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

VNP30
Version 1.1

July 2019

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List of Acronyms

ATBD	Algorithm Theoretical Basis Document
C1	Collection 1
CDR	Climate Data Record
CF-1.6	netCDF Climate and Forecast Metadata Conventions Version 1.6
DAAC	Distributed Active Archive Center
DOI	Digital Object Identifier
EDR	Environmental Data Record
ESDT	Earth Science Data Type
HDF5	Hierarchical Data Format 5
IDPS	Interface Data Processing Segment
IST	Ice Surface Temperature
L1B / L2	Level-1B, Level-2 data product
LSIPS	Land Science Investigator-led Processing System
MODIS	Moderate-resolution Imaging Spectroradiometer
netCDF	Network Common Data Form
NSIDC	National Snow and Ice Data Center
QA	Quality Assessment
S-NPP	Suomi National Polar-orbiting Partnership
VIIRS	Visible Infrared Imager Radiometer Suite
VNP30	ESDT name for the VIIRS Level-2 swath-based IST Data Product

1.0 Overview

The NASA Suomi-National Polar-orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) sea 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 Collection 6 (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).

This User Guide describes the NASA S-NPP VIIRS C1 Level-2 (L2) IST product. The IST product is produced by the LSIPS and archived at the National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC). The VIIRS IST product is referenced by its Earth Science Data Type (ESDT) name VNP30. Details of the data product content, Quality Assessment (QA) data content, and commentary on evaluation and interpretation of data are given for the product. Refer to the VIIRS IST Algorithm Theoretical Basis Document (ATBD) by Tschudi et al. (2016) and to Justice et al. (2013) for further details.

The VNP30 product file format is netCDF/HDF5 and is compliant with the netCDF Climate and Forecast Metadata Conventions Version 1.6 (CF-1.6) for attributes and georeference of variables. Information on netCDF is at www.unidata.ucar.edu/software/netcdf/docs/index.html; information on the Hierarchical Data Format 5 (HDF5) may be found at https://www.hdfgroup.org/HDF5/. Many software tools are capable of working with netCDF or HDF5 data products. A user should contact the NSIDC DAAC user support group with questions about working with these product formats.

For the C1 VNP30 algorithm the VIIRS L1B input product is the LSIPS-produced IDPS version of the Level-1B (L1B) product inputs. In the future C2 processing the VNP30 algorithm will use the NASA L1B product as input. The differences between those products is how calibration of the VIIRS bands is done and data product format. The VNP30 algorithm code will be revised to use NASA L1B inputs but the IST algorithm will remain the same 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.

Note: The User Guide is updated for each collection.

2.0 VNP30

Sea ice surface temperature is computed using the split-window technique as described by Tschudi et al. (2016) which is the same technique used for the MODIS C6 IST products based on the Key and Haefliger (1992) split-window technique but

with VIIRS specific coefficients used in the algorithm. The IST_Data group contains four variables; 1) IST, 2) IST_Basic_QA, 3) IST_map and 4) QA_Flags. The IST is calculated for day and night time data. A mask of night data is in the IST_Basic_QA variable there are no algorithm processing bit flags set in the C1 version of VNP30. A detailed explanation of the IST is given in the NASA VIIRS IST ATBD (Tschudi et al., 2016). The NASA swath product, VNP30, contains dimension-scale datasets, a geolocation data group with variables and attributes, an IST data group with variables and attributes, and root level attributes. Global attributes that provide information on provenance, time and location are included. A listing of global attributes is given in Appendix A.

2.1 Geolocation Data Group

The latitude and longitude data for each pixel in a swath are stored as coordinate variables in the Geolocation_Data data group in VNP30. The coordinate variables, attributes and datasets use the netCDF CF-1.6 conventions for georeference. Software tools that work with the netCDF4 or HDF5 data formats should be able to work with the VNP30 product. Description of the Geolocation_Data group is given in List 1.

