Provisional Maturity Science Review For NOAA-21 Snowfall Rate

Presented by Huan Meng

Date: 03/07/2024

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.

Maturity Review - Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Provisional Maturity Performance Validation
  - On-orbit instrument performance assessment
    - Identify all of the instrument and product characteristics you have verified/validated as individual bullets
    - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
- Users/Downstream-Products feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward (to the next maturity stage)
- Summary

Maturity Review - Exit Criteria

- Provisional Maturity Performance is well characterized and meets/exceeds the requirements:
  - On-orbit instrument performance assessment
    - Provide summary for each identified instrument and product characteristic you have validated/verified as part of the entry criteria
    - Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any of them are still a concern that raises any risk.
- Updated Maturity Review Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules
  - Product Requirements
  - Provisional Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward (to the next maturity stage)

NOAA-21 Snowfall Rate (SFR)
PROVISIONAL MATURITY REVIEW MATERIAL

Outline

- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Huan Meng	STAR	Snowfall Rate product lead
Yongzhen Fan	CISESS-MD	Algorithm development and validation
Jun Dong	CISESS-MD	System development, algorithm development and validation
Liqun Ma	OSPO	OSPO Precipitation PAL
Priyanka Roy	ASSISTT	Transition to operations
Tracey Dorian	ASSISTT	Transition to operations

Product Overview

Product: Liquid equivalent snowfall rate (SFR) estimate

SFR is generated from passive microwave sensors aboard polar-orbiting satellites

- Operational SFR products from NOAA-20, S-NPP, NOAA-19, Metop-B, and Metop-C
- Sensors: ATMS, AMSU-A/MHS

SFR is retrieved from a Snowfall Detection and a Snowfall Rate algorithms

- Snowfall Detection: machine learning (ML) model
- Snowfall Rate: 1DVAR-based physical algorithm with ML initialization and bias correction
- Algorithms use a combination of 'window' and temperature/water vapor sounding channels as well as NWP (GFS) model data

Product Requirements

Attribute	DPS	Requirement/Threshold	Performance
Accuracy	DPS-1756	0.3 mm/hr	
Precision	DPS-1757	1 mm/hr	

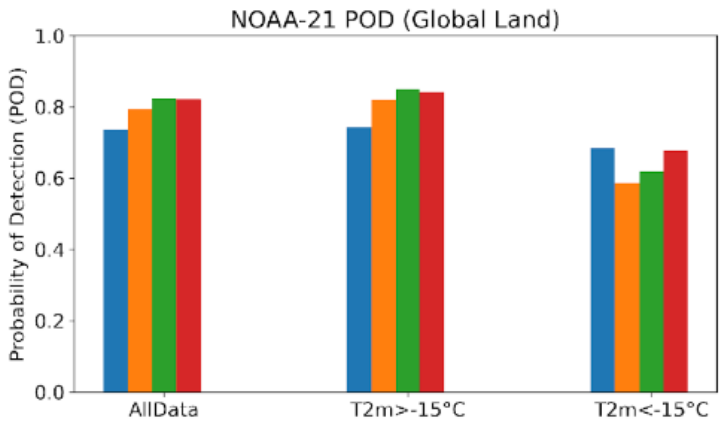
Processing Environment and Algorithms

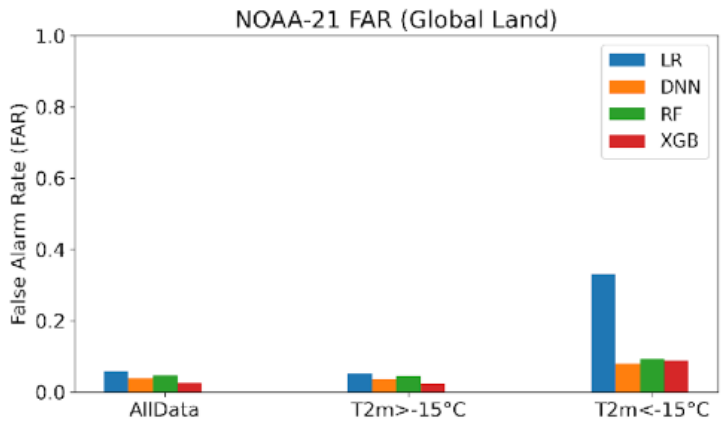
- The SFR product is operationally produced from a standalone Enterprise SFR processing system in NCCF.
  - Current algorithm v1r0 includes N21 SFR Beta
  - N21 SFR Provisional algorithm v2r0
  - LUTs / PCTs v2r0
  - Effective date: July 2024; package delivered to ASSISTT on 2/28/2024

