Provisional Maturity Science Review For Cryosphere Products – Sea Ice

Presented by Jeff Key, Rich Dworak, Xuanji Wang, Yinghui Liu

Date: 2019/5/16

JPSS NOAA NASA

JPSS Data Products Maturity Definition

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

PROVISIONAL MATURITY REVIEW MATERIAL

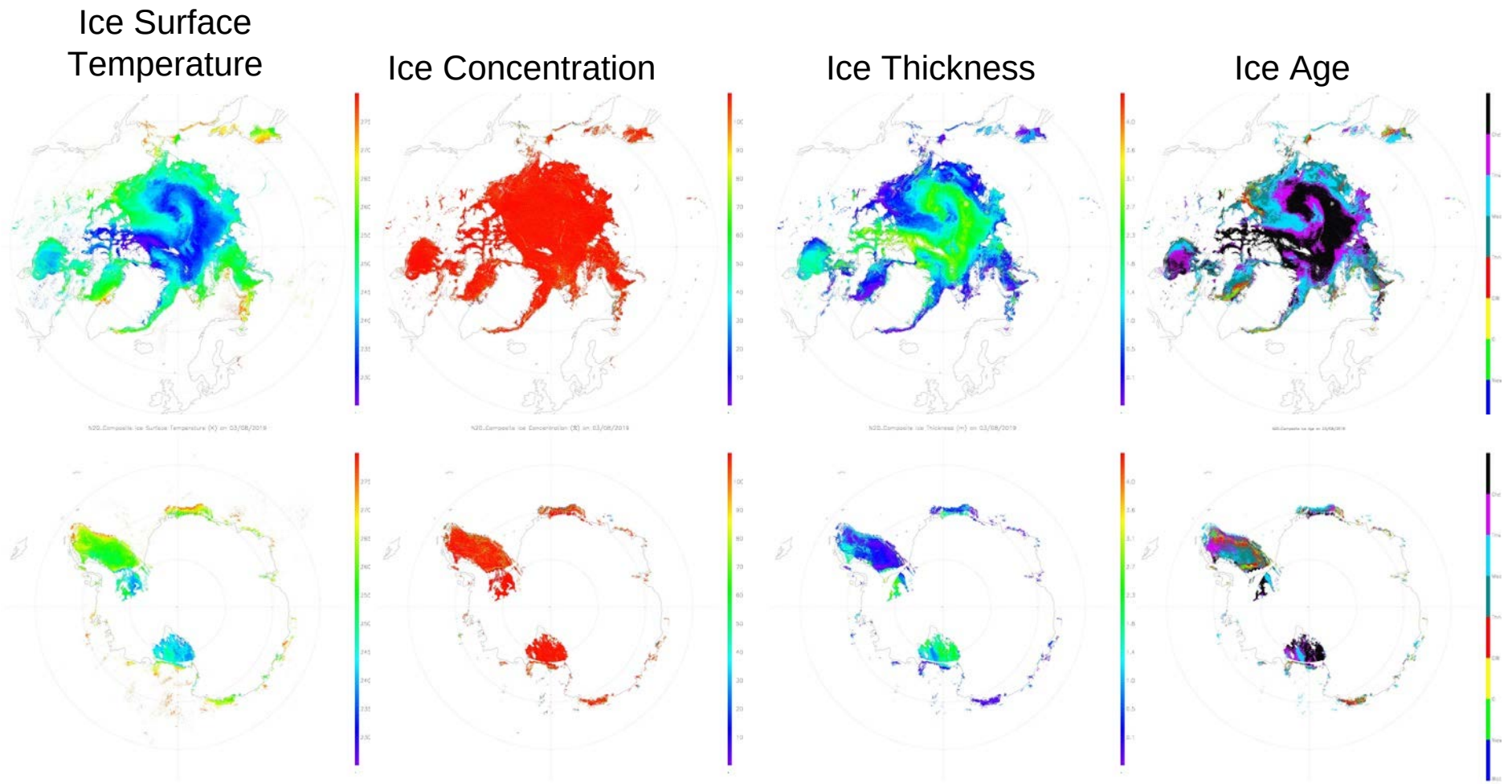
Sea Ice Cal/Val Team

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Richard Dworak	CIMSS/UW-Madison	Sea ice product analysis and validation, data processing, and project management.
Xuanji Wang	CIMSS/UW-Madison	Sea ice thickness/age algorithm development, analysis ,and validation.
Mark Tschudi	CCAR/UC-Boulder	Sea ice product analysis and validation
Yinghui Liu	NOAA/NESDIS	Sea ice temperate/concentration algorithm development, analysis ,and validation, and project management.
Jeff Key	NOAA/NESDIS	Overall snow and sea ice project management, assistance on analysis and validation

Thanks to the AIT/ASSISTT team for help with the data.

NOAA-20 Sea Ice Product Examples (NDE I&T v2r0)



Daily composites of sea ice temperature, concentration, thickness, and age on March 08, 2019. Top row is the Arctic; bottom row is the Antarctic.

(Note: Validation results in the following slides are based on individual overpasses.)

Requirements: Sea Ice Concentration

Product performance requirements from JERD Vol. II and L1RD versus observed/validated. Stats are relative to AMSR2 and S-NPP.

Attribute	Threshold	Observed/validated
Geographic coverage	All ice-covered regions of the global ocean	All ice-covered regions of the global ocean
Vertical Coverage	Ice surface	Ice surface
Vertical Cell Size	Ice surface	Ice surface
Horizontal Cell Size	1 km	1 km
Mapping Uncertainty	1 km	1 km
Measurement Range	0 – 100%	0 – 100%
Measurement Accuracy	10%	NH: -1.3%, SH: -2.2% NH: 0.05%, SH: 0.17%
Measurement Precision (L1RD, recommended)	25%	NH: 6.2%, SH: 21.7% NH: 5.0%, SH: 12.0%
Measurement Uncertainty (JERD)	25%	NH: 6.3%, SH: 21.8% NH: 5.0%, SH: 12.0%

Requirements: Sea Ice Surface Temperature

Product performance requirements from JERD Vol. II and L1RD versus observed/validated. Stats are relative to MODIS and S-NPP.

Attribute	Threshold	Observed/validated
Geographic coverage	All ice-covered regions of the global ocean	All ice-covered regions of the global ocean
Vertical Coverage	Ice surface	Ice surface
Vertical Cell Size	Ice surface	Ice surface
Horizontal Cell Size	1 km	1 km
Mapping Uncertainty	1 km	1 km
Measurement Range	213 - 275 K	213 - 275 K
Measurement Accuracy (recommended)	1 K	NH: 0.35K, SH: 0.59K NH: -0.055K, SH: 0.049
Measurement Precision (recommended)	1.5 K	NH: 1.38K, SH: 1.35K NH: 1.17, SH: 1.02
Measurement Uncertainty (L1RD and JERD)	1 K	NH: 1.42K, SH: 1.47K NH: 1.17, SH: 1.02

Requirements: Sea and Lake Ice Age

Product performance requirements from JERD Vol. II and L1RD versus observed/validated. Stats are relative to S-NPP and CryoSat-2/SMOS.

Attribute	Threshold	Observed/validated
Geographic coverage	All ice-covered regions of the global ocean	Lat.: ±45° ~ ±90° Lon.: ±180° ~ ±180°
Vertical Coverage	Ice surface	Ice surface
Vertical Cell Size	Ice surface	Ice surface
Horizontal Cell Size	1 km	1 km
Mapping Uncertainty	1 km	1 km
Measurement Range	Ice free, New/Young ice, all Other ice	Ice free, New/Young ice, all ice, and ice thickness
Measurement Accuracy (recommended)	70% probability of correct typing	>90% probability of correct typing; > 92%
Measurement Precision	n/a (see GOES-R definition for 2-category variables)	less than two category
Measurement Uncertainty (JERD and L1RD)	70% for ice age probability of correct typing	>90% probability of correct typing; > 92%

Requirements: Sea and Lake Ice Thickness

Product performance requirements from JERD Vol. II and L1RD versus observed/validated. **There is no requirement for ice thickness.**

Attribute	Threshold	Observed/validated
Measurement Range	none	0-6 m
Measurement Accuracy	none	0.16 m
Measurement Precision	none	0.24 m

NDE/STAR VIIRS Production Status

Algorithm	Suomi NPP	NOAA-20
August 2018 DAP February 2018 Science Code delivery (**v2r0**)	**STAR** Systematic production since June, 2018 **NDE** **I&T on as of 28 September, 2018**	**STAR** Systematic production since June, 2018 **NDE** **I&T on as of 28 September, 2018**
Jan/Feb 2019 DAP August 2018 Science Code delivery (**v2r1**)	**Delivery and development in progress** Delivery schedule provided by ASSISTT	**Delivery and development in progress** Delivery schedule provided by ASSISTT

Beta Review Outcomes, June 2018

- Findings/Issues from Beta - From the Review Team:
  - *Ice Age/thickness, Ice concentration, and Ice Surface Temperature products have reached **Beta Maturity**. Good results so far with SNPP, but not enough data to be provisional. Noted problem with Cloud Mask, which should be fixed with Cloud LUT fix going into NDE this week (or next). Jeff key noted the need for Cloud Mask to be provisional prior to cryosphere products being declared provisional.*
- Improvements since Beta Review
  - Sea ice thickness/age algorithm has been improved.
  - Algorithm Improvements: None for results presented here from NDE
  - LUT / PCT updates: None

First Provisional Review Outcomes, Oct 2018

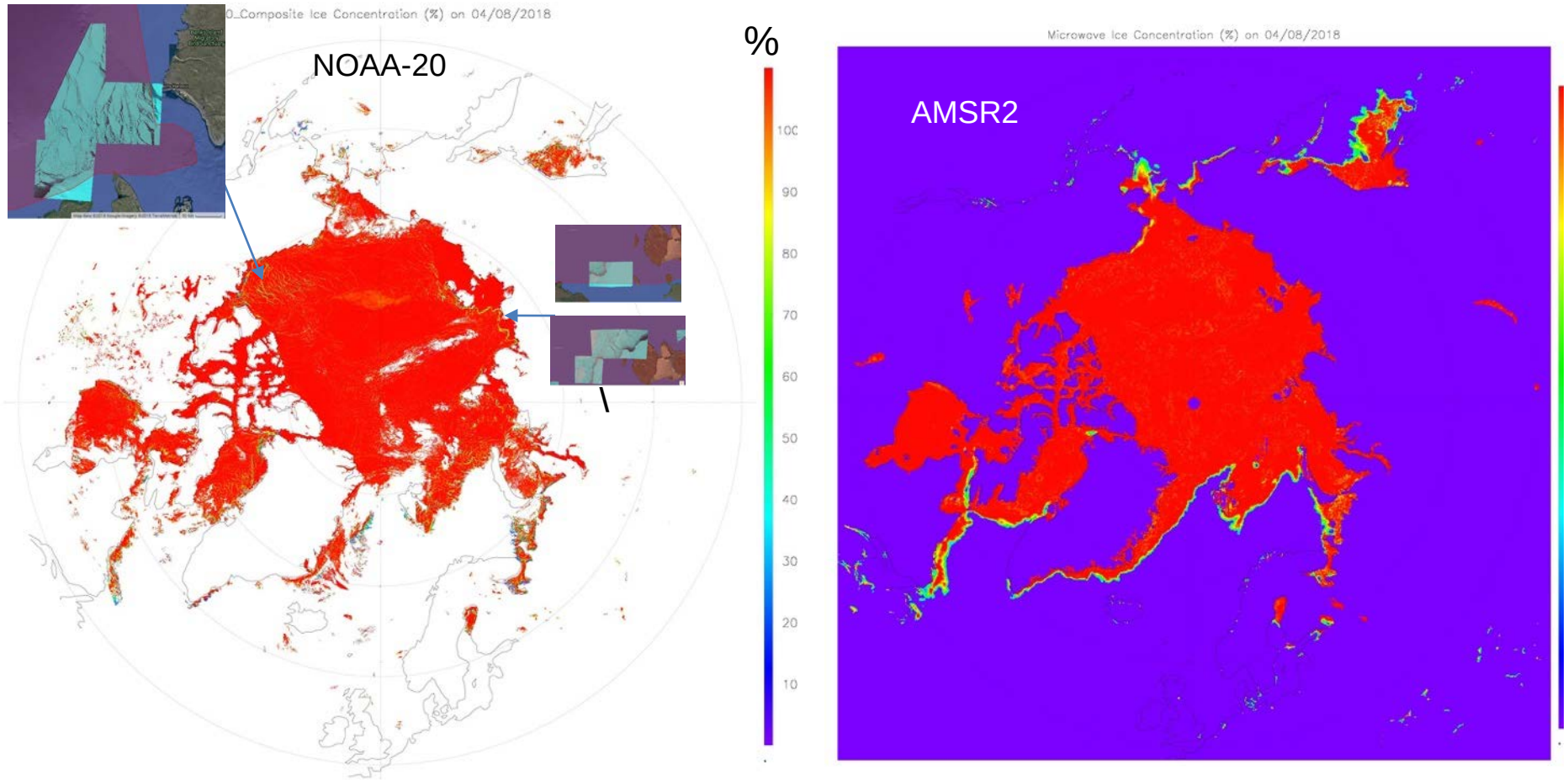
- Findings/Issues from Provisional - From the Review Team:
  - *Recommend the team take advantage of the 2018 NH winter to conduct more thorough validation (eg conduct their Provisional maturity review in March 2019). Recommend the v2r0 cryosphere products be promoted to the operational string at the beta maturity status so that the science team have a consistent data set for validation.*
- Improvements since first Provisional Review
  - V2r0 ice products from December 2018 to March 2019 have been collected and validated with products S-NPP and independent products from MODIS, AMSR2, and Cryosat-.
  - LUT / PCT updates: None
- The issues described in the October 2, 2018 maturity review have been resolved, e.g., missing granules, zero ice concentrations, some cloud mask problems, etc.

