NASA SNPP Cross Track Infrared Sounder (CrIS) Level 1B Full Spectral Resolution Sample Data Users' Guide

University of Wisconsin-Madison Space Science and Engineering Center

University of Maryland Baltimore County Atmospheric Spectroscopy Laboratory

Version 1.0

Note: this document describes a sample Full Spectral Resolution CrIS L1B data product which is provided for purposes of evaluation and development of software. This dataset should be considered preliminary, and will be replaced by the future Version 2.0 release.

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1 Introduction

1.1 Overview

This document describes the Version 1.0 CrIS Level 1B (L1B) Full Spectral Resolution (FSR) Sample Data. This sample dataset is provided for purposes of evaluation and software development. It will be replaced by the future Version 2.0 CrIS L1B Product, and should be considered an ephemeral product.

Note that users who are interested in the Normal Spectral Resolution (NSR) product should use the Version 1.0 product, which is NSR-only. For information on the difference between NSR and FSR, refer to Section 2.4.

This preliminary sample FSR product is being provided before the FSR algorithm is fully mature in order to:

1. familiarize users with the CrIS L1B FSR data format,
2. provide L1B FSR data for the Level 2 science teams to work with as they develop their own software,
3. provide L1B FSR data for use in preparing proposals, and
4. solicit feedback from users on both data format and contents.

It should be understood that the software used to generated the sample data was not fully mature or feature complete, and that the sample product has not been fully evaluated or validated. Known issues affecting the sample product are described in "Section 5: Caveats and Known Issues".

The product consists of calibrated radiance spectra and geolocation information, as well as metadata and various derived parameters related to the observations.

The goal of creating the CrIS L1B product is to provide a high-quality, consistently calibrated dataset spanning the Suomi NPP (SNPP) mission, for use in climatology and other applications where long-term stability is a primary consideration.

The mission start date for purposes of the FSR product is defined as November 2, 2015, at 1736z. At that time the SNPP satellite began transmitting extra data points in the CrIS raw data stream, which are used in the Level 1B software to calibrate the FSR product.

The file format of the CrIS L1B product is NetCDF4. The Climate and Forecast (CF) and Attribute Convention for Dataset Discovery (ACDD) standards are followed where applicable.

1.2 Software

This product was generated by Version 1.0 FSR Beta2 of the CrIS L1B software, which was developed with funding from NASA at the University of Wisconsin - Madison (UW) Space Science and Engineering Center and the University of Maryland - Baltimore County (UMBC) Atmospheric Spectroscopy Laboratory.

The data format and granulation scheme were developed in collaboration with the Advanced Technology Microwave Sounder (ATMS) L1B team, located at NASA Jet Propulsion Laboratory (JPL).

1.3 Product generation

The product was generated from EOS Data and Operations System (EDOS) Level 0 data at the SNPP Atmosphere Science Investigator-led Processing System (SIPS), located at the University of Wisconsin Space Science and Engineering Center. Level 0 data consists of packetized raw telemetry as received from the satellite, with added metadata.

1.4 Instrument Description

The Cross-track Infrared Sounder (CrIS) is a Fourier Transform Spectrometer (FTS) onboard the Suomi National Polar-Orbiting Partnership (S-NPP) satellite, launched on October 28, 2011 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 [NOAA Technical Report NESDIS 143]. S-NPP is the first in a series of next generation U.S. weather satellites of the Joint Polar Satellite System (JPSS). CrIS is a flat-mirror Michelson interferometer which measures interferograms in three Infrared (IR) bands simultaneously.

The CrIS interferometer includes a beamsplitter, a stationary and moving mirror, and a laser sampling system. The scene radiance entering the interferometer is split by the beamsplitter into two beams along two separate paths. One beam travels towards the moving mirror, while the other to a stationary mirror. The two beams are reflected from the corresponding mirrors and recombine before converging on the detector. The optical path difference (OPD) traveled by the two beams is twice the physical path difference between the two mirrors. As the moving mirror sweeps from one side of the zero path difference (ZPD) to the other, a time-varying interference pattern known as the interferogram is recorded. A convolution of the interferogram with a Finite Impulse Response (FIR) numerical filter is applied in real-time on the spacecraft to reduce the internal data rate to meet telemetry requirements. This results in a complex-valued interferogram of a fixed number of sample points which is included in the downlinked data packets.

During a single scene scan mirror dwell period, one interferogram is recorded for each of 27 detectors simultaneously (3 focal planes (LW, MW, SW) each containing 9 bore-sighted detectors in a 3x3 pattern). The CrIS uses a 45 deg scene scan mirror to provide sequential views of an internal blackbody (ICT), a deep space view (DS), and 30 Earth views in the cross-track in a repeating pattern as the spacecraft moves along-track. The interferograms associated with the ICT and DS views and a measurement of ICT temperature are used in the ground processing software to calibrate the Earth views to produce radiance spectra. Prior to calibration, a correction is applied to account for measured signal nonlinearity of selected detectors. Corrections are also applied in the ground processing software to remove FTS self-apodization effects and to resample the spectra to a predefined user spectral grid.

1.5 Contact Information

Inquiries regarding the data product can be directed to sounder.sips@jpl.nasa.gov.

Inquiries regarding the software and underlying algorithms can be directed to cris.l1b.support@ssec.wisc.edu.

1.6 Data Disclaimer

The Version 1.0 CrIS FSR Sample Data is released to the public as is.

1.7 Obtaining the Product

The CrIS Level 1B product and sample data can be downloaded from the Goddard Distributed Active Archive Center (GDAAC).

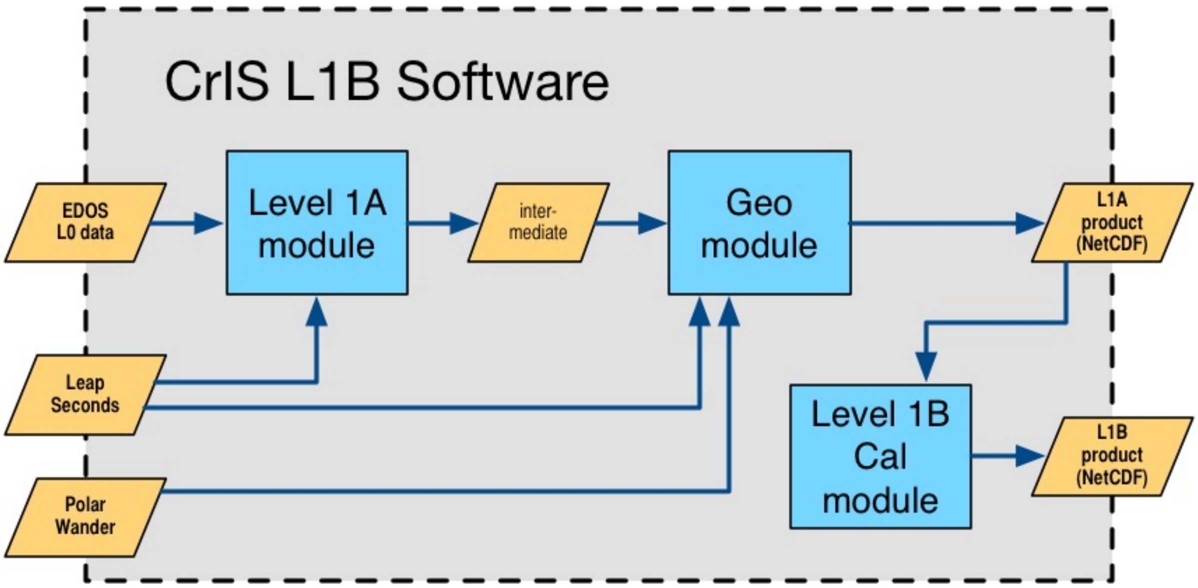
https://disc.gsfc.nasa.gov/datasets/SNPPCrISL1BFSR_V1/summary

2 CrIS L1B Product

2.1 Algorithm Background

The CrIS L1B software consists of three main processing modules: Level 1A (L1A), Geolocation and L1B Calibration. The controlling "glue" logic is written in Bash and Python.

Figure 2.1-1 CrIS L1B Software Modules and Data Flow



The L1A and Geolocation modules were developed as mostly new code, written in Python. The L1B Calibration module is written in Matlab and is based on the CrIS Calibration Algorithm and Sensor Testbed (CCAST) software developed at the UW and UMBC. The CCAST software was modified for this project to be compatible with the new L1A and Geo products. Additionally, modifications to the calibration algorithm and quality flag indicators have been incorporated.

