National Aeronautics and Space Administration
Goddard Earth Science Data Information and Services Center (GES DISC)

Data Product User Guide for Suomi-National Polar-Orbiting Partnership (S-NPP) Sounder Science Investigator-led Processing System (SIPS) Advanced Technology Microwave Sounder (ATMS) Level 1B Products

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Product Version 2.0

Software Version 2.5

Goddard Earth Sciences Data and Information Services Center (GES DISC)
http://disc.gsfc.nasa.gov
NASA Goddard Space Flight Center
Code 610.2
Greenbelt, MD 20771 USA

Prepared by:

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Ruth Monarrez, Project Element Manager
S-NPP Sounder SIPS
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

Reviewed by:

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Thomas Hearty, GES DISC Science Data Support
GSFC Code 610.2

Revision History

Revision Date	***Changes***	***Author***
2015-08-19	Initial Release	Ruth Monarrez
2016-04-06	Beta Release	Ruth Monarrez
2017-04	Version 1 Release	Ruth Monarrez
2018-05	Version 2 Release - Update Geolocation - Completed implementation of all L1a QA definitions - Updated Correction Coefficients - Re-designed calib_degraded quality flag - Added a brightness temperature status flag: antenna_temp_qc.	Ruth Monarrez

Table of Contents

1.0 Introduction

This document provides basic information for using Version 2 of the Advanced Technology Microwave Sounder (ATMS) Level 1B products produced by the Suomi-National Polar-Orbiting Partnership (S-NPP) Sounder Science Investigator-led Processing System (SIPS) at the NASA Goddard Space Flight Center (GSFC).

The ATMS Level 1B product is geolocated and calibrated to antenna temperature. This product has been annotated with both file and attribute level metdata to fully describe its contents.

The ATMS Level 1A product is not described in detail in this document.

1.1 Overview of Sounder SIPS

The Suomi-National Polar-Orbiting Partnership (S-NPP) Sounder SIPS, is one of six SIPSs formed by NASA to provide the processing of level 0 data through level 1, level 2 and level 3 from the Soumi NPP (previously known as NPP) satellite. The Suomi-NPP satellite is managed by the National Polar-orbiting Partnership (NPP) which includes elements from NASA, NOAA and DoD. Specific details about the S-NPP Mission can be found at: http://npp.gsfc.nasa.gov/index.html.

The S-NPP Sounder SIPS is a team made up of the Jet Propulsion Laboratory (JPL) and the Goddard Earth Sciences Data and Information Services Center (GES DISC). JPL provides the overall project management, science algorithm software integration, test and validation support. The GES DISC performs level 0 data acquisition, routine data processing operations. The GES DISC / Distributed Active Archive Center and distribution of the data products and associated documentation.

Table 1.1 S-NPP SIPSs.

Science Team	SIPS	Instrument(s) Analyzed
Sounder	Sounder	ATMS and CrIS
Ozone	Ozone	OMPS
Ceres	CERES CARS	CERES
Land	Land	VIIRS
Atmospheres	Atmospheres	VIIRS
Ocean	Ocean	VIIRS

The SIPSs may also develop additional products that may help their science teams analyze how well S-NPP products will be useful for continuing ongoing climate studies. Consequently, most SIPSs produce a variety of data products for their science teams. Since it is possible that many of these data products may have general utility to the science community beyond the S-NPP science teams, NASA requests that SIPS products be made

available to the public. This is consistent with NASA's Earth Science Data Policy https://science.nasa.gov/earth-science/earth-science-data/data-information-policy

1.2 Mission Instrument Description

The S-NPP satellite was launched on October 28, 2011 from Vandenburg Air Force Base in California into an orbit with an altitude of 824 km above the Earth surface, an inclination angle of 98.7 deg and a 13:30 local time ascending node [Reference 3]. SNPP is the first in a series of next generation U.S. weather satellites of the Joint Polar Satellite System (JPSS). ATMS is one of 5 instruments onboard the S-NPP satellite. The other instruments are: Clouds and the Earth's Radiant Energy System (CERES), Cross-track Infrared Sounder (CrIS), Ozone Mapping and Profiler Suite (OMPS) and Visible Infrared Imaging Radiometer Suite (VIIRS).

ATMS is a 22-channel microwave, crosstrack scanning, sounder providing both temperature and humidity soundings. Table 1.2.1and Table 1.2.2 contain a summary of the ATMS instrument and platform parameters.

The ATMS instrument's Scan Drive Mechanism on S-NPP has been experiencing additional wear on the bearings. To extend the life of the instrument, a decision was made to perform scan reversals for the purpose of 're-wetting' the bearings. The scan reversals are now occurring twice per orbit, starting Aug 9, 2016. The end result of this maneuver is a slight loss of data. This loss of data is represented by the use of Fill Values.

Table 1.2.1 Instrument parameters.

Platform	Instrument	Instrument Type	Scan Rate (s)	Scan Range (°)	Scan Pattern	FOR Dia (km, nadir)	Spectral Channels
S-NPP	ATMS	Microwave (MW)	8/3	±53	96	16-75	22

Table 1.2.2 Approximate orbital parameters.

Platform	Alt	Orbit Incl. (°)	Equator X Time	Period	Repeat Orbits	Repeat Days	Launch
S-NPP	824	98.7	13:30*	101	228	16	28 Oct 2011

1.3 Data Disclaimer

Version 2.0 ATMS Level 1B data are released to the public as is. Every effort has been made to properly represent the data for which this document describes.

1.4 Where to find the Product

The ATMS Level 1B product can be found at and downloaded from the Goddard Distributed Active Archive Center (GDAAC). There you will find additional information and documentation about this product and other products of interest.

https://disc.gsfc.nasa.gov

1.5 Contact Information

For information, questions or concerns with this ATMS L1B data set, please contact: Ruth Monarrez at Ruth.Monarrez@jpl.nasa.gov or send your question to: sounder.sips@jpl.nasa.gov.

1.6 References

1. B. Lambrigsten, Suomi National Polar Partnership Mission; Algorithm Theoretical Basis Document NASA L1b: Advanced Technology Microwave Sounder, Version 1, July 2004

2. M. Schreier, Advanced Technology Microwave Sounder (ATMS) Assessment Report for Suomi National Polar-orbiting Partnership (SNPP) Sounder Science Investigator-led Processing System (SIPS) Data Level 1, Data Product Version 2.0, March 2018

3. NOAA Technical Report NESDIS 143 Cross Track Infrared Sounder (CrIS) Sensor Data Record (SDR) User's Guide. Version 1.0, Washington, D.C., December, 2013

4. NASA ESO EARTHDATA Standards, Requirements and References, <https://earthdata.nasa.gov/user-resources/standards-and-references>

1.7 What's different/new in Version 2

- Geolocation:
  - Corrected the skewed Field of View (FOV) shapes that had appeared at edges of the granule swath.
  - Several new geolocation fields were added: local_solar_time, sat_sol_zen, sat_sol_azi, mean_anom_wrt_equat, asc_node_tai93, asc_node_lon, asc_node_local_solar_time, and solar_beta_angle.
- Complete implementation of all L1a QA definitions, including qa_pct_data_missing, qa_pct_data_geo, qa_pct_sci
- Correction coefficients were updated: warm bias and non-linearity. These coefficients were updated to stay consistent with the values used by NOAA. These changes directly affect the antenna temperatures.

- Re-designed calib_degraded quality flag. Replaced the calib_degraded quality flag with more specific quality flags: cal_qualflag, cal_space_qualflag, cal_blackbody_qualflag
- Added a brightness temperature status flag: antenna_temp_qc. The dimensions match that of antenna_temp. Basically, if any of the above three 'cal_' flags are set, then antenna_temp_qc is set to 1 per channel corresponding to the 'cal_' flag. If instrument_state or geo_qualflag is not set to zero then antenna_temp_qc is set to 2. Also, if any of the following geolocation fields (lat, lat_geoid, land_frac, surf_alt, obs_time_tai93, sol_zen, sol_azi, sat_zen, sat_azi, view_ang, sat_range) are fill-value then antenna_temp_qc is set to 2.

2.0 ATMS Level 1B Product Overview

The ATMS Level 1B product is generated using L0 data that has been processed by the Earth Observing System (EOS) Data and Operations System (EDOS) located at NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC). An ATMS Level 1A product is produced as an interim product but is not archived and distributed publically6

The ATMS Level 1B product consists of calibrated radiances and geolocation along with any metadata necessary to use and interpret this product.

2.1 Product Granulation and Identification

The ATMS product is divided into a series of 6-minute segments or granules with each granule making up one file and 240 granules per day. Each file contains all observations for a given type made during a period of exactly 6 minutes. For each day, each 240 files are identified by granule number in the filename. For example, **g156** for granule 156 out of 240.

The nominal start time of granule 1 is defined to be 00:00:00. Because both CrIS and ATMS instruments are synced to TAI, the start time of the first 8-second scanset of a day can be anywhere up to 8 seconds later. It moves 1 second with each leap second. If the first scanset starts 8 seconds after the nominal start time, then the data can extend up to 8 seconds past the nominal end time.

The ability to uniquely identify a granule is built in to the ATMS L1B product. This is extremely useful when publishing analysis results. The nominal time coverage, represented as a string: yyyymmddThhmm, is used to construct a unique granule identifier called "gran_id". gran_id is stored as a global attribute that is also used in the filename, see section 2.6 File Naming Convention.

In addition, there is an observation identifier variable called "obs_id" that can further uniquely identify an observation within the granule. The obs_id is formatted as the gran_id with observation information appended to it.

The format of obs_id is: yyyymmddThhmm.aaaExx where 'aaa' is the 3-digit along-track index (001 – 135) and xx is the cross-track index (01 – 96). The "E" indicates earth view.

Example of obs_id: `20170401T2354.001E01`

2.2 Algorithm Background

The Sounder SIPS ATMS L1B data products are a product of processing NASA Level 0 data through Level 1A/Geolocation and Level 1B. See Figure 1. For a definition of the NASA Data

Processing Levels go to: https://earthdata.nasa.gov/earth-science-data-systems-program/policies/data-information-policy/data-levels

The ATMS Level 1A processing extracts radiance counts from ATMS science telemetry, converts engineering counts from the health and status telemetries into physical measurements such as temperatures.

The L1A geolocation processing derives spacecraft positions and attitude according to spacecraft diary telemetry. It also projects ATMS sounding field-of-views (FOV) onto the topographic surface with geolocation, line-of-site (LOS) view angles, solar angles, and surface parameters such as elevations and land fractions. All the geolocation parameters from L1A processing are propagated to the L1B product.

The L1B processing then applies calibration coefficients (gain and offset) and non-linearity correction to the radiance counts to convert them to antenna temperatures. For more detail on how the calibration coefficeients and the non-lineartiy corrections are computed can be foiund in Appendix A.

Technical details of the L1B processing steps and calibrations can be found in the Algorithm Theoretical Basis Document, NASA L1b: Advanced Technology Microwave Sounder Algorithm Theoretical Basis Document (ATBD) [Reference 1].

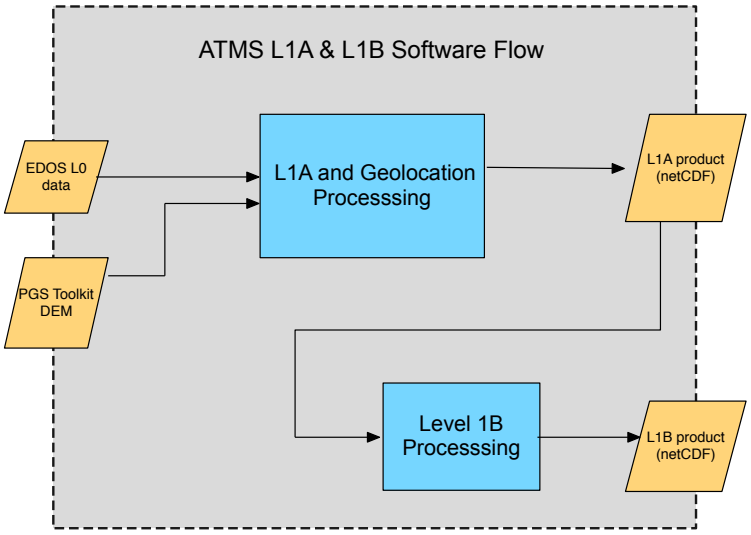

Figure 1

2.3 Data Organization

The **ATMS** products are divided into a series of 6 minute segments with one segment per file. Each file contains all observations of a given type made during a period of exactly 6

minutes. For each day there are 240 files (also known as granules), identified by granule number in the filename. For granule start time details, refer to section 2.1.