List 1. Description of the Geolocation_Data group and attributes in VNP30

```
    dimensions:
        number_of_lines = 3232;
        number_of_pixels = 3200;

group: Geolocation_Data {
  variables:
        float latitude(number_of_lines, number_of_pixels) ;
                latitude:long_name = "Latitude data" ;  latitude:units =
                "degrees_north" ;  latitude:_FillValue = -999.9f ;
                latitude:valid_range = -90.f, 90.f ;  latitude:standard_name
                = "latitude" ;
        float longitude(number_of_lines, number_of_pixels) ;
                longitude:long_name = "Longitude data" ;  longitude:units
                = "degrees_east" ;  longitude:_FillValue = -999.9f ;
                longitude:valid_range = -180.f, 180.f ;
                longitude:standard_name = "longitude" ;
  } // group Geolocation_Data
```

2.2 IST Data Group

The VNP30 product has the following variables in the IST_Data group; IST, IST_Basic_QA, IST_Map and QA_Flags, each with local attributes describing the data. Decriptions of the variables and attributes are given in List 2 and in Section 3.2 subsections and images of the variables are shown in Figure1.

List 2. Description of IST_Data group variables and attributes in VNP30 group: IST_Data {

```
  variables:
        ushort IST(number_of_lines, number_of_pixels) ;  IST:coordinates =
                "latitude longitude" ;  IST:long_name = "Ice Surface
                Temperature" ;  IST:units = "K" ;
                IST:valid_range = 21000US, 31300US ;
                IST:scale_factor = 0.01f ;  IST:_FillValue =
```

```
                65535US ;
                IST:mask_values = 0US, 1US, 11US, 25US, 37US, 39US ;
                IST:mask_meanings = "0-missing, 1-no_decision, 11-night, 25-land, 37-  inland_water,
39-open_ocean" ;
        ubyte IST_Basic_QA(number_of_lines, number_of_pixels) ;  IST_Basic_QA:coordinates =
                "latitude longitude" ;  IST_Basic_QA:long_name = "Basic QA of Ice Surface Temperature"
                ;  IST_Basic_QA:valid_range = 0UB, 6UB ;  IST_Basic_QA:QA_value_meanings = "0-
                best, 1-day_good, 2-day_cloud,
3-night_good, 4-night_cloud, 5-other,6-poor" ;  IST_Basic_QA:mask_values =
                237UB, 253UB, 254UB ;
                IST_Basic_QA:mask_meanings = "237-inland_water, 253-land_mask,  254-
bowtie_trim" ;
                IST_Basic_QA:_FillValue = 255UB ;
        ushort IST_map(number_of_lines, number_of_pixels) ;
                IST_map:scale_factor = 0.01f ;
                IST_map:units = "K" ;
                IST_map:coordinates = "latitude longitude" ;  IST_map:long_name = "Ice
                Surface Temperature with masks" ;  IST_map:valid_range = 21000US,
                31300US ;
                IST_map:mask_values = 0US, 1US, 11US, 25US, 37US, 39US, 50US ;
                IST_map:mask_meanings = "0-missing, 1-no_decision, 11-night, 25-land,  37-
inland_water, 39-open_ocean, 50-cloud" ;
                IST_map:_FillValue = 65535US ;
        ubyte QA_Flags(number_of_lines, number_of_pixels) ;
                QA_Flags:coordinates = "latitude longitude" ;  QA_Flags:long_name
                = "Algorithm QA Flags for IST" ;
                QA_Flags:comment = "No QA bit flags are set in this version, the dataset  is place holder
for future version that will have QA bit flags set" ;

  // group attributes:
                :IST_coefficient_source = "Liu, Y.; Key, J.; Tschudi, M.; Dworak, R.;  Mahoney, R.;
Baldwin, D. Validation of the Suomi NPP VIIRS Ice Surface Temperature  Environmental Data Record.
Remote Sens. 2015, 7, 17258-17271." ;
                :IST_coefficients_LT_240K = -7.335613, 1.030383, 1.264255, -0.438851 ;
                :IST_coefficients_240-260K = -8.606919, 1.03532, 0.641668, 1.83879 ;
                :IST_coefficients_GT_260K = -6.629177, 1.027197, 1.082237, 2.159417 ;
  } // group IST_Data
}
```