For information on the theoretical basis of the CrIS L1B Version 1.0 software, refer to the "NASA SNPP Cross Track Infrared Sounder (CrIS) Level 1B Delta Algorithm Theoretical Basis Document (ATBD), Version 1.0". That document describes algorithm differences relative to the JPSS SDR ATBD document.

2.2 Granulation

The data is partitioned into 6-minute granules, with one granule per file and 240 granules per day. Granules are aligned to Coordinated Universal Time (UTC) such that the nominal start time of the first granule of the day is 00:00Z, and the nominal start time of the last granule is 23:54Z.

Each granule is composed of 45 complete 8-second scans. A complete scan is included in a granule if its start time is between the nominal granule start and end times. Note that because granules are UTC-aligned and contain only complete scans, the actual data start time may be up to eight seconds after the nominal granule start time. This actual-versus-nominal time delta is generally stable, but changes after each UTC leap second adjustment.

The CrIS and ATMS products use the same granulation scheme, so that CrIS and ATMS granules can be easily matched via the filenames or file metadata. However, note that the temporal and spatial alignment of the data will not be perfect due to differences in the CrIS and ATMS scan start times and footprints.

It is notable that the granulation occurs during L1A processing and uses **direct telemetry times**. In the case of CrIS, earth scene, deep space, and internal calibration target observation times are corrected backward from telemetry times to reflect the center of the interferometer scan. This correction is done using a delta value provided by the instrument in the 4-minute engineering telemetry. As a result, the first earth scene observation time can and does sometimes land slightly (milliseconds) before the nominal start of a 6-minute UTC-aligned CrIS L1A or L1B granule. This situation occurs after the 20161231T235960 leap second adjustment and prior to the following (future) leap second adjustment.

2.3 Product Files

L1A and L1B products are written to separate files, with the same granulation.

The L1A product consists of raw telemetry values that have been decoded and unscaled, as well as bit-trimmed interferograms, geolocation data, quality flags and other metadata. The L1A product ***is not*** described in this document.

The L1B product consists of calibrated radiance spectra and the associated NEdN, auxiliary data including imaginary spectra, geolocation data (identical to L1A), quality flags and other metadata. The L1B product ***is*** described in this document.

2.4 NSR vs FSR

For the first part of the SNPP mission, the effective spectral resolution of CrIS data received from the satellite was lower in the short-wave and mid-wave infrared bands than in the long-wave infrared band. Level 0 data received during this initial period is referred to as Normal Spectral Resolution (NSR).

In December 2014, the resolution of the short-wave and mid-wave data transmitted from the satellite was increased to match the long-wave resolution. Level 0 data received from this time onward is referred to as Full Spectral Resolution (FSR). After the transition to FSR, the effective spectral resolution of short-wave data received on the ground was quadrupled, and the effective spectral resolution of mid-wave data was doubled, with the Level 0 data volume increasing accordingly.

In November 2015, the satellite began transmitting long-wave and short-wave interferograms with extra points on the ends. These points had previously been discarded, but were added to the data stream because it was determined that they could be used to improve the quality of the calibration.

The Version 1.0 CrIS L1B Product spans the mission to-date, including the NSR and FSR time periods. To produce a consistent product, Level 0 interferograms from the FSR time period were truncated to NSR prior to calibration. The resolution of the Version 1.0 CrIS L1B Product is therefore NSR, meaning that the resolution of the short-wave and mid-wave spectra is lower than the resolution of the long-wave spectra.

The Version 1.0 CrIS L1B FSR Sample Data was produced for the part of the mission starting in November 2015. This was determined to be the optimal start time of an FSR product, because of the availability of the additional points at the end of the long-wave and short-wave interferograms, and because of the desire to have a consistent product. The resolution of the Version 1.0 CrIS L1B FSR Sample Data is FSR, meaning that the long-wave, mid-wave and short-wave spectra are at the same resolution. The availability of the additional points at the end of the long-wave interferograms allows for reduced spectral ringing in the long-wave spectra in the FSR Sample Data product, compared to the CrIS L1B (NSR-only) product. However, if apodization is applied by the user, the LW radiance differences are expected to be insignificant between the two products.

Note that the future Version 2.0 CrIS L1B Product will include both NSR and FSR datasets for the portion of the mission that supports each resolution. The NSR product is intended to cover the longest possible time span, and the FSR product is intended to provide higher resolution in the short-wave and mid-wave bands.

3 File Format and Conventions

The CrIS L1B file format is similar to the ATMS L1B file format, sharing common naming conventions, file and variable attributes, and overall file organization. Both CrIS and ATMS L1B products are written and distributed as NetCDF4 files.

3.1 NetCDF4

The product files can be read and queried using the NetCDF4 library and tools maintained by Unidata (http://www.unidata.ucar.edu/software/netcdf/). Support for reading NetCDF is offered in many programming languages, including Python, Matlab, IDL, C/C++ and Fortran.

NetCDF4 files are legal HDF5 files with additional bookkeeping information managed by the NetCDF4 library. It is therefore possible to inspect and copy data out of the NetCDF4 files by using the HDF5 utilities and libraries maintained by the HDF Group (https://www.hdfgroup.org/products/hdf5_tools/index.html) or by using the HDF5 interface in your favorite programming language. However, the two libraries should not be considered fully interchangeable.

Example code showing how to read the files is shown in "Appendix A".

Matlab users should note that the Matlab NetCDF4 interface is currently (as of version R2017a) not able to read attributes that are string arrays, and will throw an exception if that is attempted. The workaround is to use the HDF5 interface to read those variables. See "Appendix A" for an example.

3.2 Metadata Conventions

Where possible, the attributes and file structure conform to the Climate and Forecasting (CF) Conventions, Version 1.6, as well as the Attribute Conventions for Data Discovery (ACDD), Version 1.3. These conventions are intended to allow CF-aware software to understand the data, and to improve usability of data by standardizing the representation.

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

3.3 Missing Data

Missing data is represented by a fill value, as recommended by the CF convention. For each product variable the fill value is indicated by the attribute "_FillValue". Every data point should be checked for fill before it is used.

3.4 File Naming

File names are composed of multiple fields, separated by the "." character:

```
<Sounder_SIPS_ID>.<platform>.<inst_ID>.<granule_ID>.<product_granularity>.<granule_number>.<product_type>.<variant>.<version>.<production_location>.<production_timestamp>.<file_extension>
```

The fields are described in the table below. For each field in the filename there is a corresponding attribute in the global metadata in the file, as shown in the table.

Table 3.4-1 CrIS L1B Filename Fields.

Filename field	**Attribute name in file**	**Format**	**Value(s) in V1 product**	**Description**
file_extension	product_name_extension	nc	nc	NetCDF file extension
granule_ID	gran_id	yyyymmddThhmm		Unique ID identifying granule (nominal granule start time)
granule_number	granule_number	g###	g001 – g240	Granule number
inst_ID	product_name_instr	iiii	CRIS	Instrument ID
platform	product_name_platform	pppp	SNPP	Satellite platform
product_granularity	product_name_duration	m##	m06	6 minute product granularity
product_type	product_name_type_id	L1B_rrr	L1B_FSR	Product type, where: FSR = Full Spectral Resolution Note: this will be changed in a future version to "L1B"

production_location	product_name_producer	p	T	Test
production_timestamp	product_name_timestamp	yymmddhhmmss		Time file was produced
Sounder_SIPS_ID	product_name_project	nnnn	SNDR	Sounder SIPS ID
variant	product_name_variant	(freeform text)	std	Used to identify special runs. The default is: std = standard.
version	product_name_version	v01_##_##	v01_00_00	Product version

Example filename:

```
SNDR.SNPP.CRIS.20151102T1848.m06.g189.L1B_FSR.std.v01_00_00.T.170316035742.nc
```

3.5 Time Representation

Times in the CrIS 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 CrIS 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.

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 CrIS 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.

4 Data Contents

CrIS L1B data is stored in NetCDF4 format data files and requires a recent version of the Unidata NetCDF library to access content. NetCDF4 is effectively a specialization of the HDF5 format, unlike NetCDF3 and prior versions. Some users may prefer to use HDF5 libraries to access the files; doing so is subject to a number of caveats outside the scope of this document.

The NetCDF4 data model allows for variables, groups (similar to directories in a file system), dimensions and attributes.

Most of the variables in the CrIS L1B files are at the root level. However, auxiliary variables, which are mainly useful for diagnostic and validation purposes, are contained in a group called "aux".

