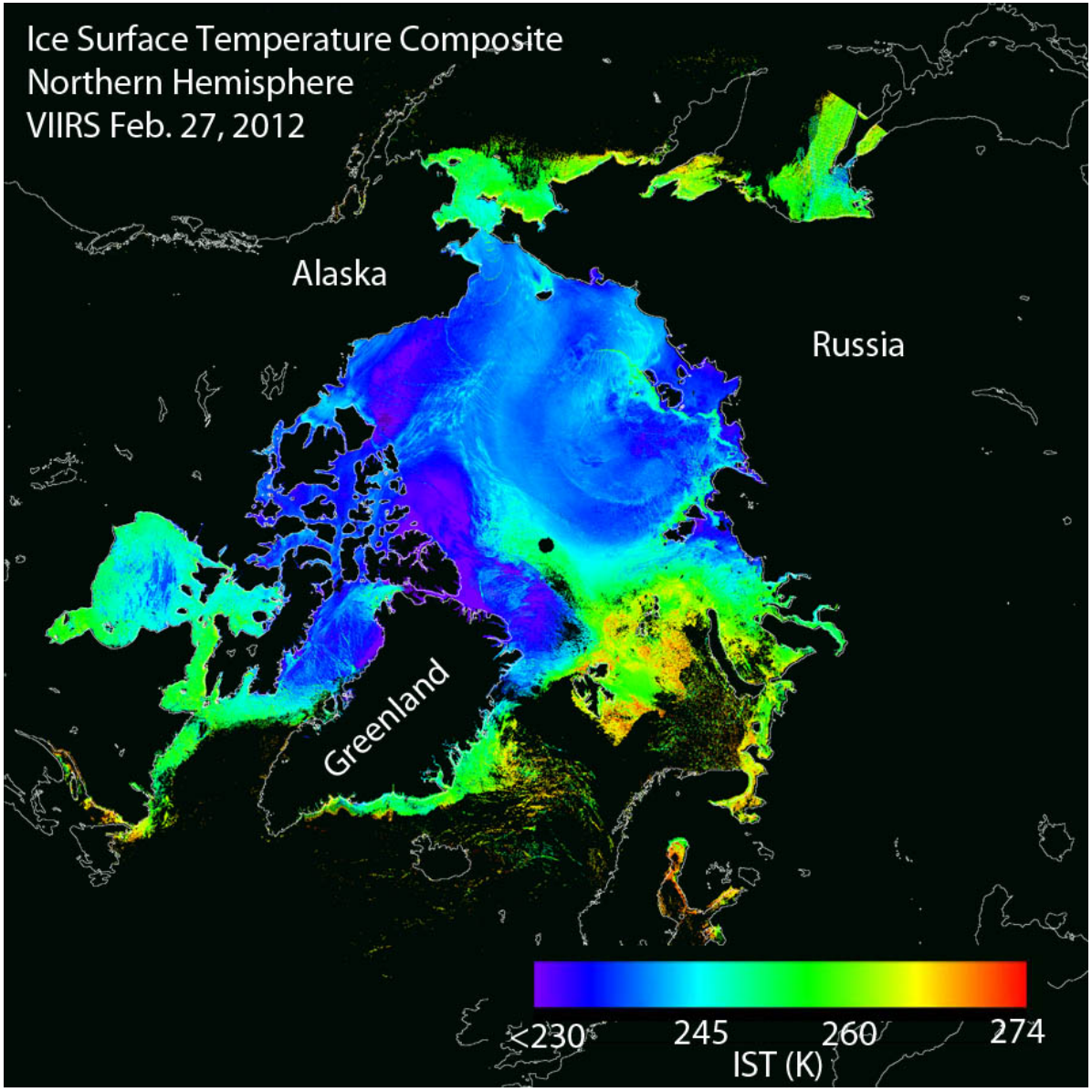
Request for
VIIRS Ice Surface Temperature EDR
Validated Stage 1 Maturity

Validated Stage 1 Effectivity Date: 15 October 2012 (MX 6.4)

Cryosphere Products Validation Team
Jeff Key, NOAA/NESDIS/STAR, Team Lead
Paul Meade, Cryosphere Products JAM

8 January 2014

VIIRS Ice Surface Temperature



Outline

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- Validated Stage 1 EDR Maturity Definition
- Summary of IST EDR
- VIIRS IST EDR requirements
- History of Algorithm Changes/Updates
- Maturity Evaluation
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- Caveats of Operational VIIRS IST EDR
- Conclusions

VIIRS IST EDR Product Users

- U.S. Users
  - NIC, National/Naval Ice Center
  - Naval Research Laboratory
  - OSPO, Office of Satellite and Product Operations
  - STAR, Center for Satellite Applications and Research
  - University of Washington, Polar Science Center
  - GSFC, NASA/Goddard Space Flight Center Hydrological Sciences Branch
  - NWS, National Weather Service, including the Alaska Ice Desk
  - CLASS, Comprehensive Large Array-data Stewardship System

- User Community
  - Navigation
  - Emergency Management
  - Operational Weather Prediction
  - Climate Research
  - DOD

Stage 1 EDR Maturity Definition

Using a **limited** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**. The list of required artifacts supporting each stage of Validated Maturity are identical:

- Algorithm Assessment
  - Evaluation of algorithm performance to specification requirements
  - Evaluation of the effect of required algorithm inputs
  - Error Budget
  - Quality Flag analysis/validation
  - Input from key users
- Identification of the processing environment
  - IDPS Build Number and effectivity date
  - Version of LUT(s) used
  - Version of PCT(s) used
  - Description of environment used to achieve particular stage of Validated
- Documentation
  - Current or updated ATBD
  - Current or updated OAD (algorithm-related redline updates, if applicable)
  - README file for CLASS
  - Product User's Guide (Recommended)
- User Precautions
  - Identification of known issues
  - List of closed Discrepancy Reports between previous maturity milestone and current maturity milestone.
- Assessment of outstanding Discrepancy Reports

Summary of the VIIRS IST EDR

- The VIIRS Ice Surface Temperature (IST) EDR provides surface temperatures retrieved at VIIRS moderate resolution, for snow/ice covered oceans for both day and night.
- The baseline split window algorithm statistical regression method uses two VIIRS Infrared bands, 10.76 µm (M15) and 12.01 µm (M16) for both day and night and is based on the Advanced Very High Resolution Radiometer (AVHRR) heritage IST algorithm (Yu *et al*., 1995).
- IST EDR performance is dependent upon on the quality of the input SDR brightness temperatures, VIIRS Cloud Mask IP cloud confidence, Ice Concentration IP, Aerosol Optical Thickness IP and regression coefficients derived from matchups between the VIIRS M15 and M16 top of atmosphere (TOA) brightness temperatures and truth surface temperature sources for snow/ice covered ocean surfaces.