2.4 File Format and Structure

The ATMS L1B files, similar to the CrIS L1B files, are in Network Common Data Form, version 4 / Hierarchical Data Format version 5 (NetCDF4/HDF5) format.

The product format takes advantage of the NetCDF4 data model and makes use of groups, dimensions, variables and attributes to fully describe the science data. Below is a basic structure of a l1b datafile.

```
netcdf l1b_atms {
      dimensions:
      // global attributes:
      variables:
      group: aux {
            variables:
      } // aux
} // l1b_atms
```

2.5 Metadata

Every effort has been made to ensure that metadata conforms to the Climate and Forecasting (CF), Version 1.6, and Attribute Conventions for Data Discovery (ACDD), Version 1.3, guidelines.

See the full product specification in Appendix C.

For more information on CF, refer to:
http://cfconventions.org/

For more information on ACDD, refer to:

http://wiki.esipfed.org/index.php?title=Category:Attribute_Conventions_Dataset_Discovery

2.6 File Naming Convention

File naming for Sounder SIPS products will be unique and include the following tokens separated by the delimiter '.' For each token that makes up the filename, there will be an attribute in the data product that it maps to (see Table 2.5 Filenaming).

<Sounder_SIPS_ID>.<platform>.<inst_ID>.<granuleID>.<product_granularity>.<granule_number>.<product_type>.<variant>.<version>.<production_location>.<prod_timestamp>.<extension>

Where:

- **Sounder_SIPS_ID** as a project identifier <product_name_project> = SNDR
- **platform** <product_name_platform> = SNPP
- **inst_ID** <product_name_instr> = ATMS
- **granuleID** (yyyymmddThhmm) <gran_id> nominal start time where:
  - yyyy = year
  - mm = month of year (01-12)
  - dd = day of month (01-31)
  - hh = hour (00-24)
  - mm = minute (00-59)
- **product_granularity** <product_name_duration> = m06 (6 minute)
- **granule_number** <granule_number> = g###
- **product_type** with an optional identifier for testing <product_type_name_id>
  - L1B for ATMS Level 1B
- **variant** <product_name_variant> = std
- **version** vmm_mm <product_name_version> - eg. v02_00
  - Versioning will be synchronized across Sounder SIPS products
- **production_location** <product_name_producer>- J=SIPS at JPL, G=Operations, T=Test, W = CrIS Team at Univ of Wisc
- **prod_timestamp** so each product has a unique name (yymmddhhmmss) <product_name_timestamp>- 150407123456
- **Extension** (.nc)

Table 2.6 ATMS Fileanaming

Filename token	Attribute name in CDF (mapping)	Format	Value(s)	Notes
Sounder_SIPS_ID	product_name_project		SNDR	
platform	product_name_platform		SNPP	
inst_ID	product_name_instr		ATMS, CrIS	
granuleID	gran_id	yyyymmddThhmm	Nominal start time	
product_granularity	product_name_duration		m06	6 minutes
granule_number	granule_number	g###	g001 – g240	Only for 6-minute granule products
product_type	product_name_type_id + optional identifier for uniqueness		L1B	
Version	product_name_version	v02_##; v02_##_##		e.g. v02_05; v02_05_00 (when produced at JPL)
variant	product_name_variant	Freeform text. No whitespace or any punctuation except underscore.	std	Used to identify special runs. The default is: std = standard.
production_location	product_name_producer		J: Jet Propulsion Laboratory	

			G: Goddard Space Flight Center T: Test W: University of Wisconsin	
prod_timestamp	product_name_timestamp	yymmddhhmmss		

Example Filename: 6-minute ATMS Level 1B granule

SNDR.SNPP.ATMS.*yyyymmdd*T*hhmm*.m06.g196.L1B.std.v*mm_mm*.G.*yymmddhhmmss*.nc

SNDR.SNPP.ATMS.20150407T1106.m06.g196.L1B.std.v02_05.G.150407123459.nc

2.7 Time Representation

Times in the ATMS L1B product are generally represented as UTC. However, observation times are provided in both UTC and TAI93 representations as a convenience to users. Coordinated Universal Time (UTC) is the international standard for representation of time. UTC times are expressed in human-readable form, as a set of values indicating year, month, day, hour and so on. In the data stream received from the satellite, observation times are represented as UTC.

Timestamps in ATMS L1B product filenames and attributes are represented as UTC and formatted according to the "ISO 8601:2004" standard. For example, the time January 25, 2016 at 13:00 may be represented as either of the following:

2016-01-25T13:00Z
20160125T1300

The longer form is used in attributes, and the more compact form is used in filenames. The character "Z" indicates "Zulu time", or UTC.

International Atomic Time (TAI) is expressed as number of seconds elapsed on the surface of the Earth since some reference UTC time. The term "TAI93" indicates that the reference time is the beginning of the year 1993, or 1993-01-01T00:00:00Z. This reference time was chosen to be consistent with data products from other instruments, and to allow for precise representation of times spanning the expected mission length.

Leap seconds are one-second adjustments that are occasionally applied to UTC as 23:59:60, to account for irregularities in the rotation of the Earth. There were 27 leap seconds applied to UTC between Jan 1, 1958 and Jan 1, 1993. Between Jan 1, 1993 and Jan 1, 2017, an additional 10 leap seconds were applied to UTC. Leap seconds must be accounted for when doing certain kinds of time calculations, especially in astronomy and satellite applications. Leap seconds can occur on December 31 or June 30 of a given year, and are announced months in advance.
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Leap seconds must be accounted for in the following operations:

- When calculating exact elapsed time between two UTC times. If one or more leap seconds were inserted between the UTC endpoints, they must be accounted for in order for the result to be accurate.
- When converting between UTC and TAI times. Any leap seconds that occurred between the TAI reference time and the UTC time must be accounted for, or the result will be wrong.
- When comparing TAI times with different reference times, or converting from one TAI reference time to the other. Any leap seconds that occurred between the reference times must be accounted for, or the result will be wrong. An example would be when comparing TAI93 times in L1B products to "IET" microseconds in operational ATMS SDR products, which use a reference time of 1958-01-01T00:00Z. In this case 27 leap seconds occurred between the reference times.

In general, these operations can be error-prone. Therefore it is recommended that time calculations and conversions be done with leap-second-aware third party tools that rely on an up-to-date table of leap seconds, such as the "astropy" python package. As a generality, it can be assumed that most computational systems use POSIX time scale and cannot represent leap seconds, unless specifically stated in the software specifications.

3.0 Data Content

The ATMS L1B data products are written in NetCDF4 format and therefore makes use of groups, dimensions, variables and attributes (global & variable). Every NetCDF4/HDF5 file contains, at a minimum, one root group which is unnamed.

Attention should be given to quality flags and checked for fill values before being used for any analysis or higher processing of the L1B product.

A full profile of the contents of the files is included in a common data language (CDL) output file in Appendix C.

Selected fields are highlighted in this section.

3.1 Dimensions

Key dimensions used throughout the ATMS L1B product.

Table 3.1 Dimensions

Dimension name	Size	Meaning
atrack	135	Along-track spatial dimension
xtrack	96	Cross-track spatial dimension
channel	22	ATMS channels
band	5	Microwave bands: K, Ka, V, W, G
utc_tuple	8	Parts of the UTC date/time: year, month, day, hour, minute, second, millisec, microsec
spatial	3	Directions: x, y, z
fov_poly	8	Lat/lon points defining the polygon bounding an fov (anticlockwise as viewed from above)
attitude	3	Roll, pitch, yaw
spacetrack	4	Space view

3.2 Global Attributes

There are two types of attributes: global & variable. In this section we will talk about global attributes. Global attributes, sometimes referred to as 'file-level attributes', provide information about the entire file or 6-minute granule. This includes observation times, publisher and creator information, data provenance, geolocation information. Many attributes are required to conform to the CF & ACDD standards while other attributes are written for consistency with legacy products, hence, you may find some information to be a little redundant or differing in the naming convention.

There are some QA global attributes that should be considered before using the data in analysis or processing. See Table 3.2.2 Global Attributes or Appendix C: CDL File Definition for full definition.

Table 3.2.1 QA

Attribute Name	Type	Dimension	Description
AutomaticQualityFlag	string		**Passed**: the granule contains a non-degraded calibrated brightness temperature or radiance for at least one channel in a geolocated FOV **Suspect**: the granule does not qualify as "Passed" but contains a (possibly degraded) calibrated brightness temperature or radiance for at least one channel (possibly without associated geolocation) **Failed**: the granule contains no calibrated brightness temperatures/radiances.
geo_qual	ushort	atrack, xtrack	Overall value of 0 indicates no critical issues. Bit 2 (surface_loc)- Failed geolocation on Earth topographic surface Bit 3 (DEM) - Could not set FOV surface elevations and land water fraction Bit 4 (geoid_loc) - Failed geolocation on Earth geoid Bit 5 (solar_ang) - Failed to set solar zenith or azimuth angles Bit 6 (spacecraft_ang) - Failed to set spacecraft zenith or azimuth angles Bit 7 - Unused (0) Bit 8 (band_specific) - Failed geolocation of some bands
qa_no_data	string		A simple indicator of whether this is an "empty" granule with no data from the instrument. "TRUE" or "FALSE".

A full definition of the global attributes can be found in Appendix C: CDL File Definition.

Table 3.2.2 Global Attributes

Attribute Name	Type	Description	Heritage
naming_authority	string	The organization that provides the initial id (see above) for the dataset. The naming authority should be uniquely specified by this attribute. We recommend using reverse-DNS naming for the naming authority; URIs are also acceptable. Example: 'edu.ucar.unidata'.	ACDD Recommended
history	string	Provides an audit trail for modifications to the original data. This attribute is also in the NetCDF Users Guide: 'This is a character array with a line for each invocation of a program that has modified the dataset. Well-behaved generic netCDF applications should append a line containing: date, time of day, user name, program name and command arguments.' To include a more complete description you can append a reference to an ISO Lineage entity; see NOAA EDM ISO Lineage guidance.	CF, ACDD Recommended
source	string	The method of production of the original data. If it was model-generated, source should name the model and its version. If it is observational, source should characterize it. This attribute is defined in the CF Conventions. Examples: 'temperature from CTD #1234'; 'world model v.0.1'.	CF, ACDD Recommended
processing_level	string	A textual description of the processing (or quality control) level of the data.	ACDD Recommended
product_name_type_id	string	Product name as it appears in product_name (L1A, L1B, L2, SNO_AIRS_CrIS)	
comment	string	Miscellaneous information about the data or methods used to produce it. Can be empty.	CF, ACDD Recommended
acknowledgment	string	A place to acknowledge various types of support for the project that produced this data.	ACDD Recommended
license	string	Provide the URL to a standard or specific license, enter "Freely Distributed" or "None", or describe any restrictions to data access and distribution in free text.	ACDD Recommended
standard_name_vocabulary	string	The name and version of the controlled vocabulary from which variable standard names are taken. (Values for any standard_name attribute must come from the CF Standard Names vocabulary for the data file or product to comply with CF.) Example: 'CF Standard Name Table v27'.	ACDD Recommended
date_created	string	The date on which this version of the data was created. (Modification of values implies a new version, hence this would be assigned the date of the most recent values modification.) Metadata changes are not considered when assigning the date_created. The ISO 8601:2004 extended date format is recommended, as described in the Attribute Content Guidance section.	ACDD Recommended, ECS/AIRS ProductionDateTime
creator_name	string	The name of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	ACDD Recommended
creator_email	string	The email address of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	ACDD Recommended