Each variable has attributes recommended by the Unidata Climate and Forecasting (CF) convention, sufficient to describe the meaning of the variable and interpret its value. Each file has a set of standard-conforming global attributes that describe the granule, including geographic information, quality flag summary statistics, and data provenance.

This section describes the variables, dimensions and attributes in the CrIS L1B files. For a complete list in Common Data form Language (CDL) format, refer to "Appendix B".

4.1 Dimensions

The key dimensions are:

```
atrack = 45;  // along-track spatial dimension

xtrack = 30;  // cross-track spatial dimension

fov = 9;  // field-of-view dimension

chan_lw = 717;  // long-wave IR channel number

chan_mw = 869;  // mid-wave IR channel number

chan_sw = 637;  // short-wave IR channel number
```

4.2 Global Attributes

There are many global (i.e. file-level) attributes that provide information about the granule, including geographic information, data provenance, and the range of observation times. Many of these attributes are recommended by the CF and ACDD standards, and some are provided for consistency with legacy products. Due to the goal of complying with multiple standards, the attributes do not follow a single naming convention, and some attributes may contain duplicate information.

Some global attributes are static, i.e. unvarying across files, some are set by the operator (typically the NASA GES DISC) via configuration files, and some are set dynamically at runtime by the L1B software based on the data being processed.

The table below describes the dynamic global attributes. For a full list of global attributes, refer to "Appendix B: CDL Files".

Table 4.2-1 CrIS L1B Dynamic Global Attributes

Attribute Name	Type	Description	Heritage
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 AutomaticQAFlag in HDF attributes but AutomaticQualityFlag in metadata.
comment	string	Miscellaneous information about the data or methods used to produce it. Can be empty.	CF, 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.	ACDD Recommended, ECS/AIRS ProductionDateTime
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 zentih 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
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	ACDD Recommended

		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))'.	
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_lat_mid	float	Granule center latitude	AIRS LatgranuleCen
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_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
geospatial_lon_mid	float	Granule center longitude	AIRS LongranuleCen
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
gran_id	string	Unique granule identifier yyyymmddThhmm of granule start	
granule_number	ushort	granule number of day (1-240)	AIRS
history	string	Provides an audit trail for modifications to the original data.	CF, ACDD Recommended

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
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
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.
processing_level	string	A textual description of the processing (or quality control) level of the data. "Dummy" when file contains no data.	ACDD Recommended
product_name	string	Canonical fully qualified product name (official file name)	ECS LocalGranuleID
product_name_granule_number	string	zero-padded string for granule number of day (g001-g240)	AIRS
product_name_timestamp	string	Processing timestamp as it appears in product_name (yymmddhhmmss)	
product_name_variant	string	Processing variant identifier as it appears in product_name	
production_host	string	Identifying information about the host computer for this run. (Output of linux "uname -a" command.)	
qa_no_data	string	A simple indicator of whether this is an "empty" granule with no data from the instrument. "TRUE" or "FALSE".	
qa_pct_data_geo	float	Percentage of expected observations that are successfully geolocated.	Maps to (part of) ISO 19115 CompletenessComission
qa_pct_data_missing	float	Percentage of expected observations that are missing.	ECS, maps to (part of) ISO 19115 CompletenessComission
qa_pct_data_sci_mode	float	Percentage of expected observations that were taken while the instrument was in science mode and are successfully	Maps to (part of) ISO 19115 CompletenessComission

		geolocated.	
time_coverage_duration	string	Describes the duration of the data set.	ACDD Recommended
time_coverage_end	string	Nominal end time. Describes the time of the last data point in the data set.	ACDD Recommended
time_coverage_mid	string	Describes the midpoint between the nominal start and end times.	Sounder SIPS extension by analogy with ACDD time_coverage_start and time_coverage_end
time_coverage_start	string	Nominal start time. Describes the time of the first data point in the data set.	ACDD Recommended
time_of_first_valid_obs	string	Describes the time of the first valid data point in the data set.	
time_of_last_valid_obs	string	Describes the time of the last valid data point in the data set.	

4.3 Variable Attributes

Variables in the NetCDF file may have the attributes shown in the table below. For a more detailed description of the standard-conforming attributes, refer to the relevant standard as noted.

Table 4.3-1 CrIS L1B Variable Attributes

Attribute	**Relevant Standard(s)**	**Description**
_FillValue	CF, NetCDF	A single sentinel value indicating the data point contains fill instead of valid 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
coordinates	CF	A space-separated list of the names of other variables that are coordinates for this variable

coverage_content_type	ACDD, ISO 19115-1	Indicates the source of the data
description		A longer description of the quantity being represented
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"
flag_meanings	CF	A space separated list of the meanings of each flag value, for variables that represent flags
flag_values	CF	A comma-separated list of flag values, for variables that represent flags
long_name	CF	A longer name describing the quantity being represented, suitable for a plot title
standard_name	CF	Standard name from the CF standard name table, if one exists for the quantity being represented
units	CF, udunits	Units, for variables that represent physical quantities
valid_range	CF	A pair of values indicating the minimum and maximum values to be considered valid

4.4 Variables

Variables in the NetCDF product files can be grouped in the following categories: science data, auxiliary, geolocation and quality flags variables. These sets of variables are described in the following sections.

4.5 Science Variables

The science variables in the product files include radiance spectra, NEdN, and other information to be used in interpreting the spectra. These variables are located in the file at the root level.

L1B quality flags should be checked before using the data in science variables (see "4.8 Quality Flags").

Note that while variables in the Version 1.0 CrIS L1B Sample Data files are not scaled, they may be scaled in a future product version.

Observation times are provided for each spectrum in both International Atomic Time (TAI) and human-readable Coordinated Universal Time (UTC) format.

The UTC observation time variable "obs_time_utc" is an 8-tuple of 16-bit unsigned integers: year (4-digit), month (1-12), day (1-31), hour (0-23), minute (0-59), second (0-60), millisecond (0-999), microsecond (0-999). For most users this will be the preferred time representation.

Refer to Section 3.5 for more information on time representation.

Table 4.5-1 CrIS L1B Science Variables

Variable Name	Type	Dims	Units	Description
! Radiance spectra				
rad_lw	float32	atrack, xtrack, fov, chan_lw	mW/(m2 sr cm-1)	Long-wave real spectral radiance
rad_mw	float32	atrack, xtrack, fov, chan_mw	mW/(m2 sr cm-1)	Mid-wave real spectral radiance
rad_sw	float32	atrack, xtrack, fov, chan_sw	mW/(m2 sr cm-1)	Short-wave real spectral radiance
! NEdN				
nedn_lw	float32	fov, chan_lw	mW/(m2 sr cm-1)	Long-wave noise equivalent differential radiance
nedn_mw	float32	fov, chan_mw	mW/(m2 sr cm-1)	Mid-wave noise equivalent differential radiance
nedn_sw	float32	fov, chan_sw	mW/(m2 sr cm-1)	Short-wave noise equivalent differential radiance
! Auxiliary coordinate variables plus others giving info on the dimensions				
scan_sweep_dir	ubyte	xtrack	1	Sweep direction of FOVs within a scan
for_num	ubyte	xtrack	1	Field of regard number
fov_num	ubyte	fov	1	Field of view number
! CrIS channel characterization				
wnum_lw	float64	chan_lw	cm-1	Long-wave wavenumber
wnum_mw	float64	chan_mw	cm-1	Mid-wave wavenumber
wnum_sw	float64	chan_sw	cm-1	Short-wave wavenumber
! Observation ID and times and associated metadata				
obs_id	string	atrack, xtrack		Unique earth view observation identifier: yyyymmddThhmm.aaExx. Includes gran_id plus 2-digit

				along-track index (01-45) and 2-digit cross-track index (01-30).
fov_obs_id	string	atrack, xtrack, fov		Unique earth view observation identifier for FOV: yyyymmddThhmm.aaExx.f. Includes obs_id plus 1-digit FOV number (1-9).
obs_time_tai	double	atrack, xtrack	seconds since 1993-01-01 00:00	Earth view observation midtime for each fov
obs_time_utc	uint16	atrack, xtrack, utc_tuple	1	UTC earth view observation time as an array of integers: year, month, day, hour, minute, second, millisecond, microsecond
utc_tuple_lbl	string	utc_tuple		Names of the elements of UTC when it is expressed as an array of integers: year, month, day, hour, minute, second, millisecond, microsecond
! Instrument state				
instrument_state	ubyte	atrack, xtrack, fov	1	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 or spacecraft maneuver); 2/'Erroneous' - Data is not usable (ex: checksum error); 3/'Missing' - No data was received.

