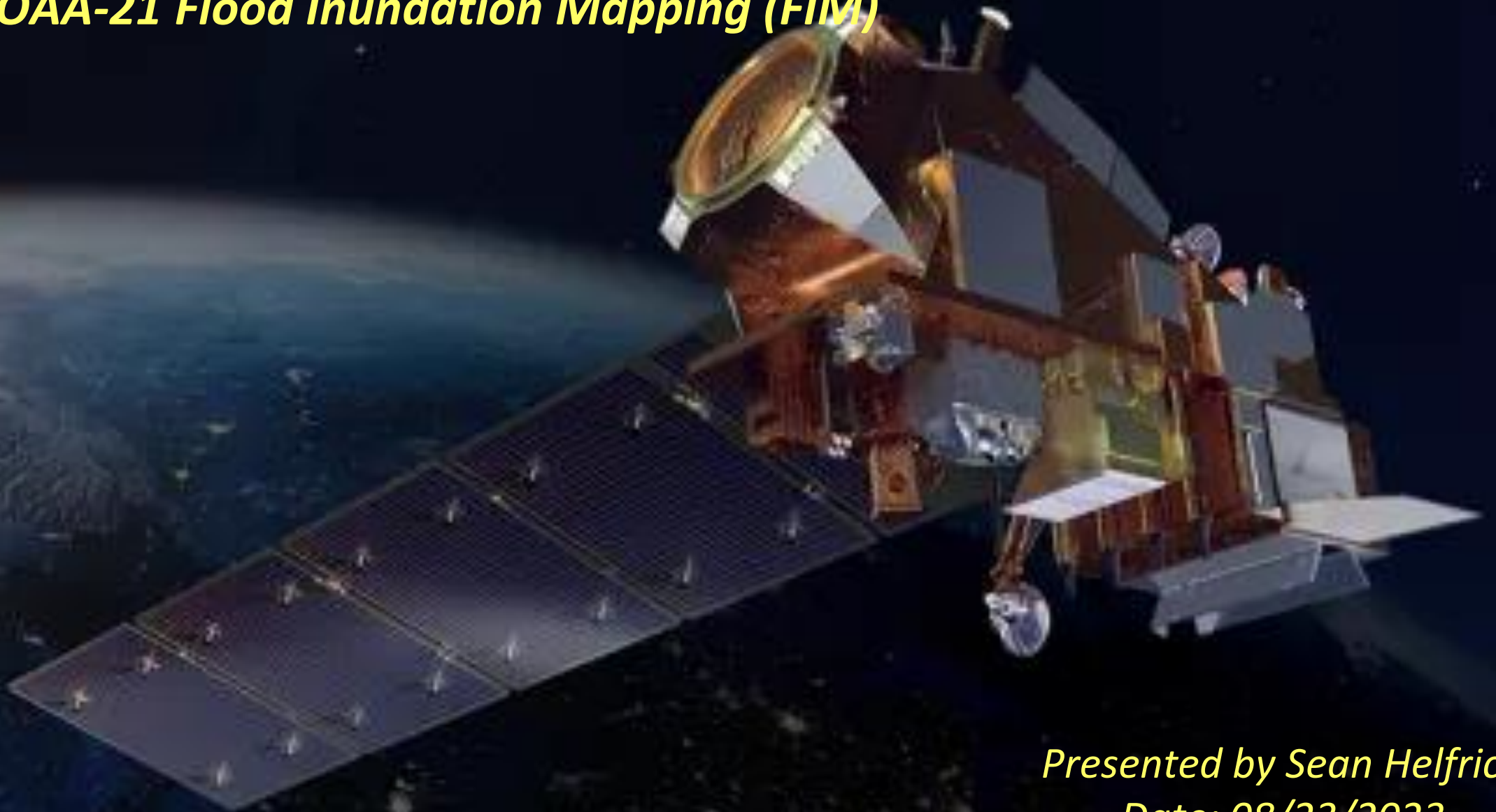


***Beta & Provisional Maturity Science Review
For NOAA-21 Flood Inundation Mapping (FIM)***



***Presented by Sean Helfrich
Date: 08/23/2023***

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
- Beta/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

- {Beta/Provisional/Validated} 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
 - Beta/Provisional Maturity Performance
 - Risks, Actions, Mitigations
 - Path forward (to the next maturity stage)



VIIRS Flood Inundation Mapping Beta and Provisional MATURITY REVIEW MATERIAL

- 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
Sean Helfrich	NOAA/NESDIS/STAR	STAR Water Surface Conditions Science Team Lead and PI
Sanmei Li	GMU	JPSS VFM Product Development Lead
William Straka	UW/SSEC/CIMSS	VFM Proving Ground Lead
Donglian Sun	GMU	JPSS VFM evaluation team
Liqun Ma	NOAA/NESDIS/OSPO	VFM Product Area Lead

