# VIIRS/NPP Sea Ice Cover 6-Min L2 Swath 375 m, Version 1

## USER GUIDE

**How to Cite These Data**

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

Tschudi, M., G. Riggs, D. K. Hall, and M. O. Román. 2017. *VIIRS/NPP Sea Ice Cover 6-Min L2 Swath 375 m, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/VIIRS/VNP29.001. [Date Accessed].

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

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

NSIDC National Snow and Ice Data Center

# TABLE OF CONTENTS

# 1 DETAILED DATA DESCRIPTION

The VIIRS sea ice extent algorithm and output data have been designed to be compatible with Version 6 MODIS sea ice extent from Aqua and Terra, to ensure continuity between the collections and facilitate climate-data records (CDRs) from the three sensors. Differences in the algorithms reflect physical differences between the instruments, for example spatial resolution and the location of spectral bands.

**Note:** Unlike MODIS, VIIRS sea ice cover and ice surface temperature (IST) are being produced as separate products: VNP29 (this data set) and VNP30 (IST). This decision allows the data to be produced at the spatial resolution of the underlying acquisition bands, or 375 m for sea ice cover (I-band) and 750 m for IST (M-band).

## 1.1 Format

Data files are provided in NetCDF-4/HDF5 (`.nc`) format, following the NetCDF Climate and Forecast (CF) Metadata Conventions (Version 1.6). JPEG browse images are also available.

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 HDF5 Home Page and Unidata's NetCDF Documentation website.

## 1.2 File Contents

VNP29 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. Sea ice cover is derived from VIIRS I bands which are equipped with 32 detectors, and thus VNP29 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.

## 1.3 File Naming Convention

VIIRS file names begin with a product identifier (VNP29) followed by the acquisition date and time. Dates are specified as a 4-digit year and 3-digit day of the year. Acquisition times are specified as HHMM and reflect the start time of the 6-minute scene, beginning with 0000 and ending with 2354. Table 1 describes the full VIIRS file naming convention.

```
VNP[PID].A[YYYY][DDD].[HHMM].[VVV].[yyyy][ddd][hhmmss].nc
```

**Example File Name:**

`VNP29.A2012019.0000.001.2017261222822.nc`

Table 1. Variables in the VNP29 File Naming Convention

| Variable | Description |
|---|---|
| `VNP` | VIIRS Suomi NPP |
| `PID` | Product ID |
| `A` | Acquisition date follows |
| `YYYY` | Acquisition year |
| `DDD` | Acquisition day of year |
| `HHMM` | Acquisition hour and minute in GMT |
| `VVV` | Version (Collection) number |
| `yyyy` | Production year |
| `ddd` | Production day of year |
| `hhmmss` | Production hour/minute/second in GMT |
| `.nc` | NetCDF-4/HDF5 formatted data file |

NetCDF-4/HDF5 data files contain important metadata including global attributes, which store details about the data, and local attributes such as keys to data fields. In addition, each data file has a corresponding XML metadata file. For detailed information about metadata fields and values, consult the NASA S-NPP VIIRS Sea Ice Cover Product Collection 1 User Guide.

## 1.4 Spatial Coverage

Coverage is global, however values are only valid for polar oceans (pixels poleward of 50°).

To locate the VIIRS sensor at a given time, the following sites offer tools that track and predict NPP's orbital path:

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

### 1.4.1 Spatial Resolution

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

## 1.5 Temporal Coverage

Data are available from 19 January 2012 to present. Because these data are generated from visible imagery, sea ice cover is only reported for pixels in daylight. If you cannot locate data for a particular date or time, check the VIIRS Data Outages web page.

### 1.5.1 Temporal Resolution

VIIRS scans the entire globe every one to two days. As such, most locations on Earth are imaged at least once per day and more frequently where swaths overlap, for example near the poles. Suomi NPP's sun-synchronous, near-circular polar orbit is timed to cross the equator from south to north (ascending node) at approximately 1:30 P.M. local time. The repeat cycle is 16 days (quasi 8-day).

## 1.6 Parameter or Variable

VNP29 data files contain two NetCDF-4/HDF5 groups: `SeaIceCover_Data` and `GeolocationData`. The following sections describe the data sets stored within these groups.