4.6 Auxiliary Variables

Auxiliary variables, including imaginary spectra and various calibration parameters, are located in the group called "aux". For more information on auxiliary variables, refer to "Appendix B: CDL File".

4.7 Geolocation Variables

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

The geolocation quality flags should be checked before using data in geolocation variables (see "4.8 Quality Flags").

Observation locations are calculated by finding the intersection of the sensor's line-of-sight both with a model of the earth's geoid (approximating sea level at all earth locations) and also with a digital elevation model of the earth's terrain. The resulting earth locations are reported separately as lat_geoid/lon_geoid for the former case and as simply lat/lon for the latter. All other geolocation variables based on earth location are derived from the terrain-corrected (lat/lon) values.

Table 4.7-1 CrIS L1B Geolocation Variables.

Variable Name	Type	Dims	Units	Description
! Basic geolocation				
lat	float	atrack, xtrack, fov	degrees_north	latitude of fov center
lon	float	atrack, xtrack, fov	degrees_east	longitude of fov center
lat_bnds	float	atrack, xtrack, fov, fov_poly	degrees_north	latitudes of points forming a polygon around the perimeter of the fov
lon_bnds	float	atrack, xtrack, fov, fov_poly	degrees_east	longitudes of points forming a polygon around the perimeter of the fov
land_frac	float	atrack, xtrack, fov	1	land fraction over the fov
surf_alt	float	atrack, xtrack, fov	m	mean surface altitude wrt earth model over the fov
surf_alt_sdev	float	atrack, xtrack, fov	m	standard deviation of surface altitude within the fov
lat_geoid	float	atrack, xtrack, fov	degrees_north	latitude of FOV center on the geoid (without terrain correction)
lon_geoid	float	atrack, xtrack, fov	degrees_east	longitude of FOV center on the geoid (without terrain correction)
! Solar geometry				
sun_glint_lat	float	atrack	degrees_north	sun glint spot latitude at scan_mid_time
sun_glint_lon	float	atrack	degrees_east	sun glint spot longitude at scan_mid_time
sol_zen	float	atrack, xtrack, fov	degree	solar zenith angle at the center of the fov
sol_azi	float	atrack, xtrack,fov	degree	solar azimuth angle at the center of the fov
sun_glint_dist	float	atrack, xtrack,fov	m	distance of sun glint spot to the center of the fov. **Note:** the valid_range attribute of this variable is incorrect in the V1 product
! FOV / satellite geometry				
view_ang	float	atrack, xtrack, fov	degree	off nadir pointing angle
sat_zen	float	atrack, xtrack, fov	degree	satellite zenith angle at the center of the fov
sat_azi	float	atrack,	degree	satellite azimuth angle at the center of the fov

		xtrack, fov		
sat_range	float	atrack, xtrack, fov	m	line of sight distance between satellite and fov center
! Spacecraft geolocation and associated metadata				
asc_flag	ubyte	atrack	1	ascending orbit flag: 1 if ascending, 0 descending
subsat_lat	float	atrack	degrees_north	sub-satellite latitude at scan_mid_time
subsat_lon	float	atrack	degrees_east	sub-satellite longitude at scan_mid_time
scan_mid_time	double	atrack	seconds since 1993-01-01 00:00	TAI93 at middle of earth scene scans
sat_alt	float	atrack	m	satellite altitude wrt earth model at scan_mid_time
sat_pos	float	atrack, spatial	m	satellite ECR position at scan_mid_time
sat_vel	float	atrack, spatial	m s-1	satellite ECR velocity at scan_mid_time
sat_att	float	atrack, attitude	degree	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.
attitude_lbl	string	attitude		List of rotational directions (roll, pitch, yaw)
spatial_lbl	string	spatial		List of spatial directions (X, Y, Z)

4.8 Quality Flags

Product files contain Quality Flag (QF) variables describing the quality of the output spectra and geolocation. Users should check quality flags before using spectra or geolocation data in analysis or Level 2+ processing.

For each QF variable, an overall value of 0 indicates good quality. A non-zero value indicates that a problem with inputs or processing was encountered, and that as a result the associated observation failed one or more quality tests.

QF variables are bit-fields, composed of flags which can be one or more bits in length.

Users can treat the QF variable as a good/bad binary, or can access the individual flags for information on the specific issues that were encountered.

The individual flags in each variable are described in "Appendix C: Quality Flag Meanings". A more complete description is provided in the document "NASA SNPP Cross-track Infrared Sounder (CrIS) Level 1B Quality Flags Description Document, Version 1.0". Note that the meanings of these flags are fully described by the attributes "flag_values", "flag_meanings" and "flag_masks", as recommended by the CF standard. It is recommended that any software that is developed to decode individual flags should use these attributes directly to interpret the meaning of the values, instead of relying on the information in this document. For information on how to apply these attributes, refer to the CF standard.

The dimensions of the QFs correspond to the dimensions of the variables that they describe. Note that there is no "band" dimension in any of the QFs; the values apply to all bands, except where individual flags are identified as describing a single band.

The primary quality test for each spectrum applies an envelope to the imaginary residual at certain wavenumber regions, and sets the flag to non-zero (bad) if the threshold is exceeded.

If additional quality tests are added in a future product version, we plan to maintain the position and meanings of the currently defined flags to avoid negatively affecting software that was developed using the current product.

Table 4.8-1 CrIS L1B Quality Variables.

Variable Name	Type	Dims	Units	Description
l1b_qual	int64	atrack, xtrack, fov	1	Indicates L1B quality for each observation, where an overall value of 0 indicates no critical issues.
geo_qual	int64	atrack, xtrack, fov	1	Indicates geolocation quality for each observation, where an overall value of 0 indicates no critical issues.

4.9 Granule and Observation IDs

Included in the product are IDs that allow a granule or observation to be uniquely identified. Users are encouraged to refer to these IDs to unambiguously identify datasets within a product, for example when plotting data or publishing results.

Granule ID: Each granule has a unique ID that is stored in a global attribute called "gran_id", which also appears in the filename. This attribute is a string representation of the nominal start time of the granule. The format of the string is "yyyymmddThhmm".

For example:

```
20160125T1300
```

Observation ID: Each field of regard (FOR), defined as a set of 9 simultaneously observed fields of view, has a globally unique ID stored in the variable "obs_id". The observation ID is created from the granule ID, with information appended to identify the FOR observation within the granule.

The dimensions of this variable (atrack=45, xtrack=30) correspond to the first two dimensions of the science data variables, such as radiances. An observation ID can be associated with data by applying the same indices into these common dimensions.

The format of the observation ID string is "yyyymmddThhmm.aaExx", where "aa" is the 2-digit along-track index (01-45), and "xx" is the 2-digit cross-track index (01-30). The "E" indicates that it is an earth view.

For example:

```
20160125T1300.01E18
```

FOV Observation ID: At the finest level of granularity, each field of view (FOV) within a FOR observation has a globally unique ID that is stored in a variable called "fov_obs_id". The FOV observation ID is created from the observation ID, with extra information appended to identify the FOV within the FOR observation.

The dimensions of this variable (atrack=45, xtrack=30, fov=9) correspond to the first three dimensions of the science data variables, such as radiances. A FOV observation ID can be associated with data by applying the same indices into these common dimensions.

The format of the FOV observation ID string is "yyyymmddThhmm.aaExx.f" where "f" is the 1-digit FOV number (1-9).

For example:

```
20160125T1300.01E18.6
```

5 Caveats and Known Issues

This section describes known issues affecting the CrIS L1B Version 1.0 CrIS L1B FSR Sample Data.