creator_url	string	The URL of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	ACDD Recommended
institution	string	Processing facility that produced this file	CF, ACDD Recommended
project	string	The name of the project(s) principally responsible for originating this data. Multiple projects can be separated by commas, as described under Attribute Content Guidelines. Examples: 'PATMOS-X', 'Extended Continental Shelf Project'.	ACDD Recommended
publisher_name	string	The name of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	ACDD Recommended
publisher_email	string	The email address of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	ACDD Recommended
publisher_url	string	The URL of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	ACDD Recommended
geospatial_bounds	string	Describes the data's 2D or 3D geospatial extent in OGC's Well-Known Text (WKT) Geometry format (reference the OGC Simple Feature Access (SFA) specification). The meaning and order of values for each point's coordinates depends on the coordinate reference system (CRS). The ACDD default is 2D geometry in the EPSG:4326 coordinate reference system. The default may be overridden with geospatial_bounds_crs and geospatial_bounds_vertical_crs (see those attributes). EPSG:4326 coordinate values are latitude (decimal degrees_north) and longitude (decimal degrees_east), in that order. Longitude values in the default case are limited to the -180, 180) range. Example: 'POLYGON ((40.26 -111.29, 41.26 -111.29, 41.26 -110.29, 40.26 -110.29, 40.26 -111.29))'.	ACDD Recommended
geospatial_bounds_crs	string	The coordinate reference system (CRS) of the point coordinates in the geospatial_bounds attribute. This CRS may be 2-dimensional or 3-dimensional, but together with geospatial_bounds_vertical_crs, if that attribute is supplied, must match the dimensionality, order, and meaning of point coordinate values in the geospatial_bounds attribute. If geospatial_bounds_vertical_crs is also present then this attribute must only specify a 2D CRS. EPSG CRSs are strongly recommended. If this attribute is not specified, the CRS is assumed to be EPSG:4326. Examples: 'EPSG:4979' (the 3D WGS84 CRS), 'EPSG:4047'.	ACDD Recommended
geospatial_lat_min	float	Describes a simple lower latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_min specifies the southernmost latitude covered by the dataset.	ACDD Recommended

geospatial_lat_max	float	Describes a simple upper latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_max specifies the northernmost latitude covered by the dataset.	ACDD Recommended
geospatial_lon_min	float	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_min specifies the westernmost longitude covered by the dataset. See also geospatial_lon_max.	ACDD Recommended
geospatial_lon_max	float	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_max specifies the easternmost longitude covered by the dataset. Cases where geospatial_lon_min is greater than geospatial_lon_max indicate the bounding box extends from geospatial_lon_max, through the longitude range discontinuity meridian (either the antimeridian for -180:180 values, or Prime Meridian for 0:360 values), to geospatial_lon_min; for example, geospatial_lon_min=170 and geospatial_lon_max=-175 incorporates 15 degrees of longitude (ranges 170 to 180 and -180 to -175).	ACDD Recommended
time_coverage_start	string	Nominal start time. Describes the time of the first data point in the data set. Use the ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.	ACDD Recommended
time_of_first_valid_obs	string	Describes the time of the first valid data point in the data set. Use the ISO 8601:2004 date extended format.	
time_coverage_mid	string	Describes the midpoint between the nominal start and end times. Use the ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.	Sounder SIPS extension by analogy with ACDD time_coverage_start and time_coverage_end
time_coverage_end	string	Nominal end time. Describes the time of the last data point in the data set. Use ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.	ACDD Recommended
time_of_last_valid_obs	string		
time_coverage_duration	string	Describes the duration of the data set. Use ISO 8601:2004 duration format, preferably the extended format as recommended in the Attribute Content Guidance section.	ACDD Recommended
product_name_duration	string	Product duration as it appears in product_name (m06 means six minutes)	
creator_type	string	Specifies type of creator with one of the following: 'person', 'group', 'institution', or 'position'. If this attribute is not specified, the creator is assumed to be a person.	ACDD Suggested

creator_institution	string	The institution of the creator; should uniquely identify the creator's institution. This attribute's value should be specified even if it matches the value of publisher_institution, or if creator_type is institution.	ACDD Suggested
product_version	string	Version identifier of the data file or product as assigned by the data creator. For example, a new algorithm or methodology could result in a new product_version.	ACDD Suggested, (ECS versionid)
keywords_vocabulary	string	If you are using a controlled vocabulary for the words/phrases in your "keywords" attribute, this is the unique name or identifier of the vocabulary from which keywords are taken. If more than one keyword vocabulary is used, each may be presented with a prefix and a following comma, so that keywords may optionally be prefixed with the controlled vocabulary key. Example: 'GCMD:GCMD Keywords, CF:NetCDF COARDS Climate and Forecast Standard Names'.	ACDD Suggested
platform	string	Name of the platform(s) that supported the sensor data used to create this data set or product. Platforms can be of any type, including satellite, ship, station, aircraft or other. Indicate controlled vocabulary used in platform_vocabulary.	ACDD Suggested
platform_vocabulary	string	Controlled vocabulary for the names used in the "platform" attribute.	ACDD Suggested
product_name_platform	string	Platform name as it appears in product_name	
instrument	string	Name of the contributing instrument(s) or sensor(s) used to create this data set or product. Indicate controlled vocabulary used in instrument_vocabulary.	ACDD Suggested
instrument_vocabulary	string	Controlled vocabulary for the names used in the "instrument" attribute.	ACDD Suggested
product_name_instr	string	Instrument name as it appears in product_name	
product_name	string	Canonical fully qualified product name (official file name)	ECS LocalGranuleID
product_name_variant	string	Processing variant identifier as it appears in product_name. 'std' (shorthand for 'standard') is to be the default and should be what is seen in all public products.	
product_name_version	string	Version number as it appears in product_name (v01_00_00)	
product_name_producer	string	Production facility as it appears in product_name (single character) 'T' is the default, for unofficial local test products	
product_name_timestamp	string	Processing timestamp as it appears in product_name (yymmddhhmmss)	
product_name_extension	string	File extension as it appears in product_name (typically nc)	
granule_number	ushort	granule number of day (1-240)	AIRS

product_name_granule_number	string	zero-padded string for granule number of day (g001-g240)	AIRS
gran_id	string	Unique granule identifier yyyymmddThhmm of granule start, including year, month, day, hour, and minute of granule start time	
geospatial_lat_mid	float	granule center latitude	AIRS LatgranuleCen
geospatial_lon_mid	float	granule center longitude	AIRS LongranuleCe n
featureType	string	structure of data in file	CF
data_structure	string	a character string indicating the internal organization of the data with currently allowed values of 'grid', 'station', 'trajectory', or 'swath'. The 'structure' here generally describes the horizontal structure and in all cases data may also be functions, for example, of a vertical coordinate and/or time. (If using CMOR pass this in a call to cmor_set_cur_dataset_attribute.)	CMIP5/CMO R
cdm_data_type	string	The data type, as derived from Unidata's Common Data Model Scientific Data types and understood by THREDDS. (This is a THREDDS "dataType", and is different from the CF NetCDF attribute 'featureType', which indicates a Discrete Sampling Geometry file in CF.)	ACDD Suggested
identifier_product_doi_authority	string	digital signature source	AIRS
algorithm_version	string	The version of the algorithm in whatever format is selected by the developers. Versions from multiple sub-algorithms may be concatenated with semicolon separators. (ex: 'CCAST 4.2; BB emis from MIT 2016-04-01')	
production_host	string	Identifying information about the host computer for this run. (Output of linux "uname -a" command.)	
format_version	string	Format version.	
input_file_names	string	Semicolon-separated list of names or unique identifiers of files that were used to make this product. There will always be one space after each semicolon. There is no final semicolon.	ECS InputPointer; ISO Source Citation
input_file_types	string	Semicolon-separated list of tags giving the role of each input file in input_file_names. There will always be one space after each semicolon. There is no final semicolon.	ISO Source Description
input_file_dates	string	Semicolon-separated list of creation dates for each input file in input_file_names. There will always be one space after each semicolon. There is no final semicolon.	ISO Source Creation Date

orbitDirection	string	Orbit is ascending and/or descending. Values are "Ascending" or "Descending" if the entire granule fits that description. "NorthPole" and "SouthPole" are used for polar-crossing granules. "NA" is used when a determination cannot be made.	SMAP uses this attribute name but only asc/desc because files are half orbits. The values used here are similar to AIRS node_type.
day_night_flag	string	Data is day or night. "Day" means subsatellite point for all valid scans has solar zenith angle less than 90 degrees. "Night" means subsatellite point for all valid scans has solar zenith angle greater than 90 degrees. "Both" means the dataset contains valid observations with solar zenith angle above and below 90 degrees. "NA" means a value could not be determined.	AIRS DayNightFlag
AutomaticQualityFlag	string	*"Passed":* the granule contains a non-degraded calibrated brightness temperature or radiance for at least one channel in a geolocated FOV *"Suspect":* the granule does not qualify as "Passed" but contains a (possibly degraded) calibrated brightness temperature or radiance for at least one channel (possibly without associated geolocation) *"Failed":* the granule contains no calibrated brightness temperatures/radiances.	ECS. AIRS called it AutomaticQA Flag in HDF attributes but AutomaticQua lityFlag in metadata.
qa_pct_data_missing	float	Percentage of expected observations that are missing.	ECS, maps to (part of) ISO 19115 Completeness Comission
qa_pct_data_geo	float	Percentage of expected observations that are successfully geolocated.	maps to (part of) ISO 19115 Completeness Comission
qa_pct_data_sci_mode	float	Percentage of expected observations that were taken while the instrument was in science mode and are successfully geolocated.	maps to (part of) ISO 19115 Completeness Comission
qa_no_data	string	A simple indicator of whether this is an "empty" granule with no data from the instrument. "TRUE" or "FALSE".	

3.3 Variable Attributes

Each variable has its own associated attributes. Variable attributes are a CF standard and are used to describe the variable in more detail to properly interpret its value.

Table 3.3: Variable Attributes

Attribute	Relevant standard(s)	Description
units	CF, UDUNITS	units, for variables that represent physical quantities
_FillValue	CF, NetCDF	a single sentinel value indicating the data point contains fill instead of valid data
standard_name	CF	standard name from the CF standard name table, if one exists for the quantity being represented
long_name	CF	a longer name describing the quantity being represented, suitable for a plot title
valid_range	CF	a pair of values indicating the minimum and maximum values to be considered valid
coordinates	CF	a space-separated list of the names of other variables that are coordinates for this variable
description		a longer description of the quantity being represented
coverage_content_type	ACDD, ISO 19115-1	indicates the source of the data
ancillary_variables	CF	a space-separated list of the names of other variables that contain information about this variable
bounds	CF	defines the extent, for cell variables
cell_methods	CF	describes statistical methods used to derive data, for cell variables
flag_values	CF	a comma-separated list of flag values, for variables that represent flags
flag_meanings	CF	a space separated list of the meanings of each flag value, for variables that represent flags
flag_masks	CF	a comma-separated list of flag masks, for variables that represent flags. If this attribute is present, the basic rule is “apply the flag mask and if you get the flag value, it means the flag meaning”

3.4 Geolocation

Geolocation variables are located in the file at the root level. The include latitudes and longitudes associated with each observation, as well as satellite and solar geometry information, spacecraft position and orbital characteristics, surface information and related metadata.

Geolocation parm are used for determining location of each observation on earth.

Table 3.4.1 Geolocation Dimensions

Dimension name	Size	Meaning
atrack	135	Along-track spatial dimension
xtrack	96	Cross-track spatial dimension

And the key geolocation variables are:

Table 3.4.2 Geolocation Variables

Geolocation Variable	Dimensions	Type	Meaning
lat	atrack, xtrack	32-bit floating-point	latitude of fov center
lon	atrack, xtrack	32-bit floating-point	longitude of fov center
obs_time_tai	atrack, xtrack	64-bit floating-point	earth view observation midtime for each fov in units of seconds since 1993-01-01T00:00:00
obs_time_utc	atrack, xtrack, utc_tuple	16-bit integer	UTC earth view observation time as an array of integers: year, month, day, hour, minute, second, msec

3.5 Key Science Data Fields

Key science data fields and the aux group and their dimensions are defined below.

