NASA S-NPP VIIRS Ice Surface Temperature Collection 1 User Guide

Version 1.0
Describes
The Swath Level Product

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List of Acronyms

ATBD	Algorithm Theoretical Basis Document
BT	Brightness Temperature
Cx	Collection number
CMG	Climate-Modeling Grid
DOI	Digital Object Identifier
EDR	Environmental Data Record
EOSDIS	Earth Observing System Data Information System
ESDT	Earth Science Data Type
HDF5	Hierarchical Data Format 5
IDPS	Interface Data Processing Segment
L1 / L2 / L3	Level 1, Level 2 or Level 3 data product
LSIPS	Land Science Investigator-led Processing System
MOD29	ESDT of the MODIS L2 IST product
MODIS	Moderate-resolution Imaging Spectroradiometer
QA	Quality Assessment
SIN	Sinusoidal Projection
S-NPP	Suomi National Polar-orbiting Partnership
SWIR	Short Wave Infrared
SZA	Solar Zenith Angle
TOA	Top-of-Atmosphere
VIIRS	Visible Infrared Imager Radiometer Suite
VNP30*	ESDT name for the VIIRS Level-2 IST Data Products
VPN30	ESDT name for the VIIRS Level-2 swath-based IST Data Product
VPN30A1	ESDT name for the VIIRS Level-3 tiled IST Data Product
VPN30C1	ESDT name for the VIIRS Level-3 global IST Data Product
VIS	visible

1.0 Overview

The NASA Suomi-National Polar-orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) ice surface temperature (IST) algorithm and data product are similar to the Moderate Resolution Imaging Spectroradiometer (MODIS) IST algorithm and data product. The overall objective for VIIRS Collection 1 (C1) is to make the NASA VIIRS IST algorithms compatible with the C6 MODIS Terra and Aqua IST algorithms to ensure continuity of the data products and enable development of a climate-data record (CDR) from the three sensors. Differences between the MODIS C6 and the NASA VIIRS algorithms originate from the physical differences between the MODIS and VIIRS instruments, including spatial resolution and band locations. The NASA VIIRS IST product is produced in the NASA Land Science Investigator-led Processing System (LSIPS). The NASA VIIRS IST data product is somewhat different from the IST product generated in the NOAA- Interface Data Processing Segment (IDPS) system.

This User Guide describes each of the three NASA VIIRS C1 IST products in sequence from Level 2 to Level 3: 1) IST swath, 2) daily IST tiled, and 3) daily climate modeling grid (global). This User Guide is a living document developed in increments for each product as they are scheduled to be released, so it is advisable to check that you are using the latest version. This version (1.0) describes the VIIRS swath level (Level-2) IST product which is the first to be produced by the LSIPS and archived at the NSIDC DAAC. The LSIPS has evolved from the LPEATE which had the task of generating and evaluating algorithms and products generated with IDPS algorithms. The LSIPS is now beginning to produce and distribute the NASA VIIRS data products. The VIIRS IST products are referenced by their Earth Science Data Type (ESDT) root name, VNP30. The ESDTs are produced as a series of products in which data and information are propagated to the higher level products. Details of the data products, Quality Assessment (QA) data content, and commentary on evaluation and interpretation of data are given for each product. The reader is referred to the VIIRS Algorithm Theoretical Basis Document (ATBD) [http://npp.gsfc.nasa.gov/documents.html] [*Tschudi et al*., 2016] and to *Justice et al*. [2013] for further details.

The data product format of the VIIRS IST data products changes with the data product level. The VNP30 product file format is NetCDF4/HDF5 and is compliant with the NetCDF Climate and Forecast (CF) Metadata Conventions Version 1.6. Information on NetCDF4.2 is at www.unidata.ucar.edu/software/netcdf/docs/index.html, Information on Hierachical Data Format 5 (HDF5) may be found at https://www.hdfgroup.org/HDF5/. Either NetCDF4 or HDF5 tools should be able to read these data products. The Level-3 products, VNP30A1 and VNP30C1, will be in HDF5-EOS file format. The user should contact the NSIDC DAAC user support group with questions about working with these files formats.