VIIRS IST EDR L1RD Requirements

Ice Surface Temperature (IST)

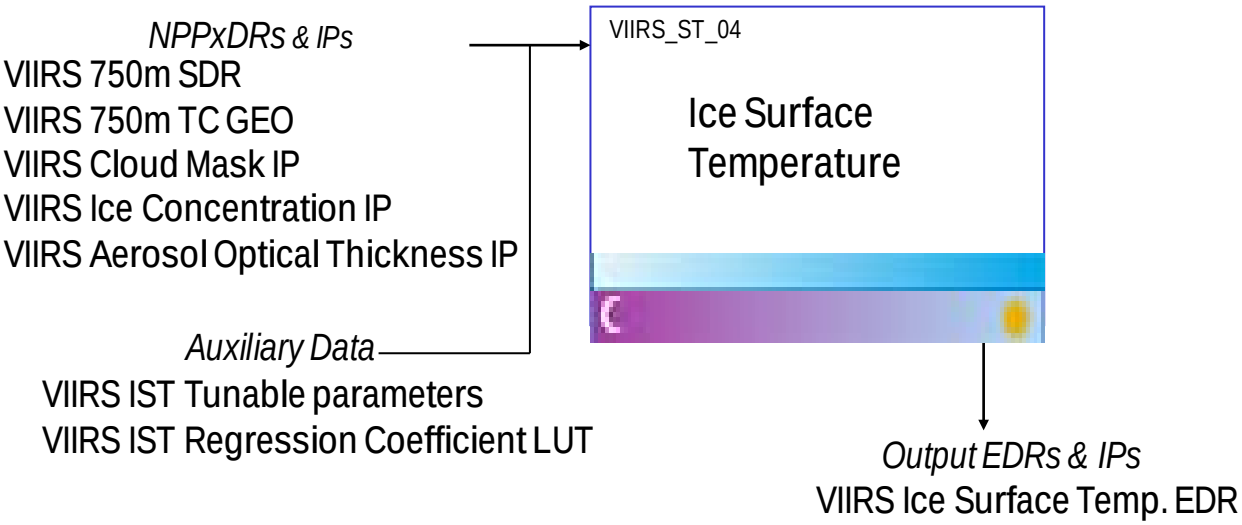
“IST is the radiating, or "skin", temperature at the ice surface. It includes the aggregate temperature of objects comprising the ice surface, including snow and melt water on the ice. Inland water bodies and coastal ice temperatures will be obtained from the LST EDR.

VIIRS IST EDR L1RD Requirements (Continued)

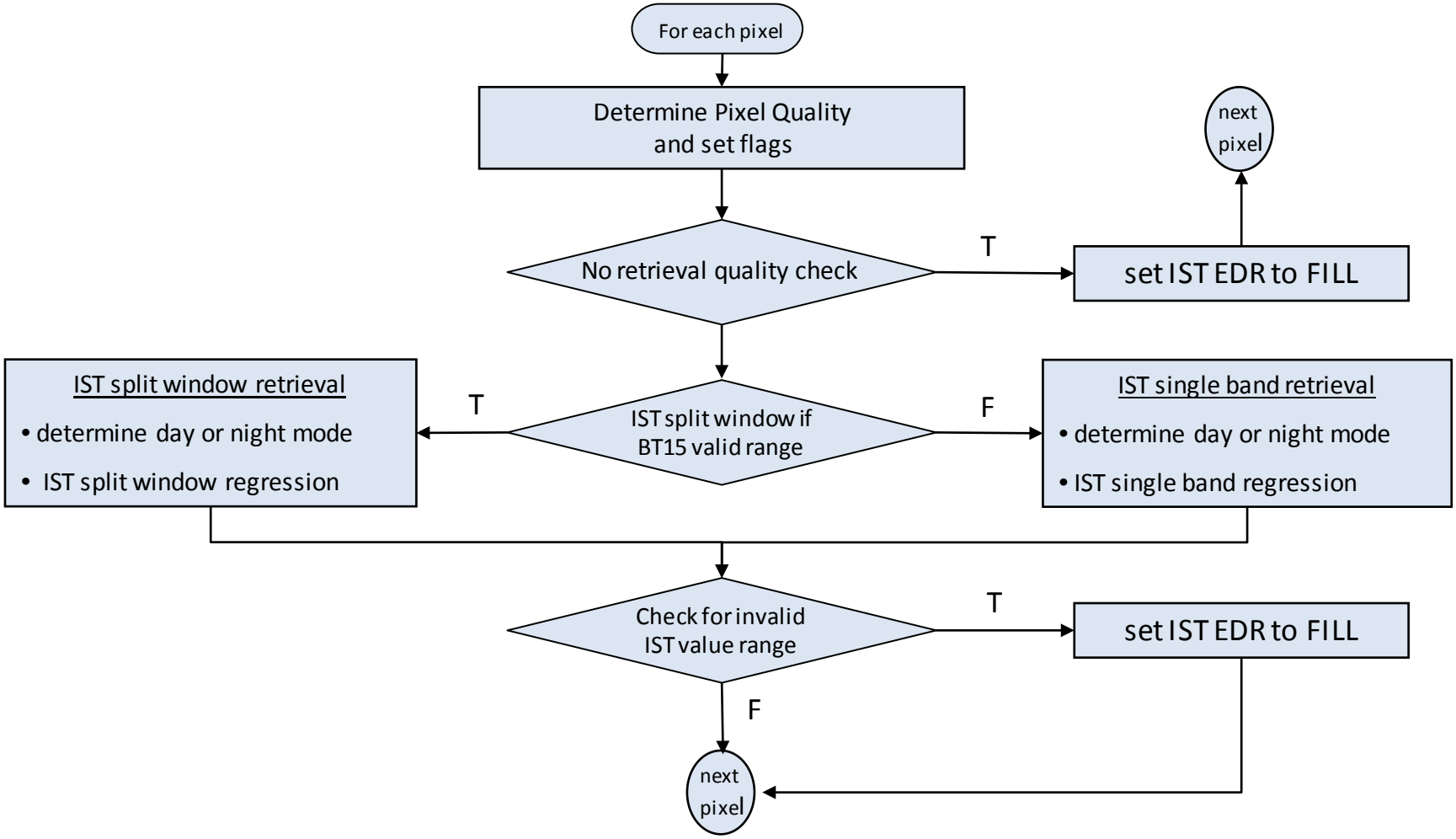
Ice Surface Temperature (IST) Requirements from L1RD Supplement. V2.9 (27 June 2013)

EDR Attribute	Threshold	Objective
IST Applicable Conditions **1. Clear, only**		
a. Sensing Depth	Ice Surface	Ice Surface
b. Horizontal Cell Size **1. Nadir** **2. Worst Case**	 1 km 1.6 km	 0.1 km 0.1 km
c. Mapping Uncertainty, 3 sigma **1. Nadir** **2. Worst Case**	 1 km 1.6 km	 0.1 km 0.1 km
d. Measure Range	213-275 K	213-293 K (2 m above ice)
e. Measurement Uncertainty	1 K	
f. Refresh	At least 90% coverage of the global every 24 hours (monthly average)	12 hrs
g. Geographic Coverage	Ice-covered oceans	All ice-covered waters