### 1.6.1 SeaIceCover_Data Group

**SeaIceCover_Map**

This variable contains the sea ice cover map generated by the algorithm. The presence of sea ice in a pixel is constrained to either completely ice-covered (100) or open ocean (0). To provide a complete view of conditions in the scene, cloud, night, and land masks are overlaid. On-board bow tie trim data (see Bow Tie Effect below) are retained and appear as horizontal stripes on both sides of the swath.

**SeaIceCover_Basic_QA**

Basic QA offers users a convenient metric to quickly assess data quality for pixels that have been evaluated for sea ice. Values range from best (0) to bad (3). Unusable results are flagged as other (4). Additional values indicate unusable or missing input data and pixels that have been masked for conditions such as night, cloud, and bow tie trim. To generate this variable, all pixels are initialized to "best" and then adjusted based on the quality of the input data and solar zenith angle (SZA). If a pixel's visible reflectance is less than 5% but still usable, the QA value is downgraded to "good." A value of "poor" indicates that the SZA lies in the range of 70° ≤ SZA < 85° and that the algorithm decision has higher uncertainty due to low illumination.

**Algorithm_QA_Flags**

This variable stores the results of data screens used to test for conditions which are known to challenge the sea ice detection algorithm. Screen results are stored as bit flags and indicate if a pixel was reversed to "not sea ice" due to failing one or more screens or has high uncertainty due to challenging conditions. Refer to Table 2 for additional details including the key to decoding the Algorithm QA bit flag. See 3.1.4 below for descriptions of the screens and masks applied in the sea ice algorithm.

### 1.6.2 Geolocation_Data Group

**Latitude, Longitude**

Separate 375 m latitude and longitude arrays are provided which together specify the center of each pixel in the data arrays.

In addition, data files contain two HDF5 dimension scales—`number_of_lines` and `number_of_pixels`—as defined by Version 1.6 of the NetCDF Climate and Forecast (CF) Metadata Conventions. Dimension scales allow GIS programs like HDFView, Panoply, and GDAL (versions 2.1.2 and higher) to properly map data arrays from index space to geographic coordinate space.

**Warning:** At this time, ArcGIS and QGIS do not properly geolocate VIIRS swath-level data because they utilize Geospatial Data Abstraction Library (GDAL) libraries which are older than Version 2.1.2. Please contact the vendors for more information. Still have questions? Email NSIDC User Services.

Consult the following tables for additional details about the variables described above, including coded integer keys, data types, and scaling factors:

Table 2. VNP29 Variable Names and Descriptions

| Variable Name | Description |
|---|---|
| `SeaIceCover_Map` | Sea ice cover plus other conditions, stored as 8-bit unsigned integers. Sea ice detections are effectively binary, either no sea ice/open ocean (0) or 100% covered (100). Valid values are:<br>0: open ocean<br>100: sea ice<br>200: missing data<br>201: no decision<br>211: night<br>225: land<br>237: inland water<br>250: cloud<br>252: unusable L1B data<br>253: bow tie trim<br>254: no L1B data<br>255: fill value |

| Variable Name | Description |
|---|---|
| SeaIceCover_Basic_QA | Basic quality assessment in pixels processed for sea ice, stored as 8-bit unsigned integers. Valid values are:<br>0: best<br>1: good<br>2: poor<br>3: bad<br>4: other<br>211: night<br>225: land<br>237: inland water<br>250: cloud<br>252: unusable L1B data<br>253: bow tie trim<br>254: no L1B data<br>255: fill value |
| Algorithm_QA_Flags | Data screen results stored as bit flags (8-bit unsigned integer). Screen criteria and flag meanings are detailed in Section 3.1.4 below. Bits are assigned as follows:<br>0: spare<br>1: low visible data screen<br>2: low NDSI screen<br>3: spare<br>4: spare<br>5: high SWIR screen<br>6: spare<br>7: low illumination screen |
| latitude | 375 m resolution (6464 x 6400) latitude array. |
| longitude | 375 m resolution (6464 x 6400) longitude array. |

