Soil Moisture Active Passive (SMAP) Project

Level 1C_S0_HiRes
Product Specification Document

Revision C

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DOCUMENT CHANGE LOG

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C	23 Oct 2015	4.5.1	Changed sc_geodetic_alt_ellipsoid valid_max to 750000 meters
C	21 Mar 2016	4.6.20	Update for cell_radar_mode_flag with more details

TBD, TBR, TBS LOG

Section/Page	Description	Due Date
Appendix E	References the other Product Specification Documents. None have been written at the time of this publication. Thus, dates of publication are not available. In some cases, document identifiers are not available as well.	7/1/14
Section 4.6	No decision has been made about whether the product will list one or many kp components. The current product lists one component.	Completion of cal/val.

Update for cell_radar_mode_flag with more details iv
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1 INTRODUCTION

1.1 Identification

This is the Product Specification Document (PSD) for Level 1C_S0_HiRes data for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The Level 1C_S0_HiRes product provides Synthetic Aperture Radar data downloaded from SMAP spacecraft. This document applies to any standard Level 1C_S0_HiRes product based upon data acquired by the SMAP radar instrument.

1.2 Scope

This Product Specification Document describes the file format of the Level 1C_S0_HiRes Product. Its intent is to elucidate the Level 1C_S0_HiRes data structure and content for external software interfaces. The SMAP Science Data Management and Archive Plan provides a more comprehensive explanation of these data within the complete context of the SMAP instrument, algorithms, and software.

1.3 The SMAP Experiment

The Soil Moisture Active Passive (SMAP) mission will enhance the accuracy and the resolution of space-based measurements of terrestrial soil moisture and freeze-thaw state. SMAP data products will have a noteworthy impact on multiple relevant and current Earth Science endeavors. These include:

- Understanding of the processes that link the terrestrial water, the energy and the carbon cycles,
- Estimations of global water and energy fluxes over the land surfaces,
- Quantification of the net carbon flux in boreal landscapes,
- Forecast skill of both weather and climate,
- Predictions and monitoring of natural disasters including floods, landslides and droughts, and
- Predictions of agricultural productivity.

To provide these data, the SMAP mission will deploy a satellite observatory in a near polar, sun synchronous orbit. The observatory will house an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments will share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath.

As the spacecraft flies from north to south on *descending* orbits, the SMAP instruments will view Earth locations at approximately 06:00 local time. As the spacecraft flies from south to north, on *ascending* orbits, the SMAP instruments will view Earth locations at approximately 18:00 local time. The spacecraft will operate in a cycle of 117 repeatable orbits.

Each time that the spacecraft repeats the orbit cycle, the nadir path on the Earth's surface may not vary by more than 20 km. The flight plan enables scientists to collect data over any region of the Earth over seasonal and annual cycles and avoid diurnal variations. The combined flight pattern and viewing design will enable the observatory to view almost all of the Earth's land mass once every three days.

The SMAP radiometer records microwave emissions from the top 5 cm in the soil with a spatial resolution of about 40 km. Scientific applications based on radiometer measure in the same frequency range have established this approach as an accurate means to detect the presence or water in near surface soil. SMAP radar will provide backscatter measurements at 1 km resolution. The combined instrumentation will enable SMAP to generate highly accurate global soil moistures at 9 km resolution.

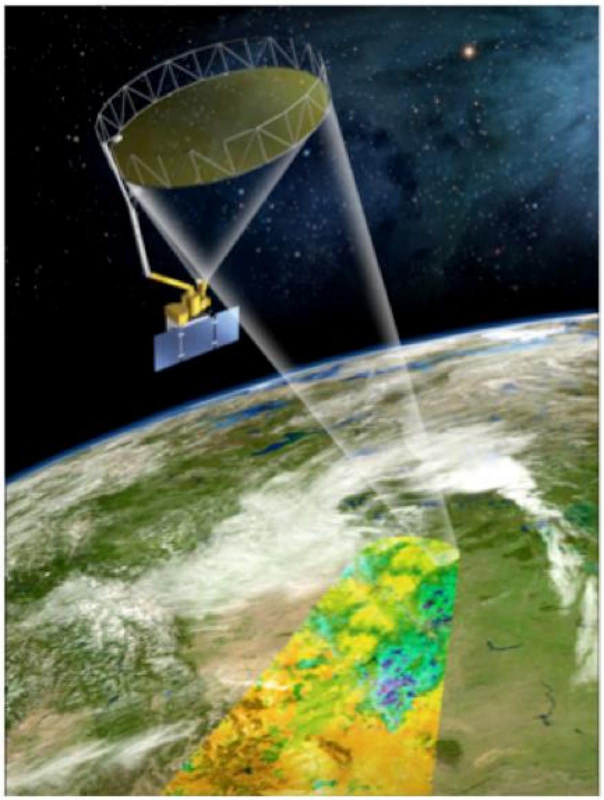

Figure 1: Artist's Concept of SMAP Observatory

Geophysical retrievals based on SMAP radar will indicate the presence of standing water, the freeze/thaw condition of the surface as well as measures of surface roughness and vegetation. The additional information will enable SMAP processors to select appropriate locations for soil moisture retrievals and modeling. In addition, the freeze/thaw data will contribute to models that measure the Net Ecosystem Exchange (NEE) of carbon between the Earth's surface and the atmosphere in Boreal regions.

1.4 SMAP Data Products

The SMAP mission will generate 15 distributable data products. The products represent four levels of data processing. Level 1 products contain instrument related data. Level 1 products appear in granules that are based on half orbits of the SMAP satellite. The Northernmost and Southernmost orbit locations demarcate half orbit boundaries. Level 2 products contain output from geophysical retrievals that are based on instrument data. Level 2 products also appear in half orbit granules. Level 3 products contain global output of the Level 2 geophysical retrievals for an entire day. Level 4 products contain output from geophysical models that employ SMAP data.

Table 1 lists the distributable SMAP data products. The colors in the table categorize the products by level. The table specifies two sets of short names. The SMAP Mission product short names were adopted by the SMAP mission to identify products. Users will find those short names in SMAP mission documentation, SMAP product file names and in the product metadata. The Data Centers will use short names defined for the Earth Observing System Data and Information System (EOSDIS) Core System (ECS). These short names categorize data products in local databases managed by the ECS. ECS short names will also appear in SMAP product metadata.

SMAP Mission Product Short Name	ECS Short Names	Description
L1A_Radar	SPL1AA	Parsed Radar Instrument Telemetry
L1A_Radiometer	SPL1AP	Parsed Radiometer Instrument Telemetry
L1B_S0_LoRes	SPL1BS0	Low Resolution Radar σ_o in Time Order
L1C_S0_HiRes	SPL1CS0	High Resolution Radar σ_o on Swath Grid
L1B_TB	SPL1BTB	Radiometer T_B in Time Order
L1C_TB	SPL1CTB	Radiometer T_B
L2_SM_A	SPL2SMA	Radar Soil Moisture, includes Freeze/Thaw State
L2_SM_P	SPL2SMP	Radiometer Soil Moisture
L2_SM_AP	SPL2SMAP	Active-Passive Soil Moisture
L3_FT_A	SPL3FTA	Daily Global Composite Freeze/Thaw State
L3_SM_A	SPL3SMA	Daily Global Composite Radar Soil Moisture
L3_SM_P	SPL3SMP	Daily Global Composite Radiometer Soil Moisture
L3_SM_AP	SPL3SMAP	Daily Global Composite Active-Passive Soil Moisture
L4_SM	SPL4TSM	Surface and Root Zone Soil Moisture
L4_C	SPL4C	Carbon Net Ecosystem Exchange

Table 1: SMAP Data Products

1.5 Content Overview

The SMAP Level 1C Radar (L1C_S0_HiRes) data product contains Synthetic Aperture Radar (SAR) normalized radar cross sections (σ_0) that are multilooked onto a grid that tracks the SMAP spacecraft nadir path. Cells in the swath grid have a 1 km resolution. The SMAP mission distributes this data product in half orbit granules. The northernmost and southernmost locations on the SMAP spacecraft path demarcate granule boundaries.

SMAP orbits begin at the southernmost point on the orbit path. The SMAP spacecraft will launch into orbit 0. Orbit 1 will begin as the spacecraft crosses the southernmost location for the first time. Based on acquired echo measurements, the radar flight software generates synthetic aperture radar data and real aperture radar data. The SMAP Level 1C Radar product contains processed synthetic aperture data. The SMAP Level 1B Radar product contains processed real aperture data.

The synthetic aperture radar (SAR) data is voluminous. Even with the high data transmission bandwidth, the SMAP spacecraft will not be able to downlink SAR resolution data all of the time. To ensure that adequate data were downlinked regularly, mission objectives determine when the spacecraft will downlink SAR data. The following criteria determine when the mission will downlink SAR data:

- The mission’s major objective is the measurement of soil moisture,
- Since heavy rainfall more often takes place during afternoon hours, soil scientists prefer acquisition of data during the early morning hours, and
- Scientists interested in freeze/thaw require some evidence of change in condition during each day.

The following downlink plan was adopted to meet those objectives:

- During the descending orbit, when local time is approximately 06:00 hours, the spacecraft downlinks SAR data over land except the Antarctic. These data are collected when the rotating antenna is looking either forward or aft of the spacecraft.
- During the descending orbit, when local time is approximately 06:00 hours, the spacecraft downlinks SAR data over coastal regions. Coastal regions are defined as ocean or sea regions that lie within 1000 km of land. These data are collected only when the rotating antenna is looking forward of the spacecraft.
- During the ascending orbit, when local time is approximately 18:00 hours, the spacecraft downlinks SAR data over land except the Antarctic. These data are collected when the rotating antenna is looking either forward or aft of the spacecraft.

On board flight software tracks radar instrument data in four distinct channels based on the polarization of the transmitted and received signal. The instrument produces h-pol chirps at a center frequency that is 1.5 MHz higher than the center of the noise channel. The instrument produces v-pol chirps at a center frequency that is 1.5 MHz lower than the center of the noise channel. Two co-polarized channels contain data transmitted and received in the same polarization. Data elements labeled with *hh* are based on horizontally polarized signals that are detected in the instrument h-pol receiver. Data elements labeled with *vv* are based on vertically polarized signals that are detected by the instrument v-pol receiver.

The two cross-pol channels contain data transmitted in one polarization but received by the receiver for the other polarization. To save space, the spacecraft downlinks data from just one of the two cross-pol channels. Flight software design includes a switch that specifies which cross-pol channel will be downlinked. Nominally, the spacecraft will downlink data based on horizontally polarized signals that the v-pol receiver detects. Thus, in the nominal case, the product contains *vh* data. To maintain the possibility that cross-polarization channel may change, the product employs the suffix *xpol* to describe all data elements associated with cross-pol data.

Most of the data in the Radar Level 1C are organized relative to the 1 km cells in the instrument swath. For each of the cells, the product lists σ_0 values for each of three channels. Those include a horizontal co-pol channel, a vertical co-pol channel and one of the two cross pol channels. The product also separates looks that were acquired forward of the spacecraft from those that were acquired aft of the spacecraft. Thus, the product provides six distinct σ_0 values for each grid cell. In addition, the product provides additional geometric information, as well as normalized standard deviations (K_p), as well as quality information.

1.6 Related SMAP Project Documents

SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document, R. West, JPL D-53052, May 31, 2012.

SMAP Science Data Management and Archive Plan, JPL D-45973, August 29, 2011.

SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems, JPL D-46018, Initial Release, May 18, 2010

1.7 Applicable Documents

ISO 19115:2003(E) International Standard – Geographic Information – Metadata, May 1, 2003.

ISO 19115-2:2009 International Standard – Geographic Information – Part 2:Extensions for imagery and gridded data, December 12, 2009.

ISO 19139:2007 International Standard – Geographic Information – Metadata – XML schema implementation, May 14 2009.

Introduction to HDF5, The HDF Group, http://www.hdfgroup.org/HDF5/doc/H5.intro.html.

HDF5: API Specification Reference Manual, The HDF Group http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Front.html

HDF5 User's Guide Release 1.8.9, The HDF Group, http://hdfgroup.com/HDF5/doc/UG, May 2012.

NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, December 5, 2011.

EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets, Brodzik, M.J., et. al., National Snow and Ice Data Center, Cooperative Institute of Environmental Sciences, University of Colorado, ISPRS International Journal of Geo-Information, ISSN 2220-9964, DOI: 10.3390/igji1010032.

2 DATA PRODUCT ORGANIZATION

2.1 File Format

All SMAP standard products are in the Hierarchical Data Format version 5 (HDF5). 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 regardless of the source. Use of the HDF library enables users to read HDF files on multiple platforms regardless of the architecture the platforms use to represent integer and floating point numbers. HDF files are equally accessible to routines written either in Fortran, C or C++.

A spin-off organization of the NCSA, named The HDF Group, is responsible for development and maintenance of HDF. Users should reference The HDF Group website at http://www.hdfgroup.org to download HDF software and documentation.

2.2 HDF5 Notation

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.

2.2.1 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.

2.2.2 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.

2.2.3 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.

2.2.4 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 2 lists the Atomic Datatypes that are used in SMAP data products.

Table 2: 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

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.

None of the SMAP data products employ Enumeration or Compound data types.

2.2.5 HDF5 Dataspace

A Dataspace describes the rank and dimension of a Dataset or Attribute. For example, a “Scalar” Dataspace has a rank of 1 and a dimension of 1. Thus, all subsequent references to “Scalar” Dataspace in this document imply a single dimensional array with a single element.

Dataspaces provide considerable flexibility to HDF5 products. They incorporate the means to subset associated Datasets along any or all of their dimensions. When associated with specific properties, Dataspaces also provide the means for Datasets to expand as the application requires.

2.2.6 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.

2.3 SMAP File Organization

2.3.1 Structure

SMAP data products follow a common convention for all HDF5 Files. Use of this convention provides uniformity of data access and interpretation.

The SMAP Project uses HDF5 Groups to provide an additional level of data organization. All metadata that pertain to the complete data granule are members of the "/Metadata" Group. All other data are organized within Groups that are designed specifically to handle the structure and content of each particular data product.

2.3.2 Data

All data in HDF5 files are stored in individual Datasets. All of the Datasets in an SMAP product are assigned to an HDF5 Group. A standard field name is associated with each Dataset. The field name is a unique string identifier. The field name corresponds to the name of the data element the Dataset stores. This document lists these names with the description of each data element that they identify.

Each Dataset is associated with an HDF5 Dataspace and an HDF5 Datatype. They provide a minimally sufficient set of parameters for reading the data using standard HDF5 tools.

2.3.3 Element Types

SMAP HDF5 employs the Data Attribute "Type" to classify every data field as a specific data type. The "Type" is an embellishment upon the standard HDF5 Datatypes that is designed specifically to configure SMAP data products.

Table 3 lists all of the "Type" strings that appear in the SMAP data products. The table maps each SMAP "Type" to a specific HDF5 Datatype in both the HDF5 file and in the data buffer. The table also specifies the common conceptual data type that corresponds to the "Type" in SMAP executable code.