Summary of the VIIRS IST EDR Algorithm Inputs



Summary of VIIRS IST EDR Processing Flow



Status of Upstream Products

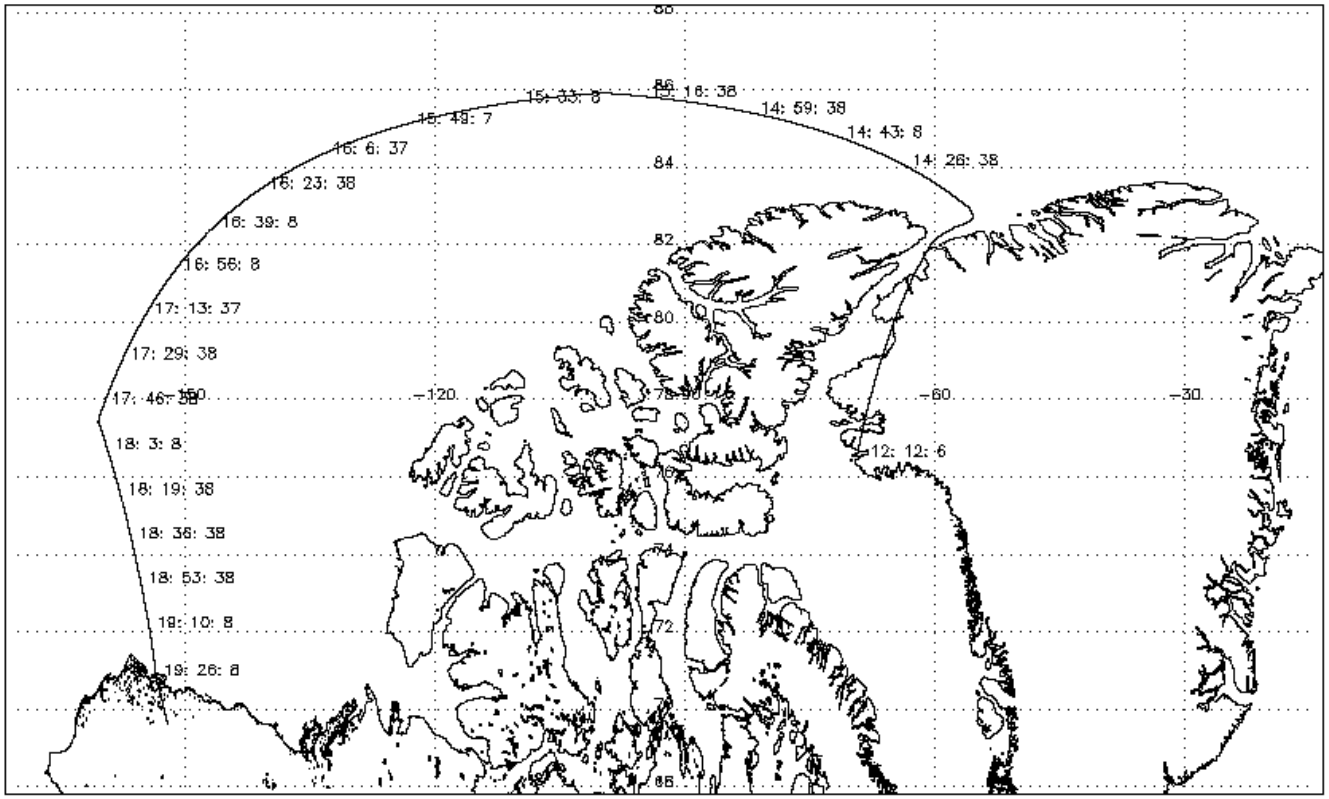
IST EDR performance is dependent on VIIRS SDR, VIIRS Cloud Mask IP, Ice Concentration IP, Aerosol Optical Thickness IP and IST Regression Coefficients

- VIIRS SDR Cal and Geo products reached *provisional* maturity in March, 2013. (*Validated* maturity review was December 2013)
- VIIRS Cloud Mask IP reached *provisional* maturity in February, 2013. (*Validated* maturity review was yesterday, January 2014)
- VIIRS Aerosol Optical Thickness reached *beta* maturity in September 2012 and *provisional* in March 2013
- VIIRS Ice Concentration IP reached *provisional* maturity in December 2013.

Stage 1 Maturity Evaluation

- Maturity Evaluation Approaches
  - Visualizations and quantitative comparisons of daily global gridded VIIRS IST, comparison with MODIS IST and NCEP surface air temperature, Ice Bridge flight IST
  - Time series analysis and bias analysis
    - NH analysis dates: 1/29/2012, 2/1/2012, 3/14/2012; Aug 2012 – Jul 2013
    - SH analysis dates: 4/10/2012; Aug 2012-Jul 2013
    - Beaufort Sea analysis dates: 3/14/2012 (IceBridge), 2/12/2012, 2/25/2012, 2/26/2012, 3/30/2012, 6/8/2012; Mar-Apr 2013
    - Terra Nova Bay analysis dates: 2/12/2012, 2/25/2012, 2/26/2012, 3/30/2012

Stage 1 Maturity Evaluation – VIIRS IST EDR and IceBridge Flight IST



Track of the NASA P-3 aircraft for the March 14, 2012 IceBridge flight. UTC times are shown along the track. The P-3 flew at an altitude of 1000 ft over the sea ice. Among several instruments, it carried a KT-19: a downward-pointing, IR pyrometer that measures the surface temperature (in this case, the IST).

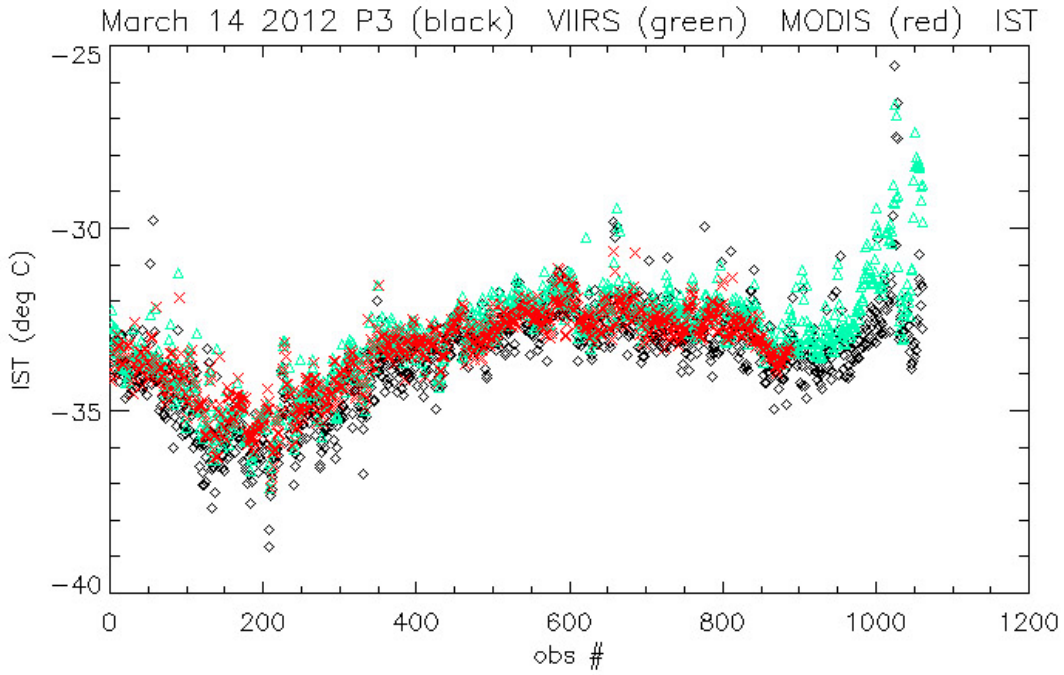
Stage 1 Maturity Evaluation – VIIRS IST EDR and IceBridge Flight IST

NASA's Land PEATE re-processed portions of the VIIRS IST EDR that are co-incident with IceBridge flights over sea ice during March and April 2012. The resulting VIIRS IST EDR shows much better agreement with the ice surface temperature observed by the IceBridge P-3's KT-19 instrument than the previous IST EDR data produced in March 2012.

A comparison of IST measured by the NASA P-3 aircraft's KT-19 instrument (J. Yungel, PI) and the VIIRS IST EDR

mean VIIRS = -33.2 ˚C
mean KT-19 = -33.7 ˚C
mean MODIS = -33.4 ˚C

RMS differences:
VIIRS - KT-19 = 0.6 ˚C
MODIS- KT-19 = 1.2 ˚C
VIIRS – MODIS = 1.1 ˚C