The LSIPS ramp-up to full production of NASA VIIRS data products began with producing the LPEATE versions of IDPS algorithms and products for Level-1B and

Level-2 products to use as inputs to the NASA algorithms and data products as they were being developed and for initial C1 production. Those LPEATE versions of the L1B products will be replaced by the NASA L1B and L2 products when they become available. The difference between those products is primarily data product format; both contain the same data but are organized in different ways. The current VNP30 uses LPEATE versions of inputs and outputs the VNP30 product. The VNP30 algorithm code will be revised to use NASA L1B inputs but the IST algorithm will not be changed and the output product will be the same. Data product inputs are listed as global attributes in VNP30 so a user can determine which L1B inputs were used.

2.0 NASA VIIRS IST Data Products

The NASA VIIRS ice surface temperature (IST) data products are listed in Table 1. IST products are produced in sequence beginning with a swath at a nominal pixel spatial resolution of 375 m with nominal swath coverage of 6400 pixels (across track) by 6464 pixels (along track), consisting of 6 minutes of VIIRS scans. (Note: 5 minutes of VIIRS scans if using LPEATE version of L1B). Products in EOSDIS are labeled as ESDT and have their heritage in the MODIS production system [*Wolfe and Ramapriyan*, 2010]. The ESDT also indicates what spatial and temporal processing has been applied to the data product. Data product levels briefly described are: Level 1B (L1B) is a swath (scene) of VIIRS data in latitude and longitude orientation. A Level 2 (L2) product is a geophysical product that remains in latitude and longitude orientation of L1B. A Level 2 gridded (L2G) product is in a gridded format of the sinusoidal projection for VIIRS land products. At L2G the data products are referred to as tiles, each tile being 10° x 10° area, of the global map projection. L2 data products are gridded into L2G tiles by mapping the L2 pixels into cells of a tile in the map projection grid. The L2G algorithm creates a gridded product necessary for the Level 3 (L3) products. An L3 product is a geophysical product that has been temporally and or spatially manipulated, and is in a gridded map projection format and comes as a tile of the global grid. The VIIRS L3 IST products are in either the sinusoidal projection (VNP30A1) or geographic projection (VNP30C1).

The series of NASA VIIRS IST products to be produced in C1 is listed in Table 1. A description of each product, synopsis of the algorithm and commentary on IST detection, quality assessment, accuracy and errors is given in following sections.

Attributes (metadata) describing the time of acquisition of the swath, input products, geographic location of swath, production of the data product, provenance and Digital Object Identifier (DOI) of the product are attached to the root group (the file). Those attributes are listed in Appendix A; they are not described further in this user guide.

Table 1: Summary of sea ice IST products produced at the Land Science Investigator-led Processing System (SIPS).

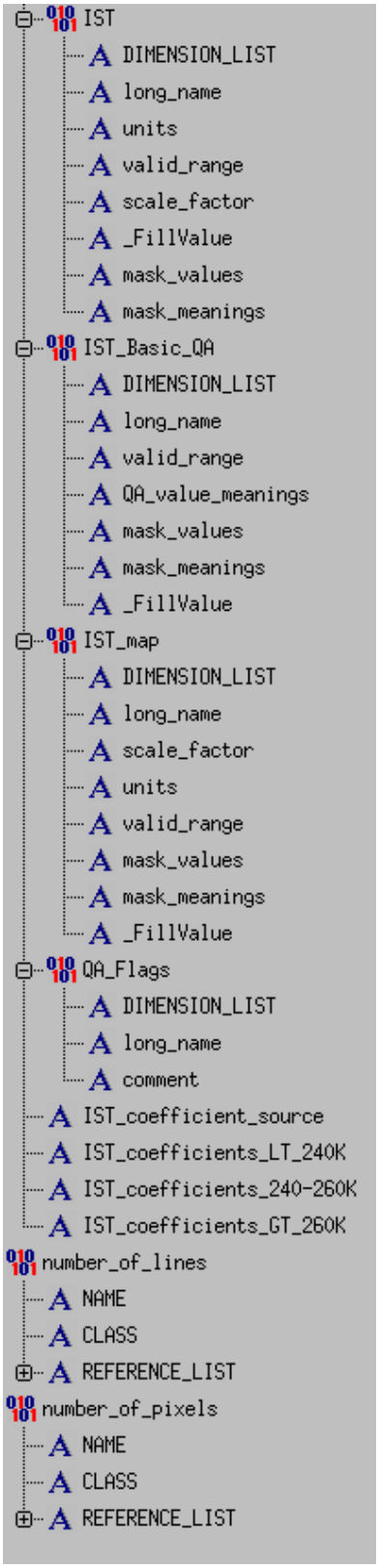
Products	ESDT	Description
IST (L2 Daily Swath product)	VNP30	VIIRS/NPP IST 6-Min Swath 375 m
IST (L2G Daily Tiled product)	VNP30A1	VIIRS/NPP IST Map Daily L2G Global 375 m SIN Grid Day
IST (L3 CMG Product)	VNP30C1	VIIRS/NPP Daily IST L3 Global 0.05° X 0.05° climate-modeling grid (CMG)