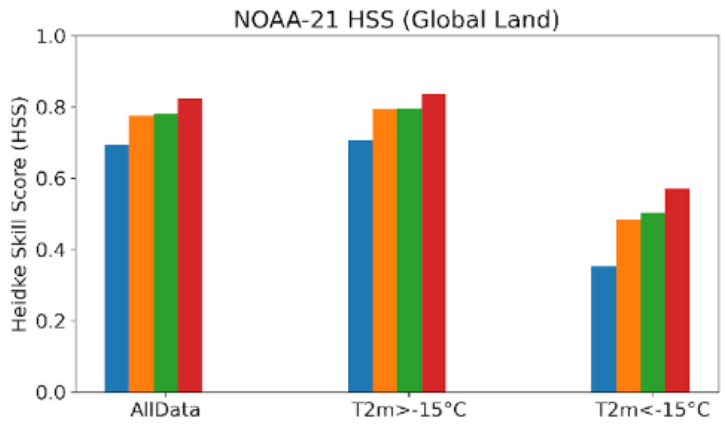
Evaluation of algorithm performance to specification requirements

- The N21 Beta Maturity SFR uses N20 SFR algorithm since not enough N21 snowfall data was available to develop N21 specific SFR algorithm
- Improvements since Beta Maturity Review
  - Trained N21 Snowfall Detection ML XGB model (included some N20 data)
  - Trained N21 1DVAR initialization ML NN model and SFR bias correction ML NN model (included some N20 data)
  - Updated N21 coefficient files
- Algorithm performance evaluation
  - Validation data sets
    - Snowfall Detection: 11-mo of NCEI global ground observations (ISD)
    - Snowfall Rate: i) Stage IV radar & gauge combined hourly precipitation, ii) ECMWF reanalysis ERA5 hourly snowfall, iii) CloudSat CPR (space-borne radar) snowfall rate estimates; 11-mo data
  - Validation strategies / methods
    - Snowfall Detection: Statistics (POD, FAR, HSS)
    - Snowfall Rate: Scatter plots, probability distribution

