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# **Surface Biology and Geology (SBG) Observing Terrestrial Thermal Emission Radiometer (OTTER)**

## **Level 2 Land Surface Temperature, Emissivity, and Cloud Product Specification Document (PSD)**

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# SBG Level 2 Product Specification Document

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**TAB**

**LE OF CONTENTS**

<b>Table of Contents</b>		<b>6</b>
<b>1</b>		<b>8</b>
<b>1.1</b>	9	
<b>1.2</b>	9	
<b>1.3</b>	9	
<b>1.4</b>	9	
1.4.1	9	
1.4.2	9	
<b>1.5</b>	9	
<b>2</b>		<b>11</b>
<b>2.1</b>	12	
<b>2.2</b>	<b>Error! Bookmark not defined.</b>	
2.2.1	<b>Error! Bookmark not defined.</b>	
2.2.2	<b>Error! Bookmark not defined.</b>	
2.2.3	<b>Error! Bookmark not defined.</b>	
2.2.4	<b>Error! Bookmark not defined.</b>	
2.2.5	<b>Error! Bookmark not defined.</b>	
2.2.6	<b>Error! Bookmark not defined.</b>	
<b>2.3</b>	<b>Error! Bookmark not defined.</b>	
2.3.1	<b>Error! Bookmark not defined.</b>	
2.3.2	<b>Error! Bookmark not defined.</b>	
2.3.3	<b>Error! Bookmark not defined.</b>	
2.3.4	12	
2.3.5	12	
<b>2.4</b>	13	
2.4.1	13	
2.4.2	13	
<b>3</b>		<b>14</b>
<b>3.1</b>	15	
<b>3.2</b>	16	
3.2.1	16	
3.2.2	17	
<b>3.3</b>	17	
3.3.1	18	
3.3.2	20	
<b>3.4</b>	21	
<b>4</b>		<b>22</b>



# 1 INTRODUCTION

## 1.1 Identification

This is the Product Specification Document (PSD) for Level 2 (L2) data products of the Surface Biology and Geology (SBG) project. The SBG L2 products provide Land Surface Temperature and Emissivity (LST&E) and a Cloud Mask generated from data acquired by the SBG radiometer instrument according to the algorithm described in the SBG L2 LST&E Algorithm Theoretical Basis Document (ATBD) (JPL D-XXXXX) and L2 Cloud ATBD (JPL-D-XXXXX).

## 1.2 Purpose and Scope

This Product Specification Document (PSD) describes the standard Level 2 LSTE and Cloud Mask products generated in the SBG SDS at JPL. These include the detailed descriptions of the format and contents of the product and ancillary files that will be delivered to the Land Process Distributed Active Archive Center (LP-DAAC).

## 1.3 Mission Overview

## 1.4 Applicable and Reference Documents

“Applicable” documents levy requirements on the areas addressed in this document. “Reference” documents are identified in the text of this document only to provide additional information to readers. Unless stated otherwise, the document revision level is Initial Release. Document dates are not listed, as they are redundant with the revision level.

### 1.4.1 Applicable Documents

### 1.4.2 Reference Documents

## 1.5 SBG Data Products

The SBG mission will generate XX different distributable data products. The products represent four levels of data processing, with data granules defined as an image scene. Each image scene consists of XX scans of the instrument mirror, each scan taking approximately X seconds, and each image scene taking approximately XX seconds. Each image scene starts at the beginning of the first target area encountered during each orbit. Each orbit is defined [insert orbit description].

SBG Level 0 data include spacecraft packets that have been pre-processed by the Ground Data System (GDS). Level 1 products include spacecraft engineering data, the time-tagged raw sensor pixels appended with their radiometric calibration coefficients, the blackbody pixels used to generate the calibration coefficients, geolocated and radiometrically calibrated at-sensor radiances of each image pixel, the geolocation tags of each pixel, and the corrected spacecraft attitude data. Level 2 products include the land surface temperature and emissivity for each spectral band retrieved from the at-sensor radiance data, and a cloud mask. Level 2 products also appear in image scene granules. Level 3/4 products include plant functional traits, geology, and snow products derived from Level 2 products.

The SBG products are listed in Table 1-1. This document will discuss only the Level 2 products.

