VIIRS/[NPP|JPSS1] Sea Ice 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:

VNP29:

Riggs, G. A., Tschudi, M. A., and D. K. Hall. 2023. *VIIRS/NPP Sea Ice 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/GKJ486GAV3HH. [Date Accessed].

VJ129:

Riggs, G. A., Tschudi, M. A., and D. K. Hall. 2023. *VIIRS/JPSS1 Sea Ice 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/LZB54MLNK98U. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/VNP29 AND https://nsidc.org/data/VJ129

National Snow and Ice Data Center

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1 DATA DESCRIPTION

These VIIRS Level 2 swath data sets contain estimates of sea ice cover. Sea ice is detected using the Normalized Difference Snow Index (NDSI). Snow-covered sea ice typically has very high reflectance in visible bands and very low reflectance in the shortwave infrared bands; the NDSI reveals the magnitude of this difference. The VIIRS sea ice 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 sea ice 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 sea ice cover data in VIIRS Collection 2.0 are nearly identical between them.

Note: Unlike with MODIS, VIIRS sea ice cover and ice surface temperature (IST) are produced as separate products: V[NP|J1]29 (sea ice cover) and V[NP|J1]30 (IST). This separation allows the data to be produced at the spatial resolution of the underlying acquisition bands, which are 375 m for sea ice cover (I-bands) and 750 m for IST (M-bands). The sea ice algorithm applied in the VIIRS products is also slightly different from the MODIS products because it uses a lower NDSI cutoff threshold and more data screens.

1.1 Parameters

The Scientific Data Sets (SDSs) included in VNP29 and VJ129 are listed in Table 1.

Table 1. SDS Details

Parameter	Description and Values
`SeaIceCover`	Binary map of sea ice cover and data flags values. 0 or 1: valid range, where 0 = 0% ice and 1 = 100% ice 200: missing; 201: no decision 211: night; 225: land 237: inland water; 250: cloud 252: L1B data failed calibration; 253: onboard VIIRS bowtie trim 254: L1B fill; 255: L2 fill

Parameter	Description and Values
`SeaIceCover_Basic_QA`	A general quality assessment estimate for pixels processed for sea ice: 0-4: valid range, where 0: best, 1: good, 2: poor, 3: bad, 4: other 211: night 225: land 237: inland water 250: cloud 252: L1B data failed calibration 253: bowtie trim 254: L1B fill 255: no data
`Algorithm_QA_Flags`	Algorithm-specific bit flags indicating data screen results. Screens are applied to pixels initially detected as sea ice. Bit flags are set if a sea ice detection was reversed or flagged as uncertain. All bits are initialized to “off” (0). A bit is set to “on” (1) if the condition described is encountered: Bit 0: spare Bit 1: Low visible screen failed; sea ice detection reversed to no sea ice Bit 2: Low NDSI screen failed; sea ice detection reversed to no sea ice Bit 3: spare Bit 4: spare Bit 5: High Shortwave IR (SWIR) reflectance screen • Sea ice pixel with SWIR > 0.45, flag set, detection reversed to no sea ice, OR; • Sea ice pixel with 0.25 < SWIR ≤ 0.45, flag set to indicate unusual sea ice condition, detection NOT reversed Bit 6: spare Bit 7: Uncertain sea ice detection due to low illumination (solar zenith flag); see Section 2.5 for details.

1.1.1 Interpreting the `Algorithm_QA_Flags` parameter

Pixels where sea ice is detected are subjected to a series of screens that have been specifically developed to alleviate sea ice commission errors (detecting ice where there is no ice) and to flag uncertain sea ice detections. In addition, ice-free ocean pixels are screened for very low illumination to prevent possible sea ice omission errors. Screen results are stored as bit flags in the `Algorithm_QA_Flags` SDS. Refer to Section 3.3 of the SNPP/JPSS1 VIIRS Sea Ice Cover Products Collection 2 User Guide (Riggs et al., 2023) 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.