Validation – N21 Snowfall Detection

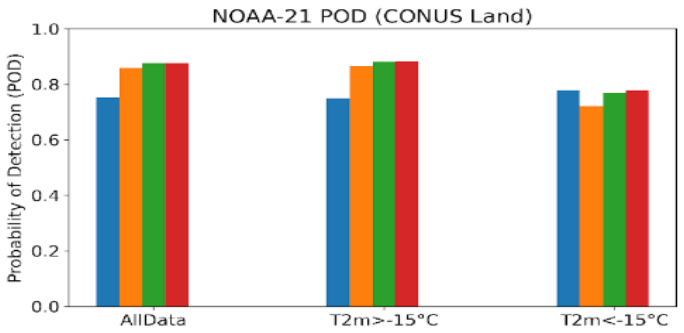


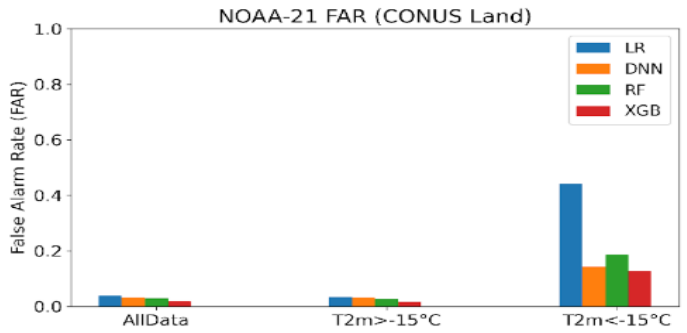


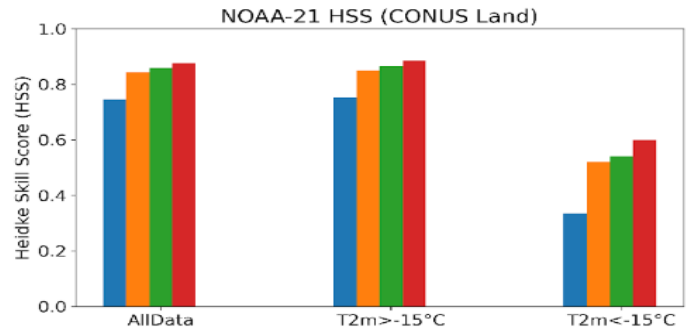


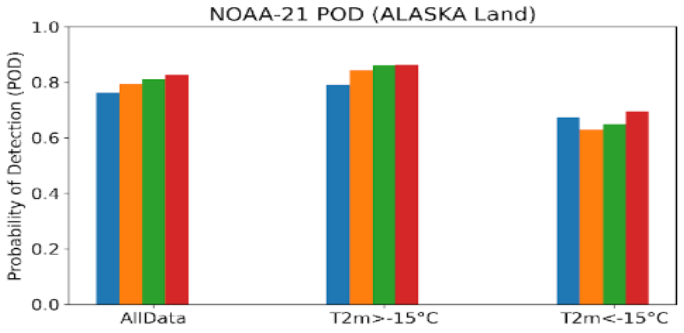
N21 Land XGB SD	POD			FAR			HSS		
	All data	Warm	Cold	All data	Warm	Cold	All data	Warm	Cold
Global	0.822	0.841	0.688	0.025	0.023	0.088	0.823	0.838	0.571

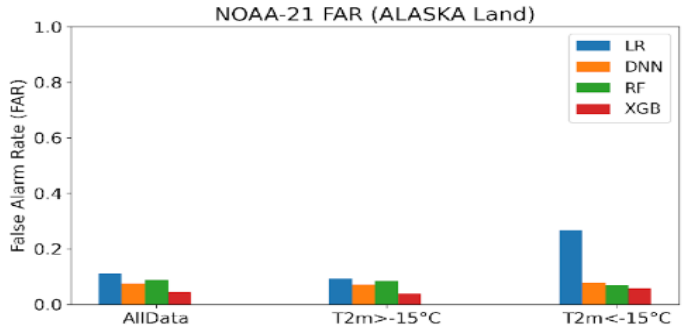
Validation – N21 Snowfall Detection (2)