Table 1-1: SBG Distributable Standard Products

<b>Product type</b>	<b>Description</b>
L0A_FLEX	Level 0 “raw” spacecraft packets
L0A_HK	Level 0 housekeeping packets
L1A_ENG	Spacecraft and instrument engineering data, including blackbody gradient coefficients
L1A_BB	Instrument Black Body calibration pixels
L1A_PIX	Raw pixel data with appended calibration coefficients
L1B_GEO	Geolocation tags, sun angles, and look angles, and calibrated, resampled at-sensor radiances
L1B_RAD	Radiometrically corrected, band-aligned, squared at-sensor radiance pixels
L2_LSTE	Land Surface temperature and emissivity
L2_CLOUD	Cloud mask

## 2 DATA PRODUCT ORGANIZATION

### 2.1 Product File Format

The Network Common Data Form 4 (NetCDF-4) format will be used to distribute SBG granules at the orbit/scene level. These product files have a .nc file extension and are internally organized using the NetCDF-4 data standard. The NetCDF-4 rmat is utilized here for long-term archiving, and is not recommended for end-user analysis. These NetCDF-4 files are compatible with NetCDF Viewer, Panoply, and the NetCDF4 package in Python.

Information on Network Common Data Form (NetCDF-4) may be found at <https://www.unidata.ucar.edu/software/netcdf/>.

#### 2.1.1 File Level Metadata

All metadata that describe the full content of each granule of the SBG data product are stored within the explicitly named “/Metadata” Group. Metadata are handled using exactly the same procedures as those that are used to handle data. The contents of each Attribute that stores metadata conform to one of the SBG Types. Most metadata elements are stored as scalars. A few metadata elements are stored as arrays. The metadata appear in a set of HDF5 Groups under the “/Metadata” Group. These HDF5 Groups contain a set of HDF5 Attributes.

#### 2.1.2 Local Metadata

SBG 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 2-3 lists the CF names for the HDF5 Attributes that SBG products typically employ.

Table 2-3: SBG Specific Local Attributes

CF Compliant Attribute Name	Description	Required?
Units	Units of measure. Appendix A 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	No

CF Compliant Attribute Name	Description	Required?
	associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding _FillValue will also be float32. Datasets that do not have a fill value will omit this attribute.	
long_name	A descriptive name that clearly describes the content of the associated Dataset.	Yes

## 2.2 Data Definition Standards

The following sections of this document specify the characteristics and definitions of every data element stored in the SBG data products. Table 2-4 defines each of the specific characteristics that are listed in those sections. Some of these characteristics correspond with the SBG HDF5 Attributes that are associated with each Dataset. Data element characteristics that correspond to SBG 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 2-4: 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 SBG type.
Units	Units of measure. Typical values include “deg”, “degC”, “Kelvin”, “meters/second”, “meters”, “m**2”, “seconds” and “counts”. Appendix A includes references to important data measurement unit symbols.

### 2.2.1 Double Precision Time Variables

SBG 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.

### 2.2.2 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 SBG PRODUCT FILES

The SBG product file will contain at least 3 groups of data: A standard metadata group that specifies the same type of contents for all products, a product specific metadata group that specifies those metadata elements that are useful for defining attributes of the product data, and the group(s) containing the product data. (Note: A product metadata is not to be confused with a HDF5 object metadata.)

All product file names will have the form:

SBG\_<PROD\_TYPE>\_<OOOOO>\_<SSS>\_<YYYYMMDD>T<hhmmss>\_<BBBB>\_<VV>.<TYPE>

Where:

PROD\_TYPE: Product type =  
 L2\_LSTE, Land surface Temperature and Emissivity data  
 L2\_CLOUD, Level 2 Cloud mask data

OOOOO: Orbit number; starting at start of mission, ascending equatorial crossing

SSS: Scene ID; starting at first scene of first orbit

YYYYMMDD: Year, month, day of scene start time

hhmmss: Hour, minute, seconds of scene start time

BBBB: Build ID of software that generated product, Major+Minor (2+2 digits)

VV: Product version number (2 digits)

TYPE: File type extension=  
 h5 for the data file  
 h5.met for the metadata file.