NOAA-20 Sea Ice Product Maturity Evaluation

Maturity Evaluation Approaches

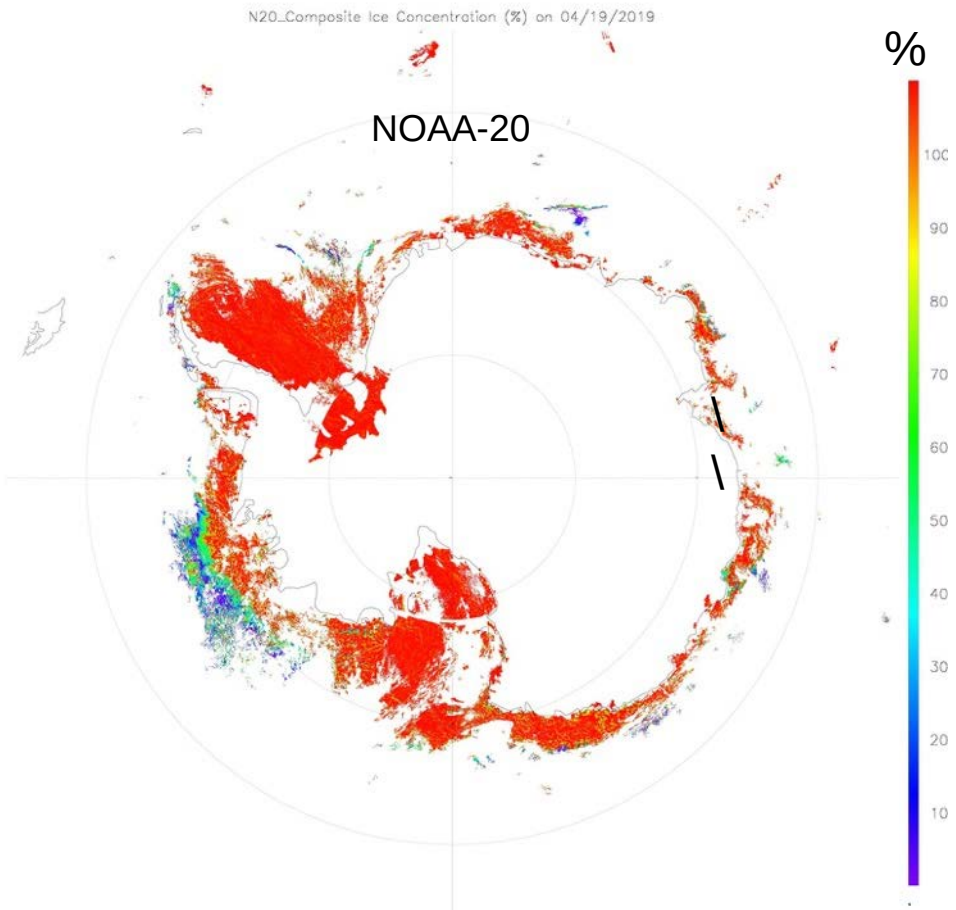
- Algorithms are described in detail in the Algorithm Theoretical Basis Documents (ATBDs) and journal papers. (See *References* slide)
- Our analysis has focused on the Arctic and Antarctic, for the period of December 16, 2018 – March 31, 2019. This is version v2r0.
- Comparisons have been done for all sea ice products with the data from NOAA-20, S-NPP, passive microwave AMSR2, MODIS, and CryoSat-2.
- Statistical comparisons have been done for most of the sea ice products, monthly and seasonally.
- Manual/visual inspection of sea ice product images have been done in some cases where temporal and spatial matching cannot be done.

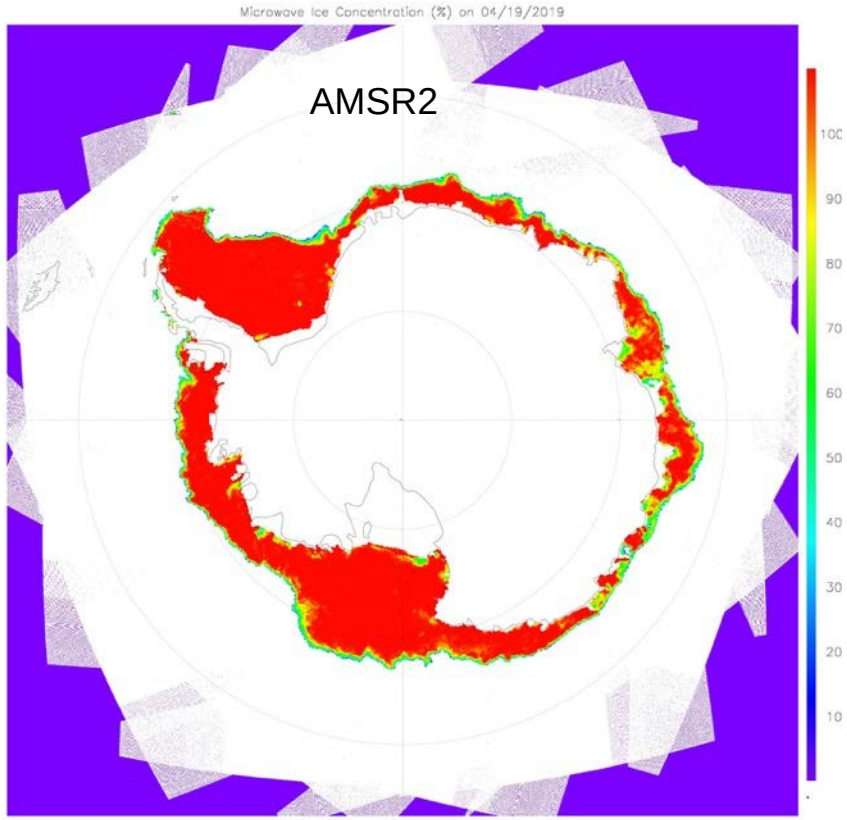
Sea Ice Concentration: NOAA-20 Examples 04-08-2018, v2r0



- Matches well with AMSR2 SIC overall.
- NDE SIC does good job capturing lead features in the SIC field. A definite improvement over AMSR2 SIC.
- Still some issues with false ice due to cloud contamination.

Sea Ice Concentration: NOAA-20 Examples 04-19-2019, v2r0

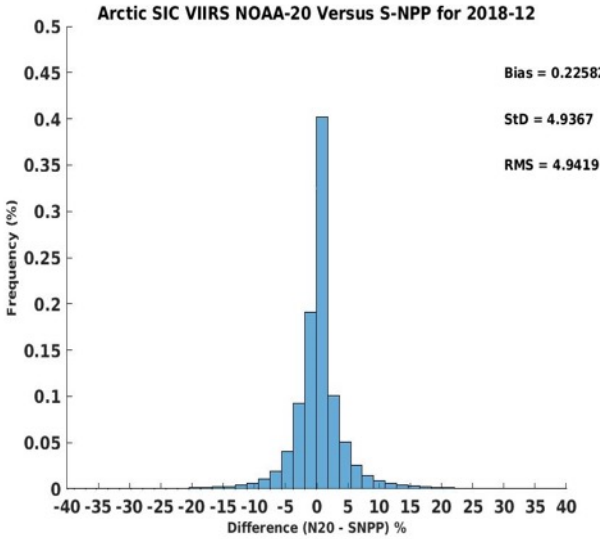




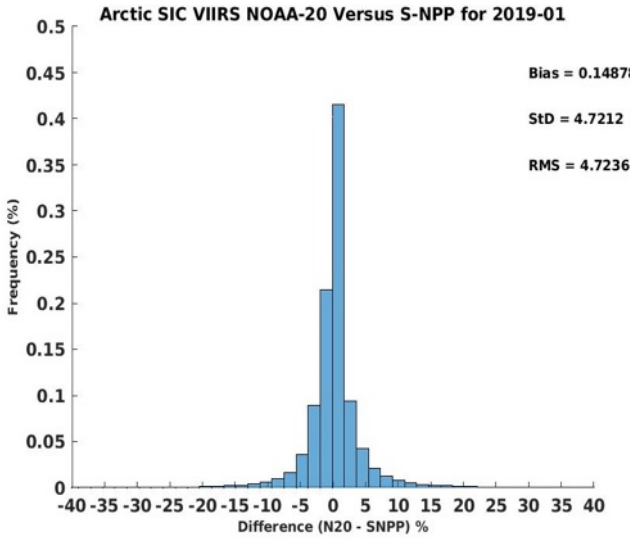
- NDE SIC also does a good job over Antarctic.
- A few false ice pixels exist due to cloud contamination. However, with each update to the cloud mask, **false ice pixels becomes less common**. To mitigate problem further, recommend using scan angle threshold.

Sea Ice Concentration: NOAA-20 (NDE I&T) vs S-NPP, Arctic

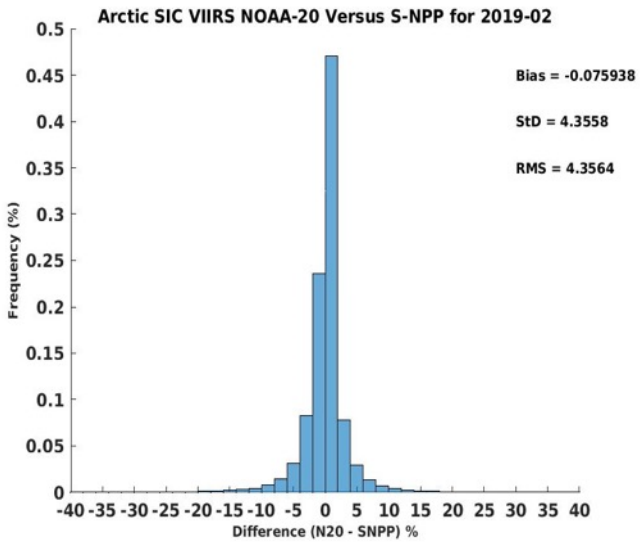
December



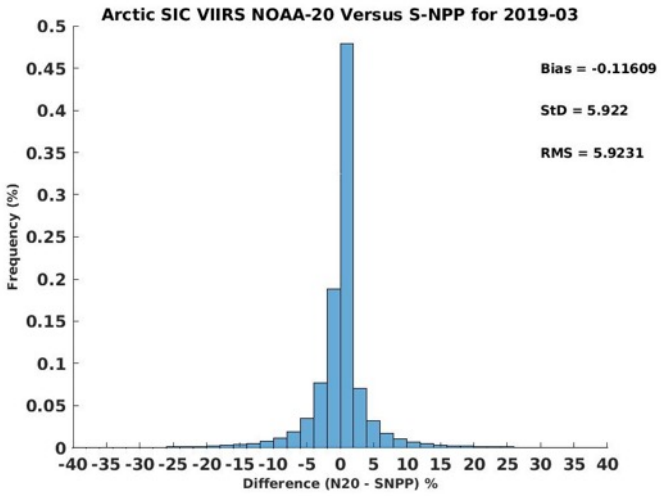
January



February



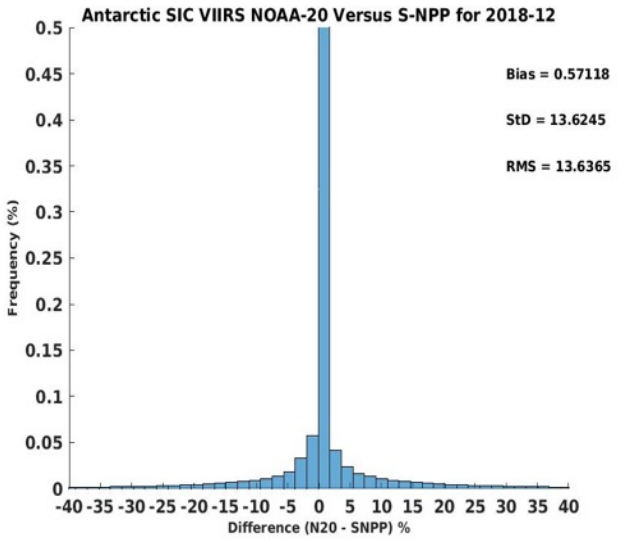
March



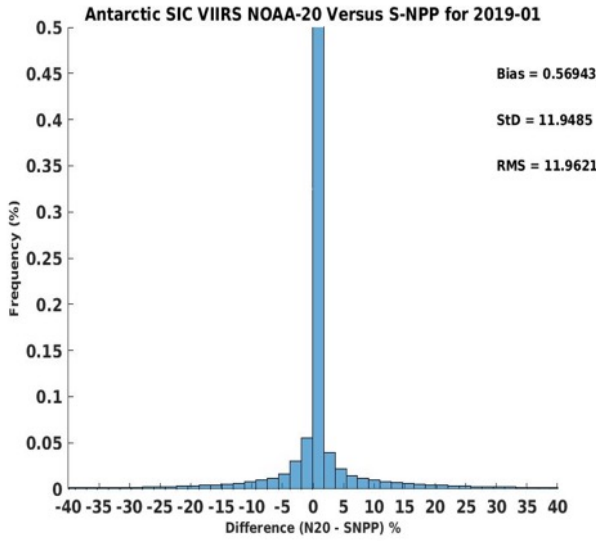
- Comparison done on individual overpasses to S-NPP (50 minutes apart)
- Histogram by month, 2018 Dec thru 2019 Mar.

