The VIIRS-CrIS Data Fusion project: Construction of Infrared Absorption Spectral Bands for VIIRS

Data product user guide and file specification document

This guide is specific to Version 1.0 of the VIIRS-CrIS Data Fusion product

Version 1.11

18 September 2019

Contents

1 Introduction

This document is designed to provide relevant information to users of the Suomi-National Polar-Orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) infrared (IR) absorption bands. It contains some background information about the data fusion approach using a combination of VIIRS and CrIS (Crosstrack Infrared Sounder) and lists and explains the content of the data files.

The primary data products are orbit-level (Level-1, L1) of VIIRS IR absorption band radiances and brightness temperatures. Other geophysical quantities and related ancillary information are also provided. More specifically, we construct narrowband radiances using an imager-sounder data fusion process (see references) that adopts the Aqua MODIS spectral response functions for MODIS bands 23–25 (in the 4.5-μm CO_2 band), 27 & 28 (in the H_2O band), 30 (in the O_3 band), 31 & 32 (11 and 12-μm window bands) and 33–36 (in the 15-μm CO_2 band).

The L2 files also include radiances for the bowtie-deleted pixels that are present in the original VIIRS L1B files. The bowtie-deleted pixels are filled using a nearest-neighbor technique. We fill these pixels in anticipation of their use in various cloud retrieval methods that use a pixel array to calculate, for example, a mean and standard deviation to help assess homogeneity.

All data files are in Network Common Data Format Version-4 (NetCDF4) and include metadata compliant with the Climate and Forecast (CF) conventions version 1.6. Note that these NetCDF4 files are also accessible via HDF5 libraries.

1.1 Algorithm background

Details of the methodology and simultaneous nadir overpass pixel comparisons between VIIRS and Aqua MODIS are provided in papers or presentations. Please contact us if you have questions about performance and likely issues within your specific application of interest.

Additional information, including links to relevant papers, is available in the References section at the end of this document and at the VIIRS-CrIS Data Fusion project website (http://stc-se.com/data/bbaum/Baum-DataFusion).

1.2 Quality flags and data use recommendations

Quality assurance (QA) flags in the level 2 products, sometimes also called confidence flags, are used to identify if there is a possible problem with an individual retrieval. Examples of this include VIIRS granules in which the M15 and M16 radiance calibration is of bad quality, or when the CrIS data quality is poor.

The location and meanings of the QA flags within the files are described in Section 2.3.

1.3 Contact information and citation for data use

If you have general questions or comments regarding our data products, please email them to Dr. Bryan A. Baum, Dr. Elisabeth Weisz, or Dr. W. Paul Menzel (baum@stcnet.com;

elisabeth.weisz@ssec.wisc.edu; and paulm@ssec.wisc.edu). More information is also available on the VIIRS-CrIS Data Fusion project website, http://stc-se.com/data/bbaum/Baum-DataFusion.

The VIIRS-CrIS IR absorption band data are available to the public without a monetary charge. If you use our data in a publication or report, we request that you read and cite the relevant paper(s) for the specific data set(s) used. The relevant data fusion papers include the following:

- Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. **11**(3), 036022 (2017), doi: 10.1117/1.JRS.11.036022.

- Cross, J. I. Gladkova, W. P. Menzel, A. Heidinger, and M. D. Grossberg, 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473. doi: 10.1117/1.JRS.7.073473.

- Weisz, E. and W. P. Menzel, 2019: Imager and Sounder Data Fusion to Generate Sounder Retrieval Products at Improved Spatial and Temporal Resolution. *J. Appl. Remote Sens*. 13 (3), 034506.

If a significant portion of our data is used in your publication, offers of co-authorship are also appreciated. In this case, please contact Dr. Bryan A. Baum (baum@stcnet.com), the PI of the data fusion project.

In addition to citation, the following text can be used in an Acknowledgements or Data Availability section of a paper:

We thank the Data Fusion science team (http://stc-se.com/data/bbaum/Baum-DataFusion) for the VIIRS-CrIS IR absorption band data record.

2 Data organization

Level-1 (L1) files are available as 6-minute granules along the orbit track.