Table 3: Element Type Definitions

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
Unsigned8	H5T_STD_U8LE	H5T_NATIVE_UCHAR	unsigned integer
Unsigned16	H5T_STD_U16LE	H5T_NATIVE_USHORT	unsigned

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
			integer
Unsigned24	H5T_STD_U16LE, with precision set to 24 bits, and size set to 3 bytes.	H5T_NATIVE_INT	unsigned integer
Unsigned32	H5T_STD_U32LE	H5T_NATIVE_UINT	unsigned integer
Unsigned64	H5T_STD_U64LE	H5T_NATIVE_ULLONG	unsigned integer
Signed8	H5T_STD_I8LE	H5T_NATIVE_SCHAR	signed integer
Signed16	H5T_STD_I16LE	H5T_NATIVE_SHORT	signed integer
Signed32	H5T_STD_I32LE	H5T_NATIVE_INT	signed integer
Signed64	H5T_STD_I64LE	H5T_NATIVE_LLONG	signed integer
Float32	H5T_IEEE_F32LE	H5T_NATIVE_FLOAT	floating point
Float64	H5T_IEEE_F64LE	H5T_NATIVE_DOUBLE	floating point
FixLenStr	H5T_C_S1	H5T_NATIVE_CHAR	character string
VarLenStr	H5T_C_S1, where the length is set to H5T_VARIABLE	H5T_NATIVE_CHAR	character string

SMAP HDF5 files employ two different types of string representation. “VarLenStr” are strings of variable length. “VarLenStr” provides greater flexibility to represent character strings. In an effort to make SMAP HDF5 more friendly to users who wish to use netCDF software, SMAP products restrict the use of “VarLenStr”. “FixLenStr” are strings with a prescribed fixed-length. “FixLenStr” are useful for fixed length strings that are stored in large multi-dimension array. UTC time stamps are an excellent example of the type of data that store well in a "FixLenStr".

2.3.4 File Level Metadata

All metadata that describe the full content of each granule of the SMAP data product are stored within the explicitly named "/Metadata" Group. SMAP metadata are handled using exactly the same procedures as those that are used to handle SMAP data. The contents of each Attribute that stores metadata conform to one of the SMAP Types. Like data, each metadata element is also assigned a shape. Most metadata elements are stored as scalars. A few metadata elements are stored as arrays.

SMAP data products represent file level metadata in two forms. One form appears in two Attributes within the Metadata Group. Combined, those two Attributes contain a complete representation of the product metadata. The content conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

The second form of the metadata appears in a set of HDF5 Groups under the "/Metadata" Group. Each of these HDF5 Groups represents one of the major classes in the ISO 19115-2 model. These HDF5 Groups contain a set of HDF5 Attributes. Each HDF5 Attributes represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the ISO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

2.3.5 Local Metadata

SMAP standards incorporate additional metadata that describe each HDF5 Dataset within the HDF5 file. Each of these metadata elements appear in an HDF5 Attribute that is directly associated with the HDF5 Dataset. Wherever possible, these HDF5 Attributes employ names that conform to the Climate and Forecast (CF) conventions. Table 4 lists the CF names for the HDF5 Attributes that SMAP products typically employ.

Table 4: SMAP Specific Local Attributes

CF Compliant Attribute Name	Description	Required?

CF Compliant Attribute Name	Description	Required?
units	Units of measure. Appendix E lists applicable units for various data elements in this product.	Yes
valid_max	The largest valid value for any element in the Dataset. The data type in valid_max matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_max will also be float32.	No
valid_min	The smallest valid value for any element in the Dataset. The data type in valid_min matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_min will also be float32.	No
_FillValue	Specification of the value that will appear in the Dataset when an element is missing or undefined. The data type of _FillValue matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding _FillValue will also be float32.	Yes for all numeric data types
long_name	A descriptive name that clearly describes the content of the associated Dataset.	Yes
coordinates	Identifies auxiliary coordinate variables in the data product.	No
flag_values	Provides a list of flag values that appear in bit flag variables. Should be used in conjunction with local HDF5 attribute *flag_meanings*. Only appears with bit flag variables.	No
flag_masks	Provides a list of bit fields that express Boolean or enumerated flags. Only appears with bit flag variables or enumerated data	No

CF Compliant Attribute Name	Description	Required?
	types.	
flag_meanings	Provides descriptive words or phrases for each potential bit flag value. Should be used in conjunction with local HDF5 attribute *flag_values*.	No

2.4 Data Definition Standards

Section 4.6 of this document specifies the characteristics and definitions of every data element stored in this SMAP data product. Table 5 defines each of the specific characteristics that are listed in that section of this document. Some of these characteristics correspond with the SMAP HDF5 Attributes that are associated with each Dataset. Data element characteristics that correspond to SMAP HDF5 Attributes bear the same name. The remaining characteristics are descriptive data that help users better understand the data product content.

In some situations, a standard characteristic may not apply to a data element. In those cases, the field contains the character string ’n/a’. Hexadecimal representation sometimes indicates data content more clearly. Numbers represented in hexadecimal begin with the character string ’0x’.

Table 5: Data Element Characteristic Definitions

Characteristic	Definition
Type	The data representation of the element within the storage medium. The storage class specification must conform to a valid SMAP type. The first column in table 3 lists all of the valid values that correspond to this characteristic.
Shape	The name of the shape data element that specifies the rank and dimension of a particular data set. Appendix C lists all of the valid shapes that appear in this data product.
Valid_max	The expected minimum value for a data element. In most instances, data element values never fall below this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that fall below this limit.
Valid_min	The expected maximum value for a data element. In most

Characteristic	Definition
	instances, data element values never exceed this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that exceed this limit.
Valid Values	Some data elements may store a restricted set of values. In those instances, this listing specifies the values that the data element may store.
Nominal Value	Some data elements have an expected value. In those instances, this listing provides that expected value. Nominal values are particularly common among a subset of the metadata elements.
String Length	This characteristic specifies the length of the data string that represents a single instance of the data element. This characteristic appears exclusively for data elements of FixLenStr type.
Units	Units of measure. Typical values include “deg”, “degC”, “Kelvins”, “m/s”, “m”, “m**2”, “s” and “counts”. Appendix A and Appendix E include references to important data measurement unit symbols.

2.4.1 Double Precision Time Variables

SMAP double precision time variables contain measurements relative to the J2000 epoch. Thus, these variables represent a real number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC.

2.4.2 Array Representation

This document employs array notation to demonstrate and clarify the correspondence among data elements in different product data elements. The array notation adopted in this document is similar to the standards of the Fortran programming language. Indices are one based. Thus, the first index in each dimension is one. This convention is unlike C or C++, where the initial index in each dimension is zero. In multidimensional arrays, the leftmost subscript index changes most rapidly. Thus, in this document, array elements ARRAY(15,1,5) and ARRAY(16,1,5) are stored contiguously.

HDF5 is designed to read data seamlessly regardless of the computer language used to write an application. Thus, elements that are contiguous using the dimension notation in this document will appear in contiguous locations in arrays for reading applications in any language with an HDF5 interface.

This document differentiates among array indices based on relative contiguity of storage of elements referenced with consecutive numbers in that index position. A faster or fastest moving index implies that the elements with consecutive numbers in that index position are stored in relative proximity in memory. A slower or slowest moving index implies that the elements referenced with consecutive indices are stored more remotely in memory. For instance, given array element ARRAY(15,1,5) in Fortran, the first index is the fastest moving index and the third index is the slowest moving index. On the other hand, given array element array[4][0][14] in C, the first index is the slowest moving index and the third index is the fastest moving index.

3 INTERFACE CHARACTERISTICS

3.1 Coordinate Systems

The SMAP mission will use the Science Orbit Reference Frame (SRF) and the Earth Centered Rotating (ECR) coordinate systems to represent spacecraft attitude, position and relative motion. The SMAP project document entitled SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems fully describes both of these coordinate systems.

The Science Orbit Reference Frame (SRF) is a right-handed coordinate system with its three axes mutually orthogonal. The SRF is defined such that the origin is at the spacecraft center of mass (CM). The +Z axis points toward Geodetic Nadir. Due to the oblateness of the Earth, the vector from the spacecraft to the geometric center of the Earth (Geocentric Nadir) is different from the vector from the spacecraft to the local WGS84 ellipsoid normal (Geodetic Nadir). The +X axis is coplanar with both the +Z axis and the spacecraft inertial velocity vector. The +X axis closely adheres to the direction of the spacecraft inertial velocity vector. The +Y axis completes the right-handed, orthogonal coordinate system. The +Y axis is normal to the orbit plane with positive sense in the direction opposite the orbit angular momentum vector.

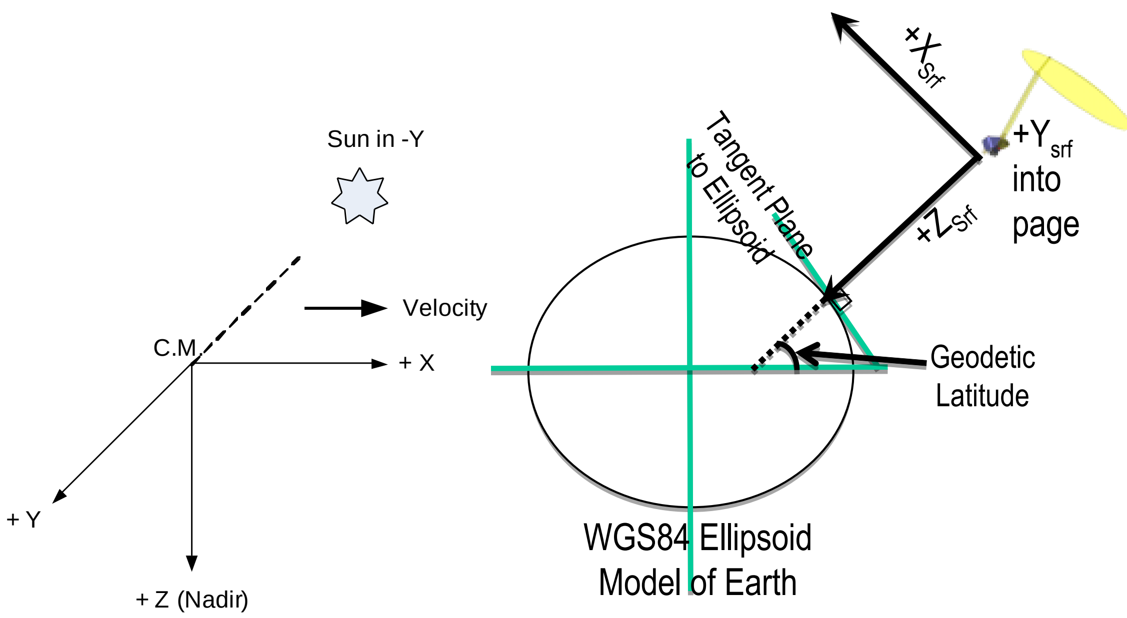

Figure 2: The Science Reference Frame Coordinate System

The Earth Centered Rotating (ECR) or Earth Centered Fixed coordinate system is a right-handed coordinate system with three mutually orthogonal axes. The origin of the system is the Earth's center of mass. The positive x-axis extends from the origin through the intersection of the Equator at 0° latitude and the Greenwich Meridian at 0° longitude. The positive z-axis extends directly North from the origin of the ECR system. Due to a slight wobbling of the Earth, the z-axis does not coincide exactly with the instantaneous rotation axis of the Earth. The y-axis completes the right-handed coordinate system as a vector from the origin to the intersection of the Equator and 90° East longitude.

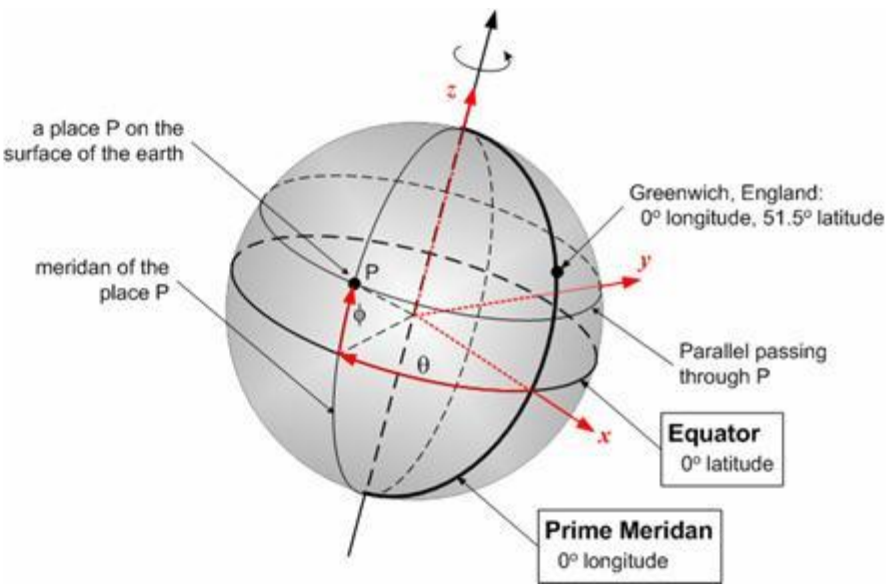

Figure 3: Earth Centered Rotating Coordinate System

The SMAP mission adopted the World Reference System WGS84 ellipsoid to define the horizontal Earth reference coordinates. The WGS84 geoid was adopted as the vertical Earth reference coordinates. Geodetic measure is used to define both the spacecraft location and the instrument target location relative to the Earth's surface.

3.2 Spacecraft Attitude and Modeling Spacecraft Slews

The SMAP SDS receives spacecraft attitude data on a regular basis from the Navigation and Ancillary Information Facility (NAIF) at JPL. Upon arrival from NAIF, these data specify the orientation of the Spacecraft Coordinate System with respect to J2000 coordinates. The NAIF data are represented in quaternions. A frames kernel describes the slight offset measured between the Spacecraft Coordinate System and the Instrument Fixed Coordinate System (INSF) from which the pitch, yaw and roll angles will be referenced.

The Science Data System converts these data into pitch, yaw and roll angles relative to the SMAP Science Orbit Reference Frame (SRF). Those angular measures appear in the SMAP Level 1 Science Data Products. Both the Science Orbit Reference Frame and the Instrument Fixed Coordinate System are defined in the SMAP Pointing, Positioning, Phasing and Coordinate System Volume 0, Revision B, April 15, 2014.

During nominal operations, after a 180 degree roll to align the Z axes of the two systems, the resulting pitch, yaw and roll angles will be very small. Indeed, in order to retain anticipated incidence angles for radar and radiometer measure, these angles will almost always be less than 1 degree. Thus, under these conditions, the definitions of pitch, yaw and roll conform to the definitions found in the SMAP Level 1 Product Specification Documents.

- Pitch is the angular rotation of the instrument fixed frame about the Y axis of the SMAP Science Orbit Reference Frame (SRF). The Y axis of the SRF is normal to the spacecraft orbital plane.
- Roll is the angular rotation of the instrument fixed frame about the X axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The X axis of the SRF approximates the direction of spacecraft motion.
- Yaw is the angular rotation of the instrument fixed frame about the Z axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The Z axis of the SRF runs from the center of mass of the spacecraft toward geodetic nadir.

The SMAP mission will maneuver the spacecraft from time to time. Of particular interest are maneuvers that enable the spacecraft antenna to view cold sky. Knowledge of the Euler angle that represents the spacecraft attitude during these maneuvers is critical. Generation of the Euler angle requires specification of the proper order of rotation from the science orbit reference frame to the spacecraft frame. The order of rotation that users should employ is pitch, followed by roll and then yaw. **If SMAP product users wish to reconstruct the Euler angles associated with spacecraft maneuvers, they should employ the following processing steps based on provided values of pitch, yaw and roll:**

- Roll the spacecraft angle by 180 degrees. The roll aligns the Z axis of the Instrument Fixed Coordinate System with the SMAP Science Orbit Reference Frame (it also changes the sign of the pitch and yaw).
- Perform a pitch rotation. The pitch rotation is executed about the position of the Y axis of the Instrument Fixed Coordinate System at the completion of the previous roll rotation.
- Perform roll rotation. The roll rotation is executed about the position of the X axis of the Instrument Fixed Coordinate System at the completion of the

previous pitch rotation.

- Perform the yaw rotation. The yaw rotation is executed about the position of the Z axis of the Instrument Fixed Coordinate System at the completion of the roll rotation.

To enable representation of maneuver conditions, the pitch, roll and yaw angles will need to take on larger measures. SMAP software thus enables pitch values to range from –180 degrees to 180 degrees, roll values to range from –90 to 90 degrees and yaw values to range from –180 degrees to 180 degrees.