2.2.1 IST

The IST variable, Fig.1 upper left, is the ice surface temperature generated by the algorithm. IST is in the range of 237 – 253K in each pixel, which is the same range as the MODIS IST data products MOD29 and MYD29 (Hall et al., 2004; Riggs et al., 2016). The IST is given for day and night pixels and does not have the cloud mask applied. The cloud mask is not applied so that a user has access to IST for all pixels regardless of cloud cover. The cloud mask is applied to the IST_Map, and in the Basic_QA datasets. Providing the data in this way allows a user access to IST for all ocean pixels in a swath and allows them to determine or interpret cloud cover from the QA data or an independent cloud data product. The onboard bowtie trim fill data is retained in the variable. An example of the IST_Map variable with a colorized range is shown in Figure 1. Attributes are attached to the variable.

2.2.2 IST_map

To give a view of cloud conditions in the scene, the cloud mask is overlaid on the IST data to make the IST_Map, Fig.1 upper right.

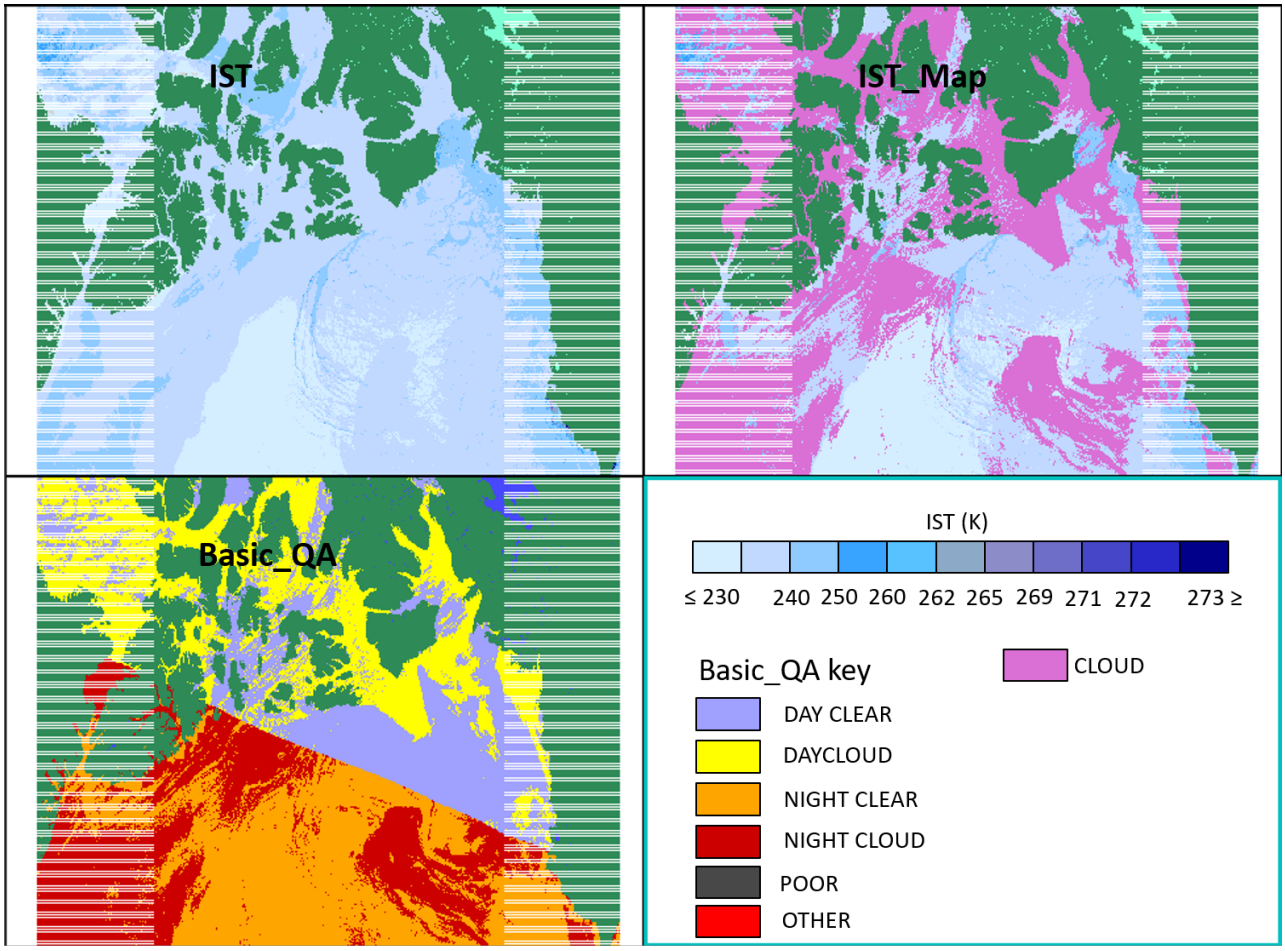

Figure 1. VNP30.A2014074.2055 IST_Data variables. This swath has both day and night observations which are delineated in the Basic_QA dataset, lower left.

2.2.3 Algorithm_Flags

Currently this dataset is set to a fill value of 255 as a place holder for a future version which will have bit flags set. Algorithm-specific bit flags will be set in this variable for data screens applied in the algorithm and for other conditions. See Section 3.3 for a description of planned data screens and bit flags.

2.2.4 IST_Basic_QA

A general quality value is given for pixels processed for ice surface temperature. Setting of basic QA value is similar to the approach used for the MODIS IST products (Riggs et al., 2016). However the setting of basic QA has been revised to include setting values for day and night