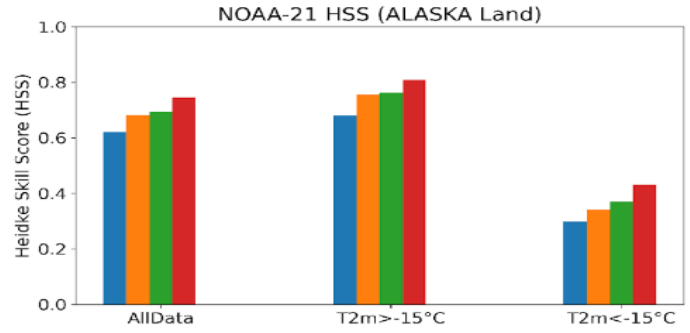








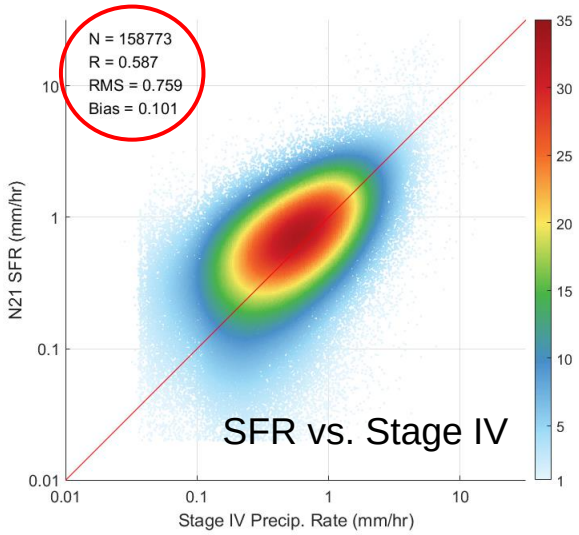


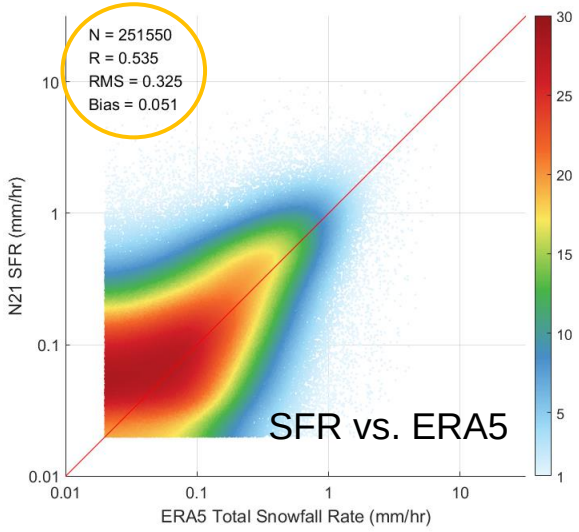


N21 Land XGB SD	POD			FAR			HSS		
	All data	Warm	Cold	All data	Warm	Cold	All data	Warm	Cold
Global	0.822	0.841	0.688	0.025	0.023	0.088	0.823	0.838	0.571
CONUS	0.877	0.882	0.779	0.018	0.017	0.128	0.878	0.884	0.600
Alaska	0.825	0.865	0.700	0.045	0.039	0.059	0.746	0.809	0.531
Eurasia	0.761	0.776	0.683	0.028	0.027	0.089	0.851	0.873	0.561
Northern Hemisphere	0.824	0.843	0.683	0.026	0.024	0.089	0.824	0.839	0.572
Southern Hemisphere	0.586	0.832	0.391	0.015	0.014	0.071	0.579	0.600	0.400