3.3 Fill and Gap Values

SMAP data products employ fill and gap values to indicate when no valid data appear in a particular data element. Fill values ensure that data elements retain the correct shape. Gap values locate portions of a data stream that do not appear in the output data file.

Fill values appear in the SMAP L1C_S0_HiRes Product when the Level 1C SPS can process some, but not all, of the input data for a particular swath grid cell. Fill data may appear in the product in any of the following circumstances:

- One of Science Production Software (SPS) executables that generate the SMAP L1C_S0_HiRes Product is unable to calculate a particular science or engineering data value. The algorithm encounters an error. The error disables generation of valid output. The SPS reports a fill value instead.
- Some of the required science or engineering algorithmic input are missing. Data over the region that contributes to particular grid cell may appear in only some of the input data streams. Since data are valuable, the L1C_S0_HiRes Product records any outcome that can be calculated with the available input. Missing data appear as fill values.
- Non-essential information is missing from the input data stream. The lack of non-essential information does not impair the algorithm from generating needed output. The missing data appear as fill values.
- Fill values appear in the input Radar_L1A product. If only some of the input that contributes to a particular grid cell is fill data, the Level 1C_S0_HiRes SPS will most likely be able to generate some output. However, some portion of the L1C_S0_HiRes output for that grid cell may appear as fill values.

SMAP data products employ a specific set of data values to connote that an element is fill. The selected values that represent fill are dependent on the data type. With the exception of bit flag variables, Table 6 lists the values that represent fill in SMAP products based on data type. Section 3.4 describes SMAP standard processing for bit flag variables.

Table 6: SMAP Product Fill Values

Type	Value	Pattern
Float32, Float64	-9999.0	Large, negative number
Signed8, NormSigned8	-127	Type minimum + 1
Signed16, NormSigned16	-32767	Type minimum + 1
Signed24	-8388607	Type minimum + 1
Signed32	-2147483647	Type minimum + 1
Signed64	-9223372036854775807	Type minimum + 1
Unsigned8	254	Type maximum - 1
Unsigned16	65534	Type maximum - 1
Unsigned24	16777214	Type maximum - 1
Unsigned32	4294967294	Type maximum - 1
Unsigned64	18446744073709551614	Type maximum - 1
FixedLenString, VarLenString	N/A	Not available

No valid value in the L1C_S0_HiRes product is equal to the values that represent fill. If any exceptions should exist in the future, the L1C_S0_HiRes content will provide a means for users to discern between elements that contain fill and elements that contain genuine data values. This document will also contain a description of the method used to ascertain which elements are fill and which elements are genuine.

The L1C_S0_HiRes product records gaps when entire frames within the time span of a particular data granule do not appear. Gaps can occur under one of two conditions:

- One or more complete frames of data are missing from all data streams.
- The subset of input data that is available for a particular frame is not sufficient to process any frame output.

The Level 1C_S0_HiRes Product records gaps in the product level metadata. The following conditions will indicate that no gaps appear in the data product:

- Only one instance of the attributes *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* will appear in the product metadata.
- The character string stored in metadata element *Extent/rangeBeginningDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStartDateTime*.
- The character string stored in metadata element *Extent/rangeEndingDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStopDateTime*.

One of two conditions will indicate that gaps appear in the data product:

- The time period covered between *Extent/rangeBeginningDateTime* and *Extent/RangeEndingDateTime* does not cover the entire half orbit as specified in *OrbitMeasuredLocation/halfOrbitStartDateTime* and *OrbitMeasuredLocation/halfOrbitStartDateTime*.
- More than one pair of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* appears in the data product. Time periods within the time span of the half orbit that do not fall within the sets of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* constitute data gaps.

Bit flag elements in the L1C_S0_HiRes product often provide additional information about missing data. For example, the data element *along_track_qual_flag* in the L1C_S0_HiRes product contains bit flags that indicate the quality of data for each along track row. Likewise, each of the *cell_sigma0_qual_flag* variables indicates the quality of the data in each swath grid cell. When a data frame is deemed unusable, the appropriate bits in the *along_track_qual_flag* or the appropriate *cell_sigma0_qual_flag* should indicate the rationale.

If data values associated with any particular look of the radar instrument creates untenable algorithmic conditions, the L1C_S0_HiRes SPS may curtail processing for that look. When these conditions take place, the L1_S0_HiRes Product displays whatever values the SPS was able to calculate. When a sigma0 measure for a particular grid cell has been deemed unusable, the appropriate bits in the *cell_sigma0_qual_flag* will provide users with a rationale for the missing data.

3.4 Bit Flag Variables

SMAP data products contain bit flag variables. Bit flag variables provide quality information and processing conditions for individual data pixels within the product. This document contains a full description of each of the bit flag variables in the correct product.

SMAP executables that generate data products employ a standard method to set and clear the values of individual bits in the bit flag variables. At the beginning of the process, the executable initializes bit flag variable content. When product content is initialized, all of the defined bits in the bit flag variable contain a value of ‘1’ and all of the bits that are undefined contain a value of ‘0’. As the process proceeds, conditions and quality information will lead the executable to convert appropriate defined bit values from ‘1’ to ‘0’.

Thus, for bit flag variables, the initialized value of the bit flag is equivalent to the Fill value.

3.5 Flexible Data Design

HDF5 format gives the SMAP Level Products a high degree of flexibility. This flexibility in turn gives SMAP end product users the capability to write software that does not need to be modified to accommodate unforeseeable changes in the SMAP products. Since changes to the products are certain to take place over the life of the SMAP mission, users are encouraged to use software techniques that take advantage of some of the features in HDF5.

For example, users can write a product reader that selects only those product data elements they wish to read from an SMAP Level Product file. With the appropriate design, this software will not need to change, regardless of the number, the size, or the order of the current data product entries. Indeed, the only changes users need to implement would take place if they should choose to read a newly defined data element after a product upgrade.

For those users who wish to extract a specific subset of the data from an SMAP Product, the HDF5 routines H5Dopen and H5Dread (h5dopen_f and h5dread_f in FORTRAN) are very useful. H5Dopen requires two input parameters, the first is an HDF5 file/group identifier, the second is a character string that contains the name of a Dataset. H5Dopen returns the identifier for the specified Dataset in the product file. HDF5 routine H5Dread then uses the Dataset identifier to fetch the contents. H5Dread places the contents of the Dataset in a specified output variable.

Once the data element is located and read, users can generate standardized code that reads the metadata associated with each element. Users of the SMAP Level Products should employ the same methods to read metadata and standard data elements.

3.6 Access to Product Element Dimensions

Each data element in every SMAP data product is assigned a specific shape. Elements with the same shape have the same number of dimensions, and each of those dimensions have the same extent and meaning. Thus, if two data elements have the same shape, then their constituent array elements with identical indices correspond.

The SMAP L1C_S0_HiRes Product employs a naming convention for shapes. The convention specifies the component dimensions. The final word in all shape names is always “Array”. The text that precedes the word “Array” provides the order of dimensions. The word that just precedes “Array” represents the dimension with the “fastest moving” index. In other words, consecutive indices in this dimension, provided the other dimension indices are identical, represent contiguous storage. For example, the Shape name AlongTrack_CrossTrack_Array implies that the dimension where consecutive indices imply contiguous storage represents cross track location. The other, slower moving, dimension represents along track positions. Appendix C provides the nominal rank and dimension sizes for each shape that appears in the L1C_S0_HiRes Product.

Appendix D provides the nominal or expected maximum product dimensions. A wise user should not, however, rely solely on Appendix D to write code that sizes arrays in the L1C_S0_HiRes. The actual dimension sizes for some of the Shapes may vary from product granule to product granule. For example, the number of frames will not remain constant among all L1C_S0_HiRes data product granules. Thus, the AlongTrack_CrossTrack_Array Shape may be 1010,20040) in one product and (1010,20015) in another.

Appendix F contains an example of code that reads dimensions for a particular data element directly from the Radar Level 1A product.

4 DATA DEFINITION

4.1 Product Overview

4.1.1 Level 1C S0 HiRes Product

Each Level 1C S0 HiRes product granule incorporates all of the synthetic aperture radar data that were downlinked from the SMAP spacecraft for one specific half orbit. The SMAP project delineates half orbits at the northernmost and southernmost point of each orbit path.

The major contents of the Level 1C S0 HiRes product are normalized radar cross section (σ_0) measurements, multilooked into 1 km square instrument swath based grid cells. The center line of the grid corresponds to the path of the spacecraft nadir on the Earth's surface. Ancillary data elements in the product provide measures of data acquisition time and geometry as well as data quality.

4.1.2 Level 1C S0 HiRes Metadata

The SMAP Level 1C S0 HiRes metadata are representative of the entire contents of the file. The metadata appear in two forms. One form of the metadata appears in single HDF5 Attribute. That Attribute contains the complete representation of the product metadata that conforms to the ISO 19115-2 model in ISO 19139 compliant XML. The second form of the metadata appears in a set of HDF5 groups. Each HDF5 group contains a set of HDF5 attributes. The arrangement and names of the groups and their attribute components approximate major contents of the ISO model.

Metadata in ISO 19139 conformant XML enables users who are familiar with the ISO metadata standards to extract the metadata they need using software that operates with the ISO 19115-2 model and its formal representation. The set of groups and attributes enable users who are not as familiar with the ISO standard to find the particular metadata elements they need to better comprehend product content and format.

4.1.3 Level 1C S0 HiRes Data

All product elements in the Level 1C S0 HiRes Product are stored as HDF5 Datasets. Each of these datasets belong to one of three distinct HDF5 Groups. The data design employs HDF5 Groups to categorize datasets that have corresponding array elements and that relate to a common application.

The HDF5 Groups in the Level 1C_S0_HiRes product include the Spacecraft Data Group, the Crosstrack Data Group and the Sigma0 Data Group. Section

4.5 of this document includes more detailed descriptions of each of the HDF5 Groups in the data product.

All of the Level 1C S0 HiRes HDF5 Groups are organized relative to the SMAP instrument swath. The single array index for all data elements in the Spacecraft Data Group denotes the position of acquired data relative to the direction of spacecraft motion. This single index in the Spacecraft Data Group corresponds to the slowest moving index for all elements in the Sigma0 Data Group. Within each data granule, the time the spacecraft flew over any given along track row is a monotonically increasing function of the along track row index. Thus, a smaller along track index represents an along track row that spacecraft passed over earlier during flight. A larger along track index represents an along track row that the spacecraft passed over later during flight. All array elements with the same along track index fall in the same along track row in the instrument swath. Thus, *along_track_time(264)* specifies the time that the spacecraft nadir crosses over the center line of the 264th cross track row. Element *yaw(264)* specifies the spacecraft yaw interpolated to that instant.

The single array index for both elements in the Crosstrack Data Group corresponds to the second index for all data elements in the Sigma0 Data Group. That index denotes the cross-track position of grid cells in the instrument swath. When facing the direction of spacecraft motion, grid cells to the left have smaller indices. Grid cells to right have larger indices. Thus, the element *cell_sigma0_hh_fore(15,264)* contains the multilooked normalized radar cross section in the 15^{th} grid cell from the left side of the grid when facing the direction of motion, and within the grid cell row that corresponds to the time of spacecraft pass recorded in element *along_track_time(264).*

4.2 Data Volume Estimates

Due to limits in communication bandwidth, complex rules dictate when synthetic aperture radar data are downlinked to the ground and subsequently processed into data products. The mission downlinks synthetic aperture radar data acquired over land and coastal ocean that are acquired at 6:00 AM local time. The mission restricts downlink of synthetic aperture radar data acquired at 6:00 PM to land that is North of 45 North latitude. Furthermore, data acquired forward of the SMAP spacecraft are always included in any downlink of synthetic aperture data. Data acquired aft of the SMAP spacecraft are downlinked only over land during an AM pass. Given these requirements, and the fact that the Earth's land mass is not evenly distributed, the volume of L1C_S0_HiRes data products varies considerably.

The Table 7 provides users with an average uncompressed volume of L1C_S0_HiRes products. The table specifies the contribution of each of the data Groups to the total data volume of the product. The final row provides an estimate of the volume of an average data granule.

Since the fraction of land mass can vary greatly from one orbit to another, users should view this estimate as a representative sample. Thus, users can apply these numbers to estimate the storage required to handle weeks, months or years of L1C_S0_HiRes data.

Table 7: Data Volume Estimates for the L1C_S0_HiRes Product

Group	Number of Entries	Bytes Per Entry	Expected Total Volume (MBytes)
Level 1C S0 HiRes Metadata	1	10000	.010
XML Version of ISO Metadata	1	124000	0.124
Spacecraft Data Group	10220	112	1.145
Crosstrack Data Group	1000	8	.008
Sigma0 Data Group	10220000	328	3352.2
Level 1C S0 HiRes Product			3353.4

4.3 SMAP Level 1C S0 HiRes Product File Names

Distributable SMAP L1C S0 HiRes data product file names are 56 characters in length. The first 5 characters in the name of all mission distributable products are 'SMAP_'. These characters identify all products generated by the SMAP mission. The following 13 characters are always 'L1C_S0_HiRes_'. These characters identify the Radar Level 1C S0_HiRes Science Data Product. The following 35 characters uniquely identify the data stored in the file. The final 3 characters of each SMAP Product file name are '.h5'. These characters specify the format of the data in the file.

More specifically, all SMAP L1C S0_HiRes data product file names must conform to the following convention:

SMAP_L1C_S0_HiRes_[Orbit Number]_[A|D]_[First Date/Time Stamp]_[Composite Release ID]_[Product Counter].[extension]

The outline below describes the content of each field in the file naming convention:

Orbit Number – The sequential number of the orbit that the SMAP spacecraft flew when the data in the associated product were acquired. Orbit 0 will begin at launch. The orbit number must occupy five digits. Orbit numbers that are smaller than 10000 will appear with leading zeroes.

The Half Orbit Designator - SMAP divides orbits into two distinct parts. Division of half orbits takes place at the northernmost and southernmost point on the spacecraft path. Half orbits where the spacecraft moves from North to South are *descending* half orbits. Local time for measurements acquired during a *descending* half orbit is approximately 6 AM. The character “D” appears as the Half Orbit Designator in the file names of products that contain data representing *descending* half orbits. Half orbits where the spacecraft moves from South to North are classified as *ascending* half orbits. Local time for measurements acquired during an *ascending* half orbit is approximately 6 PM. The character “A” appears as the Half Orbit Designator in the file names of products that contain data represent *ascending* half orbits.

First Date/Time Stamp – The date/time stamp of the first data element that appears in the product. Date/time stamps in SMAP file names are always recorded in Universal Coordinated Time (UTC). Date/time stamps conform to the following convention:

YYYYMMDD**T**hhmmss

where:

YYYY is the calendar year. The full calendar year must appear in the file name.

MM designates the month of the year. The month designator always occupies two digits. Months that can be represented with fewer than two digits must employ a leading zero.

DD designates the day of the month. The day designator always occupies two digits. Days of the month that can be represented with fewer than two digits must employ a leading zero.

T delineates the date from the time, and is a required character in all time stamps in product names.

hh designates the hour of the day on a 24 hour clock in UTC. The hour designator always occupies two digits. Hours that can be represented with fewer than two digits must employ a leading zero.

mm designates the minute of the hour in UTC. The minute designator always occupies two digits. Minutes that can be represented with fewer than two digits must employ leading zeroes.

ss designates the truncated second of the minute in UTC. Fractional second specification is not necessary in file names. The second designator always occupies two digits. Seconds that can be represented with fewer than two digits must employ leading zeroes.