pixels, and cloud cover (Fig.1 lower left). This is a basic quality value used to indicate quality ranging from best to poor to provide a convenient value for initial quality assessment of the data. Local attributes describing the data are included. The IST basic QA is defined as: IST_Basic_QA: QA_value_meanings are “0-best, 1-

day_good, 2-day cloud, 3-night good, 4-night cloud, 5-other, 6-poor". And with mask values of; IST_Basic_QA: mask_meanings = "237-inland_water, 253-land_mask, 254-bowtie_trim".

2.3 IST Algorithm

A brief description of the algorithm approach is provided to explain the flow of the algorithm and the basic technique used to calculate 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).

The IST is computed from VIIRS bands M15 and M16 brightness temperature data using the split-window method of Yu et al. (1995), updated for VIIRS M15 and M16 bands.

The IST is calculated for all polar oceans in daylight and nighttime (Fig.1). Screening for clouds is accomplished by using the IDPS VIIRS cloud mask data product, VNP35_L2 (Godin, 2014) generated in LSIPS. The VIIRS cloud mask Cloud Detection Results & Confidence Indicator flag is used to mask cloud. If that flag is set to "Confident Cloudy" then the pixel is labeled as cloud-obscured. Cloud flag settings of "Confident Clear", "Probably Clear" and "Probably Cloudy" are interpreted as clear and the IST is calculated. Note: Interpreting these cloud mask settings as all clear allows for the IST to be calculated for possibly cloud contaminated pixels.

Data product inputs to the NASA VIIRS IST algorithm are listed in Table 2, currently using the LSIPS IDPS version of inputs. 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 VNP35_L2 product. All ocean pixels in daylight and nighttime processed for IST, VIIRS radiance data are checked for nominal quality

Table 2. VIIRS data product inputs to the VNP30 algorithm.

