NASA SDS Product Specification

Level-3 Soil Moisture

L3_SME2

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

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1 INTRODUCTION

1.1 Purpose of Description

This document provides a specification of the NASA-ISRO Synthetic Aperture Radar (NISAR) L-SAR Level-3 Soil Moisture product to be generated by the NASA Science Data System (SDS) and provided to the NASA Alaska Satellite Facility Distributed Active Archive Center (ASF DAAC). This data product is referenced by the short name L3_SME2, where the numeral “2” signifies the fact that the product is on the 200-meter global Equal-Area Scalable Earth (EASE) Grid 2.0 projection [RD7][RD8].

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 a detailed identification of the individual fields within the L3_SME2 product, including for example their units, size, and coordinates.

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

1.3 Applicable and Reference Documents

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

Applicable Documents

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

Reference Documents

[RD1] NISAR L3 Soil Moisture Data Product Algorithm Theoretical Basis Document (ATBD), JPL D-107679, Release 3.3, April 28, 2023.

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

[RD3] NISAR SDS File Naming Conventions, JPL D-102255, Initial, Mar. 2, 2023

[RD4] NISAR L1_RSLC Product Specification Document, JPL D-102268, R3.1, August 05, 2022

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

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

[RD7] Brodzik, M. J., B. Billingsley, T. Haran, B. Raup, M. H. Savoie. 2012. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets. *ISPRS International Journal of Geo-Information*, 1(1):32-45, doi:10.3390/ijgi1010032.

[RD8] Brodzik, M. J., B. Billingsley, T. Haran, B. Raup, M. H. Savoie. 2014. Correction: Brodzik, M. J. et al. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets. *ISPRS International Journal of Geo-Information* 2012, 1, 32-45. ISPRS International Journal of Geo-Information, 3(3):1154-1156, doi:10.3390/ijgi3031154.

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-L3 products. These SDS requirements [AD1] fall into three general categories: resolution requirements, radiometric and spatial location accuracy requirements, and latency and throughput requirements. Note that there is no geophysical retrieval accuracy imposed on the NISAR L3_SME2 product per agreement with the product sponsor – the Satellite Needs Working Group (SNWG); retrieval performance will be attempted on a best-effort basis.

2 PRODUCT OVERVIEW

2.1 Product Background

Soil moisture is a key variable that impacts the exchange of water and heat energy between the land surface and the atmosphere. It plays an important role in the development of weather patterns and precipitation. Soil moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers. Soil moisture information can be used for reservoir management, early warning of droughts, irrigation scheduling, and crop yield forecasting. Soil moisture data has the potential to significantly improve the accuracy of short-term weather forecasts and reduce the uncertainty of long-term projections of how climate change will impact Earth's water cycle [e.g., Entekhabi et al., 2010]. Satellite remote sensing of soil moisture has advanced significantly over the last decade due to the success of the Soil Moisture and Ocean Salinity (SMOS) [Kerr et al. 2010] and Soil Moisture Active Passive (SMAP) [Entekhabi et al., 2010] missions, both of which provide global soil moisture retrievals on an approximate 3-day revisit interval at an accuracy of approximately 0.04 m^3/m^3. A key limiting factor of SMAP and SMOS soil moisture measurements is their coarse spatial resolution (~40 km), which limits their utility for field-scale (i.e., ~200 m) agricultural monitoring. The unique capabilities of the NISAR mission [Rosen et al, 2015; Rosen et al., 2017] clearly motivate the production of field-scale (~200 m) land surface soil moisture products.

The salient characteristics of NISAR L3_SME2 are:

- NISAR will produce a global soil moisture product with a repeat interval of 12 days (6 days when using both ascending/descending modes)
- Latency: 72 hours
- Resolution: 200 m
- Accuracy goal: 0.06 m^3/m^3 (over non-urban areas with VWC below 5 kg/m^2, with no permanent snow and ice cover, and no permanent inland waterbodies as shown in Figure 2.1.1.