Sea Ice Concentration: NOAA-20 (NDE I&T) vs S-NPP, Antarctic

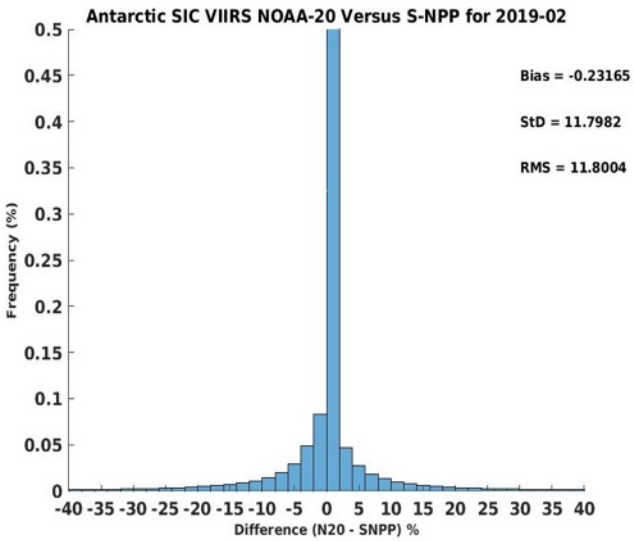
December



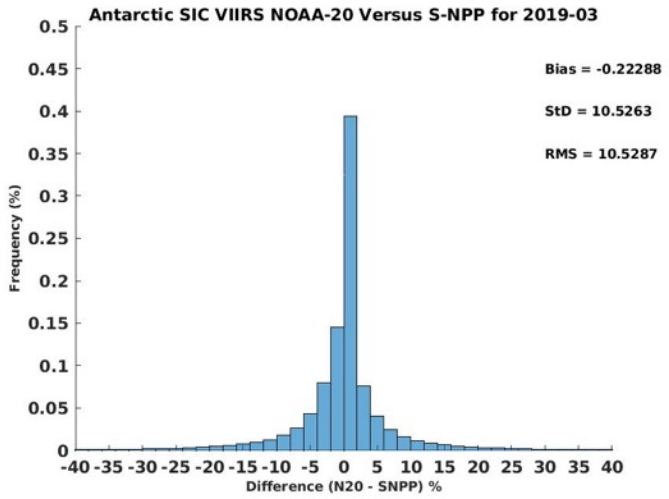
January



February



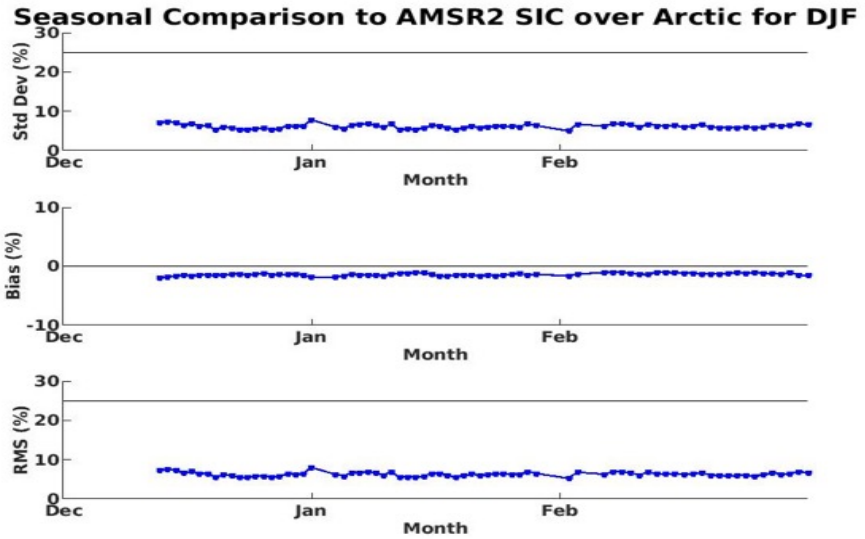
March



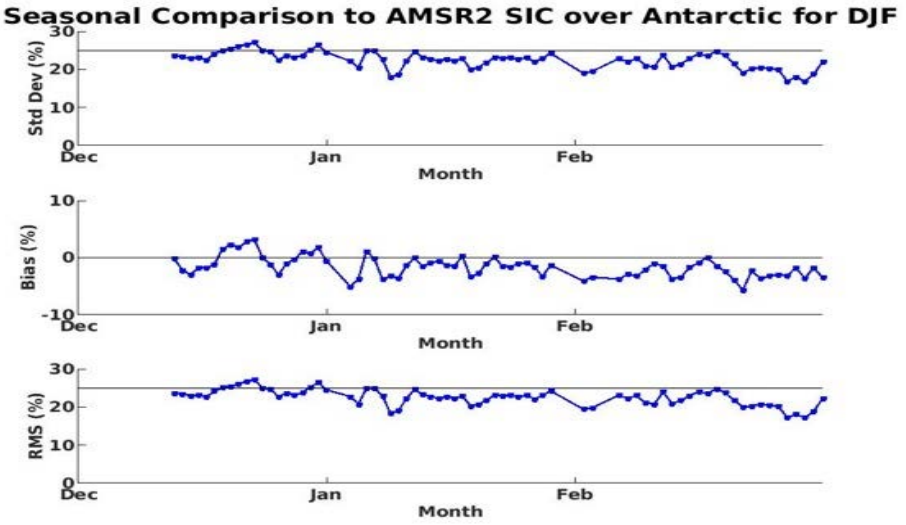
- Comparison done on individual overpasses to S-NPP (50 minutes apart)
- Histogram by month 2018 Dec thru 2019 Mar.

Sea Ice Concentration: Monitoring NOAA-20 **versus AMSR2**

12/14/2018 to 02/28/2019, Arctic

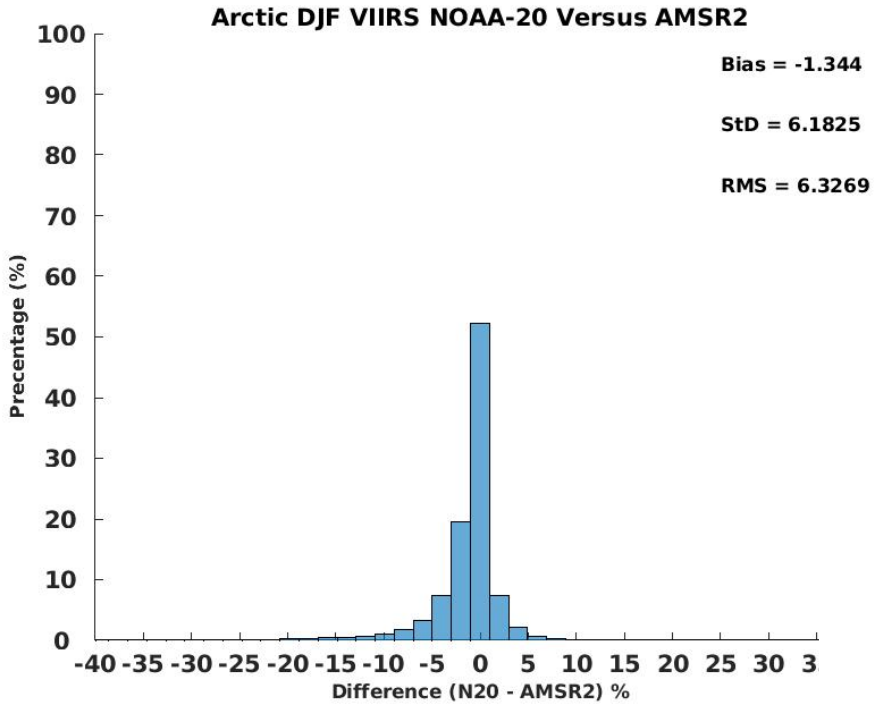


12/14/2018 to 02/28/2019, Antarctic

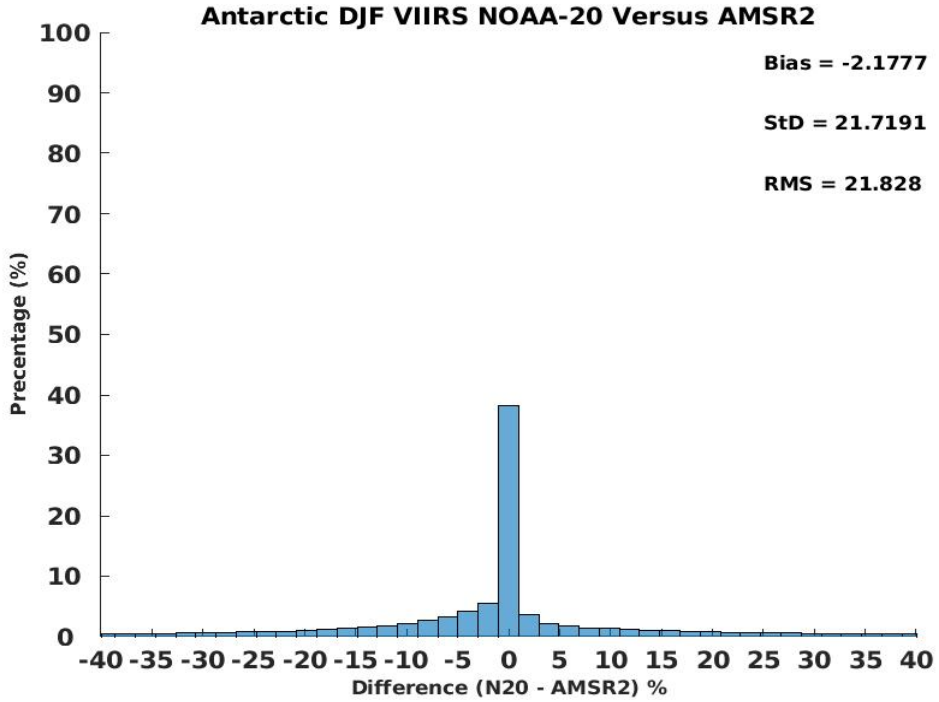


- NDE SIC meets specific requirements (25% Precision and Uncertainty) **every** day that has data available over Arctic winter when compared to AMSR2.
- NDE SIC meets specific requirements **most** days that has data available over Antarctic summer when compared to AMSR2. Note: AMSR2 has higher uncertainties in the summertime due to surface melting.

Sea Ice Concentration: Comparisons to **AMSR2** SIC

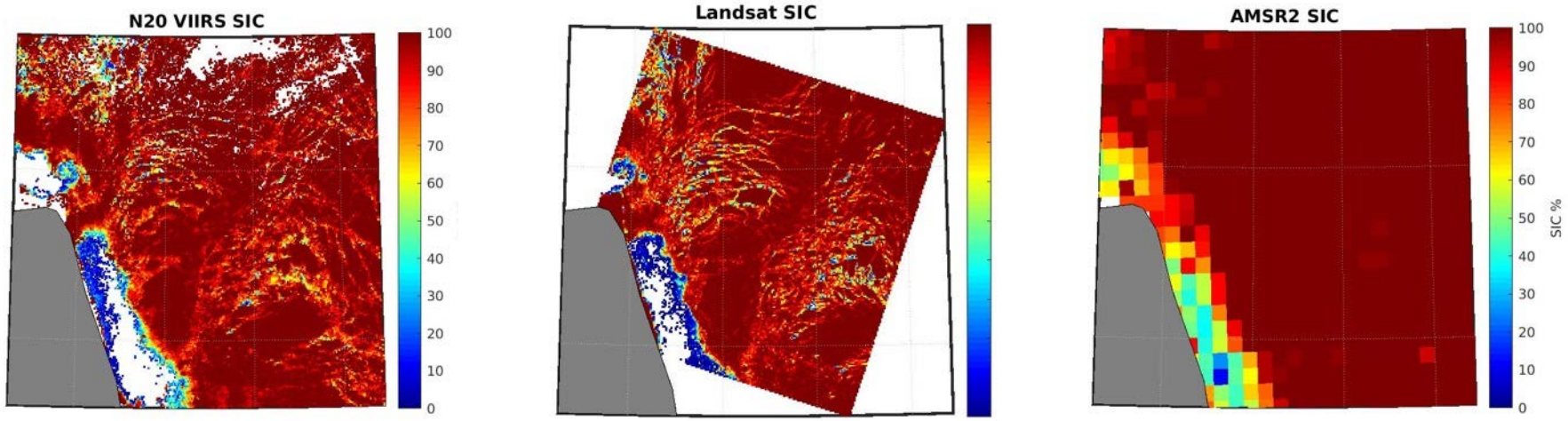


- v2r0, post-beta
- Meets requirement with measurement precision less than 25%
- Larger differences over Antarctic.



