Maturity Science Review for NOAA-20 Cryosphere Products

Sea Ice

Jeff Key and Xuanji Wang

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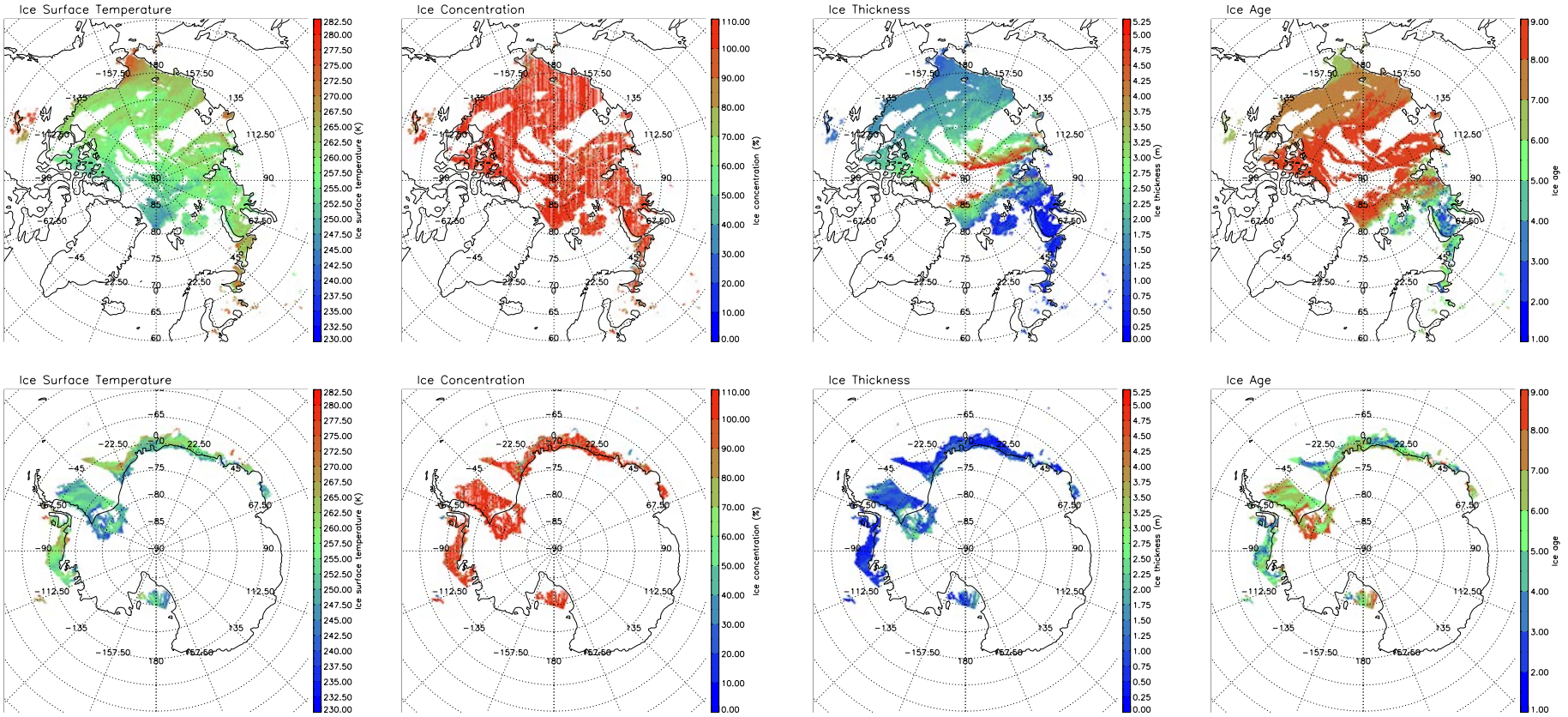
Sea Ice Cal/Val Team

Algorithm Cal/Val Team Members

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

NOAA-20 Sea Ice Product Examples



Composite sea ice temperature, concentration, thickness, and age (from left to right) over the period April 22 – May 31, 2018. The upper panel is for the Arctic, and the lower panel is for the Antarctic.

Sea Ice Product Users

- Uses
  - Navigation
  - Emergency Management
  - Operational Weather Prediction
  - Climate Research
  - Security

- U.S. Users
  - NIC, National/Naval Ice Center
  - NWS Alaska Sea Ice Program (ASIP)
  - NCEP (experimentally)

JERD Requirements: Sea Ice Concentration

Ice concentration is defined as the fraction of a given area of sea water covered by ice. The concentration of sea ice varies within the ice pack due to deformation, new ice development, melting, and motion. Total concentration includes all stages of development that are present.

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% (Notes 1, 2, 3).

JERD-2509 The algorithm shall produce an ice concentration product that has a measurement uncertainty of 25% (Notes 1, 2, 3). *(Recommended: MP=25%)*

JERD-2510 The algorithm shall produce an ice concentration product in all ice-covered regions of the global ocean.

L1RD requirements are in the Extra Slides section.

JERD Requirements: Ice Surface Temperature

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.

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. *(Recommended: MA = 1.0K; MP = 1.5K)*
JERD-2515 The algorithm shall produce an ice surface temperature product with a geographic coverage of ice-covered oceans (Note 1).

L1RD requirements are in the Extra Slides section.

JERD Requirements: Ice Surface Thickness/Age

The Ice Age/Thickness EDR provides ice age classes. Sea ice age is defined as the time that has passed since the formation of ice on the surface of sea water. Ice age is related to ice thickness.

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 (Notes 1, 2, 3).
(Recommendation: Change "uncertainty" to "accuracy")
JERD-2504 The algorithm shall produce an ice age/thickness product in all ice-covered regions of the global ocean.

L1RD requirements are in the Extra Slides section.

Beta Maturity Definition

- Early release product.
- Minimally validated.
- May still contain significant errors.
- Versioning not established until a baseline is determined.
- Available to allow users to gain familiarity with data formats and parameters.
- Product is not appropriate as the basis for quantitative scientific publication studies and applications.

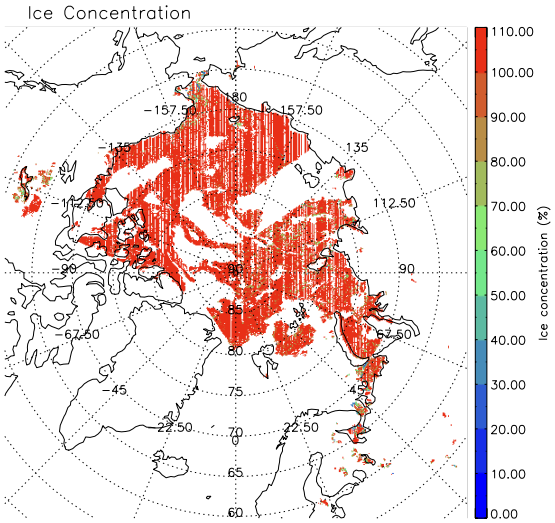
NOAA-20 Sea Ice Product Maturity Evaluation

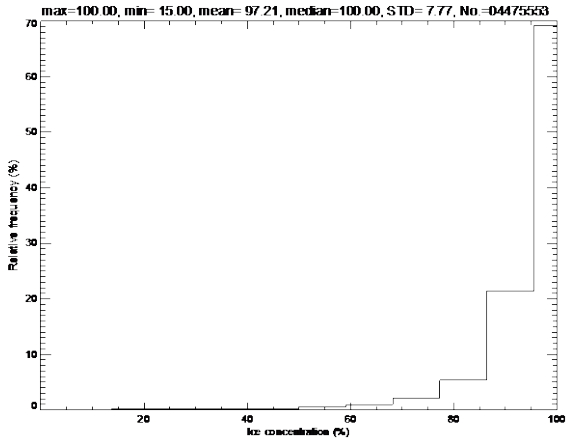
Maturity Evaluation Approaches

- Our analysis has focused on the Arctic and Antarctic, for the period of April 22 – May 31, 2018. (Effectively April 22 – May 7. Almost no data or bad data since May 7, 2018)
- Comparisons have been done for all sea ice products with the data from NOAA-20, S-NPP, passive microwave, MODIS, and CryoSat-2.
- Simple statistical comparisons have been done for most of the sea ice products.
- Manual/visual inspection of sea ice product images have been done in some cases where temporal and spatial matching cannot be done.
- Some issues have been found in sea ice products related to algorithms and/or data quality.

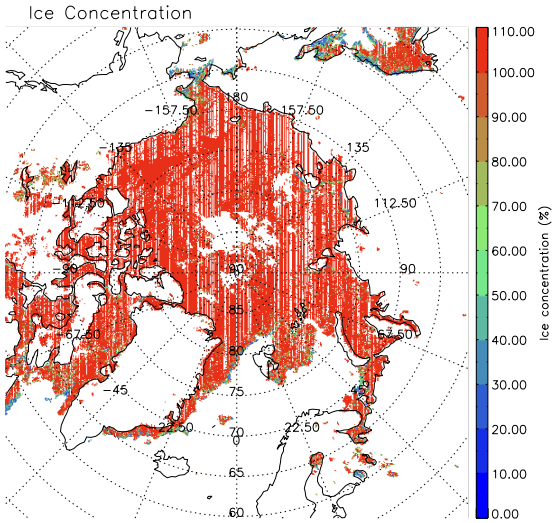
Sea Ice Concentration: NOAA-20 vs S-NPP

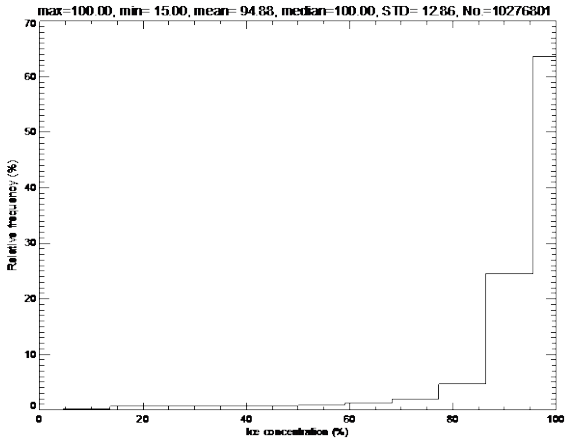
NOAA-20





S-NPP





Arctic Case

Composite period:
April 22-May 31, 2018

Statistical mean conc:

NOAA-20	S-NPP
97.21%	94.88%

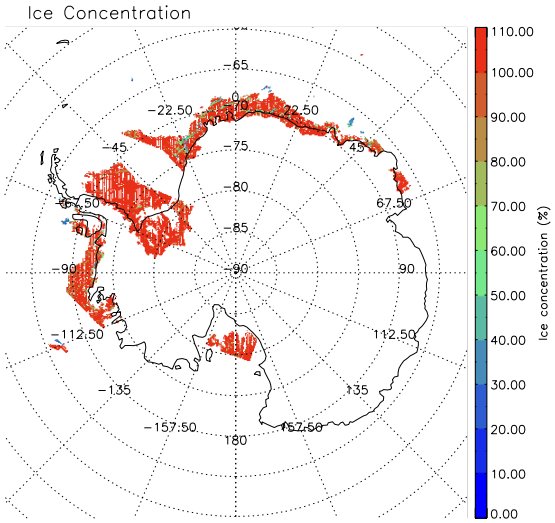
ISSUES:

NOAA-20 ice concentration has some unrealistic values (~0%) for the pack ice area. This may be due to errors in cloud masking when warmer clouds are not detected.