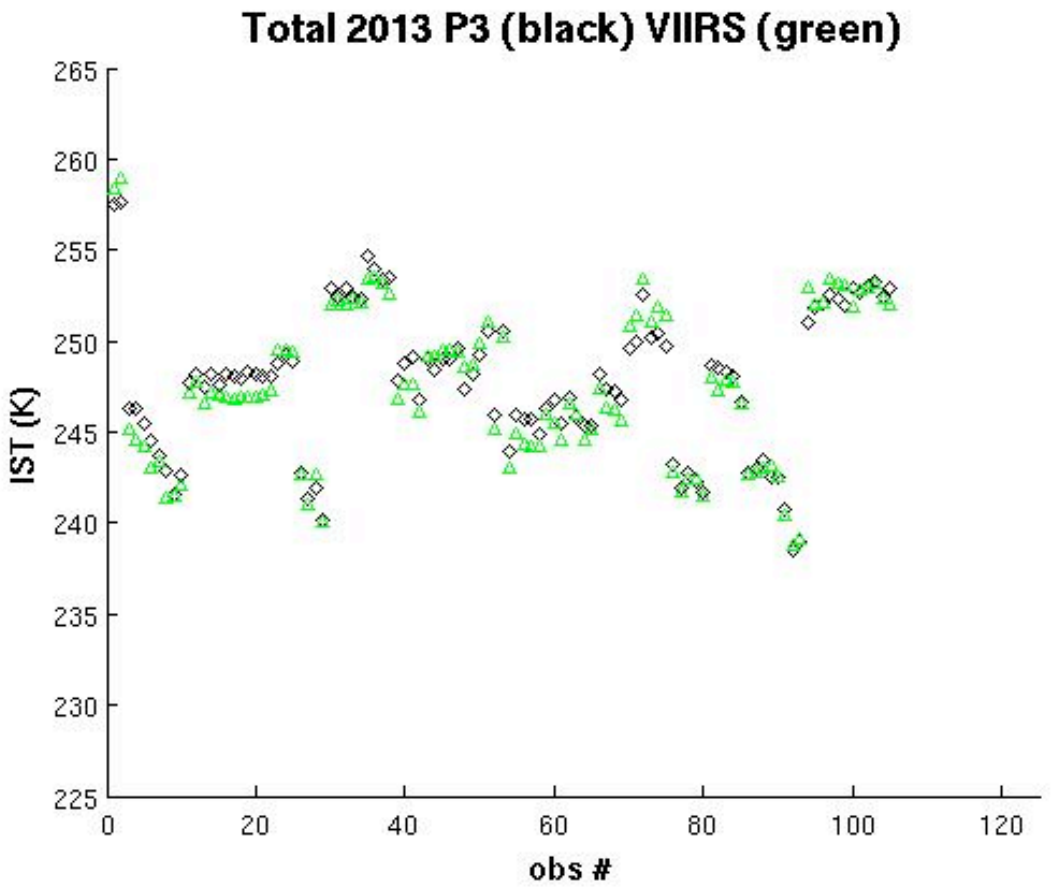


Comparison between the IST (in deg C) measured by the KT-19 (in black, smoothed over 100 points), the nearest VIIRS IST measurement (in green) and MODIS observation (red). The comparison is for the leg from 16:03:37 -19:10:08 (west of -120 lon). The VIIRS overpass occurred from 16:01 - 16:06 UTC . VIIRS, MODIS, and the KT-19 IST's show consistently good agreement along the flight track.

Stage 1 Maturity Evaluation – VIIRS IST EDR and IceBridge Flight IST

Results for March-April 2013 are similar:

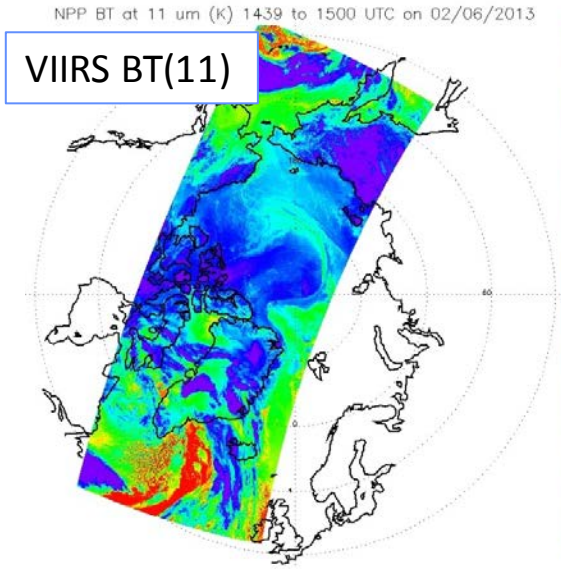
VIIRS IST bias = -0.31 K
RMS = 0.87 K
Average VIIRS IST: 247.49 K
Average KT_19 IST: 247.81 K

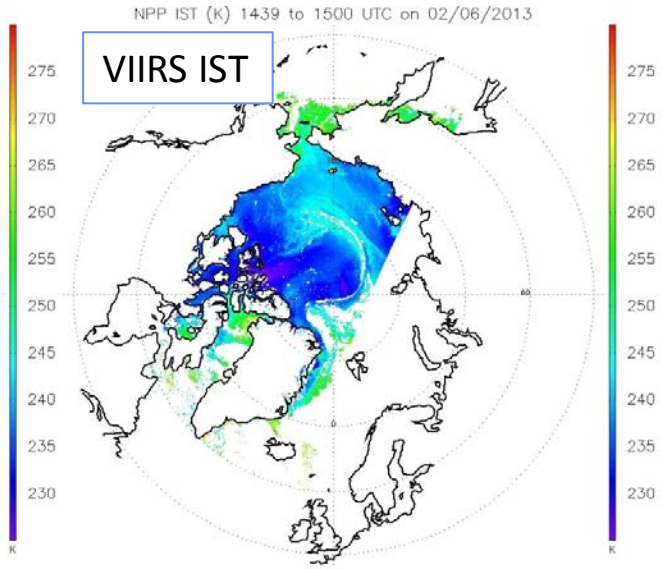


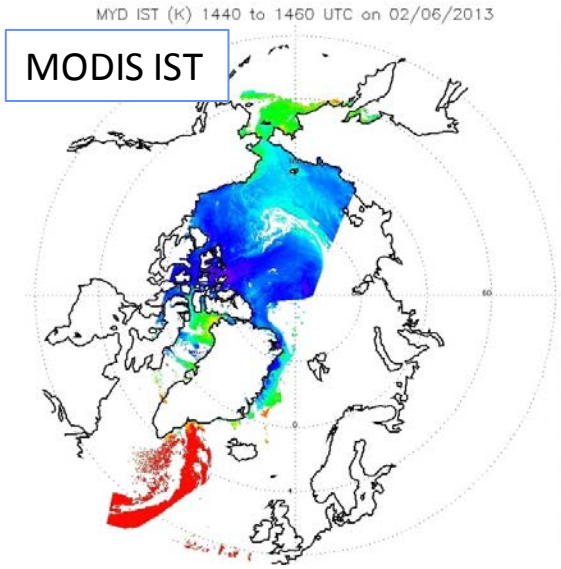
Stage 1 Maturity Evaluation – VIIRS IST, MODIS, and NCEP

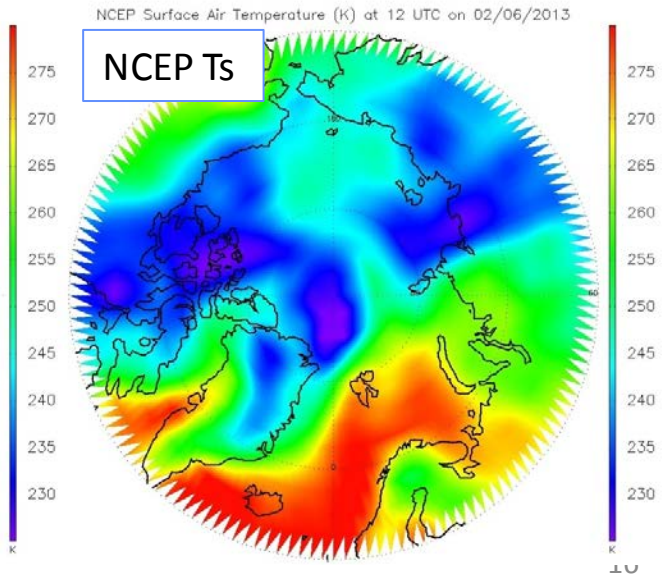
Ice Surface Temperature (IST) EDR validation activities have shown that VIIRS IST has a 0.5-2 K *cold bias* relative to the MODIS Ice Surface Temperature product. The bias for VIIRS Land Surface Temperature over the ice sheet (not shown) is less than for IST.

Comparisons to NCEP and International Arctic Buoy Program (IABP) air temperatures show a similar spatial pattern but yield a VIIRS *warm bias* of 1 K or more, which is the opposite of the MODIS comparison. The comparison confirms the validity of the MODIS IST.

