding to calibration records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/HV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/VH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/VV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/RH		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/frequencyB/nes0/RV		
Type: Float32	**Shape: (calibrationLength, calibrationWidth)**	
Description: Noise equivalent sigma zero		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/projection		
Type: Int32	**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/crosstalk/yCoordinates		
Type: Float64		**Shape: (calibrationLength)**
Description: Y coordinates dimension corresponding to crosstalk records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/xCoordinates		
Type: Float64		**Shape: (calibrationWidth)**
Description: X coordinates dimension corresponding to crosstalk records		
	units	meters
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/txHorizontalCrosspol		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Crosstalk in H-transmit channel expressed as ratio txV / txH		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/txVerticalCrosspol		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Crosstalk in V-transmit channel expressed as ratio txH / txV		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/rxHorizontalCrosspol		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Crosstalk in H-receive channel expressed as ratio rxV / rxH		
	units	unitless
/science/LSAR/GCOV/metadata/calibrationInformation/crosstalk/rxVerticalCrosspol		
Type: CFloat32		**Shape: (calibrationLength, calibrationWidth)**
Description: Crosstalk in V-recieve channel expressed as ratio rxH / rxV		
	units	unitless
/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/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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	unitless
/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 can be 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 with parameters used for processing of the source data product		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rfiDetection		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) detection		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rfiMitigation		
Type: string	**Shape: scalar**	
Description: Algorithm used for radio frequency interference (RFI) mitigation		
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rangeCompression		
Type: string	**Shape: scalar**	
Description: Algorithm for focusing the data in the range direction		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/elevationAntennaPatternCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating the antenna pattern		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/rangeSpreadingLossCorrection		
Type: string	**Shape: scalar**	
Description: Algorithm for calibrating range fading		
	algorithm_type	range processing
/science/LSAR/GCOV/metadata/sourceData/processingInformation/algorithms/dopplerCentroidEstimation		
Type: string	**Shape: scalar**	
Description: Algorithm for calculating Doppler centroid		
	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		
	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		

	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	

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: Int32	**Shape: scalar**	
Description: Number of range looks applied to the RSLC before geocoding		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyA/numberOfAzimuthLooks		
Type: Int32	**Shape: scalar**	
Description: Number of azimuth looks applied to the RSLC before geocoding		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyB/numberOfRangeLooks		
Type: Int32	**Shape: scalar**	
Description: Number of range looks applied to the RSLC before geocoding		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/preprocessing/frequencyB/numberOfAzimuthLooks		
Type: Int32	**Shape: scalar**	
Description: Number of azimuth looks applied to the RSLC before geocoding		
	units	unitless
/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: Float32	**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	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/rtc/geogridUpsampling		
Type: Float32	**Shape: scalar**	
Description: Radiometric terrain correction (RTC) geogrid upsampling		
	units	unitless
/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: Float32	**Shape: scalar**	
Description: Geocoding geogrid upsampling		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/minBlockSize		
Type: Float32	**Shape: scalar**	
Description: Minimum block size in MB per thread		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/geocoding/maxBlockSize		
Type: Float32	**Shape: scalar**	

Description: Maximum block size in MB per thread		
	units	unitless
/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: Float32	**Shape: scalar**	
Description: Slant range convergence threshold for geo2rdr transformation		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/geo2rdr/maxNumberOfIterations		
Type: Int32	**Shape: scalar**	
Description: Maximum number of iterations for geo2rdr transformation		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/geo2rdr/deltaRange		
Type: Float32	**Shape: scalar**	
Description: Step size for computing numerical gradient of Doppler in meters for geo2rdr transformation		
	units	unitless
/science/LSAR/GCOV/metadata/processingInformation/parameters/projection		
Type: Int32	**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 coordinate dimension corresponding to processing information records		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinate dimension corresponding to processing information records"		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/referenceTerrainHeight		
Type: Float32	**Shape: (dopplerCentroidLength, dopplerCentroidWidth)**	
Description: Reference Terrain Height as a function of map coordinates		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/projection		
Type: Int32	**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 coordinate dimension corresponding to processing information records		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinate dimension corresponding to processing information records"		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyA/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidLength, dopplerCentroidWidth)**	
Description: 2D LUT of Doppler Centroid for Frequency A		
	units	Hz
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/projection		
Type: Int32	**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 coordinate dimension corresponding to processing information records		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/xCoordinates		
Type: Float64	**Shape: (dopplerCentroidWidth)**	
Description: X coordinate dimension corresponding to processing information records"		
	units	meters
/science/LSAR/GCOV/metadata/processingInformation/parameters/frequencyB/dopplerCentroid		
Type: Float64	**Shape: (dopplerCentroidLength, dopplerCentroidWidth)**	