2.1 File naming convention

For L2 files, a sample filename is as follows for the Suomi-NPP platform, broadly following the conventions familiar to users of MODIS data products:

FSNRAD_L2_VIIRS_CRIS_SNPP.A2019218.1824.001.2019226170958.nc

The filename is interpreted as follows:

- **FSNRAD_L2_VIIRS_CRIS_SNPP** indicates the ESDT of the product. The ESDT is separated into 4 components <product>_<level>_<sensors>_<satellite>. In this case this is the Fusion Radiances Level-2 product from a fusion of the VIIRS and CrIS sensors on the Suomi-NPP (SNPP) satellite.
- **A2019218** indicates the data acquisition year and day: YYYY represents the year followed by the day of year (DOY from 001 to 366) per the Julian calendar.
- **1824** indicates the time (HHMM UTC) at which the 6-minute long granule begins.
- **001** indicates the algorithm processing version, also known as 'Version' (here, Version 1).
- **2019226170958** indicates the date and time (UTC) at which the file was created (YYYY DOY per the Julian calendar HHMM).
- **nc** indicates a NetCDF4 file.

For fusion radiances constructed from VIIRS and CrIS on NOAA-20, the sample filename is as follows:

FSNRAD_L2_VIIRS_CRIS_NOAA20.A2019218.1912.001.2019219210315.nc

The filename is interpreted as follows:

- **FSNRAD_L2_VIIRS_CRIS_NOAA20** indicates the ESDT of the product. The ESDT is separated into 4 components <product>_<level>_<sensors>_<satellite>. In this case this is the Fusion Radiances Level 2 product from a fusion of the VIIRS and CrIS sensors on the NOAA-20 (NOAA20) satellite, also known as JPSS-1.
- **A2019218** indicates the data acquisition year and day: YYYY represents the year followed by the day of year (DOY from 001 to 366) per the Julian calendar.
- **1912** indicates the time (HHMM UTC) at which the 6-minute long granule begins.

- **001** indicates the algorithm processing version, also known as ‘Version’ (here, Version 1).
- **2019219210315** indicates the date and time (UTC) at which the file was created (YYYY DOY per the Julian calendar HHMM).
- **nc** indicates a NetCDF4 file.

2.2 File format and structure

Each data file is in NetCDF format, compliant with climate and forecast (CF) conventions version 1.6. Each file contains multiple Scientific Data Sets (SDS), listed in Section 3.

2.3 L2 production, QC flags, and evaluation of radiances

Each L2 file contains data from a 6-minute portion of a single VIIRS+CrIS swath. We produce L2 fusion radiances at a resolution of the native VIIRS moderate-resolution (M) band pixels (i.e., 750m horizontal pixel size). The discussion of the QC flags that are provided for this product requires a basic understanding of the data fusion process. The following discussion provides a brief overview, with further details in Weisz et al. (2017).

To reduce confusion between the imager and sounder spatial resolutions, we use “pixel” for the imager (750m for M-bands) and field-of-view, or “FOV” for the sounder (about 15 km). The construction of high spatial resolution IR narrowband radiances from VIIRS and CrIS data consists of two steps:

Step 1: Figure 1a shows the methodology involved with this part of the process. The basic point here is that a geolocation routine is used to match CrIS FOVs and VIIRS pixels. The geolocation step determines which VIIRS pixels are collocated with each large CrIS FOV. All of the VIIRS high-spatial-resolution (HIRES) M15- and M16-band pixel radiances collocated with a given CrIS FOV are averaged, so that there are low-spatial-resolution (LORES) M15 and M16 radiance values for each FOV.

Based on the high-resolution VIIRS M15 and M16 pixel radiances, and the averaged M15 and M16 radiances for each CrIS FOV, the k-d tree search finds the *N* sounder FOVs that best match each imager pixel. For the results shown here, *N* is set to 5. The k-d tree search algorithm is used to provide the closest matching FOVs in the training data set (here, low spatial resolution imager data) for each pixel in a query data set (here, high spatial resolution imager data). The corresponding imager and sounder latitude and longitude values are used as additional predictors. Specifically, the inputs to the k-d tree are the split- window 11 and 12 µm imager radiances at both the pixel and FOV spatial resolution (HIRES and LORES, respectively), the number of pixels in an imager granule, and the geolocation for the radiances at the HIRES and LORES spatial resolution (i.e., latitudes and longitudes). Note that the k-d tree search in this step is solely based on imager radiances (at the pixel resolution and averaged over the FOV resolution) and not on sounder radiances.