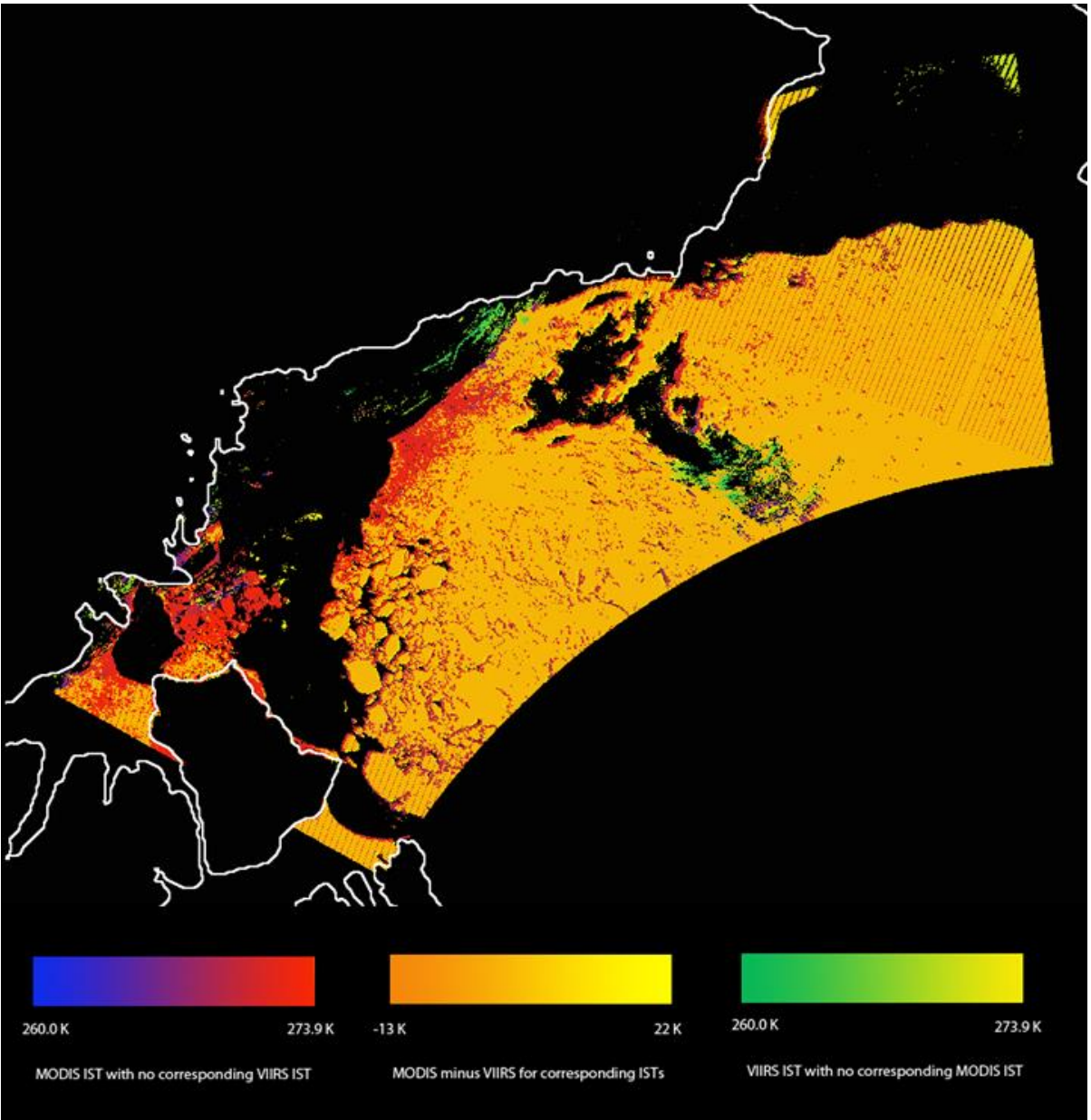








Stage 1 Maturity Evaluation – VIIRS IST EDR and MODIS IST



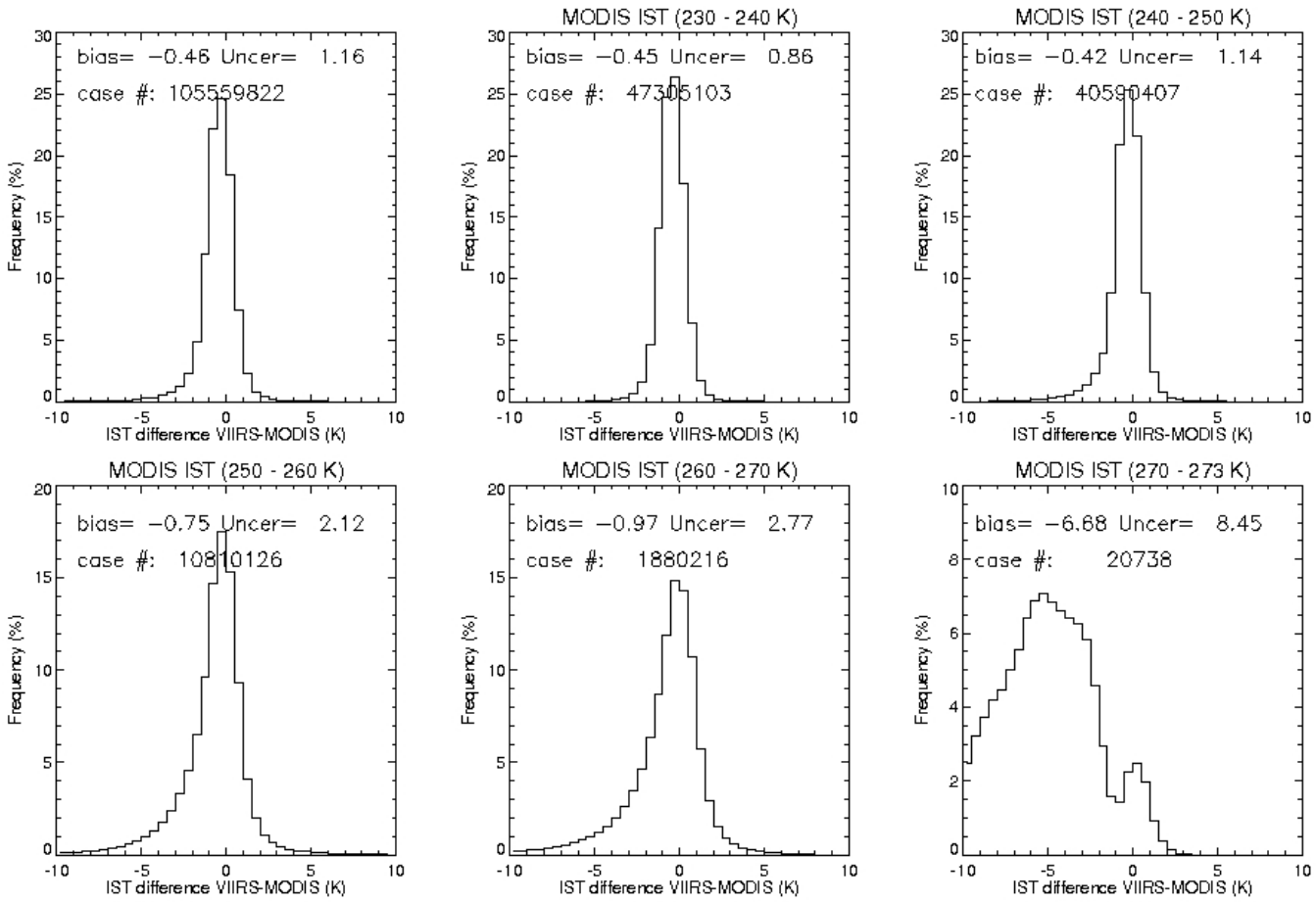
Statistics describing the MODIS/VIIRS IST comparison June 8, 2012

Bias (MODIS – VIIRS) = 0.181 K
Variance: 1.086 K

Stage 1 Maturity Evaluation – VIIRS IST vs MODIS IST

VIIRS is biased low (too cold) relative to MODIS, though the bias is relatively small for most of the temperature range.