Sea Ice Concentration: NOAA-20 Examples Compared to Landsat

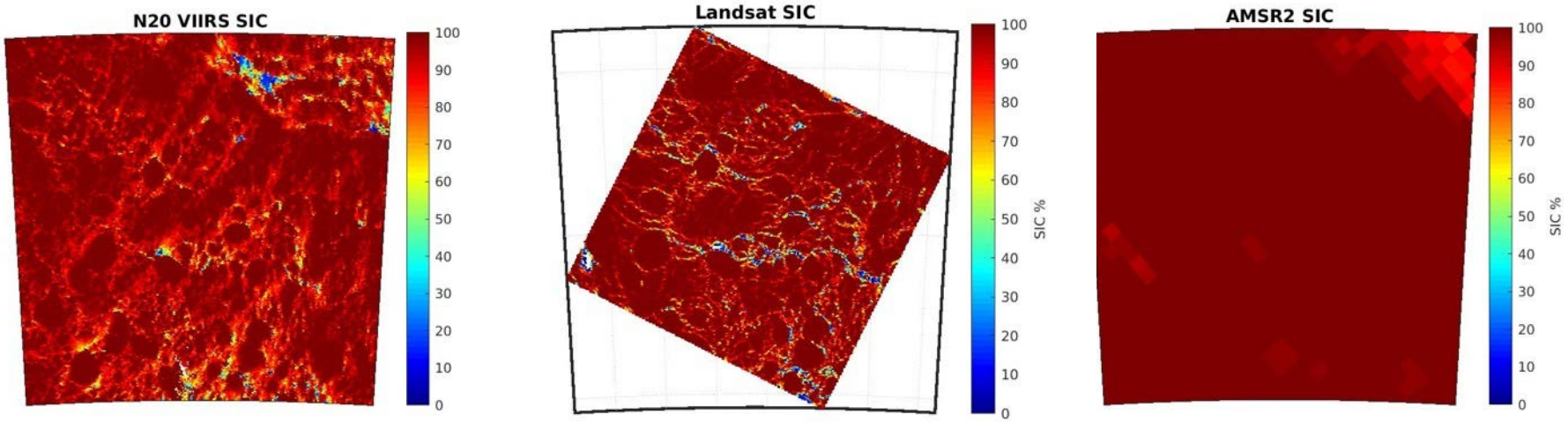
Western Hudson Bay on 2019-04-15, Arctic



- NDE SIC does a good job capturing leads and other features in Sea Ice field**. A definite improvement over AMSR2 SIC.**
- NDE SIC Matches very well with this clear-sky Landsat scene.
- NDE SIC is able resolve features in ice field that AMSR2 cannot. Also get better resolution to location of sea ice edges.

Sea Ice Concentration: NOAA-20 Examples Compared to Landsat

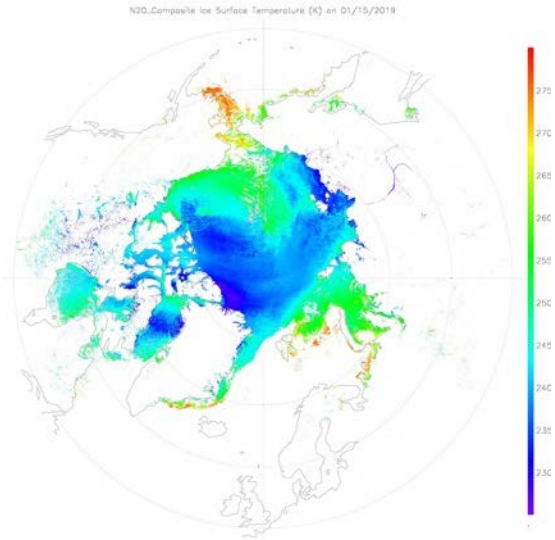
Weddell Sea on 2019-03-08, Antarctic



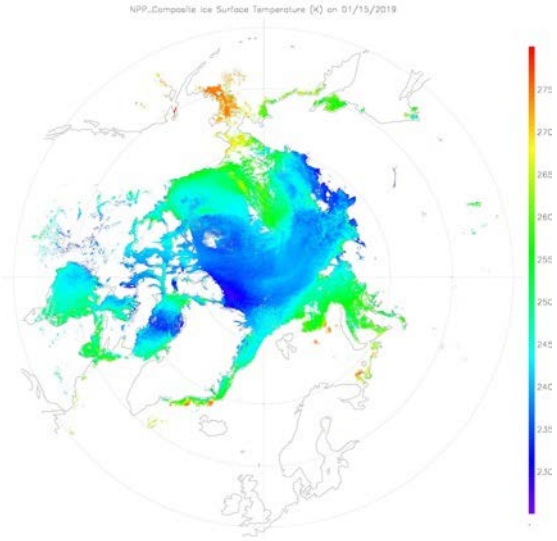
- NDE SIC does a good job capturing leads and other ice features in SIC field over Weddell Sea**. A definite improvement over AMSR2 SIC.**
- NDE SIC Matches very well with this clear-sky Landsat scene.
- NDE SIC is able resolve features in SIC field that AMSR2 cannot.

Sea Ice Temperature: NOAA-20 (NDE I&T v2r0) vs S-NPP

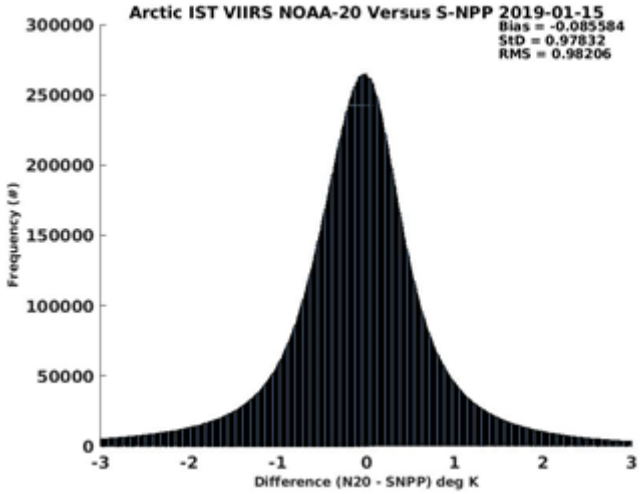
NOAA-20



S-NPP



NOAA-20 minus S-NPP



Date:

January 15, 2019

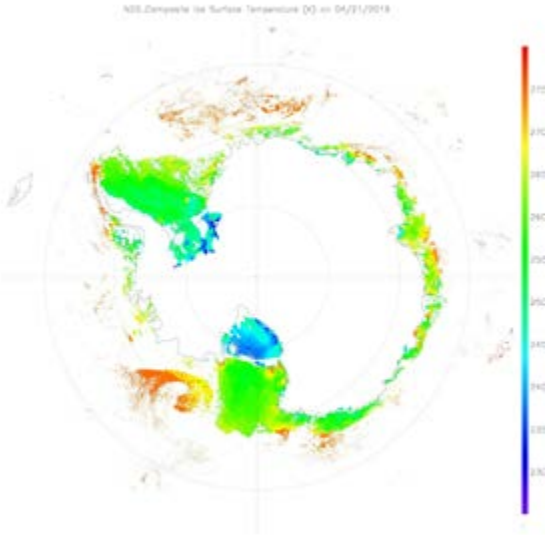
Statistical mean ice surface temperature: Comparison done with individual overpasses, NOT a daily composite

NOAA-20	S-NPP	Accuracy	Precision	Uncertainty (*matched parts*)
242.92 K	243.03K	0.65 K	0.97 K	0.98 K

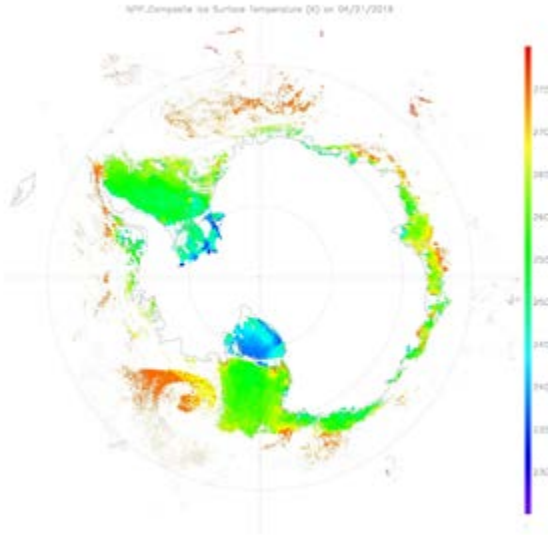
ISSUES: Some differences in cloud masking

Sea Ice Temperature: NOAA-20 (NDE I&T v2r0) vs S-NPP

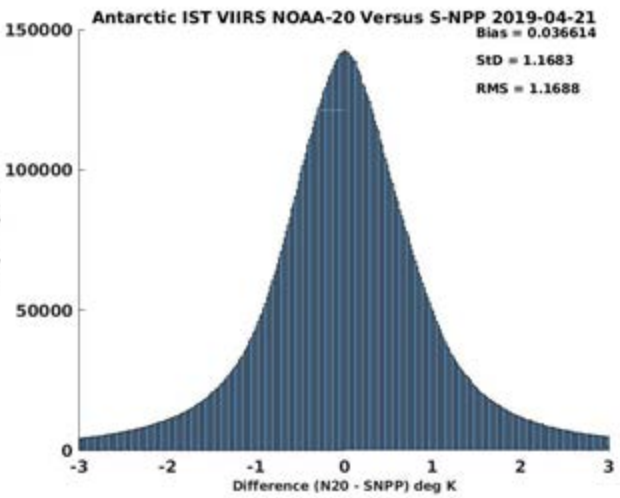
NOAA-20



S-NPP



NOAA-20 minus S-NPP



Date:
April 21, 2019

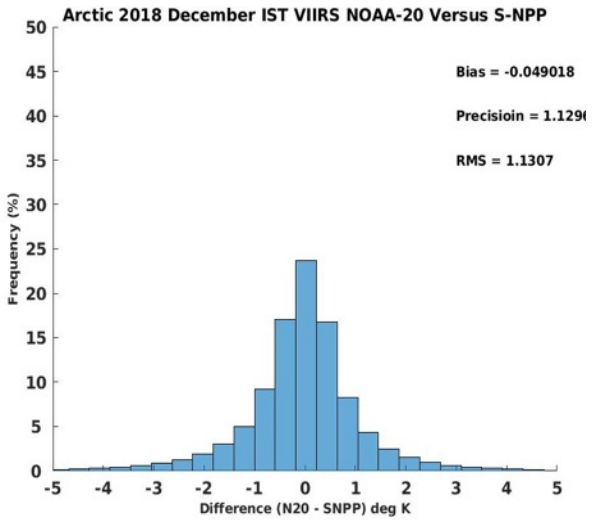
Statistical mean ice surface temperature: Comparison done with individual overpasses, NOT daily composite.

