VIIRS/[NPP|JPSS1] Snow Cover 6-Min L2 Swath 375m, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

VNP10:

Riggs, G. A. and D. K. Hall. 2021. *VIIRS/NPP Snow Cover 6-Min L2 Swath 375m, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ZZMS6RM8LQS9. [Date Accessed].

VJ110:

Riggs, G. A. and D. K. Hall. 2021. *VIIRS/JPSS1 Snow Cover 6-Min L2 Swath 375m, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/JNKFY4XFDHRN. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/VNP10 AND https://nsidc.org/data/VJ110

National Snow and Ice Data Center

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1 DATA DESCRIPTION

These VIIRS Level 2 swath data sets contain estimates of snow cover. Snow-covered land typically has very high reflectance in visible bands and very low reflectance in the shortwave infrared bands. The Normalized Difference Snow Index (NDSI) reveals the magnitude of this difference, with values greater than 0 typically indicating the presence of at least some snow. The VIIRS snow cover algorithm computes NDSI using VIIRS image bands I1 (0.64 µm, visible red) and I3 (1.61 µm, shortwave near-infrared) and then applies a series of data screens designed to alleviate likely errors and flag uncertain snow detections.

VIIRS travels on board the Suomi-NPP and JPSS-1 satellites (the latter was renamed NOAA-20 after it became operational). While VIIRS data from these satellites are stored in separate product series – VNP and VJ1, respectively – the algorithms that produce snow cover data in VIIRS Collection 2.0 are consistent between the two satellite missions and also with MODIS Collection 6.1. This is intended to simplify the process of merging snow cover data from the S-NPP, JPSS-1, Terra, and Aqua products (Riggs and Hall, 2020).

1.1 Parameters

The Scientific Data Sets (SDSs) included in VNP10 and VJ110 are listed in Table 1.

Table 1. SDS Details

Parameter	**Description and Values**
`NDSI_Snow_Cover`	NDSI snow cover values and data flags values. 0–100: NDSI snow cover valid range 201: no decision 211: night 237: lake 239: ocean 250: cloud 251: missing L1B data 252: L1B data failed calibration 253: onboard VIIRS bowtie trim 254: L1B fill 255: L2 fill
`NDSI`	Raw NDSI values before data screens are applied, scaled by 10^3. -1000 to 1000: valid range 21000: night 29000: ocean 24000: missing L1B data 25000: L1B data failed calibration 31000: onboard VIIRS bowtie trim 30000: L1B fill 32767: fill value

Parameter	**Description and Values**
`Algorithm_bit_flags_QA`	Algorithm-specific bit flags indicating data screen results and the presence of inland water. All bits are initialized to “off” (0). A bit is set to “on” (1) if the condition described is encountered: Bit 0: Inland water screen Bit 1: Low visible screen failed, snow detection reversed to no snow Bit 2: Low NDSI screen failed, snow detection reversed to no snow Bit 3: Combined temperature/height screen failed • brightness temperature ≥ 281 K, pixel height < 1300 m, flag set, snow detection reversed to not snow, OR; • brightness temperature ≥ 281 K, pixel height ≥ 1300 m, flag set, snow detection NOT reversed. Bit 4: High Shortwave IR (SWIR) reflectance screen • Snow pixel with SWIR > 0.45, flag set, snow detection reversed to not snow, OR; • Snow pixel with 0.25 < SWIR ≤ 0.45, flag set to indicate unusual snow condition, snow detection NOT reversed Bit 5: Cloud possible screen, probably cloudy Bit 6: Cloud possible screen, probably clear Bit 7: Uncertain snow detection due to low illumination (solar zenith flag)
`Basic_QA`	A general quality assessment estimate for pixels processed for snow: 0-3: valid range, where 0: best, 1: good, 2: poor, 3: other 211: night 239: ocean 250: cloud 251: missing L1B data 252: L1B data failed calibration 253: bowtie trim 254: L1B fill 255: no data

1.1.1 Interpreting the `Algorithm_bit_flags_QA` parameter

Pixels determined to have some snow present are subjected to a series of screens that have been specifically developed to alleviate snow commission errors (detecting snow where there is no snow) and to flag uncertain snow detections. In addition, snow-free pixels are screened for very low illumination to prevent possible snow omission errors. Screen results, as well as the location of inland water, are stored as bit flags in the `Algorithm_bit_flags_QA` SDS. Refer to Section 3.3.1 of the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide (Riggs and Hall, 2021) for details on the individual data screens.

