

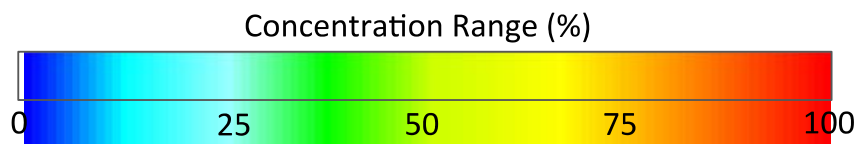
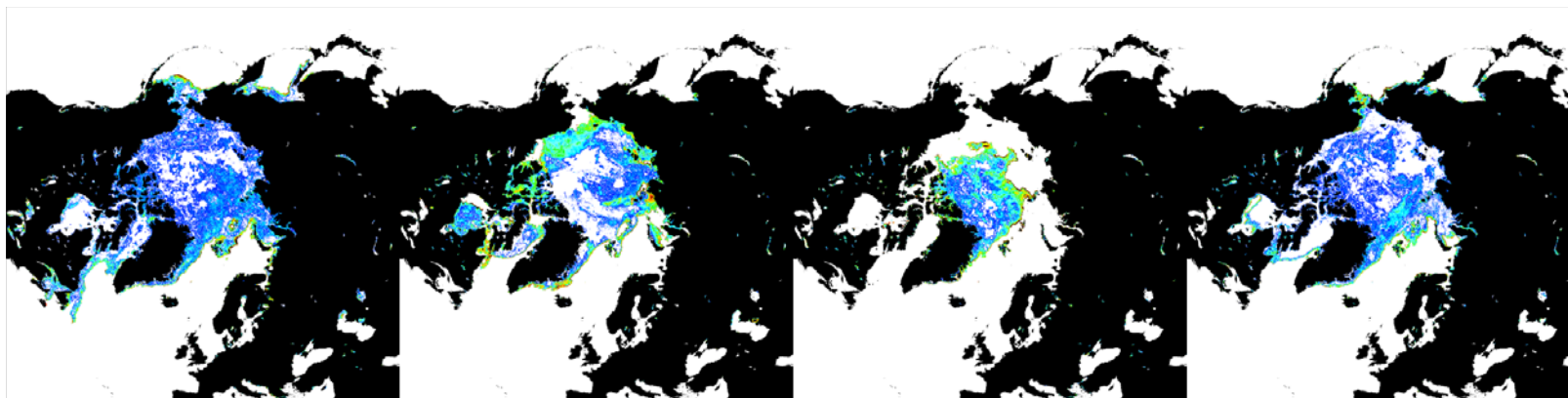
Validated Maturity Science Review for AMSR2 Sea Ice Characterization

Walt Meier and Jeff Key

Date: 2017/04/20

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Walt Meier	NASA Goddard	Sea ice product project management, consultant on analysis and validation
Scott Stewart	NSIDC	Software development, data processing, conduct analysis and validation
Jeff Key	NOAA	Overall snow and sea ice project management, assistance on analysis and validation
Julienne Stroeve	NSIDC	Project management, consultant on analysis



Daily concentration range (maximum – minimum concentration) in 2015 for the Northern Hemisphere on (a) March 15, (b) June 15, (c) September 15, (d) December 15, and (e-h) for the same dates in the Southern Hemisphere.

Requirements: Sea Ice Concentration

- Product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated

Attribute	Threshold	Observed/validated
Geographic coverage	Northern and southern hemisphere ice-covered regions	Northern and southern hemisphere ice-covered regions
Vertical Coverage	Ice surface	Ice surface
Vertical Cell Size	n/a	n/a
Horizontal Cell Size	10 km	10 km
Mapping Uncertainty	5 km	5 km
Measurement Range	0-100%	0-100%
Measurement Accuracy	(not specified, see note)	3.9% NH 4.4% SH
Measurement Precision	(not specified)	11% NH 8.8% SH
Measurement Uncertainty	10% (see note)	

Note: Measurement uncertainty should be changed to measurement accuracy (absolute value of the mean bias). The term “accuracy” and the specified value (10%) are consistent with ice concentration requirements for GOES-R ABI and JPSS VIIRS. It’s likely that accuracy is what was intended.

Requirements: Sea Ice Age Typing

- Product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated

Attribute	Threshold	Observed/validated
Geographic coverage	Northern and southern hemisphere ice-covered regions	Northern and southern hemisphere ice-covered regions
Vertical Coverage	Ice surface	Ice surface
Vertical Cell Size	n/a	n/a
Horizontal Cell Size	10 km	10 km
Mapping Uncertainty	5 km	5 km
Measurement Accuracy	70% probability of correct FYI/MYI typing	80-90% (preliminary) during winter, Arctic only
Measurement Uncertainty	n/a	

- Additional requirements from JPSS ESPC Requirements Document (JERD) Volume 2 - Science Requirements

Sea Ice Characterization constitutes the sea ice properties derived from all-weather imagery. Sea ice age is defined as the time that has passed since the formation of the surface layer of an ice covered region of the ocean. The content of the sea ice age EDR is the typing of areas of sea ice by age. The National Ice Center monitors sea ice globally to estimate sea ice growth and decay. This information is used to protect mariners, support military and civilian operations, and assess potential global climate changes since Polar Regions are more likely to exhibit early signs of global warming.

[Strangely, this says nothing about ice concentration.]

The algorithm shall produce a sea ice characterization product under all-weather conditions.