3.0 VNP30

Ice Surface Temperature over sea ice is computed using a split-window technique as in the MODIS C6 IST algorithms [*Tschudi et al*., 2016; *Yu et al*., 1995 and b]. The IST products contain an IST dataset with masks of clouds, night and oceans applied for all ocean area pixels poleward of 50°N and 50°S, Quality Assurance (QA) datasets and geolocation datasets. A detailed explanation for providing the IST is given in the NASA VIIRS IST ATBD [*Tschudi et al*., 2016] [http://npp.gsfc.nasa.gov/documents.html].

The NASA VIIRS IST swath product, VNP30, contains dimension scale datasets, an IST group and attributes for the file, data group and datasets. Contents of VNP30 are given in List 1.

List 1. Datagroups and datasets in a VNP30 product:
HDF5: " VNP30.A2014074.2055.h5"



3.1 Geolocation Data

Geolocation data are the dimension scale datasets (List 2). Latitude and longitude datasets are not written in the product, but are stored in the VNP03IMG geolocation data product corresponding to a VNP30 swath data product.

List 2. VNP30 Geolocation datasets (variables).
netcdf VNP30.A2014074.2055.h5 {
dimensions:
number_of_lines = 6496
number_of_pixels = 6400

3.2 IST Data Group

Descriptions of the IST Data group datasets and attributes are given in List 3 and in Section 3.2.1. IST Data group attributes are descriptive summary statistics compiled during a run of the algorithm that provides information on overall viewing conditions, e.g. cloud cover, daytime or nighttime, basic summary of data quality, and threshold settings of some data screens. The purpose of these attributes it to give an overall view of what might be observed in the scene.

List 3. VNP30 description of IST Data group datasets and attributes.
group:

The IST basic QA is defined as:

IST_Basic_QA:QA_value_meanings = "0-best, 1-good, 2-day cloud, 3-night good, 4-night cloud, 5-other", according to:

1 – good: daylight, clear sky
2 – day cloud: daylight, cloud
3 - night good: nighttime, clear sky
4 - night cloud: nighttime, cloudy

and
IST_Basic_QA:mask_values = 237UB, 253UB, 254UB ;
IST_Basic_QA:mask_meanings = "237-inland_water, 253-land_mask, 254-bowtie_trim";
Basic_QA _FillValue = 255UB

The VNP30 product has the following datasets: IST, Basic_QA, and Algorithm_bit_flags_QA, each with local attributes describing the data.

3.2.1 IST

The IST dataset is the sea ice surface temperature generated by the algorithm. IST is represented by values in the range of 237 – 253K in each pixel, as was done in the MODIS data products [*Hall et al*., 2004; *Riggs et al*., 2016). To give a complete view of conditions in the scene, the cloud mask and night mask are overlaid on the IST data. The onboard bowtie trim fill data is retained in the dataset. An example of the IST dataset with a colorized range is shown in Figure 1. Local attributes are attached to the dataset.