To interpret bit flag values, convert the decimal grid cell value to its binary equivalent. Bit values default to 0 and are set to 1 if the screen result is true. Figure 1 shows how to convert the decimal value 129 to bit flags.

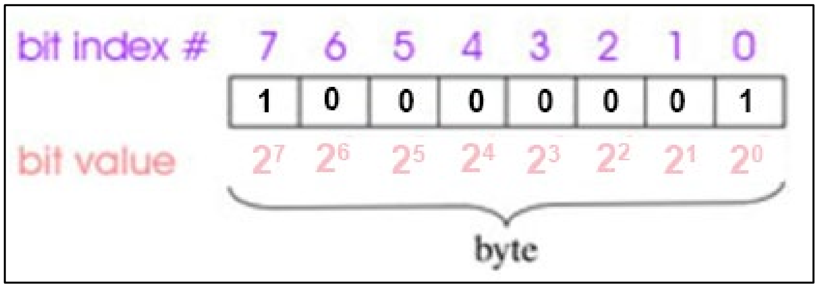


Figure 1. Decoding a bit flag. Bits store values. Bit locations within a byte are numbered, i.e., indexed. Bit positions are indexed from right (0) to left (7), and each bit stores the result (0 or 1) of a screen test. The bit values are the index in base 2 and solve respectively to 1, 2, 4, 8, 16, 32, 64, and 128. In this example, the decimal value 129 is equal to 128+1 (or 2^7+2^0), meaning that the conditions specified in Bit 7 and Bit 0 were encountered (see Table 1).

1.2 File Information

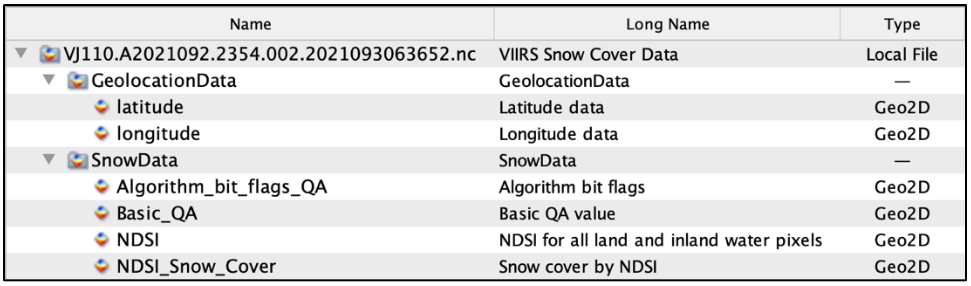
1.2.1 Format

These swath L2 products are available in NetCDF-4/ HDF5 and use NetCDF Climate and Forecast (CF-1.6) conventions for global and local attributes and to geolocate the variables.

NetCDF is a set of software libraries and self-describing, machine-independent data formats that are specifically designed to help create, access, and share array-oriented scientific data sets. Note that NetCDF-4 is not a file format. It is a convention for storing data as HDF using the NetCDF data model. For more information, visit the HDF Group's Knowledge Base and Unidata's NetCDF Documentation.

1.2.2 File Contents

As shown in Figure 2, each data file includes two data fields (`NDSI_Snow_Cover` and `NDSI`), two data quality fields (`Algorithm_bit_flags_QA` and `Basic_QA`), and two geolocation data fields (`latitude` and `longitude`). All data fields are two-dimensional arrays, with a typical size of 6464 by 6400 (the along-track swath dimension size can be 6432, 6464, or 6496, depending on the file).