1. An issue has been reported where processing fails on granules adjacent to data gaps. Controlling logic may be optimized in a future software version to handle these situations better, improving overall granule yield.
2. The imaginary part of the calibrated radiances (rad_imag_lw, rad_imag_mw, rad_imag_sw) and the NEdN estimates (nedn_lw, nedn_mw, nedn_sw) contained in the netcdf files are on a wavenumber scale that is shifted relative to wavenumber scale used for the corresponding calibrated radiances. This error will be corrected in a future product release. For more information, please contact the software maintainers.
3. Due to leap second implementation errors both in the CrIS L1A software and the SNPP CrIS instrument system, data is not produced surrounding leap second transitions. Partial resolution to this is implemented for a future release, but full resolution of this issue may not be available until JPSS-1 CrIS or later.
4. The valid_range attribute for the geolocation variable sun_glint_dist is incorrectly expressed in kilometers, not meters as identified by the units attribute.
5. The "product_name_type_id" field in the L1B filename will be changed in a future version from "L1B_FSR" to "L1B". This also applies to the "product_name_type_id" and "product_name" file attributes.
6. In the V2.0 FSR Alpha sample product, the Noise Equivalent Differential Radiances (NEdN; nedn_lw, nedn_mw, and nedn_sw) are inadvertently provided in raw instrument counts units (inconsistent with the naming convention and attributes). To convert these values to their approximate radiance equivalents, multiply by a Planck radiance for a blackbody at a temperature of 280K. This issue will be corrected in the next release.
7. Principal Component filtering has not been applied to the NEdN estimate for the V2.0 Alpha sample (FSR) product.

6 References

1. NASA SNPP Cross Track Infrared Sounder (CrIS) Level 1B Delta Algorithm Theoretical Basis Document (ATBD), Version 1.0
2. NASA SNPP Cross Track Infrared Sounder (CrIS) Level 1B Quality Flags Description Document, Version 1.0
3. Joint Polar Satellite System (JPSS) Cross Track Infrared Sounder (CrIS) Sensor Data Records (SDR) Algorithm Theoretical Basis Document (ATBD), Rev C, Code 474, 474-00032
4. 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

Appendix A: Example Data Ingest Code

1. Python code snippet, showing how to read the variable "rad_lw" from a file and grab a single spectrum. *rad_mw* and *rad_sw* variables are accessed similarly and have corresponding wnum_{l,m,s}w wavenumber vectors.

```
import netCDF4 as nc4
ncf = nc4.Dataset(filename, 'r')
rad_lw = ncf.variables['rad_lw']
atrack, xtrack, fov = 0, 0, 0
spectrum = rad_lw[atrack, xtrack, fov, :]
wnum_lw = ncf.variables['wnum_lw']
wavenumbers = wnum_lw[:]
```

2. Matlab code snippet, showing a simple function to read the root-level variables from a file. Note that this function reads the file as an HDF5 file for certain variable types not supported by the MATLAB NetCDF API.

```
function s = read_netcdf_lls(fn);
% A generic reader for netcdf files.  Only reads first-level
groups
% Top Level
ni = ncinfo(fn);
if isfield(ni,'Variables')
  n = length(ni.Variables);
  for i=1:n
    try
    s.(ni.Variables(i).Name) = ncread(fn,ni.Variables(i).Name);
    catch
    s.(ni.Variables(i).Name) = h5read(fn,
    strcat('/',ni.Variables(i).Name));
    end
  end
 end
 % Groups
 ng = length(ni.Groups);
 for g = 1:ng
   n = length(ni.Groups(g).Variables);
   for i=1:n
      s.(ni.Groups(g).Name).(ni.Groups(g).Variables(i).Name) =
 ncread(fn,['/' ni.Groups(g).Name '/'
 ni.Groups(g).Variables(i).Name]);
    end
  end
```