NOAA-20	S-NPP	Accuracy	Precision	Uncertainty (matched parts)
253.96 K	253.93 K	0.81 K	1.16 K	1.16 K

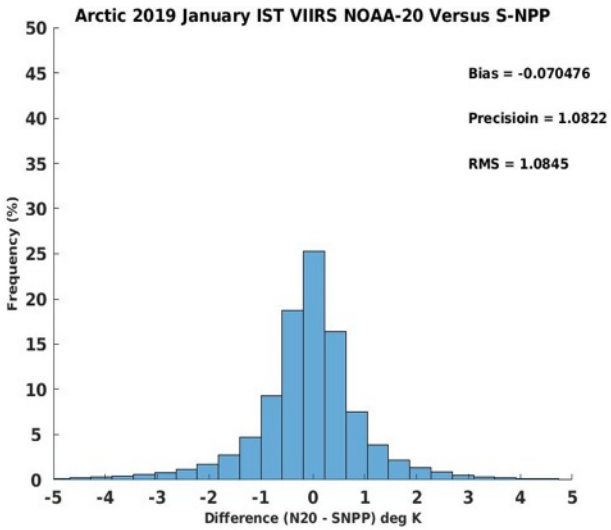
ISSUES: Some differences in cloud masking

Sea Ice Temperature: NOAA-20 (NDE I&T) vs S-NPP, Arctic

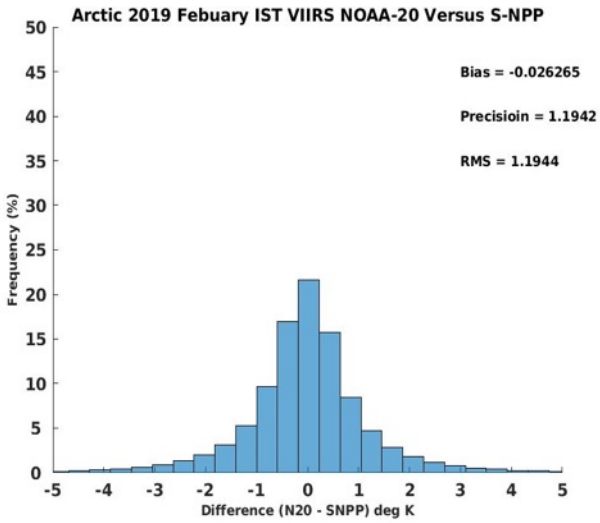
December



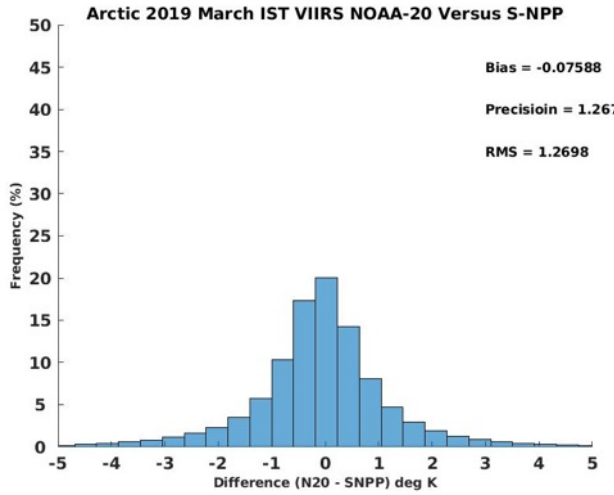
January



February



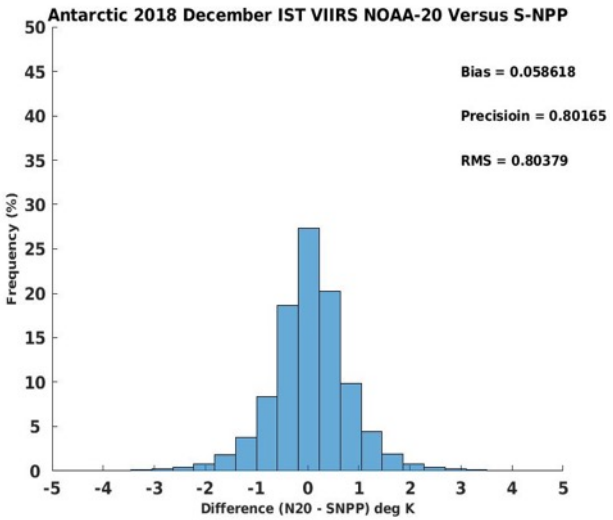
March



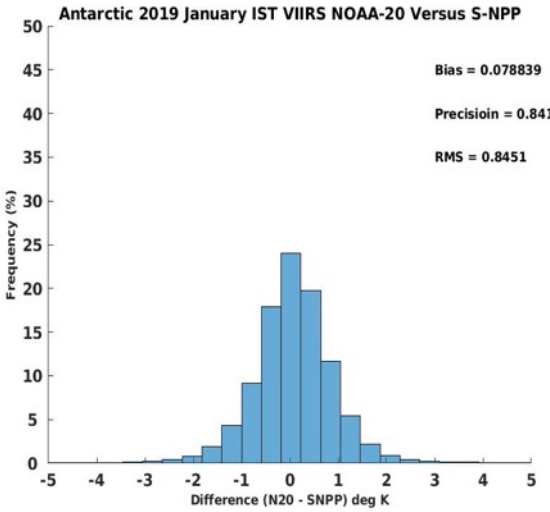
- Comparison done on individual overpasses
- Histogram by month, 2018 Dec thru 2019 Mar.
- S-NPP matches well with NOAA-20. Differences can be contributed to slight differences in cloud mask and moving surface temperature gradients over 50 minute period.

Sea Ice Temperature: NOAA-20 (NDE I&T) vs S-NPP, Antarctic

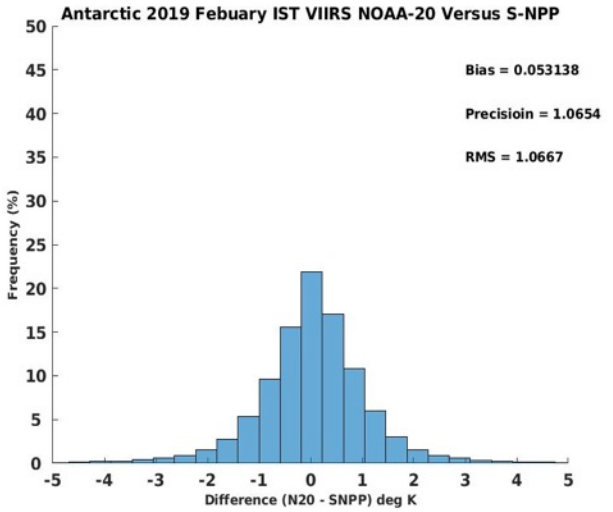
December



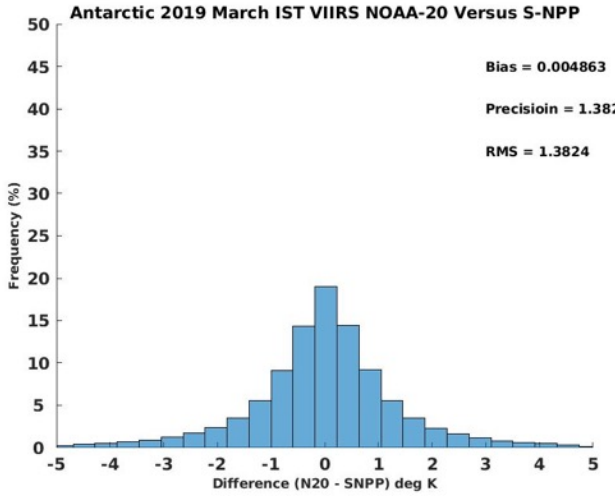
January



February



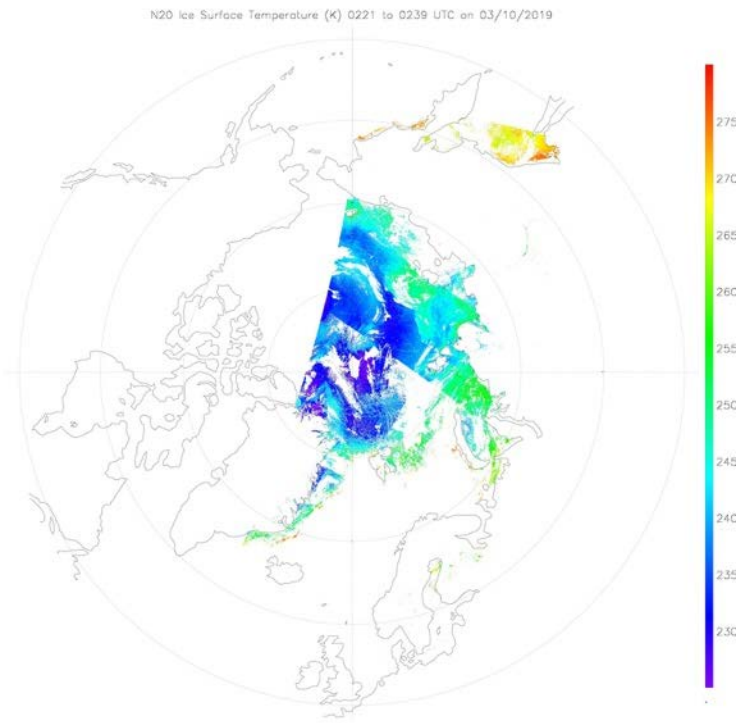
March



- Comparison done on individual overpasses
- Histogram by month, 2018 Dec thru 2019 Mar.
- NPP matches well with NOAA-20. Slightly larger differences in March. Differences can be contributed to slight differences in cloud mask and moving surface temperature gradients over 50 minute period.

Sea Ice Temperature: NOAA-20 vs MODIS

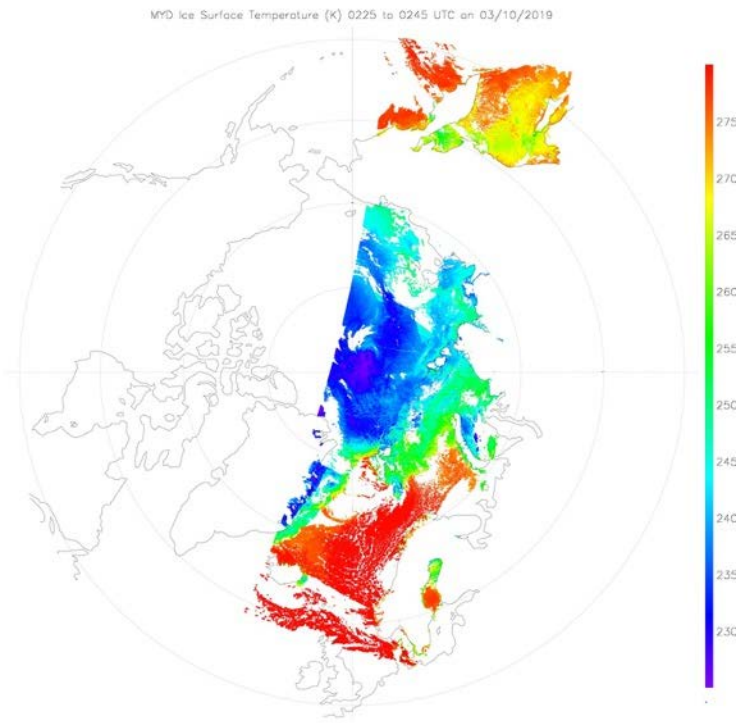
NOAA-20



March 10, 2019 0221 to 239 UTC

MODIS

Includes SSTs

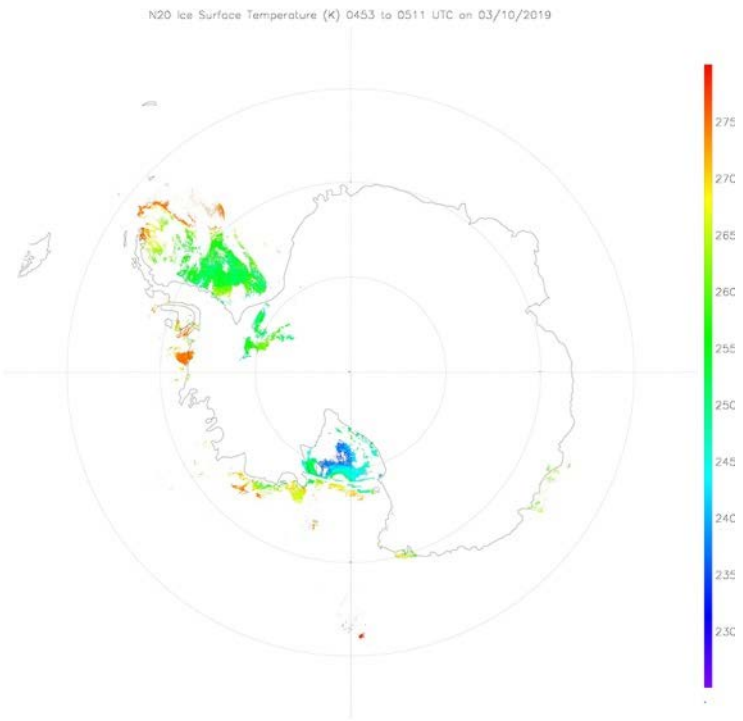


March 10, 2019 0225 to 0245 UTC

Note: MODIS has sea surface temperature included.