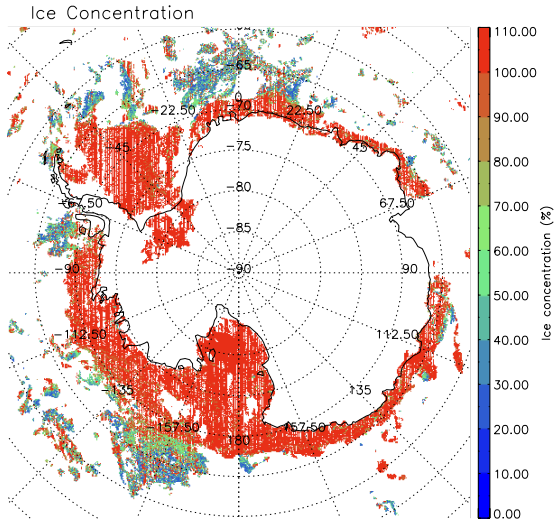
Composite over the period of April 22-May 31, 2018

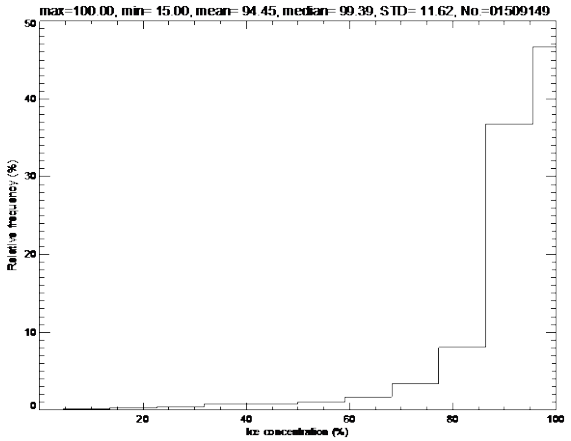
Sea Ice Concentration: NOAA-20 vs S-NPP

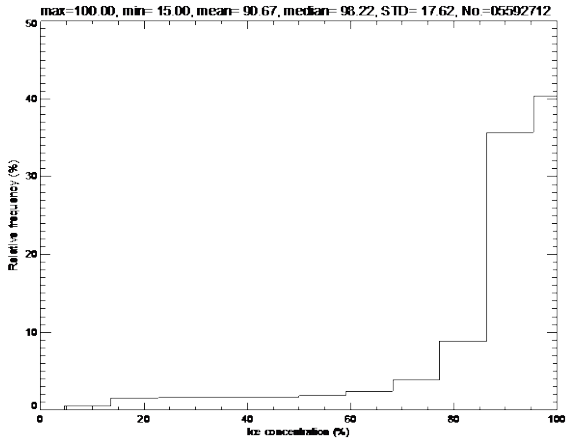
NOAA-20



S-NPP







Antarctic Case

Composite period:
April 22-May 31, 2018

Statistical mean:

NOAA-20	S-NPP
94.45%	90.67%

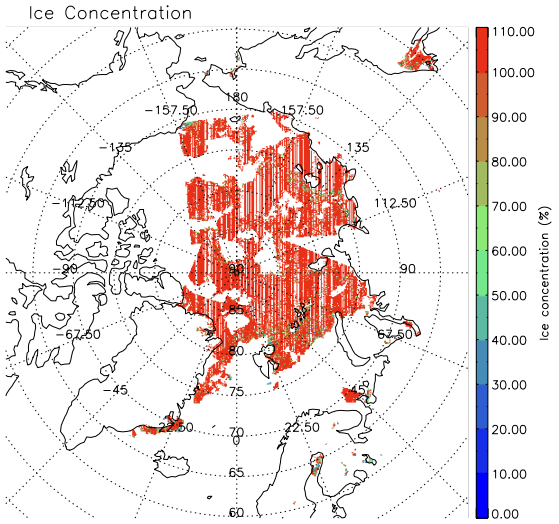
ISSUES:

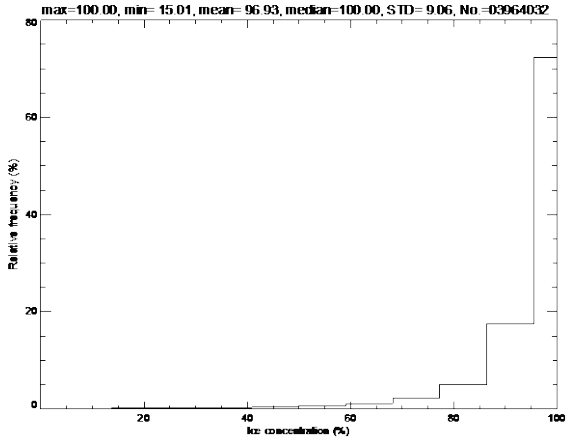
NOAA-20 ice concentration has some unrealistic values (~0%) for the pack ice areas, and also less data than S-NPP.

Composite over the period of April 22-May 31, 2018

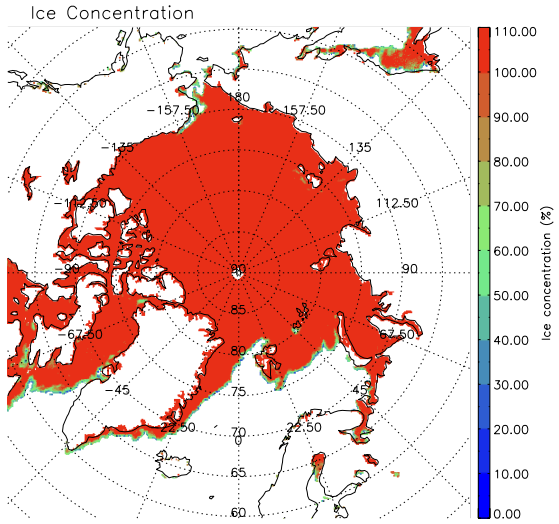
Sea Ice Concentration: NOAA-20 vs Microwave

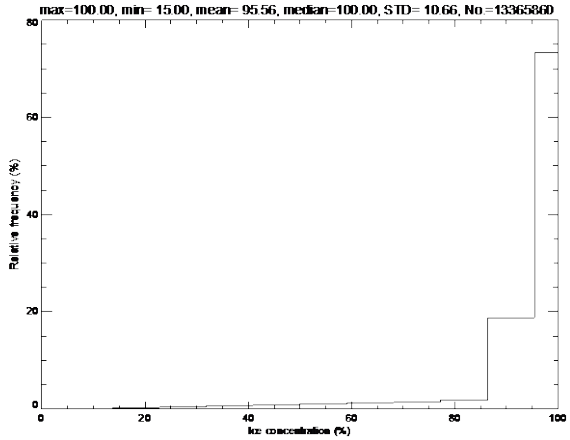
NOAA-20





Passive Microwave (AMSR2)





April 28, 2018

Arctic Case

Composite period:
April 28, 2018

Statistical mean:

NOAA-20	Microwave
96.93%	95.56%

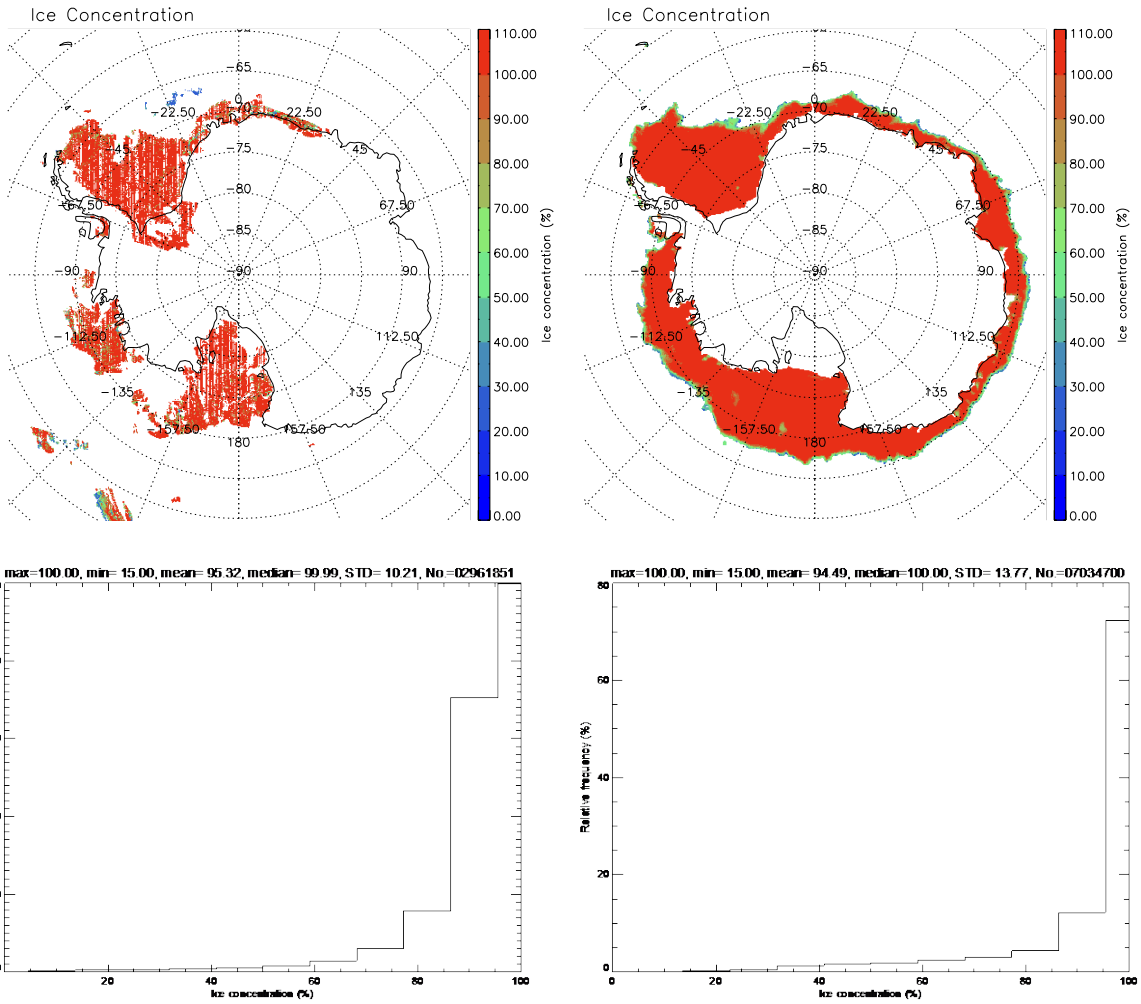
ISSUES:

NOAA-20 ice concentration has some unrealistic values (~0%) for the pack ice area.