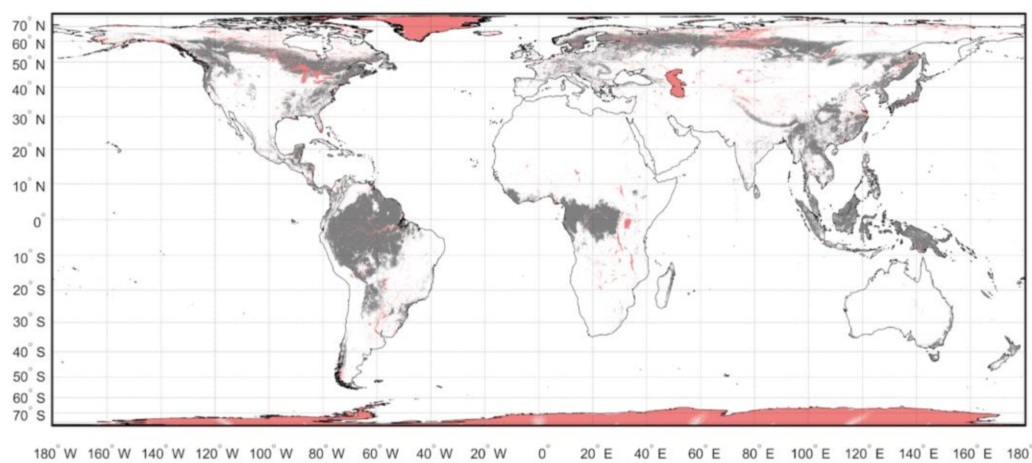

Figure 2.1.1: Soil moisture retrieval coverage. White land areas: retrievals performed with quality flag raised only in case of time-varying properties (e.g., heavy precipitation). Light red areas (urban build-up, permanent snow and ice cover, or permanent inland waterbodies) will be flagged and no NISAR soil moisture retrievals will be performed. Gray areas (VWC > 5 kg/m^2) will be flagged but soil moisture retrievals will be performed.

Table 2.1.1 NISAR L0-L3 products by lineage

Product	Scope	Description	Granularity
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	Granularity
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 resolution obtained from coherent and incoherent speckle tracking.	On pre-defined track/frame.
Range-Doppler Nearest-Time Unwrapped Interferogram (RUNW)	Antarctica, Greenland, and selected mountain glaciers. Nearest pair in time and co-pol channels only.	Multi-looked, unwrapped differential interferogram in range-Doppler coordinates with geometrical phase (including topographic phase) removed.	On pre-defined track/frame

Product	Scope	Description	Granularity
Geocoded SLC (GSLC)	Global (Antarctica and Greenland excluded) and all channels.	Geocoded version of RSLC product using the MOE state vectors and a DEM.	On pre-defined track/frame

Product	Scope	Description	Granularity
Geocoded Nearest-Time Pixel Offsets (GOFF)	Antarctica, Greenland, and 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
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 complex 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
Geocoded Soil Moisture on the 200-meter global EASE Grid 2.0 projection	Global; Snapshot algorithms require a single GCOV granule; time series algorithms require up to three GCOV granules	Soil moisture inferred from NISAR backscatter observations posted on the 200-meter global EASE Grid 2.0 projection. The resulting geographical extent is bounded by that of the L2 GCOV on UTM projection.	On pre-defined track/frame

Table 2.1.2 NISAR L0-L3 products by science

Product	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 2 data that have been spatially and/or temporally re-sampled to a global grid.

2.2 L3_SME2 Overview

NISAR backscatter observations will be used to estimate a global high resolution soil moisture product (200 m). This product will be provided on average twice every 12 days. The NISAR soil moisture product is expected to have a data latency of 72 hours (3 days). The NISAR L2 backscatter product has a data latency of 48 hours. Soil moisture estimates will be provided over areas with dense vegetation (VWC greater than 5 kg/m^2) but will be flagged during the retrieval process. Areas with urban build-up, permanent snow and ice cover, and permanent inland waterbodies (shown in red) will be flagged and no soil moisture retrieval will be performed. No soil moisture retrieval will be performed over areas with excessive precipitation, frozen ground, or areas with snow on ground. The NISAR soil moisture will have an accuracy goal of 0.06 m^3/m^3 over unflagged areas with vegetation water content below 5 kg/m^2.