Sea Ice Temperature: NOAA-20 vs MODIS

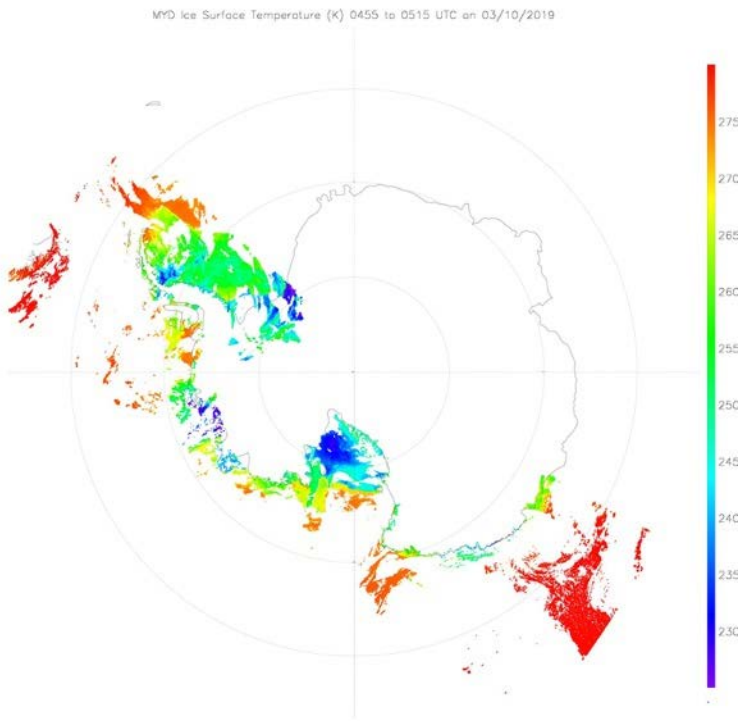
NOAA-20



March 10, 2019 2018 0453 to 0511 UTC

MODIS

Includes SSTs

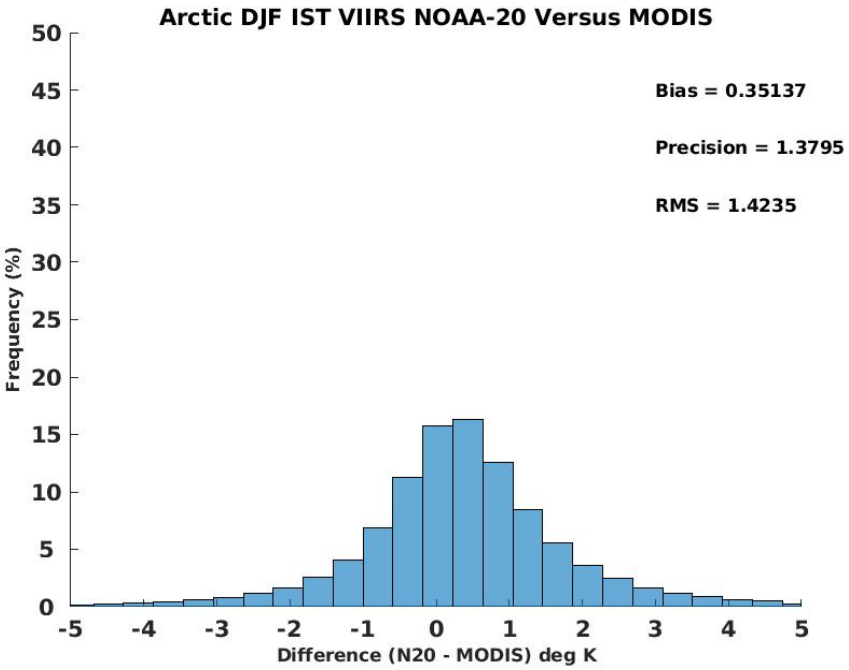


March 10, 2019 0455 to 515 UTC

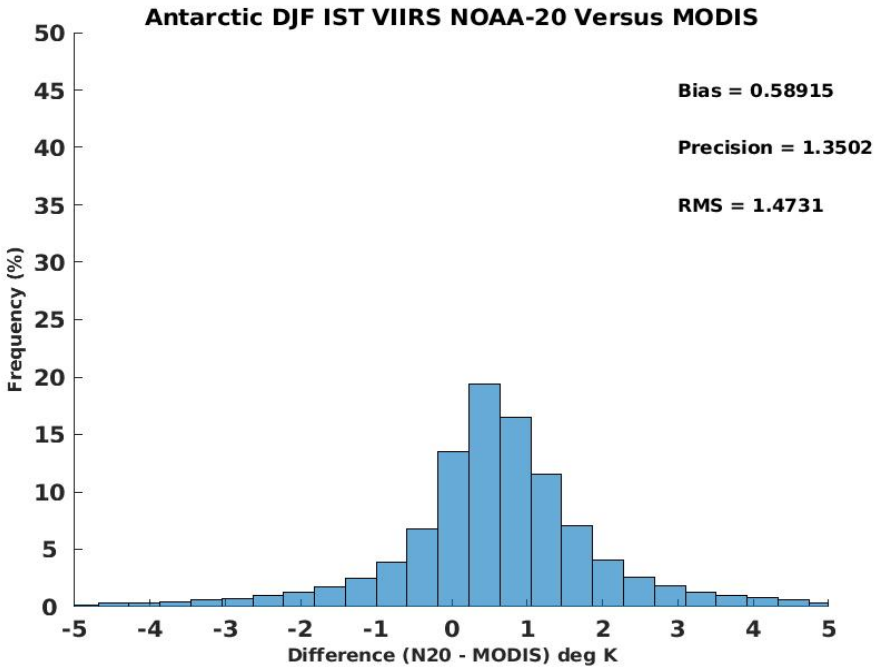
Note: MODIS has sea surface temperature included.

Sea Ice Temperature: NOAA-20 vs MODIS

Arctic

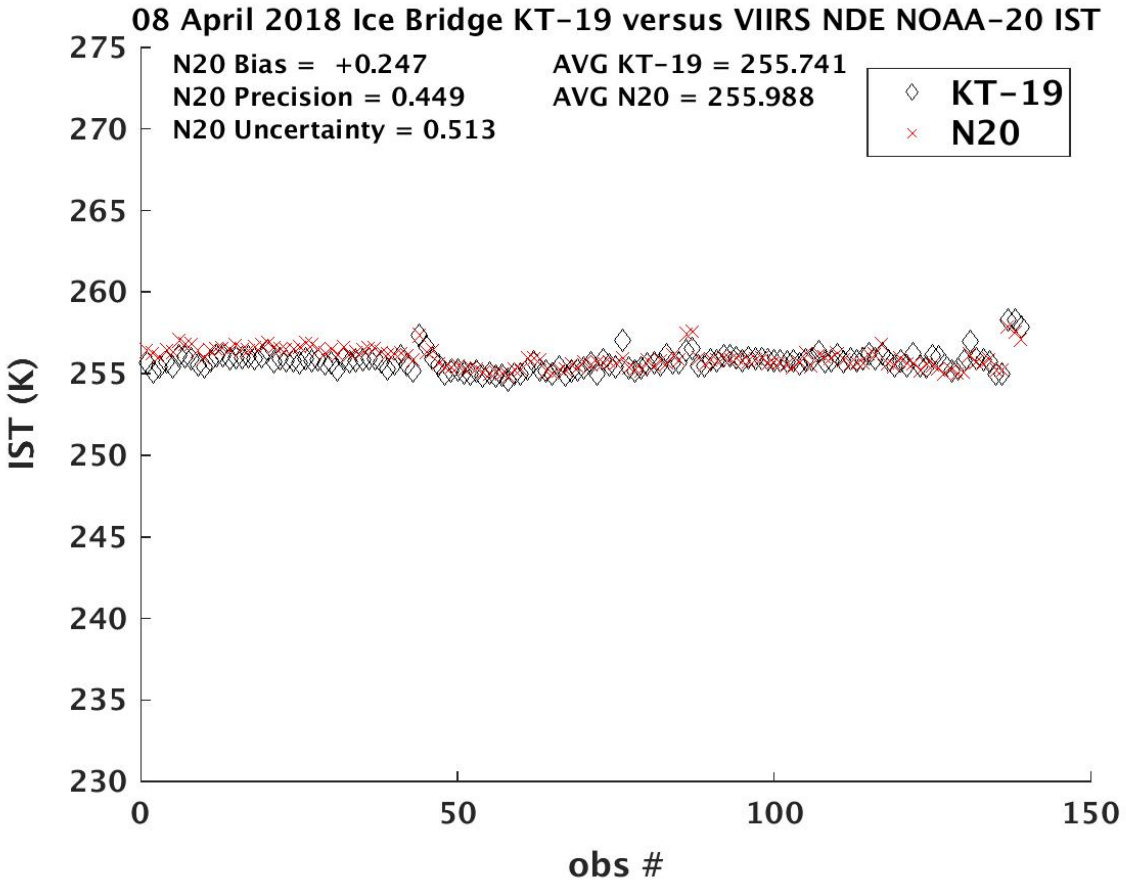


Antarctic



- December 14, 2018 thru February 28, 2019, v2r0
- Comparisons done at 5 minute time threshold on same 1 km EASE grid.
- **Meets requirements**.
- Warm bias in NDE NOAA-20 IST compared to MODIS.
- Larger uncertainties observed, likely due to differences in cloud mask.

Sea Ice Temperature: NOAA-20 vs KT-19

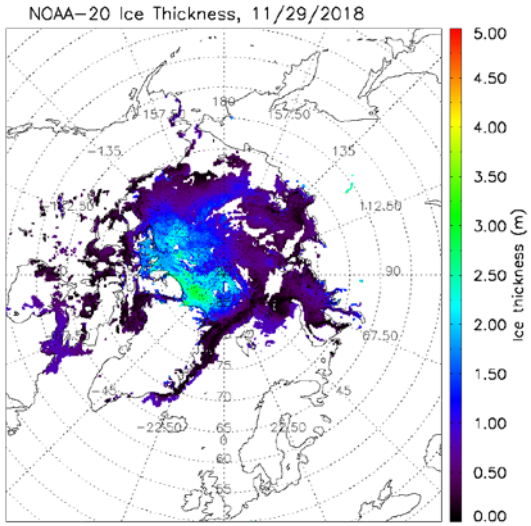


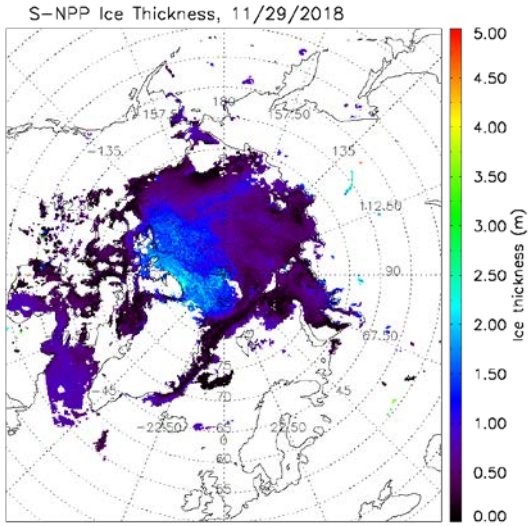
Note: 08 April 2018 only day **v2r0** is available for Ice Bridge KT-19 comparison . Antarctic spring (Oct-Nov) dataset not available for Provisional Review.

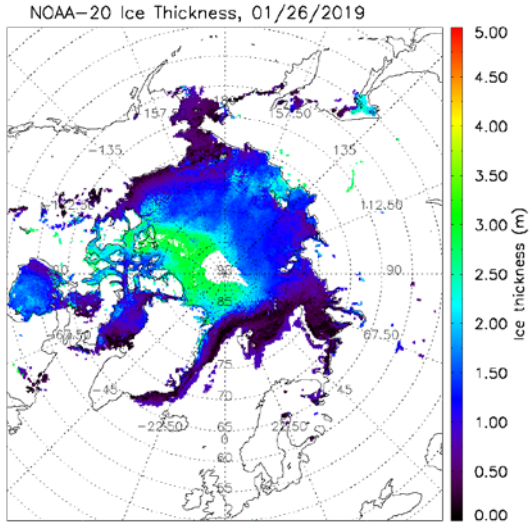
- April 08, 2018, 2101-05 and 2244-46 UTC over Beaufort Sea, totalling 139 Samples.
- Comparisons done with **v2r0** at 30 minute time threshold with KT-19 temperatures (15 m resolution) averaged over 750 m VIIRS pixel.
- **Meets requirements**, however slight warm bias in NDE NOAA-20 IST compared to KT-19.
- Limited dataset, more robust comparisons expected over upcoming year to include Antarctic region and FLIR datasets.

