VIIRS/[NPP|JPSS1] Snow Cover Daily L3 Global 375m SIN Grid, Version 2

USER GUIDE

How to Cite These Data

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

VNP10A1:

Riggs, G. A. and D. K. Hall. 2021. *VIIRS/NPP Snow Cover Daily L3 Global 375m SIN Grid, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/45VDCKJBXWEE. [Date Accessed].

VJ110A1:

Riggs, G. A. and D. K. Hall. 2021. *VIIRS/JPSS1 Snow Cover Daily L3 Global 375m SIN Grid, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/UAJGR7WVWDDI. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/VNP10A1 AND https://nsidc.org/data/VJ110A1

National Snow and Ice Data Center

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1 DATA DESCRIPTION

These VIIRS Level 3 data sets are composites of daily snow cover generated from the respective satellite 6-minute swath data sets (V[NP|J1]10) and regridded into 10° by 10° tiles at a 375-meter resolution sinusoidal grid.

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 VNP10A1 and VJ110A1 are listed in Table 1.

Table 1. SDS Details

Parameter	Description and Values
`NDSI_Snow_Cover`	Gridded NDSI snow cover values drawn from the selected best observations from the V[NP|J1]10 products for the day. Includes the data flags determined in the processing of the Level 2 product. 0–100: NDSI snow cover valid range 201: no decision; 211: night 237: lake / inland water; 239: ocean 250: cloud; 251: missing L1B data 252: L1B data failed calibration; 253: onboard VIIRS bowtie trim 254: L1B fill; 255: L2 fill

Parameter	Description and Values
`NDSI`	Gridded raw NDSI values for all land and inland water pixels without the cloud mask applied, which correspond to the “best” observations selected from V[NP|J1]10. NDSI values are packed; to unpack, use the *scale_factor* attribute (0.001). -1000 to 1000: valid range (packed) 21000: night; 29000: ocean 24000: missing L1B data; 25000: L1B data failed calibration 31000: onboard VIIRS bowtie trim; 30000: L1B fill 32767: fill value
`Algorithm_bit_flags_QA`	Algorithm-specific bit flags indicating data screen results applied in the V[NP|J1]10 algorithm. These bit flags can be read to assess the quality of an observation, and multiple bit flags masks may be set for an observation. 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: spare Bit 5: 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 6: spare 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

Parameter	Description and Values
`granule_pnt`	A numeric value that, when used in conjunction with the file global attributes *GranulePointerArray*, *GranuleBeginningDateTime*, and *GranuleEndingDateTime*, identifies which V[NP|J1]10 swath granule provided the selected best observation for each pixel. 0-254: valid range 255: fill value
`Projection`	Sinusoidal projection attributes: *grid_mapping_name* = "sinusoidal" *longitude_of_central_meridian* = 0. *false_easting* = 0. *false_northing* = 0. *earth_radius* = 6371007.181

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.

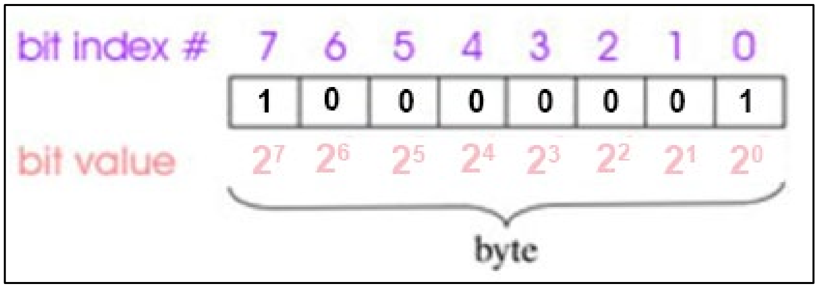

Figure 1. Decoding a bit flag. Bits store values. Bit locations within a byte are numbered, i.e., indexed. Bit positions are indexed from right (0) to left (7), and each bit stores the result (0 or 1) of a screen test. The bit values are the index in base 2 and solve respectively to 1, 2, 4, 8, 16, 32, 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).