Step 2: For each of the *N* FOVs chosen as the best match for each VIIRS pixel in Step 1, we integrate over a set of specified spectral response functions to obtain a set of narrowband radiances. In this step, CrIS provides the spectral radiance measurements necessary to construct the fusion spectral bands for VIIRS. The mean of the convolved radiances for the *N* FOVs is computed; the mean radiance is what is provided to each VIIRS pixel as the fusion radiance. This process is repeated for every imager pixel in the granule.

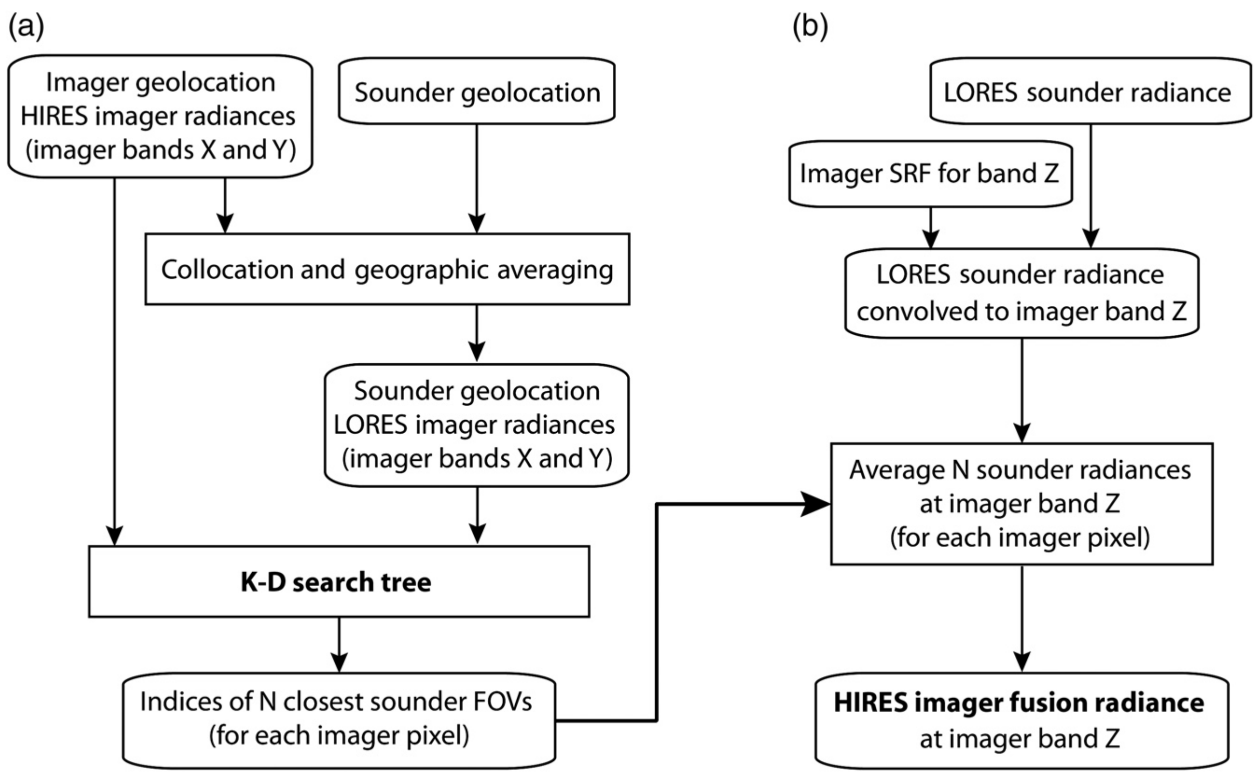

Figure 1: (a) The process for creating a multidimensional search tree using high spatial resolution (HIRES) and low spatial resolution (LORES) imager radiance and geolocation information. (b) Based on the k-d tree neighbor results, IR band radiances are constructed for each of the N CrIS FOVs selected as providing the closest radiance match for a given VIIRS pixel. The N radiances are averaged and stamped onto the VIIRS pixel. This process is repeated for each target IR radiance band for which a specified SRF (spectral response function) is given.