Description: 2D LUT of Doppler Centroid for Frequency B		
	units	Hz
/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/rfiCorrection		
Type: string	**Shape: scalar**	
Description: RFI correction algorithm		
/science/LSAR/GCOV/metadata/processingInformation/algorithms/polarimetricSymmetrization		
Type: string	**Shape: scalar**	
Description: Polarimetric symmetrization algorithm		
/metadata/processingInformation/algorithms/radiometricTerrainCorrectionAlgorithmReference		
Type: string	**Shape: scalar**	
Description: Reference to the radiometric terrain correction (RTC) algorithm applied (if applicable)		
/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/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		
/metadata/orbit/referenceEpoch		
Type: string	**Shape: scalar**	
Description: Reference epoch in the format YYYY-MM-DDTHH:MM:SS.SSS		
/metadata/orbit/interpMethod		
Type: string	**Shape: scalar**	
Description: Orbit interpolation method		
/science/LSAR/GCOV/metadata/orbit/time		
Type: Float64	**Shape: (orbitListLength)**	
Description: Time vector record. This record contains the time corresponding to position, velocity, acceleration records		
	units	seconds since YYYY-MM-DD HH:MM:SS
/science/LSAR/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 per second
/science/LSAR/GCOV/metadata/orbit/acceleration		
Type: Float64	**Shape: (orbitListLength, tripletxyz)**	
Description: Acceleration vector record. This record contains the platform acceleration data with respect to WGS84 G1762 reference frame		
	units	meters per second squared
/science/LSAR/GCOV/metadata/orbit/orbitType		
Type: string	**Shape: scalar**	
Description: PrOE (or) NOE (or) MOE (or) POE (or) Custom		
/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-DD HH:MM:SS
/science/LSAR/GCOV/metadata/attitude/quaternions		
Type: Float64	**Shape: (attitudeListLength, quaternions)**	
Description: Attitude quaternions (q0, q1, q2, q3)		
	units	unitless
/science/LSAR/GCOV/metadata/attitude/angularVelocity		
Type: Float64	**Shape: (attitudeListLength, tripletxyz)**	
Description: Attitude angular velocity vectors (wx, wy, wz)		
	units	radians per second
/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: PrOE (or) NOE (or) MOE (or) POE (or) Custom		

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-dd HH: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		
	max	90.0
	min	0.0
	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		
	max	-1.0
	min	1.0
	units	unitless
/science/LSAR/GCOV/metadata/radarGrid/losUnitVectorY		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: North component of unit vector of LOS from target to sensor		
	max	-1.0
	min	1.0
	units	unitless
/science/LSAR/GCOV/metadata/radarGrid/alongTrackUnitVectorX		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: East component of unit vector along ground track		
	max	-1.0
	min	1.0
	units	unitless
/science/LSAR/GCOV/metadata/radarGrid/alongTrackUnitVectorY		
Type: Float32	**Shape: (radarCubeHeight, radarCubeLength, radarCubeWidth)**	
Description: North component of unit vector along ground track		
	max	-1.0
	min	1.0
	units	unitless
/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		
	max	90.0
	min	0.0
	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		
	units	meters per second
/science/LSAR/GCOV/metadata/radarGrid/projection		
Type: Int32	**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 coordinate values corresponding to the radar grid		
	units	meters
/science/LSAR/GCOV/metadata/radarGrid/yCoordinates		
Type: Float64	**Shape: (radarCubeWidth)**	
Description: Y coordinate values corresponding to the radar grid		
	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. Note that this sparse representation is to assist users in ingesting and analyzing NISAR products within existing GIS software and is not meant to replace traditional representations of SAR data within the product granules or traditional processing approaches with radar geometry-aware software.

Metadata cubes are represented as three-dimensional arrays in the NISAR product HDF5 modules (Figure 6-1). The axes of the array are interpreted as (height, increasing azimuth time, and increasing slant range) in case of radar geometry products and as (height, decreasing northing, and increasing easting) in case of geocoded products. The data is organized with height as the first axis, as this allows one to directly ingest data as GCPs or rasters into existing GIS software. Each height layer is the same size. Metadata cubes will have fixed grid spacing (3 km in azimuth/northing x 1 km in slant range/easting x 1.5 km in height and will allow for easy merging when multiple products along the same imaging track are to be concatenated. The metadata fields on this coarse resolution grid will be evaluated using traditional radar processing approaches without approximations. The metadata cube will also span a field slightly larger than the original image product to allow users to interpolate data without introducing edge effects. Such low-resolution representation of slowly varying parameters has been demonstrated for InSAR products and processing [RD7].

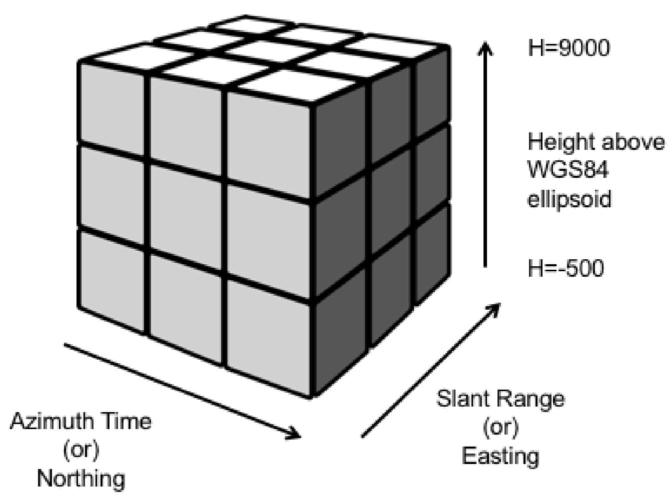

Figure 6-1. Metadata cube layer schematic.