1.1.2 Using the `granule_pnt` field

The `granule_pnt` field includes pointer values for identifying the V[NP|J1]10 swath mapped into each grid cell. The *GranulePointerArray* global attribute in each V[NP|J1]10A1 contains a pointer for each V[NP|J1]10 granule that was staged for input to a tile; however, more granules are staged than are actually used. Each granule that is mapped into a tile is assigned a unique positive pointer value, while those that are not are assigned a value of -1. To determine the V[NP|J1]10 swath from which a cell observation originated, link all the pointers in *GranulePointerArray* (by index) to the corresponding comma-separated list of dates and times in *GranuleBeginningDateTime* (another global attribute). Then locate the granule in *GranulePointerArray* with the pointer value contained in the `granule_pnt` cell being queried, and use its index to extract the date and beginning-time string from *GranuleBeginningDateTime*.

1.2 File Information

1.2.1 Format

These L3 products are available in HDF-EOS5 32-bit signed integer format and use NetCDF Climate and Forecast (CF-1.6) conventions for global and local attributes and to geolocate the variables. For software and more information, visit the HDF-EOS website.

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 ancillary fields with projection attributes and identification of the swath source data (`Projection` and `granule_pnt`). X and Y coordinate arrays are included for the specified projection (`XDim` and `YDim`).

> The metadata within HDF-EOS5 data files contain global attributes, which store important details about the data, and local attributes such as keys to data fields. Each data file also 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.

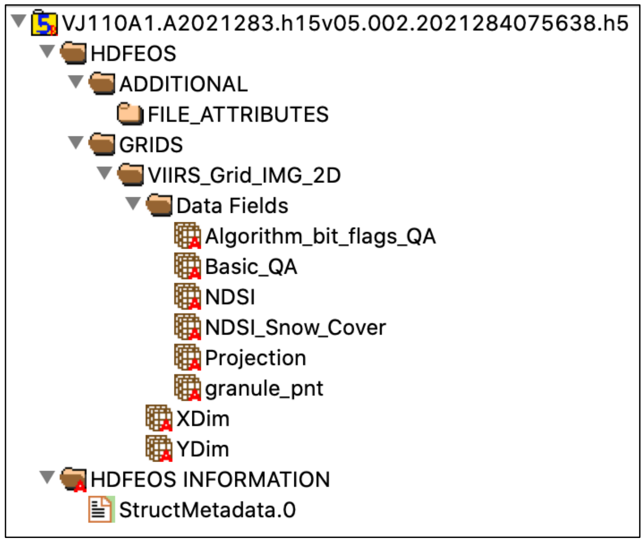

Figure 2. Data fields included in each VNP10A1 and VJ110A1 file, as displayed with HDFView software. All data fields are two-dimensional except for `Projection`, which is an empty, attribute-only field.

1.2.3 Naming Convention

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

File naming convention:

`V[SAT]10A1.A[YYYY][DDD].h[NN]v[NN].[VVV].[yyyy][ddd][hhmmss].h5`

Table 2. File Name Variables

SAT	Satellite designator: NP (Suomi-NPP) or J1 (JPSS-1)
10A1	Product ID
A	Acquisition date follows
YYYY	Acquisition year
DDD	Acquisition day of year
h[NN]v[NN]	Horizontal tile number and vertical tile number (see *Grid* section for details)
VVV	Version (Collection) number
yyyy	Production year
ddd	Production day of year
hhmmss	Production hour/minute/second in Greenwich Mean Time (GMT)
.h5	HDF-EOS5 formatted data file

File name examples:

`VNP10A1.A2019011.h11v05.002.2020245061200.h5`

`VJ110A1.A2021092.h31v11.002.2021093085704.h5`

1.3 Spatial Information

1.3.1 Coverage

Global

1.3.2 Projection

The V[NP|J1]10A1 data sets are georeferenced to an equal-area sinusoidal projection. Areas on the grid are proportional to the same areas on Earth and distances are correct along all parallels and the central meridian. Shapes become increasingly distorted away from the central meridian and near the poles. The data are neither conformal, perspective, nor equidistant. Meridians, except for the central meridian, are represented by sinusoidal curves and parallels are represented by straight lines. The central meridian and parallels are lines of true scale.