In each L2 data granule, the QC flags are intended to provide insight into the two steps in the data fusion process. If more than 50% of the VIIRS pixels are not of sufficient quality, then the data fusion process will not run. The primary reason for this is that the geolocation process in Step 1 becomes suspect. If the data fusion process is run, then other QC flags are provided based on the VIIRS and CrIS radiances as detailed below.

Three QC flags are provided for a subset of the VIIRS M bands listed in the global attribute called ‘viirs_qc_bands’. Two VIIRS bands, M15 and M16, are used currently in the data fusion process in Step 1. For each of these VIIRS bands, a global attribute called viirs_qc_flag_meanings provides information on ‘Missing_EV’, ‘Cal_Fail’, and ‘Fill’, where Missing_EV means missing measurements from the Earth View (EV), Cal_Fail means calibration failure, and Fill means that pixels are given fill values. The values for these three QC flags are 65532, 65534, and 65535, respectively, in the global attribute called viirs_qc_flag_values.

To evaluate the percentage of pixels that are impacted by one of the three QC flags in ‘viirs_qc_bands’, there are 3 additional QC flags provided. The global attribute ‘viirs_qc_missing_ev’ provides a value for each of the bands in ‘viirs_qc_bands’, or M15 and M16, where ‘ev’ means Earth View. The value is given as a percentage of the pixels in the granule that have the value provided for ‘Missing_EV’. In theory, the percentage ranges from 0 to 100, but as stated above, if the value is > 50, the data fusion process is not run. Similarly, the values provided in ‘viirs_qc_cal_fail’ and ‘viirs_qc_fill’ will range between 0 and 50. The user should be aware that if any of these three QC flags have high values, the fusion radiances could be suspect. To summarize, if the percentages provided for ‘viirs_qc_missing_ev’, ‘viirs_qc_cal_fail’ or ‘viirs_qc_fill’ are 0, this means that the VIIRS data for M15 and M16 are of the highest quality.

Based on the QC flags for the VIIRS bands used for data fusion (M15 and M16), and those provided in the CrIS Level-1B granules, the data fusion process is initiated. Subsequently, we provide the percentage of the pixels in the VIIRS granule where the fusion radiances are successfully created for each target fusion band. The target fusion bands are given in the global variable ‘cris_qc_bands’ and in the example are MODIS23, MODIS24, MODIS25, MODIS27, MODIS28, MODIS30, MODIS31, MODIS32, MODIS33, MODIS34, MODIS35, and MODIS36. The nomenclature used here means that the Aqua MODIS sensor’s Spectral Response Functions (SRFs) were specified to generate fusion radiances. For example, MODIS33 means that the SRF for Aqua MODIS band 33 was used to convolve the CrIS radiances for the data fusion process.

In reference to Step 2, there are QC flags that pertain specifically to this part of the process. Basically, the question is: when the fusion radiances are generated, how good are the radiances based on the CrIS QC flags? The CrIS Level-1B granules provide 3 QC flags (variable: cris_qc_flag_meanings): Best, Good, and Do_Not_Use. The integer values for these flags is provided in cris_qc_flag_values as 0 (best), 1 (good), or 2 (worst), respectively. These QC flags are used in the generation of the various absorption band radiances.

For each of the fusion bands listed in ‘cris_qc_bands’, currently numbering 12, a percentage (an integer) is provided in each of these 3 QC fields: cris_qc_best, cris_qc_good, and cris_qc_do_not_use. A value of ‘100’, for example, for a band in cris_qc_best implies that 100% of the pixels were successfully constructed based on the best CrIS data quality. However, if a value of ‘100’ is given for a band in cris_qc_do_not_use, this implies that 100% of the pixels were successfully constructed but were based on the worst CrIS data quality, and likely should not be used in your application.