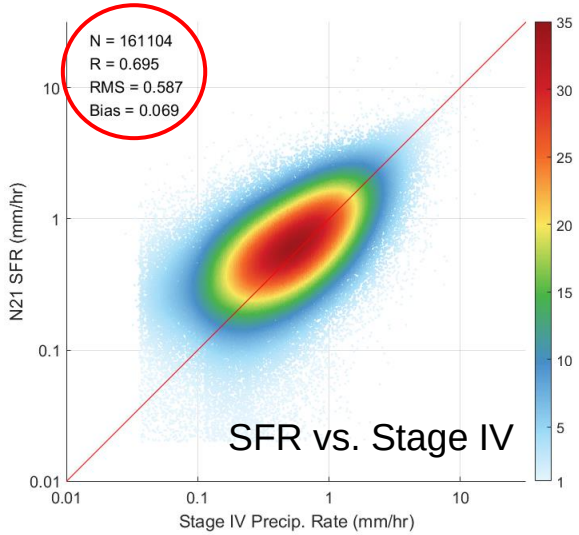
Validation – N21 Snowfall Rate

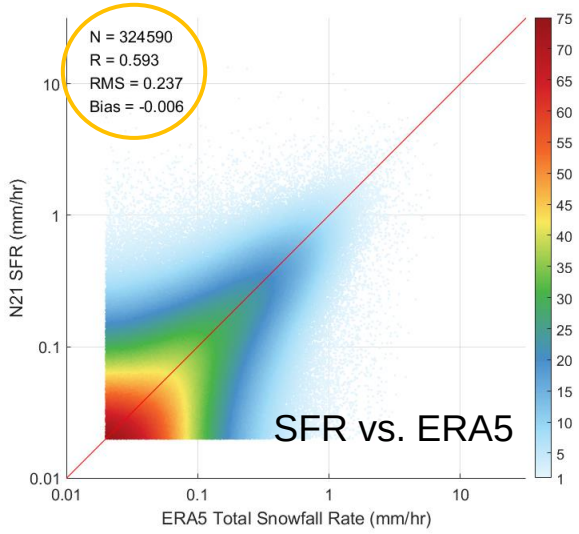
Beta



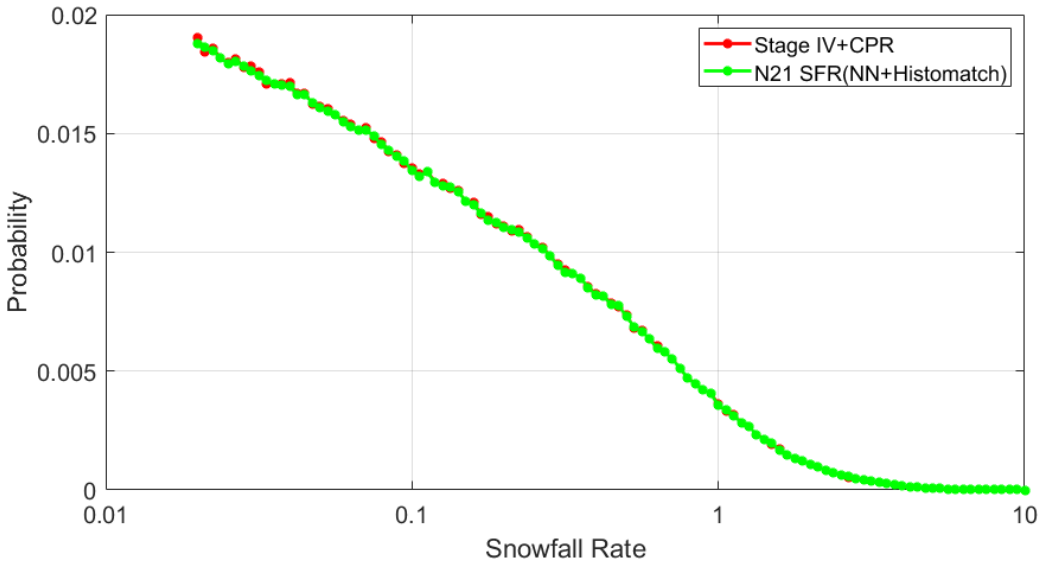


Provisional



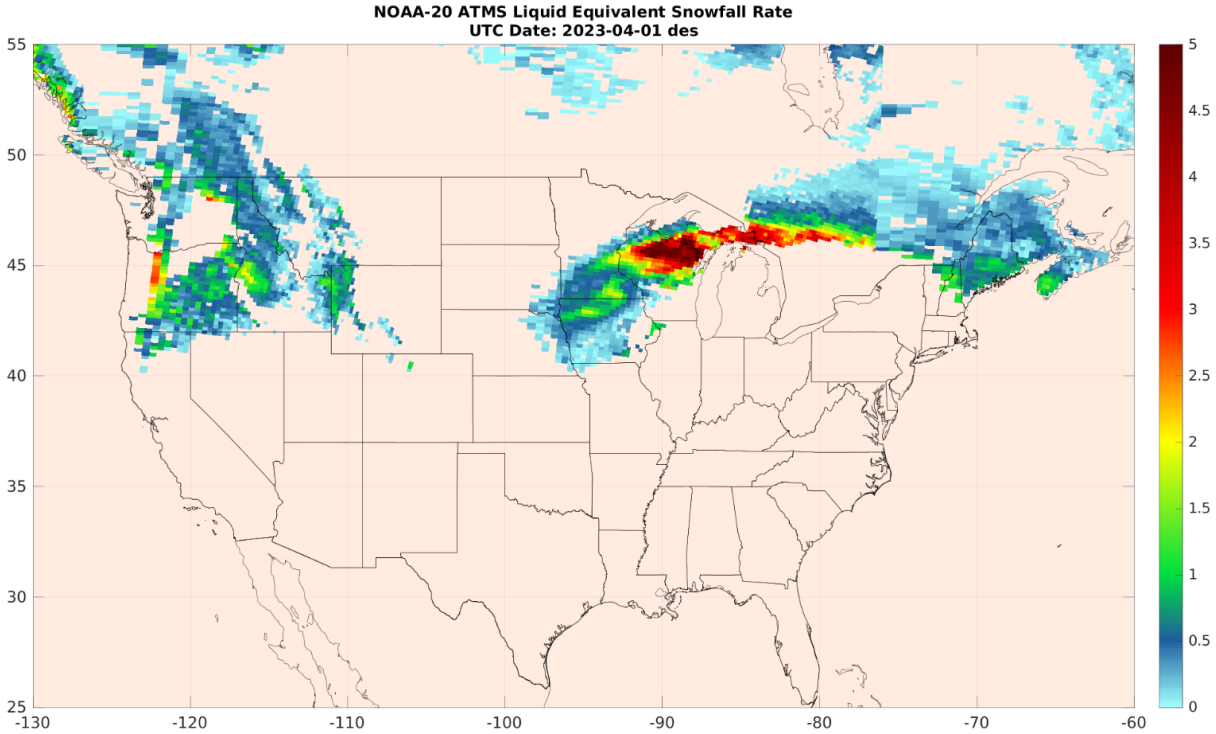