Composite Release ID – The Composite Release ID incorporates changes to any processing condition that might impact product results. The format of the Composite Release ID is as follows:

"R"	The character "R" always precedes this identifier
Launch indicator	Distinguishes between pre-launch or pre-instrument commissioned data and data generated under mission operation conditions. A launch indicator of "0" implies the data are simulated or acquired under early mission conditions that exempt the content from mission requirements. A launch indicator of "1" implies the data are acquired by the instrument at or after the time of instrument commissioning, and must therefore meet mission requirements.
Major ID	One digit that indicates major releases. Major changes in algorithm or processing approach will generate an update to this identifier.
Minor ID	Three digits that indicate minor releases. Any change to any component that impacts data processing, such as algorithm, software or parameters will lead to a change in this identifier.

Product Counter – Files that represent the same half orbit of any particular product type may be generated multiple times over the life of the mission. This counter tracks the number of times that a particular product type for a specific half orbit was generated. The system assigns the first instance of a file that represents a half orbit of a particular product type with a Product Counter of 001. The system assigns each subsequent instance of the same half orbit and same product type with the next consecutive integer. The Product Counter always occupies three digits. Product Counters that do not require three digits contain leading zeroes.

Extension – The extension for all SMAP L1C_S0_HiRes data products is "h5". That extension indicates that the product contents are in HDF5 format. The SMAP SDS will generate a QA file with every data granule. The QA file contains statistical information that will enable users to better assess the quality of the associated granule. QA products bear exactly the same name as the products that they represent. The only difference in names is the extension. The extension for all QA products is ".qa".

Example File Names – Based on the above standard, the following name describes a simulated data product from pre-launch release 4 of the Radar Level 1C S0_HiRes data product that is labeled to cover the ascending half of orbit 934. The first data point acquired 7:49:51 UTC on December 25, 2014. The file represents the second time a Radar L1C S0_HiRes product was generated for the ascending half of orbit 924:

SMAP_L1C_S0_HiRes_00934_A_20141225T074951_R00400_002.h5

The name of the QA product that assesses the output of the above L1C_S0_HiRes granule would be:

SMAP_L1C_S0_HiRes_00934_A_20141225T074951_R00400_002.qa

4.4 L1C_S0_HiRes Product Metadata

The metadata elements in the Level 1C S0_HiRes product appear in two forms.

One form appears in two specific HDF Attributes within the Metadata Group. The content of the first of these two HDF Attributes is the complete set of series metadata. The series metadata apply to all L1C_S0_HiRes files in a SMAP mission release. The content of the second HDF Attribute is the complete set of dataset metadata. The dataset metadata are specific to each product file. Combined, these two Attributes represent all of the metadata associated with the L1C_S0_HiRes product. The content of these Attributes conforms to the ISO 19115-2 models

The second form of the metadata appears in a set of HDF5 groups under the Metadata Group. Each of these HDF5 Groups represents one of the major classes in the ISO structure. These groups contain a set of HDF5 attributes. Each HDF5 Attribute represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the ISO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

In addition, the Metadata group includes two attributes that contain MD5 checksums. These two checksum attributes specify the size of the two ISO metadata sets expressed in XML. Thus, *attribute iso_19139_dataset_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_dataset_xml*. Likewise, attribute *iso_19139_series_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_series_xml*.

Table 8 describes the subgroups of the Metadata group, and the attributes within each group. The first column of table 8 specifies a major class in the ISO 19115-2 metadata model. The second column provides the name of the HDF5 Group under "/Metadata" where attributes associated with the corresponding class will appear. The third column lists the names of the subgroups and attributes where specific metadata values appear. The fourth column provides valid values for each element. Constant values appear with no diacritical marks. Variable values are encapsulated by brackets <>. All of the metadata elements that appear in table 8 should also appear in every Level 1C_S0_HiRes Product file.

Table 8: Granule Level Metadata in the L1C_S0_HiRes Product

ISO Major Class	SMAP HDF5 Metadata SubGroup	Subgroup/Attribute in SMAP HDF5	Valid Values
DQ_DataQuality	DataQualiity	Scope	cell_sigma0_hh_fore, cell_sigma0_hh_aft, cell_sigma0_xpol_fore, cell_sigma0_xpol_aft, cell_sigma0_vv_fore, cell_sigma0_vv_aft
		CompletenssOmission/evaluationMethodType	directInternal
		CompletenessOmission/measureDescription	Percent of grid cells that lack radar data relative to the total number of grid cells that fall within the mission acquisition mask.
		CompletenessOmission/nameOfMeasure	Percent of Missing Data
		CompletenessOmission/value	<A measure between 0 and 100>
		CompletenessOmission/unitOfMeasure	Percent
		RFICompletenssOmission/evaluationMethodType	directInternal
		RFICompletenessOmission/measureDescription	Percent of grid cells where RFI was detected and the algorithm was unable to remove the RFI contamination from the backscatter measure.

		RFICompletenessOmission/nameOfMeasure	Percent of Missing Data due to Radio Frequency Interference (RFI)
		RFICompletenessOmission/value	<A measure between 0 and 100>
		RFICompletenessOmission/unitOfMeasure	Percent
		domainConsistency/evaluationMethodType	directInternal
		DomainConsistency/measureDescription	Percent of sigma0 measures in the data product that fall within a predefined acceptable range of measure.
		DomainConsistency/nameOfMeasure	Percent of Sigma0s that are within the Acceptable Range.
		DomainConsistency/value	<A measure between 0 and 100>
		DomainConsistency/unitOfMeasure	Percent
EX_Extent	Extent	description	The SMAP spacecraft downlinks SAR data that were acquired under following data conditions: 1) While acquiring forward looking and aft looking data over all land surfaces except Antarctica when the satellite is viewing the Earth at approximately 6 AM local time, 2) While acquiring forward looking data over all land surfaces North of 45 degrees North latitude when the satellite is viewing the Earth at approximately 6 PM local time, and 3) While acquiring forward

			looking data over coastal ocean regions when the satellite is viewing the Earth at approximately 6 AM local time. Coastal ocean regions are defined as ocean areas within 1000 km of land.
		polygonPosList	<An array of vertices of a polygon the defines the region occupied by the data set in the corresponding data product. Each vertex is represented by an ordered pair. Latitudes precede longitudes. Vertices appear in clockwise order. Spaces delineate each value.>
		westBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		eastBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		southBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		northBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		rangeBeginningDateTime	<Character string that indicates the date and time of the initial data element in the product>
		rangeEndingDateTime	<Character string that indicates the date and time of the final data element in the product.>

algoriLI_Lineage/LE_ProcessStepso	ProcessStep	Processor	Soil Moisture Active Passive (SMAP) Mission Science Data System (SDS) Operations Facility
		stepDateTime	< A character string that specifies the date and the time when the product was generated.>
		processDescription	Converts instrument telemetry into a data set that contains horizontally polarized, vertically polarized and cross polarized normalized radar cross sections, each of which are multilooked onto a 1 km swath oriented grid.
		Identifier	L1C_S0_HIRES_SPS
		SWVersionID	<A software version identifier that runs from 001 to 999>
		softwareDate	<A date stamp that specifies when software used to generate this product was released.>
		softwareTitle	L1C S0 HiRes SPS
		documentation	<A reference to software description document.>
		documentVersion	<Version identifier for the software description document.>
		documentDate	<Release date for the software description document.>

		runTimeParameters	<Specify any run time parameters if they were used.>
		RFIThreshold	<A threshold the algorithm uses to specify whether a particular measure was contaminated by Radio Frequency Interference.>
		longTermCalibrationFactor_hh	<The long term calibration factor that was used to process the data that were transmitted and received in the horizontal polarization channel.>
		longTermCalibrationFactor_vv	<The long term calibration factor that was used to process the data that were transmitted and received in the vertical polarization channel.>
		longTermCalibrationFactor_vh	<The long term calibration factor that was used to process the data that were transmitted from the horizontal polarization channel and received in the vertical polarization channel.>
		longTermCalibrationFactor_hv	<The long term calibration factor that was used to process the data that were transmitted from the vertical polarization channel and received in the horizontal polarization channel.>
		timeVariableEpoch	J2000
		epochJulianDate	2451545.00
		epochUTCDateTime	2000-01-01T11:58:55.816Z

		parameterVersionID	<Identifier that specifies the current version of processing parameters. Value runs from 001 to 999.>
		algorithmTitle	Soil Moisture Active Passive Synthetic Aperture Radar Processing Algorithm
		algorithmVersionID	<Identifier that specifies the current algorithm version. Value runs from 001 to 999>
		algorithmDate	<Date associated with current version of the algorithm.>
		algorithmDescription	<Descriptive text about the algorithm used in the L1C_S0_HiRes SPS.>
		ATBDTitle	Soil Moisture Active Passive (SMAP) L1B_S0_LoRes/L1C_S0_HiRes Algorithm Theoretical Basis Document (ATBD).
		ATBDDate	<Time stamp that specifies the release date of the ATBD>
		ATBDVersion	<Version identifier for the ATBD.>
LI_Lineage/LE_Source	L1A_Radar. Ephemeris. Attitude, Antenna Azimuth. SCLK-UTC Correlation, Reconstructed High	description	<Description of each of the input files used to generate the L1C S0 HiRes Data product.>
		fileName	<Complete file name of the input data product>

	Resolution Earth Orientation, Ionosphere Total Electron Content [1]	creationDate	<A date stamp that specifies when the input data product was generated.>
		version	<The SMAP Composite Version ID associated with the input data product.>
		identifier	<The short name associated with the product. This field appears only for the Lineage class that describes the L1A_Radar product. >
		DOI	<A digital object identifier associated with the product. This field appears only for the Lineage class that describes the L1A_Radar product.>
DS_Dataset/MD_DataIdentification	DataSetIdentification	creationDate	<Date when the L1C_S0_HiRes data product file was created>
		CompositeReleaseID	<SMAP Composite Release ID associated with this data product – See section 3.3>
		fileName	<Name of the L1C_S0_HiRes output data file.>
		originatorOrganizationName	Jet Propulsion Laboratory
		shortName	SPL1CS0
		UUID	<A universally unique identifier for each data granule.>

		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>
		SMAPShortName	L1C_S0_HiRes
		abstract	Calibrated normalized synthetic aperture radar cross section measures multilooked onto a 1 km grid conforms to the SMAP spacecraft path.
		purpose	The SMAP L1C radar data product delivers the basic radar backscatter measurements at sufficiently high resolution (1 km) to meet SMAP soil moisture retrieval requirements as well as support other scientific studies while keeping the file sizes manageable for most scientific data users.
		credit	The software that generates the Level 1C S0 HiRes product and the data system that automates its production were designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		status	onGoing
		spatialRepresentationType	grid
		language	eng

		characterSet	utf8
		topicCategory	geoscientificInformation
	QADatasetIdentification	fileName	<The name of QA product.>
		creationDate	<The date that the QA product that accompanies the L1C_S0_HiRes data granule was generated.>
		abstract	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
DS_Series/MD_DataIdentification	SeriesIdentification	revisionDate	<Date and time of the software release that was used to generate this data product.>
		CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product – See section 3.3>
		longName	SMAP L1C Radar Half-Orbit High-Resolution σ_o Data on 1 km Swath Grid
		shortName	SPL1CS0
		identifier_product_DOI	<digital object identifier for the Level 1C S0 HiRes Product>

		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>
		resourceProviderOrganizationName	National Aeronautics and Space Administration
		abstract	Calibrated normalized synthetic aperture radar cross section measures multilooked onto a 1 km grid that conforms to the SMAP spacecraft path.
		purpose	The SMAP L1C radar data product delivers the basic radar backscatter measurements at sufficiently high resolution (1 km) to meet SMAP soil moisture retrieval requirements as well as support other scientific studies while keeping the file sizes manageable for most scientific data users.
		credit	The software that generates the Level 1C S0 HiRes product and the data system that automates its production were designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		status	onGoing
		spatialRepresentationType	grid

		characterSet	utf8
		language	eng
		topicCategory	geoscientificInformation
		pointOfContact	Alaska Satellite Facility, Fairbanks, Alaska
		mission	Soil Moisture Active Passive (SMAP)
		maintenanceAndUpdateFrequency	asNeeded
		maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
		format	HDF5
		formatVersion	1.8.11
	ProductSpecificationDocument	language	eng
		characterSet	utf8
		publicationDate	<Date of publication of the Product Specification Document>
		edition	<Edition identifier for the Product Specification Document>
		title	Soil Moisture Active Passive Mission L1C_S0_HiRes Product Specification Document

		SMAPShortName	L1C_S0_HiRes
MD_GridSpatialRepresentation	GridSpatialRepresentation	numberOfDimensions	2
		cellGeometry	area
		transformationParameterAvailability	0 (implies not available)
		crossTrack/dimensionSize	<The size of the cross track dimension. Should vary between 1000 to 1020>
		crossTrack/resolution	1 km
		track/dimensionSize	<The size of the along track dimension. Nominal value for descending half orbit products will be close to 20000>
		track/resolution	1 km
MD_AcquisitionInformation	AcquisitionInformation	platform/antennaRotationRate	14.6 rpm OR 13.0 rpm
		platformDocument/publicationDate	<The date of publication of the document that describes the SMAP platform, if available to the general public>
		platformDocument/edition	<The edition of publication of the document that describes the SMAP platform, if available to the general public.>
		platformDocument/title	<The title of the publication of the document that describes the SMAP

			platform, if available to the general public.>
		platform/description	The SMAP observatory houses an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath. The bus is a 3 axis stabilized spacecraft that provides momentum compensation for the rotating antenna.
		platform/identifier	SMAP
		radarDocument/publicationDate	<The date of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/edition	<The edition of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/title	<The title of the publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radar/description	The SMAP radar instrument employs an L-band conically scanned system and SAR processing techniques to achieve moderate resolution (1 km) backscatter measurements over a

			very wide 1000 km swath.
		radar/identifier	SMAP SAR
		radar/type	L-band Synthetic Aperture Radar
		radiometerDocument/publicationDate	<The date of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/edition	<The edition of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/title	<The title of the publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometer/description	The SMAP L-band Radiometer records V-pol, H-pol, 3rd and 4th Stokes brightness temperatures at 40 km resolution at 4.3 Megatbits per second with accuracies of 1.3 Kelvin or better.
		radiometer/identifier	SMAP RAD
		radiometer/type	L-band Radiometer
SD_OrbitMeasuredLocation	OrbitMeasuredLocation	argumentOfPerigee	<The angle in the satellite's orbit plane between the point of perigee

			and ascending node. The angle is measured in the direction of spacecraft motion.>
		cycleNumber	<The SMAP satellite flies in a cycle that repeats after 117 orbits. This element specifies the cycle of orbits when the data were taken. First cycle is assigned the number 1.>
		eccentricity	<The eccentricity of the satellite orbit.>
		epoch	<The effective time of the data in the OrbitMeasuredLocation class. This may be identical to the equatorCrossingDateTime.>
		equatorCrossingDateTime	<A time stamp that specifies the date and time of ascending node crossing for the current orbit.>
		equatorCrossingLongitude	<The longitude of the ascending node crossing for the current orbit.>
		inclination	<The angle between the spacecraft's orbital plane and the Earth's equatorial plane. An angle greater than 90 degrees indicates a orbit retrograde path.>
		meanMotion	<The constant angular speed that would be required for a body travelling in an undisturbed elliptical orbit with the specified semimajor axis to complete one revolution in the

			actual orbital period, expressed as a number of revolutions per day.>
		orbitDirection	<SMAP Level 1 and Level 2 products appear in half orbit granules. This element provides direction of orbital path relative to equatorial plane. Values are "ascending" or "descending":>
		halfOrbitStartDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the beginning of the half orbit.>
		halfOrbitStopDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the end of the half orbit.>
		orbitPathNumber	< The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies which of the 117 possible paths the spacecraft flew when the data in the file were acquired. The orbitPathNumber varies from 1 to 117.>
		orbitPeriod	<Time required to complete a the spacecraft orbit.>
		referenceCRS	<A description of the coordinate

			reference system used to describe spacecraft orbital data.>
		revNumber	<The count of orbits from beginning of mission to the orbit that the spacecraft flew when the data in the file were acquired. Orbit zero begins at launch and extends until the spacecraft crosses the southernmost point in its path for the first time. Orbit one commences at that instant.>
		rightAscensionAscendingNode	<The angle eastward on the equatorial plan from the vernal equinox to the orbit ascending node.>
		semiMajorAxis	<The length of the semi-major axis of the spacecraft orbit.>

[1] The metadata will allocate a group for each input data set that requires provenance tracking. The most critical ones listed in this document are those that are likely to vary from one orbit granule to the next. The metadata will track and list additional files for user information.

