Read-me for Data Users

MEMORANDUM FOR:	The JPSS Program Record
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SUBJECT:	NOAA-21 ice products Validated maturity status
DATE:	01/25/2024

Validated maturity status declaration for Sea Ice Concentration and Ice Surface Temperature.

Maturity Review Date:	**10/26/2023**
Effective Date:	**05/01/2023**
Operational System:	**NCCF, V3R2**

Validated maturity status declaration for Sea Ice Thickness and Age.

Maturity Review Date:	**01/25/2024**
Effective Date:	**05/01/2023**
Operational System:	**NCCF, V3R3**

The JPSS Algorithm Maturity Readiness Review Board approved the release of the NOAA-21 Ice product to the public with a Validated Maturity level quality for sea ice surface temperature, ice concentration, and ice thickness and age as of 05/01/2023 (effective date), based on JPSS Validated Maturity Review held on 10/26/2023 and 01/25/2024.

Validated Maturity Definition

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. http://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php)

Algorithm and Product Information

Ice surface temperature is retrieved using brightness temperatures at split window channels at 10 and 11 μm, and satellite sensor scan angle derived from sensor zenith angle. The retrieval algorithm is from

the work of Key et al. (1997).

Ice cover is detected at the pixel level over water under clear-sky conditions. Clear-sky is determined from the cloud mask. Ice cover is first determined by a group-criteria technique by using Normalized Difference Snow Index (NDSI) for daytime and threshold surface temperature for nighttime. Then ice concentration is retrieved based on the determined normalized reflectance/BT of pure ice and pure water through the application of a tie point algorithm, which determines "pure" ice pixels. Ice concentration for each pixel is then calculated by interpolating between pure ice and pure, unfrozen water.

Ice thickness and age algorithm use a One-dimensional Thermodynamic Ice Model (OTIM) developed by Wang et al. (2010). OTIM is based on the surface energy balance and contains all components of the surface energy budget to estimate sea and lake ice thickness up to 5 meters. Ice age is based on ice thickness as follows:

- Free or Open water: thickness = 0
- New: $0.00 < \text{thickness} \leq 0.10$
- Grey: $0.10 < \text{thickness} \leq 0.15$
- Grey-white: $0.15 < \text{thickness} \leq 0.30$
- First year Thin: $0.30 < \text{thickness} \leq 0.70$
- First year Medium: $0.70 < \text{thickness} \leq 1.20$
- First year Thick: $1.20 < \text{thickness} < 1.80$
- Older: $\text{thickness} \geq 1.80$

The JPSS Mission required ice age categories are : open water, new/young ice (thickness < 0.30 m), and all other ice (thickness >= 0.30 m).

Additional information is available in the Sea Ice algorithm theoretical basis document (ATBD) and validation maturity review briefing, which can be accessed at:
http://www.star.nesdis.noaa.gov/jpss/Docs.php.

List of Products:

EDR Output	Description	Unit
Ice surface temperature (IST)	Skin temperature at ice surface	Kelvin
Ice cover (IC)	A pixel is ice covered or not. Value 1: ice detected using daytime tests 2: ice detected using nighttime tests 0: cloud -1: land -2: water surface	Unitless

	-3: non-retrievable due to sunglint, cloud shadow, and missing pixels	
Ice concentration (SIC)	The fraction (in tenths or percentage) of the sea or lake surface covered by ice, 0 ~ 100%	Unitless
Ice thickness (IT)	Ice thickness is defined as the total vertical length of the ice under and above water surface. The reliable ice thickness retrieved from this algorithm ranges between 0 ~ 5.0 m	Meter
Ice age (IA)	Ice age is classified based on the ice thickness. 1 = Free or Open water: thickness = 0 2= New: 0.00 < thickness ≤ 0.10 3= Grey: 0.10 < thickness ≤ 0.15 4= Grey-white: 0.15 < thickness ≤ 0.30 5= First year Thin: 0.30 < thickness ≤ 0.70 6= First year Medium: 0.70 < thickness ≤ 1.20 7= First year Thick: 1.20 < thickness < 1.80 8= Older: thickness ≥ 1.80 The JPSS Mission required ice age categories are : open water, new/young ice (thickness < 0.30 m), and all other ice (thickness >= 0.30 m).	Unitless

Product requirements/Exclusions (L1RDS):