Name	Long Name	Type
▼ VJ110.A2021092.2354.002.2021093063652.nc	VIIRS Snow Cover Data	Local File
▼ GeolocationData	GeolocationData	—
latitude	Latitude data	Geo2D
longitude	Longitude data	Geo2D
▼ SnowData	SnowData	—
Algorithm_bit_flags_QA	Algorithm bit flags	Geo2D
Basic_QA	Basic QA value	Geo2D
NDSI	NDSI for all land and inland water pixels	Geo2D
NDSI_Snow_Cover	Snow cover by NDSI	Geo2D

Figure 2. *SnowData* and *GeolocationData* groups and their respective data fields included in each VNP10 and VJ110 file, as displayed with Panoply software.

NetCDF-4/HDF5 data files contain metadata including global attributes, which store important details about the data, and local attributes such as keys to data fields. In addition, each data file has a corresponding XML (.xml) metadata file. For detailed information about metadata fields and values, consult the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide.

1.2.3 Naming Convention

Files are named according to the following convention and as described in Table 2.

File naming convention:

`V[SAT]10.A[YYYY][DDD].[HHMM].[VVV].[yyyy][ddd][hhmmss].nc`

Table 2. File Name Variables

`SAT`	Satellite designator: `NP` (Suomi-NPP) or `J1` (JPSS-1)
`10`	Product ID
`A`	Acquisition date follows
`YYYY`	Acquisition year
`DDD`	Acquisition day of year
`HHMM`	Acquisition hour and minute in Greenwich Mean Time (GMT)
`VVV`	Version (Collection) number
`yyyy`	Production year
`ddd`	Production day of year
`hhmmss`	Production hour/minute/second in GMT
`.nc`	NetCDF formatted data file

File name examples:

`VNP10.A2019195.2042.002.2020281095351.nc`

`VJ110.A2021092.2354.002.2021093063652.nc`

1.3 Spatial Information

VNP10 and VJ110 data files contain six minutes of swath data (a scene), during which the instrument sweeps out 202 (and occasionally 203) cross-track scans along a 12 km viewing path. VIIRS Imagery-resolution (I) bands are equipped with 32 detectors and thus the L2 scenes typically contain 6,464 I-band pixels in the along-track direction. The instrument's ±56.28° Earth-view scan width produces 6,400 I-band pixels in the cross-track direction.

VIIRS orbits the globe about 14 times a day and as such, most locations on Earth are imaged at least once per day and more frequently where swaths overlap (at higher latitudes). Suomi-NPP's sun-synchronous, near-circular polar orbit is timed to cross the equator from south to north at approximately 1:30 p.m. local time (and from north to south at 1:30 a.m.). JPSS-1 follows the same orbit, lagging S-NPP by 50 minutes.

The following sites offer tools that track and predict each satellite's orbital path:

- Space Science and Engineering Center (SSEC) Polar Orbit Tracks
- NASA LaRC Satellite Overpass Predictor (includes viewing zenith, solar zenith, and ground track distance to specified lat/lon)

1.3.1 Coverage

Global coverage is achieved in less than two days.

1.3.2 Resolution

VIIRS I-bands have a spatial resolution of 375 m at nadir.

1.3.3 Geolocation

These L2 swath data are not projected. Latitude and longitude for each pixel in a swath are stored as auxiliary coordinate variables in the *GeolocationData* group found in each VNP10 and VJ110 file. The coordinate variables, attributes and datasets follow netCDF CF-1.6 conventions for geolocation.

1.4 Temporal Information

1.4.1 Coverage

VNP10 data are available from 19 January 2012 to present.
VJ110 data are available from 5 January 2018 to present.

Because computation of the NDSI depends on visible light, data are not produced for the night phase of each orbital period or for those portions of fall and winter in polar regions when viewing conditions are too dark. If you cannot locate data for a particular date or time, check the MODIS & VIIRS Data Outages Web page.