Table 3. VNP29 Dimension Scale Data Sets

| Variable Name | Description |
|---|---|
| number_of_lines | HDF5 scalar data set/NetCDF shared dimension. 32-bit floating point (6464,1) |
| number_of_pixels | HDF5 scalar data set/NetCDF shared dimension, 32-bit floating point (6400,1) |

# 2 SOFTWARE AND TOOLS

VIIRS NetCDF4/HDF5 data files can be accessed using either NetCDF4 or HDF5 tools. In addition, NASA has two online tools that can help you find the right data for your project. Worldview offers users an interactive interface to view full-resolution, global, near real-time satellite imagery projected on Earth. EarthData allows users to search for and order NASA data sets.

# 3 DATA ACQUISITION AND PROCESSING

## 3.1 Derivation Techniques and Algorithms

The following sections offer a brief outline of the approach used to detect sea ice from VIIRS observations. Users seeking a complete description of the sea ice detection algorithm should consult the Suomi-NPP VIIRS Sea Ice Cover Algorithm Theoretical Basis Document (ATBD).

Table 4 lists the products that are input to the VIIRS sea ice cover algorithm:

Table 4. Input products to the VIIRS sea ice cover algorithm

| Product | Data Arrays | Spatial Resolution | Descriptor |
|---|---|---|---|
| NPP_VIAES_L1 | Reflectance_I1 | 375 m | Reflectance (band I1) |
| | Reflectance_I2 | | Reflectance (band I2) |
| | Reflectance_I3 | | Reflectance (band I3) |
| | QF_VIIRSIBANDSDR_I1 | | Quality flags (band I1) |
| | QF_VIIRSIBANDSDR_I2 | | Quality flags (band I2) |
| | QF_VIIRSIBANDSDR_I3 | | Quality flags (band I3) |
| NPP_IMFTS_L1 | SolarZenithAngle | 375 m | Solar zenith angle |
| VNP35_L2 | QF1_VIIRSCMIP | 750 m | Cloud confidence flag |
| | QF2_VIIRSCMIP | | Land/water mask |

### 3.1.1 Sea Ice Detection Algorithm

Similar to MODIS, the VIIRS sea ice cover algorithm utilizes the Normalized Difference Snow Index (NDSI) to differentiate sea ice from open water. Like snow, 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) and applies threshold test using visible radiance from band I2 (0.865 µm). NDSI is calculated as follows:

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

The algorithm sets pixels to sea ice if the NDSI > 0.4 and the band I2 reflectance > 0.11 (Tschudi et al., 2017).

Ocean pixels are identified using the NASA VIIRS land/water mask in the VNP35_L2 product. VNP35_L2 also contains the VIIRS cloud confidence flag, which is read to create a cloud mask. A pixel is only processed for sea ice cover if its cloud confidence flag is set to “confident clear.” Values of “confident cloudy,” “probably cloudy,” and “probably clear” are masked as cloud.

The sea ice detection algorithm is run for all clear-sky ocean pixels poleward of 50° N and 50° S in daylight, where daylight is defined as a solar zenith angle less than 85°. The reflectance data are first checked for nominal quality and, if unusable, the pixel is flagged and skipped. Otherwise processing continues.

Several data screens, masks, and threshold tests are applied within the algorithm to alleviate and flag certain conditions that are known to challenge sea ice detection using the NDSI. Data screens can reverse a sea ice detection to no sea ice, change it to no decision, or simply flag it as highly uncertain. 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.

The following sections describe the masks and data screens applied within the algorithm.

### 3.1.2 Land/Water Mask

The land/water mask for this data set is read from the VIIRS/NPP Cloud Mask 6-Min L2 Swath 750m (VNP35_L2) product. Users should be aware this mask is not the same as that used by the MODIS Collection 6 sea ice extent product, which was derived specifically for MODIS from the University of Maryland 250m MODIS Water Mask. Future versions of VIIRS sea cover data sets will incorporate a new land/water mask adapted specifically for VIIRS from the MODIS Collection 6 mask.