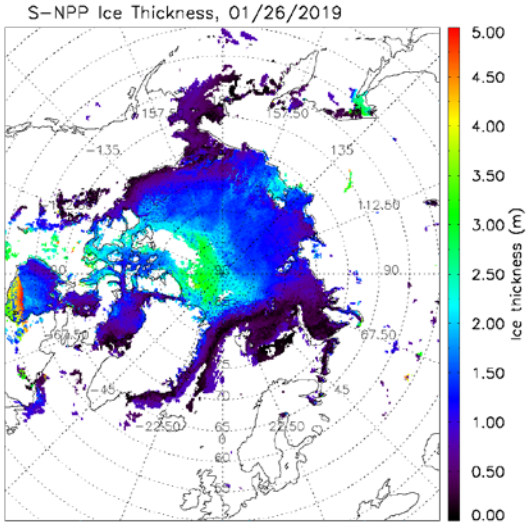
Sea Ice Thickness/Age: NOAA-20 vs S-NPP, Arctic

NOAA-20 S-NPP *(Original resolution, daily composite)*









No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	0	778123	4263132
TMP	5473155		
PCT	92%		

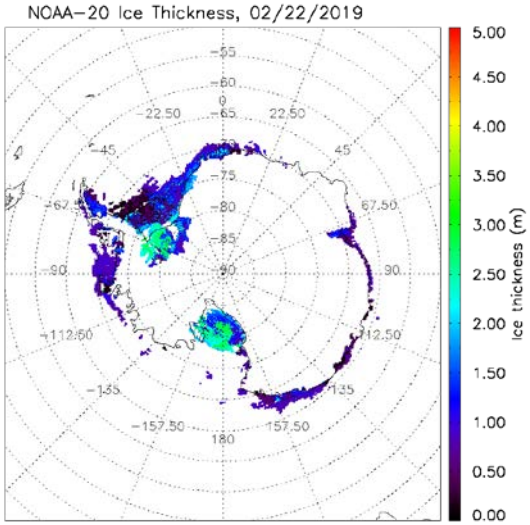
CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

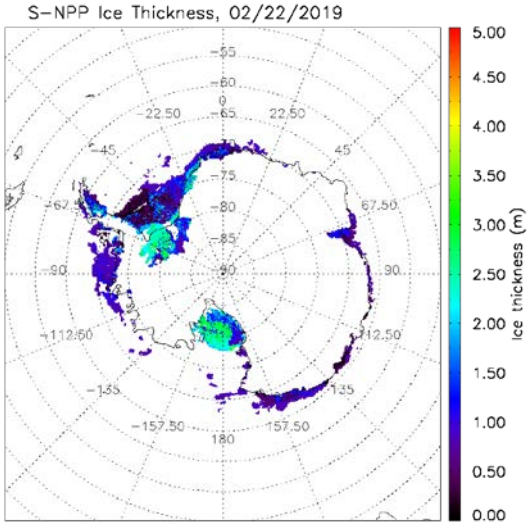
No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	0	562520	8767035
TMP	9192899		
PCT	95%		

Sea Ice Thickness/Age: NOAA-20 vs S-NPP, Antarctic

NOAA-20

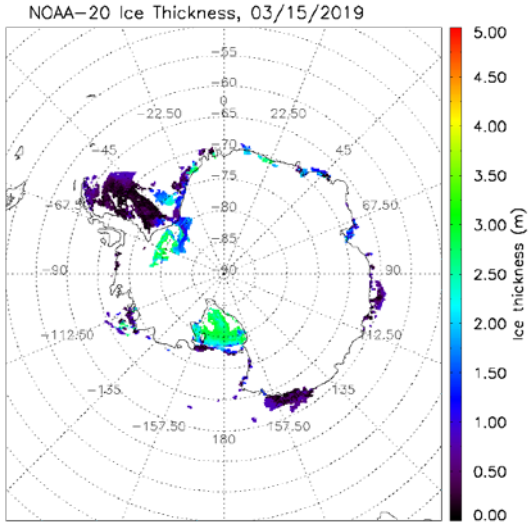
S-NPP *(Original resolution, daily composite)*

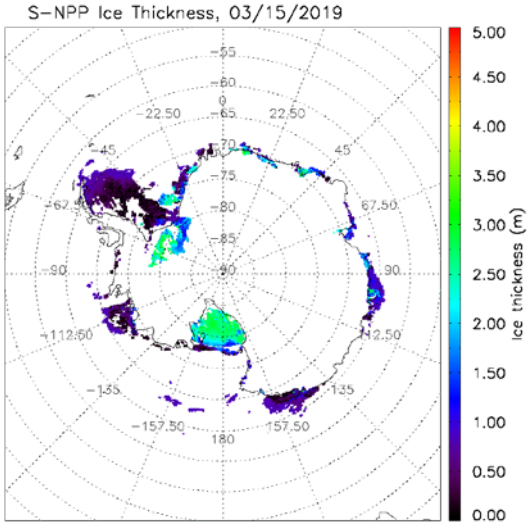




No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	0	119260	1479897
TMP	1727519		
PCT	93%		

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

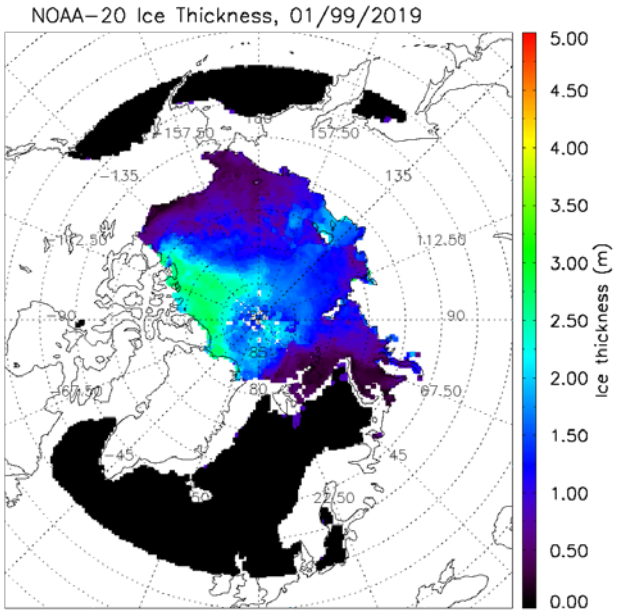




No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	0	152631	734136
TMP	9566864		
PCT	93%		

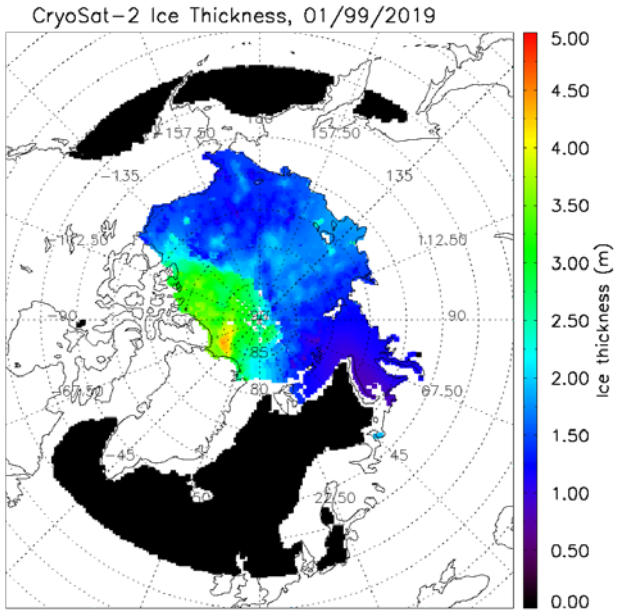
Sea Ice Thickness/Age: NOAA-20 vs CryoSat-2, Arctic

NOAA-20



Period composite of ice thickness over January 3 - 28, 2019 from NOAA-20.

CryoSat-2



Monthly mean of ice thickness for January 2019 from CryoSat-2.

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	10106		7046
TMP	17639		
PCT	97%		

Important: CryoSat-2 cannot estimate sea ice thinner than about 0.5 m.

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

Sea Ice Age: NOAA-20 vs CryoSat-2, Arctic

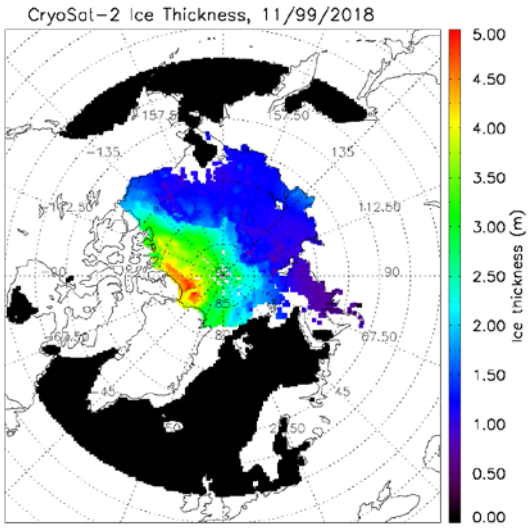
Ice age category: Ice free, New/Young Ice (<0.30m), Other ice (>=0.30cm)

Important: CryoSat-2 cannot estimate sea ice thinner than about 0.5 m.

November 2018

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	11621		5191
TMP	18627		
PCT	90%		

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing



December 2018

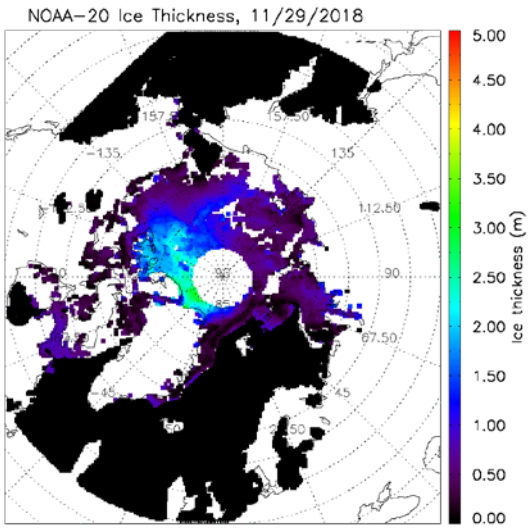
No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	10939		6054
TMP	18068		
PCT	94%		

January 2019

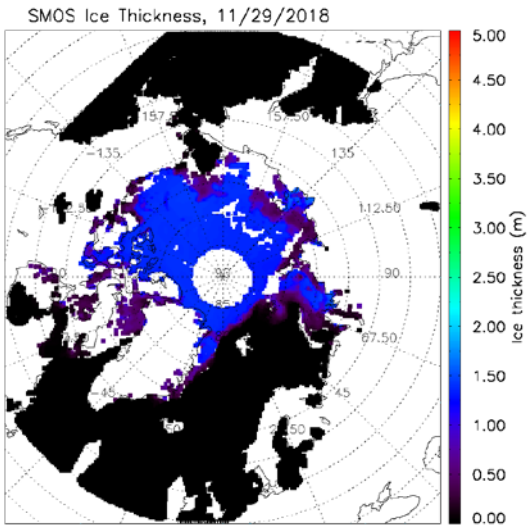
No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	10106		7046
TMP	17639		
PCT	97%		

Sea Ice Thickness/Age: NOAA-20 vs SMOS, Arctic

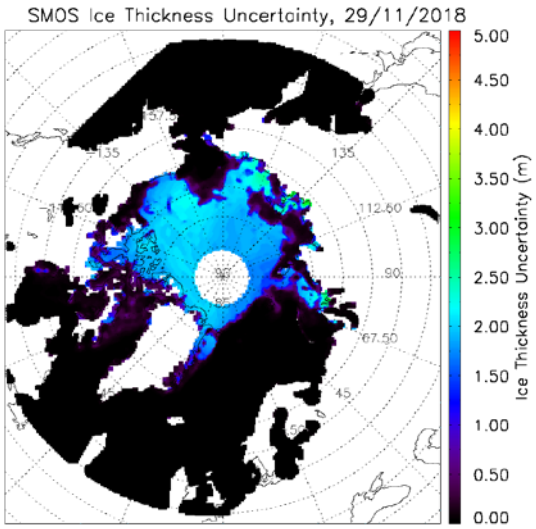
NOAA-20 Thickness



SMOS Thickness



SMOS Uncertainty



Daily composite of ice thickness on November 29, 2018 from NOAA-20 (left) and SMOS (middle), and SMOS sea ice uncertainty (right).

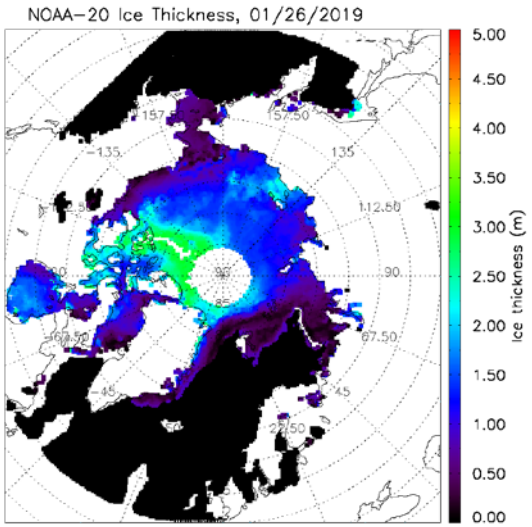
No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	24028	301	5900
TMP	32384		
PCT	93%		

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

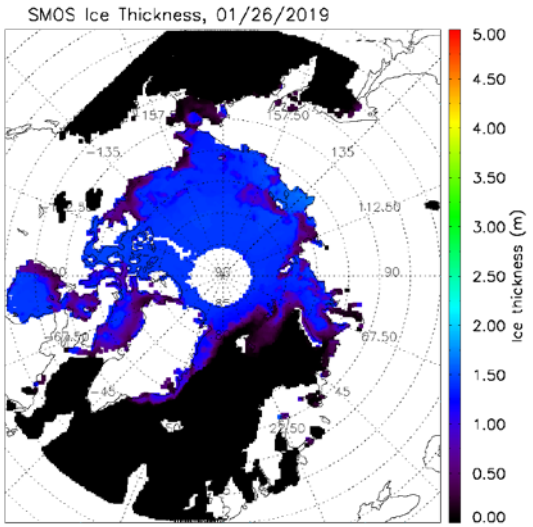
SMOS: ESA's Soil Moisture Ocean Salinity satellite (passive microwave, L-band at 1.4 GHz).