Product Overview/Requirements

- Product Overview
- Product performance requirements from JPSS Data Product Specification (DPS)
- **NOTE - Floods is not in the current DPS. We will check with PPM for product requirement specifications. Analysis will use requirements from ORR for analysis.**

Attribute	DPS	Requirement/Threshold	Performance
Accuracy		80% under clear-sky conditions	
Precision			
Uncertainty			

Product performance requirements

Attribute	Threshold	Observed/validated
Geographic coverage	CONUS and Alaska region	Same as requested
Mapping Accuracy	80%	Same as requested
Latency	40 min	Same as requested
Horizontal Cell Size	375 m	Same as requested
Timeliness	3 hours (after last measurement)	Same as requested
Measurement Range	Water fractions between 25% and 100%	Same as requested
Measurement Accuracy	80% under clear-sky conditions	Same as requested
Measurement Precision	NA	NA

Product performance requirements

Attribute	Threshold	Observed/validated
Geographic coverage	Global Land	Same as requested
Mapping Accuracy	80%	Same as requested
Latency	4 hours	Same as requested
Horizontal Cell Size	375 m	Same as requested
Timeliness	3 hours (after last measurement)	Same as requested
Measurement Range	Water fractions between 25% and 100%	Same as requested
Measurement Accuracy	80% under clear-sky conditions	Same as requested
Measurement Precision	NA	NA

Processing Environment and Algorithms

- Pre-launch delivery: In 2022, a version has been delivered to use simulated NOAA-21/VIIRS data for flood mapping.
- Post-launch delivery: In May 2023, the post-launch version was delivered after preliminary test on the NOAA-21/VIIRS data.
- Beta and Provisional delivery: In Aug. 2023, a new version was delivered to fix a few algorithm and software issues and limitations. Another version will be delivered in September together as v1.1. This will include the new blended VIIRS/ABI flood mapping software and the updated ancillary datasets.

- Description of processing environment and algorithms used to achieve the maturity stage:
 - Algorithm version: v1.1
 - Version of LUTs used: Nov 2020
 - Version of PCTs used: n/a
 - Effective date: July 20, 2022 (for v1.0 for SNPP and NOAA-20)
 - NOAA-21 data available from PDA-IT, which is from NCCF IT, since May 2023.
 - Testing for NOAA-21 using Algorithm v1.1



VIIRS Flood Inundation Mapping Algorithm overview and updates

Algorithm inputs -SDR data

VIIRS Bands	Central Wavelength (μm)	Bandwidth (μm)	Wavelength Range (μm)	Band Explanation	Spatial Resolution (m) at nadir
I1 (Vis)	0.64	0.08	0.60 - 0.68	Visible/ Reflective	375 m
I2 (NIR)	0.865	0.039	0.85 - 0.88	Near IR	375 m
I3 (SWIR)	1.61	0.06	1.58 - 1.64	Shortwave IR	375 m
I5 (IR)	11.45	1.9	10.5 - 12.4	Longwave IR	375 m

The NOAA-21/VIIRS flood detection algorithm requires Imager bands 1, 2, 3 and 5, together with solar zenith angle, solar azimuth angle, sensor zenith angle, sensor azimuth angle and terrain-corrected navigation data (GITCO).

The NOAA-21 VFM algorithm also requires two types of ancillary datasets:

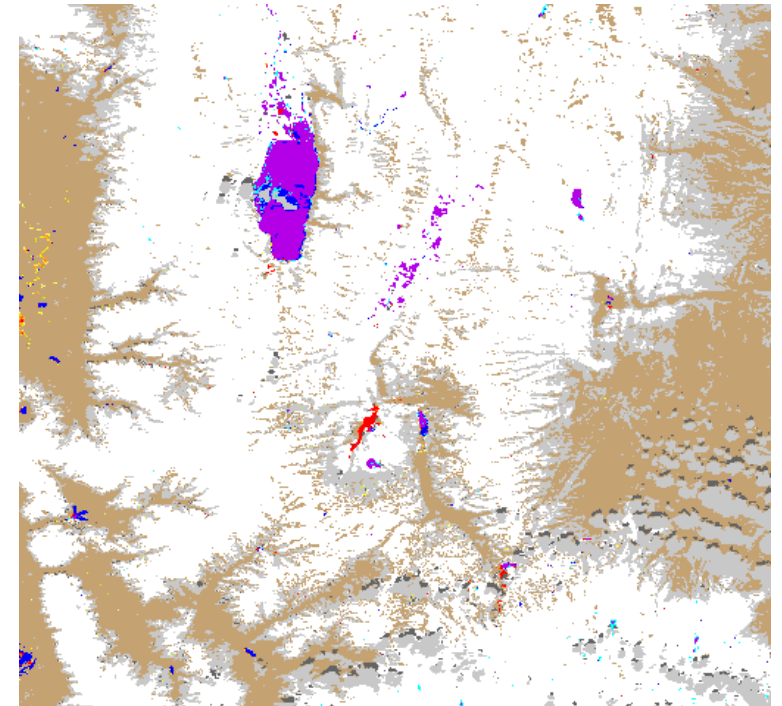
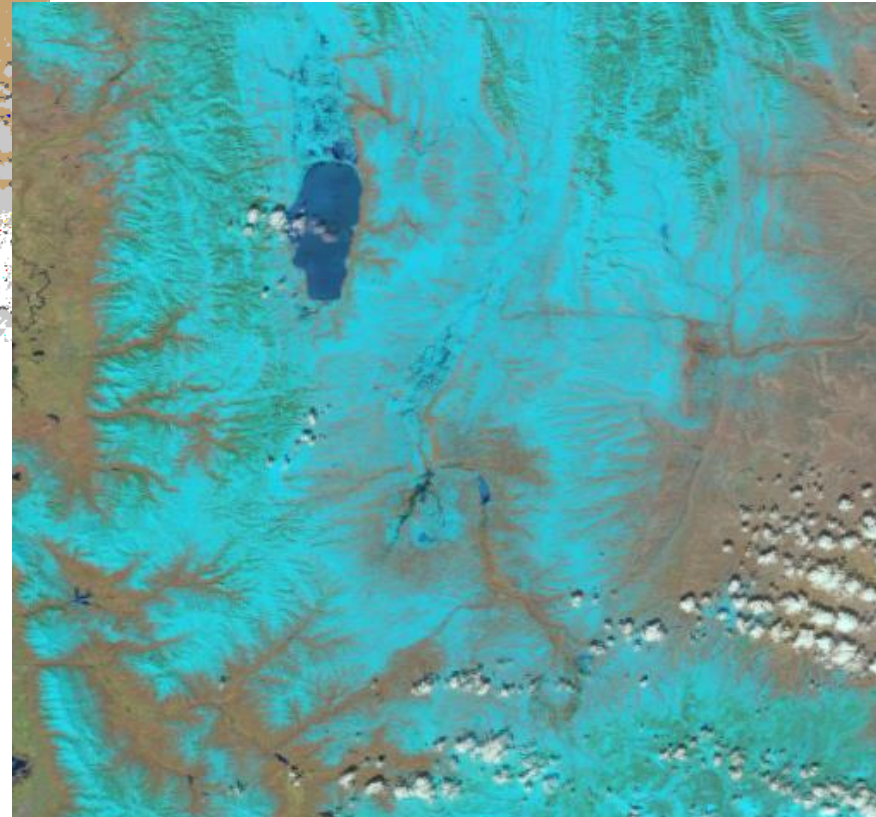
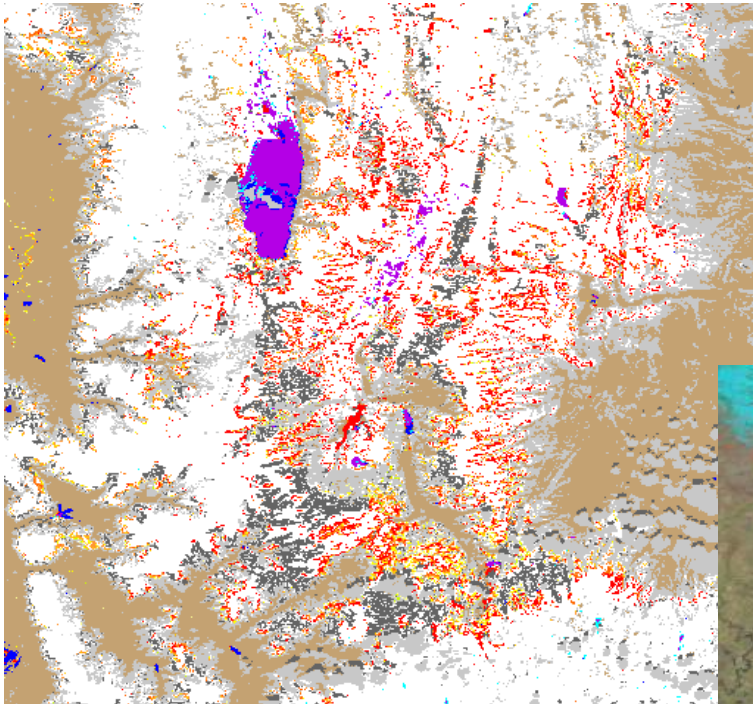
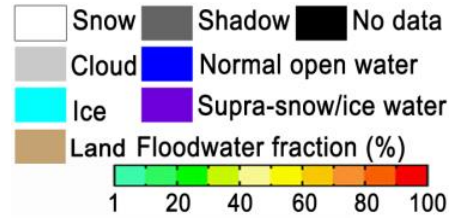
- VIIRS cloud mask data (VIIRS EDR data, optional)
- Other static ancillary datasets:
 - Global 1-km land cover
 - Global 1-km land/sea mask
 - Global 375-m water reference mask
 - Sun-glint lookup table
 - Global 375-m DEM
 - Global 5-km climatology of land surface temperature and sea surface temperature
 - Global 5-km albedo climatology
 - Pre-trained decision trees and tree attribute
 - User AOI definition text file