Sea Ice Concentration: NOAA-20 vs Microwave

NOAA-20

Passive Microwave (AMSR2)



April 28, 2018

Antarctic Case

Composite period:

April 28, 2018

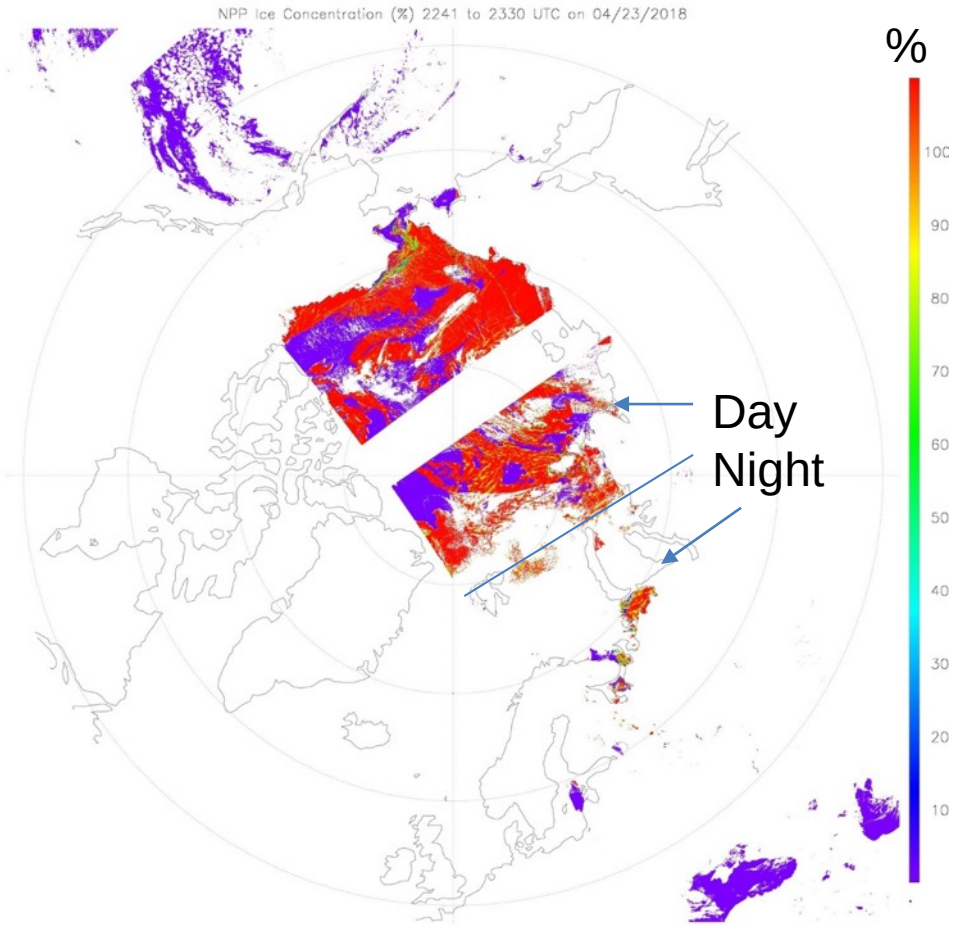
Statistical mean:

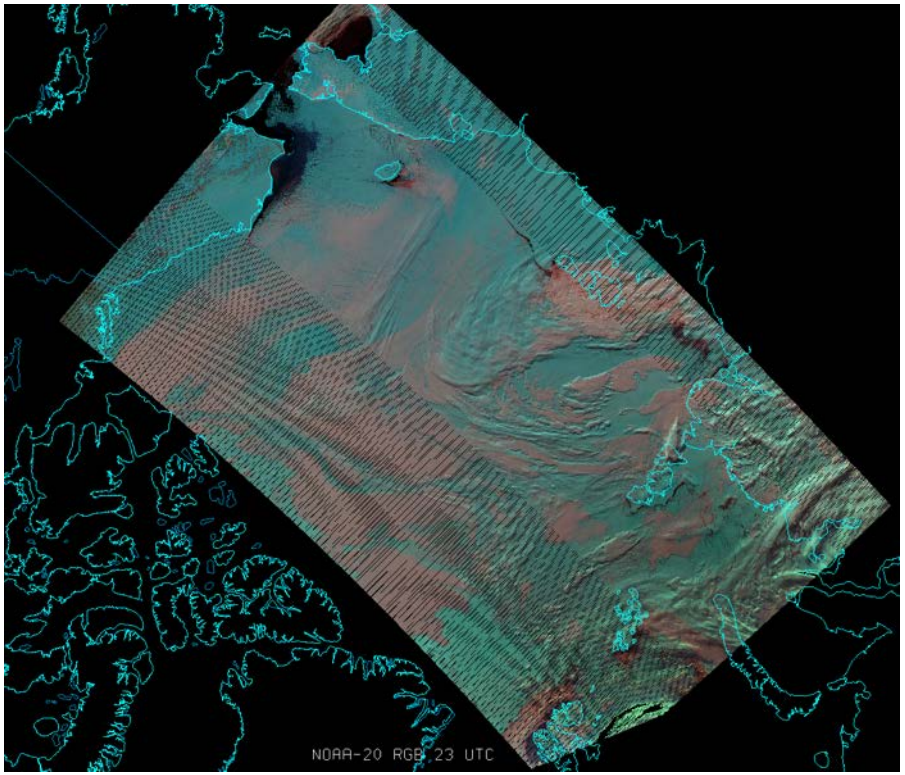
NOAA-20	Microwave
95.32%	94.49%

ISSUES:

NOAA-20 ice concentration has some unrealistic values (~0%) for the pack ice area.

Sea Ice Concentration: NOAA-20 Examples local run with updated algorithm



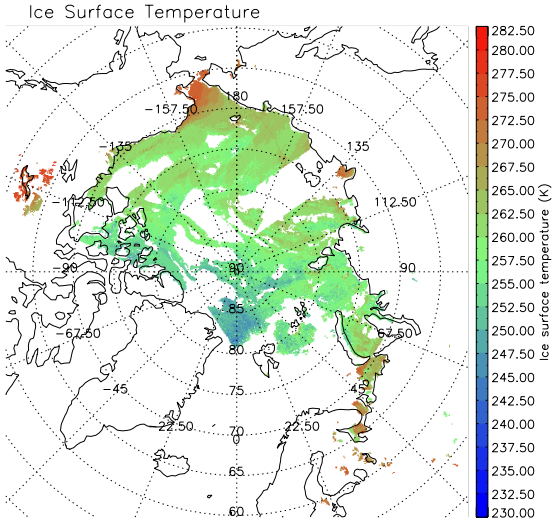


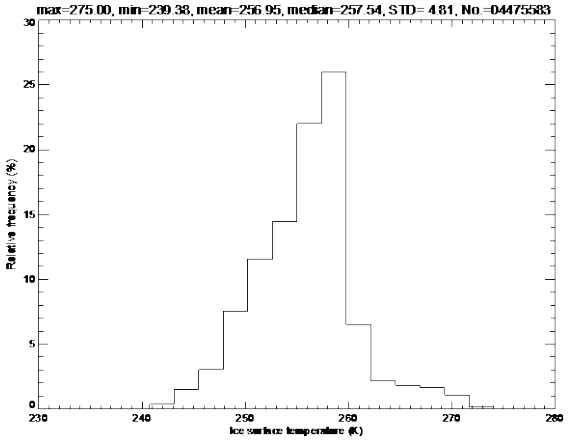
RGB (M5-7-10) over Arctic 23 April 2241-2330 UTC

- Large areas of zero ice concentration during the day.
- Evidence that the issue is with the cloud masking during day.
- Undetected warm water clouds at 1.6 µm appears to be the problem (cloud “leakage”).
- Nighttime cases to not have this issue.

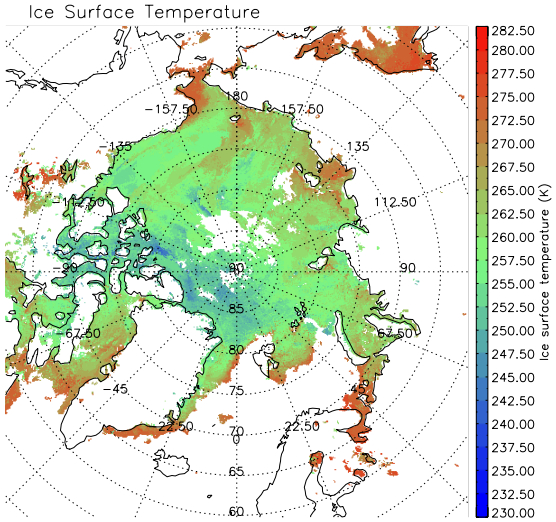
Sea Ice Temperature: NOAA-20 vs S-NPP

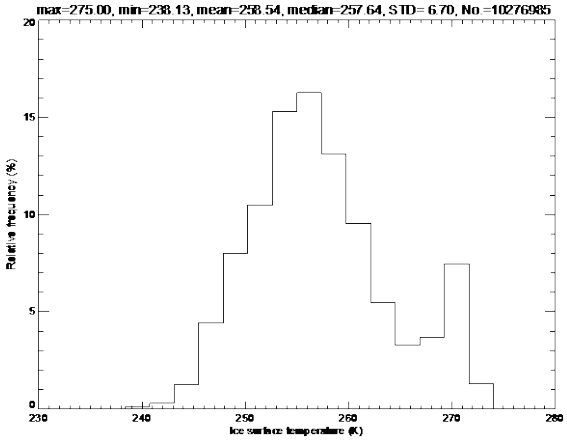
NOAA-20





S-NPP





Arctic Case

Composite period:
April 22-May 31, 2018

Statistical mean:

NOAA-20	S-NPP
256.95 K	258.54 K

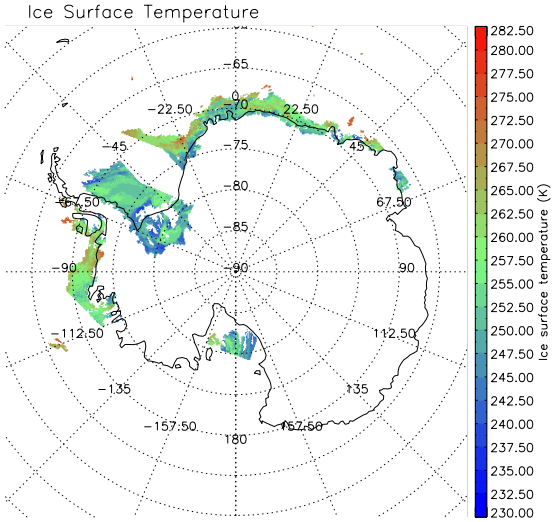
ISSUES:

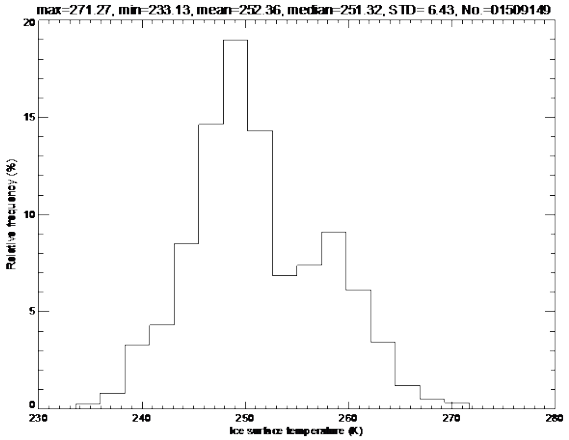
More data from operational S-NPP than operational NOAA-20, which might be related to the bad data quality from the Integration and Testing (I&T) string for NOAA-20.