4.5 Data Structure

4.5.1 Spacecraft Data Group

The Spacecraft Data contain elements that specify either geometric or geographic information that are representative of an entire along track row in the instrument swath in the Radar L1C_S0_HiRes product. All of the product elements in the Spacecraft Data Group are stored in a single HDF5 Group named "/Spacecraft_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 9 lists all of the elements in the Spacecraft Data Group.

All the HDF5 Datasets in the Spacecraft Data Group have AlongTrack_Array shape. The AlongTrack_Array shape describes a one-dimensional array, where each array element represents a specific along track row in the instrument swath. Thus, array element *x_pos(6212)* lists the representative spacecraft position in the x dimension, array element *yaw(6212)* lists the representative spacecraft yaw, and array element *sc_geodetic_alt(6212)* lists the representative spacecraft altitude for the along track row that the spacecraft passed over at the time specified in array element *along_track_time_utc(6212).*

Table 9: The Spacecraft Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
along_track_time	Float64	AlongTrack_Array	465156000	946000000	seconds
along_track_time_utc	FixedLenString	AlongTrack_Array	n/a	n/a	n/a
along_track_mode_flag	Uint16	AlongTrack_Array	n/a	n/a	n/a
along_track_qual_flag	Uint16	AlongTrack_Array	n/a	n/a	n/a
sc_nadir_lat	Float32	AlongTrack_Array	-90	90	degrees
sc_nadir_lon	Float32	AlongTrack_Array	-180.0	179.999	degrees
sc_geodetic_alt_ellipsoid	Float32	AlongTrack_Array	700000.0	900000.0	meters

sc_alongtrack_velocity	Float32	AlongTrack_Array	-8000.0	8000.0	meters/second
sc_radial_velocity	Float32	AlongTrack_Array	-8000	8000	meters/second
x_pos	Float32	AlongTrack_Array	-999999	9999999	meters
y_pos	Float32	AlongTrack_Array	-999999	9999999	meters
z_pos	Float32	AlongTrack_Array	-999999	9999999	meters
x_vel	Float32	AlongTrack_Array	-8000.0	8000.0	meters/second
y_vel	Float32	AlongTrack_Array	-8000.0	8000.0	meters/second
z_vel	Float32	AlongTrack_Array	-8000.0	8000.0	meters/second
roll	Float32	AlongTrack_Array	-3.0	3.0	degrees
pitch	Float32	AlongTrack_Array	-3.0	3.0	degrees
yaw	Float32	AlongTrack_Array	-3.0	3.0	degrees
sc_nadir_angle	Float32	AlongTrack_Array	0.0	180.0	degrees
declination	Float32	AlongTrack_Array	-90.0	90.0	degrees
right_ascension	Float32	AlongTrack_Array	0.0	359.999	degrees
antenna_scan_angle	Float32	AlongTrack_Array	0.0	359.999	degrees
antenna_look_angle	Float32	AlongTrack_Array	0.0	180.0	degrees

4.5.2 Crosstrack Data Group

The Crosstrack Data provides information about the instrument swath that the SMAP L1C_S0_HiRes data product employs to store SAR data. All of the product elements in the Crosstrack Data are stored in a single HDF5 Group named "/Crosstrack_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 10 lists the elements in the Crosstrack Data Group.

All the data elements in the Crosstrack Data Group have the CrossTrack_Array shape. The CrossTrack_Array shape describes a one-dimensional array, where each array element represents a specific cross track column in the instrument swath.

Table 10: The Crosstrack Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
distance_from_nadir	Float32	CrossTrack_Array	-550000	550000.0	meters
sigma0_resolution	Float32	CrossTrack_Array	0.0	10000.0	meters

4.5.3 Sigma0 Data Group

The Sigma0 Data Group contains a representative normalized radar cross section (σ_0) data for each of the individual grid cells in the instrument swath grid. In addition to σ_0 measurements, the Sigma0 Data group provides the location as well as geometry and quality information for each pixel in the swath grid. Table 11 lists all of the elements in the Sigma0 Data Group.

All of the product elements in the Sigma0 Group data are stored in a single HDF5 Group called "/Sigma0 Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores.

With the exception of the six data elements that specify Kp, all of the HDF5 Datasets in the Sigma0 Data Group store two-dimensional arrays. HDF5 Datasets *cell_kp_hh_fore*, *cell_kp_hh_aft*, *cell_kp_vv_fore*, *cell_kp_vv_aft*, *cell_kp_xpol_fore* and *cell_kp_xpol_aft* store three-dimensional arrays.

For all Datasets in the Sigma0 Group, the dimension that contains the slowest moving indices represents the AlongTrack position of the associated swath pixel. All elements that share the same index in this dimension represent grid cells that fall within the same along track row of the instrument swath.

For all two dimensional Datasets in the Sigma0 Group, the dimension that contains the faster moving indices represents the CrossTrack position of the pixel. For all three dimensional Datasets in the Sigma0 Group, the middle index represents the CrossTrack position of the pixel. All elements that share the same value of this dimension index represent grid cells that fall within the same cross track column of the instrument swath.

Thus, *cell_lat(251,1250)* and *cell_lon(251,1250)* are respectively the latitude and longitude of the grid cell in the instrument swath where the representative forward viewing cross polarized σ_0 is stored in *cell_sigma0_xpol_fore(251,1250)*. The mean of the azimuth of the instrument boresight on the Earth's surface for all data elements that contribute to this measure appears in *earth_azimuth_mean_fore(251,1250)*.

All of the Datasets that store Kp employ a third dimension. The third dimension lists components of Kp. The specific Kp components, and the position where they appear in the product is **TBD**.

Table 11: The SIgma0 Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
cell_lat	Float32	AlongTrack_CrossTrack_Array	-90.0	90.0	degrees
cell_lon	Float32	AlongTrack_CrossTrack_Array	-180.0	179.999	degrees
cylindrical_grid_row_index	Float32	AlongTrack_CrossTrack_Array	0.0	14616.0	n/a
cylindirical_grid_column_index	Float32	AlongTrack_CrossTrack_Array	0.0	34704.0	n/a
polar_grid_row_index	Float32	AlongTrack_CrossTrack_Array	0.0	18000.0	n/a
polar_grid_column_index	Float32	AlongTrack_CrossTrack_Array	0.0	18000.0	n/a
cell_altitude	Float32	AlongTrack_CrossTrack_Array	-100.0	9000.0	meters
cell_altitude_std_dev	Float32	AlongTrack_CrossTrack_Array	0.0	100.0	meters
cell_gradient	Float32	AlongTrack_CrossTrack_Array	0.0	90.0	degrees
number_of_cell_looks_fore	Uint16	AlongTrack_CrossTrack_Array	0.0	20 .0	n/a
number_of_cell_looks_aft	Uint16	AlongTrack_CrossTrack_Array	0.0	20.0	n/a
cell_radar_mode_flag	Uint16	AlongTrack_CrossTrack_Array	n/a	n/a	n/a
cell_sigma0_qual_flag_hh	Uint16	AlongTrack_CrossTrack_Array	n/a	n/a	n/a
cell_sigma0_qual_flag_vv	Uint16	AlongTrack_CrossTrack_Array	n/a	n/a	n/a

cell_sigma0_qual_flag_xpol	Uint16	AlongTrack_CrossTrack_Array	n/a	n/a	n/a
slant_range_fore	Float32	AlongTrack_CrossTrack_Array	700000.0	1100000.0	meters
earth_azimuth_mean_fore	Float32	AlongTrack_CrossTrack_Array	0.0	359.999	degrees
earth_azimuth_std_dev_fore	Float32	AlongTrack_CrossTrack_Array	0.0	359.999	degrees
earth_incidence_mean_fore	Float32	AlongTrack_CrossTrack_Array	0.0	90.0	degrees
earth_incidence_std_dev_fore	Float32	AlongTrack_CrossTrack_Array	0.0	90.0	degrees
cell_sigma0_hh_fore	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_vv_fore	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_xpol_fore	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_hh_fore_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_vv_fore_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_xpol_fore_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_area_fore	Float32	AlongTrack_CrossTrack_Array	100.0	100000.0	m**2
cell_kp_hh_fore	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a
cell_kp_vv_fore	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a

cell_kp_xpol_fore	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a
slant_range_aft	Float32	AlongTrack_CrossTrack_Array	700000.0	1100000.0	meters
earth_azimuth_mean_aft	Float32	AlongTrack_CrossTrack_Array	0.0	359.999	degrees
earth_azimuth_std_dev_aft	Float32	AlongTrack_CrossTrack_Array	0.0	359.999	degrees
earth_incidence_mean_aft	Float32	AlongTrack_CrossTrack_Array	0.0	90	degrees
earth_incidence_std_dev_aft	Float32	AlongTrack_CrossTrack_Array	0.0	90	degrees
cell_sigma0_hh_aft	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_vv_aft	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_xpol_aft	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_hh_aft_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_vv_aft_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_sigma0_xpol_aft_noise	Float32	AlongTrack_CrossTrack_Array	-0.01	10.0	n/a
cell_area_aft	Float32	AlongTrack_CrossTrack_Array	10.0	100000.0	m**2
cell_kp_hh_aft	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a
cell_kp_vv_aft	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a
cell_kp_xpol_aft	Float32	AlongTrack_CrossTrack_KpComp_Array	0.0	10.0	n/a
selected_frequency_aft	Float32	AlongTrack_CrossTrack_Array	1218.75	1296.25	MHz

selected_frequency_fore	Float32	AlongTrack_CrossTrack_Array	1218.75	1296.25	MHz
polarization_rotation_angle_aft	Float32	AlongTrack_CrossTrack_Array	-90.0	90.0	degrees
polarization_rotation_angle_fore	Float32	AlongTrack_CrossTrack_Array	-90.0	90.0	degrees
faraday_rotation_angle_fore	Float32	AlongTrack_CrossTrack_Array	-90.0	90.0	degrees
faraday_rotation_angle_aft	Float32	AlongTrack_CrossTrack_Array	-90.0	90.0	degrees
faraday_rotation_corr_hh_fore	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
faraday_rotation_corr_vv_fore	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
faraday_rotation_corr_xpol_fore	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
faraday_rotation_corr_hh_aft	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
faraday_rotation_corr_vv_aft	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
faraday_rotation_corr_xpol_aft	Float32	AlongTrack_CrossTrack_Array	0.0	10.0	n/a
xpol_correlation_fore	Float32	AlongTrack_CrossTrack_ComplexComp_Array	0.0	1.0	n/a
xpol_correlation_aft	Float32	AlongTrack_CrossTrack_ComplexComp_Array	0.0	1.0	n/a

4.6 Element Definitions

4.6.1 along_track_mode_flag

Bit flags that indicate operational conditions for each cross track row in the 1 km swath based grid. Table 12 specifies the meaning of individual bits in the *along_track_mode_flag*:

Table 12: The along_track_mode_flag

Bits	Value	Interpretation
0		**Instrument viewing mode**
	0	Spacecraft antenna is positioned so that the SMAP instrument views locations on the Earth's surface over the entire antenna scan.
	1	Spacecraft antenna is positioned so that the SMAP instrument does not view the Earth over the entire antenna scan. During the associated scan, the SMAP spacecraft is either in maneuver, running a cold sky calibration or in a transition state.
1		**Ephemeris Usage Flag**
	0	Processing employed reconstructed ephemeris
	1	Processing employed predicted ephemeris
2		**Cross Polarization Data Flag**
	0	Cross polarized data in this along track row are h-pol transmitted and v-pol received.
	1	Cross polarized data in this along track row are v-pol transmitted and h-pol received.
3		**Cross Polarization Transition Flag**
	0	Cross polarized data in this along track row are consistent. All cross polarized data have the same polarization characteristic.
	1	Cross polarized data in this along track row are in transition. Some cross polarized data are h-pol transmitted and v-pol received, others are v-pol transmitted and h-pol received.

Bits	Value	Interpretation
4-15		**Undefined**

along_track_mode_flag is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Uint16

Group: Spacecraft Data

Shape: AlongTrack_Array

Units: n/a

4.6.2 along_track_qual_flag

Bit flags that indicate the quality of spacecraft position and orientation, or antenna azimuth data for each cross track row in the 1 km swath based grid. Table 13 specifies the meaning of individual bits in the *along_track_qual_flag*:

Table 13: The along_track_qual_flag

Bits	Value	Interpretation
0		**Ephemeris Quality**
	0	Quality and frequency of the ephemeris data is within acceptable range.
	1	Quality or frequency of the ephemeris data may not be adequate to yield a sufficiently accurate measure of spacecraft location to meet mission geolocation requirements.
1		**Attitude Quality**
	0	Quality and frequency of the attitude data is within acceptable range.
	1	Quality or frequency of the attitude data may not be adequate to interpolate a sufficiently accurate measure of spacecraft attitude to meet mission requirements.
2		**Antenna Pointing Quality**
	0	Quality and frequency of the antenna pointing data is within acceptable range.

Bits	Value	Interpretation
	1	Quality or frequency of the antenna pointing data may not be adequate to yield a sufficiently accurate position measure to meet mission geolocation requirements.
3-15		**Undefined**

along_track_qual_flag is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Uint16

Group: Spacecraft Data

Shape: AlongTrack_Array

Units: n/a

4.6.3 along_track_time

The time when the SMAP spacecraft crossed the center line of each cross track row along the spacecraft nadir swath. Time values are counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch starting point is January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC).

along_track_time is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Float64

Group: Spacecraft Data

Shape: AlongTrack_Array

Valid_min: 465156000.0

Valid_max: 946000000.0

Units: seconds

4.6.4 along_track_time_utc

The Universal Coordinated Time (UTC) when the SMAP spacecraft crossed center line of each cross track row along the spacecraft nadir swath. Within each frame, the *along_track_time_utc* records the same time instant as the *along_track_time*. The *along_track_time_utc* appears as an easily interpretable character string, while the *along_track_time* is the count of Ephemeris Time (ET) International System (SI) seconds since 12:00 hours on January 1, 2000

Greenwich Mean Time.