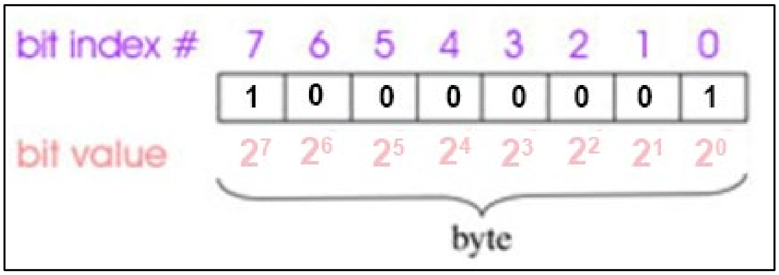

Figure 1. Decoding a bit flag. Bits store values. Bit locations within a byte are numbered, i.e., indexed. Bit positions are indexed from right (0) to left (7), and each bit stores the result (0 or 1) of a screen test. The bit values are the index in base 2 and solve respectively to 1, 2, 4, 8, 16, 32, 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 one data field (`SeaIceCover`), two data quality fields (`SeaIceCover_Basic_QA` and `Algorithm_QA_Flags`), and two geolocation data fields (`latitude` and `longitude`). All data fields represent 6 minutes of scans, which are two-dimensional, and are typically 6464 lines by 6400 pixels in size. Although the number of pixels in each swath remains constant, the number of lines may vary, depending on the length of the swath.

Name	Long Name	Type
VJ129.A2021092.2354.002.2021093063745.nc	VIIRS Sea Ice Cover	Local File
▼ GeolocationData	GeolocationData	—
latitude	Latitude data	Geo2D
longitude	Longitude data	Geo2D
▼ SeaIceCoverData	SeaIceCoverData	—
Algorithm_QA_Flags	Algorithm QA Flags for Ice Cover	Geo2D
SeaIceCover	Sea Ice Cover	Geo2D
SeaIceCover_Basic_QA	Basic QA Ice Cover	Geo2D

Figure 2. *SeaIceCoverData* and *GeolocationData* groups and their respective data fields included in each VNP29 and VJ129 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 Sea Ice 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]29.A[YYYY][DDD].[HHMM].[VVV].[yyyy][ddd][hhmmss].nc`

Table 2. File Name Variables

SAT	Satellite designator: NP (Suomi-NPP) or J1 (JPSS-1)
29	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:

`VNP29.A2019195.2224.002.2020281100047.nc`

`VJ129.A2021101.0730.002.2021101124615.nc`

1.3 Spatial Information

VNP29 and VJ129 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

Coverage is global, however sea ice is only estimated for ocean pixels poleward of 40ºN and 50ºS.

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 VNP29 and VJ129 file. The coordinate variables, attributes and datasets follow netCDF CF-1.6 conventions for geolocation.

1.4 Temporal Information

1.4.1 Coverage

VNP29 data are available from 19 January 2012 to present.
VJ129 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 an orbital swath.

The satellites orbit the 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 sea ice detection algorithm in VIIRS Collection 2.0 utilizes the Normalized Difference Snow Index (NDSI) to classify the ocean surface poleward of 40ºN and 50ºS as ice-covered or ice-free. Unlike the snow cover products, no fractional ice cover is detected within a pixel. For a detailed description of the VIIRS sea ice detection algorithm, see Tschudi et al. (2017). The following sections offer a brief outline of the process.

2.2 Instrumentation

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument collects visible and infrared imagery on 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
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 sea ice detection algorithm. These data are used to check the quality of radiance measurements, identify land and water pixels, detect ice/snow on water, and compute screen pass/fail thresholds:

Table 4. VIIRS data product inputs to the V[NP|J1]29 algorithm

ESDT	Variables (description)	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	
V[NP|J1]03IMG	latitude, longitude, solar_zenith (angle), land_water_mask	N/A	375 m
V[NP|J1]35_L2	QF1_VIIRSCMIP (cloud confidence flag)	N/A	750 m

2.4 Processing

Similar to the MODIS sea ice algorithm and analogous to the VIIRS snow cover algorithm, the VIIRS sea ice cover algorithm utilizes the NDSI to differentiate sea ice from open water. Like snow-covered land, snow-covered sea ice has a strong visible reflectance and strong short-wave IR absorption characteristics, especially compared with open water. Additionally, some snow/cloud confusion can be alleviated using the NDSI.

To detect sea ice, the algorithm computes the NDSI using VIIRS image-quality bands I1 (0.64 μm) and I3 (1.61 μm) as follows:

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

If NDSI ≥ 0.4 and visible reflectance in band I1 is > 0.11, the pixel is set to sea ice. These thresholds were established based on known reflectance values for a variety of sea ice types (Tschudi et al., 2017).