A SITE name is added to the ALEXI-USDA file name:

SBG\_<PROD\_TYPE>\_<OOOOO>\_<SSS>\_<YYYYMMDD>T<hhmmss>\_<BBbb>\_<VV>.<SITE>  
 .<TYPE>

#### 3.1 Standard Metadata

This is the minimal set of metadata that must be included with each product file. The standard metadata consists of the following:

Table 3-1: Standard Product Metadata

Name	Type	Size	Example
<b>Group</b>	<b>StandardMetadata</b>		
AncillaryInputPointer	String	variable	Group name of ancillary file list
AutomaticQualityFlag	String	variable	PASS/FAIL (of product data)
BuildId	String	variable	
CollectionLabel	String	variable	
DataFormatType	String	variable	NCSAHDF5
DayNightFlag	String	variable	
EastBoundingCoordinate	LongFloat	8	
HDFVersionId	String	variable	1.8.16
ImageLines	Int32	4	5632

ImageLineSpacing	Float32	4	68.754
ImagePixels	Int32	4	5400
ImagePixelSpacing	Float32	4	65.536
InputPointer	String	variable	
InstrumentShortName	String	variable	SBG
LocalGranuleID	String	variable	
LongName	String	variable	SBG
NorthBoundingCoordinate	LongFloat	8	
PGEName	String	variable	L2_LSTE (L2_CLOUD)
PGEVersion	String	variable	
PlatformLongName	String	variable	
PlatformShortName	String	variable	
PlatformType	String	variable	Spacecraft
ProcessingLevelID	String	variable	1
ProcessingLevelDescription	String	variable	Level 2 Land Surface Temperatures and Emissivity (Level 2 Cloud mask)
ProducerAgency	String	variable	JPL
ProducerInstitution	String	variable	Caltech
ProductionDateTime	String	variable	
ProductionLocation	String	variable	
CampaignShortName	String	variable	Primary
RangeBeginningDate	String	variable	
RangeBeginningTime	String	variable	
RangeEndingDate	String	variable	
RangeEndingTime	String	variable	
SceneID	String	variable	
ShortName	String	variable	L2_LSTE (L2_CLOUD)
SISName	String	variable	
SISVersion	String	variable	
SouthBoundingCoordinate	LongFloat	8	
StartOrbitNumber	String	variable	
StopOrbitNumber	String	variable	
WestBoundingCoordinate	LongFloat	8	

### 3.2 Product-Specific Metadata

Any additional metadata necessary for describing the product will be recorded in this group.

#### 3.2.1 L2 LSTE Metadata

Table 3-2: L2 LSTE Metadata Definitions

Name	Type	Size	Example
<b>Group</b>	<b>L2 LSTE Metadata</b>		



QAPercentCloudCover	Int	4	80
CloudMeanTemperature	Long Float	8	231
CloudMaxTemperature	Long Float	8	275
CloudMinTemperature	Long Float	8	221
CloudSDevTemperature	Long Float	8	0.45
QAFractionGoodQuality	Int	4	0.7
LSTGoodAvg	Long Float	8	285.4
Emis3GoodAvg	Long Float	8	0.95
Emis4GoodAvg	Long Float	8	0.95
Emis5GoodAvg	Long Float	8	0.95
Emis6GoodAvg	Long Float	8	0.95
Emis7GoodAvg	Long Float	8	0.95
Emis8GoodAvg	Long Float	8	0.95
Emis9GoodAvg	Long Float	8	0.95
Emis10GoodAvg	Long Float	8	0.95
AncillaryGEOS5	Str	255	GEOS.fp.asm.inst3_3d_asm_Np.20140702_0000.V01
BandSpecification	Float 32	μm	Wavelength of pixel data in corresponding datasets for bands 3 through 10: 4, 4.8, 8.3, 8.6, 9.1, 10.2, 11.3, 12.0; 0=fill data

### 3.2.2 L2 CLOUD Metadata

Table 3-3: L2 CLOUD Metadata Definitions

Name	Type	Size	Example
<b>Group</b>	<b>L2 CLOUD Metadata</b>		
QAPercentCloudCover	Int	4	80
CloudMeanTemperature	LongFloat	8	231
CloudMaxTemperature	LongFloat	8	275
CloudMinTemperature	LongFloat	8	221
CloudSDevTemperature	LongFloat	8	0.45

### 3.3 Product Data

The product data will be stored in this group.