Composite over the period of April 22-May 31, 2018

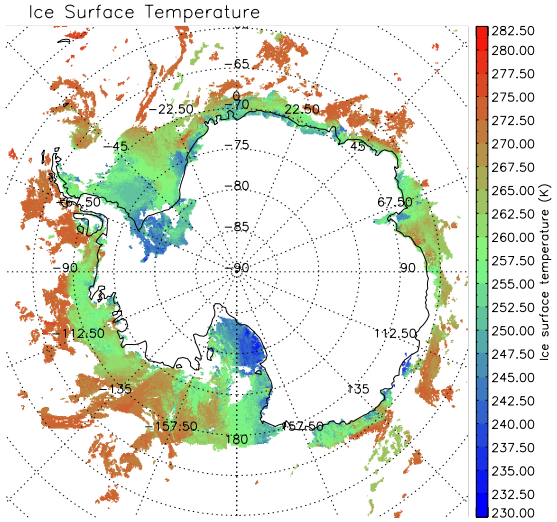
Sea Ice Temperature: NOAA-20 vs S-NPP

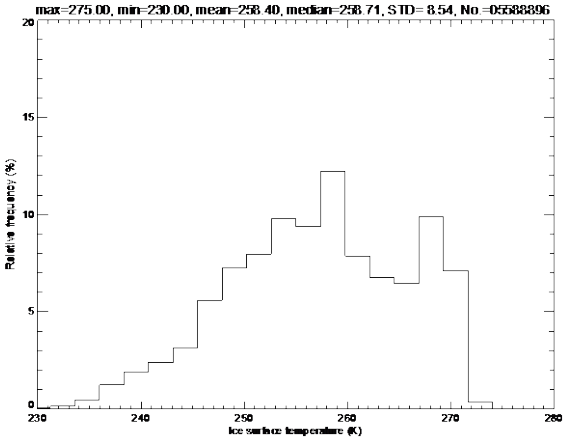
NOAA-20





S-NPP





Antarctic Case

Composite period:
April 22-May 31, 2018

Statistical mean:

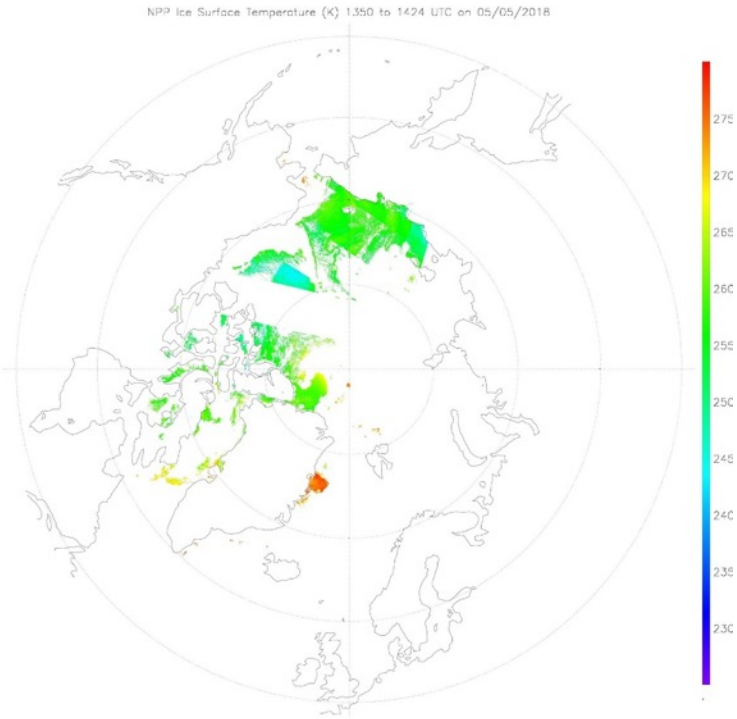
NOAA-20	S-NPP
252.36 K	258.40 K

ISSUES:
More data from S-NPP than NOAA-20 in general.

Composite over the period of April 22-May 31, 2018

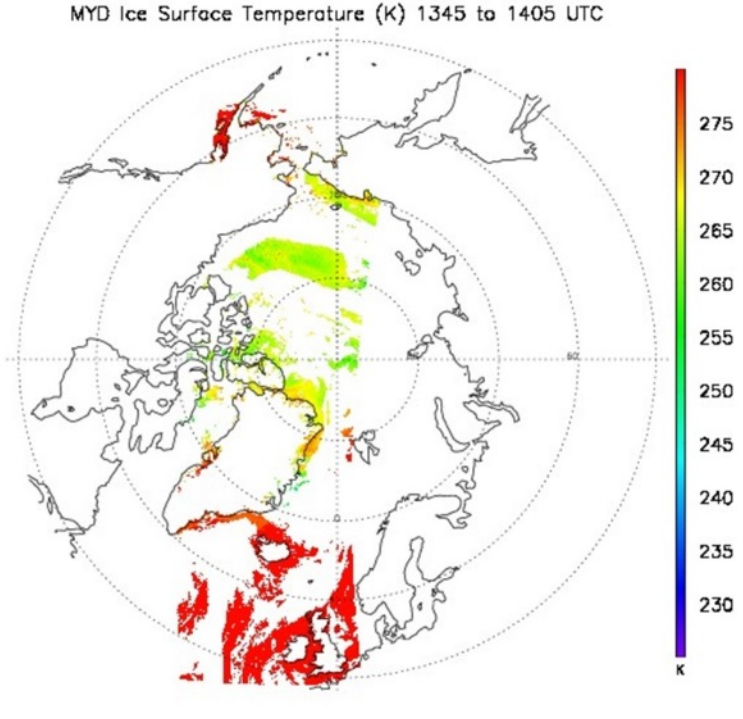
Sea Ice Temperature: NOAA-20 vs MODIS

NOAA-20



May 5,2018 1350 to 1424 UTC

MODIS



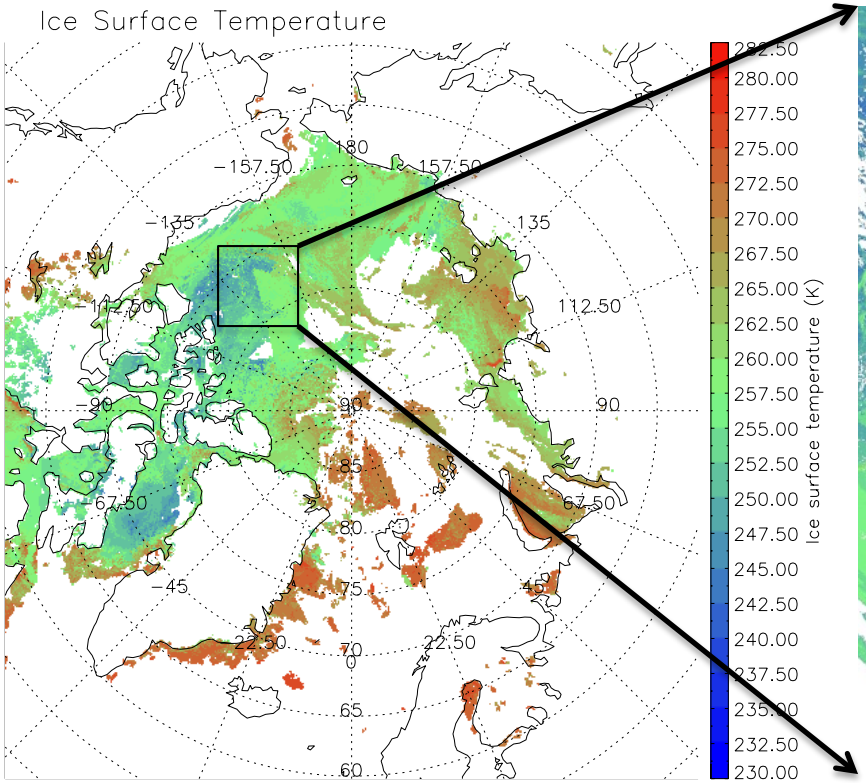
May 28,2018 1345 to 1400 UTC

Unfortunately, there are no data for ice products from NOAA-20 since May 7, 2018, and MODIS data are available May 27 onward so far. We will collect more NOAA-20 and MODIS data for further comparison in ice surface temperature. *(Note: dates and color scales are different for those two cases. The point of this slide is that we use MODIS IST for comparison.)*