A single NISAR L3_SME2 granule provides (1) instrument observations, (2) geolocation, (3) geophysical retrieval, and (4) science quality. The output HDF5 product file in Table 2.2.1 for one granule stores the information in various data elements at 200 m resolution.

Table 2.2.1 NISAR L3_SME2 product output fields

Fields	Name	Data Type	Units
1	Algorithm/DSG/Algorithm_Param_Beta	32-bit little-endian floating point	$m^3/(dB \cdot m^3)$
2	Algorithm/DSG/Algorithm_Param_Gamma	32-bit little-endian floating point	unitless
3	Algorithm/DSG/Retrieval_Qflag	16-bit little-endian signed integer	unitless
4	Algorithm/DSG/Soil_moisture	32-bit little-endian floating point	m^3/m^3
5	Algorithm/DSG/Soil_moisture_uncertainty	32-bit little-endian floating point	m^3/m^3
6	Algorithm/TSR/Alpha1_parameter	32-bit little-endian floating point	m^3/m^3
7	Algorithm/TSR/Alpha1_parameter_uncertainty	32-bit little-endian floating point	m^3/m^3
8	Algorithm/TSR/Alpha2_parameter	32-bit little-endian floating point	m^3/m^3
9	Algorithm/TSR/Alpha2_parameter_uncertainty	32-bit little-endian floating point	m^3/m^3
10	Algorithm/TSR/Retrieval_Qflag	16-bit little-endian signed integer	unitless
11	Algorithm/TSR/Soil_moisture	32-bit little-endian floating point	m^3/m^3
12	Algorithm/TSR/Soil_moisture_uncertainty	32-bit little-endian floating point	m^3/m^3
13	Algorithm/PMI/Croptype	8-bit little-endian signed integer	unitless
14	Algorithm/PMI/Dielectric_constant	32-bit little-endian floating point	unitless
15	Algorithm/PMI/Retrieval_Qflag	16-bit little-endian signed integer	unitless
16	Algorithm/PMI/Roughness	32-bit little-endian floating point	meters
17	Algorithm/PMI/Soil_moisture	32-bit little-endian floating point	m^3/m^3
18	Algorithm/PMI/Soil_moisture_uncertainty	32-bit little-endian floating point	m^3/m^3
19	Algorithm/PMI/Vegetation_water_content_HV	32-bit little-endian floating point	kg/m^2
20	Algorithm/PMI/Vegetation_water_content_NDVI	32-bit little-endian floating point	kg/m^2
21	Algorithm/PMI/Vegetation_water_content_estimate	32-bit little-endian floating point	kg/m^2
22	EASE_column_index	32-bit little-endian signed integer	unitless
23	EASE_row_index	32-bit little-endian signed integer	unitless
24	IncidenceAngle_aggregated	32-bit little-endian floating point	degree
25	IncidenceAngle_aggregated_std	32-bit little-endian floating point	degree
26	NES0_hh	32-bit little-endian floating point	dB
27	NES0_hv	32-bit little-endian floating point	dB
28	NES0_vh	32-bit little-endian floating point	dB
29	NES0_vv	32-bit little-endian floating point	dB
30	Landcover	8-bit little-endian signed integer	unitless
31	Numberoflooks_hh	16-bit little-endian signed integer	unitless
32	Numberoflooks_hv	16-bit little-endian signed integer	unitless
33	Numberoflooks_vh	16-bit little-endian signed integer	unitless
34	Numberoflooks_vv	16-bit little-endian signed integer	unitless
35	Sigma0_hh_aggregated	32-bit little-endian floating point	linear
36	Sigma0_hv_aggregated	32-bit little-endian floating point	linear
37	Sigma0_vh_aggregated	32-bit little-endian floating point	linear
38	Sigma0_vv_aggregated	32-bit little-endian floating point	linear
39	Surface_Qflag	16-bit little-endian signed integer	unitless