- The NOAA-21/VIIRS data has been integrated into the VFM software using a similar framework and similar algorithm to the Suomi-NPP & NOAA-20/VIIRS data.
- Some minor revisions have been made on the VFM software and algorithm to incorporate with the NOAA-21/VIIRS data:
 - The projection module has been adjusted to include NOAA-21 data
 - The flood detection module has been adjusted to incorporate with NOAA-21/VIIRS data with bug fix on the water fraction retrieval, and detection of salt-like water
 - Ancillary datasets have been updated for more reliable flood detection with VIIRS imagery: Climatic albedo, water reference map, surface type and land/sea mask
 - The composition module and mosaic module have also been adjusted to incorporate with NOAA-21/VIIRS data.

Correction for False Detection for NOAA 21

Before

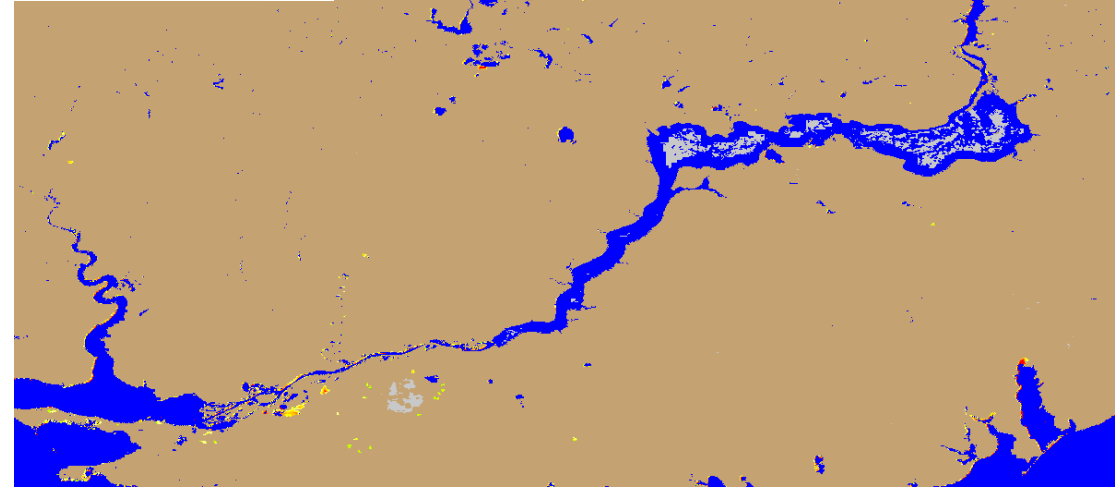
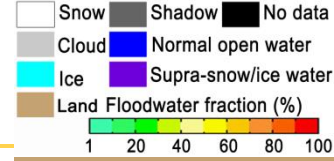
After