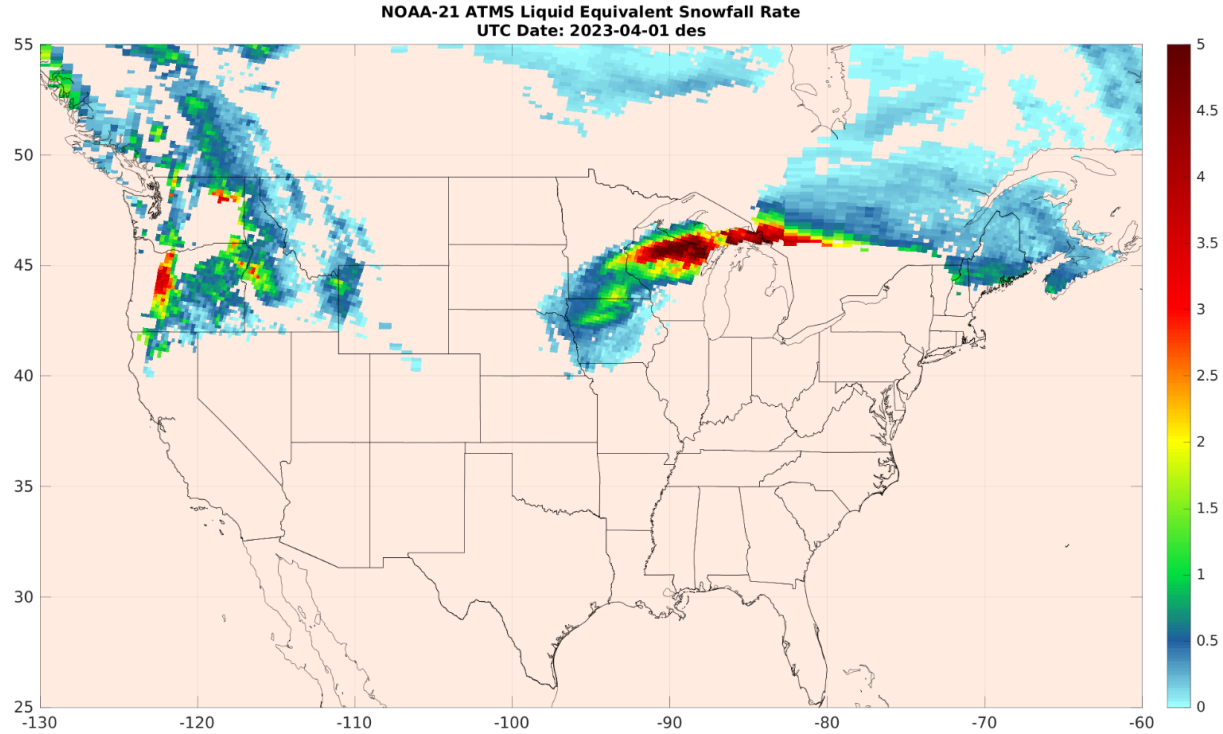
Probability Distribution



Validation – Comparison with NOAA-20 SFR

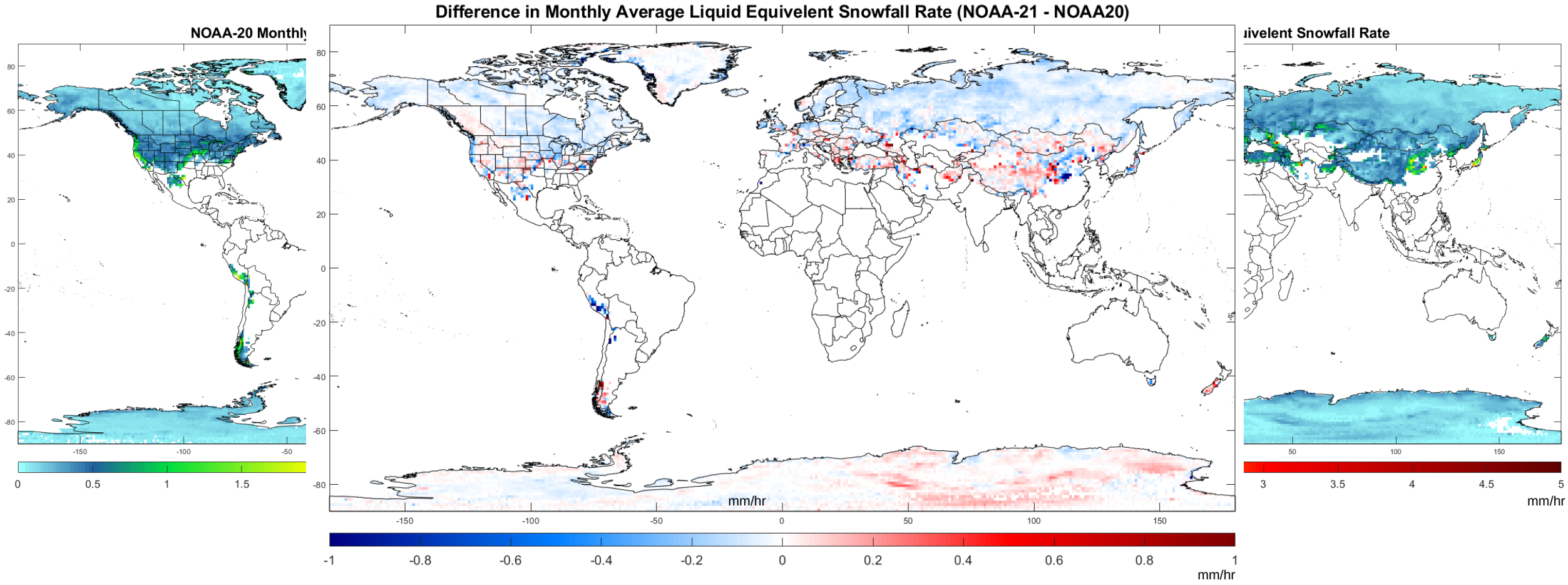
- Case study comparison between NOAA-21 and NOAA-20 SFR on April 1, 2023