Table 3.5.1 Science Data Fields

Variable Name	Dimensions	Type	Meaning
antenna_temp	atrack, xtrack, channel	32-bit floating-point	Calibrated scene brightness temperature for each ATMS channel

			and beam position. This output is the Rayleigh equivalent temperature and not the Planck blackbody equivalent temperature
cold_nedt	channel	32-bit floating-point	Noise equivalent delta temperature derived from observations of cold space
warm_nedt	channel	32-bit floating-point	Noise equivalent delta temperature derived from observations of the warm calibration target

The auxillary information, provided in an aux group, is not readily used by the wider user community but is provided here for completeness.

Table 3.5.2 Aux Group

Variable Name	Dimensions	Type	Description
geo_qualflag	atrack, xtrack	int32	Bit 7 - Failed geolocation on Earth topographic surface (surface_loc)
			Bit 6 - Could not set FOV surface elevations and land water fraction (DEM)
			Bit 5 - Failed geolocation on Earth geoid (geoid_loc)
			Bit 4 - Failed to set solar zenith or azimuth angles (solar_ang)
			Bit 3 - Failed to set spacecraft zenith or azimuth angles (spacecraft_ang)
			Bit 2 - Unused (0)
			Bit 1 (LSB) - Failed geolocation of some bands (band_specific)
cal_qualflag	atrack, channel	int32	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
			Bit 7 : No usable calibration. Scan is not calibrated. (cal_failed)
			Bit 6 : Calibration values used from different scan. (cal_from_diff_scan)
			Bit 5: Insufficient valid shelf temperature values to use in a scan calibration. Fall-back constant shelf temperatures are used. (shelf_temp_bad)
			Bit 4: Excess noise (noise)
			Bit 3: Telemetry out of limits (telem)

			Bit 2: Spectral quality is poor (spectral)
			Bit 1 (LSB): reserved (0)
cal_space_qualflag	atrack, channel	int32	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
			Bit 14 : Insufficient valid space (cold calibration) observation counts to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (cold_cal_bad)
			Bit 13: Insufficient effective space temperature values to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (space_temp_bad)
			Bit 12: This scan's space view #1 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv1_bad)
			Bit 11: This scan's space view #2 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv2_bad)
			Bit 10 : This scan's space view #3 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv3_bad)
			Bit 9 : This scan's space view #4 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv4_bad)
			Bit 8: Missing moon angle for this scan's space view #1. Lunar intrusion status is unknown. (sv1_moon_unknown)
			Bit 7: Missing moon angle for this scan's space view #2. Lunar intrusion status is unknown. (sv2_moon_unknown)
			Bit 6: Missing moon angle for this scan's space view #3. Lunar intrusion status is unknown. (sv3_moon_unknown)
			Bit 5: Missing moon angle for this scan's space view #4. Lunar intrusion status is unknown. (sv4_moon_unknown)
			Bits 1-4: reserved (0)

cal_blackbody_qualflag	atrack, channel	int32	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
			Bit 3: Insufficient valid black body (warm calibration) observation counts to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (warm_cal_bad)
			Bit 2: Insufficient valid black body temperature readings to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (bb_temp_bad)
			Bit 1 (LSB): This scan's black body view not used. A scan-specific calibration may still be calculated using black body views from neighboring scans. (bb_bad)
offset	atrack, channel	float	Offset used in calibrating earth scene brightness temps.
gain	atrack, channel	float	Gain factor used in calibrating earth scene brightness temps.
nonlin	atrack, xtrack, channel	float	Nonlinearity correction used in calibrating earth scene brightness temps.
cold_temp	atrack, channel	float	Effective temperature of cold calibration view (space) (Tcc)
warm_temp	atrack, channel	float	Effective temperature of warm calibration view (black body) (Twc)

3.6 Missing Data / Fill Values

On occasion, there will be data that is missing for whatever reason. In the situation where there are incomplete granules within the 6-minute product granule, the missing data will be filled with a 'Fill Values'. The fill value is indicated by the attribute '_FillValue'. The fill value will exist in the same location the missing data would exist. This will preserve the shape of the 6-minute granule. Should the data for an entire 6-minute granule be missing, a granule will still be produced and will contain all fill values. In other words, a full fill-value granule will be produced. With this in mind, it is advised to check the data for fill values before it is used. The fill values per variable datatype are listed in the table below.

Table: 3.6.1 Fill Values

Variable Type	Fill Value
ubyte	255UB
ushort	65535US
uint	4294967295U
float	9.96921e+36f
double	9.96920996838687e+36

At the scan level, the ATMS L1B Program Generation Executive (PGE) tries to calculate antenna temperature for all scans, even there is not enough information to calculate scan-specific calibration coefficients. If we can't calculate coefficients for a particular scan, but we do have science counts for this scan, then we use calibration coefficients from the nearest, earlier scan. If we don't have good coefficients from the earlier scan, we use nearest coefficients from the later scan. So, in fact, if we can calculate a calibration coefficients for any scan within a 10 minute interval from a current scan, we will calculate a 'degraded' antenna temperature for a current scan. The PGE sets the corresponding quality flags if the antenna temperature for a scan was calculated using calibration coefficients from a different scan.

4.0 Options for Reading the Data

The ATMS L1B files are written in NetCDF4/HDF5. Because NetCDF4 builds upon the classic NetCDF data model using HDF5 as the storage layer, a user of the data product can take full advantage of tools and libraries readily available to access the data.

Every NetCDF4 file is considered an HDF5 file, however, not every HDF5 file is necessarily a NetCDF4 file. A limited subset of the HDF5 data model and file format features are used in NetCDF4 files. Conformance to the earlier mentioned CF & ACDD standards allows for users to take advantage of most NetCDF interfaces.

Tools and libraries for reading NetCDF4 as well as a NetCDF Users' Guide are written and maintained by Unidata and can be found online at:

http://www.unidata.ucar.edu/software/netcdf/

There are a number of interfaces available for reading NetCDF for different programming languages including: C/C++, Fortran, Matlab, IDL, Python and Perl.

Additionally, but can also be accessed with HDF5 tools and libraries available at:

https://www.hdfgroup.org/products/hdf5_tools/

5.0 Data Services

The ATMS Level 1B products are available to the user community via the Goddard Distributed Active Archive Center (GDAAC).
https://disc.sci.gsfc.nasa.gov/gesNews/goddard-daac-home-page

The ATMS Level 1A products are not archived at the GDAAC and therefore not made publicly available. No other Data Services are provided for these products.

Appendix A: Differences in implementation between Algorithm Theoretical Basis Document (ATBD) and ATMS L1B V2

A.1 Calculation of Calibration Coefficients and Non-Linearity Correction

The implementation of calculation of calibration coefficients differs from the one described in the ATBD [1] section 5.5.4 (page 37). The approach described in the ATBD does not work with the non-linearity coefficients that we have from NOAA's Interface Data Prcessing Segment (IDPS) calibration coefficients file. Version 2 of L1B PGE uses the same approach as NOAA's IDPS' software. We do not calculate a_0, a_1, a_2 coefficients, instead, we calculate 'offset', 'gain' and 'non linearity correction'. The implemented algorithm is as follows:

Tb = Tbl + Q

Tbl = Twc + (Cs-Cwa)/gain
Q = Tnl*(1-4*[(Tbl-Tcc)/(Twc-Tcc) -0.5]^2)

where

Tb = Brightness temperature, as reported in antenna_temp parameter
Q = non-linearity correction
Tnl = Peak nonlinearity, as determined from calibration tests (non-linear term interpolated for cold plate temperature)
Tbl = Brightness temperature assuming linear transfer function
Twc = Effective temperature of warm calibration (hot target)
Cs = Number of counts for the scene sample
Cwa = Number of counts from the warm calibration view, averaged
Tcc = Brightness temperature of cold calibration (cold space view) for each channel
Ccca =Number of counts from the cold calibration view, averaged

The "offset" is the temperature used when scene counts are 0 assuming linear transfer function. We calculate offset as:

Toffset = Twc – Cwa/gain

A.2 Lunar Intrusion or Contamination

The lunar contamination threshold is a configurable parameter that is defined for each ATMS channel. If the angle between moon center and field-of-view center for space view is less then a threshold, the count for such space view are not included in the calculation of the averaged cold calibration counts. The lunar contamination threshold is a configurable parameter, defined for

each channel. It could be changed in APF XML configuration file. This approach is different from the IDPS handling of lunar contamination.

A.3 Smoothing of Calibration Counts

The ATBD [1] describes a triangular smoothing function for calibration counts on section 5.4 (page 34). Version 2 of the ATMS L1B PGE uses a rectangular smoothing function (calibration counts from 9 scans are averaged with the same weight). This is similar to what NOAA IDPS does. This is done to make a comparison with IDPS antenna temperature more straightforward. The smoothing weights are configurable parameters that are defined for each channel. They can be changed in APF XML configuration files.

A.4 Blackbody Emissivity

The black body emissivity for warm calculation black body temperature is currently set to 1 for all channels. This is the same value that NOAA IDPS uses.

Appendix B: Geolocation Quality Flags

Flag name	Bit Index	Num Bits	Meaning
geo_qualflag	7	1	Failed geolocation on Earth topographic surface (surface_loc)
	6	1	Could not set FOV surface elevations and land water fraction (DEM)
	5	1	Failed geolocation on Earth geoid (geoid_loc)
	4	1	Failed to set solar zenith or azimuth angles (solar_ang)
	3	1	Failed to set spacecraft zenith or azimuth angles (spacecraft_ang)
	2	1	Unused (0)
	1	1	(LSB) - Failed geolocation of some bands (band_specific)
cal_qualflag	32	1	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
	7	1	No usable calibration. Scan is not calibrated. (cal_failed)
	6	1	Calibration values used from different scan. (cal_from_diff_scan)
	5	1	Insufficient valid shelf temperature values to use in a scan calibration. Fall-back constant shelf temperatures are used. (shelf_temp_bad)
	4	1	Excess noise (noise)
	3	1	Telemetry out of limits (telem)
	2	1	Spectral quality is poor (spectral)
	1	1	(LSB): reserved (0)
cal_space_qualflag	32	1	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
	14	1	Insufficient valid space (cold calibration) observation counts to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (cold_cal_bad)
	13	1	Insufficient effective space temperature values to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (space_temp_bad)

	12	1	This scan's space view #1 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv1_bad)
	11	1	This scan's space view #2 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv2_bad)
	10	1	This scan's space view #3 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv3_bad)
	9	1	This scan's space view #4 not used because of lunar intrusion or other problem. A scan-specific calibration may still be calculated using space views from neighboring views and scans. (sv4_bad)
	8	1	Missing moon angle for this scan's space view #1. Lunar intrusion status is unknown. (sv1_moon_unknown)
	7	1	Missing moon angle for this scan's space view #2. Lunar intrusion status is unknown. (sv2_moon_unknown)
	6	1	Missing moon angle for this scan's space view #3. Lunar intrusion status is unknown. (sv3_moon_unknown)
	5	1	Missing moon angle for this scan's space view #4. Lunar intrusion status is unknown. (sv4_moon_unknown)
	Bits 1 - 4	1	reserved (0)
cal_blackbody_qualflag	32	1	(Bit 32 is most significant. It is not used because it can cause confusion when this flag is used as a signed or unsigned integer.)
	3	1	Insufficient valid black body (warm calibration) observation counts to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (warm_cal_bad)
	2	1	Insufficient valid black body temperature readings to produce a scan-specific calibration. Scan may still be calibrated using coefficients from another scan. (bb_temp_bad)
	1	1	(LSB): This scan's black body view not used. A scan-specific calibration may still be calculated using black body views from neighboring scans. (bb_bad)

offset	atrack, channel	float	Offset used in calibrating earth scene brightness temps.
gain	atrack, channel	float	Gain factor used in calibrating earth scene brightness temps.
nonlin	atrack, xtrack, channel	float	Nonlinearity correction used in calibrating earth scene brightness temps.
cold_temp	atrack, channel	float	Effective temperature of cold calibration view (space) (Tcc)
warm_temp	atrack, channel	float	Effective temperature of warm calibration view (black body) (Twc)

Appendix C: CDL File Definition

A full data product specification is generated by using the NetCDF4 library and using the ncdump utility. This produces a CDL text file showing the full structure of the ATMS L1b datafile.