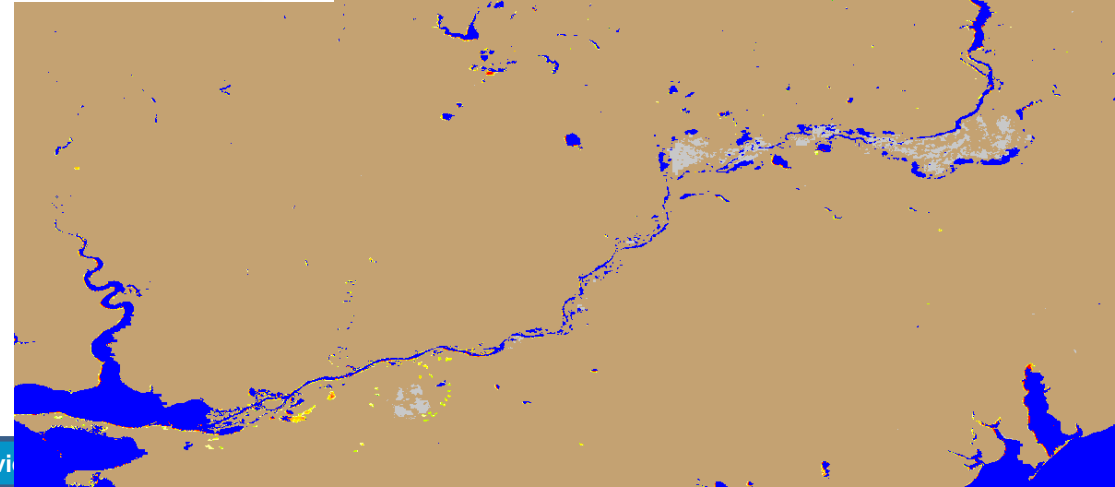
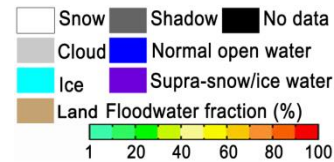
NOAA-21/VIIRS false-color image and flood maps on April 30, 2023 20:25 (UTC)

- Fix the algorithm bug between salt-like water and melting snow surface

- Update ancillary datasets including water reference map, land/sea mask and climatic albedo data to improve VFM product quality.



NOAA-21/VIIRS daily composited flood map before (top) and after (bottom) on Aug. 06, 2023 in Ukraine