ESDT	Data array names	Nominal spatial resolution	Descriptor
NPP_VMAES_L1	BrightnessTemperature_M15	750 m	T_b
	QF1_VIIRSMBANDSDR_M15		Quality flag
	BrightnessTemperature_M16	750 m	T_b
	QF1_VIIRSMBANDSDR_M16		Quality flag
	SolarZenithAngle	750 m	Solar zenith angle
	SatelliteZenithAngle	750 m	Satellite zenith angle

	Latitude	750 m	latitude
	Longitude	750	longitude
VNP35_L2	QF1_VIIRSCMIP (bits 2-3)	750 m	Cloud mask confidence
	QF2_VIIRSCMIP (bits 0-2)	750 m	Land/water mask

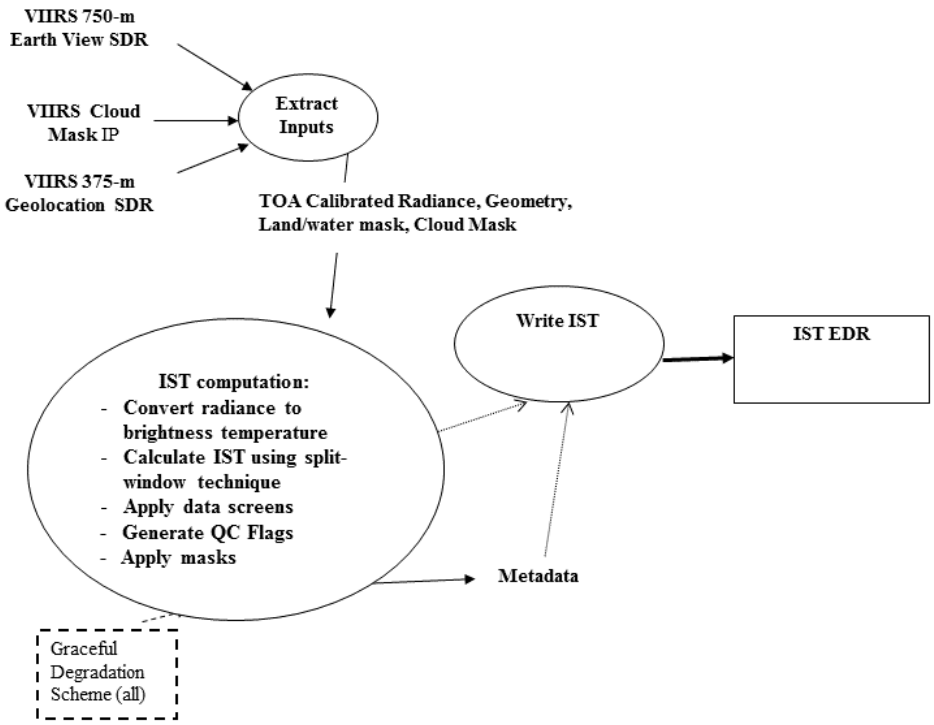

Figure 2. IST Environmental Data Record (EDR) processing architecture.

2.3.1 Data Screens

The M15 and M16 quality flag (QF) data is checked. If the QF data flag is set to other than good data, the basic QA value is set to poor and the IST is calculated. IST is given in Kelvin, with values in the expected range of 213-275 K for each pixel. In next version of the algorithm other data screens will be added and bit flags will be set for screens applied in the algorithm.

2.3.2 Cloud Masking

The cloud confidence flag from VNP35_L2 is used to mask clouds. The cloud confidence flag gives four levels of confidence; Confident Cloudy, Probably Cloudy, Confident Clear and Probably Clear. The cloud mask is not applied to the IST variable so that the IST is calculated for all ocean pixels. The cloud mask is applied

to the IST_map variable. If the cloud mask flag is Confident Cloudy then a pixel is masked as cloud. If the cloud mask flag is set to Confident Clear or Probably Clear or Probably Cloudy it is interpreted as “clear”.

2.3.3 Quality Assessment (QA)

Two QA variables are output: 1) the IST_Basic_QA which gives a simple value, and 2) the QA_Flags 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 then set based on the quality of the L1B input data, and the day/night flag and the cloud mask.