The format of the *along_track_time_utc* is YYYY-MM-DDThh:mm:ss.dddZ, where YYYY represents the calendar year, MM represents the month of the year and DD represents the day of the month. The character 'T' demarcates the date from the time. hh represents the hour in twenty-four hour time, mm represents the minutes, ss represents the seconds, and ddd represents thousandths of a second. The character 'Z' designates Greenwich Mean Time. All numerical fields must occupy the allotted space. If any numerical value does not require the allotted space to represent the appropriate number, the field that specifies the number must contain leading zeroes.

along_track_time_utc is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	FixLenStr
String Length:	24 characters
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	'2014-10-31T00:00:00.000Z'
Valid_max:	'2030-12-31T23:59:60.999Z'
Units:	n/a

4.6.5 antenna_look_angle

The angle defined by the intersection of the antenna boresight vector and the spacecraft nadir vector. Each measure in this array is interpolated to an instant of time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

antenna_look_angle is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	0.0
Valid_max:	180.0
Units:	degrees

4.6.6 antenna_scan_angle

The angle in the X-Y plane of the spacecraft coordinate system that specifies the angular position of the antenna assembly. Each measure in this array is interpolated to an instant of time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

antenna_scan_angle is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	0.0
Valid_max:	359.999
Units:	degrees

4.6.7 cell_altitude

The representative altitude of the Earth's surface for each 1 km swath grid cell relative to sea level.

cell_altitude is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-100.0
Valid_max:	9000.0
Units:	meters

4.6.8 cell_altitude_std_dev

The standard deviation of the altitude of the Earth's surface for each 1 km swath grid cell relative to sea level.

cell_altitude_std_dev is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32

Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	100.0
Units:	meters

4.6.9 cell_area_aft

The sum of the topographic areas that were used to normalize all of the forward looking sigma0s in the corresponding 1 km grid cell.

cell_area_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	10.0
Valid_max:	100000.0
Units:	m**2

4.6.10 cell_area_fore

The sum of the topographic areas that were used to normalize all of the forward looking sigma0s in the corresponding 1 km grid cell.

cell_area_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	10.0
Valid_max:	100000.0
Units:	m**2

4.6.11 cell_gradient

The acute angle between the zenith vector and representative normal to the Earth's surface for each 1 km swath grid cell.

cell_gradient is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	90.0
Units:	degrees

4.6.12 cell_kp_hh_aft

The normalized standard deviation of σ_0 for all horizontally polarized looks that are aft of the SMAP spacecraft within the 1 km swath grid cell.

cell_kp_hh_aft is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument. Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(\ X\ )}{mean(\ \sigma_0)} \right)$$

where $stdev(\mathrm{X})$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_KpComp_Array

Valid_min: 0.0

Valid_max: 10.0

Units: n/a

4.6.13 cell_kp_hh_fore

The normalized standard deviation of σ_0 for all horizontally polarized looks that are forward of the SMAP spacecraft within the 1 km swath grid cell.

cell_kp_hh_fore is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument. Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(X)}{mean(\sigma_0)} \right)$$

where $stdev(X)$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_KpComp_Array

Valid_min: 0.0

Valid_max: 10.0

Units: n/a

4.6.14 cell_kp_xpol_aft

The normalized standard deviation of σ_0 for all cross polarized looks that are aft of the SMAP spacecraft within the 1 km swath grid cell.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_kp_xpol_aft*.

cell_kp_xpol_aft is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument. Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(\,X\,)}{mean(\,\sigma_0)} \right)$$

where $stdev(\,X\,)$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_KpComp_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.15 cell_kp_xpol_fore

The normalized standard deviation of σ_0 for all cross polarized looks that are forward of the SMAP spacecraft within the 1 km swath grid cell.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_kp_xpol_fore*.

cell_kp_xpol_fore is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument. Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(X)}{mean(\sigma_0)} \right)$$

where $stdev(X)$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_KpComp_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.16 cell_kp_vv_aft

The normalized standard deviation of σ_0 for all vertically polarized looks that are aft of the SMAP spacecraft within the 1 km swath grid cell.

cell_kp_vv_aft is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument.

Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(\ X\ )}{mean(\ \sigma_0)}\right)$$

where $stdev(\ \mathrm{X}\ )$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_KpComp_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.17 cell_kp_vv_fore

The normalized standard deviation of σ_0 for all vertically polarized looks that are forward of the SMAP spacecraft within the 1 km swath grid cell.

cell_kp_vv_fore is a three-dimensional array.

The slowest moving index represents specific components of Kp for each grid cell. The current version of the L1C_S0_HiRes product populates only the first of these three components. That component contains Kpc, which is the inherent physical uncertainty of the σ_0 measure attributable to the radar instrument. Random effects generated by radar speckle and multi-look statistics are typical sources of Kpc.

Potential values for the other components include Kpr, which is attributed largely to environmentally induced errors for which the measurement system can not compensate, and the uncertainty in RFI measure.

The following equation expresses the means that the SMAP Level 1C_S0_HiRes SPS uses to calculate each component of Kp:

$$K_p = \left(\frac{stdev(\,X\,)}{mean(\,\sigma_0)} \right)$$

where $stdev(\,X\,)$ represents the portion of the standard deviation of σ_0 that can be attributed to the corresponding Kp component.

The middle dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_KpComp_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.18 cell_lat

The geodetic latitude of the center of each cell in the 1 km swath grid. Zero latitude represents the Equator. Positive latitudes represent locations North of the Equator. Negative latitudes represent locations South of the Equator.

cell_lat is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.19 cell_lon

The longitude of the center of each cell in the 1 km swath grid. Zero longitude represents the Prime Meridian. Positive longitudes represent locations to the East of the Prime Meridian. Negative longitudes represent locations to the West of the Prime Meridian.

cell_lon is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-180.0
Valid_max:	179.999
Units:	degrees

4.6.20 cell_radar_mode_flag

Bit flags that indicate operational conditions for each cell in the 1 km swath based grid. Table 14 specifies the meaning of individual bits in the *cell_radar_mode_flag*:

Table 14: The cell_radar_mode_flag

Bits	Value	Interpretation
0		**Receive Only Mode**
	0	Radar is operating in transmit-receive mode.
	1	Radar is operating in receive only mode.
1		**Forward Looking Cross-Pol Data**
	0	Forward looking cross polarized data are h-pol transmitted, v-pol received.
	1	Forward looking cross polarized data are v-pol transmitted, h-pol received.
2		**Aft Looking Cross-Pol Data**
	0	Aft looking cross polarized data are h-pol transmitted, v-pol received.
	1	Aft looking cross polarized data are v-pol transmitted, h-pol received.
3		**Nadir region flag**

Bits	Value	Interpretation
	0	Data employed to generate a representative value for the grid cell were not acquired within the nadir region of the swath where sigma0 scaling errors are larger than 1 dB and radar looks do not meet the SMAP mission’s 3 km resolution requirement.
	1	A significant fraction of the data employed to generate a representative value for the grid cell were acquired within the nadir region of the swath where sigma0 scaling errors are larger than 1 dB and radar looks do not meet the SMAP mission’s 3 km resolution requirement.
4-15		**Undefined**

cell_mode_flag is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Uint16

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Units: n/a

4.6.21 cell_sigma0_hh_aft

The representative value of the normalized radar cross section for all horizontally polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_hh_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.22 cell_sigma0_hh_aft_noise

The representative value of the normalized radar cross section for all horizontally polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_hh_aft_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.23 cell_sigma0_hh_fore

The representative value of the normalized radar cross section for all horizontally polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_hh_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.24 cell_sigma0_hh_fore_noise

The representative value of the normalized radar cross section for all horizontally polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_hh_fore_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.25 cell_sigma0_qual_flag_hh

Bit flags that indicate the character and quality of the horizontally polarized normalized radar cross section measurements. Table 15 indicates the value of individual bits in the *cell_sigma_qual_flag_hh*:

Table 15: The cell_sigma0_qual_flag_hh

Bits	Value	Interpretation
0		**Forward looking horizontally polarized quality flag**
	0	Forward looking horizontally polarized σ_0 has acceptable quality.

Bits	Value	Interpretation
	1	Use of the forward looking horizontally polarized σ_0 is not recommended.
1		**Aft looking horizontally polarized quality flag**
	0	Aft looking horizontally polarized σ_0 has acceptable quality.
	1	Use of the aft looking horizontally polarized σ_0 is not recommended.
2		**Forward looking horizontally polarized range flag**
	0	Forward looking horizontally polarized σ_0 falls within expected range.
	1	Forward looking horizontally polarized σ_0 is outside of expected range.
3		**Aft looking horizontally polarized range flag**
	0	Aft looking horizontally polarized σ_0 falls within expected range.
	1	Aft looking horizontally polarized σ_0 is outside of expected range.
4		**Forward looking horizontally polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the forward looking horizontally polarized σ_0s in the grid cell.
	1	RFI contaminates forward looking horizontally polarized σ_0s in the grid cell.
5		**Forward looking horizontally polarized RFI removal flag**
	0	Either RFI was not detected, or the forward looking horizontally polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative forward looking horizontally polarized σ_0 for the grid cell.

Bits	Value	Interpretation
6		**Aft looking horizontally polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the aft looking horizontally polarized σ_0s in the grid cell.
	1	RFI contaminates aft looking horizontally polarized σ_0s in the grid cell.
7		**Aft looking horizontally polarized RFI removal flag**
	0	Either RFI was not detected, or the aft looking horizontally polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative aft looking horizontally polarized σ_0 for the grid cell.
8		**Forward looking horizontally polarized Faraday Rotation flag**
	0	Faraday correction for forward looking horizontally polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking horizontally polarized σ_0 is greater than or equal to the uncertainty of the Faraday Rotation measure.
9		**Aft looking horizontally polarized Faraday Rotation flag**
	0	Faraday correction for aft looking horizontally polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking horizontally polarized σ_0 is greater than or equal to the uncertainty of the Faraday Rotation measure.
10		**Forward looking horizontally polarized Kp flag**
	0	Kp for forward looking horizontally polarized σ_0 is acceptably low.
	1	Kp for forward looking horizontally polarized σ_0 is unacceptably high.

Bits	Value	Interpretation
11		**Aft looking horizontally polarized Kp flag**
	0	Kp for aft looking horizontally polarized σ_0 is acceptably low.
	1	Kp for aft looking horizontally polarized σ_0 is unacceptably high.
12		**Forward looking horizontal polarization null value**
	0	The corresponding forward looking horizontal polarization sigma0 contains a calculated value.
	1	The corresponding forward looking horizontal polarization sigma0 element is null.
13		**Aft looking horizontal polarization null value**
	0	The corresponding aft looking horizontal polarization sigma0 contains a calculated value.
	1	The corresponding aft looking horizontal polarization sigma0 element is null.
14		**Forward looking pointing nadir angle**
	0	Spacecraft nadir angle at forward measurement time is nominal
	1	Spacecraft nadir angle at forward measurement time is off nominal
15		**Aft looking pointing nadir angle**
	0	Spacecraft nadir angle at aft measurement time is nominal
	1	Spacecraft nadir angle at aft measurement time is off nominal

cell_sigma0_qual_flag_hh is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Uint16

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Units: n/a

4.6.26 cell_sigma0_qual_flag_xpol

Bit flags that indicate the character and quality of the cross polarized normalized radar cross section measurements. Table 16 indicates the value of individual bits in the *cell_sigma_qual_flag_xpol*:

Table 16: The cell_sigma0_qual_flag_xpol

Bits	Value	Interpretation
0		**Forward looking cross polarized quality flag**
	0	Forward looking cross polarized σ_0 has acceptable quality.
	1	Use of the forward looking cross polarized σ_0 is not recommended.
1		**Aft looking cross polarized quality flag**
	0	Aft looking cross polarized σ_0 has acceptable quality.
	1	Use of the aft looking cross polarized σ_0 is not recommended.
2		**Forward looking cross polarized range flag**
	0	Forward looking cross polarized σ_0 falls within expected range.
	1	Forward looking cross polarized σ_0 is outside of expected range.
3		**Aft looking cross polarized range flag**
	0	Aft looking cross polarized σ_0 falls within expected range.
	1	Aft looking cross polarized σ_0 is outside of expected range.
4		**Forward looking cross polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the forward looking cross polarized σ_0s in the grid cell.

Bits	Value	Interpretation
	1	RFI contaminates forward looking cross polarized σ_0s in the grid cell.
5		**Forward looking cross polarized RFI removal flag**
	0	Either RFI was not detected, or the forward looking cross polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative forward looking cross polarized σ_0 for the grid cell.
6		**Aft looking cross polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the aft looking cross polarized σ_0s in the grid cell.
	1	RFI contaminates aft looking cross polarized σ_0s in the grid cell.
7		**Aft looking cross polarized RFI removal flag**
	0	Either RFI was not detected, or the aft looking cross polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative aft looking cross polarized σ_0 for the grid cell.
8		**Forward looking cross polarized Faraday Rotation flag**
	0	Faraday correction for forward looking cross polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking cross polarized σ_0 is greater than or equal to the uncertainty of the Faraday Rotation measure.
9		**Aft looking cross polarized Faraday Rotation flag**
	0	Faraday correction for aft looking cross polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking cross polarized σ_0 is greater than or equal to the uncertainty of the Faraday

Bits	Value	Interpretation
		Rotation measure.
10		**Forward looking cross polarized Kp flag**
	0	Kp for forward looking cross polarized σ_0 is acceptably low.
	1	Kp for forward looking cross polarized σ_0 is unacceptably high.
11		**Aft looking cross polarized Kp flag**
	0	Kp for aft looking cross polarized σ_0 is acceptably low.
	1	Kp for aft looking cross polarized σ_0 is unacceptably high.
12		**Forward looking cross polarized null value**
	0	The corresponding forward looking cross polarized sigma0 contains a calculated value.
	1	The corresponding forward looking cross polarized sigma0 element is null.
13		**Aft looking cross polarized null value**
	0	The corresponding aft looking cross polarized sigma0 contains a calculated value.
	1	The corresponding aft looking cross polarized sigma0 element is null.
14		**Forward looking pointing nadir angle**
	0	Spacecraft nadir angle at forward measurement time is nominal
	1	Spacecraft nadir angle at forward measurement time is off nominal
15		**Aft looking pointing nadir angle**
	0	Spacecraft nadir angle at aft measurement time is nominal
	1	Spacecraft nadir angle at aft measurement time is off nominal

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data described the *cell_sigma0_qual_flag_xpol*.

cell_sigma0_qual_flag_vv is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Uint16

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Units: n/a

4.6.27 cell_sigma0_qual_flag_vv

Bit flags that indicate the character and quality of the vertically polarized normalized radar cross section measurements. Table 17 indicates the value of individual bits in the *cell_sigma_qual_flag_vv*:

Table 17: The cell_sigma0_qual_flag_vv

Bits	Value	Interpretation
0		**Forward looking vertically polarized quality flag**
	0	Forward looking vertically polarized σ_0 has acceptable quality.
	1	Use of the forward looking vertically polarized σ_0 is not recommended.
1		**Aft looking vertically polarized quality flag**
	0	Aft looking vertically polarized σ_0 has acceptable quality.
	1	Use of the aft looking vertically polarized σ_0 is not recommended.
2		**Forward looking vertically polarized range flag**
	0	Forward looking vertically polarized σ_0 falls within expected range.
	1	Forward looking vertically polarized σ_0 is outside of expected range.

Bits	Value	Interpretation
3		**Aft looking vertically polarized range flag**
	0	Aft looking vertically polarized σ_0 falls within expected range.
	1	Aft looking vertically polarized σ_0 is outside of expected range.
4		**Forward looking vertically polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the forward looking vertically polarized σ_0s in the grid cell.
	1	RFI contaminates forward looking vertically polarized σ_0s in the grid cell.
5		**Forward looking vertically polarized RFI removal flag**
	0	Either RFI was not detected, or the forward looking vertically polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative forward looking vertically polarized σ_0 for the grid cell.
6		**Aft looking vertically polarized RFI clean flag**
	0	Insignificant levels of RFI detected in the aft looking vertically polarized σ_0s in the grid cell.
	1	RFI contaminates aft looking vertically polarized σ_0s in the grid cell.
7		**Aft looking vertically polarized RFI removal flag**
	0	Either RFI was not detected, or the aft looking vertically polarized σ_0 was corrected for the presence of RFI.
	1	Unable to remove RFI from representative aft looking vertically polarized σ_0 for the grid cell.
8		**Forward looking vertically polarized Faraday Rotation flag**

Bits	Value	Interpretation
	0	Faraday correction for forward looking vertically polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking vertically polarized σ_0 is greater than or equal to the uncertainty of the Faraday Rotation measure.
9		**Aft looking vertically polarized Faraday Rotation flag**
	0	Faraday correction for aft looking vertically polarized σ_0 is less than the uncertainty of the Faraday Rotation measure.
	1	Faraday correction for forward looking vertically polarized σ_0 is greater than or equal to the uncertainty of the Faraday Rotation measure.
10		**Forward looking vertically polarized Kp flag**
	0	Kp for forward looking vertically polarized σ_0 is acceptably low.
	1	Kp for forward looking vertically polarized σ_0 is unacceptably high.
11		**Aft looking vertically polarized Kp flag**
	0	Kp for aft looking vertically polarized σ_0 is acceptably low.
	1	Kp for aft looking vertically polarized σ_0 is unacceptably high.
12		**Forward looking vertical polarization null value**
	0	The corresponding forward looking vertical polarization sigma0 contains a calculated value.
	1	The corresponding forward looking vertical polarization sigma0 element is null.
13		**Aft looking vertical polarization null value**
	0	The corresponding aft looking vertical polarization sigma0 contains a calculated value.