The command used to generate the CDL file is: ncdump –h <filename>.nc

```
netcdf SNDR.SNPP.ATMS.20180501T2354.m06.g240.L1B.std.v02_05.G.180502084029 {
dimensions:
       spatial = 3;         // directions: x, y, z
       fov_poly = 8;        // lat/lon points defining the ploygon bounding an fov
                                  (anticlockwise as viewed from above)
       utc_tuple = 8;       // parts of UTC time
       attitude = 3;        // roll, pitch, yaw
       atrack = 135;        // along-track spatial dimension
       xtrack = 96;         // cross-track spatial dimension
       channel = 22;        // channel number
       band = 5;            // Microwave bands
       spacextrack = 4;     // space view


// global attributes:
              string :keywords = "EARTH SCIENCE > SPECTRAL/ENGINEERING > MICROWAVE >
                     ANTENNA TEMPERATURE" ;
              string :Conventions = "CF-1.6, ACDD-1.3" ;
              string :source = "ATMS instrument telemetry" ;
              string :processing_level = "1B" ;
              string :product_name_type_id = "L1B" ;
              string :comment = "" ;
              string :acknowledgment = "Support for this research was provided by
                     NASA." ;
              string :standard_name_vocabulary = "CF Standard Name Table v28" ;
              string :project = "Sounder SIPS" ;
              string :product_name_project = "SNDR" ;
              string :geospatial_bounds_crs = "EPSG:4326" ;
              string :time_coverage_duration = "P0000-00-00T00:06:00" ;
              string :product_name_duration = "m06" ;
              string :creator_type = "institution" ;
              string :keywords_vocabulary = "GCMD:GCMD Keywords" ;
              string :platform = "SUOMI-NPP > Suomi National Polar-orbiting
                     Partnership" ;
              string :platform_vocabulary = "GCMD:GCMD Keywords" ;
              string :instrument = "ATMS > Advanced Technology Microwave Sounder" ;
              string :instrument_vocabulary = "GCMD:GCMD Keywords" ;
              string :product_name_instr = "ATMS" ;
              string :product_name_extension = "nc" ;
              string :featureType = "point" ;
              string :data_structure = "swath" ;
              string :cdm_data_type = "Swath" ;
              string :format_version = "v02.00.08" ;
              string :title = "SNPP ATMS Level-1B" ;
              string :summary = "The Level-1B ATMS product includes data from the ATMS
                     instrument for one six-minute interval. Data is geolocated and
                     calibrated to antenna temperature." ;
              string :shortname = "SNPPATMSL1B" ;
              string :product_group = "l1b_atms" ;
              string :references = "ATMS ATBD is in review.  It will be published at
       http://eospso.gsfc.nasa.gov/content/algorithm-theoretical-basis-documents" ;
              string :contributor_name = "Jet Propulsion Laboratory: Bjorn Lambrigtsen"
                     ;
```

```
        string :contributor_role = "ATMS Scientist" ;
        string :naming_authority = "http://dx.doi.org/" ;
        string :history = "Created on 2018-05-02T05:22:07Z by L1A ATMS PGE at
               Sounder SIPS: GES DISC, v02.05.00; Created on 2018-05-02T08:40:29Z
               by Level 1B ATMS PGE at Sounder SIPS: GES DISC, version v02_05" ;
        string :license = "Freely Distributed" ;
        string :date_created = "2018-05-02T08:40:29Z" ;
        string :creator_name = "Sounder SIPS: GES DISC" ;
        string :creator_email = "gsfc-help-disc@lists.nasa.gov" ;
        string :creator_url = "http://disc.sci.gsfc.nasa.gov/" ;
        string :institution = "Goddard Space Flight Center - National Aeronautics
               and Space Administration" ;
        string :publisher_name = "Goddard Earth Science Data and Information
               Services Center" ;
        string :publisher_email = "gsfc-help-disc@lists.nasa.gov" ;
        string :publisher_url = "http://disc.sci.gsfc.nasa.gov/" ;
        string :geospatial_bounds = "POLYGON ((-76.78 36.36, -65.81 -34.66, -
               68.10 -90.00, -81.73 179.71, -76.78 36.36))" ;
               :geospatial_lat_min = -81.7347f ;
               :geospatial_lat_max = -65.81644f ;
               :geospatial_lon_min = 179.7167f ;
               :geospatial_lon_max = -90.00987f ;
        string :time_coverage_start = "2018-05-01T23:54:00Z" ;
        string :time_of_first_valid_obs = "2018-05-01T23:54:00Z" ;
        string :time_coverage_mid = "2018-05-01T23:57:00Z" ;
        string :time_coverage_end = "2018-05-02T00:00:00Z" ;
        string :time_of_last_valid_obs = "2018-05-01T23:59:59Z" ;
        string :creator_institution = "Goddard Space Flight Center - National
               Aeronautics and Space Administration" ;
        string :product_version = "v02.05.00" ;
        string :product_name_platform = "SNPP" ;
        string :product_name =
"SNDR.SNPP.ATMS.20180501T2354.m06.g240.L1B.std.v02_05.G.180502084029.nc" ;
        string :product_name_variant = "std" ;
        string :product_name_version = "v02_05" ;
        string :product_name_producer = "G" ;
        string :product_name_timestamp = "180502084029" ;
               :granule_number = 240US ;
        string :product_name_granule_number = "g240" ;
        string :gran_id = "20180501T2354" ;
               :geospatial_lat_mid = -73.77557f ;
               :geospatial_lon_mid = -135.1466f ;
        string :identifier_product_doi_authority = "http://dx.doi.org/" ;
        string :algorithm_version = "2017-08 IDPS emulation" ;
        string :production_host = "Linux gs6102dsc-ac16.gesdisc.eosdis.nasa.gov
               2.6.32-696.20.1.el6.x86_64 #1 SMP Fri Jan 26 17:51:45 UTC 2018
               x86_64 x86_64 x86_64 GNU/Linux" ;
        string :input_file_names =
               "SNPPATMSL1A.A2018121.2348.2.2018121234057.hdf;
               SNPPATMSL1A.A2018121.2354.2.2018122012148.hdf;
               SNPPATMSL1A.A2018122.0000.2.2018122012148.hdf;
               SNDR.SNPP.L1bMw.apf.171115000000.xml;
               SNDR.SNPP.L1bMw.template.170907000000.nc" ;
        string :input_file_types = "ATMS_L1A; ATMS_L1A; ATMS_L1A;
               ATMS_L1B_AlgParam; ATMS_L1B_Template" ;
        string :input_file_dates = "2018-05-01; 2018-05-01; 2018-05-02; N/A; N/A"
               ;
        string :orbitDirection = "SouthPole" ;
        string :day_night_flag = "Both" ;
        string :AutomaticQualityFlag = "Passed" ;
               :qa_pct_data_missing = 7.121915f ;
               :qa_pct_data_geo = 92.87808f ;
               :qa_pct_data_sci_mode = 100.f ;
```

```
            string :qa_no_data = "FALSE" ;
            string :id = "10.5067/HFDD6A30MA10" ;
            string :identifier_product_doi = "10.5067/HFDD6A30MA10" ;
            string :metadata_link = "http://disc.sci.gsfc.nasa.gov/" ;

variables:
      string obs_id(atrack, xtrack) ;
            string obs_id:units = "1" ;
            string obs_id:long_name = "earth view observation id" ;
            string obs_id:description = "unique earth view observation identifier:
                  yyyymmddThhmm.aa[a]Exx .  Includes gran_id plus two- or three-
                  digit along-track index (01-45 or 001-135) and 2-digit cross-track
                  index (01-96)." ;
            string obs_id:coverage_content_type = "referenceInformation" ;
      ubyte instrument_state(atrack, xtrack) ;
            string instrument_state:units = "1" ;
            string instrument_state:long_name = "instrument state" ;
            string instrument_state:coordinates = "lon lat" ;
            string instrument_state:description = "instrument/data state:
                        0 'Process' - Data is usable for science;
                        1 'Special' - Observations are valid but instrument is not
                                    configured for science data (ex: stare mode);
                        2 'Erroneous' - Data is not usable (ex: checksum error);
                        3 'Missing' - No data was received." ;
                  instrument_state:_FillValue = 255UB ;
            string instrument_state:coverage_content_type = "qualityInformation" ;
            string instrument_state:flag_meanings = "Process Special Erroneous
                  Missing" ;
                  instrument_state:flag_values = 0UB, 1UB, 2UB, 3UB ;
      double obs_time_tai93(atrack, xtrack) ;
            string obs_time_tai93:units = "seconds since 1993-01-01 00:00" ;
                  obs_time_tai93:valid_range = -2934835217., 3376598410. ;
            string obs_time_tai93:long_name = "earth view FOV midtime" ;
            string obs_time_tai93:standard_name = "time" ;
            string obs_time_tai93:description = "earth view observation midtime for e
                  ach FOV" ;
                  obs_time_tai93:_FillValue = 9.96920996838687e+36 ;
            string obs_time_tai93:coverage_content_type = "referenceInformation" ;
      ushort obs_time_utc(atrack, xtrack, utc_tuple) ;
            string obs_time_utc:units = "1" ;
            string obs_time_utc:long_name = "earth view UTC FOV time" ;
            string obs_time_utc:coordinates = "utc_tuple_lbl" ;
            string obs_time_utc:description = "UTC earth view observation time as an
                  array of integers: year, month, day, hour, minute, second,
                  millisec, microsec" ;
                  obs_time_utc:_FillValue = 65535US ;
            string obs_time_utc:coverage_content_type = "referenceInformation" ;
      float lat(atrack, xtrack) ;
            string lat:units = "degrees_north" ;
                  lat:valid_range = -90.f, 90.f ;
            string lat:long_name = "latitude" ;
            string lat:standard_name = "latitude" ;
            string lat:description = "latitude of FOV center" ;
                  lat:_FillValue = 9.96921e+36f ;
            string lat:coverage_content_type = "referenceInformation" ;
            string lat:bounds = "lat_bnds" ;
      float lat_geoid(atrack, xtrack) ;
            string lat_geoid:units = "degrees_north" ;
                  lat_geoid:valid_range = -90.f, 90.f ;
            string lat_geoid:long_name = "latitude" ;
            string lat_geoid:standard_name = "latitude" ;
            string lat_geoid:description = "latitude of FOV center on the geoid
                  (without terrain correction)" ;
```

```
              lat_geoid:_FillValue = 9.96921e+36f ;
       string lat_geoid:coverage_content_type = "referenceInformation" ;
float lon(atrack, xtrack) ;
       string lon:units = "degrees_east" ;
              lon:valid_range = -180.f, 180.f ;
       string lon:long_name = "longitude" ;
       string lon:standard_name = "longitude" ;
       string lon:description = "longitude of FOV center" ;
              lon:_FillValue = 9.96921e+36f ;
       string lon:coverage_content_type = "referenceInformation" ;
       string lon:bounds = "lon_bnds" ;
float lon_geoid(atrack, xtrack) ;
       string lon_geoid:units = "degrees_east" ;
              lon_geoid:valid_range = -180.f, 180.f ;
       string lon_geoid:long_name = "longitude" ;
       string lon_geoid:standard_name = "longitude" ;
       string lon_geoid:description = "longitude of FOV center on the geoid (
              without terrain correction)" ;
              lon_geoid:_FillValue = 9.96921e+36f ;
       string lon_geoid:coverage_content_type = "referenceInformation" ;
float lat_bnds(atrack, xtrack, fov_poly) ;
       string lat_bnds:units = "degrees_north" ;
              lat_bnds:valid_range = -90.f, 90.f ;
       string lat_bnds:long_name = "FOV boundary latitudes" ;
       string lat_bnds:description = "latitudes of points forming a polygon
              around the perimeter of the FOV" ;
              lat_bnds:_FillValue = 9.96921e+36f ;
       string lat_bnds:coverage_content_type = "referenceInformation" ;
float lon_bnds(atrack, xtrack, fov_poly) ;
       string lon_bnds:units = "degrees_east" ;
              lon_bnds:valid_range = -180.f, 180.f ;
       string lon_bnds:long_name = "FOV boundary longitudes" ;
       string lon_bnds:description = "longitudes of points forming a polygon