An example of where the CrIS QC flags would be important is for the sensor on the Suomi-NPP platform for the period in 2019 when the mid-wave IR focal plane stopped working. The result of this focal plane issue is that MODIS27 and MODIS28 (6.7 and 7.3 μm, respectively) could not be constructed for VIIRS, but the other MODIS-like bands are still constructed and available for use.

3 Data content

Each L2 granule provides a number of constructed radiance spectral bands for both VIIRS and MODIS along with the information necessary to convert the radiances to brightness temperatures.

3.1 Dimensions

Three dimensions are defined within the L2 files:

- number_of_LUT_values, around 65536.
- number_of_lines, the index of the L2 cell in the along-track (roughly North-South) direction. This number is around 3248.
- number_of_pixels, the index of the L2 cell in the across-track (roughly East-West) direction. Denotes the number of pixels in a scan line, which is around 3200.

The radiances and brightness temperatures each have a defined size. The radiances are provided in a 2D array defined as (number of pixels, number of lines). The brightness temperature LUT is a 1D array defined as (number_of_LUT_values x 1).

3.2 Global attributes

The global attributes in the table below are present in the L2 files. In a few cases, metadata are duplicated in multiple attributes to meet specific system needs or maintain data continuity with heritage sensors. For attributes which differ between the Suomi-NPP and NOAA-20 platforms, examples of both are given and prepended or appended with the platform in parenthesis ("(Suomi-NPP)" or "(NOAA-20)").

Attribute Name	Example
format_version	'1'
processing_level	'L2'
cdm_data_type	'swath'
institution	'NASA Atmosphere SIPS'
keywords_vocabulary	'NASA Global Change Master Directory (GCMD) Science Keywords'
license	'http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/'

stdname_vocabulary	'NetCDF Climate and Forecast (CF) Metadata Convention'
naming_authority	'gov.nasa.gsfc.sci.atmos'
fusion_viirs	'VNP02MOD.A2019218.1824.001.2019219000034.uwssec.bowtie_restored.nc' (Suomi-NPP), 'VJ102MOD.A2019218.1912.001.2019219001549.uwssec.bowtie_restored.nc' (NOAA-20)
viirs_qc_flag_meanings	'Missing_EV, Cal_Fail, Fill'
viirs_qc_flag_values	[65532 65534 65535]
viirs_qc_bands	'M15, M16'
viirs_qc_missing_ev	[0 0]
viirs_qc_cal_fail	[0 0]
viirs_qc_fill	[0 0]
cris_qc_flag_meanings	'Best, Good, Do_Not_Use'
cris_qc_flag_values	[0 1 2]
cris_qc_bands	'MODIS23, MODIS24, MODIS25, MODIS27, MODIS28, MODIS30, MODIS31, MODIS32, MODIS33, MODIS34, MODIS35, MODIS36'
cris_qc_best	[100 100 100 100 100 100 100 100 100 100 100 100]
cris_qc_good	[0 0 0 0 0 0 0 0 0 0 0 0]
cris_qc_do_not_use	[0 0 0 0 0 0 0 0 0 0 0 0]
fusion_mat	'fusion_output.mat'
fusion_mat_sha256	'9e535ae1061e906e4988e87e86313803672480c48686b8c92c52489340c3fa54' (Suomi-NPP), '433e2bffe8c0c0836353a59d9d69a49e205f5ec8ea4112e4eae33bec1ac20f7b' (NOAA-20)
conventions	'CF-1.6, ACDD-1.3'
creator_email	'sips.support@ssec.wisc.edu'
creator_url	'https://sips.ssec.wisc.edu'