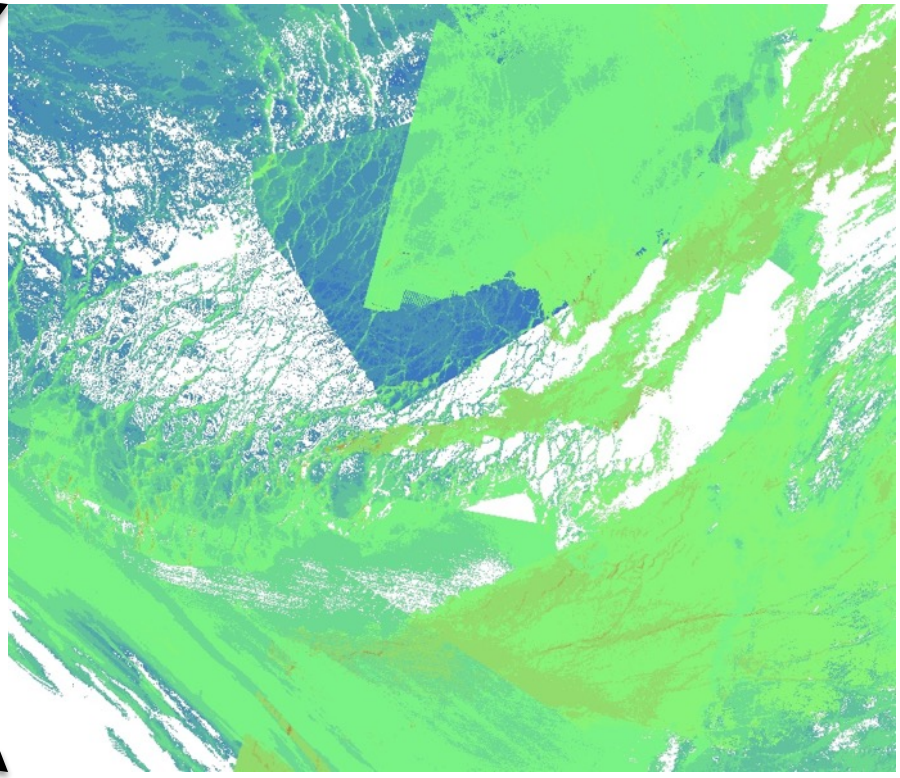
Sea Ice Temperature: NOAA-20

NOAA-20

Mapped reduced resolution



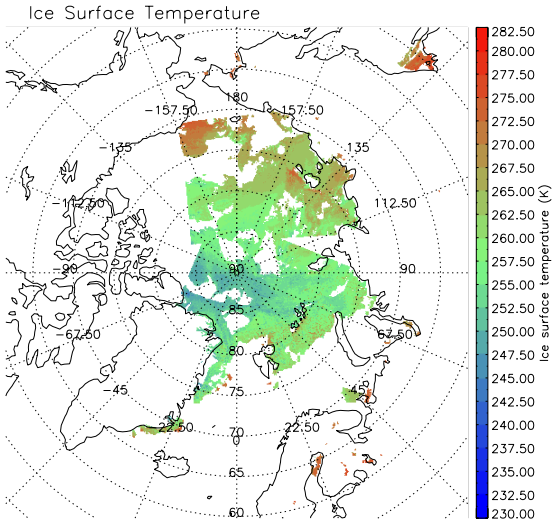
Original resolution (1 km), part

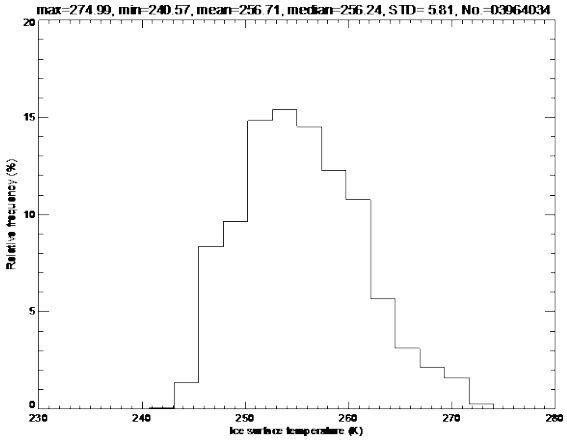


Daily composite on May 5, 2018, ice surface temperature (K).

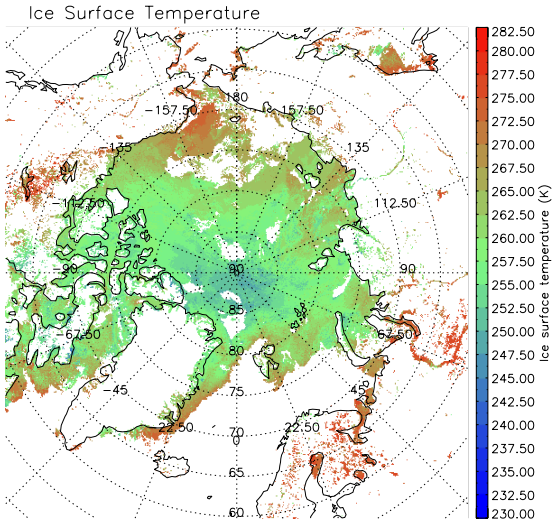
Sea Ice Temperature: NOAA-20 vs S-NPP local run with updated algorithm

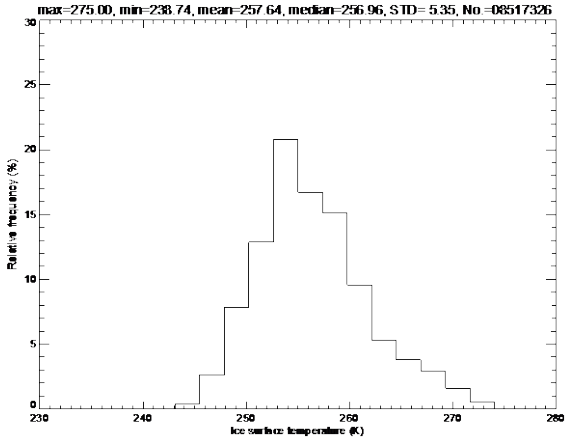
NOAA-20





S-NPP local run with updated algorithm





April 28, 2018

Arctic Case

Composite period:
April 28, 2018

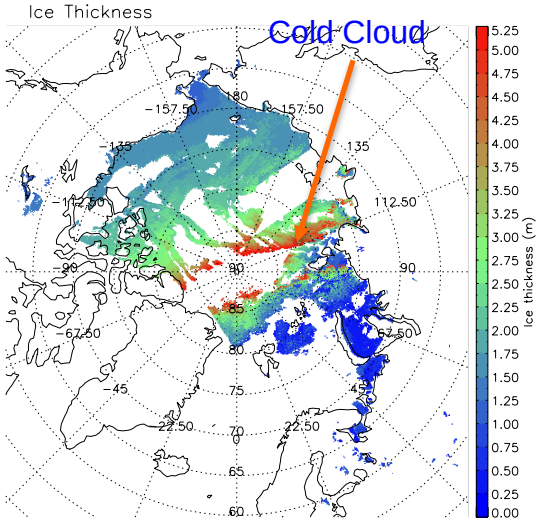
Statistical mean:

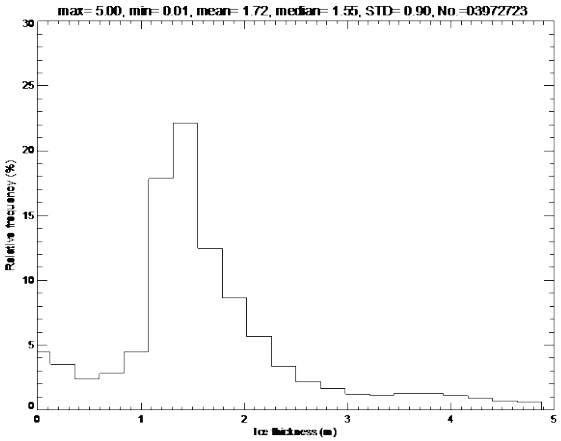
NOAA-20	S-NPP
256.71 K	257.64 K

ISSUES:
Less data for NOAA-20 than the S-NPP on April 28, 2018 and in general.

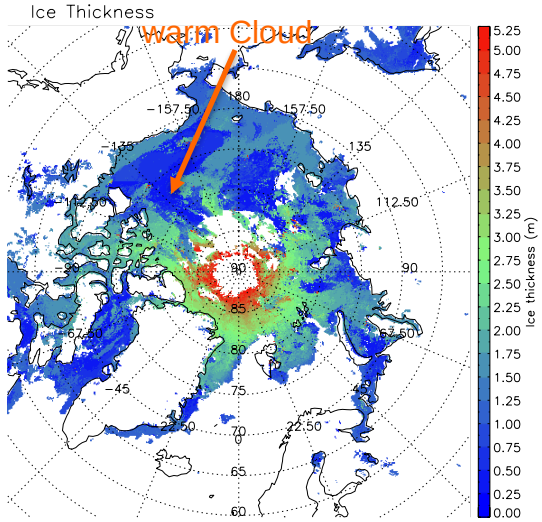
Sea Ice Thickness: NOAA-20 vs S-NPP

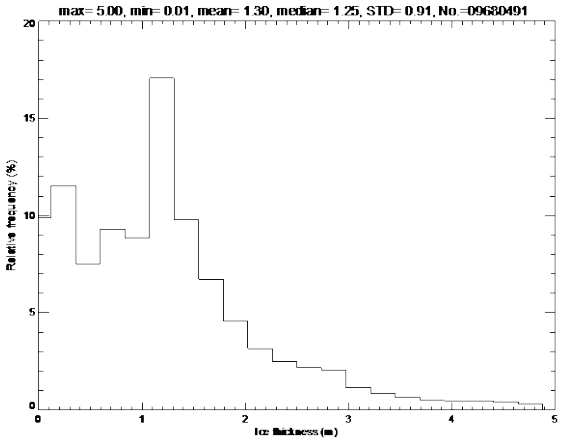
NOAA-20





S-NPP





April 22-May 31, 2018

Arctic Case

Composite period:
April 22-May 31, 2018

Statistical mean:

NOAA-20	S-NPP
1.72 m	1.30 m

ISSUES:

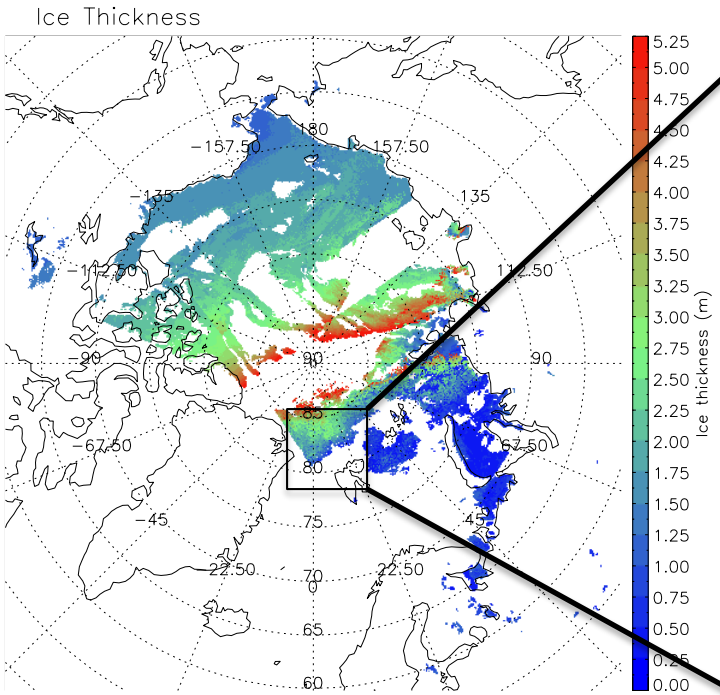
Wrong cloud clearing and low sun conditions cause larger uncertainty in sea ice thickness, especially when warm clouds are identified as clear areas and therefore an incorrect (higher) surface temperature, as seen in S-NPP case. Also cold cloud areas can be mislabeled clear, leading to unrealistic thicker ice as seen in both cases.