              around the perimeter of the FOV" ;
              lon_bnds:_FillValue = 9.96921e+36f ;
       string lon_bnds:coverage_content_type = "referenceInformation" ;
float land_frac(atrack, xtrack) ;
       string land_frac:units = "1" ;
              land_frac:valid_range = 0.f, 1.f ;
       string land_frac:long_name = "land fraction" ;
       string land_frac:standard_name = "land_area_fraction" ;
       string land_frac:coordinates = "lon lat" ;
       string land_frac:description = "land fraction over the FOV" ;
              land_frac:_FillValue = 9.96921e+36f ;
       string land_frac:coverage_content_type = "referenceInformation" ;
       string land_frac:cell_methods = "area: mean (beam-weighted)" ;
float surf_alt(atrack, xtrack) ;
       string surf_alt:units = "m" ;
       string surf_alt:ancillary_variables = "surf_alt_sdev" ;
              surf_alt:valid_range = -500.f, 10000.f ;
       string surf_alt:long_name = "surface altitude" ;
       string surf_alt:standard_name = "surface_altitude" ;
       string surf_alt:coordinates = "lon lat" ;
       string surf_alt:description = "mean surface altitude wrt  earth model
              over the FOV" ;
              surf_alt:_FillValue = 9.96921e+36f ;
       string surf_alt:coverage_content_type = "referenceInformation" ;
       string surf_alt:cell_methods = "area: mean (beam-weighted)" ;
float surf_alt_sdev(atrack, xtrack) ;
       string surf_alt_sdev:units = "m" ;
              surf_alt_sdev:valid_range = 0.f, 10000.f ;
       string surf_alt_sdev:long_name = "surface altitude standard deviation" ;
       string surf_alt_sdev:coordinates = "lon lat" ;
```

```
        string surf_alt_sdev:description = "standard deviation of surface
               altitude within the FOV" ;
               surf_alt_sdev:_FillValue = 9.96921e+36f ;
        string surf_alt_sdev:coverage_content_type = "qualityInformation" ;
        string surf_alt_sdev:cell_methods = "area: standard_deviation (beam-
               weighted)" ;
    float sun_glint_lat(atrack) ;
        string sun_glint_lat:units = "degrees_north" ;
               sun_glint_lat:valid_range = -90.f, 90.f ;
        string sun_glint_lat:long_name = "sun glint latitude" ;
        string sun_glint_lat:standard_name = "latitude" ;
        string sun_glint_lat:coordinates = "subsat_lon subsat_lat" ;
        string sun_glint_lat:description = "sun glint spot latitude at
               scan_mid_time.  Fill for night observations." ;
               sun_glint_lat:_FillValue = 9.96921e+36f ;
        string sun_glint_lat:coverage_content_type = "referenceInformation" ;
    float sun_glint_lon(atrack) ;
        string sun_glint_lon:units = "degrees_east" ;
               sun_glint_lon:valid_range = -180.f, 180.f ;
        string sun_glint_lon:long_name = "sun glint longitude" ;
        string sun_glint_lon:standard_name = "longitude" ;
        string sun_glint_lon:coordinates = "subsat_lon subsat_lat" ;
        string sun_glint_lon:description = "sun glint spot longitude at
               scan_mid_time.  Fill for night observations." ;
               sun_glint_lon:_FillValue = 9.96921e+36f ;
        string sun_glint_lon:coverage_content_type = "referenceInformation" ;
    float sol_zen(atrack, xtrack) ;
        string sol_zen:units = "degree" ;
               sol_zen:valid_range = 0.f, 180.f ;
        string sol_zen:long_name = "solar zenith angle" ;
        string sol_zen:standard_name = "solar_zenith_angle" ;
        string sol_zen:coordinates = "lon lat" ;
        string sol_zen:description = "solar zenith angle at the center of the
               spot" ;
               sol_zen:_FillValue = 9.96921e+36f ;
        string sol_zen:coverage_content_type = "referenceInformation" ;
    float sol_azi(atrack, xtrack) ;
        string sol_azi:units = "degree" ;
               sol_azi:valid_range = 0.f, 360.f ;
        string sol_azi:long_name = "solar azimuth angle" ;
        string sol_azi:standard_name = "solar_azimuth_angle" ;
        string sol_azi:coordinates = "lon lat" ;
        string sol_azi:description = "solar azimuth angle at the center of the
               spot (clockwise from North)" ;
               sol_azi:_FillValue = 9.96921e+36f ;
        string sol_azi:coverage_content_type = "referenceInformation" ;
    float sun_glint_dist(atrack, xtrack) ;
        string sun_glint_dist:units = "m" ;
               sun_glint_dist:valid_range = 0.f, 3.e+07f ;
        string sun_glint_dist:long_name = "sun glint distance" ;
        string sun_glint_dist:coordinates = "lon lat" ;
        string sun_glint_dist:description = "distance of sun glint spot to the
               center of the spot.  Fill for night observations." ;
               sun_glint_dist:_FillValue = 9.96921e+36f ;
        string sun_glint_dist:coverage_content_type = "referenceInformation" ;
    float view_ang(atrack, xtrack) ;
        string view_ang:units = "degree" ;
               view_ang:valid_range = 0.f, 180.f ;
        string view_ang:long_name = "view angle" ;
        string view_ang:standard_name = "sensor_view_angle" ;
        string view_ang:coordinates = "lon lat" ;
        string view_ang:description = "off nadir pointing angle" ;
               view_ang:_FillValue = 9.96921e+36f ;
```

```
        string view_ang:coverage_content_type = "referenceInformation" ;
    float sat_zen(atrack, xtrack) ;
        string sat_zen:units = "degree" ;
            sat_zen:valid_range = 0.f, 180.f ;
        string sat_zen:long_name = "satellite zenith angle" ;
        string sat_zen:standard_name = "sensor_zenith_angle" ;
        string sat_zen:coordinates = "lon lat" ;
        string sat_zen:description = "satellite zenith angle at the center of the
            spot" ;
            sat_zen:_FillValue = 9.96921e+36f ;
        string sat_zen:coverage_content_type = "referenceInformation" ;
    float sat_azi(atrack, xtrack) ;
        string sat_azi:units = "degree" ;
            sat_azi:valid_range = 0.f, 360.f ;
        string sat_azi:long_name = "satellite azimuth angle" ;
        string sat_azi:standard_name = "sensor_azimuth_angle" ;
        string sat_azi:coordinates = "lon lat" ;
        string sat_azi:description = "satellite azimuth angle at the center of
            the spot (clockwise from North)" ;
            sat_azi:_FillValue = 9.96921e+36f ;
        string sat_azi:coverage_content_type = "referenceInformation" ;
    float sat_range(atrack, xtrack) ;
        string sat_range:units = "m" ;
            sat_range:valid_range = 100000.f, 1.e+07f ;
        string sat_range:long_name = "satellite range" ;
        string sat_range:coordinates = "lon lat" ;
        string sat_range:description = "line of sight distance between satellite
            and spot center" ;
            sat_range:_FillValue = 9.96921e+36f ;
        string sat_range:coverage_content_type = "referenceInformation" ;
    ubyte asc_flag(atrack) ;
        string asc_flag:units = "1" ;
            asc_flag:valid_range = 0UB, 1UB ;
        string asc_flag:long_name = "ascending orbit flag" ;
        string asc_flag:coordinates = "subsat_lon subsat_lat" ;
        string asc_flag:description = "ascending orbit flag: 1 if ascending, 0
            descending" ;
            asc_flag:_FillValue = 255UB ;
        string asc_flag:coverage_content_type = "referenceInformation" ;
        string asc_flag:flag_meanings = "descending ascending" ;
            asc_flag:flag_values = 0UB, 1UB ;
    float subsat_lat(atrack) ;
        string subsat_lat:units = "degrees_north" ;
            subsat_lat:valid_range = -90.f, 90.f ;
        string subsat_lat:long_name = "sub-satellite latitude" ;
        string subsat_lat:standard_name = "latitude" ;
        string subsat_lat:description = "sub-satellite latitude at scan_mid_time"
            ;
            subsat_lat:_FillValue = 9.96921e+36f ;
        string subsat_lat:coverage_content_type = "referenceInformation" ;
    float subsat_lon(atrack) ;
        string subsat_lon:units = "degrees_east" ;
            subsat_lon:valid_range = -180.f, 180.f ;
        string subsat_lon:long_name = "sub-satellite longitude" ;
        string subsat_lon:standard_name = "longitude" ;
        string subsat_lon:description = "sub-satellite longitude at
            scan_mid_time" ;
            subsat_lon:_FillValue = 9.96921e+36f ;
        string subsat_lon:coverage_content_type = "referenceInformation" ;
    double scan_mid_time(atrack) ;
        string scan_mid_time:units = "seconds since 1993-01-01 00:00" ;
            scan_mid_time:valid_range = -2934835217., 3376598410. ;
        string scan_mid_time:long_name = "midscan TAI93" ;
```

```
        string scan_mid_time:standard_name = "time" ;
        string scan_mid_time:coordinates = "subsat_lon subsat_lat" ;
        string scan_mid_time:description = "TAI93 at  middle of earth scene
               scans" ;
               scan_mid_time:_FillValue = 9.96920996838687e+36 ;
        string scan_mid_time:coverage_content_type = "referenceInformation" ;
float sat_alt(atrack) ;
        string sat_alt:units = "m" ;
               sat_alt:valid_range = 100000.f, 1000000.f ;
        string sat_alt:long_name = "satellite altitude" ;
        string sat_alt:standard_name = "altitude" ;
        string sat_alt:coordinates = "subsat_lon subsat_lat" ;
        string sat_alt:description = "satellite altitude with respect to earth
              model at scan_mid_time" ;
               sat_alt:_FillValue = 9.96921e+36f ;
        string sat_alt:coverage_content_type = "referenceInformation" ;
float sat_pos(atrack, spatial) ;
        string sat_pos:units = "m" ;
        string sat_pos:long_name = "satellite position" ;
        string sat_pos:coordinates = "subsat_lon subsat_lat spatial_lbl" ;
        string sat_pos:description = "satellite ECR position at scan_mid_time" ;
               sat_pos:_FillValue = 9.96921e+36f ;
        string sat_pos:coverage_content_type = "referenceInformation" ;
float sat_vel(atrack, spatial) ;
        string sat_vel:units = "m s-1" ;
        string sat_vel:long_name = "satellite velocity" ;
        string sat_vel:coordinates = "subsat_lon subsat_lat spatial_lbl" ;
        string sat_vel:description = "satellite ECR velocity at scan_mid_time" ;
               sat_vel:_FillValue = 9.96921e+36f ;
        string sat_vel:coverage_content_type = "referenceInformation" ;
float sat_att(atrack, attitude) ;
        string sat_att:units = "degree" ;
               sat_att:valid_range = -180.f, 180.f ;
        string sat_att:long_name = "satellite attitude" ;
        string sat_att:coordinates = "subsat_lon subsat_lat angular_lbl" ;
        string sat_att:description = "satellite attitude at scan_mid_time. An
               orthogonal triad. First element is angle about the +x (roll) ORB
               axis. +x axis is positively oriented in the direction of orbital
               flight. Second element is angle about +y (pitch) ORB axis. +y axis
               is oriented normal to the orbit plane with the positive sense
               opposite to that of the orbit's angular momentum vector H. Third
               element is angle about +z (yaw) axis. +z axis is positively
               oriented Earthward parallel to the satellite radius vector R from
               the spacecraft center of mass to the center of the Earth." ;
               sat_att:_FillValue = 9.96921e+36f ;
        string sat_att:coverage_content_type = "referenceInformation" ;
float moon_ang(atrack, spacextrack) ;
        string moon_ang:units = "degree" ;
               moon_ang:valid_range = 0.f, 180.f ;
        string moon_ang:long_name = "moon angle" ;
        string moon_ang:coordinates = "subsat_lon subsat_lat" ;
        string moon_ang:description = "angle between moon and FOV center for
               space view" ;
               moon_ang:_FillValue = 9.96921e+36f ;
        string moon_ang:coverage_content_type = "referenceInformation" ;
float local_solar_time(atrack, xtrack) ;
        string local_solar_time:units = "hours" ;
               local_solar_time:valid_range = 0.f, 24.f ;
        string local_solar_time:long_name = "local apparent solar time" ;
        string local_solar_time:coordinates = "lon lat" ;