publisher_name	'LAADS'
publisher_email	'modis-ops@lists.nasa.gov'
publisher_url	'https://ladsweb.modaps.eosdis.nasa.gov/'
history	(Suomi-NPP): Wed Aug 14 17:10:38 2019: ncks --fix_rec_dmn all -o FSNRAD_L2_VIIRS_CRIS_SNPP.A2019218.1824.001.2019226170958.nc.tmp FSNRAD_L2_VIIRS_CRIS_SNPP.A2019218.1824.001.2019226170958.nc, (NOAA-20): Wed Sep 4 22:36:13 2019: ncks --fix_rec_dmn all -o FSNRAD_L2_VIIRS_CRIS_NOAA20.A2019218.1912.001.2019247223537.nc.tmp FSNRAD_L2_VIIRS_CRIS_NOAA20.A2019218.1912.001.2019247223537.nc
source	'collopak 0.1.71, cris_l1 2.0.16, fusion_matlab 20190805-1, viirs_l1 2.0.2, viirsmend 1.2.12' (Suomi-NPP), 'collopak 0.1.71, cris_l1 2.1.3, fusion_matlab 20190820-1, viirs_l1 3.0.0, viirsmend 1.2.12' (NOAA-20)
date_created	''
product_name	'FSNRAD_L2_VIIRS_CRIS_SNPP.A2019218.1824.001.2019226170958.nc' (Suomi-NPP), 'FSNRAD_L2_VIIRS_CRIS_NOAA20.A2019218.1912.001.2019247223537.nc' (NOAA-20)
LocalGranuleID	'FSNRAD_L2_VIIRS_CRIS_SNPP.A2019218.1824.001.2019226170958.nc', (Suomi-NPP) 'FSNRAD_L2_VIIRS_CRIS_NOAA20.A2019218.1912.001.2019247223537.nc' (NOAA-20)
ShortName	'FSNRAD_L2 _VIIRS_CRIS _SNPP' (Suomi-NPP), 'FSNRAD_L2_VIIRS_CRIS_NOAA20' (NOAA-20)
product_version	'1.0.0'
AlgorithmType	'OPS'
identifier_product_doi	'10.5067/VIIRS/FSNRAD_L2_VIIRS_CRIS_SNPP.001' (Suomi-NPP), '10.5067/VIIRS/FSNRAD_L2_VIIRS_CRIS_NOAA20.001' (NOAA-20)
identifier_product_doi_authority	'http://dx.doi.org'
ancillary_files	' '
DataCenterId	'UWI-MAD/SSEC/ASIPS'
creator_institution	'Space Science & Engineering Center, University of Wisconsin - Madison'
publisher_institution	'NASA Level-1 and Atmosphere Archive & Distribution System'
GRingPointSequenceNo	[1 2 3 4]
GRingPointLatitude	[45.3283 51.5425 30.6510 25.9752] (Suomi-NPP), [39.4976f 44.9364 24.0322 19.6860] (NOAA-20)
GRingPointLongitude	[-106.0517 -64.9039 -63.7931 -94.7061] (Suomi-NPP), [-113.9155 -77.6222 -75.6945 -104.5849] (NOAA-20)
geospatial_lat_units	'degrees_north'

geospatial_lon_units	'degrees_east'
geospatial_lat_min	25.9752 (Suomi-NPP), 19.6860 (NOAA-20)
geospatial_lat_max	51.6061 (Suomi-NPP), 44.9445 (NOAA-20)
geospatial_lon_min	-106.0517 (Suomi-NPP), -113.9155 (NOAA-20)
geospatial_lon_max	-63.7931 (Suomi-NPP), -75.6945 (NOAA-20)
NorthBoundingCoordinate	51.6061 (Suomi-NPP), 44.9445 (NOAA-20)
SouthBoundingCoordinate	25.9752 (Suomi-NPP), 19.6860 (NOAA-20)
EastBoundingCoordinate	-63.7931 (Suomi-NPP), -75.6945 (NOAA-20)
WestBoundingCoordinate	-106.0517 (Suomi-NPP), -113.9155 (NOAA-20)
time_coverage_start	'2019-08-06T18:24:00.000Z' (Suomi-NPP), '2019-08-06T19:12:00.000Z' (NOAA-20)
time_coverage_end	'2019-08-06T18:30:00.000Z' (Suomi-NPP), '2019-08-06T19:18:00.000Z' (NOAA-20)
startDirection	'Ascending'
endDirection	'Ascending'
OrbitNumber	40284 (Suomi-NPP), 8888 (NOAA-20),
DayNightFlag	'Day'
NCO	'netCDF Operators version 4.7.9 (Homepage = http://nco.sf.net, Code = http://github.com/nco/nco)'
title	'SNPP VIIRS+CrIS Fusion (FSNRAD_L2_VIIRS_CRIS_SNPP)' (Suomi-NPP), 'NOAA20 VIIRS+CrIS Fusion (FSNRAD_L2_VIIRS_CRIS_NOAA20)' (NOAA-20)
long_name	'SNPP VIIRS+CrIS Fusion 6-Min L2 Swath 750m' (Suomi-NPP), 'NOAA20 VIIRS+CrIS Fusion 6-Min L2 Swath 750m' (NOAA-20)
processing_version	'20190820-1'
instrument	'VIIRS+CrIS'
platform	'Suomi-NPP', 'NOAA-20'
creator_name	'NASA Atmosphere SIPS'
project	'NASA Atmosphere Discipline'