EDR Attribute	**Threshold**	**Objective**
Applicable conditions	Delivered under "clear sky" conditions	Delivered under "all sky“ conditions
Horizontal cell size	1 km	1 km
Mapping uncertainty, 3 sigma	1 km	1 km
Measurement range	213-275 K for IST 0 or 1 for IC (0=ice free, 1=ice covered) 0-100% for SIC 0-5 m for IT 1-8 for IA	213-275 K for IST 0 or 1 for IC 0-100% for SIC 0-8 m for IT 1-8 for IA
Measurement uncertainty	1.5 K precision for IST 80% correct identification for IC 25% uncertainty for SIC	1 K precision for IST 90% correct identification for IC 10% uncertainty for SIC
Refresh	At least 90% coverage of the globe about every 24 hours (monthly average)	Not Specified

Quality flags (bitwise):

Table 1. Ice Cover and Concentration Quality Information (4 bytes)

Byte	Bit	Quality Flag Name	Description	Meaning
1	0	QC_output	Output product quality	00 - normal 01 - uncertain 10 – non-retrievable 11 – bad data
	1			
	2	QC_INPUT_CLD	Input cloud mask	00 - clear 01 - probably clear 10 -probably cloudy 11-cloudy
	3			
	4	QC_INPUT_DAY	Day/Night	0-Day 1-Night
	5	QC_INPUT_SUNGLINT	Sunglint or not	0-Yes 1-No
	6	QC_INPUT_CLDSHADOW	Cloud shadow or not	0-Yes 1-No
	7	empty		
2	0	QC_INPUT_SOLZEN	Valid solar zenith angle (0-180 degree)	0-Yes 1-No
	1	QC_INPUT_SATZEN	Valid satellite zenith angle (0-180 degree)	0-Yes 1-No
	2	QC_INPUT_REFL	Valid reflectance at 0.47 ⌈m (0.0-1.0)	0-Yes 1-No
	3		Valid reflectance at 0.64 ⌈m (0.0-1.0)	0-Yes 1-No
	4		Valid reflectance at 0.86 ⌈m (0.0-1.0)	0-Yes 1-No
	5		Valid reflectance at 1.6 ⌈m (0.0-1.0)	0-Yes 1-No
	6	QC_INPUT_THERMAL	Valid brightness temperature at 10 ⌈m (100-390 k)	0-Yes 1-No
	7		Valid brightness temperature at 11 ⌈m (100-390 k)	0-Yes 1-No
3	0	QC_INPUT_SURFACE	Surface type flag	00 - in-land water 01 - sea water 10- land 11 - others
	1			
	2	QC_TEST_REFL	Success of reflectance test in ice cover detection	0-Yes 1-No
	3	QC_TEST_NDSI	Success of NDSI test in ice cover detection	0-Yes 1-No
	4	QC_TEST_SKINTEMP	Success of skin temperature test in ice cover detection	0-Yes 1-No
	5	QC_TIE_REFL	Success of visible band tie-point algorithm	0-Yes 1-No
	6	QC_TIE_SKINTEMP	Success of skin temperature tie-point algorithm	0-Yes 1-No
	7	empty		
4	0	QC_READ_INPUT	Success in reading input	0-Yes 1-No
	1			

	2			
	3			
	4			
	5			
	6			
	7			

Table 2. Ice Age and Thickness Quality Information (4 bytes)