The algorithm shall produce the sea ice characterization product that has a vertical coverage of the ice surface.

The algorithm shall produce the sea ice characterization product that has a horizontal cell size of 10 km.

The algorithm shall produce the sea ice characterization product that has a mapping uncertainty (3 sigma) of 5 km.

The algorithm shall produce the sea ice characterization product that has a measurement range of: 1/10 – 10/10 for ice concentration and ice free, first-year, multiyear ice for ice age classes.

The algorithm shall produce the sea ice characterization product that has a measurement uncertainty of 10% for ice concentration.

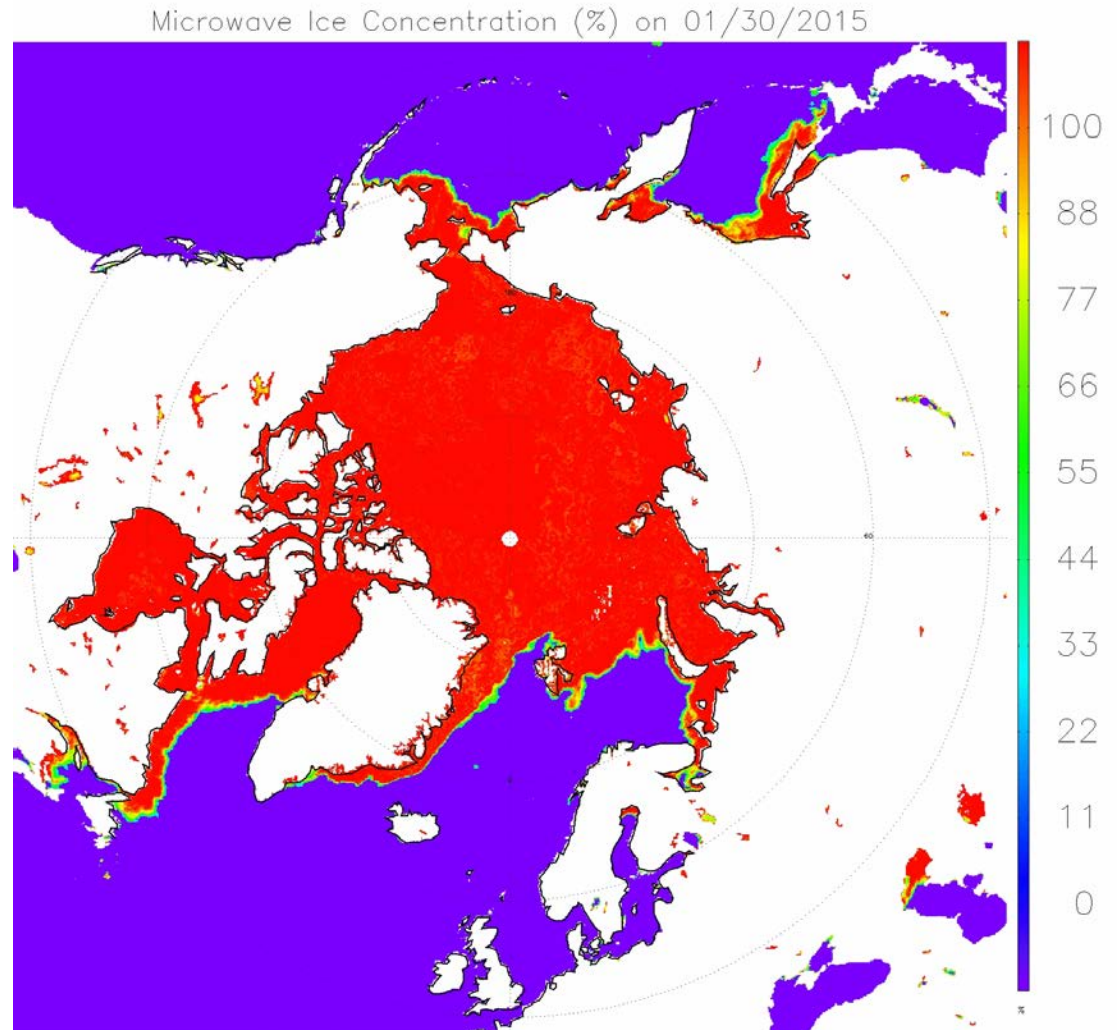
The algorithm shall produce the sea ice characterization product that has a probability of correct typing of 70% for typing of Ice Age Classes.

The algorithm shall produce the sea ice characterization product that has a geographic coverage of all ice-covered regions of the global ocean.