viirs_l1_version	'2.0.2' (Suomi-NPP), '3.0.0' (NOAA-20)
viirs_lut_version	'2.0.0.33' (Suomi-NPP), '3.0.0.7' (NOAA-20)
viirs_lut_created	'2019-08-02T00:00:00' (Suomi-NPP), '2019-06-25T00:00:00' (NOAA-20)
cris_l1_version	'2.0.16' (Suomi-NPP), '2.1.3' (NOAA-20)
input_files	(Suomi-NPP): VNP03MOD.A2019218.1824.001.2019218235945.uwssec.nc, VNP02MOD.A2019218.1824.001.2019219000034.uwssec.bowtie_restored.nc, SNDR.SNPP.CRIS.20190806T1824.m06.g185.L1B.std.v2_0_16.W.190807001854.nc (NOAA-20): VJ103MOD.A2019218.1912.001.2019219001501.uwssec.nc, VJ102MOD.A2019218.1912.001.2019219001549.uwssec.bowtie_restored.nc, SNDR.J1.CRIS.20190806T1912.m06.g193.L1B.std.v2_1_3.W.190807004327.nc
xmlmetadata	' '

3.3 Data field attributes

The attributes in the tables below are present for the SDS group called "geophysical_data" in the L2 files. One table is for the radiances; the other is for the brightness temperature look-up table (LUT) associated with the radiances. The brightness temperature LUT is used to convert radiances to brightness temperatures.

The attributes for each radiance variable are in the following table:

Attribute name	**Description**	**Data type**
_FillValue	Value assigned to missing/invalid data (65535)	same type as data field
scale_factor	Value assigned for the scale factor	float
add_offset	Value assigned for the offset	float
long_name	Long, descriptive name of data field	string
valid_min	Minimum value to consider valid in the data	same type as data field
valid_max	Maximum value to consider valid in the data	same type as data field
flag_meanings	"Missing_EV Bowtie_Deleted Cal_Fail"	string
flag_values	[65532 65533 65534]	Same type as data field
units	W m^2 μm^{-1} str^{-1} ("Watts/m^2/micrometer/steradian")	string

The attributes for the brightness temperature LUT variable are as follows:

Attribute name	**Description**	**Data type**
_FillValue	Value assigned to missing/invalid data	same type as data field
units	"Kelvin"	string
long_name	Long, descriptive name of data field	string
valid_min	Minimum value to consider valid in the data	same type as data field
valid_max	Maximum value to consider valid in the data	same type as data field

3.4 SDS names and descriptions

3.4.1 Level-2 data fields

A number of variables are contained within these files. Each variable is for a specific wavelength band and has a related brightness temperature LUT. The following table groups related variables together.

Note that there are SDSs for the brightness temperature differences (measured – constructed) for bands M15 and M16. These brightness temperature differences may be useful to methods that involve an optimal estimation approach, where some *a priori* estimate is required of uncertainties.