In this version of the algorithm the QA_Flags variable is set to a fill value of 255. In a future version of the algorithm, the QA_Flags variable will contain bit flags set for data screens applied in the algorithm.

2.4 Interpretation of IST Detection Accuracy, Uncertainty and Errors

The accuracy of the IST algorithm for the IDPS VIIRS IST product is approximately 1K (Key et al., 2013). The NASA VIIRS IST accuracy is approximately 1K and continues to 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). An example of autumn freeze up and formation of ice in the Beaufort Sea by the VIIRS IST is shown in Figure 3. A comparison of those IST datasets from an Operation IceBridge flight is shown in Figure 4. The VIIRS IST was found to be within ± 1K of the airborne IST measurements.

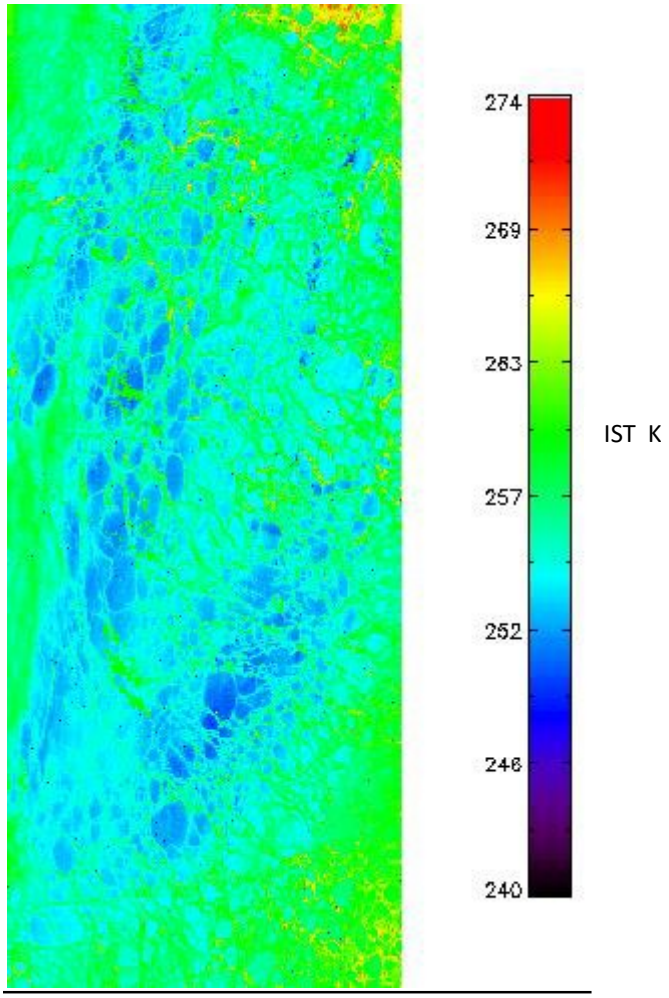

Figure 3. VNP30.A2014255.2110, 2110 UTC, 12 September 2014. IST during fall freeze-up in the Beaufort Sea.