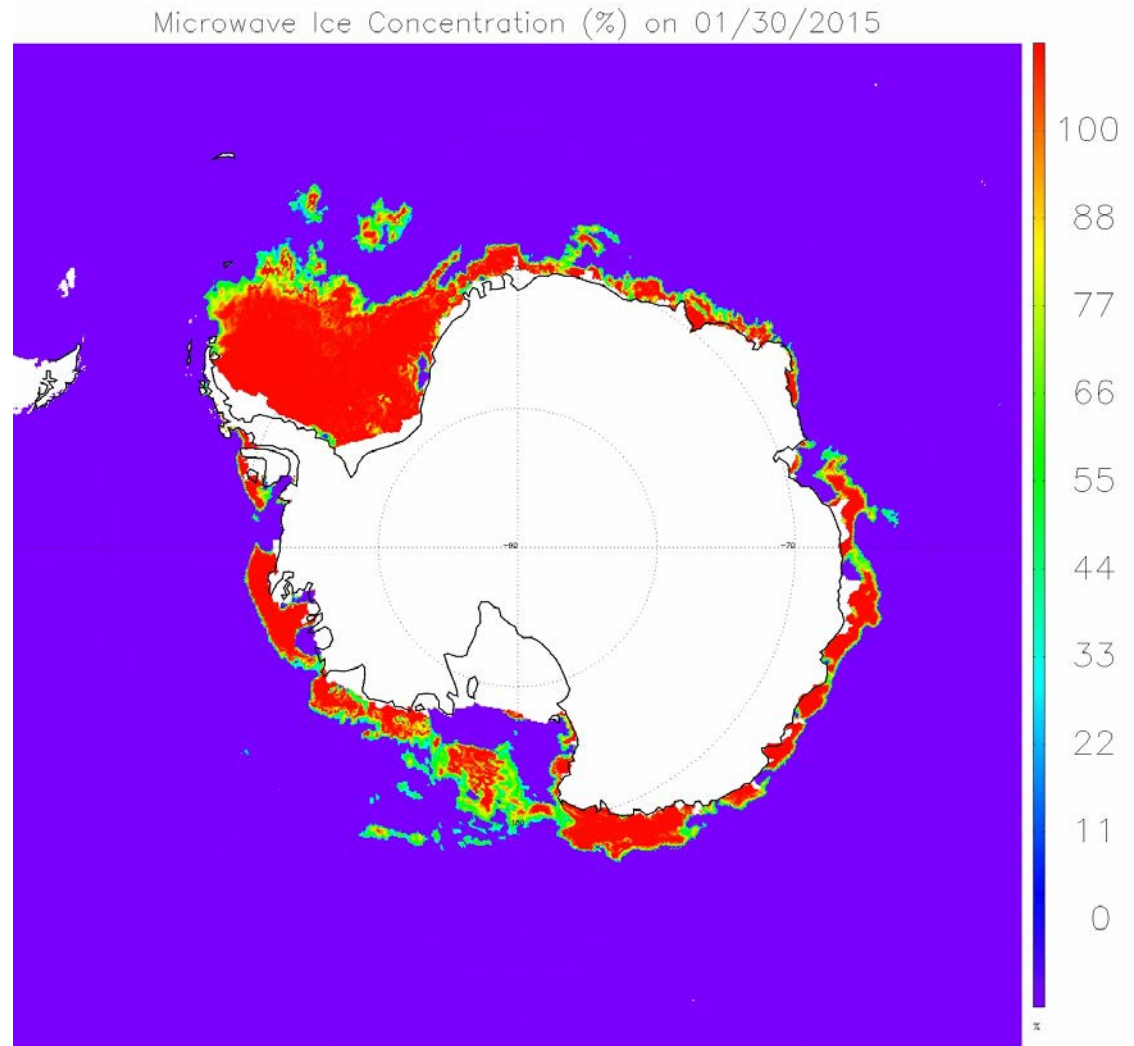
- Improvements since Algorithm Readiness Review (ARR, Provisional)
 - No algorithm improvements since ARR
 - No LUT / PCT updates
- Cal/Val activities for evaluating algorithm performance since ARR have been focused on further validation of ice age typing
 - Validation strategy / method: comparison of AMSR2 age with other age data products:
 - ASCAT scatterometer fields
 - PM fields from EUMETSAT OSI-SAF
 - Lagrangian ice age parcel tracking (NSIDC)
 - Canadian Ice Service ice charts
 - Validation results are currently being evaluated; quantitative results for ice typing will be submitted in a journal manuscript in the next few months. Initial evaluation indicates that the AMSR2 ice typing will meet the 70% accuracy threshold requirement.
- Cal/val activities for ice concentration are being published (paper “in press”).

- Numerous validation studies have been done on BT and NT2 algorithms via comparisons with aircraft and other satellite (vis/IR, SAR) imagery
 - » e.g., Cavalieri et al., 2006; Meier, 2005; Comiso et al., 1997; Comiso and Nishio, 2008; Andersen et al., 2007; Ivanova et al., 2014
 - » Concentration errors for the central ice pack during cold, winter periods are <5%
 - » Errors for melting ice, thin ice, and near the ice edge may be higher
 - » Precision of the ice edge limited by spatial resolution of the channel with the largest footprint (IFOV), ~25 km for AMSR2
- Test cases were validated through a comparison of the AMSR2 ice concentration results to S-NPP VIIRS sea ice concentration. Differences are expected due to:
 - » Cloud cover – VIIRS retrievals are clear-sky only
 - » Spatial resolution – VIIRS is < 1 km