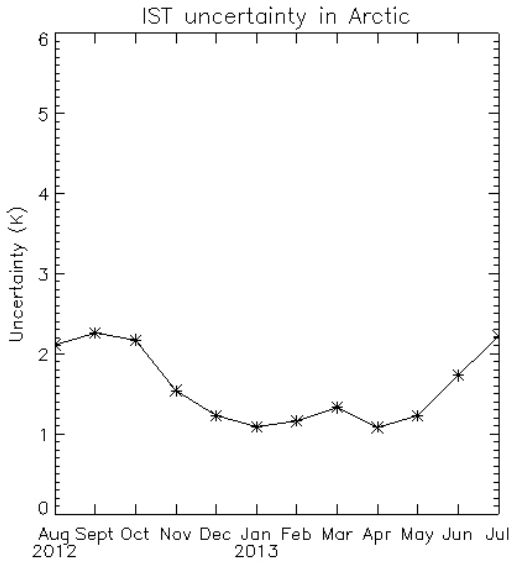
Of greater concern is the uncertainty, which is large at higher temperatures.

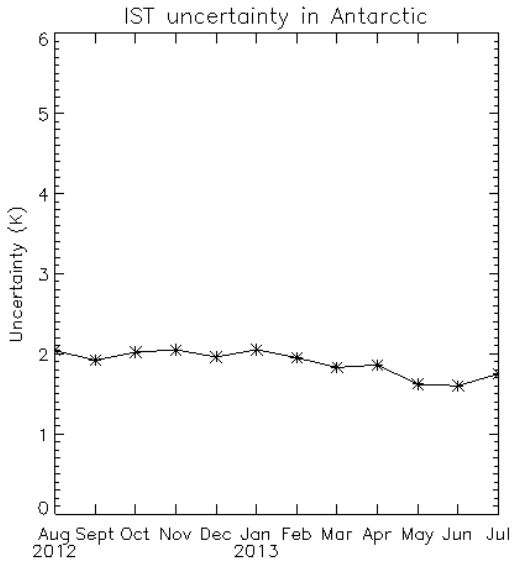


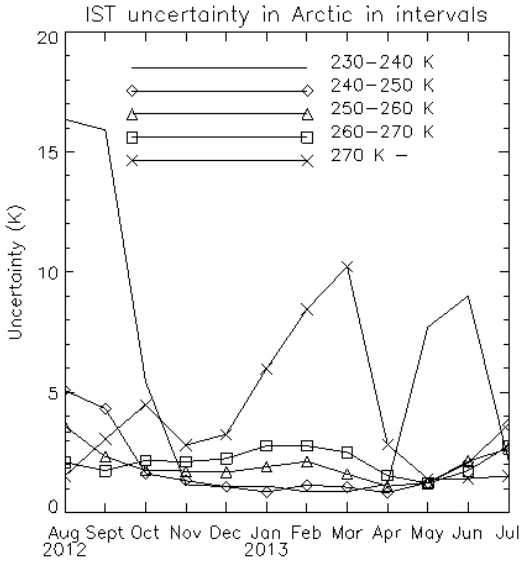
Histogram of ice surface temperature differences of NPP VIIRS and MODIS (Aqua and Terra) in February 2013 in the Arctic for all cases (upper left), and for cases with MODIS ice surface temperature in the ranges 230-240 K, 240-250 K, 250-260 K, 260-270 K, and 270-273 K. Measurement bias (bias) and measurement uncertainty (Prec) are indicated for each bin.

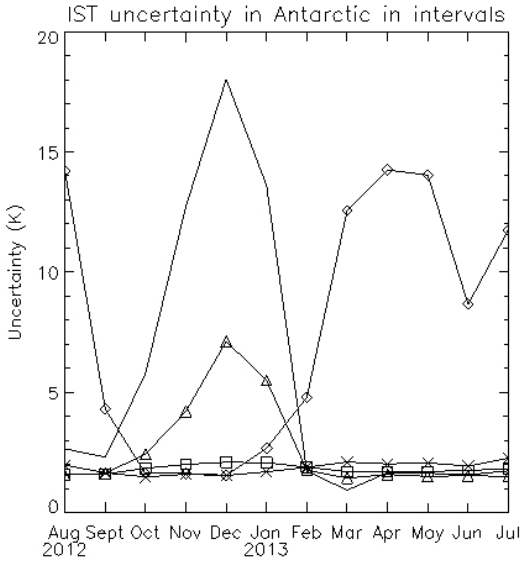
Stage 1 Maturity Evaluation – VIIRS IST vs MODIS IST

Uncertainties of VIIRS ice surface temperature (IST) based on collocated VIIRS and MODIS (Terra and Aqua) from August 2012 to July 2013 for all cases in the Arctic (upper left), for all cases in the Antarctic (upper right), for cases in different MODIS IST intervals in the Arctic (lower left), and in the Antarctic (lower right).





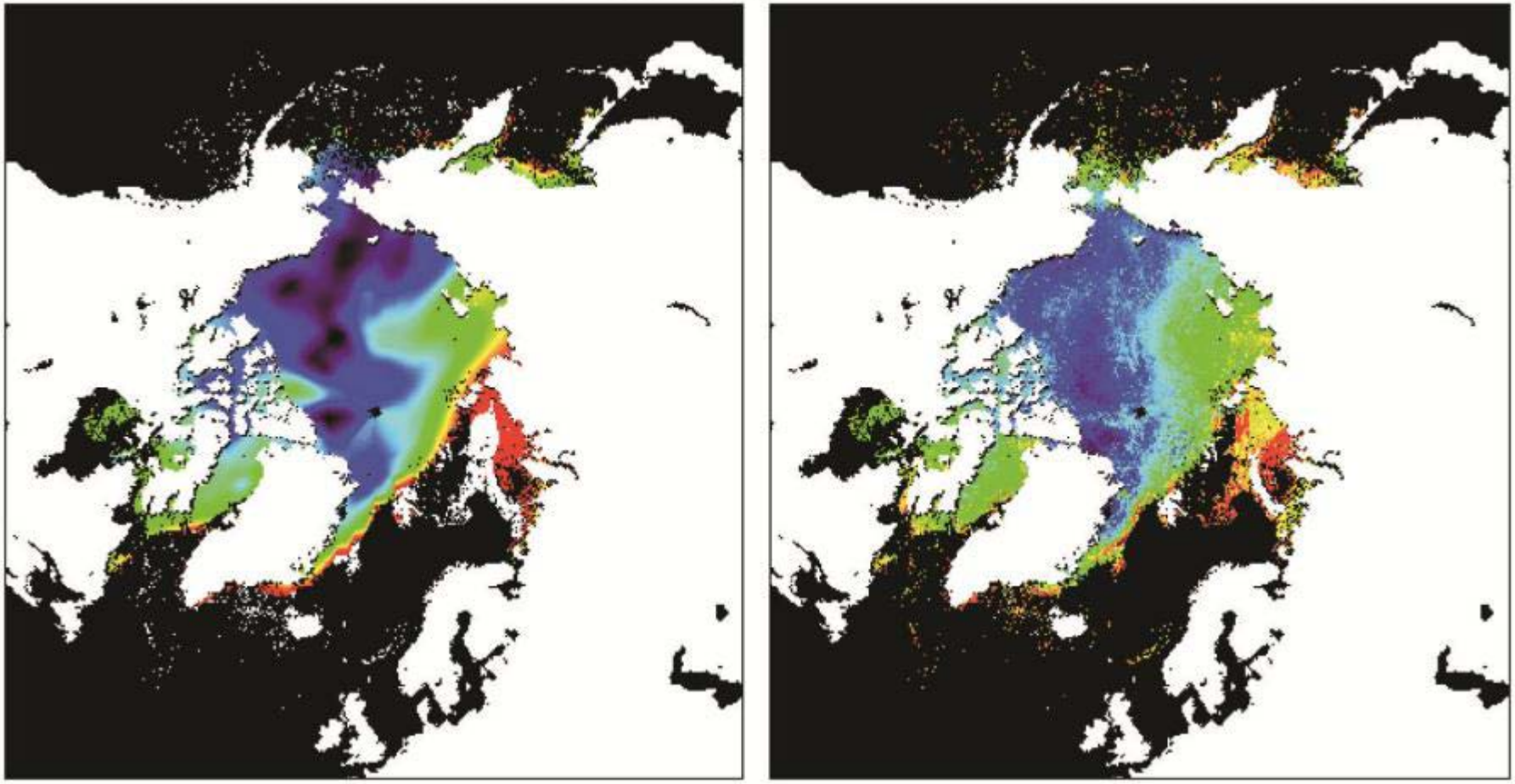




Stage 1 Maturity Evaluation – NH comparison

NCEP surface temperature (range = 220K to 270K)