Fields	Name	Data Type	Units
40	Waterbody_fraction	32-bit little-endian floating point	unitless
41	latitude	32-bit little-endian floating point	degree
42	longitude	32-bit little-endian floating point	degree
43	identification/boundingPolygon	character string made up of one or more bytes	unitless
44	identification/absoluteOrbitNumber	32-bit little-endian unsigned integer	unitless
45	identification/frameNumber	16-bit little-endian unsigned integer	unitless
46	identification/trackNumber	8-bit little-endian unsigned integer	unitless
47	identification/zeroDopplerStartTime	character string made up of one or more bytes	unitless
48	identification/zeroDopplerEndTime	character string made up of one or more bytes	unitless

2.3 L3_SME2 Filename Convention

The following syntax governs the filename convention for NISAR L3_SME2 granules available from the ASF DAAC:

NISAR_*IL_PT_PROD_CYL_REL_P_FRM_MODE_POLE_S_StartDateTime_EndDateTime_CRID_A_C_LOC_CTR*.EXT

where

- NISAR – 5 char for mission: **NISAR**
- *I* – 1 char for Instrument: **L** for L-SAR, **S** for S-SAR
- *L* – 1 char for Level: **1** or **2** or **3**
- *PT* – 2 char for Processing Type:
    - **PR –** Production
    - **UR –** Urgent Response
- *PROD* – 4 chars for Product Identifier: **RSLC, GSLC, GCOV, SME2**
- *CYL* – 3 chars for CYcLe number in the mission, each cycle represents 12 days, zero padded, starting at 001.
- *REL* – 3 chars for RELative orbit track number within a cycle, resets to 1 with a cycle number increment, zero padded.Valid values: 001-173.
- *P* – 1 char for direction of movement of the satellite at the time of imaging]:
    - **A** for Ascending
    - **D** for Descending
- *FRM* – 3 chars for track frame number, a segment of an orbital track corresponding to the product, zero padded Valid Values: 001-176 on each track. See sec 4.5 [RD3]
- *MODE* – 4 chars for Bandwidth Mode Code of Primary and Secondary Bands: **40, 20, 77, 05, or 00** (only if the secondary band is missing)

- *POLE* – 4 chars for Polarization of the data for the primary and secondary bands. Each band uses a two character code among the following:
  - **SH** = HH – Single Polarity (H transmit and receive)
  - **SV** = VV – Single Polarity (V transmit and receive)
  - **DH** = HH/HV – Dual Polarity (H transmit)
  - **DV** = VV/VH – Dual Polarity (V transmit)
  - **CL**= LH/LV – Compact Polarity (Left transmit)
  - **CR** = RH/RV – Compact Polarity (Right transmit)
  - **QP** = HH/HV/VV/VH – Quad Polarity
  - **NA** if band does not exist

    For example, a “quasi-quad” polarization mode would be noted **DHDV** while a “quasi-dual” polarization mode would be noted **SHSV**.
- **S – 1 char for source of data for the product**
  - **A = Acquired source of the observation, single mode**
  - **M = Mixed source of observations, mixed mode**
- *StartDateTime* – 15 chars for Radar Start Time of the data processed as zero Doppler contained in the file as YYYYMMDDTHHMMSS, UTC
- *EndDateTime* – 15 chars for Radar End Time of the data processed as zero Doppler contained in the file as YYYYMMDDTHHMMSS, UTC
- *CRID* – 6 chars for Composite Release Identifier
  - Format of EPMMmm (See section 4.1 [RD3])
- *A* – 1 char for Product Accuracy or Fidelity of the Orbit Ephemeris and Radar Pointing:

  • **P, M, N,** or **F**, See section 4.2 [RD3]
- *C* – 1 char as Coverage Indicator: **F** for Full or **P** for Partial. See section 4.3 [RD3]
- *LOC* – 1 char to represent the location of the Science Data System. J for JPL, recommends N for NRSC. See section 4.6 [RD3]
- *CTR* – 3 chars for Product Version. See section 4.4 [RD3]
- *EXT* – 1 to n chars for Extension: **h5, met, log**

NOTES:

- 17 spacing characters: 16 for underscores plus one period
- Total number of characters: **90** excluding extension

Examples:

NISAR_L3_PR_SME2_001_005_A_219_4020_DHDV_M_20220104T182346_20220104T183426_P01101_M_P_J_001.h5

3 PRODUCT ORGANIZATION

3.1 File Format

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

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

3.1.1 HDF5 File

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

3.1.2 HDF5 Group

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

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

3.1.3 HDF5 Dataset

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

3.1.4 HDF5 Datatype

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

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

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

HDF5 provides a large set of predefined Atomic Datatypes. Table 3.1.4.1 lists the Atomic Datatypes that are used in NISAR data products.