NOAA-21/VIIRS false-color image on Aug. 06, 2023

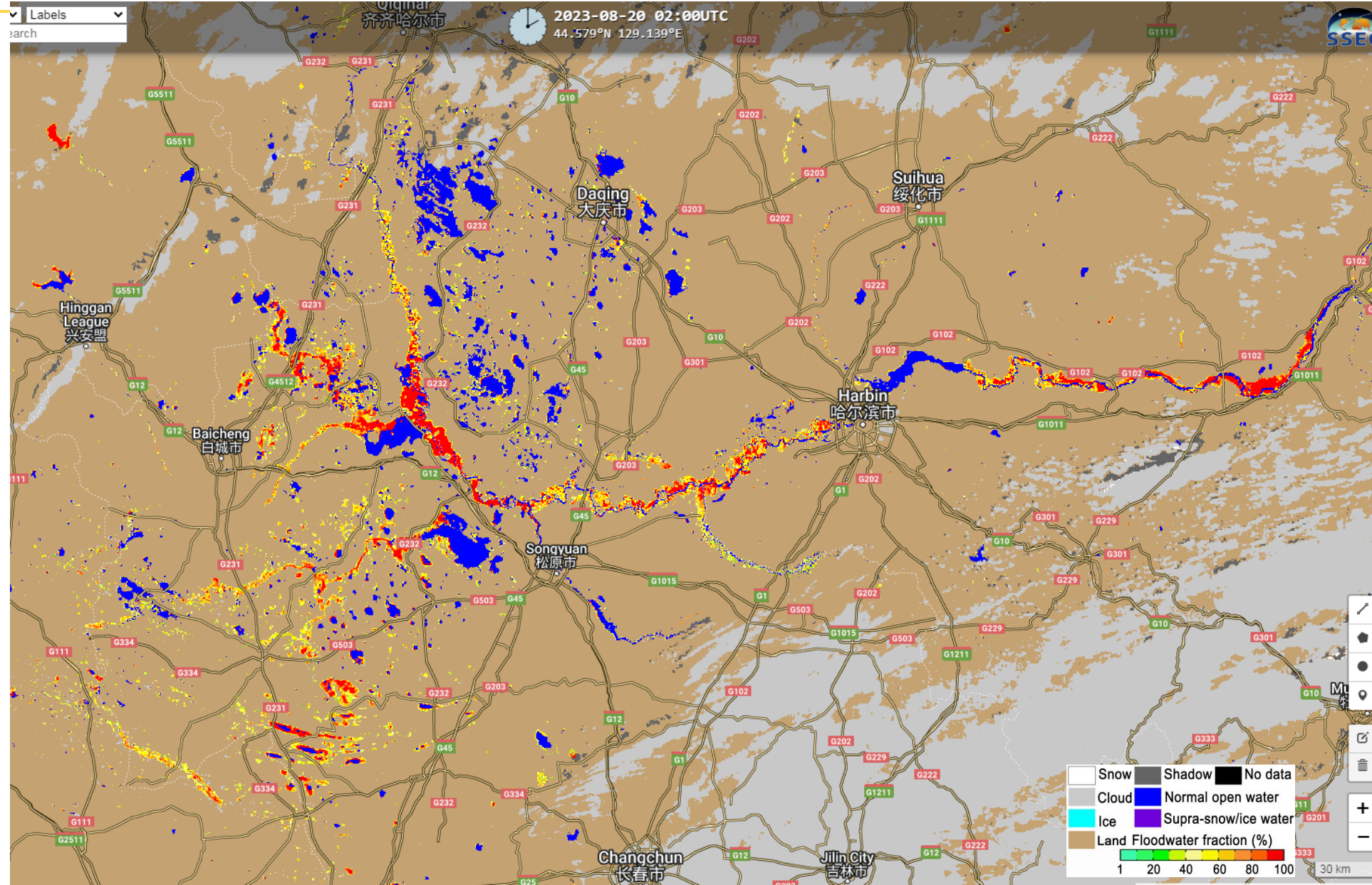


Validation of VIIRS Flood Inundation Mapping

- The VFM software has been tested using NOAA-21/VIIRS data covering different regions from May to August, 2023
- A demonstration system has been set up to process global NOAA-21/VIIRS data routinely in CIMSS since May 2023 for algorithm and software performance test.
- Overall, the software runs steadily with reliable performance on the product quality from NOAA-21/VIIRS data.

Implementation testing into CIMSS JPSS proving ground

An example of NOAA-21/VIIRS flood map from CIMSS's demonstration system on Aug. 20, 2023: <https://floods.ssec.wisc.edu/?products=RIVER-FLDJ02>



- Output formats and contents check
 - NetCDF4 check
 - Geotiff check
 - Shapefile check
- Algorithm performance check
 - Visual inspection with the NOAA-21/VIIRS false-color images
 - Cross comparison with Suomi-NPP & NOAA-20/VIIRS flood product
 - Quantitative analysis with Landsat-09/OLI images

NetCDF4 check

Properties - /WaterDetection

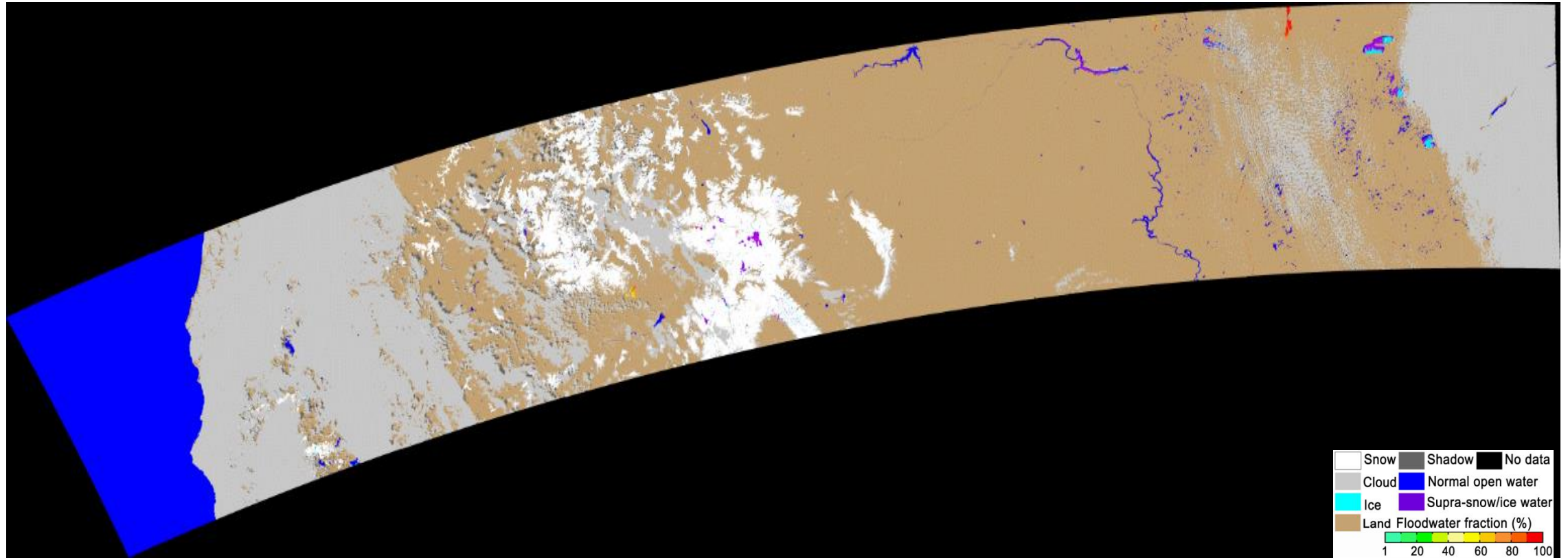
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DIMENSION_LIST	1758973, 331	Variable-length of Object ...	2
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ProjectionMaxLongitude	-105.00134	32-bit floating-point	1
ProjectionMinLatitude	35.0	32-bit floating-point	1
ProjectionMinLongitude	-120.0	32-bit floating-point	1
ProjectionResolution	0.003372	32-bit floating-point	1
Type	1, 15, 16, 17, 20, 27, 30, ...	32-bit integer	11
TypeDescription	1: no_valid_data; 15: Flo...	String, length = 250	Scalar
_FillValue	1	16-bit integer	1
_Netcdf4Dimid	1	32-bit integer	Scalar
add_offset	0.0	32-bit floating-point	1
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scale_factor	1.0	32-bit floating-point	1
units	1	String, length = 1	Scalar