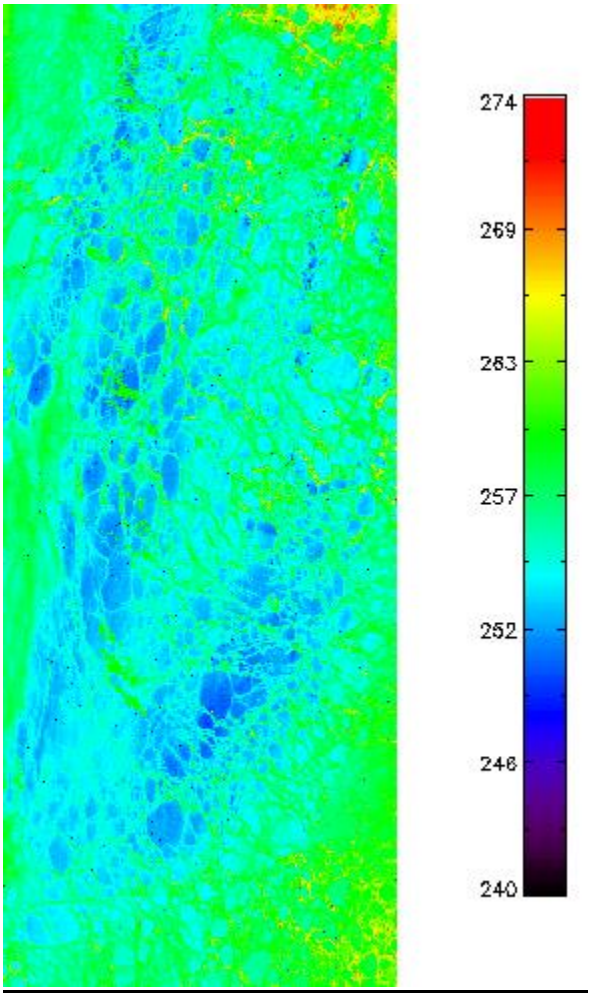


Figure 1. VNP30.A2014255.2110, 2110 UTC, 12 September 2014. IST map during fall freeze-up in the Beaufort Sea.

3.2.2 Algorithm_ bit_flags_QA

Algorithm-specific bit flags are set in this dataset for the data screens that are applied in the algorithm. Multiple bit flags may be set for a pixel. Some of the bit flags identify an uncertain pixel result. See Section 3.3 for a description of bit flags. Local attributes describing the data, i.e. each bit flag, are included.

3.2.3 Basic QA

A general quality value is given for pixels processed for sea ice surface temperature as in the MODIS IST products [*Riggs et al*., 2016]. This is a basic quality value used to indicate quality ranging from best to poor to provide a user with a convenient value for initial quality assessment of the data. Local attributes describing the data are included.

3.3 Ice Surface Temperature Algorithm

A brief description of the algorithm approach is provided to explain the flow of the algorithm and the basic technique used to detect sea ice surface temperature. A detailed description of the algorithm can be found in the NASA VIIRS ATBD [*Tschudi et al*., 2016].

The basis of the NASA VIIRS IST algorithm is the work of *Key et al*. [1997], who state that the demonstrated accuracy of the algorithm is sufficient for most climate process studies. The major caveat with the algorithm is that it is applicable only to clear-sky conditions. Inadequate cloud masking may result in significant error in estimating the IST. The heritage of the VIIRS IST algorithm is *Key and Haefliger* [1992] with substantiation of robustness and accuracy by later work [*Key et al.*, 2013, 1994; *Yu et al*., 1995; *Lindsay and Rothrock*, 1994; *Massom and Comiso*, 1994).

To compute the IST from VIIRS band M15 and M16, we use the VIIRS Level 1B data for these thermal channels, which are stored as calibrated radiance data. The calibrated radiance data for VIIRS bands M15 and M16 are converted to brightness temperature (*T*), using the method of *Key et al.* [1994]. Once the brightness temperature *T* has been computed for each band (T11 and T12), the IST is calculated using the split-window method of *Yu et al*. [1995], updated for VIIRS M15 and M16 bands.

The IST is calculated for all polar ocean water bodies in daylight and nighttime. Screening for clouds is accomplished by applying the VIIRS Cloud Mask (VCM) data product [*Godin*, 2014]. The VCM Cloud Detection Results & Confidence Indicator flag is used to mask cloud and cloud contamination from pixels. If that flag is set to “confident cloudy” or “probably cloudy,” then the pixel is labeled as cloud obscured in the sea ice map, and IST is not calculated.

Data product inputs to the NASA VIIRS IST algorithm are listed in Table 2, currently using the LPEATE version of inputs. The LISPS ESDT names are listed in parentheses and italicized. The basic processing flow is depicted in Figure 2. The processing flow

for a pixel is determined based on the land/water mask read from the geolocation data product. All ocean pixels in daylight and nighttime are processed for IST VIIRS radiance data is checked for nominal quality and converted to top-of-atmosphere (TOA) reflectance.