SDS name	Type	Description	Units
BTD_15	float	Difference of measured minus fusion-reconstructed VIIRS M15 brightness temperature.	Kelvin
BTD_16	float	Difference of measured minus fusion-reconstructed VIIRS M16 brightness temperature.	Kelvin
MODIS23	ushort	Radiances constructed for MODIS band 23 (2D)	W m^2 μm^{-1} str^{-1}
MODIS23_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 23 (2D)	Kelvin
MODIS24	ushort	Radiances constructed for MODIS band 24 (2D)	W m^2 μm^{-1} str^{-1}
MODIS24_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 24 (2D)	Kelvin
MODIS25	ushort	Radiances constructed for MODIS band 25 (2D)	W m^2 μm^{-1} str^{-1}
MODIS25_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 25 (2D)	Kelvin
MODIS27	ushort	Radiances constructed for MODIS band 27 (2D)	W m^2 μm^{-1} str^{-1}
MODIS27_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 27 (2D)	Kelvin

MODIS28	ushort	Radiances constructed for MODIS band 28 (2D)	W m^2 μm^{-1} str^{-1}
MODIS28_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 28 (2D)	Kelvin
MODIS30	ushort	Radiances constructed for MODIS band 30 (2D)	W m^2 μm^{-1} str^{-1}
MODIS30_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 30 (2D)	Kelvin
MODIS31	ushort	Radiances constructed for MODIS band 31 (2D)	W m^2 μm^{-1} str^{-1}
MODIS31_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 31 (2D)	Kelvin
MODIS32	ushort	Radiances constructed for MODIS band 32 (2D)	W m^2 μm^{-1} str^{-1}
MODIS32_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 32 (2D)	Kelvin
MODIS33	ushort	Radiances constructed for MODIS band 33 (2D)	W m^2 μm^{-1} str^{-1}
MODIS33_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 33 (2D)	Kelvin
MODIS34	ushort	Radiances constructed for MODIS band 34 (2D)	W m^2 μm^{-1} str^{-1}
MODIS34_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 34 (2D)	Kelvin
MODIS35	ushort	Radiances constructed for MODIS band 35 (2D)	W m^2 μm^{-1} str^{-1}
MODIS35_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 35 (2D)	Kelvin

MODIS36	ushort	Radiances constructed for MODIS band 36 (2D)	W m^2 μm^{-1} str^{-1}
MODIS36_brightness_temperature_lut	float	LUT to convert radiances to brightness temperatures for MODIS band 36 (2D)	Kelvin

4 Reading the data

We use CF-compliant NetCDF4 to maximize the usability and accessibility of our data now and into the future. If you have trouble reading our data, or have suggestions on how to make it more useful, please contact us.

More information on NetCDF, including tools to access files in this format, is available at https://www.unidata.ucar.edu/software/netcdf/ . For quick browsing of the contents of individual files, the Panoply tool (http://www.giss.nasa.gov/tools/panoply/) provides a quick and easy interface. NetCDF libraries are also available in a variety of programming languages such as IDL, Python, C/C++, and FORTRAN.

The Data Fusion website includes a page with more information about the content, assessment, and validation of the constructed IR absorption band radiances. More information is available at: http://stc-se.com/data/bbaum/Baum-DataFusion/index.html

5 Where to download the data

The data set is currently available through the NASA Level-1 and Atmosphere Archive & Distribution System (LAADS) at https://ladsweb.modaps.eosdis.nasa.gov/, which is the same place which hosts (among others) MODIS Deep Blue Aerosol data products.

All data products are accessible from LAADS without a monetary charge, but users do need to register with NASA Earthdata and obtain a login account. First-time users who need to register may access the NASA User Registration System page via the following URL: https://urs.earthdata.nasa.gov

Users who may want to conduct a specific geographical/temporal search can do so via the LAADS Web search & order interface: https://ladsweb.modaps.eosdis.nasa.gov/search/

Remember to select the sensor “VIIRS:Suomi-NPP”, or “VIIRS:JPSS1” (for NOAA-20), and select the version before you define your spatial and temporal search parameters. If you have difficulties using the LAADS portal, please use the contact information on that webpage for support.

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References

Scientific references about our data fusion algorithm development and validation are available at the website http://stc-se.com/data/bbaum/Baum-DataFusion/index.html. Some key references that explain the algorithm and assessment of the radiances and resulting cloud products are additionally listed below:

- Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. 11(3), 036022 (2017), doi: 10.1117/1.JRS.11.036022.
- Cross, J. I. Gladkova, W. P. Menzel, A. Heidinger, and M. D. Grossberg, 2013: Statistical estimation of a 13.3-*μ*m Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473. doi: 10.1117/1.JRS.7.073473.