Appendix B: CDL file

Common Data form Language (CDL) text files can be generated from product files by running the ncdump utility that comes with the NetCDF4 library ("ncdump -h"). A CDL file shows the structure of the product file, including global attributes, groups, variables and variable attributes.

```
netcdf SNDR.SNPP.CRIS.20160130T1200.m06.g121.L1B_FSR.std.v01_00_00.T.170315152758 {
dimensions:
	spatial = 3 ;
	fov_poly = 8 ;
	utc_tuple = 8 ;
	attitude = 3 ;
	atrack = 45 ;
	xtrack = 30 ;
	fov = 9 ;
	chan_lw = 717 ;
	chan_mw = 869 ;
	chan_sw = 637 ;
variables:
	string obs_id(atrack, xtrack) ;
		string obs_id:units = "1" ;
		string obs_id:long_name = "earth view observation id for FOR" ;
		string obs_id:description = "unique earth view observation identifier: 
yyyymmddThhmm.aaExx.  Includes gran_id plus 2-digit along-track index (1-45) and 2-digit 
cross-track index (1-30)." ;
		string obs_id:coverage_content_type = "referenceInformation" ;
	string fov_obs_id(atrack, xtrack, fov) ;
		string fov_obs_id:units = "1" ;
		string fov_obs_id:long_name = "earth view observation id for FOV" ;
		string fov_obs_id:description = "unique earth view observation identifier for 
FOV: yyyymmddThhmm.aaExx.f .  Includes gran_id plus 2-digit along-track index (1-45), 2-digit 
cross-track index (1-30), and 1-digit FOV number (1-9)." ;
		string fov_obs_id:coverage_content_type = "referenceInformation" ;
	ubyte instrument_state(atrack, xtrack, fov) ;
		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_tai(atrack, xtrack) ;
		string obs_time_tai:units = "seconds since 1993-01-01 00:00" ;
		obs_time_tai:valid_range = -2934835217., 3376598409. ;
		string obs_time_tai:long_name = "earth view FOV midtime" ;
		string obs_time_tai:standard_name = "time" ;
		string obs_time_tai:description = "earth view observation midtime for each 
FOV" ;
		obs_time_tai:_FillValue = 9.96920996838687e+36 ;
		string obs_time_tai: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 = -1US ;
		string obs_time_utc:coverage_content_type = "referenceInformation" ;
	float lat(atrack, xtrack, fov) ;
		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, fov) ;
                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, fov) ;
                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, fov) ;
                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, 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, 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, fov) ;
                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, fov) ;
                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, fov) ;
		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, fov) ;
		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 FOV" ;
		sol_zen:_FillValue = 9.96921e+36f ;
		string sol_zen:coverage_content_type = "referenceInformation" ;
	float sol_azi(atrack, xtrack, fov) ;
		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 FOV" ;
		sol_azi:_FillValue = 9.96921e+36f ;
		string sol_azi:coverage_content_type = "referenceInformation" ;
	float sun_glint_dist(atrack, xtrack, fov) ;
		string sun_glint_dist:units = "m" ;
		sun_glint_dist:valid_range = 0.f, 30000.f ;
		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 FOV" ;
		sun_glint_dist:_FillValue = 9.96921e+36f ;
		string sun_glint_dist:coverage_content_type = "referenceInformation" ;
	float view_ang(atrack, xtrack, fov) ;
		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, fov) ;
		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
FOV" ;
                sat_zen:_FillValue = 9.96921e+36f ;
                string sat_zen:coverage_content_type = "referenceInformation" ;
        float sat_azi(atrack, xtrack, fov) ;
                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
FOV" ;
                sat_azi:_FillValue = 9.96921e+36f ;
                string sat_azi:coverage_content_type = "referenceInformation" ;
        float sat_range(atrack, xtrack, fov) ;
                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
FOV 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., 3376598409. ;
                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" ;
        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 = "auxillaryInformation" ;
        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 = "auxillaryInformation" ;
        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 = "auxillaryInformation" ;
        float rad_lw(atrack, xtrack, fov, chan_lw) ;
                string rad_lw:units = "mW/(m2 sr cm-1)" ;
                string rad_lw:long_name = "longwave real spectral radiance" ;
                string rad_lw:standard_name = "toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_lw:coordinates = "lon lat" ;
                string rad_lw:description = "longwave real spectral radiance" ;
                rad_lw:_FillValue = 9.96921e+36f ;
                string rad_lw:coverage_content_type = "physicalMeasurement" ;
        float rad_mw(atrack, xtrack, fov, chan_mw) ;
                string rad_mw:units = "mW/(m2 sr cm-1)" ;
                string rad_mw:long_name = "midwave real spectral radiance" ;
                string rad_mw:standard_name = "toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_mw:coordinates = "lon lat" ;
                string rad_mw:description = "midwave real spectral radiance" ;
                rad_mw:_FillValue = 9.96921e+36f ;
                string rad_mw:coverage_content_type = "physicalMeasurement" ;
        float rad_sw(atrack, xtrack, fov, chan_sw) ;
                string rad_sw:units = "mW/(m2 sr cm-1)" ;
                string rad_sw:long_name = "shortwave real spectral radiance" ;
                string rad_sw:standard_name = "toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_sw:coordinates = "lon lat" ;
                string rad_sw:description = "shortwave real spectral radiance" ;
                rad_sw:_FillValue = 9.96921e+36f ;
                string rad_sw:coverage_content_type = "physicalMeasurement" ;
        int64 l1b_qual(atrack, xtrack, fov) ;
                string l1b_qual:units = "1" ;
                l1b_qual:valid_range = -9223372036854775808L, 9223372036854775806L ;
                string l1b_qual:long_name = "L1B quality flags" ;
                string l1b_qual:coordinates = "lon lat" ;
                string l1b_qual:description = "per-observation L1B product quality" ;
                l1b_qual:_FillValue = -1L ;
```

```
		string l1b_qual:coverage_content_type = "qualityInformation" ;
		string l1b_qual:flag_meanings = "lw_quality_degraded lw_quality_invalid
mw_quality_degraded mw_quality_invalid sw_quality_degraded sw_quality_invalid
geo_quality_invalid lw_rad_cal_qual_degraded lw_rad_cal_qual_invalid mw_rad_cal_qual_degraded
mw_rad_cal_qual_invalid sw_rad_cal_qual_degraded sw_rad_cal_qual_invalid
lw_spectral_cal_qual_degraded lw_spectral_cal_qual_invalid mw_spectral_cal_qual_degraded
mw_spectral_cal_qual_invalid sw_spectral_cal_qual_degraded sw_spectral_cal_qual_invalid
lw_imag_rad_anomaly mw_imag_rad_anomaly sw_imag_rad_anomaly lw_lunar_intrusion
mw_lunar_intrusion sw_lunar_intrusion inv_instrument_temp excess_temp_drift
neon_cal_quality_flag isa_degraded_flag l1a_lw_missing_es l1a_mw_missing_es l1a_sw_missing_es
l1a_bit_trim_mismatch l1a_eight_sec_missing" ;
		l1b_qual:flag_masks = 3L, 3L, 12L, 12L, 48L, 48L, 64L, 384L, 384L, 1536L,
1536L, 6144L, 6144L, 24576L, 24576L, 98304L, 98304L, 393216L, 393216L, 524288L, 1048576L,
2097152L, 4194304L, 8388608L, 16777216L, 33554432L, 67108864L, 536870912L, 1073741824L,
281474976710656L, 562949953421312L, 1125899906842624L, 2251799813685248L, 4503599627370496L ;
		l1b_qual:flag_values = 1L, 2L, 4L, 8L, 16L, 32L, 64L, 128L, 256L, 512L, 1024L,
2048L, 4096L, 8192L, 16384L, 32768L, 65536L, 131072L, 262144L, 524288L, 1048576L, 2097152L,
4194304L, 8388608L, 16777216L, 33554432L, 67108864L, 268435456L, 536870912L, 1073741824L,
281474976710656L, 562949953421312L, 1125899906842624L, 2251799813685248L, 4503599627370496L ;
	int64 geo_qual(atrack, xtrack, fov) ;
		string geo_qual:units = "1" ;
		geo_qual:valid_range = -9223372036854775808L, 9223372036854775806L ;
		string geo_qual:long_name = "geolocation quality flags" ;
		string geo_qual:coordinates = "lon lat" ;
		string geo_qual:description = "per-observation L1B geolocation quality" ;
		geo_qual:_FillValue = -1L ;
		string geo_qual:coverage_content_type = "qualityInformation" ;
		string geo_qual:flag_meanings = "obs_time_missing servo_error_missing
scd_gap_sm scd_gap_md scd_gap_lg stale_utcpole" ;
		geo_qual:flag_masks = 1L, 2L, 12L, 12L, 12L, 16L ;
		geo_qual:flag_values = 1L, 2L, 4L, 8L, 12L, 16L ;
	float nedn_lw(fov, chan_lw) ;
		string nedn_lw:units = "mW/(m2 sr cm-1)" ;
		string nedn_lw:long_name = "longwave noise equivalent differential radiance" ;
		string nedn_lw:description = "longwave noise equivalent differential
radiance" ;
		nedn_lw:_FillValue = 9.96921e+36f ;
		string nedn_lw:coverage_content_type = "qualityInformation" ;
	float nedn_mw(fov, chan_mw) ;
		string nedn_mw:units = "mW/(m2 sr cm-1)" ;
		string nedn_mw:long_name = "midwave noise equivalent differential radiance" ;
		string nedn_mw:description = "midwave noise equivalent differential
radiance" ;
		nedn_mw:_FillValue = 9.96921e+36f ;
		string nedn_mw:coverage_content_type = "qualityInformation" ;
	float nedn_sw(fov, chan_sw) ;
		string nedn_sw:units = "mW/(m2 sr cm-1)" ;
		string nedn_sw:long_name = "shortwave noise equivalent differential
radiance" ;
		string nedn_sw:description = "shortwave noise equivalent differential
radiance" ;
		nedn_sw:_FillValue = 9.96921e+36f ;
		string nedn_sw:coverage_content_type = "qualityInformation" ;
	ubyte scan_sweep_dir(xtrack) ;
		string scan_sweep_dir:units = "1" ;
		scan_sweep_dir:valid_range = 0UB, 1UB ;
		string scan_sweep_dir:long_name = "sweep direction of FOVs within a scan" ;
		string scan_sweep_dir:description = "sweep direction of FOVs within a scan" ;
		scan_sweep_dir:_FillValue = 255UB ;
		string scan_sweep_dir:coverage_content_type = "auxillaryInformation" ;
		string scan_sweep_dir:flag_meanings = "forward reverse" ;
		scan_sweep_dir:flag_values = 0UB, 1UB ;
	ubyte for_num(xtrack) ;
		string for_num:units = "1" ;
		for_num:valid_range = 1UB, 30UB ;
		string for_num:long_name = "field of regard number" ;
		string for_num:description = "field of regard number" ;
		for_num:_FillValue = 255UB ;
		string for_num:coverage_content_type = "auxillaryInformation" ;
	ubyte fov_num(fov) ;
		string fov_num:units = "1" ;
		fov_num:valid_range = 1UB, 9UB ;
```

```
                string fov_num:long_name = "field of view number" ;
                string fov_num:description = "field of view number" ;
                fov_num:_FillValue = 255UB ;
                string fov_num:coverage_content_type = "auxillaryInformation" ;
        double wnum_lw(chan_lw) ;
                string wnum_lw:units = "cm-1" ;
                wnum_lw:valid_range = 648.75, 1096.25 ;
                string wnum_lw:long_name = "longwave wavenumber" ;
                string wnum_lw:standard_name = "sensor_band_central_radiation_wavenumber" ;
                string wnum_lw:description = "longwave wavenumber" ;
                wnum_lw:_FillValue = 9.96920996838687e+36 ;
                string wnum_lw:coverage_content_type = "auxillaryInformation" ;
        double wnum_mw(chan_mw) ;
                string wnum_mw:units = "cm-1" ;
                wnum_mw:valid_range = 1207.5, 1752.5 ;
                string wnum_mw:long_name = "midwave wavenumber" ;
                string wnum_mw:standard_name = "sensor_band_central_radiation_wavenumber" ;
                string wnum_mw:description = "midwave wavenumber" ;
                wnum_mw:_FillValue = 9.96920996838687e+36 ;
                string wnum_mw:coverage_content_type = "auxillaryInformation" ;
        double wnum_sw(chan_sw) ;
                string wnum_sw:units = "cm-1" ;
                wnum_sw:valid_range = 2150., 2555. ;
                string wnum_sw:long_name = "shortwave wavenumber" ;
                string wnum_sw:standard_name = "sensor_band_central_radiation_wavenumber" ;
                string wnum_sw:description = "shortwave wavenumber" ;
                wnum_sw:_FillValue = 9.96920996838687e+36 ;
                string wnum_sw:coverage_content_type = "auxillaryInformation" ;

// global attributes:
                string :keywords = "EARTH SCIENCE > SPECTRAL/ENGINEERING > INFRARED
WAVELENGTHS > INFRARED RADIANCE" ;
                string :Conventions = "CF-1.6, ACDD-1.3" ;
                string :naming_authority = "Unassigned" ;
                string :source = "CrIS instrument telemetry" ;
                string :processing_level = "1B" ;
                string :comment = "" ;
                string :acknowledgment = "Support for this research was provided by NASA." ;
                string :license = "Limited to Sounder SIPS affiliates" ;
                string :standard_name_vocabulary = "CF Standard Name Table v28" ;
                string :product_name_project = "SNDR" ;
                string :geospatial_bounds_crs = "EPSG:4326" ;
                string :product_name_duration = "m06" ;
                string :keywords_vocabulary = "GCMD:GCMD Keywords" ;
                string :platform = "SUOMI-NPP > Suomi National Polar-orbiting Partnership" ;
                string :platform_vocabulary = "GCMD:GCMD Keywords" ;
                string :product_name_platform = "SNPP" ;
                string :instrument = "CRIS-NPP > Cross-track Infrared Sounder" ;
                string :instrument_vocabulary = "GCMD:GCMD Keywords" ;
                string :product_name_instr = "CRIS" ;
                string :product_name_extension = "nc" ;
                string :featureType = "point" ;
                string :data_structure = "swath" ;
                string :cdm_data_type = "Swath" ;
                string :format_version = "v01.04.02" ;
                :qa_pct_data_missing = 0.f ;
                :qa_pct_data_geo = 100.f ;
                :qa_pct_data_sci_mode = 100.f ;
                string :title = "SNPP CrIS Level-1B FSR" ;
                string :summary = "The Level-1B CrIS product includes normal spectral
resolution data from the CrIS instrument for one six-minute interval.  Data is geolocated and
calibrated." ;
                string :shortname = "SNPPCrISL1BFSR" ;
                string :references = "" ;
                string :contributor_name = "UW-Madison", " Space Science and Engineering
Center: Hank Revercomb; UMBC", " Atmospheric Spectroscopy Laboratory: Larrabee Strow" ;
                string :contributor_role = "SNPP CrIS Scientist; SNPP CrIS Scientist" ;
                :creator_type = "institution" ;
                :product_version = "v01.00.00" ;
                :product_name_variant = "std" ;
                :product_name_producer = "T" ;
                :product_group = "l1b_cris" ;
```