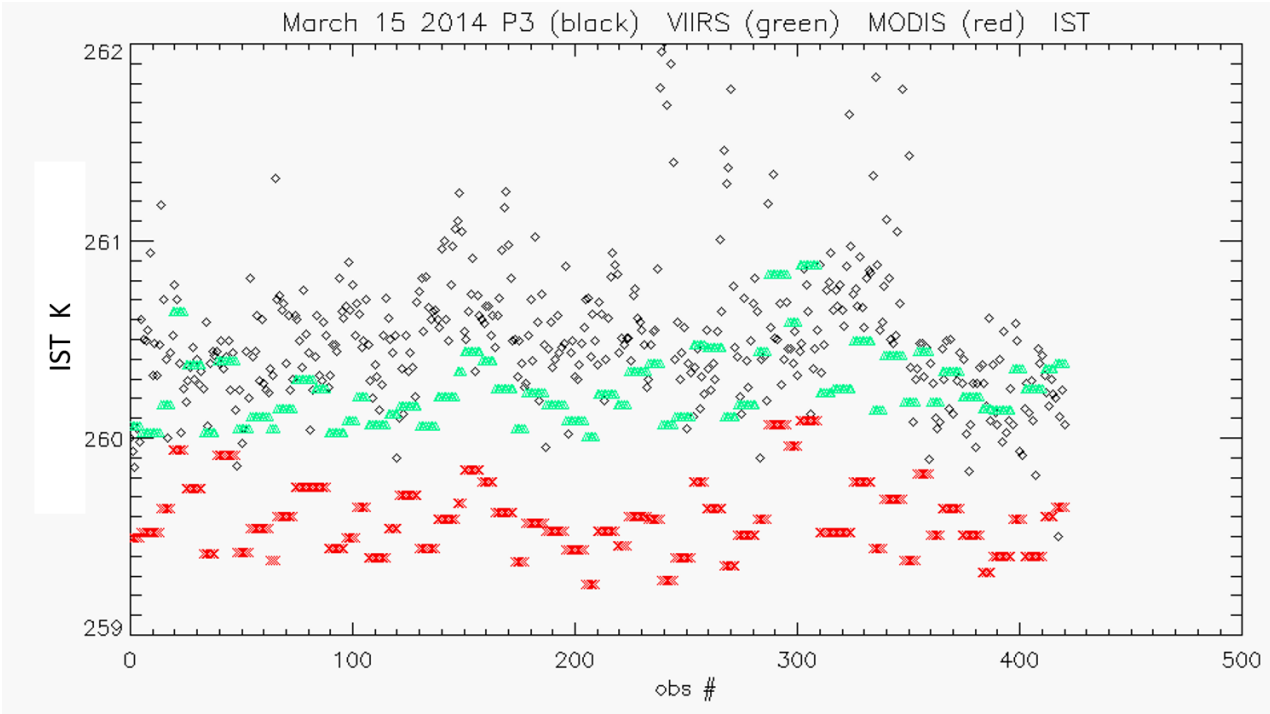

Figure 4. Validation of VIIRS IST. Validation of VIIRS IST (green) with Operation IceBridge flight P3 K19 sensor data (black); P3 IST mean 260.523K, std dev 0.379906K; VIIRS IST mean 260.261K, std dev 0.192122K; MODIS IST (red) 259.593K std dev 0.186308K.

Coefficients obtained from Liu et al. (2015) are 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 be done to ensure accuracy of the IST data.

2.4.1 Uncertainty Estimate

Because sea ice can vary in concentration from near zero to 100 percent in a 750 m pixel, the IST can vary 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 surface and therefore the calculation of ice surface temperature.

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.

2.4.2 Land/water mask

In this version of the algorithm the land/water mask is extracted from the VNP35_L2 product and used to mask land and inland water bodies from processing. When the NASA L1B products become available the algorithm will change to using the land/water mask in the NASA VIIRS geolocation product. That 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 . The LSIPS adapted the MODIS land/water mask to create the VIIRS land/water mask in the geolocation product.

2.4.3 Geolocation accuracy

Geolocation accuracy in NASA VIIRS is in range of ±60 m, providing consistent high accuracy in mapping of the VIIRS data products (Lin et al., 2018). The geolocation uncertainty is negligible in the L2 products, however, geolocation error may be observed from day to day as a shifting of features, e.g., changes in the location of a shoreline from day to day.