Sea Ice Thickness/Age: NOAA-20 vs SMOS, Arctic

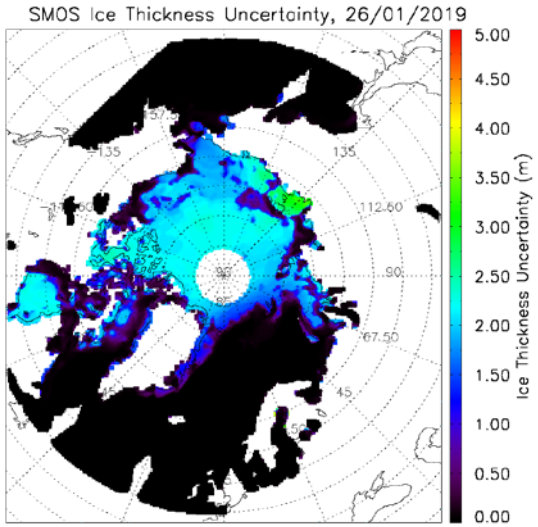
NOAA-20 Thickness



SMOS Thickness



SMOS Uncertainty



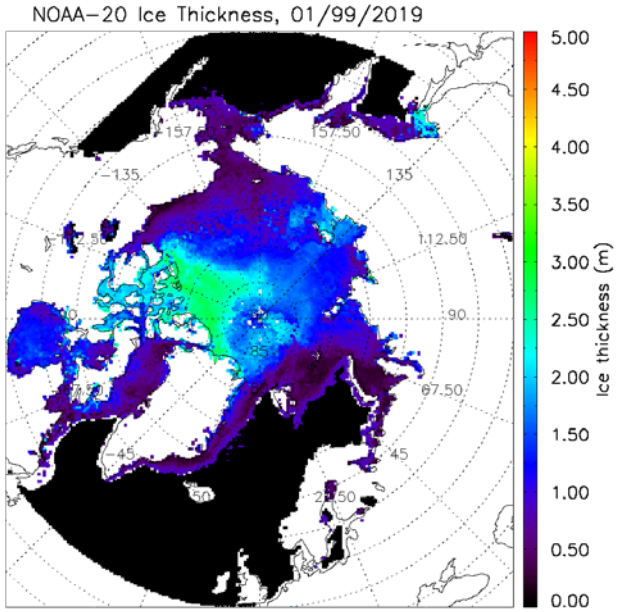
Daily composite of ice thickness on January 26, 2019 from NOAA-20 (left) and SMOS (middle), and SMOS sea ice uncertainty (right).

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	19755	375	12641
TMP	34693		
PCT	94%		

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

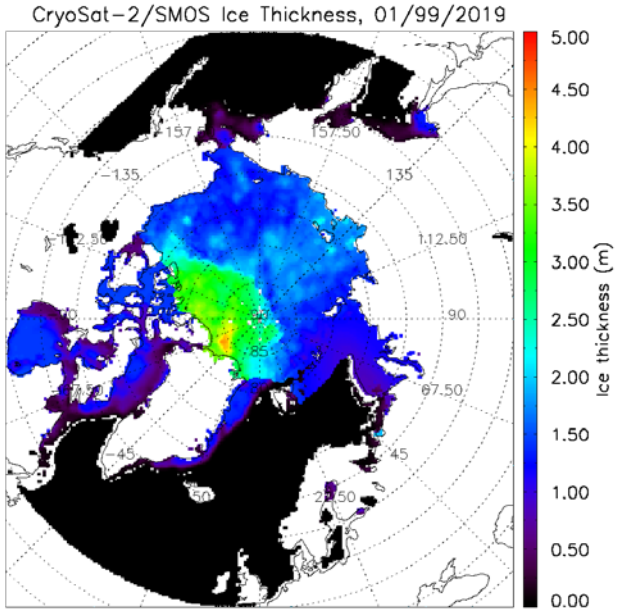
Sea Ice Thickness/Age: NOAA-20 vs CryoSat-2/SMOS, Arctic

NOAA-20



Period composite of ice thickness over January 3 - 28, 2019 from NOAA-20.

CryoSat-2/SMOS



Monthly mean of ice thickness for January 2019 from CryoSat-2 and SMOS combined (Created by CIMSS).

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	19228	273	17156
TMP	39962		
PCT	92%		

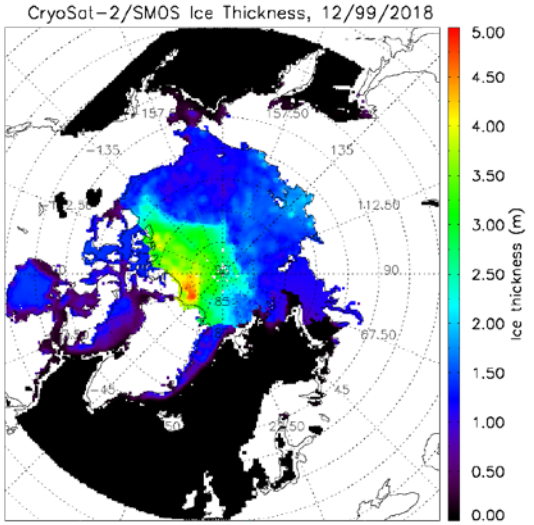
CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

Sea Ice Age: NOAA-20 vs CryoSat-2/SMOS, Arctic

Ice age category: Ice free, New/Young Ice (<0.30m), Other ice (>=0.30cm)

November 2018

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	22133	468	11603
TMP	40274		
PCT	85%		



December 2018

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	20636	413	14852
TMP	40059		
PCT	90%		

January 2019

No. of Pixels	Water	New/Young Ice (< 0.30 m)	Other ice (>= 0.30 m)
CTP	19228	273	17156
TMP	39962		
PCT	92%		

CTP: Correctly Typed Pixels
TMP: Total Matched Pixels
PCT: Probability of Correct Typing

Evaluation of the effect of required algorithm inputs

- Required Algorithm Inputs
  - Primary Sensor Data: Ice products
  - Ancillary Data:
    - Surface mask
    - Atmospheric profile data and snow depth data (optional)
  - Upstream algorithms: Cloud mask
  - LUTs / PCTs: internal LUT for ice cover/concentration algorithm to solve optimal LUT concentration
- Evaluation of the effect of required algorithm inputs
  - The effect of the cloud mask depends on conditions: it will mask false ice due to wrong cloud mask.
  - Low Sun conditions (solar zenith angle between 86^{o}~93^{o}) will cause larger uncertainties on ice products due to larger uncertainties for cloud masking and surface albedo. Suggest not to make estimates for any ice product under low Sun condition.

Error Budget: versus S-NPP and independent data

Attribute Analyzed	L1RD Threshold	On-orbit Performance	Meet Spec?	Additional Comments
Concentration: Accuracy	10%	NH: -1.3%, SH: -2.2% NH: 0.05%, SH: 0.17%	Yes	
Precision	25%	NH: 6.2%, SH: 21.7% NH: 5.0%, SH: 12.0%	Yes	
Temperature: Accuracy	1K	NH: 0.35K, SH: 0.59K NH: -0.055K, SH: 0.049	Yes	
Precision	1.5K	NH: 1.38K, SH: 1.35K NH: 1.17, SH: 1.02	Yes	
Age/Thickness: Accuracy	70% probability of correct typing	> 88% for all conditions; generally > 90%	Yes	
Precision	n/a	n/a	n/a	

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Mike Lawson	NWS AK Sea Ice Program (ASIP)	Ice operations around Alaska	Concentration: Very useful. Temperature: Useful for certain analyses. Thickness: Useful in limited circumstances.
Various	National Ice Center (NIC)	Ice operations, global	Training done at the NIC in August; expressed interest in products
Bob Grumbine	NCEP/EMC	Forecast modeling	Concentration has been tested with positive results; thickness will be useful in the future.
Mark Middlebusher	NAVOCEAN	Ice forecasting (modeling)	Concentration improved the accuracy of the ice edge forecast by more than 30%.

Downstream Product Feedback

There are no products that use the ice products as input.

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts
None		

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
Cloud mask	Still some false clear in Antarctic, in particular, but improved over v1r2.	Some false ice	Work with cloud team (ongoing)

Documentation

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes (README files with software)
System Maintenance Manual (for ESPC products)	Unknown
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	As requested

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.	All requirements have been met with very limited datasets. Spatial coverage is adequate; seasonal coverage is not. Some Antarctic results did not meet requirements, possibly due to cloud mask errors.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	Yes (no significant anomalies or weaknesses). However, important updates were recently made to the ice thickness algorithm. The updated code has been delivered to the AIT.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes, at least for operational testing

Conclusion

Cal/Val results summary:

- Based on the findings presented, the Team recommends that all three ice products be declared Provisional Maturity.

Path Forward

- Planned improvements:
  - Ice thickness algorithm has significant improvements since the February DAP (since delivered)
  - Further evaluate the cause of a positive IST bias, particularly in the Antarctic.
  - Further evaluate the optimal scanning angle limit for ice products
- Future Cal/Val activities / milestones
  - MOSAIC field experiment: on-ice sea ice measurements over winter 2019-2020 as icebreaker drifts along trans-polar drift stream
  - IceBridge: more KT-19 data for IST, thickness
  - Use additional ice charts (NIC, Canadian Ice Service, AARI)
  - More comparison during Arctic (Antarctic) summer (winter) for Validated Maturity review.

References

ATBDs

Wang, X. and J. Key, 2019, ABI and VIIRS ice thickness and age algorithm theoretical basis document, version 2.2, NOAA/NESDIS Center for Satellite Applications and Research, 71 pp.

Liu, Y. and J. Key, 2019, ABI and VIIRS ice surface temperature, ice concentration, and ice cover algorithm theoretical basis document, version 1.2, NOAA/NESDIS Center for Satellite Applications and Research, 42 pp.

Journal Papers

Key, J. R., R. Mahoney, Y. Liu, P. Romanov, M. Tschudi, I. Appel, J. Maslanik, D. Baldwin, X. Wang, and P. Meade, 2013, Snow and ice products from Suomi NPP VIIRS, J. Geophys. Res. Atmos., 118, doi:10.1002/2013JD020459.

Liu, Y., J. Key, and R. Mahoney, 2016, Sea and Freshwater Ice Concentration from VIIRS on Suomi NPP and the Future JPSS Satellites, Remote. Sens., 8(6), 523; doi:10.3390/rs8060523.

Wang, X., J. Key, R. Kwok, and J. Zhang, 2016, Comparison of sea ice thickness from satellites, aircraft, and PIOMAS data, Remote. Sens., 8, 713, doi:10.3390/rs8090713.

Wang, X., J. Key, and Y. Liu, 2010, A thermodynamic model for estimating sea and lake ice thickness with optical satellite data, J. Geophys. Res.-Oceans, 115, C12035, doi:10.1029/2009JC005857.

Extra Slides

Requirement Check List – Ice Concentration

JERD	Requirement	Meet Requirement (Y/N)?
JERD-2436	The algorithm shall produce an ice concentration product that has a vertical coverage of the ice surface	
JERD-2505	The algorithm shall produce an ice concentration product that has a horizontal cell size of 1.0 km in clear conditions	
JERD-2506	The algorithm shall produce an ice concentration product that has a mapping uncertainty (3 sigma) of 1 km at Nadir for clear pixels	
JERD-2507	The algorithm shall produce an ice concentration product that has a measurement range of 0 – 100%	
JERD-2508	The algorithm shall produce an ice concentration product that has a measurement accuracy of 10%	
JERD-2509	The algorithm shall produce an ice concentration product that has a measurement uncertainty of 25%	
JERD-2510	The algorithm shall produce an ice concentration product in all ice-covered regions of the global ocean	

Requirement Check List – Ice Surface Temperature

JERD	Requirement	Meet Requirement (Y/N)?
JERD-2437	The algorithm shall produce an ice surface temperature product with a sensing depth of the ice surface	
JERD-2511	The algorithm shall produce an ice surface temperature product with a horizontal cell size of 1 km at Nadir and 1.6 km at worst case	
JERD-2512	The algorithm shall produce an ice surface temperature product with a mapping uncertainty (3 sigma) of 1 km at Nadir and 1.6 km at worst case	
JERD-2513	The algorithm shall produce an ice surface temperature product with a measurement range of 213-275 K	
JERD-2514	The algorithm shall produce an ice surface temperature product with a measurement uncertainty of 1 K	
JERD-2515	The algorithm shall produce an ice surface temperature product with a geographic coverage of ice-covered oceans	

Requirement Check List – Ice Age/Thickness

JERD	Requirement	Meet Requirement (Y/N)?
JERD-2435	The algorithm shall produce an ice age/thickness product that has a vertical coverage of the ice surface	
JERD-2500	The algorithm shall produce an ice age/thickness product that has a horizontal cell size of 1.0 km in clear conditions	
JERD-2501	The algorithm shall produce an ice age/thickness product that has a mapping uncertainty (3 sigma) of 1 km at Nadir for clear pixels	
JERD-2502	The algorithm shall produce an ice age/thickness product that has a measurement range of: Ice free, New/Young Ice, all other ice for Ice Age	
JERD-2503	The algorithm shall produce an ice age/thickness product that has a measurement uncertainty of 70% for Ice Age probability of correct typing	
JERD-2504	The algorithm shall produce an ice age/thickness product in all ice-covered regions of the global ocean	