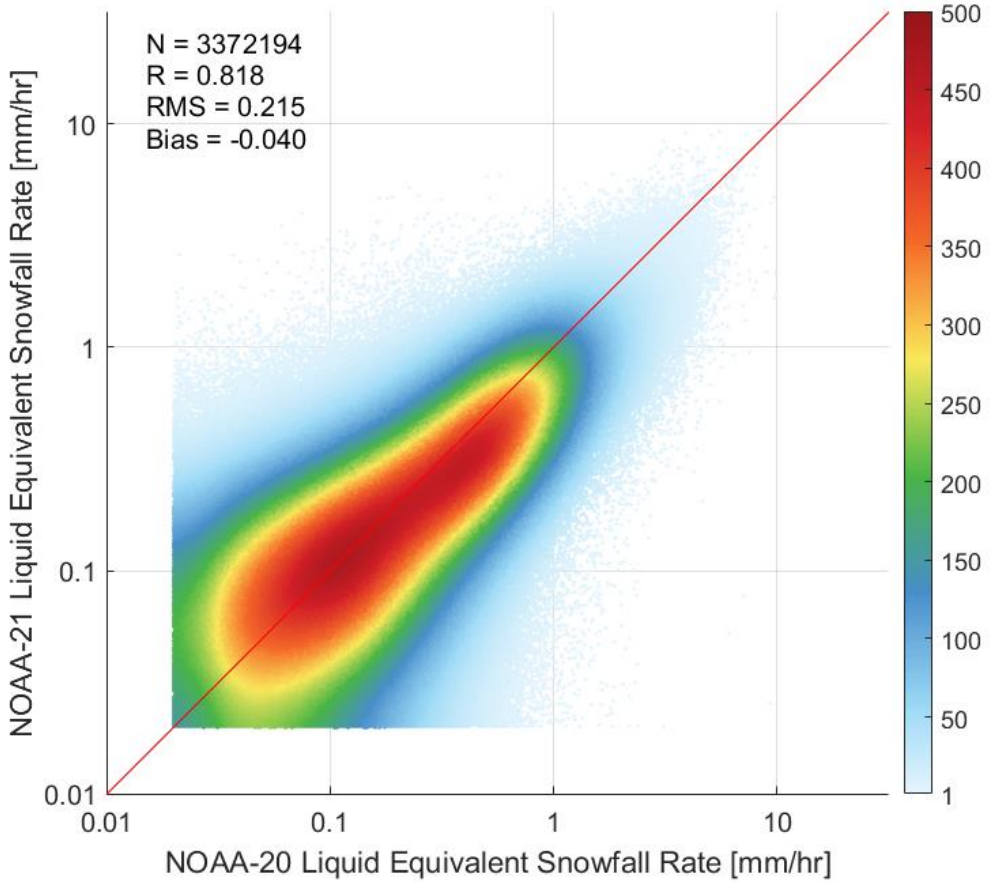


Validation – Comparison with NOAA-20 SFR (2)

- Monthly average (March 2023) SFR



Validation – Comparison with NOAA-20 SFR (3)