The algorithm is applied to all ocean pixels poleward of 40°N and 50°S latitude, and in daylight determined as solar zenith angle < 85°. The land/water mask from the geolocation product V[NP|J1]03IMG is used to guide processing over oceans. The cloud mask product V[NP|J1]35_L2 is used for cloud masking, by the way of a cloud confidence flag. Cloud mask performance was improved though use of a 1 km rolling gridded snow input and a 1 km vegetation index (VI) file, and algorithm improvements for better delineation of snow at higher latitudes in C2 as described in VIIRS Land C2 Changes. If the cloud confidence flag has a setting of "confident cloudy", "probably cloudy", or "probably clear" the pixel is masked as "cloud". If the cloud confidence flag setting is "confident clear" the pixel is processed for sea ice cover. The reflectance data is checked for nominal quality; if unusable data is found it is flagged and the pixel is skipped, otherwise processing continues. The VIIRS bands are also checked for noisy detectors. If a noisy detector is encountered the reflectance from the noisy detector is replaced by the mean reflectance of the corresponding detectors in the preceding and following scan lines. Data screens are applied and QA bit flags are set for pixels processed for sea ice cover and for other conditions, e.g. solar zenith angle.

The results of the screens are coded into a bit flag which is then written to the `Algorithm_QA_Flags` variable. All data screens and masks are applied within the algorithm using data read from the input products listed in Table 4. No ancillary data are used. Refer to the SNPP/JPSS1 VIIRS Sea Ice Cover Products Collection 2 User Guide for more details on the individual data screens.

2.5 Quality Assessment

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

At the pixel level, the `SeaIceCover_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 the visible reflectance data is outside the range of 5%-100% but still usable, the QA value is set to “good”. If the SZA is between 70° and 85°, the QA value is set to “poor” to indicate high uncertainty due to low illumination. If input data is unusable, the QA value is set to “other”. The “bad” QA flag indicated in the data field attributes is reserved for future use and is currently not used in the algorithm.

2.6 Interpretation of Snow Cover Detection Accuracy, Uncertainty and Errors

The VIIRS sea ice algorithm identifies sea ice by its reflectance characteristics in the visible and near IR and its sharp contrast to open water. The targeted uncertainty of these NASA sea ice cover products is 5%, i.e., the product should correctly classify 95% of the viewable surface as either sea ice or open water.

The darkness of polar winters will be a limiting factor in the use of visible channels. Otherwise, a major caveat with the sea ice algorithm is that it is applicable only to clear-sky conditions. Inadequate cloud masking, by either an overly conservative cloud mask or cloud/ice confusion that results in ice being flagged as cloud, may result in significant error in estimating the presence of sea ice.

The confusion between clouds and sea ice is similar to the MODIS Collection 6.1 sea ice products. Errors most commonly occur when: 1) the cloud mask does not correctly flag cloudy or clear conditions; and 2) cloudiness at scales below 750 meters escapes detection by the 750 m resolution cloud mask. The cloud mask algorithm in V[NP|J1]35_L2 uses a suite of tests to detect clouds that depends on whether the ocean surface is open water or has sea ice cover. If the initial underlying sea ice determination is incorrect, the wrong processing path is followed and erroneous cloud determinations are possible—for example, sea ice being flagged as "certain cloud."

Small-scale clouds that escape detection by the 750 m cloud mask can be erroneously detected as sea ice because their spectral properties over open water appear similar to sea ice. This can result in sea ice errors of commission at the periphery of clouds, especially when scattered, popcorn-like clouds are present. Multilayer cloud formations can also confound the algorithm, if the layers consist of both warm and cold cloud types and cloud shadows fall on other clouds. When this occurs, regions of the cloud cover can escape detection by the cloud mask and then subsequently be classified as sea ice.

Errors in sea ice detection are also more probable in the summer when the algorithm can misclassify surface melt ponds as open water. Similar errors may occur where sea ice concentration is low. Furthermore, conditions which affect reflectance can impact the quality of the sea ice detection results. For example, low solar illumination due to high solar zenith angles, low light near the day/night terminator, and low reflectance combined with high SWIR that minimizes the magnitude of the NDSI represent significant challenges to sea ice detection. These conditions and their implications are discussed in detail in the SNPP/JPSS1 VIIRS Sea Ice Cover Products Collection 2 User Guide.

3 VERSION HISTORY

Table 5. Version History Summary

Version / Collection	Release Date	Description of Changes
V2 / C2	June 2023	The sea ice 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 sea ice cover algorithms were made consistent with MODIS Collection 6.1 algorithms. Initial release of VJ129.
V1 / C1	07 November 2017	Initial release of VNP29.

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

Riggs, G.A., M.A. Tschudi, and D.K. Hall. 2023. SNPP/JPSS1 VIIRS Sea Ice Cover Products Collection 2 User Guide. (See PDF)

Tschudi, M.A., G.A. Riggs, D.K. Hall, and M.O. Román. 2017. Suomi-NPP VIIRS Sea Ice Cover Algorithm Theoretical Basis Document (ATBD). (See PDF)

7 DOCUMENT INFORMATION

7.1 Publication Date

June 2023

7.2 Date Last Updated

June 2023