Bits	Value	Interpretation
	1	The corresponding aft looking vertical polarization sigma0 element is null.
14		**Forward looking pointing nadir angle**
	0	Spacecraft nadir angle at forward measurement time is nominal
	1	Spacecraft nadir angle at forward measurement time is off nominal
15		**Aft looking pointing nadir angle**
	0	Spacecraft nadir angle at aft measurement time is nominal
	1	Spacecraft nadir angle at aft measurement time is off nominal

cell_sigma0_qual_flag_vv is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Uint16

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Units: n/a

4.6.28 cell_sigma0_vv_aft

The representative value of the normalized radar cross section for all vertically polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_vv_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.29 cell_sigma0_vv_aft_noise

The representative value of the normalized radar cross section for all vertically polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_vv_aft_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.30 cell_sigma0_vv_fore

The representative value of the normalized radar cross section for all vertically polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0

Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_vv_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.31 cell_sigma0_vv_fore_noise

The representative value of the normalized radar cross section for all vertically polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

cell_sigma0_vv_fore_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: -0.01

Valid_max: 10.0

Units: n/a

4.6.32 cell_sigma0_xpol_aft

The representative value of the normalized radar cross section for all cross polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_sigma0_xpol_aft*.

cell_sigma0_xpol_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-0.01
Valid_max:	10.0
Units:	n/a

4.6.33 cell_sigma0_xpol_aft_noise

The representative value of the normalized radar cross section for all cross polarized radar looks that are aft of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_sigma0_xpol_aft_noise*.

cell_sigma0_xpol_aft_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-0.01

Valid_max:	10.0
Units:	n/a

4.6.34 cell_sigma0_xpol_fore

The representative value of the normalized radar cross section for all cross polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_sigma0_xpol_fore*.

cell_sigma0_xpol_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-0.01
Valid_max:	10.0
Units:	n/a

4.6.35 cell_sigma0_xpol_fore_noise

The representative value of the normalized radar cross section for all cross polarized radar looks that are forward of the SMAP spacecraft within a 1 km swath grid cell before the L1C_S0_HiRes algorithm applies noise subtraction. SAR processing employs a process known as multi-looking to generate these representative values. The multi-look process weights the contribution of each radar look within each swath grid cell based on the area of the look footprint that falls within the cell boundary. The SMAP L1B_S0, L1C_S0 Algorithm Theoretical Basis Document (ATBD) provides considerably more detail about the multi-looking approach.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *cell_sigma0_xpol_fore_noise*.

cell_sigma0_xpol_fore_noise is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-0.01
Valid_max:	10.0
Units:	n/a

4.6.36 cylindrical_grid_row_index

The cylindrical Equal Area Scalable Earth (EASE) grid index in the latitudinal direction for the center of each cell in the 1 km swath based grid. The referenced cylindrical EASE grid has 1 km resolution and employs a reference latitude of 30°. To provide greater precision, the Level 1C_S0_HiRes product provides the EASE grid index as a floating point number.

cylindrical_grid_row_index is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	14616.0
Units:	n/a

4.6.37 cylindrical_grid_column_index

The cylindrical Equal Area Scalable Earth (EASE) grid index in the longitudinal direction for the center of each cell in the 1 km swath based grid. The referenced cylindrical EASE grid has 1 km resolution and employs a reference latitude of 30°. To provide greater precision, the Level 1C_S0_HiRes product provides the EASE grid index as a floating point number.

cylindrical_grid_column_index is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	34704.0
Units:	n/a

4.6.38 declination

The declination of the antenna boresight vector. Each measure in this array is interpolated to an instant of time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

declination is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.39 distance_from_nadir

The representative distance on the Earth's surface from the center line of each along track column in the 1 km swath grid to the spacecraft nadir path.

This measure provides users with an estimate of the native resolution of the Synthetic Aperture Radar looks. Resolution is best near the swath edges where the iso-doppler and iso-range lines that define each look are very nearly orthogonal. Resolution degrades as the looks approach the spacecraft nadir where iso-doppler and iso-range lines are parallel. Analysis indicates that SMAP radar will not meet the 3 km resolution required in the L1C S0 HiRes product for all looks that are acquired within 150 km of the spacecraft nadir.

distance_from_nadir is a one-dimensional array. Each array index is representative of a specific along track column in the swath grid.

Type:	Float32
Group:	Crosstrack Data

Shape: CrossTrack_Array

Valid_min: -55,000.0

Valid_max: 550000.0

Units: meters

4.6.40 earth_azimuth_mean_aft

The mean boresight azimuth for all of the radar looks acquired aft of the spacecraft that fall within a given 1 km swath grid cell. The azimuth represents the clockwise rotation from local North of the projection of the radar instrument boresight onto the Earth’s surface.

earth_azimuth_mean_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0.0

Valid_max: 360.0

Units: degrees

4.6.41 earth_azimuth_mean_fore

The mean boresight azimuth for all of the radar looks acquired forward of the spacecraft that fall within a given 1 km swath grid cell. The azimuth represents the clockwise rotation from local North of the projection of the radar instrument boresight onto the Earth’s surface.

earth_azimuth_mean_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0.0

Valid_max: 360.0

Units: degrees

4.6.42 earth_azimuth_std_dev_aft

The standard deviation of the boresight azimuths of all of the radar looks acquired aft of the spacecraft that fall within a given 1 km swath grid cell. The azimuth represents the clockwise rotation from local North of the projection of the radar instrument boresight onto the Earth's surface.

earth_azimuth_std_dev_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0

Valid_max: 360

Units: degrees

4.6.43 earth_azimuth_std_dev_fore

The standard deviation of the boresight azimuths of all of the radar looks acquired forward of the spacecraft that fall within a given 1 km swath grid cell. The azimuth represents the clockwise rotation from local North of the projection of the radar instrument boresight onto the Earth's surface.

earth_azimuth_std_dev_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0.0

Valid_max: 360.0

Units: degrees

4.6.44 earth_incidence_mean_aft

The mean boresight incidence angle for all of the radar looks acquired aft of the spacecraft that fall within a given 1 km swath grid cell. The incidence angle is the angle subtended by the boresight vector and the surface normal vector relative to Earth topography at the center of the 1 km cell and on the Earth's reference surface.

earth_incidence_mean_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	90.0
Units:	degrees

4.6.45 earth_incidence_mean_fore

The mean boresight incidence angle for all of the radar looks acquired forward of the spacecraft that fall within a given 1 km swath grid cell. The incidence angle is the angle subtended by the boresight vector and the surface normal vector relative to Earth topography at the center of the 1 km cell and on the Earth's reference surface.

earth_incidence_mean_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	90.0
Units:	degrees

4.6.46 earth_incidence_std_dev_aft

The standard deviation of the boresight incidence angles of all of the radar looks acquired aft of the spacecraft that fall within a given 1 km swath grid cell. The incidence angle is the angle subtended by the boresight vector and the surface normal vector relative to Earth topography at the center of the 1 km cell and on the Earth's reference surface.

earth_incidence_std_dev_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	90.0
Units:	degrees

4.6.47 earth_incidence_std_dev_fore

The standard deviation of the boresight incidence angles of all of the radar looks acquired forward of the spacecraft that fall within a given 1 km swath grid cell. The incidence angle is the angle subtended by the boresight vector and the surface normal vector relative to Earth topography at the center of the 1 km cell and on the Earth's reference surface.

earth_incidence_std_dev_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	359.999
Units:	degrees

4.6.48 faraday_rotation_angle_aft

The net rotation of the polarization plane of the transmitted radar signal for all of the radar looks acquired aft of the spacecraft that fall within a given 1 km swath grid cell. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_angle_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.49 faraday_rotation_angle_fore

The net rotation of the polarization plane of the transmitted radar signal for all of the radar looks acquired forward of the spacecraft that fall within a given 1 km swath grid cell. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_angle_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.50 faraday_rotation_corr_hh_aft

The correction that the L1C_S0_HiRes algorithm applies to the representative horizontal polarization sigma0 within a given 1 km swath grid cell that is based on measurements acquired aft of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_corr_hh_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0.0

Valid_max: 10.0

Units: n/a

4.6.51 faraday_rotation_corr_hh_fore

The correction that the L1C_S0_HiRes algorithm applies to the representative horizontal polarization sigma0 within a given 1 km swath grid cell that is based on measurements acquired forward of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_corr_hh_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 0.0

Valid_max: 10.0

Units: n/a

4.6.52 faraday_rotation_corr_vv_aft

The correction that the L1C_S0_HiRes algorithm applies to the representative vertical polarization sigma0 within a given 1 km swath grid cell that is based on measurements acquired aft of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_corr_vv_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.53 faraday_rotation_corr_vv_fore

The correction that the L1C_S0_HiRes algorithm applies to the representative vertical polarization sigma0 within a given 1 km swath grid cell that is based on measurements acquired forward of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

faraday_rotation_corr_vv_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.54 faraday_rotation_corr_xpol_aft

The correction that the L1C_S0_HiRes algorithm applies to the representative cross polarized sigma0 within a given 1 km swath grid cell that is based on measurements acquired aft of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *faraday_rotation_corr_xpol_aft*.

faraday_rotation_corr_xpol_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.55 faraday_rotation_corr_xpol_fore

The correction that the L1C_S0_HiRes algorithm applies to the representative cross polarized sigma0 within a given 1 km swath grid cell that is based on measurements acquired forward of the spacecraft. L-band radar waves are subject to Faraday Rotation as they travel through ionized atmosphere. Factors that impact the intensity of Faraday Rotation include the Total Electron Content (TEC) of the ionosphere, the Earth magnetic field and the impact of solar radiation on the ionosphere.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of the cross-pol data that appears in *faraday_rotation_corr_xpol_fore*.

faraday_rotation_corr_xpol_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	10.0
Units:	n/a

4.6.56 number_of_cell_looks_aft

The number of statistically independent looks that are aft of the spacecraft that contribute to the representative normalized radar cross section measurements for each cell in the 1 km swath grid.

number_of_cell_looks_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Uint16
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0
Valid_max:	20
Units:	n/a

4.6.57 number_of_cell_looks_fore

The number of statistically independent looks that are forward of the spacecraft that contribute to the representative normalized radar cross section measurements for each cell in the 1 km swath grid.

number_of_cell_looks_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Uint16
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0
Valid_max:	20
Units:	n/a

4.6.58 pitch

The interpolated angular rotation of the instrument fixed frame about the Y axis of the SRF after a 180 degree roll is performed. The Y axis of the SRF is normal to the spacecraft orbital plane.

Under nominal conditions, the absolute value of the pitch should be very small. The number may appear abnormally large during spacecraft maneuvers or when the mission is recording a cold sky calibration.

pitch is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32

Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-3.0
Valid_max:	3.0
Units:	degrees

4.6.59 polar_grid_row_index

The polar Equal Area Scalable Earth (EASE) grid index in the latitudinal direction for the center of each cell in the 1 km swath based grid. The referenced polar EASE grid employs a Lambert equal area projection with 1 km resolution. The L1C_S0_HiRes product contains two polar grids to represent global data. Cells with center points in the Northern Hemisphere appear on a grid centered about the North pole. Cells with center points in the Southern Hemisphere appear on a grid centered about the South pole. To provide greater precision, the Level 1C_S0_HiRes product provides the EASE grid index as a floating point number.

polar_grid_row_index is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	18000.0
Units:	n/a

4.6.60 polar_grid_column_index

The polar Equal Area Scalable Earth (EASE) grid index in the longitudinal direction for the center of each cell in the 1 km swath based grid. The referenced polar EASE grid employs a Lambert equal area projection with 1 km resolution. The L1C_S0_HiRes product contains two polar grids to represent global data. Cells with center points in the Northern Hemisphere appear on a grid centered about the North pole. Cells with center points in the Southern Hemisphere appear on a grid centered about the South pole. To provide greater precision, the Level 1C_S0_HiRes product provides the EASE grid index as a floating point number.

polar_grid_column_index is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	0.0
Valid_max:	18000.0
Units:	n/a

4.6.61 polarization_rotation_angle_aft

The representative angle of rotation of the orientation of polarization of the radar signal for samples acquired when the SMAP antenna is looking aft of the spacecraft.

polarization_rotation_angle is a 2-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-90.0
Valid_max:	90
Units:	degrees

4.6.62 polarization_rotation_angle_fore

The representative angle of rotation of the orientation of polarization of the radar signal for samples acquired when the SMAP antenna is looking forward of the spacecraft.

polarization_rotation_angle is a 2-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32

Group:	Sigma0 Group
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.63 right_ascension

The right ascension of the antenna boresight vector. Each measure in this array is interpolated to an instant of time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

right_ascension is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	0.0
Valid_max:	359.999
Units:	degrees

4.6.64 roll

The interpolated angular rotation of the instrument fixed frame about the Y axis of the SRF after a 180 degree roll is performed. The Y axis of the SRF is normal to the spacecraft orbital plane.

Under nominal conditions, the absolute value of the pitch should be very small. The number may appear abnormally large during spacecraft maneuvers or when the mission is recording a cold sky calibration.

roll is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-3.0
Valid_max:	3.0
Units:	degrees

4.6.65 sc_alongtrack_velocity

The instantaneous velocity of the SMAP spacecraft that is tangent to the spacecraft path within the orbital plane interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

sc_alongtrack_velocity is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Float32

Group: Spacecraft Data

Shape: AlongTrack_Array

Valid_min: -8000.0

Valid_max: 8000.0

Units: meters/second

4.6.66 sc_geodetic_alt_ellipsoid

The geodetic altitude of the spacecraft above the Earth's reference ellipsoid interpolated to the time when the spacecraft nadir crosses the center line of the corresponding cross track row in the 1 km swath grid.

sc_geodetic_alt_ellipsoid is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Float32

Group: Spacecraft Data

Shape: AlongTrack_Array

Valid_min: 700000.0

Valid_max: 900000.0

Units: meters

4.6.67 sc_nadir_angle

The angle defined by the spacecraft geodetic nadir vector and the Z-axis of the spacecraft coordinate system. Each measure in this array is interpolated to an instant of time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

sc_nadir_angle is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	0.0
Valid_max:	180.0
Units:	degrees

4.6.68 sc_nadir_lat

The geodetic latitude of the ground track position interpolated to the time when the spacecraft nadir crosses the center line of the corresponding cross track row in the 1 km swath grid.

sc_nadir_lat is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-90.0
Valid_max:	90.0
Units:	degrees

4.6.69 sc_nadir_lon

The longitude of the ground track position interpolated to the time when the spacecraft nadir crosses the center line of the corresponding cross track row in the 1 km swath grid.

sc_nadir_lon is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-180.0
Valid_max:	179.999

Units: degrees

4.6.70 sc_radial_velocity

The velocity of the SMAP spacecraft in the direction of the vector that runs from the instantaneous spacecraft position to the center of the Earth interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

sc_radial_velocity is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Float32

Group: Spacecraft Data

Shape: AlongTrack_Array

Valid_min: -8000.0

Valid_max: 8000.0

Units: meters/second

4.6.71 selected_frequency_aft

The mid-point frequency of the noise-only channel of the radar instrument when the aft looking data in the specified grid cell were acquired.

selected_frequency_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 1218.75

Valid_max: 1296.25

Units: MHz

4.6.72 selected_frequency_fore

The mid-point frequency of the noise-only channel of the radar instrument when the forward looking data in the specified grid cell were acquired.

selected_frequency_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_Array
Valid_min:	1218.75
Valid_max:	1296.25
Units:	MHz

4.6.73 sigma0_resolution

The estimated resolution of the normalized radar cross section measures for all of the cells in the 1 km swath based grid that lie within the same along track column.

sigma0_resolution is a one-dimensional array. Each array index is representative of a specific along track column in the swath grid.