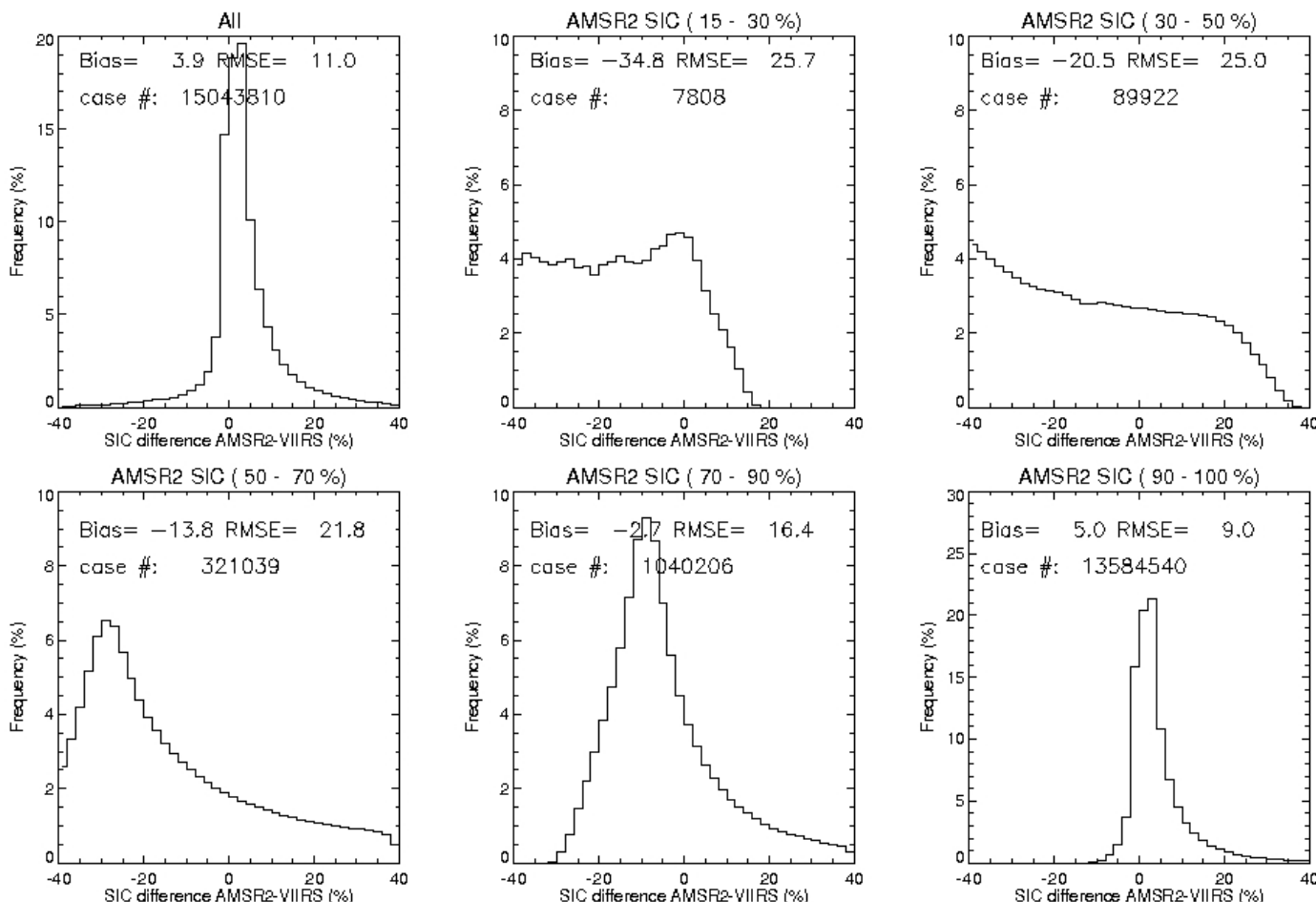
Comparison of
AMSR2 and VIIRS
sea ice concentration
over the Arctic on 31
January 2015.
(animation)



Comparison of
AMSR2 and VIIRS
sea ice concentration
over the Antarctic on
31 January 2015.
(animation)