### 3.1.3 Cloud Mask

Clouds are masked using the 750 m cloud confidence flag in VNP35_L2. Values in the 750 m mask value are applied to all four corresponding 375 m pixels in the sea ice cover product. As described previously, pixels are masked as cloud if the flag is set to “confident cloudy,” “probably cloudy,” or "probably clear." Only the "confident clear" flag is interpreted as cloud free.

### 3.1.4 Data Screens

Screen results are stored as bit flags in the Algorithm_QA_Flags variable. If a pixel fails a screen, the bit corresponding to that screen is set to on (1). Note that when a flag is set its meaning depends on the screen. E.g., the pixel may have been reversed from "sea ice" to "no ice sea," changed from any result to "no decision," or left unchanged and flagged to indicate a high level of uncertainty.

All pixels are evaluated for all screens, and thus a pixel can have more than one flag set. For Version 1, only bits 1, 2, 5, and 7 are in use; bits 0, 3, 4, and 6 are spare (set to 0). Additional screens may be added for subsequent versions.

The following sections detail the criteria applied by each data screen and how to interpret its flag.

**Low Visible Data Screen (bit 1)**
Pixels with an I2 reflectance < 0.10 are set to “no decision” and bit 1 is set to on (1).

**Low NDSI Data Screen (bit 2)**
Pixels with 0.0 < NDSI < 0.1 are set to “not sea ice” and bit 2 is set to on (1).

**High Short-Wave Infrared (SWIR) Data Screen (bit 5)**
If a pixel detected as sea ice by the algorithm has a band I3 reflectance ≥ 0.45, the result is changed from "sea ice" to “not sea ice” and bit 5 is set to on (1).

**Solar Zenith Angle Screen (bit 7)**
Solar zenith angle (SZA) data are input from the NPP_IMFS_L2 product to create a night mask and identify low illumination conditions which challenge the sea ice detection algorithm. Bit 7 is set to on (1) for pixels with 70° ≤ SZA < 85° to indicate a high degree of uncertainty. Pixels with SZA ≥ 85° are masked as night and not evaluated for sea ice.

### 3.1.5 Bow Tie Effect

VIIRS M bands have 16 rectangular detectors in the along-track direction, oriented with the smaller dimension along-scan. The detector size and scan timing are designed to produce a scan width at nadir that matches the ground-track distance traveled by satellite during one scan period, thus leaving no gap between adjacent scans. However, the along-track width of the VIIRS scan at Earth's surface increases from 11.7 km at nadir to 25.8 km at ±56.28°, due primarily to the increasing distance between the sensor and the ground and Earth's curvature. As a result, the scan footprint has the shape of a bow tie (see Figure 1).

Adjacent scans thus begin to visibly overlap at angles greater than approximately 19°, and in M bands by more than 1 pixel at angles greater than 32°. To save transmission bandwidth, VIIRS removes duplicated pixels in off-nadir portions of scans; however, this introduces visual artifacts in the raw swath images. Users who wish may remove these artifacts via interpolation when images are displayed. Note, however, that the artifacts do not appear in higher-level products in which the scans have been projected and gridded onto Earth’s surface.

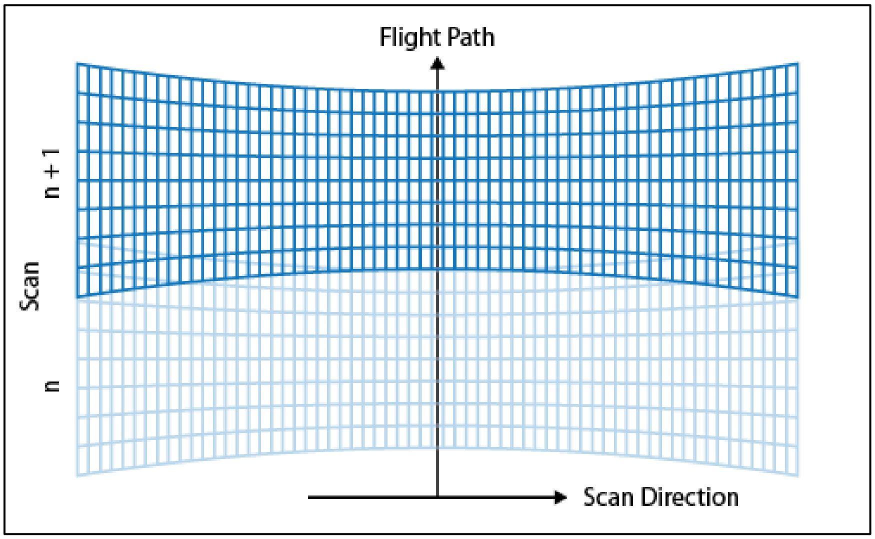


Figure 1. Illustration of the bow tie effect. Increasing scan width away from nadir leads to pixel overlap in adjacent scans.