Table 2. VIIRS data product inputs to the VNP10 algorithm.

ESDT	Data array names	Nominal spatial resolution	Descriptor
NPP_VMAE_L1	BrightnessTemperature_M15	750 m	TOA
	QF1_VIIRSMBANDSDR_M15		Poor quality flag
	BrightnessTemperature_M16	750 m	TOA
	QF1_VIIRSMBANDSDR_M16		Poor quality flag
	SolarZenithAngle	750 m	Solar zenith angle
	SatelliteZenithAngle	750 m	Satellite zenith angle
NPP_CMIP_L2	QF1_VIIRSCMIP (bits 2-3)	750 m	Cloud mask confidence
	QF2_VIIRSCMIP (bits 0-2)	750 m	Land/water mask

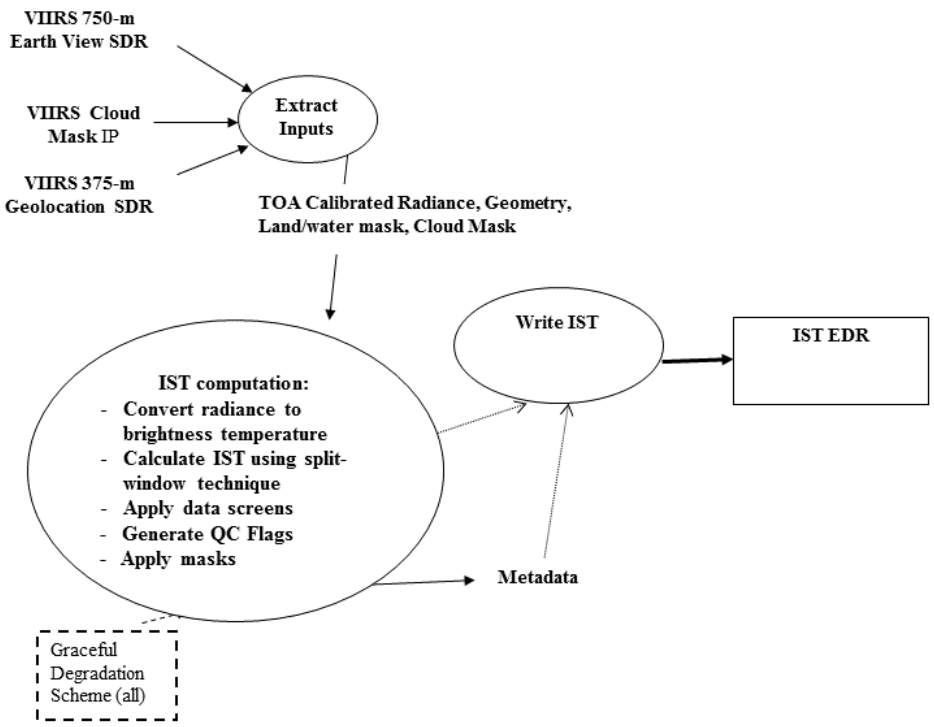


Figure 2. IST Environmental Data Record (EDR) processing architecture.

3.3.1 Data Screens

If a pixel has been determined to have an IST, it is subjected to a series of data screens. The Screened IST data array is the IST map generated by the algorithm with clouds (VCM) and an ocean mask (>271.4K) overlaid by setting the IST to a fill value corresponding to each mask. IST is represented in Kelvins, with values in the expected range of 213-275K for each pixel.

3.3.1.1 Low thermal band screen.
If the VIS reflectance from VIIRS band M15 band M4 is less than a threshold, then a pixel fails to pass this screen resulting in a “no decision” result. This screen is tracked in bit 1 of the Algorithm_bit_flags_QA.

3.3.1.5 Solar zenith angle screen.
Low illumination conditions exist at SZAs > 70°. A SZA mask of > 70° is made by setting bit 7 of the Algorithm_bit_flags_QA. This mask is set across the entire swath. Night is defined as the SZA ≥ 85° and pixels are masked as night.

3.3.2 Cloud Masking

The cloud confidence flag from NPP_CMIP_L2 is used to mask clouds. The 750 m cloud mask is applied to the four corresponding 375 m pixels. The cloud confidence flag gives four levels of confidence: confident clear, probably clear, probably cloudy, and certain cloud. If the cloud mask flags "certain cloud" then the pixel is masked as "cloud." If the cloud mask flag is set "confident clear," "probably clear" or "uncertain clear" it is interpreted as "clear" in the algorithm.