        string local_solar_time:description = "local apparent solar time in hours
               from midnight" ;
               local_solar_time:_FillValue = 9.96921e+36f ;
```

```
        string local_solar_time:coverage_content_type = "referenceInformation" ;
float mean_anom_wrt_equat(atrack) ;
        string mean_anom_wrt_equat:units = "degrees" ;
               mean_anom_wrt_equat:valid_range = 0.f, 360.f ;
        string mean_anom_wrt_equat:long_name = "mean anomaly with respect to the
               equator" ;
        string mean_anom_wrt_equat:coordinates = "subsat_lon subsat_lat" ;
        string mean_anom_wrt_equat:description = "spacecraft mean anomaly
               measured with respect to the ascending node" ;
               mean_anom_wrt_equat:_FillValue = 9.96921e+36f ;
        string mean_anom_wrt_equat:coverage_content_type = "referenceInformation"
               ;
float sat_sol_zen(atrack) ;
        string sat_sol_zen:units = "degrees" ;
               sat_sol_zen:valid_range = 0.f, 180.f ;
        string sat_sol_zen:long_name = "satellite solar zenith" ;
        string sat_sol_zen:coordinates = "subsat_lon subsat_lat" ;
        string sat_sol_zen:description = "solar zenith angle at the satellite" ;
               sat_sol_zen:_FillValue = 9.96921e+36f ;
        string sat_sol_zen:coverage_content_type = "referenceInformation" ;
float sat_sol_azi(atrack) ;
        string sat_sol_azi:units = "degrees" ;
               sat_sol_azi:valid_range = 0.f, 360.f ;
        string sat_sol_azi:long_name = "satellite solar azimuth" ;
        string sat_sol_azi:coordinates = "subsat_lon subsat_lat" ;
        string sat_sol_azi:description = "solar azimuth angle at the satellite
               (clockwise from North)" ;
               sat_sol_azi:_FillValue = 9.96921e+36f ;
        string sat_sol_azi:coverage_content_type = "referenceInformation" ;
float asc_node_lon ;
        string asc_node_lon:units = "degrees_east" ;
               asc_node_lon:valid_range = -180.f, 180.f ;
        string asc_node_lon:long_name = "ascending node" ;
        string asc_node_lon:description = "Longitude of the last ascending node
               of spacecraft orbit before time_coverage_end." ;
               asc_node_lon:_FillValue = 9.96921e+36f ;
        string asc_node_lon:coverage_content_type = "referenceInformation" ;
double asc_node_tai93 ;
        string asc_node_tai93:units = "seconds since 1993-01-01 00:00" ;
        asc_node_tai93:valid_range = -2934835217., 3376598410. ;
        string asc_node_tai93:long_name = "ascending node time" ;
        string asc_node_tai93:description = "TAI93 time of the last ascending
               node of spacecraft orbit before time_coverage_end." ;
        asc_node_tai93:_FillValue = 9.96920996838687e+36 ;
        string asc_node_tai93:coverage_content_type = "referenceInformation" ;
float asc_node_local_solar_time ;
        string asc_node_local_solar_time:units = "hours" ;
               asc_node_local_solar_time:valid_range = 0.f, 24.f ;
        string asc_node_local_solar_time:long_name = "local apparent solar time
               at the ascending node" ;
        string asc_node_local_solar_time:description = "local apparent solar time
               at the last ascending node before time_coverage_end in hours from
               midnight" ;
               asc_node_local_solar_time:_FillValue = 9.96921e+36f ;
        string asc_node_local_solar_time:coverage_content_type =
               "referenceInformation" ;
float solar_beta_angle ;
        string solar_beta_angle:units = "degrees" ;
               solar_beta_angle:valid_range = -90.f, 90.f ;
        string solar_beta_angle:long_name = "beta angle" ;
        string solar_beta_angle:description = "Beta angle for the spacecraft
               orbit, determining the percentage of the orbit that the spacecraft
               is in direct sunlight." ;
```

```
            solar_beta_angle:_FillValue = 9.96921e+36f ;
      string solar_beta_angle:coverage_content_type = "referenceInformation" ;
string attitude_lbl(attitude) ;
      string attitude_lbl:long_name = "rotational direction" ;
      string attitude_lbl:description = "list of rotational directions (roll,
            pitch, yaw)" ;
      string attitude_lbl:coverage_content_type = "auxiliaryInformation" ;
string spatial_lbl(spatial) ;
      string spatial_lbl:long_name = "spatial direction" ;
      string spatial_lbl:description = "list of spatial directions (X, Y, Z)" ;
      string spatial_lbl:coverage_content_type = "auxiliaryInformation" ;
string utc_tuple_lbl(utc_tuple) ;
      string utc_tuple_lbl:long_name = "UTC date/time parts" ;
      string utc_tuple_lbl:description = "names of the elements of UTC when it
            is expressed as an array of integers
            year,month,day,hour,minute,second,millisecond,microsecond" ;
      string utc_tuple_lbl:coverage_content_type = "auxiliaryInformation" ;
float band_lat(atrack, xtrack, band) ;
      string band_lat:units = "degrees_north" ;
            band_lat:valid_range = -90.f, 90.f ;
      string band_lat:long_name = "band latitude" ;
      string band_lat:standard_name = "latitude" ;
      string band_lat:description = "band-specific fov center latitude" ;
            band_lat:_FillValue = 9.96921e+36f ;
      string band_lat:coverage_content_type = "referenceInformation" ;
      string band_lat:bounds = "band_lat_bnds" ;
float band_lon(atrack, xtrack, band) ;
      string band_lon:units = "degrees_east" ;
            band_lon:valid_range = -180.f, 180.f ;
      string band_lon:long_name = "band longitude" ;
      string band_lon:standard_name = "longitude" ;
      string band_lon:description = "band-specific fov center longitude" ;
            band_lon:_FillValue = 9.96921e+36f ;
      string band_lon:coverage_content_type = "referenceInformation" ;
      string band_lon:bounds = "band_lon_bnds" ;
float band_lat_bnds(atrack, xtrack, band, fov_poly) ;
      string band_lat_bnds:units = "degrees_north" ;
            band_lat_bnds:valid_range = -90.f, 90.f ;
      string band_lat_bnds:long_name = "band fov boundary latitudes" ;
      string band_lat_bnds:description = "latitudes of points forming a polygon
            around the perimeter of the band-specific fov" ;
            band_lat_bnds:_FillValue = 9.96921e+36f ;
      string band_lat_bnds:coverage_content_type = "referenceInformation" ;
float band_lon_bnds(atrack, xtrack, band, fov_poly) ;
      string band_lon_bnds:units = "degrees_east" ;
      band_lon_bnds:valid_range = -180.f, 180.f ;
      string band_lon_bnds:long_name = "band fov boundary longitudes" ;
      string band_lon_bnds:description = "longitudes of points forming a
            polygon around the perimeter of the band-specific fov" ;
            band_lon_bnds:_FillValue = 9.96921e+36f ;
      string band_lon_bnds:coverage_content_type = "referenceInformation" ;
float band_land_frac(atrack, xtrack, band) ;
      string band_land_frac:units = "1" ;
            band_land_frac:valid_range = 0.f, 1.f ;
      string band_land_frac:long_name = "band land fraction" ;
      string band_land_frac:standard_name = "land_area_fraction" ;
      string band_land_frac:coordinates = "band_lbl band_lat band_lon" ;
      string band_land_frac:description = "band-specific land fraction over the
            fov" ;
            band_land_frac:_FillValue = 9.96921e+36f ;
      string band_land_frac:cell_methods = "area: mean (beam-weighted)" ;
      string band_land_frac:coverage_content_type = "referenceInformation" ;
float band_surf_alt(atrack, xtrack, band) ;
```

```
        string band_surf_alt:units = "m" ;
               band_surf_alt:valid_range = -500.f, 10000.f ;
        string band_surf_alt:long_name = "band surface altitude" ;
        string band_surf_alt:standard_name = "surface_altitude" ;
        string band_surf_alt:coordinates = "band_lbl band_lat band_lon" ;
        string band_surf_alt:description = "band-specific mean surface altitude
               over the fov" ;
               band_surf_alt:_FillValue = 9.96921e+36f ;
        string band_surf_alt:cell_methods = "area: mean (beam-weighted)" ;
        string band_surf_alt:coverage_content_type = "referenceInformation" ;
ushort band_geoloc_chan(band) ;
        string band_geoloc_chan:units = "1" ;
               band_geoloc_chan:valid_range = 1US, 22US ;
        string band_geoloc_chan:long_name = "band geolocation channel" ;
        string band_geoloc_chan:coordinates = "bad_lbl" ;
        string band_geoloc_chan:description = "Channel used in determining the
               geolocation information for each band" ;
               band_geoloc_chan:_FillValue = 65535US ;
        string band_geoloc_chan:coverage_content_type = "referenceInformation" ;
float antenna_temp(atrack, xtrack, channel) ;
        string antenna_temp:units = "Kelvin" ;
        string antenna_temp:ancillary_variables = "antenna_temp_qc" ;
               antenna_temp:valid_range = 0.f, 400.f ;
        string antenna_temp:long_name = "antenna temperature" ;
        string antenna_temp:standard_name = "brightness_temperature" ;
        string antenna_temp:coordinates = "lon lat" ;
        string antenna_temp:description = "Calibrated scene brightness
               temperature for each ATMS channel and beam position. This output
               is the Rayleigh equivalent temperature and not the Planck
               blackbody equivalent temperature" ;
               antenna_temp:_FillValue = 9.96921e+36f ;
        string antenna_temp:coverage_content_type = "physicalMeasurement" ;
byte antenna_temp_qc(atrack, xtrack, channel) ;
        string antenna_temp_qc:units = "1" ;
               antenna_temp_qc:valid_range = 0b, 2b ;
        string antenna_temp_qc:long_name = "antenna_temp QC" ;
        string antenna_temp_qc:standard_name = "brightness_temperature
               status_flag" ;
        string antenna_temp_qc:coordinates = "lon lat" ;
        string antenna_temp_qc:description = "antenna_temp QC flag" ;
               antenna_temp_qc:_FillValue = -1b ;
        string antenna_temp_qc:coverage_content_type = "qualityInformation" ;
        string antenna_temp_qc:flag_meanings = "Best Good Do_Not_Use" ;
               antenna_temp_qc:flag_values = 0b, 1b, 2b ;
float cold_nedt(channel) ;
        string cold_nedt:units = "Kelvin" ;
               cold_nedt:valid_range = 0.001f, 100.f ;
        string cold_nedt:long_name = "cold NEdT" ;
        string cold_nedt:description = "Noise equivalent delta temperature
               derived from observations of cold space" ;
               cold_nedt:_FillValue = 9.96921e+36f ;
        string cold_nedt:coverage_content_type = "qualityInformation" ;
float warm_nedt(channel) ;
        string warm_nedt:units = "Kelvin" ;
               warm_nedt:valid_range = 0.001f, 100.f ;
        string warm_nedt:long_name = "warm NEdT" ;
        string warm_nedt:description = "Noise equivalent delta temperature
               derived from observations of the warm calibration target" ;
               warm_nedt:_FillValue = 9.96921e+36f ;
        string warm_nedt:coverage_content_type = "qualityInformation" ;
string band_lbl(band) ;
        string band_lbl:long_name = "Band name" ;
        string band_lbl:standard_name = "sensor_band_identifier" ;
```

```
            string band_lbl:description = "List of Microwave bands (K, Ka, V, W, G)"
                  ;
            string band_lbl:coverage_content_type = "auxillaryInformation" ;
      ushort channel(channel) ;
            string channel:units = "1" ;
            string channel:long_name = "channel number" ;
            string channel:description = "Number for each channel (1-22)" ;
                  channel:_FillValue = 65535US ;
            string channel:coverage_content_type = "auxillaryInformation" ;
      string chan_band(channel) ;
            string chan_band:long_name = "channel band" ;
            string chan_band:description = "Name of band for each channel" ;
            string chan_band:coverage_content_type = "auxillaryInformation" ;
      char antenna(channel) ;
            string antenna:long_name = "antenna name" ;
            string antenna:description = "Name of antenna for each channel" ;