## 3.2 Error Sources

The targeted uncertainty of the NASA sea ice cover product is 5%, or the product should correctly classify 95% of the viewable surface as either sea ice or open water.

Errors in sea ice detection are more probable in the summer when the algorithm can misclassify surficial 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.

Confusion between clouds and sea ice, another potential source of error in these data, is similar to the MODIS Version 6 (C6) sea ice product. 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 VNP35_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.

Users may wish develop techniques for their particular study areas that account for the transient nature of clouds. For example, cloud/sea ice confusion can potentially be alleviated using temporal and/or spatial filtering.

## 3.3 Instrument Description

The VIIRS instrument is a whiskbroom scanning radiometer with 22 bands (see VIIRS Bands and Bandwidths) covering the spectrum between 0.412 µm and 12.01 µm. 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. M-bands include 11 Reflective Solar Bands (RSB) and 5 Thermal Emissive Bands (TEBs). I-bands include 3 RSBs and 2 TEBs. More details about the VIIRS instrument are available in the Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor Data Record (SDR) User's Guide and the Joint Polar Satellite System (JPSS) VIIRS Radiometric Calibration Algorithm Theoretical Basis Document (ATBD). Table 5 lists select technical specifications for the VIIRS instrument:

Table 5. VIIRS Specifications

| Variable | Description |
|---|---|
| Orbit | 829 km (nominal) altitude, 1:30 P.M. ascending node, sun-synchronous, near-polar, circular |
| Scan Rate | 1.779 sec/rev, 202.3 deg/sec |
| Scan Width | ±56.28° (Earth view) |
| Imaging Optics | 19.1 cm aperture, 114 cm focal length |
| Swath Dimensions | 3060 km cross-track, 12 km along track at nadir |
| Samples per Band | M-bands: 6304 samples at 0.312 mrad/sample (3200 aggregated pixels)<br>I-bands: 12608 samples at 0.156 mrad/sample (6400 aggregated pixels)<br>DNB: 4064 pixels at 0.149 to 0.894 mrad/pixel |
| Weight | 275 kg |
| Power | 200 W (single orbit average) |
| Data Rate | 10.5 Mbps (max) |
| Quantization | 12 bit –14 bit A/D converters for lower noise |
| Launch date | 28 October, 2011 |
| Design Life | 7 years (5-year mission) |

# 4 REFERENCES AND RELATED PUBLICATIONS

## 4.1 References

Justice, C.O., M.O. Román, I. Csiszar, E.F. Vermote, R.E. Wolfe, S.J. Hook, M. Friedl, Z. Wang, C.B. Schaaf, T. Miura, M. Tschudi, G. Riggs, D.K. Hall, A.L. Lyapustin, S. Devadinga, C. Davidson, and E.J. Masuoka. 2013. Land and cryosphere products from Suomi NPP VIIRS: Overview and status. *Journal of Geophysical Research – Atmospheres*, 118(17): 9753-9765. http://dx.doi.org/10.1002/jgrd.50771

Riggs, G.A., D.K. Hall, and M.O. Román. 2015. MODIS sea ice products user guide for Collection 6 (C6). (See PDF)

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

## 4.2 Related Websites

- Nasa Goddard Space Flight Center | Polar Orbiting Missions | Suomi-NPP
- Nasa Goddard Space Flight Center | Suomi-NPP VIIRS Land
- MODIS Snow/Ice Global Mapping Project
- Earthdata | VIIRS is Here

# 5 DOCUMENT INFORMATION

## 5.1 Publication Date

November 2017

## 5.2 Date Last Updated

December 2020