3.3.3 Quality Assessment (QA)

Two QA datasets are output: 1) the Basic_QA which gives a simple value score, and 2) the Algorithm_bit_flags_QA which reports results of data screens as bit flags. The basic QA value is a qualitative estimate of the algorithm result for a pixel. The basic QA value is initialized to the best value and is adjusted based on the quality of the L1B input data and the solar zenith data screen. If the calculated top-of-atmosphere (TOA) reflectance is outside the range of 5-100% but still usable, the QA value is set to 'good.' If the SZA is in the range of $70° \leq SZA < 85°$, the QA is set to 'okay,' which means increased uncertainty in results because of low illumination. If input data is unusable the QA value is set to 'other.' Conditions for a poor result are not defined. For features that are masked, e.g. ocean and night, the mask values are applied.

The Algorithm_bit_flags_QA dataset contains bit flags of the results of the data screens that are applied in the algorithm. More than one bit flag may be set because all data screens are applied to a pixel. By examining the bit flags a user can determine if an IST pixel has certain screens set to "on" indicative of an uncertain IST estimate. The screens and bit flags flag where IST detection was "uncertain." More than one data screen can be "on" for uncertain IST detection.

Bits for the data screens are set to "on" if the screen was failed. An example of some of the bit flags and combinations of bit flags is shown in Figure 2. Many combinations of bit flags may be set. A user can investigate any bit flag or combinations of bit flags. The inland water mask is also set as a bit flag (bit 0) to support future analysis of inland waters for snow/ice cover.

3.4 Interpretation of IST Detection Accuracy, Uncertainty and Errors

Sea ice identification does not have many of the complicating factors of varying surface covers that affect mapping features on land, but there are complications that make sea ice mapping difficult. Because sea ice can vary in concentration from near zero to 100 percent, sea ice can give different IST within a scene, due to mixed-pixel effects. The presence of melt ponds and leads in the summer months will affect the emissivity of the ice surface and therefore the calculation of ice surface temperature.

The accuracy of the IST algorithm for the IDPS VIIRS IST product is approximately 1K [*Key et al*., 2013]. The NASA VIIRS IST accuracy will be similar, and will be assessed via comparisons with the NASA MODIS IST product [*Hall et al*., 2004] and validated with NASA Operation IceBridge airborne IST measurements [*Krabill and Buzay*, 2012].

Coefficients obtained from *J. Key* and *Y. Liu* [personal communication] are initially used in the NASA VIIRS IST algorithm. The coefficients are based on VIIRS-specific calculations they performed. Further analysis of NASA VIIRS IST evaluations will likely result in changes to the coefficients.

Clouds pose many of the same problems in mapping IST as they do when mapping other surface features, such as snow. Sea ice may move relatively rapidly and clouds may obscure this movement or make the movement of the sea ice appear incoherent when an 8-day time series, partially obscured by clouds, is compiled. Small ice floes, polynyas, and leads at subpixel resolution contribute error to identification and mapping of sea ice. Global error analysis is ongoing with other sources of data, e.g. passive-microwave and regional operational sea ice data products, to estimate error at regional and global scales in the post-launch time period.

3.4.1 Uncertainty Estimate

The targeted uncertainty of the NASA VIIRS IST product is ±1K over a measurement range of 213-275K. Previous estimation of the IDPS VIIRS IST uncertainty with comparisons to the NASA MODIS IST Product approach this uncertainty overall, but show a greater uncertainty (2-3K) for warmer IST (>250K) [*Key et al*., 2013], with the VIIRS IST cooler than MODIS. Measurement uncertainty is defined as the root-mean-square of the measurement errors.

3.4.2 Land/water mask

The land/water mask in the NASA VIIRS geolocation product is the MODIS C6 land/water mask which was derived from the UMD 250m MODIS Water Mask data product (UMD Global Land Cover Facility http://glcf.umd.edu/data/) [*Carroll et al*., 2009]. The UMD 250 m Water Mask was converted to a 500 m seven class land/water mask for use in the production of MODIS products in C6 to maintain continuity with the land/water mask used in C5. The new land/water mask more accurately provides the location of water bodies [http://landweb.nascom.nasa.gov/QA_WWW/forPage/MODIS_C6_Water_Mask_v3.pdf . Thus LSIPS adapted the MODIS land/water mask to create the VIIRS land/water mask in the geolocation product.