1.4.2 Resolution

Each data file contains six minutes of the orbital swath.

The satellites orbit Earth from pole-to-pole approximately every 101 minutes, observing low latitude locations twice per day (albeit only once during daylight). At higher latitudes, observations are more frequent due to overlapping swaths (up to 14 per day near the poles). The satellites repeat the exact orbit every 16 days.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The snow detection algorithm in VIIRS Collection 2.0 is consistent with MODIS Collection 6.1. For a detailed description of the MODIS snow detection algorithm, see Hall et al. (2001). For a revised explanation of the NDSI snow cover algorithm theory, see Riggs et al. (2015). The MODIS and VIIRS snow cover algorithms both use the NDSI snow detection algorithm, albeit adjusted for sensor and input data product differences.

2.2 Instrumentation

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument collects visible and infrared imagery in 22 spectral bands ranging from 0.412 to 12.01 micrometers. Sixteen moderate resolution bands (M-bands), five imaging resolution bands (I-bands), and one panchromatic day-night band (DNB) acquire spatial resolutions at nadir of 750 m, 375 m, and 750 m, respectively (see the VIIRS Bands and Bandwidth Technical Reference for details on wavelength and resolution of individual bands). More details about the VIIRS instrument are available in the VIIRS Sensor Data Record User Guide and the JPSS VIIRS Radiometric Calibration Algorithm Theoretical Basis Document.

Table 3 lists technical specifications for the VIIRS instrument:

Table 3. VIIRS Technical Specifications

Variable	**Description**
Orbit	829 km (nominal) altitude, 1:30 p.m. mean local solar time, sun-synchronous, polar, near-circular (Suomi-NPP orbit; JPSS-1 flies on the same orbit, lagging by 50 minutes)
Scan Rate	1.779 sec/rev or 202.3 deg/sec
Swath Dimensions	3060 km (cross track) by ~12 km (along track at nadir) – nearly global coverage every day
Size	1.34 m x 1.41 m x 0.85 m
Weight	275 kg
Power	319 W (single orbit average)
Data Rate	7.674 Mbps (average), 10.5 Mbps (max)
Quantization	12 bits

Variable	Description
Spatial Resolution (at nadir)	375 m (Imagery resolution bands) 750 m (Moderate resolution bands)
Design Life	7 years

2.3 Inputs

Table 4 lists the data products that are input to the VIIRS snow detection algorithm. These data are used to check the quality of radiance measurements, identify land and water pixels, detect snow or ice/snow on water, and compute screen pass/fail thresholds:

Table 4. VIIRS data product inputs to the V[NP|J1]10 algorithm

ESDT	Variable	Center wavelength	Spatial resolution
V[NP|J1]02IMG	I01 (reflectance), I01_quality_flags	0.640 µm	375 m
	I02 (reflectance), I02_quality_flags	0.865 µm	
	I03 (reflectance), I03_quality_flags	1.61 µm	
	I05, I05_brightness_temperature_lut	11.450 µm	
V[NP|J1]02MOD	Reflectance_M4	0.555 µm	750 m
V[NP|J1]03IMG	latitude, longitude, solar_zenith, land_water_mask, height	N/A	375 m
V[NP|J1]35_L2	QF1_VIIRSCMIP (cloud confidence flag)	N/A	750 m

2.4 Processing

2.4.1 Snow Cover

The VIIRS snow cover algorithm calculates snow cover using the Normalized Difference Snow Index (NDSI) technique. Snow typically has a very high reflectance in visible bands (VIS) and very low reflectance in shortwave infrared bands (SWIR). The relative difference between the two is used to detect and distinguish snow-covered from snow-free land and from most cloud types.