Table 3.1.4.1 HDF5 Atomic Datatypes

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	8-bit little-endian unsigned integer
H5T_STD_U16LE	16-bit little-endian unsigned integer
H5T_STD_U32LE	32-bit little-endian unsigned integer
H5T_STD_U64LE	64-bit little-endian unsigned integer
H5T_STD_I8LE	8-bit little-endian signed integer
H5T_STD_I16LE	16-bit little-endian signed integer
H5T_STD_I32LE	32-bit little-endian signed integer
H5T_STD_I64LE	64-bit little-endian signed integer
H5T_IEEE_F32LE	32-bit little-endian floating point
H5T_IEEE_F64LE	64-bit little-endian 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 3.1.4.2 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.

Description	Comments

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 3.2.1.1 shows the general layout of the HDF5 files that are generated by the NISAR Science Data System. All data are organized under “/science/LSAR/” with data from the L-SAR instrument.

Table 3.2.1.1 Group organization at the top level of a NISAR HDF5 File

Group Name	Description
/Metadata	File level metadata required for archiving. This group does not exist in the current product.
/science/LSAR	All science data from the L-SAR instrument is organized under this group

3.2.2 File Level Metadata

As noted in Table 3.2.1.1 above, the explicitly named “/Metadata” Group does not appear in the current product. The representation of file level metadata is currently under discussion.

Global metadata at the file level are currently given as Global Attributes shown in Table 3.2.2.1.

Table 3.2.2.1 Global Attributes of L3_SME2

Attribute	Format	Description
Conventions	string	NetCDF-4 conventions adopted in this product. This attribute should be set to CF-1.7 to indicate that the group is compliant with the Climate and Forecast NetCDF conventions
title	string	NISAR L3_SME2 Product
institution	string	NASA Jet Propulsion Laboratory, California Institute of Technology (?)
mission_name	string	NISAR
reference_document	string	Name and version of Product Description Document to use as reference for product
contact	string	Contact information for producer of product

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 appears in an HDF5 Attribute that is directly associated with the HDF5 Dataset.

Table 3.2.3.1 lists the CF names for the HDF5 Attributes that NISAR products typically employ.

Table 3.2.3.1 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)

3.3 Granule Definition

NISAR L3_SME2 granules will be posted on the 200-meter global Equal-Area Scalable Earth (EASE) Grid 2.0 projection [RD7][RD8] and are expected to have a ground footprint of about 240 km x 240 km.

3.4 File Naming Convention

NISAR L3_SME2 Granule names will conform to the Standard Product File Naming Scheme [RD3]. See Section 2.

3.5 Temporal Organization

Temporal organization is not specifically applicable to the L3_SME2 product, although it is generally arranged in order of increasing azimuth time.

3.6 Spatial Organization

The L3_SME2 product is arranged on an equal-area Earth-fixed grid. Each grid cell is referenced by its zero-based row and column indices. Decreasing North is denoted by monotonic increasing row indices in the row direction, whereas increasing East is denoted by monotonic increasing column indices in the column direction.

3.7 Spatial Sampling and Resolution

Some salient characteristics of the output grid for the L3_SME2 product are:

1. (0,0) denotes the grid cell *center* of the northernmost-westernmost grid cell
2. (-0.5,-0.5) denotes the northernmost-westernmost grid *corner* of grid cell (0,0)
3. There are 73,080 rows and 173,520 columns in the global 200-m EASE Grid 2.0 projection on which L3_SME2 is posted.

4 LEVEL 3 SOIL MOISTURE PRODUCT

4.1 Dimensions and Shapes of Data

To simplify the description of the layout of data within the HDF5 file, a table of dimensions and shapes is used to represent the relationship between similarly sized datasets. This table is meant to be a guide to illustrate the shapes of the datasets in L3_SME2.