3.4.3 Geolocation accuracy

Geolocation accuracy in NASA VIIRS is very high, providing consistent high accuracy in mapping of the VIIRS data products. The very small errors in geolocation are negligible in the L2 products, however, geolocation error may be observed in the daily gridded products as a shifting of features, e.g., changes in the location of a lake in cells from day to day. That possible cell shifting of features in daily gridded products will be addressed in later version of this user guide).

3.4.4 Antarctic sea ice

The VPN30* IST products are also generated for Antarctic sea ice.

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3.5 Related Web Sites

Suomi-NPP
http://npp.gsfc.nasa.gov/suomi.html

VIIRS
VIIRS Land: http://viirsland.gsfc.nasa.gov/
MODIS Snow/Ice Global Mapping Project:
http://modis-snow-ice.gsfc.nasa.gov

Imagery and Data Product Viewing
Worldview: https://worldview.earthdata.nasa.gov
LANCE: https://wiki.earthdata.nasa.gov/display/GIBS/2015/12/10/VIIRS+is+Here
https://earthdata.nasa.gov

NSIDC Data Ordering & User Services
National Snow and Ice Data Center: http://nsidc.org/data/viirs

HDF5
The HDF Group: https://www.hdfgroup.org/HDF5/

NetCDF4
www.unidata.ucar.edu/software/netcdf/docs/index.html

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Appendix A

Listing of global attributes in VNP30

```
// global attributes:
                :PGE_StartTime = "2016-03-07 20:48:00.000" ;
                :ProductionTime = "2016-09-09 13:06:07.000" ;
                :ProcessingEnvironment = "Linux minion5581 2.6.18-410.el5 #1 SMP Wed May 11
06:00:14 EDT 2016 x86_64 x86_64 x86_64 GNU/Linux" ;
                :publisher_url = "http://ladsweb.nascom.nasa.gov" ;
                :processing_level = "Level 2" ;
                :PGE_EndTime = "2016-03-07 20:54:00.000" ;
                :naming_authority = "gov.nasa.gsfc.VIIRSland" ;
                :creator_url = "http://ladsweb.nascom.nasa.gov" ;
                :cdm_data_type = "swath" ;
                :InputPointer =
"VNP30_L2.A2016067.2048.001.2016139201152.hdf,NPP_VIAES_L1.A2016067.2048.001.2016097134
203.hdf,NPP_VMAES_L1.A2016067.2048.001.2016097134203.hdf,NPP_IMFTS_L1.A2016067.2048.001
.2016095195212.hdf" ;
                :PGEVersion = "1.0.3" ;
                :creator_name = "VIIRS Land SIPS Processing Group" ;
                :PGE_Name = "PGE507" ;
                :RangeEndingDate = "2016-03-07" ;
                :publisher_email = "modis-ops.nasa.gov" ;
                :LocalGranuleID = "VNP10.A2016067.2048.001.2016253130607.nc" ;
                :title = "VIIRS IST Data" ;
                :project = "VIIRS IST Project" ;
                :LongName = "VIIRS/NPP Level 2 IST - 750m" ;
                :RangeBeginningDate = "2016-03-07" ;
                :AlgorithmType = "OPS" ;
                :LSIPS_AlgorithmVersion = "NPP_PR10 1.0.3" ;
                :Product_authority = "http://dx.doi.org" ;
                :creator_email = "modis-ops.nasa.gov" ;
                :Conventions = "CF-1.6" ;
                :ProcessVersion = "001" ;
                :SatelliteInstrument = "NPP_OPS" ;
                :ProcessingCenter = "MODAPS-NASA" ;
                :ShortName = "VNP30" ;
                :RangeEndingTime = "20:54:00.000000" ;
                :license = "http://science.nasa.gov/earth-science/earth-science-data/data-information-
policy/" ;
                :publisher_name = "LAADS" ;
                :stdname_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention" ;
                :Product_doi = "10.5067/VIIRS/VNP30.v001" ;
                :RangeBeginningTime = "20:48:00.000000" ;
                :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
Keywords" ;
                :institution = "NASA Goddard Space Flight Center" ;
```