1.3.3 Grid

As shown in Figure 3, data are gridded using the MODIS Sinusoidal Tile Grid, which comprises 460 non-fill tiles that each cover 10° by 10° at the equator or approximately 1,200 km by 1,200 km. Each data granule (file) covers one tile and consists of 3,000 rows and 3,000 columns.

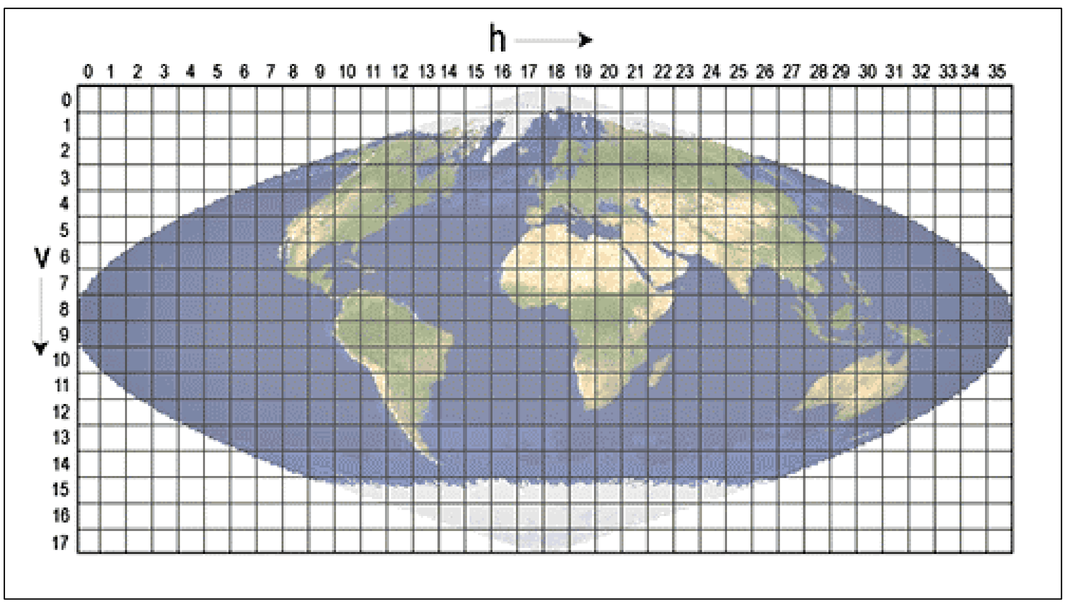

Figure 3. The MODIS Sinusoidal Tile Grid

1.3.4 Resolution

The nominal spatial resolution is 375 meters.

1.3.5 Geolocation

The following tables provide information for geolocating this data set.

Table 3. Projection Details

Region	Global
Geographic coordinate system	WGS84
Projected coordinate system	Sinusoidal Grid
Longitude of true origin	0°
Latitude of true origin	0°
Scale factor at longitude of true origin	1.0
Datum	WGS 84
Ellipsoid/spheroid	6371007.181000 meters
Units	Meter
False easting	0°
False northing	0°
EPSG code	N/A
PROJ4 string	+proj=sinu +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
Reference	https://spatialreference.org/ref/sr-org/6974/html/

Table 4. Grid Details

Grid cell size (x, y pixel dimensions)	375 m
Number of rows	3000
Number of columns	3000
Nominal gridded resolution	375 m
Grid rotation	N/A
Upper left corner point (m)	`XDim(0)`, `YDim(0)`
Lower right corner point (m)	`XDim(2999)`, `YDim(2999)`

1.4 Temporal Information

1.4.1 Coverage

VNP10A1 data are available from 19 January 2012 to present.