Properties - /

Number of attributes = 53

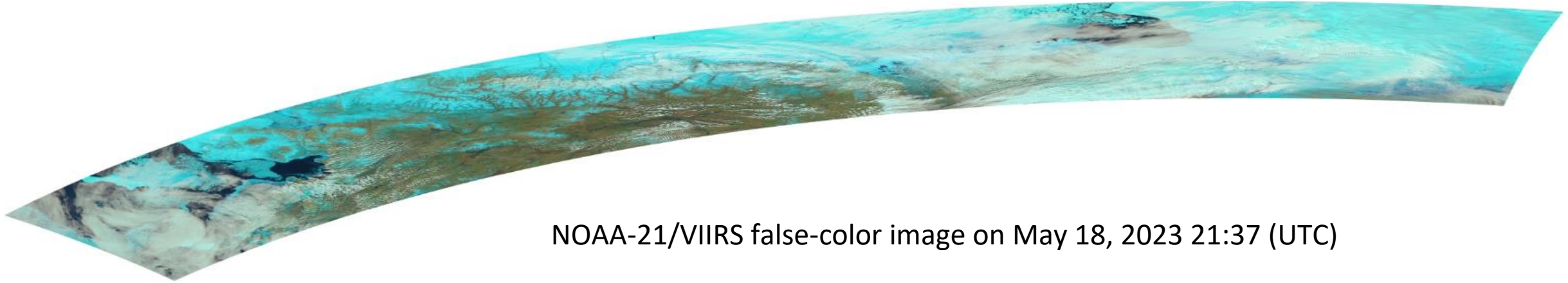
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Observingtime	200613.534703Z	String, length = 14	Scalar
Resolution	0.003372	32-bit floating-point	1
Satellitename	n21	String, length = 3	Scalar
SensorIdentifyCode	VIIRS	String, length = 5	Scalar
_NCProperties	version=1 netcdflibversi...	String, length = 57	Scalar
ascend_descend_data_...	0	32-bit integer	1
cdm_data_type	Grid	String, length = 4	Scalar
creator_email	slia@gmu.edu	String, length = 12	Scalar
creator_name	The VIIRS Flood Team i...	String, length = 76	Scalar
creator_url	https://jpsflood.gmu.edu	String, length = 25	Scalar
date_created	2023-08-07T18:46:01Z	String, length = 20	Scalar
day_night_data_flag	day	String, length = 3	Scalar
end_orbit_number	2448	32-bit integer	1
fillvalue_pixel_percent	46.795532	32-bit floating-point	1
flood_pixel_count	13095	32-bit integer	1
flood_pixel_percent	0.18655463	32-bit floating-point	1
geospatial_lat_max	45.0	32-bit floating-point	1
geospatial_lat_min	35.0	32-bit floating-point	1
geospatial_lat_resolution	0.003372	32-bit floating-point	1
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metadata_link	VIIRS-Flood_v2r0_n21_...	String, length = 74	Scalar
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naming_authority	gov.noaa.nesdis.ospo	String, length = 20	Scalar
platform	n21	String, length = 3	Scalar
processing_level	NOAA Level 3	String, length = 12	Scalar
production_environment	rhw1194 pkeehn	String, length = 14	Scalar
production_site	NOAANESDIS/STAR	String, length = 17	Scalar
project	NESDIS Common Clou...	String, length = 29	Scalar
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publisher_name	DOC/NOAA/NESDIS/OS...	String, length = 109	Scalar
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references	https://www.ssec.wisc.e...	String, length = 56	Scalar