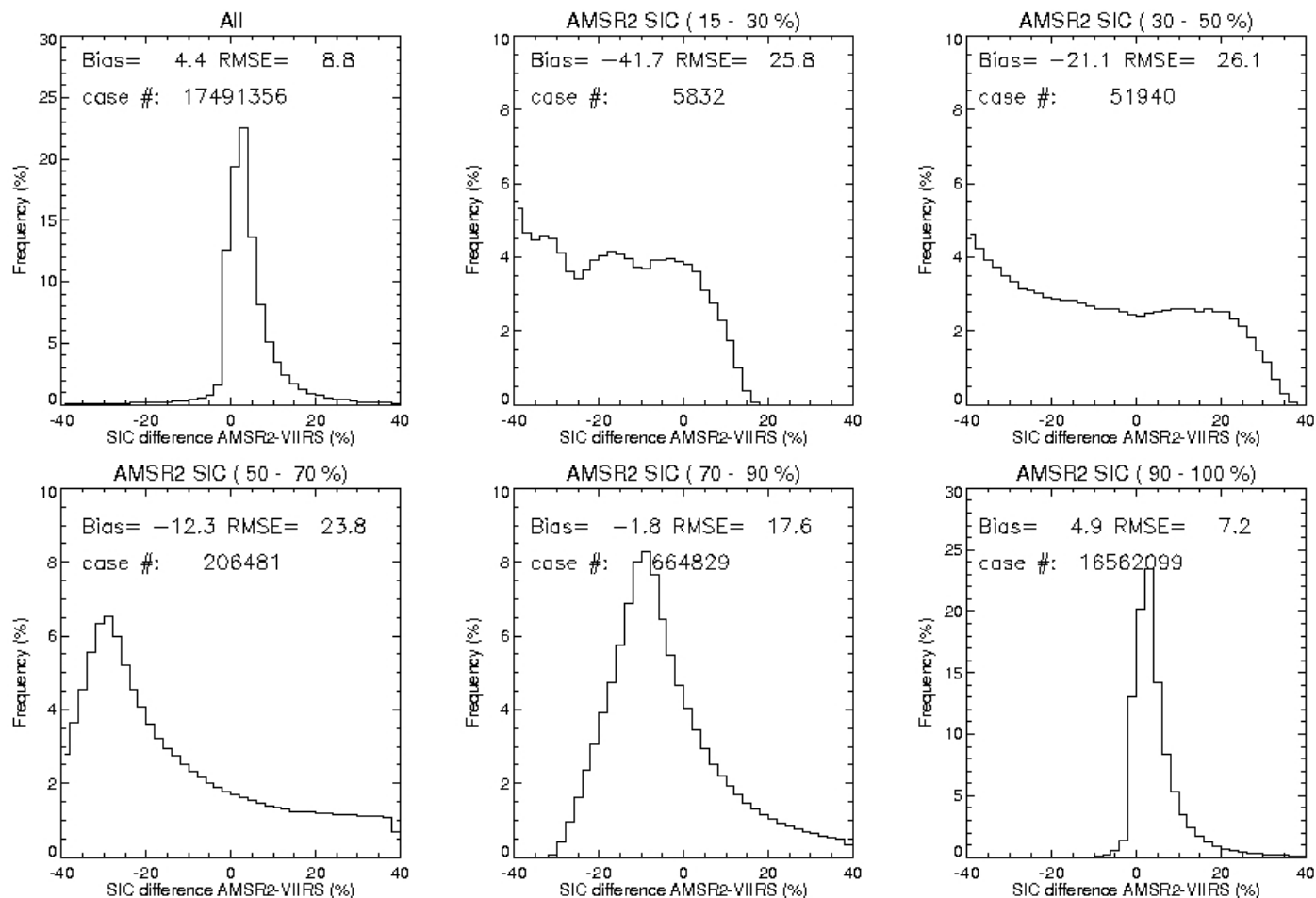


Sea Ice Concentration Validation



Comparison of AMSR2 minus VIIRS ice concentrations for different AMSR2 ice concentration ranges/bins in the Arctic. The AMSR2 concentration is computed with the NASA Team 2 algorithm. Note that the y-axis range is different for "All", "90-100%", and the other plots. Data are from January to October 2016.

Sea Ice Concentration Validation



Same as previous slide except for the Antarctic.

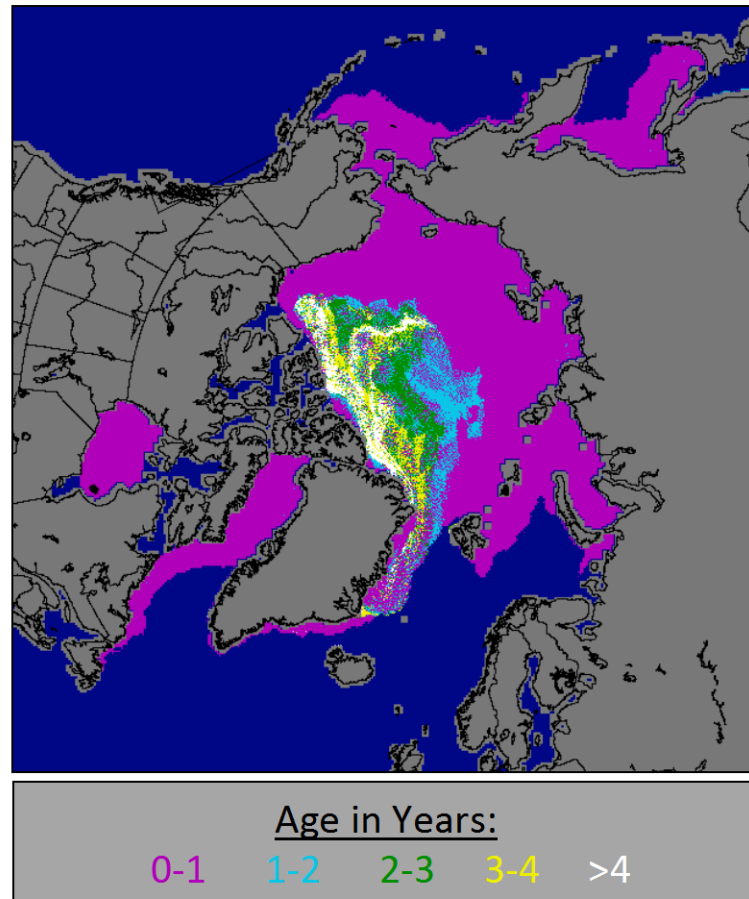
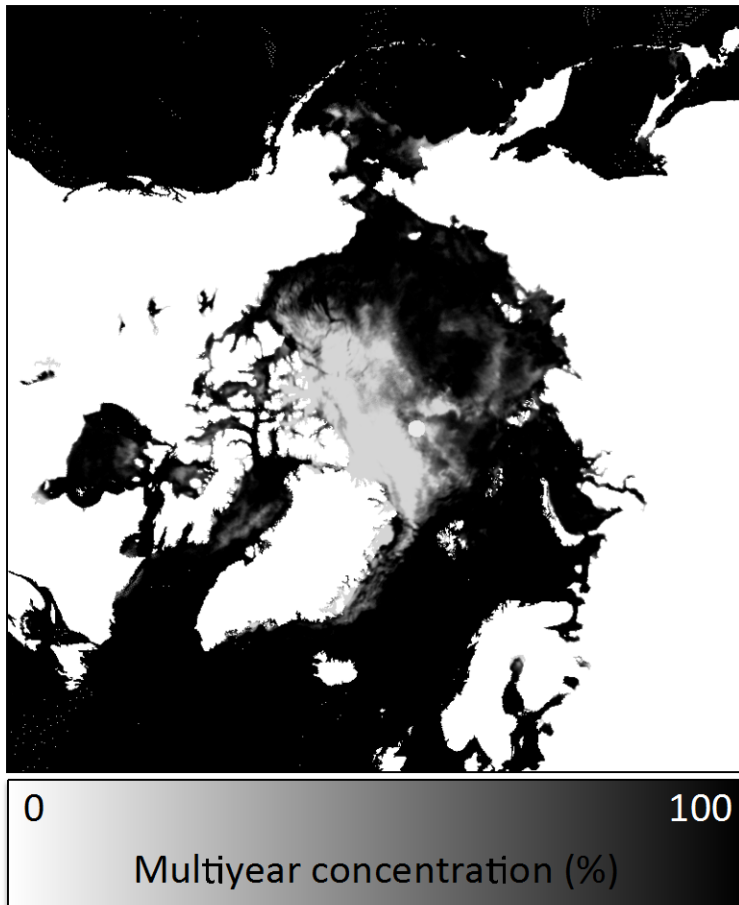
Sea Ice Concentration Validation