                  antenna:_FillValue = "," ;
            string antenna:coverage_content_type = "auxillaryInformation" ;
      float center_freq(channel) ;
            string center_freq:units = "MHz" ;
            string center_freq:long_name = "channel center frequency" ;
            string center_freq:standard_name =
                  "sensor_band_central_radiation_frequency" ;
            string center_freq:description = "Channel center frequency" ;
                  center_freq:_FillValue = 9.96921e+36f ;
            string center_freq:coverage_content_type = "auxillaryInformation" ;
      float if_offset_1(channel) ;
            string if_offset_1:units = "MHz" ;
            string if_offset_1:long_name = "first intermediate frequency offset" ;
            string if_offset_1:description = "Offset of first intermediate frequency
                  stage (zero for no mixing)" ;
                  if_offset_1:_FillValue = 9.96921e+36f ;
            string if_offset_1:coverage_content_type = "auxillaryInformation" ;
      float if_offset_2(channel) ;
            string if_offset_2:units = "MHz" ;
            string if_offset_2:long_name = "second intermediate frequency offset" ;
            string if_offset_2:description = "Offset of second intermediate frequency
                  stage (zero for no mixing)" ;
                  if_offset_2:_FillValue = 9.96921e+36f ;
            string if_offset_2:coverage_content_type = "auxillaryInformation" ;
      float bandwidth(channel) ;
            string bandwidth:units = "MHz" ;
            string bandwidth:long_name = "total bandwidth" ;
            string bandwidth:description = "bandwidth of sum of 1, 2, or 4 channels"
                  ;
                  bandwidth:_FillValue = 9.96921e+36f ;
            string bandwidth:coverage_content_type = "auxillaryInformation" ;
      char polarization(channel) ;
            string polarization:long_name = "Polarization" ;
            string polarization:description = "Nominal polarization: Vertical or
                  Horizontal" ;
                  polarization:_FillValue = "," ;
            string polarization:coverage_content_type = "auxillaryInformation" ;
      float beam_width(channel) ;
            string beam_width:units = "degrees" ;
            string beam_width:long_name = "Beam width" ;
            string beam_width:description = "Nominal beam width" ;
                  beam_width:_FillValue = 9.96921e+36f ;
            string beam_width:coverage_content_type = "auxillaryInformation" ;


group: aux {
  variables:
```

```
int geo_qualflag(atrack, xtrack) ;
       string geo_qualflag:units = "1" ;
       string geo_qualflag:long_name = "geolocation quality" ;
       string geo_qualflag:description = "
              Bit 7 - Failed geolocation on Earth topographic surface
                     (surface_loc)
              Bit 6 - Could not set FOV surface elevations and land water
                     fraction (DEM)
              Bit 5 - Failed geolocation on Earth geoid (geoid_loc)
              Bit 4 - Failed to set solar zenith or azimuth angles (solar_ang)
              Bit 3 - Failed to set spacecraft zenith or azimuth angles
                     (spacecraft_ang)
              Bit 2 - Unused (0)
              Bit 1 (LSB) - Failed geolocation of some bands (band_specific)" ;
              geo_qualflag:_FillValue = -2147483647 ;
       string geo_qualflag:coverage_content_type = "qualityInformation" ;
       string geo_qualflag:flag_meanings = "surface_loc DEM geoid_loc solar_ang
              spacecraft_ang band_specific" ;
              geo_qualflag:flag_values = 64, 32, 16, 8, 4, 1 ;
int cal_qualflag(atrack, channel) ;
       string cal_qualflag:units = "1" ;
       string cal_qualflag:long_name = "calibration quality flags" ;
       string cal_qualflag:coordinates = "subsat_lon subsat_lat" ;
       string cal_qualflag:description = "(Bit 32 is most significant. It is not
                     used because it can cause confusion when this flag is used
                     as a signed or unsigned integer.)
              Bit 7 : No usable calibration. Scan is not calibrated.
                     (cal_failed)
              Bit 6 : Calibration values used from different scan.
                     (cal_from_diff_scan)
              Bit 5: Insufficient valid shelf temperature values to use in a
                     scan calibration. Fall-back constant shelf temperatures are
                     used. (shelf_temp_bad)
              Bit 4: Excess noise (noise)
              Bit 3: Telemetry out of limits (telem)
              Bit 2: Spectral quality is poor (spectral)
              Bit 1 (LSB): reserved (0)" ;
              cal_qualflag:_FillValue = -2147483647 ;
       string cal_qualflag:coverage_content_type = "qualityInformation" ;
       string cal_qualflag:flag_meanings = "spectral telem noise shelf_temp_bad
              cal_from_diff_scan cal_failed" ;
              cal_qualflag:flag_values = 2, 4, 8, 16, 32, 64 ;
int cal_space_qualflag(atrack, channel) ;
       string cal_space_qualflag:units = "1" ;
       string cal_space_qualflag:long_name = "space view calibration quality
              flags" ;
       string cal_space_qualflag:coordinates = "subsat_lon subsat_lat" ;
       string cal_space_qualflag:description = "(Bit 32 is most significant. It
                     is not used because it can cause confusion when this flag
                     is used as a signed or unsigned integer.)
              Bit 14 : Insufficient valid space (cold calibration) observation
                     counts to produce a scan-specific calibration. Scan may
                     still be calibrated using coefficients from another scan.
                     (cold_cal_bad)
              Bit 13: Insufficient effective space temperature values to produce
                     a scan-specific calibration. Scan may still be calibrated
                     using coefficients from another scan.(space_temp_bad)
              Bit 12: This scan's space view #1 not used because of lunar
                     intrusion or other problem. A scan-specific calibration may
                     still be calculated using space views from neighboring
                     views and scans.(sv1_bad)
              Bit 11: This scan's space view #2 not used because of lunar
                     intrusion or other problem. A scan-specific calibration may
```

```
                    still be calculated using space views from neighboring
                    views and scans.(sv2_bad)
                Bit 10 : This scan's space view #3 not used because of lunar
                    intrusion or other problem. A scan-specific calibration may
                    still be calculated using space views from neighboring
                    views and scans.(sv3_bad)
                Bit 9 : This scan's space view #4 not used because of lunar
                    intrusion or other problem. A scan-specific calibration may
                    still be calculated using space views from neighboring
                    views and scans.(sv4_bad)
                Bit 8: Missing moon angle for this scan's space view #1. Lunar
                    intrusion status is unknown. (sv1_moon_unknown)
                Bit 7: Missing moon angle for this scan's space view #2. Lunar
                    intrusion status is unknown. (sv2_moon_unknown)
                Bit 6: Missing moon angle for this scan's space view #3. Lunar
                    intrusion status is unknown. (sv3_moon_unknown)
                Bit 5: Missing moon angle for this scan's space view #4. Lunar
                    intrusion status is unknown. (sv4_moon_unknown)
                Bits 1-4: reserved (0)" ;
                cal_space_qualflag:_FillValue = -2147483647 ;
        string cal_space_qualflag:coverage_content_type = "qualityInformation" ;
        string cal_space_qualflag:flag_meanings = "sv4_moon_unknown
                sv3_moon_unknown sv2_moon_unknown sv1_moon_unknown sv4_bad sv3_bad
                sv2_bad sv1_bad space_temp_bad cold_cal_bad" ;
        cal_space_qualflag:flag_values = 16, 32, 64, 128, 256, 512, 1024, 2048,
                4096, 8192 ;
int cal_blackbody_qualflag(atrack, channel) ;
        string cal_blackbody_qualflag:units = "1" ;
        string cal_blackbody_qualflag:long_name = "blackbody calibration quality
                flags" ;
        string cal_blackbody_qualflag:coordinates = "subsat_lon subsat_lat" ;
        string cal_blackbody_qualflag:description = "(Bit 32 is most significant.
                    It is not used because it can cause confusion when this
                    flag is used as a signed or unsigned integer.)
                Bit 3: Insufficient valid black body (warm calibration)
                    observation counts to produce a scan-specific calibration.
                    Scan may still be calibrated using coefficients from
                    another scan. (warm_cal_bad)
                Bit 2: Insufficient valid black body temperature readings to
                    produce a scan-specific calibration. Scan may still be
                    calibrated using coefficients from another scan.
                    (bb_temp_bad)
                Bit 1 (LSB): This scan's black body view not used.  A scan-
                    specific calibration may still be calculated using black
                    body views from neighboring scans.(bb_bad)" ;
                cal_blackbody_qualflag:_FillValue = -2147483647 ;
        string cal_blackbody_qualflag:coverage_content_type =
                "qualityInformation" ;
        string cal_blackbody_qualflag:flag_meanings = "bb_bad bb_temp_bad
                warm_cal_bad" ;
        cal_blackbody_qualflag:flag_values = 1, 2, 4 ;
float offset(atrack, channel) ;
        string offset:units = "Kelvin" ;
        string offset:long_name = "calibration offset" ;
        string offset:coordinates = "subsat_lon subsat_lat" ;
        string offset:description = "Offset used in calibrating earth scene
                brightness temps." ;
                offset:_FillValue = 9.96921e+36f ;
        string offset:coverage_content_type = "auxillaryInformation" ;
float gain(atrack, channel) ;
        string gain:units = "Count/Kelvin" ;
        string gain:long_name = "calibration gain" ;
        string gain:coordinates = "subsat_lon subsat_lat" ;
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```
            string gain:description = "Gain factor used in calibrating earth scene
                  brightness temps." ;
                  gain:_FillValue = 9.96921e+36f ;
            string gain:coverage_content_type = "auxillaryInformation" ;
      float nonlin(atrack, xtrack, channel) ;
            string nonlin:units = "Kelvin" ;
                  nonlin:valid_range = 0.f, 400.f ;
            string nonlin:long_name = "nonlinearity correction" ;
            string nonlin:coordinates = "lon lat" ;
            string nonlin:description = "Nonlinearity correction used in calibrating
                  earth scene brightness temps." ;
                  nonlin:_FillValue = 9.96921e+36f ;
            string nonlin:coverage_content_type = "auxillaryInformation" ;
      float cold_temp(atrack, channel) ;
            string cold_temp:units = "Kelvin" ;
            string cold_temp:long_name = "cold space temperature" ;
            string cold_temp:coordinates = "subsat_lon subsat_lat" ;
            string cold_temp:description = "Effective temperature of cold calibration
                  view (space) (Tcc)" ;
                  cold_temp:_FillValue = 9.96921e+36f ;
            string cold_temp:coverage_content_type = "auxillaryInformation" ;
      float warm_temp(atrack, channel) ;
            string warm_temp:units = "Kelvin" ;
            string warm_temp:long_name = "warm calibration temperature" ;
            string warm_temp:coordinates = "subsat_lon subsat_lat" ;
            string warm_temp:description = "Effective temperature of warm calibration
                  view (black body) (Twc)" ;
                  warm_temp:_FillValue = 9.96921e+36f ;
            string warm_temp:coverage_content_type = "auxillaryInformation" ;
  } // group aux
}
```