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                :metadata_link = "http://disc.sci.gsfc.nasa.gov/" ;
                :gran_id = "20160130T1200" ;
                :product_name_granule_number = "g121" ;
                :date_created = "2017-03-15T15:27:54Z" ;
                :input_file_names =
"SNDR.SNPP.CRIS.20160130T1200.m06.g121.L1A.std.v01_00_00.T.170315145514.nc;
isa_snpp_fsr_773p1307.mat; FIRfilter.mat; nedn_filt_LR.mat; l1b_template.nc;
SNDR.SNPP.CRIS.20160130T1154.m06.g120.L1A.std.v01_00_00.T.170315145514.nc;
SNDR.SNPP.CRIS.20160130T1206.m06.g122.L1A.std.v01_00_00.T.170315145514.nc" ;
                :input_file_dates = "2017-03-15; 2017-02-27; 2017-02-27; 2017-02-27; 2017-03-
15; 2017-03-15; 2017-03-15" ;
                :input_file_types = "CRIS_L1A; isa_file; NF_file; nedn_filt; template_netcdf;
CRIS_L1A; CRIS_L1A" ;
                :history = "2017-03-15,15:27:55,,ccast_main
/mnt/software/flo/cris_l1b/v1.0fsrbeta2/cris_l1b_v1.0fsrbeta2/l1b/inst_data/isa_snpp_fsr_773p
1307.mat
/mnt/software/flo/cris_l1b/v1.0fsrbeta2/cris_l1b_v1.0fsrbeta2/l1b/inst_data/FIRfilter.mat
/mnt/software/flo/cris_l1b/v1.0fsrbeta2/cris_l1b_v1.0fsrbeta2/l1b/inst_data/nedn_filt_LR.mat
/dev/shm/dir_4051996/tmpP_roOo/7/tmpuFihD_/l1b_template.nc snpp_nsr_A4
/dev/shm/dir_4051996/tmpP_roOo/7/tmpuFihD_
SNDR.SNPP.CRIS.20160130T1200.m06.g121.L1A.std.v01_00_00.T.170315145514.nc
SNDR.SNPP.CRIS.20160130T1154.m06.g120.L1A.std.v01_00_00.T.170315145514.nc
SNDR.SNPP.CRIS.20160130T1206.m06.g122.L1A.std.v01_00_00.T.170315145514.nc" ;
                :production_host = "Linux p217.sips 3.10.0-514.2.2.el7.x86_64 #1 SMP Tue Dec 6
23:06:41 UTC 2016 x86_64 x86_64 x86_64 GNU/Linux" ;
                :product_name_type_id = "L1B_FSR" ;
                :AutomaticQualityFlag = "Passed" ;
                :qa_no_data = "FALSE" ;
                :geospatial_lat_min = -34.91936f ;
                :geospatial_lat_max = -11.23147f ;
                :geospatial_lon_min = -177.2163f ;
                :geospatial_lon_max = -150.1837f ;
                :time_coverage_duration = "P0000-00-00T00:06:00" ;
                :granule_number = 121US ;
                :geospatial_lat_mid = -23.30635f ;
                :geospatial_lon_mid = -162.8324f ;
                :time_coverage_start = "2016-01-30T12:00:00Z" ;
                :time_of_first_valid_obs = "2016-01-30T12:00:01.167118Z" ;
                :time_coverage_mid = "2016-01-30T12:03:00Z" ;
                :time_coverage_end = "2016-01-30T12:06:00Z" ;
                :time_of_last_valid_obs = "2016-01-30T12:06:01.167118Z" ;
                :algorithm_version = "v1.0fsrbeta2" ;
                :geospatial_bounds = "POLYGON ((-13.95 -150.49, -11.35 -170.03, -31.67 -176.86,
-34.79 -153.99, -13.95 -150.49))" ;
                :orbitDirection = "Descending" ;
                :day_night_flag = "Night" ;
                :product_name =
"SNDR.SNPP.CRIS.20160130T1200.m06.g121.L1B_FSR.std.v01_00_00.T.170315152758.nc" ;
                :product_name_timestamp = "170315152758" ;
                :product_name_version = "v01_00_00" ;

group: aux {
 variables:
        float rad_imag_lw(atrack, xtrack, fov, chan_lw) ;
                string rad_imag_lw:units = "mW/(m2 sr cm-1)" ;
                string rad_imag_lw:long_name = "longwave imaginary spectral radiance" ;
                string rad_imag_lw:standard_name =
"toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_imag_lw:coordinates = "lon lat" ;
                string rad_imag_lw:description = "longwave imaginary spectral radiance" ;
                rad_imag_lw:_FillValue = 9.96921e+36f ;
                string rad_imag_lw:coverage_content_type = "qualityInformation" ;
        float rad_imag_mw(atrack, xtrack, fov, chan_mw) ;
                string rad_imag_mw:units = "mW/(m2 sr cm-1)" ;
                string rad_imag_mw:long_name = "midwave imaginary spectral radiance" ;
                string rad_imag_mw:standard_name =
"toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_imag_mw:coordinates = "lon lat" ;
                string rad_imag_mw:description = "midwave imaginary spectral radiance" ;
                rad_imag_mw:_FillValue = 9.96921e+36f ;
                string rad_imag_mw:coverage_content_type = "qualityInformation" ;
        float rad_imag_sw(atrack, xtrack, fov, chan_sw) ;
```