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 L2_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 Perpendicular Baseline (Bperp) at a pixel of interest located at UTM coordinates point (Px,Py). Since these are coordinates on a map domain, we can look up a DEM to get the height at this point. The three-dimensional point of interest then becomes (Px, Py, h(Px,Py)).

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

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

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

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

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

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

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

6.2 Metadata Cube Usage Note

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

APPENDIX A: ACRONYMS

ADT	Algorithm Development Team
ANF	Area Normalization Factor
AT	Along Track
ATBD	Algorithm Theoretical Basis Document
AWS	Amazon Web Services
BFPQ	Block (adaptive) Floating-Point Quantization (adaptive may indicate implementation options)
Cal/Val	Calibration and Validation (also sometimes cal/val)
CDR	Critical Design Review
CF	Climate and Forecast
CPU	Central Processing Unit
CRSD	Calibration Raw Signal Data
CSV	Comma-separated values
DAAC	Distributed Active Archive Center
DBF	Digital Beam Forming
DEM	Digital Elevation Model
DM	Diagnostic Mode
DN	Digital Number
EAR	Export Administration Regulations
EASE	Equal-Area Scalable Earth
ECMWF	European Centre for Medium-Range Weather Forecasts
ECEF	Earth Centered Earth Fixed
EOSDIS	Earth Observing System and Data Information System
EPSG	European Petroleum Survey Group
ER#.#	Engineering Release #.#
ERA5	ECMWF Reanalysis 5th generation
FFT	Fast Fourier Transform
FM	Frequency Modulation
FOE	Forecast Orbit Ephemeris
FOV	Field of View
GCOV	Geocoded Polarimetric Covariance (L2_GCOV)
GCP	Ground Control Point
GDAL	Geospatial Data Abstraction Library
GDS	Ground Data System
GeoTIFF	Geographic Tagged Image File Format
GIS	Geographic Information System
GMTED	Global Multi-resolution Terrain Elevation Data
GNSS	Global Navigation Satellite System
GOFF	Geocoded Pixel Offsets (L2_GOFF)
GPU	Graphics Processing Unit
GSLC	Geocoded Single Look Complex (L2_GSLC)
GUNW	Geocoded Unwrapped Interferogram (L2_GUNW)

HH	Horizontal-transmit, Horizontal-receive polarization
HK, HKTM	Housekeeping Telemetry
HDF5	Hierarchical Data Format version 5
HV	Horizontal-transmit, Vertical-receive polarization
ICU	Integrated Correlation Unit
InSAR	Interferometric Synthetic Aperture Radar
ISCE	InSAR Scientific Computing Environment
ISCE3	InSAR Scientific Computing Environment Enhanced Edition (for NISAR)
ISO	International Organization for Standardization
ISRO	Indian Space Research Organisation (British spelling)
JPL	Jet Propulsion Laboratory
JSON	JavaScript Notation
L0B	Level-0B (data)
L1	Level-1 (data)
L2	Level-2 (data)
L3	Level-3 (data)
LRR	[JPL] Limited Release Request
LRS	[JPL] Limited Release System
LUT	Lookup Table
Mbps	Megabits per second
MHz	Megahertz
MOE	Medium-precision Orbit Ephemeris
NASA	National Aeronautics and Space Administration
NETCDF4	Network Common Data Format 4 (also netCDF4)
NISAR	NASA-ISRO Synthetic Aperture Radar
NOE	Near-Realtime Orbit Ephemeris
OpenMP	Open Multi-Processing
PCM	Process Control Management
PDF	Portable Document Format (often pdf)
PDR	Preliminary Design Review
POD	Precision Orbit Determination
POE	Precision Orbit Ephemeris
PRF	Pulse Repetition Frequency
QA	Quality Assurance
R#.#	Release #.# (.0 often not used)
REE	Radar Echo Emulator
RFI	Radio Frequency Interference
RIFG	Range-Doppler Interferogram (L1_RIFG)
ROFF	Range-Doppler Pixel Offsets (L1_ROFF)
RRSD	Raw Radar Signal Data
RRST	Raw Radar Signal Telemetry
RSLC	Range-Doppler Single Look Complex (L1_RSLC)
RTC	Radiometric Terrain Correction

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

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

Grid Alignment

NISAR L2 products will use a "pixel is area" convention (http://geotiff.maptools.org/spec/geotiff2.5.html , "The "PixelIsArea" raster grid space R, which is the default, uses coordinates I and J, with (0,0) denoting the upper-left corner of the image, and increasing I to the right, increasing J down. The first pixel-value fills the square grid cell with the bounds: top-left = (0,0), bottom-right = (1,1)").