Type:	Float32
Group:	Crosstrack Data
Shape:	CrossTrack_Array
Valid_min:	250.0
Valid_max:	10000.0
Units:	meters

4.6.74 slant_range_aft

The mean of the sight distance between the instantaneous location of the SMAP antenna and the center location of each of the radar looks that are aft of the spacecraft and that fall within a specific 1 km grid cell.

slant_range_aft is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 700000.0

Valid_max: 1100000.0

Units: meters

4.6.75 slant_range_fore

The mean of the sight distance between the instantaneous location of the SMAP antenna and the center location of each of the radar looks that are aft of the spacecraft and that fall within a specific 1 km grid cell.

slant_range_fore is a two-dimensional array. The slower moving dimension index represents the along track location in the swath grid. The faster moving dimension index represents the cross track location in the swath grid.

Type: Float32

Group: Sigma0 Data

Shape: AlongTrack_CrossTrack_Array

Valid_min: 700000.0

Valid_max: 1100000.0

Units: meters

4.6.76 xpol_correlation_aft

The co-pol to cross-pol correlation for sigma0s based on measurements acquired aft of the spacecraft within a given 1 km swath grid cell. The co-pol and cross-pol measurements in the correlation employ a common transmitter and different receivers.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of available cross-pol data and thus identifies the polarization of the common transmitter in the correlation.

xpol_correlation_aft is a three-dimensional array. The slowest moving dimension index represents the along track location in the swath grid. The middle dimension index represents the cross track location in the swath grid. The fastest moving index represents the two components of a complex number. The first element in the fastest moving dimension contains the real component of the complex number. The second element in the fastest moving dimension contains the imaginary component of the complex number.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_ComplexComp_Array
Valid_min:	0.0
Valid_max:	1.0
Units:	n/a

4.6.77 xpol_correlation_fore

The co-pol to cross-pol correlation for sigma0s based on measurements acquired forward of the spacecraft within a given 1 km swath grid cell. The co-pol and cross-pol measurements in the correlation employ a common transmitter and different receivers.

Bit 1 of the *along_track_mode_flag* for the corresponding along track row indicates the transmitted and received polarization of available cross-pol data and thus identifies the polarization of the common transmitter in the correlation.

xpol_correlation_fore is a three-dimensional array. The slowest moving dimension index represents the along track location in the swath grid. The middle dimension index represents the cross track location in the swath grid. The fastest moving index represents the two components of a complex number. The first element in the fastest moving dimension contains the real component of the complex number. The second element in the fastest moving dimension contains the imaginary component of the complex number.

Type:	Float32
Group:	Sigma0 Data
Shape:	AlongTrack_CrossTrack_ComplexComp_Array
Valid_min:	0.0
Valid_max:	1.0
Units:	n/a

4.6.78 x_pos

The X component of spacecraft position in the Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

X_pos is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.79 x_vel

The X component of spacecraft velocity in the Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

X_vel is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-8000.0
Valid_max:	8000.0
Units:	meters/second

4.6.80 yaw

The interpolated angular rotation of the instrument fixed frame about the Z axis of the SRF after a 180 degree roll is performed. The Z axis of the SRF runs from the center of mass of the spacecraft toward geodetic nadir.

Under nominal conditions, the absolute value of the yaw should be very small. The number may appear abnormally large during spacecraft maneuvers or when the mission is recording a cold sky calibration.

Yaw is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-3.0

Valid_max:	3.0
Units:	degrees

4.6.81 y_pos

The Y component of spacecraft position in the Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

Y_pos is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.82 y_vel

The Y component of spacecraft velocity in the Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

Y_vel is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-8000.0
Valid_max:	8000.0
Units:	meters/second

4.6.83 z_pos

The Z component of spacecraft position in Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

Z_pos is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.84 z_vel

The Z component of spacecraft velocity in the Earth Centered Rotating (ECR) coordinate system interpolated to the time when the spacecraft nadir crosses the center line of the corresponding along track row in the 1 km swath grid.

Z_vel is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type:	Float32
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	-8000.0
Valid_max:	8000.0
Units:	meters/second

5 APPENDIX A – ACRONYMS AND ABBREVIATIONS

This is the standard Soil Moisture Active Passive (SMAP) Science Data System (SDS) list of acronyms and abbreviations. Not all of these acronyms and abbreviations appear in every SMAP SDS document.

ADT	Algorithm Development Team
AMSR	Advanced Microwave Scanning Radiometer
ANSI	American National Standards Institute
AOS	Acquisition of Signal
APF	Algorithm Parameter File
ARS	Agricultural Research Service
ASF	Alaska Satellite Facility
ATBD	Algorithm Theoretical Basis Document
ATLO	Assembly Test Launch and Operations
BFPQ	Block Floating Point Quantization
BIC	Beam Index Crossing
CARA	Criticality and Risk Assessment
CBE	Current Best Estimate
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
CEOS	Committee on Earth Observing Systems
CF	Climate and Forecast (metadata convention)
CM	Configuration Management
CM	Center of Mass
CONUS	Continental United States
COTS	Commercial Off the Shelf
CR	Change Request
DAAC	Distributed Active Archive Center
DB	Database
DBA	Database Administrator
dB	decibels
deg	degrees

deg/sec	degrees per second
deg C	degrees Celsius
DEM	Digital Elevation Model
DFM	Design File Memorandum
DIU	Digital Interface Unit
DN	Data Number
DOORS	Dynamic Object Oriented Requirements
DQC	Data Quality Control
DSK	Digital Skin Kernel
DVD	Digital Versatile Disc
EASE	Equal Area Scalable Earth
ECMWF	European Centre for Medium Range Weather Forecasts
ECHO	EOS Clearing House
ECI	Earth Centered Inertial Coordinate System
ECR	Earth Centered Rotating Coordinate System
ECR	Engineering Change Request
ECS	EOSDIS Core System
EDOS	EOS Data Operations System
EM	Engineering Model
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EPO	Education and Public Outreach
ESDIS	Earth Science Data and Information System Project
ESDT	Earth Science Data Type
ESH	EDOS Service Header
ESSP	Earth Science System Pathfinder
ET	Ephemeris TIme
EU	Engineering Units
FOV	Field of View
FRB	Functional Requirements Baseline

FS	Flight System
FSW	Flight Software
F/T	Freeze/Thaw
FTP	File Transfer Protocol
GByte	gigabyte
GDS	Ground Data System
GHA	Greenwich Hour Angle
GHz	gigahertz
GLOSIM	Global Simulation
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GN	Ground Network
GPMC	Governing Program Management Council
GPP	Gross Primary Production
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HK	Housekeeping (telemetry)
Hz	Hertz
HSD	Health and Status Data
ICE	Integrated Control Electronics
ICESat	Ice, Cloud and Land Elevation Satellite
IDL	Interactive Data Language
I&T	Integration and Test
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IFOV	Instantaneous Field of View
I/O	Input/Output
IOC	In-Orbit Checkout
IRU	Inertial Reference Unit
ISO	International Organization for Standardization

IV&V	Independent Verification and Validation
ITAR	International Traffic in Arms Regulations
I&T	Integration and Test
JPL	Jet Propulsion Laboratory
KHz	kilohertz
km	kilometers
LAN	Local Area Network
LBT	Loopback Trap
LEO	Low Earth Orbit
LEOP	Launch and Early Operations
LOE	Level Of Effort
LOM	Life Of Mission
LOS	Loss of Signal
LSK	Leap Seconds Kernel
LZPF	Level Zero Processing Facility
m	meters
MHz	megahertz
MIT	Massachusetts Institute of Technology
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Mission Operations System
m/s	meters per second
ms	milliseconds
MS	Mission System
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Protection
NCP	North Celestial Pole
NCSA	National Center for Supercomputing Applications
NEDT	Noise Equivalent Diode Temperature

NEE	Net Ecosystem Exchange
NEN	Near Earth Network
netCDF	Network Common Data Form
NFS	Network File System/Server
NISN	NASA Integrated Services Network
NRT	Near Real Time
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NVM	Non-Volatile Memory
NWP	Numerical Weather Product
n/a	not applicable
OCO	Orbiting Carbon Observatory
OEF	Orbit Events File
ORBNUM	Orbit Number File
OODT	Object Oriented Data Technology
ORR	Operational Readiness Review
ORT	Operational Readiness Test
OSSE	Observing System Simulation Experiment
OSTC	One Second Time Command
PALS	Passive and Active L-Band System
PALSAR	Phased Array L-Band Synthetic Aperture Radar
PcK	Planetary Constants Kernel
PDR	Preliminary Design Review
PPPCS	Pointing, Position, Phasing and Coordinate System
PR	Problem Report
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PROM	Programmable Read Only Memory
PSD	Product Specification Document
QA	Quality Assurance
rad	radians
RAM	Random Access Memory

RBA	Reflector Boom Assembly
RBD	Rate Buffered Data
RBE	Radiometer Back End
RDD	Release Description Document
RDE	Radiometer Digital Electronics
RF	Radio Frequency
RFA	Request For Action
RFE	Radiometer Front End
RFI	Radio Frequency Interference
RMS	root mean square
RSS	root sum sqaure
ROM	Read Only Memory
RPM	revolutions per minute
RVI	Radar Vegetation Index
SA	System Administrator
SAR	Synthetic Aperture Radar
S/C	Spacecraft
SCE	Spin Control Electronics
SCLK	Spacecraft Clock
SDP	Software Development Plan
SDS	Science Data System
SDT	Science Definition Team
SI	International System
SITP	System Integration and Test Plan
SMAP	Soil Moisture Active Passive
SMEX	Soil Moisture Experiment
SMOS	Soil Moisture and Ocean Salinity Mission
SMP	Software Management Plan
SNR	signal to noise ratio
SOC	Soil Organic Carbon
SOM	Software Operators Manual
SQA	Software Quality Assurance

SPDM	Science Process and Data Management
SPG	Standards Process Group
SPK	Spacecraft Kernel
SQA	Software Quality Assurance
SPS	Science Production Software
SRF	Science Orbit Reference Frame
SRR	System Requirements Review
SRTM	Shuttle Radar Topography Mission
SSM/I	Special Sensor Microwave/Imager
STP	Software Test Plan
sec	seconds
TAI	International Atomic Time
T_b	Brightness Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Specified
TCP/IP	Transmission Control Protocol/Internet Protocol
TEC	Total Electron Content
TM	Trademark
TOA	Time of Arrival
TPS	Third Party Software
UML	Unified Modeling Language
U-MT	University of Montana
USDA	United States Department of Agriculture
UTC	Coordinated Universal Time
V&V	Verification and Validation
VWC	Vegetation Water Content

6 APPENDIX B - SMAP Data Product Specification Documents

SMAP Level 1A Radar Product Specification Document, JPL D-72543 Revision B, July 20, 2015.

SMAP Level 1B Radar (L1B_S0_LoRes) Product Specification Document, JPL D-72544 Revision A, July 20, 2015.

SMAP Level 1A Radiometer Product Specification Document, JPL D-92340 Revision A, July 20, 2015.

SMAP Level 1B Radiometer (L1B_TB) Product Specification Document, JPL D-92339 Revision A, July 20, 2015.

SMAP Level 1C Radiometer (L1C_TB) Product Specification Document, JPL D-72545, Date (**TBD)**.

SMAP Level 2 Active Soil Moisture (L2_SM_A) Product Specification Document, JPL D-72546, Date (**TBD)**.

SMAP Level 2 Passive Soil Moisture (L2_SM_P) Product Specification Document, JPL D-72547, Date (**TBD)**.

SMAP Level 2 Active/Passive Soil Moisture (L2_SM_AP) Product Specification Document, JPL D-72548, Date (**TBD)**.

SMAP Level 3 Freeze-Thaw (L3_FT_A) Product Specification Document, JPL D-72549, Date (**TBD)**.

SMAP Level 3 Active Soil Moisture (L3_SM_A) Product Specification Document, JPL D-72550, Date (**TBD)**.

SMAP Level 3 Passive Soil Moisture (L3_SM_P) Product Specification Document, JPL D-72551, Date (**TBD)**.

SMAP Level 3 Active/Passive Soil Moisture (L3_SM_AP) Product Specification Document, JPL D-72552, Date (**TBD)**.

SMAP Level 4 Carbon (L4_C) Product Specification Document, Document Identifier (**TBD)**, Date (**TBD)**.

SMAP Level 4 Soil Moisture (L4_SM) Product Specification Document, Document Identifier (**TBD)**, Date (**TBD)**.

7 APPENDIX C – SHAPES IN THE L1C S0_HiRes PRODUCT

Table 18 lists all of the Shapes that appear in the L1C_S0_HiRes Product. The table also lists the rank, the nominal dimensions and the maximum dimensions for each Shape in the L1C_S0_HiRes Product.

The naming convention for shape names places the dimension where consecutive indices represent contiguous storage positions last. The naming convention thus conforms to index representation in the C language.

On the other hand, since a large contingent of the SMAP science community programs are in Fortran, index order of arrays in this document conforms to the Fortran standard. Thus, in array dimension representation, the dimension where consecutive indices represent contiguous storage appears first.

Table18: Shapes in the SMAP L1C_S0_HiRes Data Product

Shape	Rank	Nominal Product Dimensions	Maximum Product Dimensions
AlongTrack_Array	1	(20000)	(20040)
CrossTrack_Array	1	(1000)	(1020)
AlongTrack_CrossTrack_Array	2	(1000,20000)	(1020,20040)
AlongTrack_CrossTrack_KpComp_Array	3	(2,1000,20000)	(3,1020,20040)

8 APPENDIX D – L1C_S0_HiRes DIMENSIONS

Table 19 lists all of the Dimensions that are used by data elements in the L1C_S0_HiRes Product. The name of each Dimension matches the name given in the Dimension column below. The table also lists the anticipated nominal value and the maximum value for each dimension that appears in the L1C_S0_HiRes Product.

Table 19: Dimensions in the SMAP L1C_S0_HiRes Product

Dimension	Nominal Size	Maximum Size
AlongTrack	20000	20040
CrossTrack	1000	1020
KpComp	2	3

9 APPENDIX E – L1C_S0_HiRes UNITS

Table 20 lists the Units that are used by the L1C_S0_HiRes product elements. The SMAP implementation of HDF5 stores unit information for each data element in local metadata. The first column in the Table 20 identifies units that apply to data in the L1C_S0_HiRes Product. The second column lists the Common Symbol used to represent the unit. The third column lists the matching Label that appears in the local metadata in the L1C_S0_HiRes Product.

Table 20: Units in the SMAP L1C_S0_HiRes Product

Unit	Common Symbol	Level 1C_S0_HiRes Label	Typical Use
counts	Counts	counts	number of elements in a set
degrees	degrees	degrees	angular measure
dimensionless	n/a		dimensionless quantity
Gigahertz	GHz	GHz	frequency measure
meters per second	m/s	m/s	velocity measure
megabytes	MBytes	MBytes	computer storage units
meters	m	m	distance measure
kilometers	km	km	distance measure
percent	%	percent	per hundred
seconds	s	sec	time measure
revolutions per minute	rpm	rpm	rotational measure
degrees Celsius	°C	degrees_Celsius	temperature measure