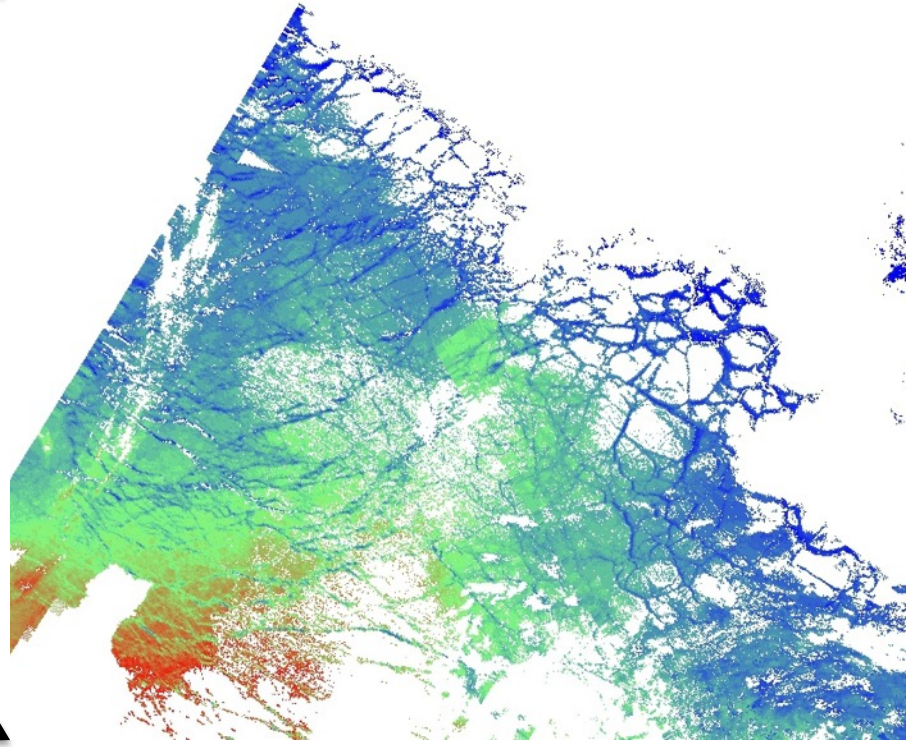
Sea Ice Thickness: NOAA-20

NOAA-20

Mapped reduced resolution

Original resolution (1 km), part

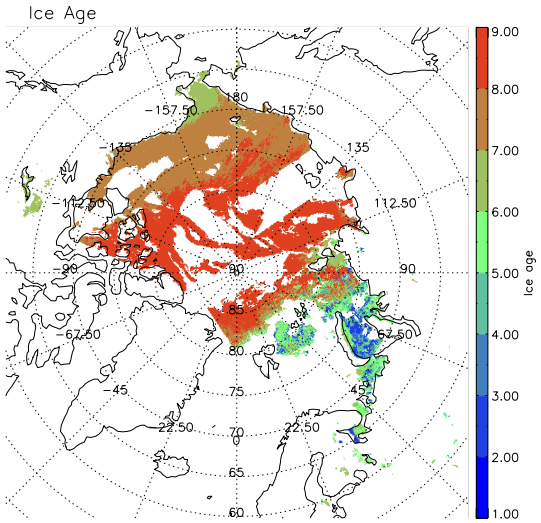


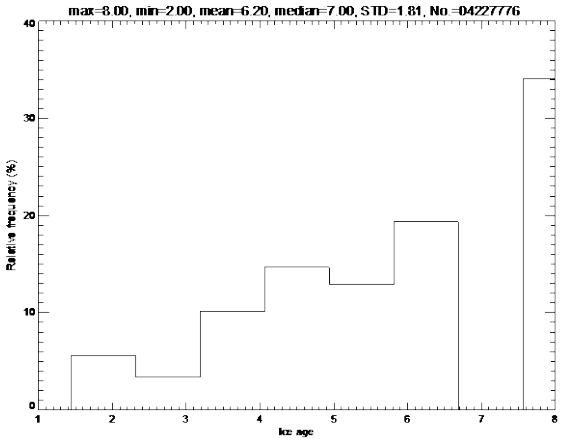


Daily composite on April 23, 2018, ice thickness (m).

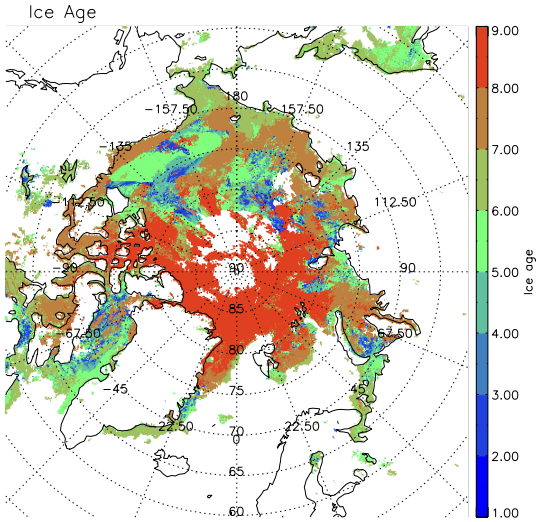
Sea Ice Age: NOAA-20 vs S-NPP

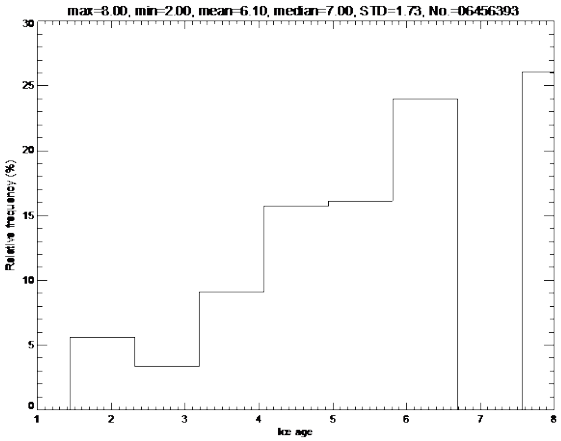
NOAA-20





S-NPP





April 22-May 31, 2018

Arctic Case

Composite period:
April 22-May 31, 2018

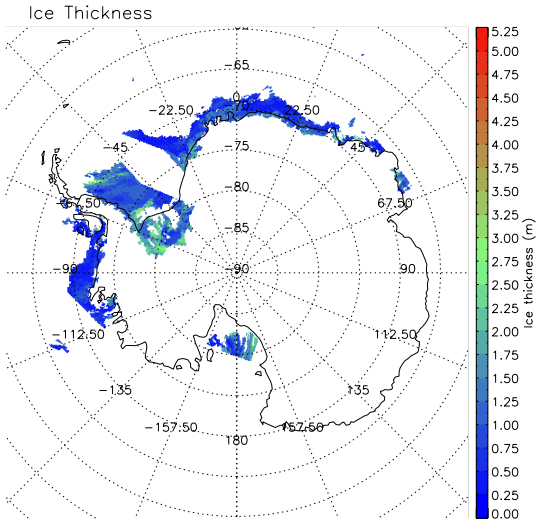
Statistical mean:

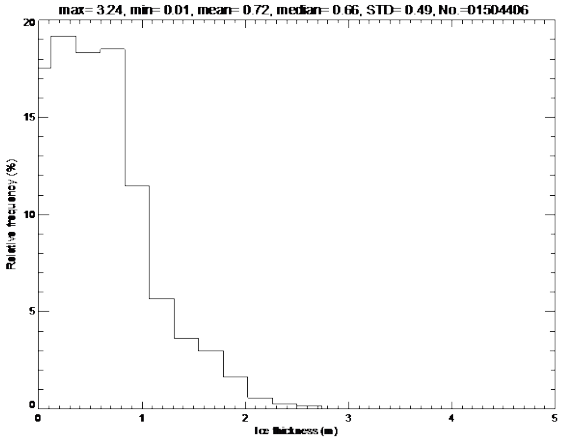
NOAA-20	S-NPP
6.20	6.10

ISSUES:
Cloud and low sun conditions cause larger uncertainty in sea ice thickness estimation as stated in the previous slides.

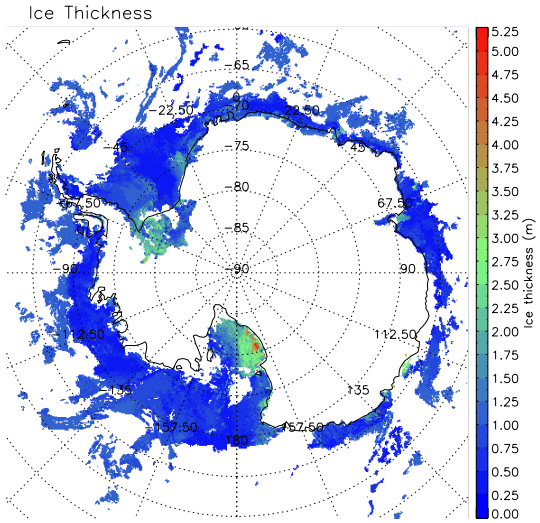
Sea Ice Thickness: NOAA-20 vs S-NPP

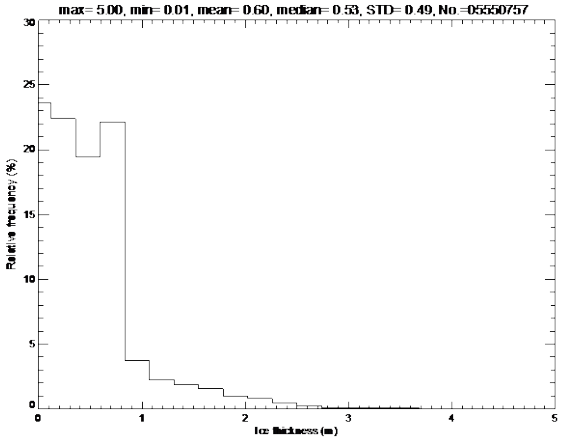
NOAA-20





S-NPP





April 22-May 31, 2018

Antarctic Case

Composite period:
April 22-May 31, 2018

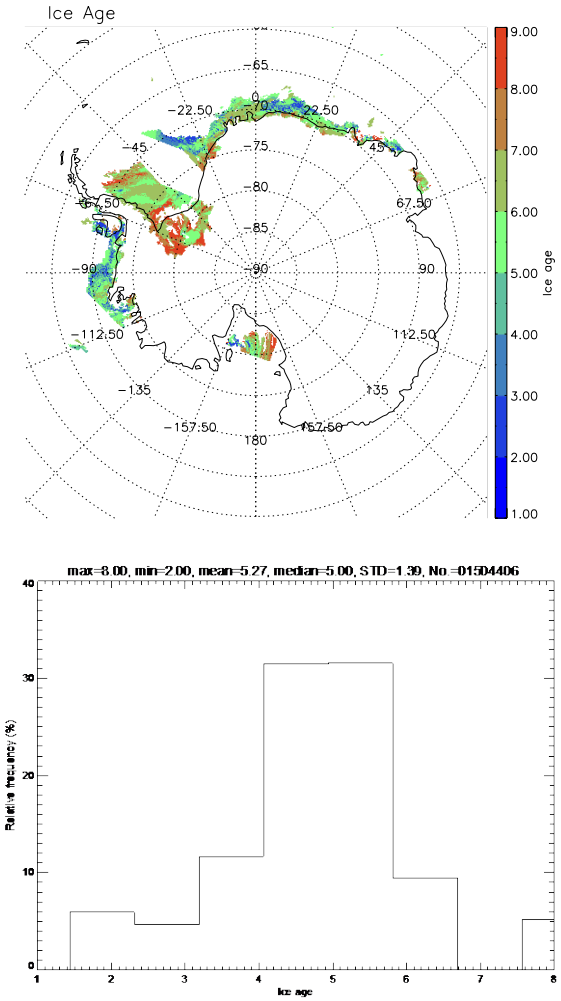
Statistical mean:

NOAA-20	S-NPP
0.72 m	0.60 m

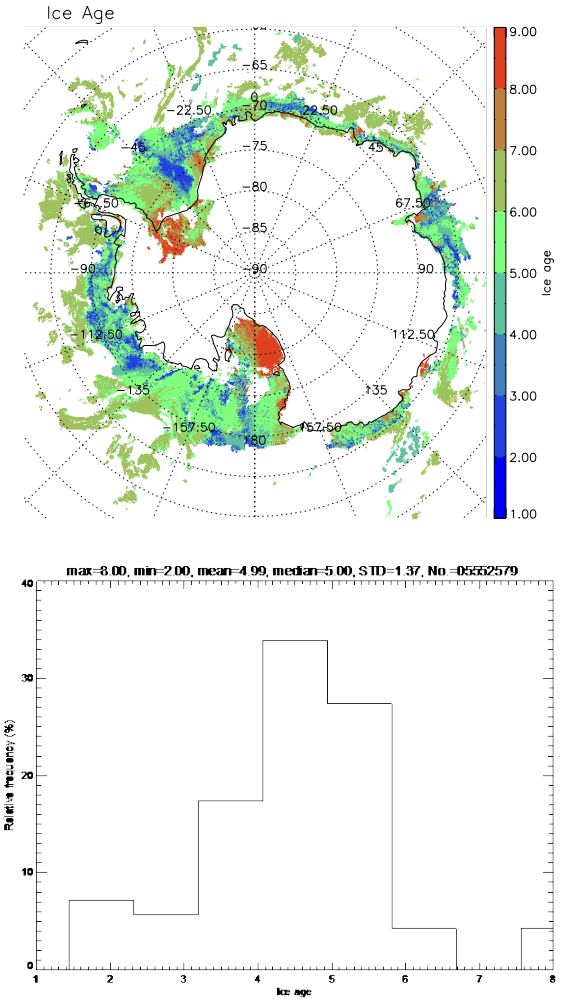
ISSUES:
Nighttime cases.

Sea Ice Age: NOAA-20 vs S-NPP

NOAA-20



S-NPP



April 22-May 31, 2018

Antarctic Case

Composite period:
April 22-May 31, 2018

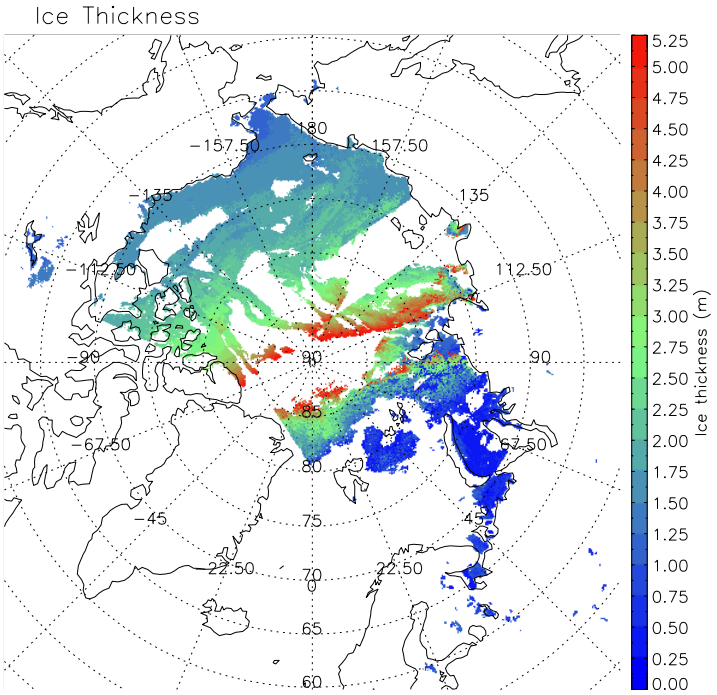
Statistical mean:

NOAA-20	S-NPP
5.27	4.99

ISSUES:
Cloud and low sun conditions cause larger uncertainty in sea ice thickness estimation.

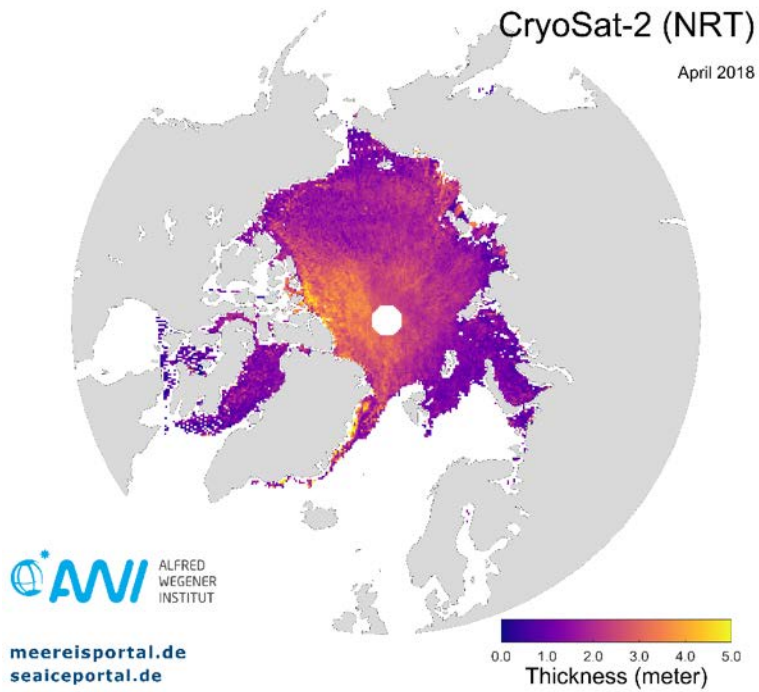
Sea Ice Thickness: NOAA-20 vs CryoSat-2

NOAA-20



Period composite of ice thickness over April 22-30, 2018 from NOAA-20.

CryoSat-2

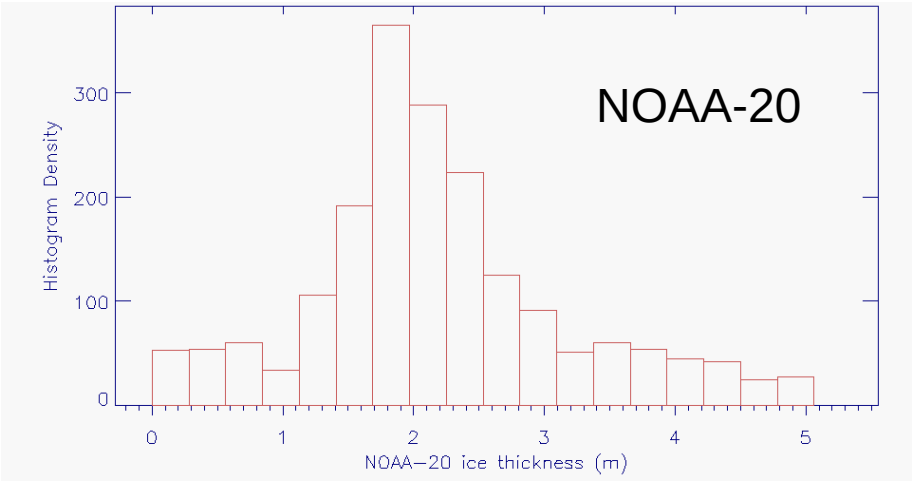


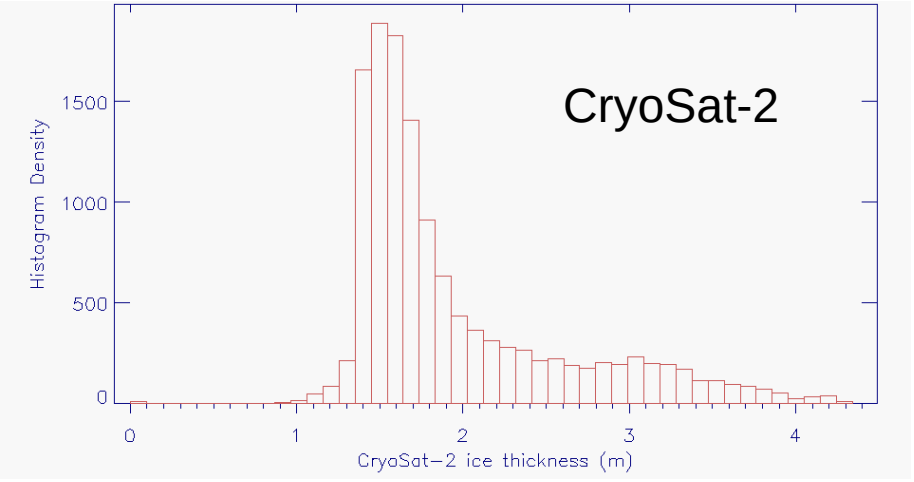
Monthly mean of ice thickness for April from CryoSat-2.

(Note: The dates and spatial coverage are different between two.)