The NDSI is derived from VIIRS data by normalizing the difference in reflectance between image bands I1 and I3, which measure visible red light at 0.64 µm and shortwave near-infrared at 1.61 µm, respectively. NDSI is calculated for all land and inland water pixels using the following equation and the raw value is written to the NDSI data array.:

$$NDSI = \frac{band\ I1 - band\ I3}{band\ I1 + band\ I3}$$

Computed in this manner, the NDSI lies in the theoretical range of -1.0 ≤ NDSI ≤ 1.0. If snow is present and viewable by the satellite, the NDSI > 0. Values of NDSI ≤ 0 indicate no snow.

Given clear skies, good viewing geometry, and good solar illumination, the NDSI has proven effective at detecting snow cover on the landscape. However, errors of omission or commission can occur under certain conditions: for example, surface features which exhibit snow-like reflectances, some cloud types, and low illumination at high solar zenith angles. During the course of the MODIS mission, the Science Team and user community identified the most common drivers of snow confusion and devised screens that examine the NDSI relationship more closely to help circumvent these potential error sources.

This approach has been adapted for and applied to snow detection with the VIIRS instrument. Once the NDSI is calculated for all land and inland water bodies in daylight, pixels determined to have some snow present are subjected to a series of screens designed to detect reflectance relationships that are atypical of snow. Pixels that fail a screen are either: reversed to "no snow" or "other"; or left unchanged but flagged to indicate higher uncertainty. All pixels—snow and no snow—are screened for high solar zenith angle/low illumination.

Each screen has a corresponding bit flag in the `Algorithm_bit_flags_QA` data array that is set to on (1) when a pixel fails, allowing users to extract specific flags for analysis. All data screens are applied to all snow detections. As such, a single pixel can have multiple flags set. In addition, inland water bodies are mapped using bit 0. Note that inland water is also stored in the NDSI snow cover array, along with cloud, ocean, and night, to provide a thematic map of snow cover.

If radiance data are missing in any of the bands used by the algorithm, the pixel is set to “missing data” and is not processed for snow cover. Unusable radiance data are set to “no decision”. Refer to the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide for more details on the individual data screens.

2.4.2 Lake Ice

Lake ice is detected when the NDSI snow algorithm is applied to inland water bodies. Inland water bodies are identified in bit 0 in `Algorithm_bit_flags_QA`. Users can extract or mask inland water in the `NDSI_Snow_Cover` SDS using this flag bit. The algorithm relies on the basic assumption that a water body is deep and clear and therefore absorbs all of the solar radiation incident upon it. Water bodies with algal blooms, high turbidity, or other relatively high reflectance conditions may be erroneously detected as ice- or snow-covered.

2.4.3 Cloud Masking

Clouds are masked using the 750 m cloud confidence flag from V[NP|J1]35_L2, which reports four levels of cloud confidence: “confident clear”, “probably clear”, “probably cloudy”, and “confident cloudy”. If the confidence flag is “confident cloudy”, the pixel is flagged as “cloud”, but if the flag indicates “confident clear”, “probably clear”, or “probably cloudy”, then the pixel is flagged as “clear” in the algorithm. Cloud mask values at 750 m are applied to the four corresponding V[NP|J1]10 pixels.

The cloud confidence flags of “probably cloudy” and “probably clear” are set as bit flags in the `Algorithm_bit_flags_QA` variable, bits 5 and 6, respectively. The cloud confidence bit flags can be used to assess quality or investigate cloud/snow confusion.

2.5 Quality Assessment

Two quality assessment parameters are available: the `Algorithm_bit_flags_QA`, which reports results of the individual data screens, and `Basic_QA`, which gives a qualitative estimate of the algorithm result for the pixel.

At the pixel level, the `Basic_QA` array is initialized to “best” and is adjusted based on the quality of the L1B input data and the solar zenith angle (SZA) screen (which is reported in the `Algorithm_bit_flags_QA` array). If L1B detector flags indicate poor quality data or if reflectance data is outside the range of 7%-100%, then the `Basic_QA` value is “poor”. If the SZA is between 70° and 85°, the `Basic_QA` value is set to “other” to indicate high uncertainty due to low illumination. Pixels are set to “good” depending on the data screens.