VJ110A1 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

Daily

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 the 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 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.

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. Table 5 lists technical specifications for the VIIRS instrument, and 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)

Table 5. 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
Spatial Resolution (at nadir)	375 m (Imagery resolution bands) 750 m (Moderate resolution bands)
Design Life	7 years

2.3 Inputs

The V[NP|J1]10A1 Level-3 data sets are generated from VIIRS/[NPP|JPSS1] Snow Cover 6-Min L2 Swath 375m, Version 2 data sets.

2.4 Processing

The V[NP|J1]10A1 algorithms select the best Level-2 swath observation of the day for the `NDSI_Snow_Cover` parameter and the NDSI parameter at each grid cell. To do this, the swath data that cover a 10° x 10° area on the sinusoidal projection are mapped to a tile. If there is more than one observation in a grid cell, the observations are stacked to produce an intermediate product (V[NP|J1]10L2G, not archived at NSIDC). A selection algorithm is then run on this intermediate product to identify the "best" observation based on (1) solar zenith angle (seeking the nearest to local solar noon time), (2) distance from nadir (seeking the nearest to orbit nadir track), and (3) coverage in a grid cell (seeking the most coverage). The results of the selection algorithm are mapped to a second intermediate product (V[NP|J1]10GA, also not archived at NSIDC). The data are then reformatted into the Level-3 products, where new variables and summary snow cover statistics are added (see global and local attributes in the V[NP|J1]10A1 data files).

For a detailed description of the snow cover detection algorithm see the *Data Acquisition and Processing* section of the V[NP|J1]10 User Guide or Section 3.3 of the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide.

2.5 Quality Information

The same quality assessment information included in the Level-2 swath products is carried over into the Level-3 products. The `Basic_QA` parameter is a general quality value assigned to grid cells in V[NP|J1]10 and carried over to V[NP|J1]10A1 along with the selected "best" swath observation.

In the same fashion, the `Algorithm_bit_flags_QA` parameter reports the results of individual data screens carried out in the production of the Level-2 products and is carried over in the Level-3 products. Bit flags can be used to investigate results for all pixels which have been processed for snow. By examining the bit flags, users can determine if any of the data screens a) changed a pixel's initial result from *snow* to *not snow* or b) flagged snow cover in a pixel as *uncertain*. See Section 1.1.1 above for instructions on how to decode the screen results. For details on the individual data screens, refer to Section 3.3.1 of the SNPP/JPSS1 VIIRS Snow Cover Products Collection 2 User Guide.

2.6 Errors

2.6.1 Snow Cover

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]10A1 products for accuracy and quality.

2.6.2 Swath Selection

Choosing a single, best observation of the day results in a weave or stitch pattern along the edges of adjacent swaths. This pattern is most apparent where cloud cover changed between the acquisition times of overlapping swaths. In addition, users may encounter interwoven cloud and clear observations in images with snow cover. Differences in viewing geometry can also produce discontinuities in regions where adjacent swaths overlap.

2.6.3 Geolocation

Geolocation error may be visible due to: a) uncertainty in swath geolocation; and b) the process of gridding and projecting the swaths into the MODIS Sinusoidal Tile Grid from day to day. This latter effect, a so-called geolocation wobble, is most commonly observed as daily shifts in the position of a lake, by one or more cells, in the horizontal or vertical directions. Thus, compositing tiles over the course of several consecutive days may result in blurred lake outlines.

3 VERSION HISTORY

Table 6. Version History Summary

Version / Collection	Release Date	Description of Changes
V2 / C2	June 2023	Certain global and local attributes were revised to conform with NetCDF CF-1.6 conventions. C1 local attributes *mask_values* and *mask_meanings* were renamed as *flag_values* and *flag_meanings*, respectively. The `Projection` parameter was added to conform with CF-1.6 conventions on projection of data. Initial release of VJ110A1.
V1 / C1	29 April 2019	Initial release of VNP10A1.

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