```
                string rad_imag_sw:units = "mW/(m2 sr cm-1)" ;
                string rad_imag_sw:long_name = "shortwave imaginary spectral radiance" ;
                string rad_imag_sw:standard_name =
"toa_outgoing_radiance_per_unit_wavenumber" ;
                string rad_imag_sw:coordinates = "lon lat" ;
                string rad_imag_sw:description = "shortwave imaginary spectral radiance" ;
                rad_imag_sw:_FillValue = 9.96921e+36f ;
                string rad_imag_sw:coverage_content_type = "qualityInformation" ;
        double max_opd_lw ;
                string max_opd_lw:units = "cm" ;
                string max_opd_lw:long_name = "maximum longwave optical path difference" ;
                string max_opd_lw:description = "maximum longwave optical path difference" ;
                max_opd_lw:_FillValue = 9.96920996838687e+36 ;
                string max_opd_lw:coverage_content_type = "qualityInformation" ;
        double max_opd_mw ;
                string max_opd_mw:units = "cm" ;
                string max_opd_mw:long_name = "maximum midwave optical path difference" ;
                string max_opd_mw:description = "maximum midwave optical path difference" ;
                max_opd_mw:_FillValue = 9.96920996838687e+36 ;
                string max_opd_mw:coverage_content_type = "qualityInformation" ;
        double max_opd_sw ;
                string max_opd_sw:units = "cm" ;
                string max_opd_sw:long_name = "maximum shortwave optical path difference" ;
                string max_opd_sw:description = "maximum shortwave optical path difference" ;
                max_opd_sw:_FillValue = 9.96920996838687e+36 ;
                string max_opd_sw:coverage_content_type = "qualityInformation" ;
        short spectral_fold_point_lw ;
                string spectral_fold_point_lw:units = "1" ;
                string spectral_fold_point_lw:long_name = "longwave spectral folding index" ;
                string spectral_fold_point_lw:description = "one-based index for unfolding
uncalibrated longwave spectrum into ascending wavenumbers" ;
                spectral_fold_point_lw:_FillValue = -32767s ;
                string spectral_fold_point_lw:coverage_content_type = "auxillaryInformation" ;
        short spectral_fold_point_mw ;
                string spectral_fold_point_mw:units = "1" ;
                string spectral_fold_point_mw:long_name = "midwave spectral folding index" ;
                string spectral_fold_point_mw:description = "one-based index for unfolding
uncalibrated midwave spectrum into ascending wavenumbers" ;
                spectral_fold_point_mw:_FillValue = -32767s ;
                string spectral_fold_point_mw:coverage_content_type = "auxillaryInformation" ;
        short spectral_fold_point_sw ;
                string spectral_fold_point_sw:units = "1" ;
                string spectral_fold_point_sw:long_name = "shortwave spectral folding index" ;
                string spectral_fold_point_sw:description = "one-based index for unfolding
uncalibrated shortwave spectrum into ascending wavenumbers" ;
                spectral_fold_point_sw:_FillValue = -32767s ;
                string spectral_fold_point_sw:coverage_content_type = "auxillaryInformation" ;
        double measured_laser_wlen ;
                string measured_laser_wlen:units = "nm" ;
                measured_laser_wlen:valid_range = 695., 850. ;
                string measured_laser_wlen:long_name = "measured metrology laser half-
wavelengths" ;
                string measured_laser_wlen:description = "measured metrology laser half-
wavelengths" ;
                measured_laser_wlen:_FillValue = 9.96920996838687e+36 ;
                string measured_laser_wlen:coverage_content_type = "qualityInformation" ;
        double smoothed_laser_wlen ;
                string smoothed_laser_wlen:units = "nm" ;
                string smoothed_laser_wlen:long_name = "smoothed metrology laser half-
wavelengths" ;
                string smoothed_laser_wlen:description = "smoothed metrology laser half-
wavelengths" ;
                smoothed_laser_wlen:_FillValue = 9.96920996838687e+36 ;
                string smoothed_laser_wlen:coverage_content_type = "qualityInformation" ;
        double smoothed_neon_wlen ;
                string smoothed_neon_wlen:units = "nm" ;
                string smoothed_neon_wlen:long_name = "smoothed neon laser half-wavelengths" ;
                string smoothed_neon_wlen:description = "smoothed neon laser half-
wavelengths" ;
                smoothed_neon_wlen:_FillValue = 9.96920996838687e+36 ;
                string smoothed_neon_wlen:coverage_content_type = "qualityInformation" ;
        double neon_wlen ;
```

```
                string neon_wlen:units = "nm" ;
                string neon_wlen:long_name = "neon laser half-wavelengths" ;
                string neon_wlen:description = "neon laser half-wavelengths" ;
                neon_wlen:_FillValue = 9.96920996838687e+36 ;
                string neon_wlen:coverage_content_type = "qualityInformation" ;
 } // group aux
}
```

Appendix C: Quality Flag Meanings

Table C - 1 CrIS L1B "geo_qual" Variables.

flag	bit index	num. bits	meaning
obs-time-missing	0	1	observation time not available
servo-errors-missing	1	1	SSM in-track and cross-track servo errors not available
spacecraft-diary-missing	2-3	2	Gap in available spacecraft ephemeris and attitude information. 00 means no gap; 01, 10, and 11 indicate data gaps of increasing size. Exact meanings TBD.
stale-utcpole	4	1	An out-of-date ancillary file was used to determine axial rotation (UT1 - UTC) at the observation time.

Table C - 2 CrIS L1B "l1b_qual" Variables.

flag	bit index	num. bits	meaning
LW L1B quality	0-1	2	0 = no L1B quality issues 1 = L1B quality 'Degraded'. Refer to L1a, geo, L1b quality flags for more information 2 = L1B quality 'Invalid'. Refer to L1a, geo, L1b quality flags for more information
MW L1B quality	2-3	2	0 = no L1B quality issues 1 = L1B quality 'Degraded'. Refer to L1a, geo, L1b quality flags for more information 2 = L1B quality 'Invalid'. Refer to L1a, geo, L1b quality flags for more information
SW L1B quality	4-5	2	0 = no L1B quality issues 1 = L1B quality 'Degraded'. Refer to L1a, geo, L1b quality flags for more information 2 = L1B quality 'Invalid'. Refer to L1a, geo, L1b quality flags for

			more information
Geo Quality	6	1	0 = No geolocation quality issues 1 = Geolocation quality issues. Refer to geo_qual for more information.
LW Radiometric Calibration Quality	7-8	2	0 = Good radiometric calibration 1 = Degraded radiometric calibration 2 = Invalid radiometric calibration
MW Radiometric Calibration Quality	9-10	2	0 = Good radiometric calibration 1 = Degraded radiometric calibration 2 = Invalid radiometric calibration
SW Radiometric Calibration Quality	11-12	2	0 = Good radiometric calibration 1 = Degraded radiometric calibration 2 = Invalid radiometric calibration
LW Spectral Calibration Quality	13-14	2	0 = Good spectral calibration 1 = Degraded spectral calibration 2 = Invalid spectral calibration
MW Spectral Calibration Quality	15-16	2	0 = Good spectral calibration 1 = Degraded spectral calibration 2 = Invalid spectral calibration
SW Spectral Calibration Quality	17-18	2	0 = Good spectral calibration 1 = Degraded spectral calibration 2 = Invalid spectral calibration
LW Imaginary Radiance Anomaly	19	1	0 = Imaginary component of the calibrated radiance is within the threshold value 1 = Imaginary component of the calibrated radiance exceeds the threshold value
MW Imaginary Radiance Anomaly	20	1	0 = Imaginary component of the calibrated radiance is within the threshold value 1 = Imaginary component of the calibrated radiance exceeds the

			threshold value
SW Imaginary Radiance Anomaly	21	1	0 = Imaginary component of the calibrated radiance is within the threshold value 1 = Imaginary component of the calibrated radiance exceeds the threshold value
LW Lunar Intrusion Detected	22	1	0 = No DS views affected by lunar intrusion 1 = At least one DS view is affected by lunar intrusion within the moving window
MW Lunar Intrusion Detected	23	1	0 = No DS views affected by lunar intrusion 1 = At least one DS view is affected by lunar intrusion within the moving window
SW Lunar Intrusion Detected	24	1	0 = No DS views affected by lunar intrusion 1 = At least one DS view is affected by lunar intrusion within the moving window
Invalid Instrument Temperature	25	1	0 = All instrument temperatures within respective thresholds 1 = Instrument temperature outside of respective threshold
Excess Thermal Drift	26	1	0 = No excess thermal drift of instrument temperatures 1 = Thermal drift between measurements exceeds respective threshold
FCE Detected	27	1	0 = No fringe count error detected 1 = Fringe count error detected Not Implemented for this version
FCE Correction Failed	28	1	0 = FCE correction successful 1 = FCE correction failed Not implemented for this version
Neon Calibration Quality	29	1	0 = Less than 25% of the neon calibration dataset varied from the mean by greater than the 28ppm threshold 1 = 25% or greater of the neon calibration dataset varied from the mean by greater than the 28ppm threshold
ISA Degraded	30	1	0 = Current laser wavenumber value differs by less than 15 ppm with respect to the laser wavenumber used to calculate the ISA

			matrices 1 = Current laser wavenumber value differs by 15 ppm or greater with respect to the laser wavenumber used to calculate the ISA matrices
Spare	31-47	17	Unassigned
LW L1a ES Missing	48	1	Replicated from ES/l1a_qual lw-missing
MW L1a ES Missing	49	1	Replicated from ES/l1a_qual mw-missing
SW L1a ES Missing	50	1	Replicated from ES/l1a_qual sw-missing
Bit Trim Mismatch	51	1	Replicated from ES/l1a_qual bit-trim-mismatch
Scan Line Missing 8 Sec Sci	52	1	Replicated from ES/l1a_qual scan-line-missing-8sec-sci
Spare	53-63	11	Unassigned