Sea Ice Thickness: NOAA-20 vs CryoSat-2

Arctic Case, April 22-28, 2018





Arctic Case

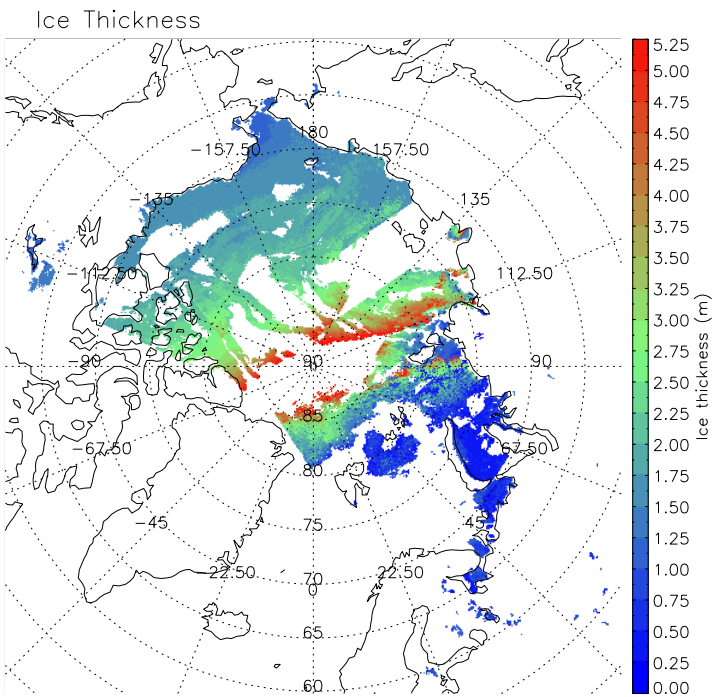
Composite period:

April 22 - April 28, 2018

	NOAA-20	CryoSat-2
Mean	2.19 m	2.03 m
St. Dev.	0.99 m	0.75 m

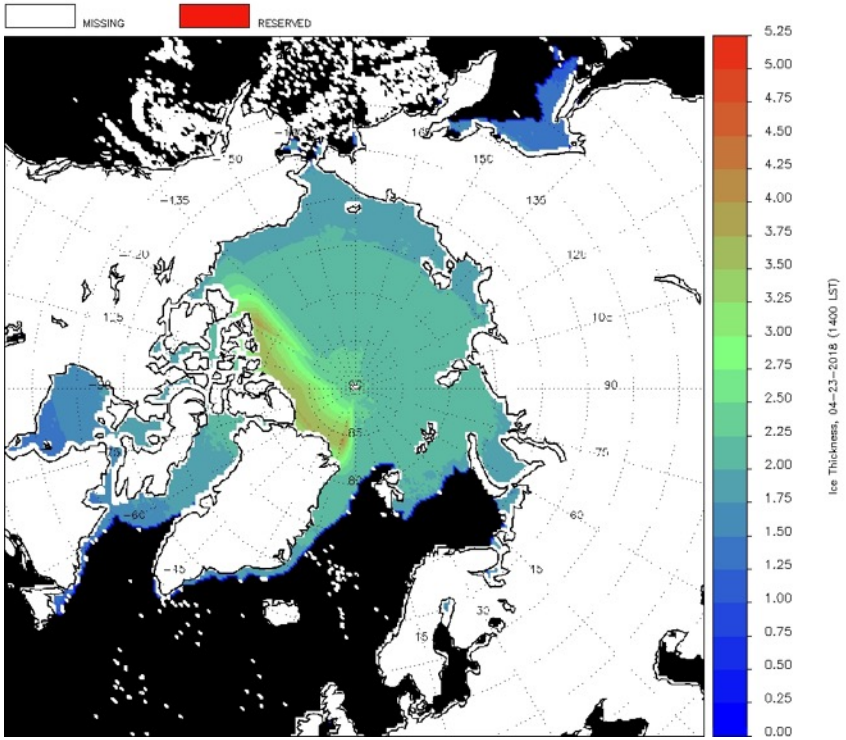
Sea Ice Thickness: NOAA-20 vs APP-x (NOAA-19)

NOAA-20



Daily composite of ice thickness for April 23, 2018 from operational NOAA-20. Resolution is 1 **km**.

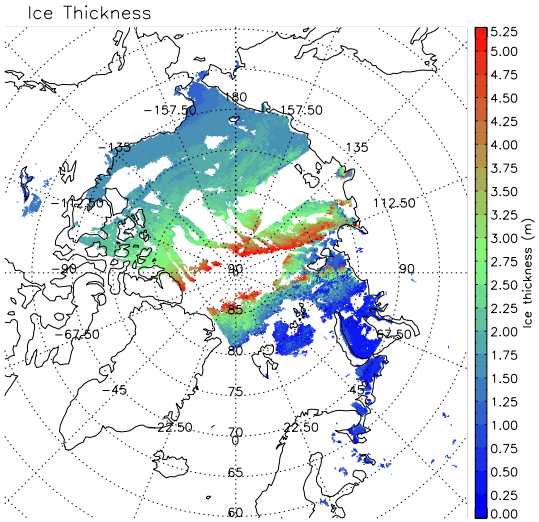
APP-x (NOAA-19, **25 km**)

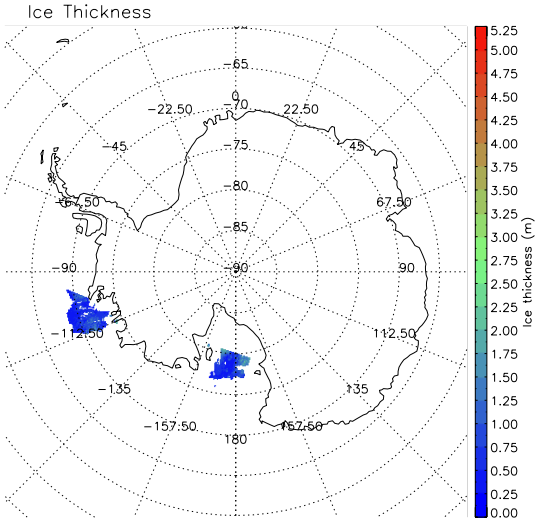


Ice thickness for April 23, 2018 from APP-x dataset (NOAA-19 data used for this date). Resolution is **25 km**.

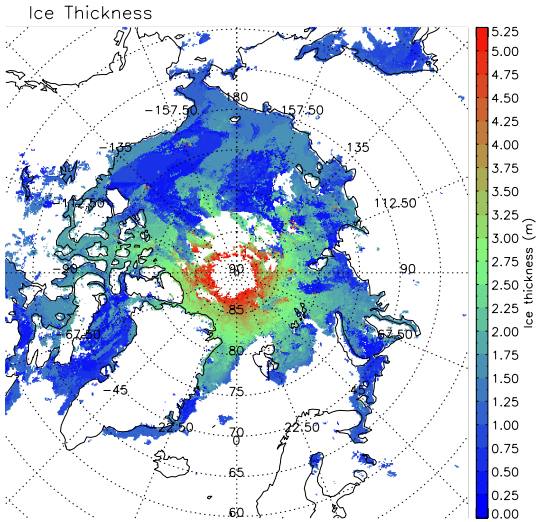
Sea Ice Thickness/Age: Current NDE vs Updated Algorithms

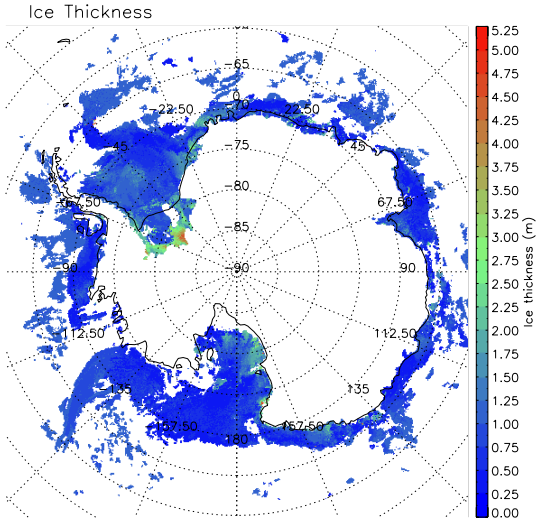
NOAA-20



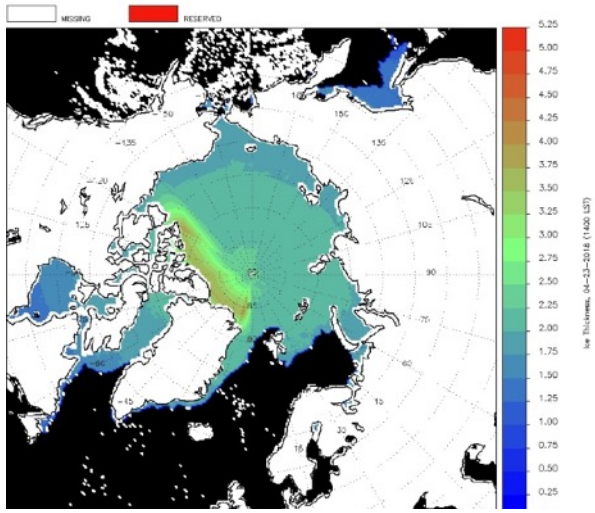


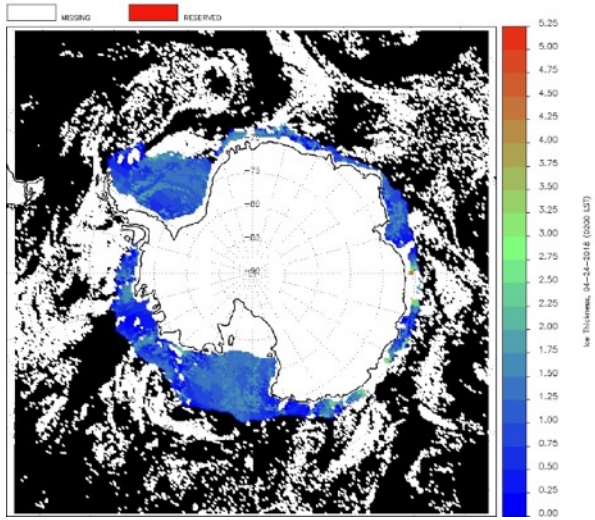
S-NPP





APP-x local run with updated algorithm (25 km)





Daily composite on April 23 (Arctic) and 24 (Antarctic), 2018, ice thickness (m).

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.

Documentations (Check List)

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)	
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least. annually) (Demonstrates long-term performance of the algorithm)	As requested

Conclusion (Known Issues)

- Beta maturity review summary:
  - Sea ice cover/temperature/concentration
    - **Team recommends algorithm maturity status as “Beta”**
    - Higher errors near ice edge due to ice dynamics, algorithm limitations with thin and melting
    - Higher errors under low Sun condition
    - QC filters may not eliminate all spurious ice due to weather or along coast
  - Sea ice thickness/age
    - **Team recommends algorithm maturity status as “beta”**
    - Higher errors near ice edge due to ice dynamics, especially during melting season
    - Higher errors under low Sun condition
    - Larger uncertainties with larger/unknown input uncertainties such as cloud mask, snow depth, and et al
    - Validation continuity
  - Cloud masking
    - Errors in cloud masking resulting in areas of very low sea ice concentration and unrealistic ice thickness as well.

Path Forward

- Algorithm Updates
  - Ice thickness/age algorithm is undergoing updating/implementing now.
  - Ice cover/temperature/concentration algorithms need to be updated as well.
- Focus on ice age/thickness validation
  - Finish comparison with other data product
  - Improve quantification of errors/uncertainties
  - Publish manuscript on algorithm and validation studies
- Further ice concentration validation focusing on marginal ice zone (near the ice edge) to better assess and understanding performance in region of higher errors
- Further ice temperature validation will continue to be validated against in-situ measurements and data products from other satellites, e.g., MODIS.

Check List - Beta Maturity

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

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.	No
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes, except for cloud mask issues and a possible problem with the implementation of ice concentration (vertical lines)
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
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	No, but it probably would be if the cloud mask were Provisional.

Extra Slides

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

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.