#### 3.3.1 L2 LSTE data

Table 3-4: Product Data Definitions for the L2 LSTE Product

SDS	Long Name	Data type	Units	Valid Range	Fill Value	Scale Factor	Offset
<b>Group</b>	<b>SDS (per pixel, 5400 * 5632)</b>						
LST	Land Surface Temperature	uint16	K	7500-65535	0	0.02	0.0
QC	Quality control for LST and emissivity	uint16	n/a	0-65535	n/a	n/a	n/a
Emis3	Band 3 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis4	Band 4 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis5	Band 5 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis6	Band 6 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis7	Band 7 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis8	Band 8 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis9	Band 9 emissivity	uint8	n/a	1-255	0	0.002	0.49
Emis10	Band 10 emissivity	uint8	n/a	1-255	0	0.002	0.49
LST_Err	Land Surface Temperature error	uint8	K	1-255	0	0.04	0.0
Emis3_Err	Band 3 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
Emis4_Err	Band 4 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
Emis5_Err	Band 5 emissivity err	uint16	n/a	0-65535	0	0.0001	0.0
Emis6_Err	Band 6 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
Emis7_Err	Band 7 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0

Emis8_Err	Band 8 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
Emis9_Err	Band 9 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
Emis10_Err	Band 10 emissivity error	uint16	n/a	0-65535	0	0.0001	0.0
EmisWB	Wideband emissivity	uint8	n/a	1-255	0	0.002	0.49
PWV	Precipitable Water Vapor	uint16	cm	0-65535	n/a	0.001	0.0
water_mask	Land/water mask	uint8	1=water 0=land	0-1	255	1	0
cloud_mask	Land/water mask	uint8	1=cloud 0=clear	0-1	255	1	0
height	Ground elevation	int16	meters	-1000-10000	-32768	1	0
Range	Satellite to pixel range	int16	meters	0-32767	-32768	100	800000
view_zenith	Sensor zenith angle	int16	degrees	0-18000	-32768	0.01	0.0

Table 3-5: Bit flags defined in the QC SCS

Bits	Long Name	Description
1&0	Mandatory QA flags	<p>00 = Pixel produced, best quality</p> <p>01 = Pixel produced, nominal quality. Either one or more of the following conditions are met:</p> <ol style="list-style-type: none"> <li>1. emissivity in both bands 9 and 10 &lt; 0.95, i.e. possible cloud contamination</li> <li>2. low transmissivity due to high water vapor loading (&lt;0.4), check PWV values and error estimates</li> </ol> <p>Recommend more detailed analysis of other QC information</p> <p>10 = Pixel produced, but cloud detected</p> <p>11 = Pixel not produced due to missing/bad data, user should check Data quality flag bits</p>
3 & 2	Data quality flag	00 = Good quality L1B data

		01 = not set 10 = not set 11 = Missing/bad L1B data
5 & 4	Cloud/Ocean Flag	Not set. Please check SBG GEO and CLOUD products for this information.
7 & 6	Iterations	00 = Slow convergence 01 = Nominal 10 = Nominal 11 = Fast
9 & 8	Atmospheric Opacity	00 = $\geq 3$ (Warm, humid air; or cold land) 01 = 0.2 - 0.3 (Nominal value) 10 = 0.1 - 0.2 (Nominal value) 11 = $< 0.1$ (Dry, or high altitude pixel)
11 & 10	MMD	00 = $> 0.15$ (Most silicate rocks) 01 = 0.1 - 0.15 (Rocks, sand, some soils) 10 = 0.03 - 0.1 (Mostly soils, mixed pixel) 11 = $< 0.03$ (Vegetation, snow, water, ice)
13 & 12	Emissivity accuracy	00 = $> 0.02$ (Poor performance) 01 = 0.015 - 0.02 (Marginal performance) 10 = 0.01 - 0.015 (Good performance) 11 = $< 0.01$ (Excellent performance)
15 & 14	LST accuracy	00 = $> 2$ K (Poor performance) 01 = 1.5 - 2 K (Marginal performance) 10 = 1 - 1.5 K (Good performance) 11 = $< 1$ K (Excellent performance)

### 3.3.2 L2 CLOUD data

Table 3-6: Product Data Definitions for the L2 Cloud Product

SDS	Long Name	Data type	Units	Valid Range	Fill Value	Scale Factor	Offset
Cloud_confidence	Brightness temperature LUT test	uint8	3=confident cloudy 2=probably cloudy 1=probably clear 0=confident clear	0-1	255	1	0
Cloud_final	Final cloud mask	uint8	1=cloud 0=clear	0-1	255	1	0

Table 3-7: Metadata Definitions for the L2 Cloud Product

Name	Type	Size	Example
<b>Group</b>	<b>L2 CLOUD Metadata</b>		
QAPercentCloudCover	Int	4	80
CloudMeanTemperature	LongFloat	8	231
CloudMaxTemperature	LongFloat	8	275
CloudMinTemperature	LongFloat	8	221
CloudSDevTemperature	LongFloat	8	0.45

### 3.4 Low latency product

A low latency (< 24 hour) product will be created in addition to the standard product. It may or may not be archived. The product contents will be the same as the standard product, although the method to obtain it will be different (see the relevant ATBD).