Statistical results of the comparison in sea ice concentration between AMSR2 and VIIRS.

Maximum (red) and minimum (blue) values in each column are highlighted.

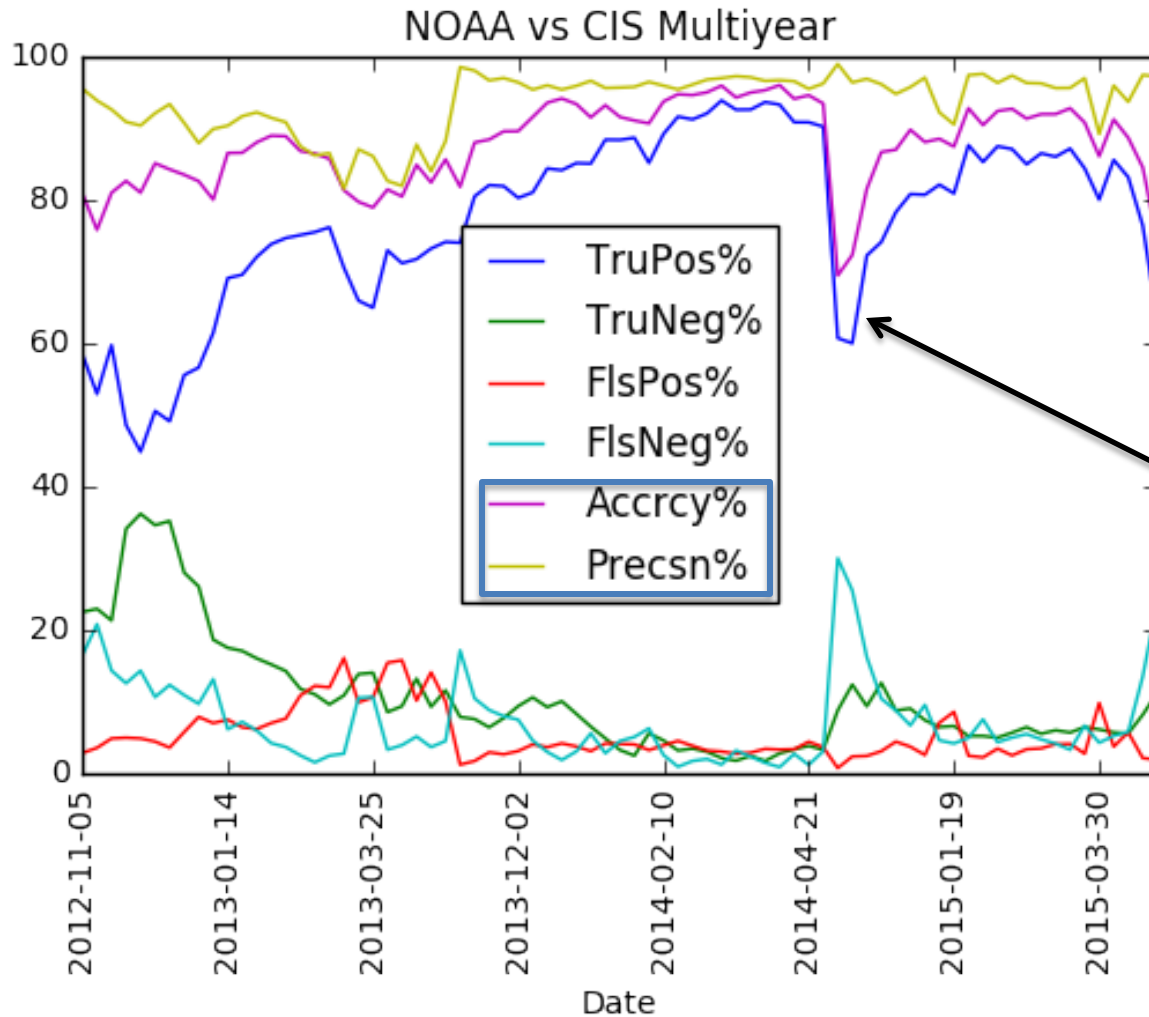
	Arctic			Antarctic		
	Accu	Prec	Cases	Accu	Prec	Cases
01/30	1.61	8.76	123747	0.50	21.45	22776
01/31	1.62	9.10	124514	1.53	22.03	19556
02/27	2.05	9.91	122376	1.04	20.19	20101
02/28	2.03	9.35	120343	0.21	20.88	22256
03/30	2.45	10.01	122108	1.52	14.90	48343
03/31	2.12	9.39	118841	2.48	15.24	43737
04/30	3.02	11.98	88959	1.85	12.64	79228
04/31	3.01	11.87	79756	2.24	12.62	82094
05/30	3.20	11.46	65418	2.19	13.03	99093
05/31	3.22	11.92	70990	1.80	12.97	104142
06/30	2.19	14.05	56864	1.55	11.08	121964
06/31	1.89	14.41	55580	1.56	11.78	123805
07/30	1.89	18.33	35577	2.43	12.62	142350
07/31	2.53	18.20	38069	2.58	12.34	138524
08/30	0.25	18.48	28727	2.79	11.87	133027
08/31	0.61	17.19	27315	2.95	12.71	142208