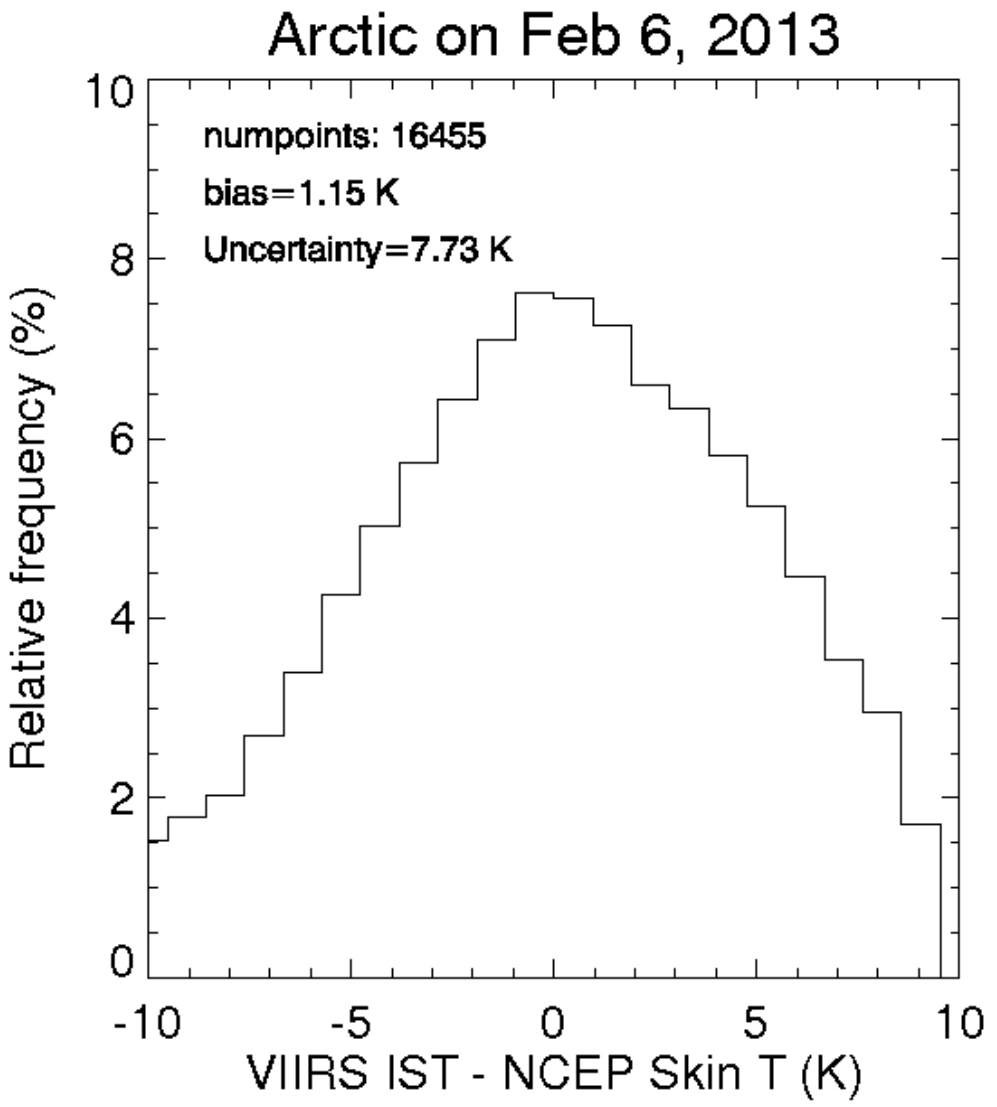
VIIRS IST (range = 220K to 270K)



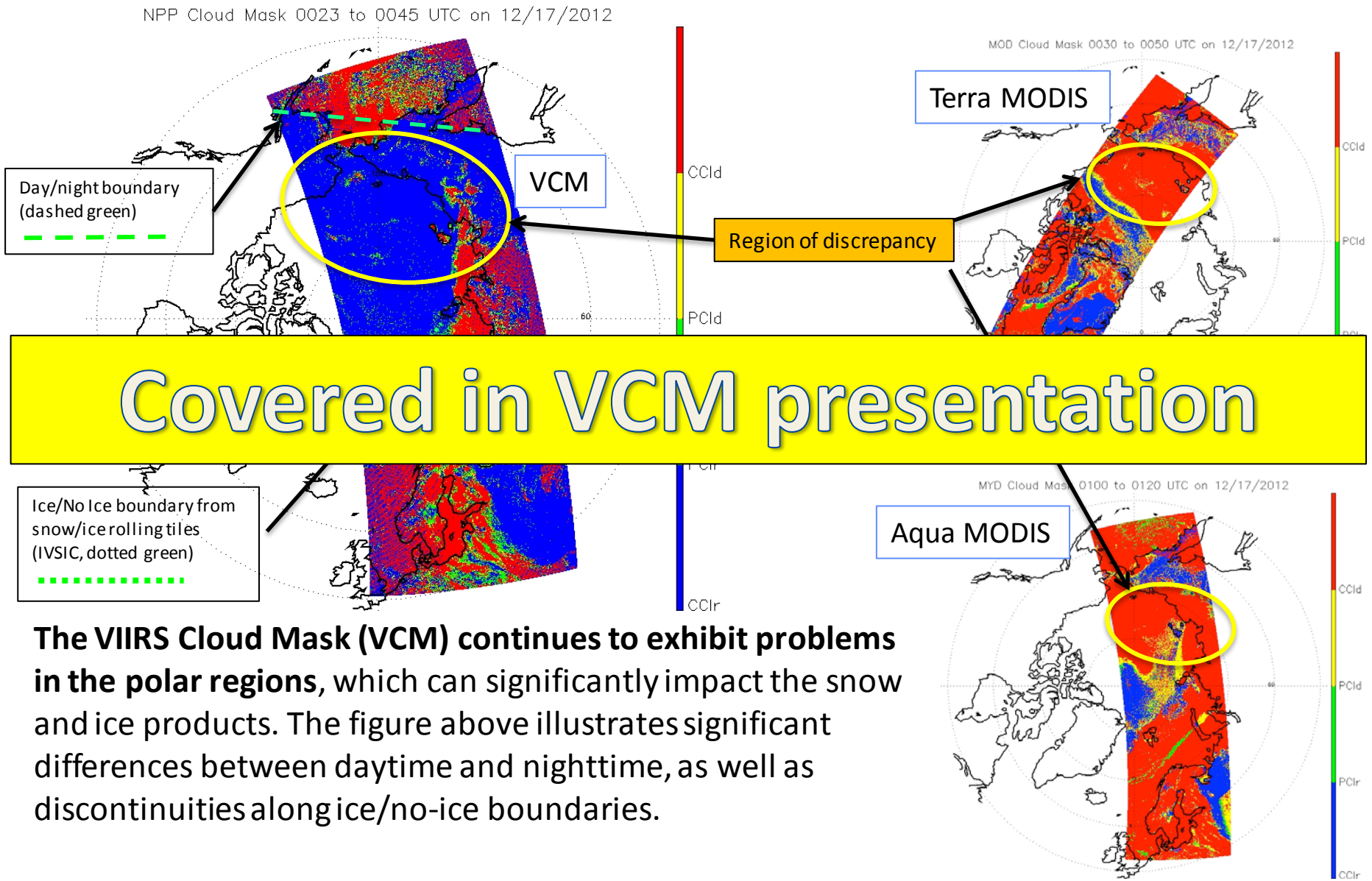
NCEP vs. VIIRS IST, Feb 27, 2012. Spatial patterns are similar.