4.2 Product Specification

Table 4.2.1 NISAR L3_SME2 output fields

DSG Product Variables	
/Algorithm/DSG/Algorithm_Param_Beta	
Type: Float32	Shape: (productWidth, productLength)
Description: DSG algorithm regression parameter	
Unit: $m^3/(dB \cdot m^3)$	
/Algorithm/DSG/Algorithm_Param_Gamma	
Type: Float32	Shape: (productWidth, productLength)
Description: DSG algorithm regression parameter	
Unit: unitless	
/Algorithm/DSG/Retrieval_Qflag	
Type: Int16	Shape: (productWidth, productLength)
Description: DSG retrieval quality flag	
Unit: unitless	
/Algorithm/DSG/Soil_moisture	
Type: Float32	Shape: (productWidth, productLength)
Description: DSG soil moisture	
Unit: m^3/m^3	
/Algorithm/DSG/Soil_moisture_uncertainty	
Type: Float32	Shape: (productWidth, productLength)
Description: DSG soil moisture uncertainty	
Unit: m^3/m^3	
TSR Product Variables	
/Algorithm/TSR/Alpha1_parameter	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR alpha1 parameter	
Unit: m^3/m^3	
/Algorithm/TSR/Alpha1_parameter_uncertainty	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR alpha1 parameter uncertainty	
Unit: m^3/m^3	
/Algorithm/TSR/Alpha2_parameter	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR alpha2 parameter	
Unit: m^3/m^3	
/Algorithm/TSR/Alpha2_parameter_uncertainty	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR alpha2 parameter uncertainty	
Unit: m^3/m^3	
/Algorithm/TSR/Retrieval_Qflag	

Type: Int16	Shape: (productWidth, productLength)
Description: TSR retrieval quality flag	
Unit: unitless	
/Algorithm/TSR/Soil_moisture	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR soil moisture	
Unit: m^3/m^3	
/Algorithm/TSR/Soil_moisture_uncertainty	
Type: Float32	Shape: (productWidth, productLength)
Description: TSR soil moisture uncertainty	
Unit: m^3/m^3	
PMI Product Variables	
/Algorithm/PMI/Croptype	
Type: Int8	**Shape: (productWidth, productLength)**
Description: Crop type	
Unit: unitless	
/Algorithm/PMI/Dielectric_constant	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI dielectric constant	
Unit: unitless	
/Algorithm/PMI/Retrieval_Qflag	
Type: Int16	Shape: (productWidth, productLength)
Description: PMI retrieval quality flag	
Unit: unitless	
/Algorithm/PMI/Roughness	
Type: Float32	Shape: (productWidth, productLength)
Description: Surface roughness	
Unit: meters	
/Algorithm/PMI/Soil_moisture	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI soil moisture	
Unit: m^3/m^3	
/Algorithm/PMI/Soil_moisture_uncertainty	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI soil moisture uncertainty	
Unit: m^3/m^3	
/Algorithm/PMI/Vegetation_water_content_HV	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI vegetation water content from HV	
Unit: kg/m^2	
/Algorithm/PMI/Vegetation_water_content_NDVI	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI vegetation water content from NDVI	
Unit: kg/m^2	
/Algorithm/PMI/Vegetation_water_content_estimate	
Type: Float32	Shape: (productWidth, productLength)
Description: PMI estimated vegetation water content	
Unit: kg/m^2	
Common Variables	
/EASE_column_index	
Type: Int32	Shape: productLength
Description: EASE grid column index	
Unit: unitless	