Multiyear Ice Validation



Initial comparison with independent ice age fields (Lagrangian tracking of ice parcels) indicates good agreement in terms of spatial distribution of multi-year ice cover.

Ice Age Type Validation

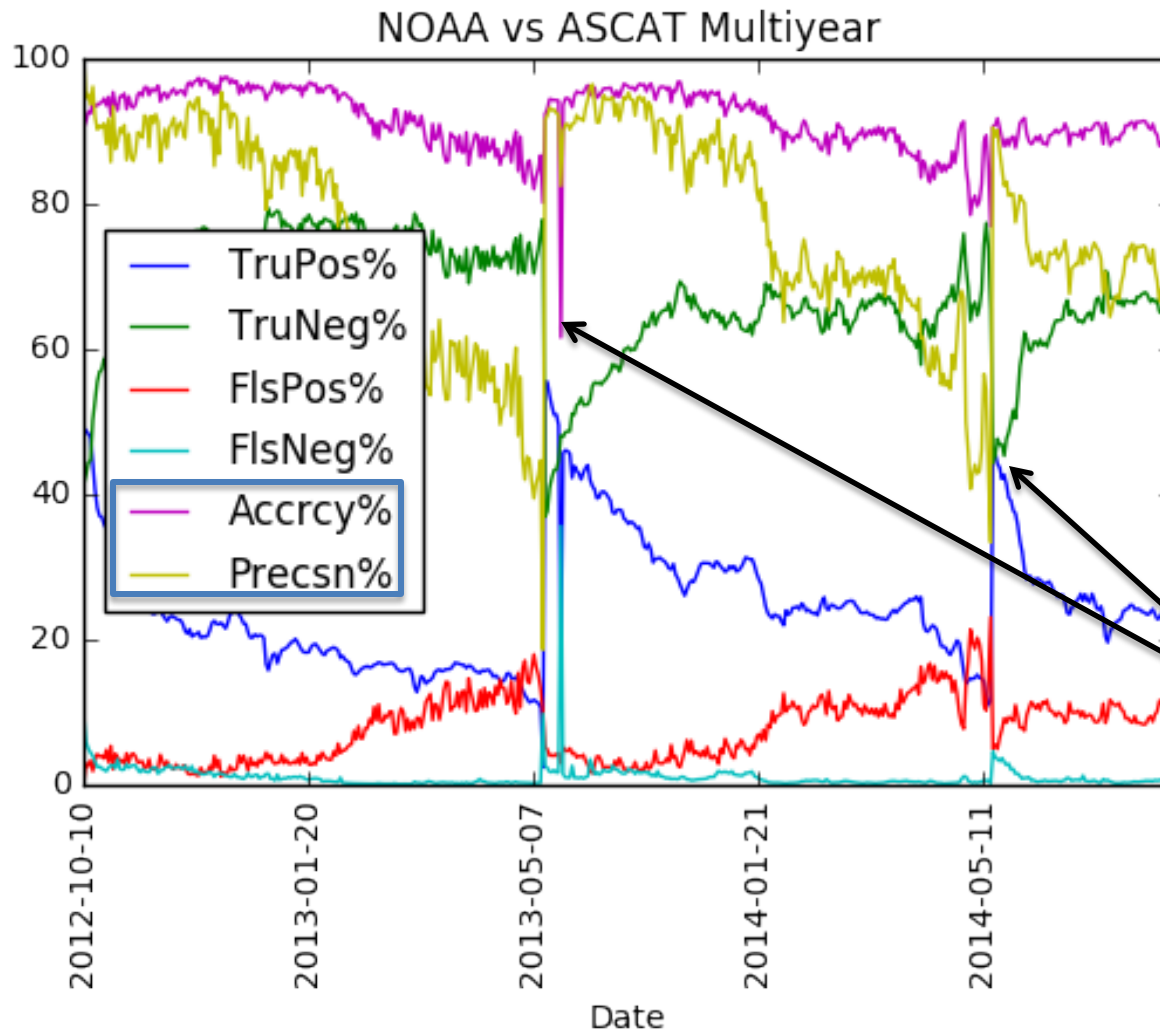


Comparison of NOAA vs. Canadian Ice Service (CIS) charts in high Arctic

Performance drops in May (melt onset)

NOTE: Summer months are not included in plot.