Stage 1 Maturity Evaluation – Global comparison to NCEP

VIIRS is biased high (warm) compared to NCEP reanalysis. However, the NCEP skin temperature used in this analysis is a forecast, not an analysis. This result is the opposite of the MODIS & IceBridge results.



Stage 1 Maturity Evaluation – Cloud Mask Impacts



The VIIRS Cloud Mask (VCM) continues to exhibit problems in the polar regions, which can significantly impact the snow and ice products. The figure above illustrates significant differences between daytime and nighttime, as well as discontinuities along ice/no-ice boundaries.

Exclusion Conditions

From L1RD Supplement, v2.9, Table D1, S-NPP Performance Exclusions:

5.6.1, e	IST Measurement Uncertainty	APU performance excluded in the presence of thin cirrus clouds	The definition of Clear/Cloudy Conditions is new and depends on the results of S-NPP Cal/Val to establish the required threshold for a detectable cloud; science algorithms require enhancement for handling thin cirrus radiative transfer

This is an exclusion for S-NPP, which apparently is being interpreted as a requirement for J1.

Neither the SST nor cryosphere teams think that retrieving surface temperature under any cloud cover is a good idea from a scientific perspective. The uncertainty would be too large. It is not clear who requested this.

From a technical perspective it's not currently possibly for IST. IST is only retrieved for *confidently clear* pixels. Pixels with thin cirrus might still be *confidently cloudy*. To do a retrieval under thin cirrus we would need cloud optical depth, but optical depth is not retrieved for *confidently clear* pixels.

Discrepancy Reports (DRs)

Date	Update/DR#	Reason	Status
04-17-2013	7138	IST EDR OAD Corrections	open technical memo provided in April 2013 NPP_VIIRS_IST_EDR_OAD_corrections_10April2013.docx
04-17-2013	7137	IST EDR ATBD Section 2.3 Wording Error Correction	open technical memo provided in April 2013 NPP_VIIRS_IST_EDR_ATBD_corrections_10April2013.docx
11-18-2011	4457	EDR PR to define mid quality criteria	open EDR PR draft updates prepared
11-18-2011	4456	EDR PR update to Define the exclusion criteria for quality summations	open EDR PR draft updates prepared
11-18-2011	4455	Update EDR PR to define high quality retrievals	open EDR PR draft updates prepared
12-22-2010	4136	ECR A-337 Dec 10 Look Up Table drop	request closure LUT update implemented in MX6.2 (08/10/2012)
07-17-2009	2936	Ice Surface Temp and IST use different emissivities for ice	plan to deliver updated Surface Temperature IP coefficients in Jan 2014; updated coefficients are currently being verified

Data Quality Threshold Tables (DQTT)

Synthesizing from the EDR PR, the CDFCB-X Vol. VI, and the IST DQTT XML file:

1. There are three Data Quality Flags that are linked to potential Data Quality Notifications (DQNs):
   a) EDR Summary Quality - The percentage of pixels within a granule with a high retrieval quality
   b) Exclusion Summary - The percentage of pixels within a granule with excluded conditions
   c) Summary Range Check - The percentage of retrieved pixels outside of the expected range (213 K to 275 K)
2. For each of these, the current Data Quality Threshold Table (DQTT) specifies that a DQN will occur if (and only if) the percentage in question is less than 0% AND that this has occurred a minimum of 80 times. Furthermore, the DQN "severity" in each case (if one is issued) is "Normal" (i.e., not severe).
3. The DQTT specifies that each of the three DQN is currently OFF (the <active> tag is "false").

This table is currently a placeholder DQTT, as none of these DQN's can be triggered as currently specified. The Cryosphere Team will coordinate with Raytheon OAA to define appropriate DQTTs.

Val Stage 1 Justification Summary

Algorithm Assessment

- *Performance*: The product meets accuracy requirements under some, but not all, conditions. Evaluation is based on a limited number of focus days (global comparisons for retrieval products). The product has known flaws but these products are of sufficient quality to justify use by a broader community.
- *Impact of algorithm inputs*: Some false ice retrieved by the VIIRS Sea Ice Concentration IP has been linked to cloud leakage from a VIIRS Cloud Mask (VCM). IST EDR performance is expected to benefit from improvements to resolve the current VCM bias toward over-prediction of confidently clear regions at night in polar regions.
- *Error budget*: Uncertainties for primary sample sets are 0.6-1.0K (requirement is 1K). Uncertainties when compared to MODIS IST are larger than requirement at higher temperatures.
- *Quality flag analysis*: Ability to check for reduced quality VIIRS Ice Concentration IP input based on quality flags with additional quality checks to be added to the Ice Concentration IP.
- *Input from users*: The primary user is the National Ice Center. A NIC presentation was given at the IST Provisional Maturity Review.

Val Stage 1 Justification Summary

Processing Environment

- *IDPS build and effectivity date*: MX 6.4, 15 October 2012 (same as Beta and Provisional)
- *Version of LUT(s)*: VIIRS-IST-Coef-LUT, version PS-1-D-NPP-2-PE (December 2010 prelaunch regression coefficients)
- *Version of PCT(s)*: VIIRS-IST-EDR-AC, version 1_devel_dev_all-all
- *Description of environment used*: Build MX 6.4, data from CLASS with the exception of reprocessed IST EDR by Land PEATE for Feb 2012 case

Documentation

- *ATBD*: Minor corrections to the ATBD have been submitted
- *OAD*: Minor corrections to the OAD have been submitted
- *README file for CLASS*: To be extracted from Report
- *Product user guide*: Deemed unnecessary given the abundance of other documentation on algorithms, data formats, and cautionary notes

Val Stage 1 Justification Summary

User Precautions

- *Identification of known issues*: Larger uncertainty at high temperatures; cloud mask errors; discrepancy with Surface Temperature IP (solution has been proposed)
- *Discrepancy reports*: Issues are being addressed.

Additional Supporting Documentation

- TIM Meetings and Presentations (*most were not on IST*)
  - DRAT on DRs (ice characterization and IST), March 2012
  - Cal/Val Team Meeting, April 2012
  - TIM on snow/ice rolling tiles, June 2012
  - TIM on snow/ice rolling tiles, July 2012
  - DRAT on gridding, September 2012
  - TIM on issues near cloud edges, January 2013
  - TIM on automated snow/ice map use in Rolling Tiles, February 2013
  - TIM on gridding, April 2013
  - TIM on snow cover fraction, May 2013
  - TIM on ancillary data in gridding, June 2013
  - Meeting with Surface Type EDR group, July 2013

- Monthly/weekly reports
  https://groups.ssec.wisc.edu/groups/jpss/cryosphere/reports

Future Plans and Issues

- No code changes currently planned
- Detailed performance characterization requires:
  - Update of IST regression coefficients based on matchup with VIIRS and truth IST sources
  - Improvements, consistency, and stability in the VIIRS cloud mask
- Other actions:
  - Ability to check for reduced quality VIIRS Ice Concentration IP input based on quality flags with additional quality checks to be added to the Ice Concentration IP

Conclusion

- VIIRS IST EDR has met the Validated Stage 1 maturity level based on the the evidence shown
- Some issues have been uncovered during validation and solutions are being evaluated.
  - Improvements in IST EDR performance may be realized as the VIIRS Cloud Mask IP matures and additional quality flags become available in the VIIRS Ice Concentration IP to avoid IST retrievals near clouds.
- The Validated Stage 1 effectivity date is 15 October 2012 (MX 6.4). VIIRS Cloud Mask IP improvements in this build notably improved product performance.