/EASE_row_index	
Type: Int32	Shape: productWidth
Description: EASE grid row index	
Unit: unitless	
/IncidenceAngle_aggregated	
Type: Float32	Shape: (productWidth, productLength)
Description: 200m Incidence angle in EASE grid 2.0 projection	
Unit: degree	
/IncidenceAngle_aggregated_std	
Type: Float32	Shape: (productWidth, productLength)
Description: 200m Incidence angle standard deviation in EASE grid 2.0 projection	
Unit: degree	
/Landcover	
Type: Int8	Shape: (productWidth, productLength)
Description: 200m Land cover in EASE grid 2.0 projection	
Unit: unitless	
/Numberoflooks_hh	
Type: Int16	Shape: (productWidth, productLength)
Description: Number of 200m HH cells within the 9km EASE grid cell	
Unit: unitless	
/Numberoflooks_hv	
Type: Int16	Shape: (productWidth, productLength)
Description: Number of 200m HV cells within the 9km EASE grid cell	
Unit: unitless	
/Numberoflooks_vh	
Type: Int16	Shape: (productWidth, productLength)
Description: Number of 200m VH cells within the 9km EASE grid cell	
Unit: unitless	
/Numberoflooks_vv	
Type: Int16	Shape: (productWidth, productLength)
Description: Number of 200m VV cells within the 9km EASE grid cell	
Unit: unitless	
/NES0_hh	
Type: Float32	Shape: (productWidth, productLength)
Description: Noise equivalent sigma nought of HH polarization	
Unit: dB	
/NES0_hv	
Type: Float32	Shape: (productWidth, productLength)
Description: Noise equivalent sigma nought of HV polarization	
Unit: dB	
/NES0_vh	
Type: Float32	Shape: (productWidth, productLength)
Description: Noise equivalent sigma nought of VH polarization	
Unit: dB	
/NES0_vv	
Type: Float32	Shape: (productWidth, productLength)
Description: Noise equivalent sigma nought of VV polarization	
Unit: dB	
/Sigma0_hh_aggregated	
Type: Float32	Shape: (productWidth, productLength)
Description: 200m HH sigma nought in EASE grid 2.0 projection	
Unit: linear	
/Sigma0_hv_aggregated	

Type: Float32	Shape: (productWidth, productLength)
Description: 200m HV sigma nought in EASE grid 2.0 projection	
Unit: linear	
/Sigma0_vh_aggregated	
Type: Float32	Shape: (productWidth, productLength)
Description: 200m VH sigma nought in EASE grid 2.0 projection	
Unit: linear	
/Sigma0_vv_aggregated	
Type: Float32	Shape: (productWidth, productLength)
Description: 200m VH sigma nought in EASE grid 2.0 projection	
Unit: linear	
/Surface_Qflag	
Type: Int16	Shape: (productWidth, productLength)
Description: Surface quality flag	
Unit: unitless	
/Waterbody_fraction	
Type: Float32	Shape: (productWidth, productLength)
Description: Water body fraction [0-1]	
Unit: unitless	
/latitude	
Type: Float32	Shape: productWidth
Description: Latitude	
Unit: degree	
/longitude	
Type: Float32	Shape: productLength
Description: Longitude	
Unit: degree	
/identification/boundingPolygon	
Type: String	Shape: N/A
Description: Bounding box of the soil moisture product	
Unit: unitless	
/identification/absoluteOrbitNumber	
Type: UInt32	Shape: N/A
Description: Absolute orbit number	
Unit: unitless	
/identification/frameNumber	
Type: UInt16	Shape: N/A
Description: Frame number	
Unit: unitless	
/identification/trackNumber	
Type: UInt8	Shape: N/A
Description: Track number	
Unit: unitless	
/identification/zeroDopplerStartTime	
Type: String	Shape: N/A
Description: Zero doppler start time	
Unit: unitless	
/identification/zeroDopplerEndTime	
Type: String	Shape: N/A
Description: Zero doppler end time	
Unit: unitless	

5 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
DSG	Disaggregation
EAR	Export Administration Regulations
EASE	Equal-Area Scalable Earth
ECMWF	European Centre for Medium-Range Weather Forecasts
ECEF	Earth Centered Earth Fixed
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
PMI	Physical Model Inversion
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)
RMS	Root Mean Square
RMSE	Root Mean Square Error
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)
SMOS	Soil Moisture and Ocean Salinity
SNAPHU	Statistical-cost, Network-flow Algorithm for Phase Unwrapping
SWST	Sampling Window Start Time
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
TSR	Time Series Ratio
UR	Urgent Response
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VH	Vertical-transmit, Horizontal-receive polarization
VV	Vertical-transmit, Vertical-receive polarization
VWC	Vegetation Water Content
WGS84	World Geodetic System 84
XML	eXtensible Markup Language (xml in code)
YAML	YAML Ain’t Markup Language