Ice Age Type Validation



Comparison of NOAA
vs. ASCAT
scatterometer

Lower performance
expected from
ASCAT as well

Performance
drops in May

*NOTE: Summer
months are not
included in plot.*

- Required Algorithm Inputs
 - Primary Sensor Data: L2A TBs
 - Ancillary Data:
 - Ocean SST climatology mask monthly maps to remove spurious retrievals
 - Coastal filter maps to remove effects of land-ocean mixed pixels
 - Upstream algorithms: None
 - LUTs / PCTs: internal LUT for NT2 algorithm to solve optimal LUT concentration that matches observed TBs
- Evaluation of the effect of required algorithm inputs
 - The effect of the ocean SST mask depends on conditions: it will mask out false ice due to significant storms (precip). In the absence of storms the effect will be minimal.
 - The coastal filter generally removes one or two pixels along the coast. This simply reduces the possible ice area.

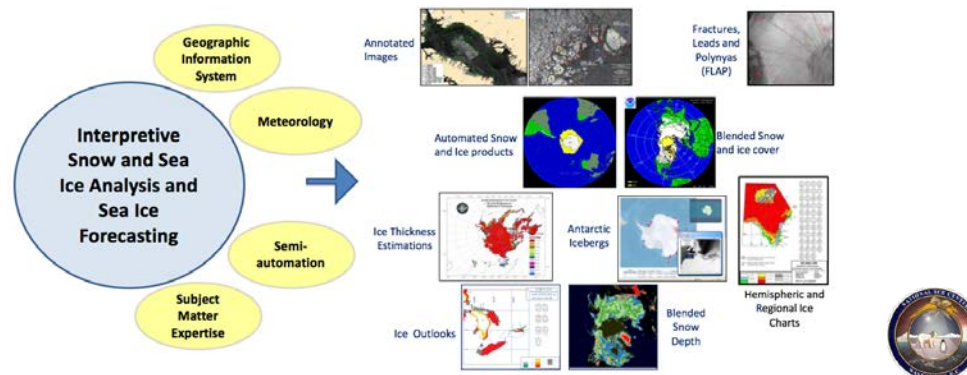
- Defined Quality Flags
 - Latency: time since observation for each grid cell (0-1440 minutes)
 - Concentration range: max – min concentration during last 24 hours
 - NT2-Bootstrap concentration difference: -100% to +100%
 - Quality filter field, bitwise combination:
 - SST ocean mask applied
 - Weather filter threshold exceeded
 - Land-spillover correction (coastal ice removed)
 - Spatially interpolated (bi-linear) missing grid cells
 - Missing (no data)
- Quality flag analysis/validation
 - Concentration range indicates stability – of ice conditions and/or algorithm
 - Larger differences observed near the ice edge (ice growth/melt/advection; lower accuracy of algorithm near ice edge and in thin ice)
 - Larger difference observed during summer melt – melt limits algorithm effectiveness; also, more atmospheric emission during summer
 - NT2-Bootstrap provides confidence level – higher confidence when both algorithm retrievals agree. Also, Bootstrap does not include QC post-processing, so difference indicates where post-processing removed spurious retrievals
 - Analysis/validation plan – none yet

Error Budget

Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Error Summary	Support Artifacts
Concentration	10%	1-3% accuracy 9-15% precision	Most errors well below 10% threshold, higher errors near ice edge	Comparison with VIIRS concentration fields; manuscript currently in press
Ice type (MYI)	70% correct typing	~80-90% (preliminary) during winter season	Multiyear ice (MYI) detection only	Comparison with other MYI fields; ongoing, manuscript in preparation

- ESPC (e.g., NDE, Okeanos) build (version) number: 1.8 (release 1); effective date: March 8, 2017
- Algorithm version – 1.0
- Version of LUTs used – n/a
- Version of PCTs used – n/a
- Description of environment used to achieve validated maturity stage – Linux server

- Primary users: National Ice Center (NIC; Sean Helfrich); NAVO (Bruce McKenzie)
- Feedback from users
 - NIC has been waiting for the sea ice product to go operational. It only recently became available. They plan to switch from the AWI (Germany) product to NOAA's this summer. The sea ice characterization product will be used by NIC in the production of the IMS product and ice charts. It will also be used in a blended ice concentration product.
 - NAVO currently assimilates the JAXA AMSR2 ice concentration product into their operational model. We need to work with NAVO on switching to the NOAA product. (See Notes section for characteristics of JAXA's product.)



Documentations (Check List)

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

- Cal/Val results summary:
 - Sea ice concentration
 - **Team recommends algorithm maturity status as “validated”**
 - Manuscript is in press with IEEE JSTARS
 - Higher errors near ice edge due to ice dynamics, algorithm limitations with thin and melting
 - Higher errors during summer melt season
 - QC filters may not eliminate all spurious ice due to weather or along coast
 - Sea ice type
 - **Team recommends algorithm maturity status as “beta” (possibly provisional)**
 - Initial validation indicates that threshold criteria are satisfied
 - Only validated in the Arctic and only during winter months (~Nov – Apr)
 - Validation continuity, manuscript in preparation

- Focus on ice age/type validation
 - Finish comparison with other MYI data product
 - Improve quantification of errors/uncertainties
 - Publish manuscript on algorithm and validation studies
- Further concentration validation focusing on marginal ice zone (near the ice edge) to better assess and understanding performance in region of higher errors

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.