### 3.5 Product Metadata File

The product metadata for each product file will be generated by the PCS from the metadata contents of each product file. The metadata will be converted into extensible markup language (XML). These will be used by the DAAC for cataloging. Exact contents and layout to be defined by PCS.

## 4 APPENDIX A: ABBREVIATIONS AND ACRONYMS

ALEXI	Atmospheric-Land Exchange Inversion
ARS	Agricultural Research Service
ASD	Algorithm Specifications Document
ATBD	Algorithm Theoretical Basis Document
CCB	Change Control Board
CDR	Critical Design Review
CF	Climate and Forecast (metadata convention)
CM	Configuration Management
CONUS	Continental United States
COTS	Commercial Off The Shelf
DAAC	Distributed Active Archive Center
dB	DeciBel
DCN	Document Change Notice
deg	Degrees
deg/sec	Degrees per Second
DEM	Digital Elevation Model
DisALEXI	ALEXI Disaggregation algorithm
DN	Data Number
EASE	Equal Area Scalable Earth
ECI	Earth Centered Inertial coordinate system
ECR	Earth Centered Rotating coordinate system
ECS	EOSDIS Core System
SBG	ECOSystem Spaceborne Thermal Radiometer on Space Station
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ESDIS	Earth Science Data and Information System
ESDT	Earth Science Data Type
FOV	Field of View
FSW	Flight Software
GB	gigabytes, $10^9$ bytes
GDS	Ground Data System
GHA	Greenwich Hour Angle
GHz	Gigahertz, $10^9$ hertz
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GPP	Gross Primary Production
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HK	Housekeeping (telemetry)
HRSL	Hydrology and Remote Sensing Laboratory
Hz	Hertz

HSD	Health and Status Data
I&T	Integration and Test
ICD	Interface Control Document
I/O	Input/Output
IOC	In-Orbit Checkout
IPA	Inter-Project Agreement
ITAR	International Traffic in Arms Regulation
JPL	Jet Propulsion Laboratory
K	Kelvin
KHz	Kilohertz
Km	kilometer, 1000 meters
L0 – L4	Level 0 through Level 4
LAN	Local Area Network
LEO	Low Earth Orbit
LOE	Level of Effort
LOM	Life of Mission
LP	Land Processes
LSTE	Land Surface Temperature and Emissivity
m	meter
MB	megabytes, $10^6$ bytes
Mbps	Mega bits per second
MHz	Megahertz
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Mission Operations System
m/s	meters per second
ms	milliseconds
MS	Mission System
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Protection
NCSA	National Center for Supercomputing Applications
netCDF	Network Common Data Format
NISN	NASA Integrated Services Network
NOAA	National Oceanic and Atmospheric Administration
OA	Operations Agreement
ODL	Object Description Language
ODT	Object Oriented Data Technology
ORR	Operational Readiness Review
ORT	Operational Readiness Test
PDR	Preliminary Design Review
percent	%, per hundred
PR	Problem Report
PSD	Product Specifications Document
PT-JPL	Priestly-Taylor-JPL
QA	Quality Assurance

rad	radians
RDD	Release Description Document
RFA	Request For Action
S/C	Spacecraft
SCP	Secure Copy
SDP	Software Development Plan
SDS	Science Data System
sec, s	seconds
SITP	System Integration and Test Plan
SMP	Software Management Plan
SOM	Software Operators Manual
TAI	International Atomic Clock
T <sub>b</sub>	Brightness Temperature
TBD	To Be Determined
TBS	To Be Specified
TOA	Time of Arrival
TPS	Third Party Software
USDA	United State Department of Agriculture
USGS	United States Geological Society
UTC	Coordinated Universal Time
V&V	Verification and Validation
XML	Extensible Markup Language

## 2.