Byte	Bit	Quality Flag Name	Description	Meaning
1	0	QC_INPUT_CLD	Cloud mask	00 - clear 01 - probably clear 10 – probably cloudy 11 - cloudy
	1			
	2	QC_INPUT_DAY	Day/Night	0-Day 1-Night
	3	QC_INPUT_SUNGLINT	Sunglint or not	0-Yes 1-No
	4	QC_INPUT_CLDSHADOW	Cloud shadow or not	0-Yes 1-No
	5	QC_INPUT_ICEIDEN	Ice identification	0-Yes 1-No
	6	QC_INPUT_ICECONC	Ice concentration	0-Yes 1-No
	7	QC_INPUT_ICETRAN	Ice transmittance	0-Yes 1-No
2	0	QC_INPUT_SOLZEN	Valid solar zenith angle	0-Yes 1-No
	1	QC_INPUT_SATZEN	Valid satellite zenith angle	0-Yes 1-No
	2	QC_INPUT_ALBEDO	Surface broadband albedo	0-Yes 1-No
	3	QC_INPUT_TSURF	Surface skin temperature	0-Yes 1-No
	4	QC_INPUT_SNOW	Surface snow depth	0-Yes 1-No
	5	QC_INPUT_WIND	Surface wind speed	0-Yes 1-No
	6	QC_INPUT_SURFACE	Surface background flag	00 - in-land water 01 - sea water 10 - land 11 - others
	7			
3	0	QC_INPUT_TAIR	Surface air temperature	0-Yes 1-No
	1	QC_INPUT_PRESSURE	Surface air pressure	0-Yes 1-No
	2	QC_INPUT_HUMIDITY	Surface air relative humidity	0-Yes 1-No
	3	QC_INPUT_SSWD	Surface shortwave downward radiative flux	0-Yes 1-No
	4	QC_INPUT_SLWD	Surface longwave downward radiative flux	0-Yes 1-No
	5	QC_INPUT_SLWU	Surface longwave upward radiative flux	0-Yes 1-No
	6	QC_INPUT_SSHF	Surface turbulent sensible heat flux	0-Yes 1-No
	7	QC_INPUT_SLHF	Surface turbulent latent heat flux	0-Yes 1-No

4	0	QC_INPUT_SCHF	Surface conductive heat flux	0-Yes 1-No
	1	QC_INPUT_SRHF	Surface residual heat flux	0-Yes 1-No
	2	QC_RET_ALGO	Day/Night algorithm selection	0-Day 1-Night
	3	QC_RET_METH	Math method for solution	0-Analytical 1-Numerical
	4	QC_RET_RESU	Retrieval success or fail	0-Success 1-Fail
	5			
	6			
	7			

Product evaluation/validation

The ice surface temperature product has been validated against similar products from Suomi-NPP and NOAA-20, and meets the accuracy and precision specifications. Ice concentration has been validated against lower-resolution passive microwave ice concentration and against higher-resolution Landsat data, and meets the accuracy and precision specifications. Ice thickness/age product has been validated against similar products from Suomi-NPP, NOAA-20, CryoSat-2/SMOS (CS2SMOS), and IceBridge field campaign measurements. It meets the product requirement.

Product Availability/Reliability

NOAA-21 VIIRS ice products are available from the NDE I&T processing string.

Known errors/issues/limitations

Cloud contamination from errors in the cloud mask cause errors in ice temperature, ice cover, ice concentration, ice thickness and age. Cloud detection is more difficult at night than in sunlit conditions, so errors in the ice products are likely to be more numerous for nighttime data.

Ice concentration is not retrieved if less than 10% of all pixels surrounding the target pixel are covered by ice, in which case the ice concentration cannot be determined because of lack of information. However, the ice cover (binary identification of ice/not-ice) can still be identified. Quality flags are set in the final ice concentration product for this condition. Furthermore, the assumption that completely ice-covered pixels are the majority of pixels surrounding the target pixel can be violated under some conditions, which results in larger uncertainties in the retrievals.

Ice thickness and age product quality is heavily dependent upon its model input variables such as atmospheric profiles, radiative fluxes, snow depth, ice thermal and physical dynamic process parameterization schemes, and snow and ice physical macro- and micro-physical properties. Due to the assumption of a linear ice temperature profile within the ice slate and no freezing at the bottom of the ice slate, ice thickness can only be correctly estimated up to about 5 meters. The effective maximum

retrievable ice thickness may be much less in practice. In addition, daytime retrievals are much more complicated in the presence of sunlight. A more advanced physical and statistical hybrid model that improves ice thickness and age retrievals has been developed and implemented locally that will be used in the next version of this product.

Changes since last maturity stage

None

Review board recommendations

Based on our evaluation, the NOAA-21 Ice Products meet all requirements for the validated level of maturity. Although some issues still exist, our evaluation shows that the ice products are reasonably accurate and well agree to other remote-sensing based products and *in situ* measurements. We conclude that NOAA-21 VIIRS Ice Products have reached the validated maturity level and thus can be made publicly available. The validated maturity effectivity date is May 1, 2023.

Path Forward/Future Plans

Continue evaluation/validation of the product with similar products from NOAA-20, and independent data sets.

Additional items to note

None

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