2.6 Interpretation of Snow Cover Detection Accuracy, Uncertainty and Errors

The NDSI technique for snow detection has been shown to be a robust indicator of snow around the globe. Numerous studies using the MODIS snow products have reported accuracy statistics under cloud-free conditions in the range of 88-93% (see list of publications on the NASA MODIS website). The S-NPP snow cover is 98% consistent with MODIS snow cover (Thapa et al., 2019). Accuracy of the VIIRS snow cover detection algorithm (from S-NPP data) is similar to the accuracy reported for the MODIS sensors, varying with landscape (Zhang et al., 2020). Accuracy assessments using JPSS-1 data are underway and have not yet been published.

Warm surfaces, low reflectance in the visible range (which may falsely lead to low positive NDSI), unusually high SWIR reflectance, cloud/snow confusion, lake ice, and bright surface features are conditions known to adversely affect snow cover detection and may also interfere with the data screens, leading to uncertainty and errors in snow cover reporting. These conditions and their implications are discussed in detail in the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide.

Snow cover on the Antarctica Peninsula – While the continent of Antarctica is mostly ice- and snow-covered year-round, some changes are observable on the Peninsula. The snow cover detection algorithm is run for the region without any Antarctica-specific processing paths. The resulting snow cover map may show some erroneous snow-free areas due to the great difficulty in detecting clouds over Antarctica. Similarity in reflectance and lack of thermal contrast between clouds and ice/snow cover, sometimes related to thermal inversions, are major challenges to accurate snow/cloud discrimination over Antarctica. Users interested in snow cover data for that area should scrutinize the V[NP|J1]10 products for accuracy and quality.

3 VERSION HISTORY

Table 5. Version History Summary

Version / Collection	Release Date	Description of Changes
V2 / C2	June 2023	The snow cover detection algorithm was revised to read detector QA flags in V[NP|J1]02IMG to find noisy detectors and to average over noisy detectors. VIIRS snow cover algorithms were made consistent with MODIS Collection 6.1 algorithms. Initial release of VJ110.
V1 / C1	29 June 2017	Initial release of VNP10.

4 RELATED DATA SETS

VIIRS data @ NSIDC

MODIS data @ NSIDC

5 RELATED WEBSITES

NASA Goddard Space Flight Center | Suomi-NPP VIIRS Land

MODIS Snow/Ice Global Mapping Project

Earthdata | VIIRS is Here

6 REFERENCES

Hall, D.K., Riggs, G.A. and Salomonson, V.V. 2001. Algorithm Theoretical Basis Document (ATBD) for MODIS Snow and Sea Ice-Mapping Algorithms. Guide. NASA Goddard Space Flight Center, Greenbelt, MD.

Riggs, G.A., Hall, D.K. and Roman, M.O. 2015. VIIRS Snow Cover Algorithm Theoretical Basis Document (ATBD). NASA Goddard Space Flight Center, Greenbelt, MD. (See PDF)

Riggs, G.A. and Hall, D.K. 2020. Continuity of MODIS and VIIRS Snow Cover Extend Data Products for Development of an Earth Science Data Record. *Remote Sensing*, 12, no 22: 3781. https://doi.org/10.3390/rs12223781

Riggs, G.A. and Hall, D.K. 2021. NASA VIIRS Snow Cover Products, Collection 2: User Guide. (See PDF)

Thapa, S., Chhetri, P.K., and Klein, A.G. 2019. Cross-comparison between MODIS and VIIRS snow cover products for 2016 Hydrological Year. *Climate*, **7:** 57, https://doi.org/10.3390/cli7040057.

Zhang, H., Zhang, F., Che, T., and Wang, S. 2020. Comparative evaluations of VIIRS daily snow cover product with MODIS for snow detection in China based on ground observations. *Science of the Total Environment*, **724**: 138156, https://doi.org/10.1016/j.scitotenv.2020.138156.

7 DOCUMENT INFORMATION

7.1 Publication Date

June 2023

7.2 Date Last Updated

June 2023