3.0 Related Web Sites

Suomi-NPP
https://www.nasa.gov/mission_pages/NPP/main/index.html 0(6/25/19)

Suomi-NPP VIIRS Land
https://viirsland.gsfc.nasa.gov/index.html (6/25/19)

VIIRS
VIIRS Land: https://viirsland.gsfc.nasa.gov/ (06/25/19)
MODIS Snow/Ice Global Mapping Project: https://modis-snow-ice.gsfc.nasa.gov (6/25/19)

Imagery and Data Product Viewing
Worldview: https://worldview.earthdata.nasa.gov (6/25/19)
LDOPE Global Browse: https://landweb.modaps.eosdis.nasa.gov/cgi-bin/browse/browseMODIS.cgi (06/14/19)

NSIDC Data Ordering & User Services
National Snow and Ice Data Center: https://nsidc.org/data/viirs (6/25/19)

HDF5
The HDF Group: https://www.hdfgroup.org/solutions/hdf5/ (6/25/19)

NetCDF
https://www.unidata.ucar.edu/software/netcdf/docs/index.html (06/14/19)

4.0 References

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Appendix A

Listing of global attributes in VNP30

```
// global attributes:
                :ProcessingCenter = "MODAPS-NASA" ;
                :InputPointer =
"VNP35_L2.A2017258.1448.001.2017259050825.hdf,NPP_VMAES_L1.A2017258.1448.001.20172590129
34.hdf" ;
                :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
Keywords" ;
                :LocalGranuleID = "VNP30.A2017258.1448.001.2017259053001.nc" ;
                :PGE_Name = "PGE505" ;
                :publisher_name = "LAADS" ;
                :processing_level = "Level 2" ;
                :EastBoundingCoord = 170.476f ;
                :publisher_email = "modis-ops@lists.nasa.gov" ;
                :Conventions = "CF-1.6" ;
                :publisher_url = "http://ladsweb.nascom.nasa.gov" ;
                :RangeBeginningDate = "2017-09-15" ;
                :PGEVersion = "1.0.5" ;
                :PGE_StartTime = "2017-09-15 14:48:00.000" ;
                :AlgorithmType = "OPS" ;
                :NorthBoundingCoord = -24.78844f ;
                :stdname_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention" ;
                :EndTime = "2017-09-15 14:54:00.000" ;
                :LongName = "VIIRS/NPP Ice Surface Temperature 6-Min L2 Swath 750m" ;
                :ShortName = "VNP30" ;
                :institution = "NASA Goddard Space Flight Center" ;
                :title = "VIIRS Ice Surface Temperature" ;
                :license = "http://science.nasa.gov/earth-science/earth-science-data/data-information-
policy/" ;
                :SatelliteInstrument = "NPP_OPS" ;
                :PGE_EndTime = "2017-09-15 14:54:00.000" ;
                :identifier_product_doi = "10.5067/VIIRS/VNP30.001" ;
                :RangeBeginningTime = "14:48:00.000000" ;
                :GRingPointLatitude = -24.7884, -29.5674, -50.2948, -44.0018 ;
                :LSIPS_AlgorithmVersion = "NPP_PR30 2.2.3" ;
                :VersionID = "001" ;
                :DayNightFlag = "Night" ;
                :project = "VIIRS Land SIPS Ice Surface Temperature Project" ;
                :RangeEndingTime = "14:54:00.000000" ;
                :GRingPointLongitude = 139.534, 170.476, 169.458, 128.476 ;
                :creator_name = "VIIRS Land SIPS Processing Group" ;
                :StartTime = "2017-09-15 14:48:00.000" ;
                :RangeEndingDate = "2017-09-15" ;
                :cdm_data_type = "swath" ;
                :creator_url = "http://ladsweb.nascom.nasa.gov" ;
```

:ProcessingEnvironment = "Linux minion7421 3.10.0-514.21.2.el7.x86_64 #1 SMP Tue Jun 20 12:24:47 UTC 2017 x86_64 x86_64 x86_64 GNU/Linux" ;
:naming_authority = "gov.nasa.gsfc.VIIRSland" ;
:ProductionTime = "2017-09-16 05:30:01.000" ;
:creator_email = "modis-ops@lists.nasa.gov" ;
:identifier_product_doi_authority = "http://dx.doi.org" ;
:SouthBoundingCoord = -50.35314f ;
:WestBoundingCoord = 128.4755f ;