Evaluation of the effect of required algorithm inputs

- Required Algorithm Inputs
  - Primary Sensor Data
    - ATMS TDR window, and temperature and water vapor sounding channels (23.8 GHz - 183±1 GHz)
  - Ancillary Data
    - GFS surface and atmospheric variables
  - Upstream algorithms
    - None
  - LUTs / PCTs
    - Ice particle optical properties LUT
    - Algorithm coefficient files
    - Land-sea mask
    - Other ancillary files

Quality flag analysis/validation

- Defined Quality Flags
  - There is one quality flag (32 bit) in the SFR file that specifies two quality variables:

Quality flag bit	Meaning	Value
0	1DVAR Convergence	1: Non-convergent 0: Convergent
1	SFR threshold	1: SFR is below threshold, set to 0 0: SFR is above threshold, value unchanged

Error Budget

Compare analysis/validation results against requirements, present as a table. Error budget limitations should be explained. Describe prospects for overcoming error budget limitations with future improvements of the algorithm, test data, and error analysis methodology.

Attribute Analyzed	DPS	Requirement/ Threshold	Pre-Launch Performance	On-orbit Performance			Meet Requirement?	Additional Comments
				NOAA-21	NOAA-20	S-NPP		
Accuracy	DPS-1756	0.3 mm/hr		0.07	0.02	0.02	Yes	N20 and NPP validation against 3-year of Stage IV data; N21 11-mo of data
Precision	DPS-1757	1 mm/hr		0.59	0.57	0.57	Yes	N20 and NPP validation against 3-year of Stage IV data; N21 11-mo of data

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Pingping Xie	NCEP/CPC	Level-3 global blended precipitation analysis CMORPH2	The NCEP/CPC CMORPH team will be ready to ingest the NOAA-21 SFR data and bring the data to CPC operations once the SFR data becomes operational
Weather forecasters	NWS Alaska	Winter weather nowcasting	- Product was a big help in showing higher SFR rates in areas just outside radar coverage which seem to verify. - An NWS employee in a vessel in the Arctic Ocean confirmed snowfall at the time the SFR product indicated snow could be occurring. Indicating the product was viable at higher latitudes in that synoptic scenario. - 76% of the responses from forecasters ranked SFR as Useful or Very Useful for their operations
Luis Rosa	NWS Sterling, Virginia WFO	Winter weather nowcasting	- SFR extremely helpful/useful this morning in western MD and eastern WV panhandle; very accurate with the snow reports. - Mentioned SFR in the local Area Forecast Discussion multiple times.
Matthew Brothers, Michasel Charnick (SOO)	NWS Cheyenne, Wyoming WFO	Winter weather nowcasting	SFR provides snowfall estimates where radar overshoots and over the mountains where radar does not have coverage

Downstream Product Feedback

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts
Second-generation CPC MORPHing technique	CMORPH2	The NCEP/CPC CMORPH2 global blended precipitation product requires the NESDIS SFR product as a critical input. The NOAA-21 SFR will further improve the accuracy of the CMORPH2 winter precipitation.

Risks, Actions, and Mitigations

- Provide updates for the status of the risks/actions identified during the previous maturity review(s); add new ones as needed

Identified Risk	Description	Impact	Action/Mitigation and Schedule
None			

Documentations

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
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	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.	Yes
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
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes

Conclusion

- Cal/Val results summary:
  - The SFR team recommends the NOAA-21 SFR algorithm Provisional Maturity
    - Snowfall Detection and Snowfall Rate algorithms were developed using NOAA-21 observations (with additional NOAA-20 data)
    - Validation of NOAA-21 SFR against ground observations, radar estimates, and reanalysis reveals that the product performance meet the JPSS DPS requirements
    - NOAA-21 and NOAA-20 SFR are consistent visually and statistically both on orbital and monthly scales
    - Collection of more NOAA-21 snowfall data will allow the development of NOAA-21 specific algorithms and further improve product performance

Path Forward

- Lessons learned for NOAA-21 Cal/Val
  - Adequate amount of data is required to train Snowfall Detection and Snowfall Rate models
- Planned improvements
  - Orographic snowfall
  - Snowfall over ocean
  - Inter-satellite calibration
- Future Cal/Val activities / milestones
  - Collect additional NOAA-21 snowfall data
  - Develop NOAA-21 Snowfall Detection and Snowfall Rate models using only NOAA-21 data
  - Validated Maturity

Potential Benefits of 3 JPSS Satellites

- Provide observations of storm evolution and sub-hourly refresh rate; both are important for nowcasting
- The long SNPP record contributes to snowfall rate CDR
- SNPP can serve as a reference satellite to cross calibrate other satellites