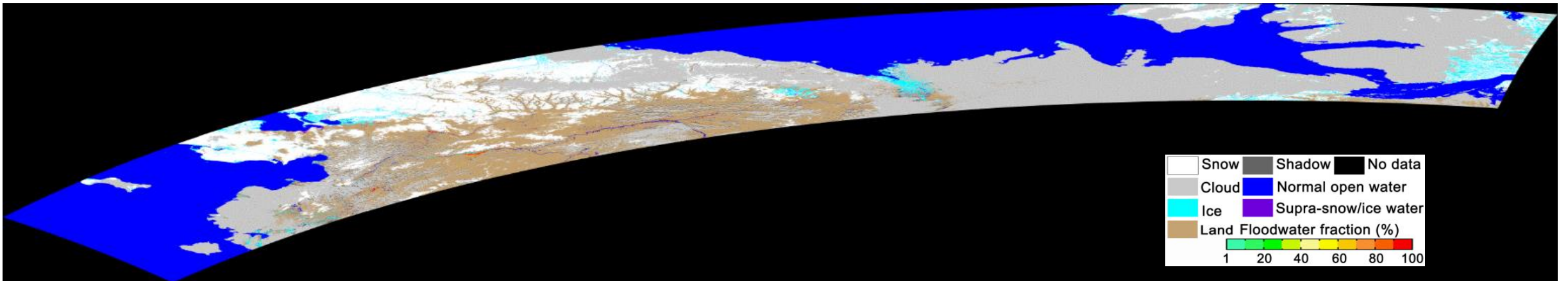
NOAA-21/VIIRS granule flood map in geotiff format May 01, 2023 20:07 (UTC)

- About 400 NOAA-21/VIIRS flood maps are visually inspected with the corresponding false-color images one-by-one.
- These images cover Asia, Africa, North America and South America
- Inspection of all formats to generate identical results
- Inspection of NWS Regional and Global products over common AOIs
- Visual inspection shows reliable results from the NOAA-21/VIIRS flood detection.

Algorithm Performance – Visual Inspection



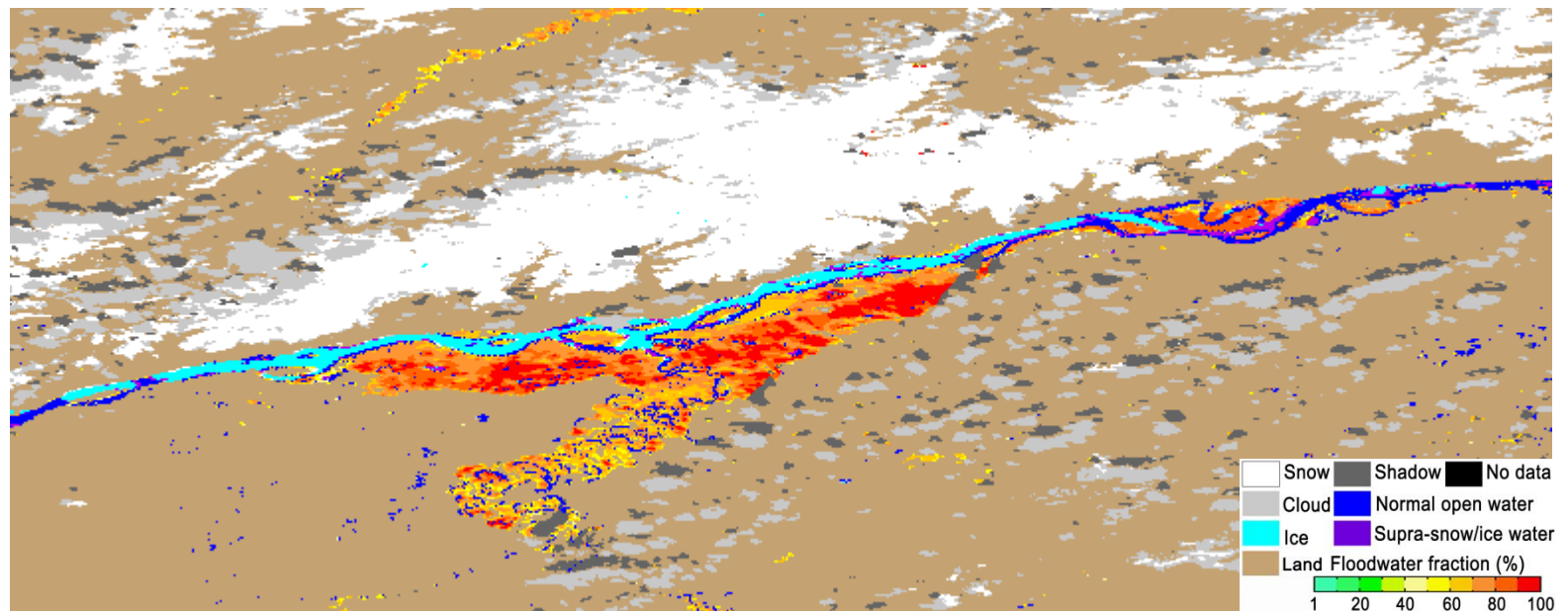
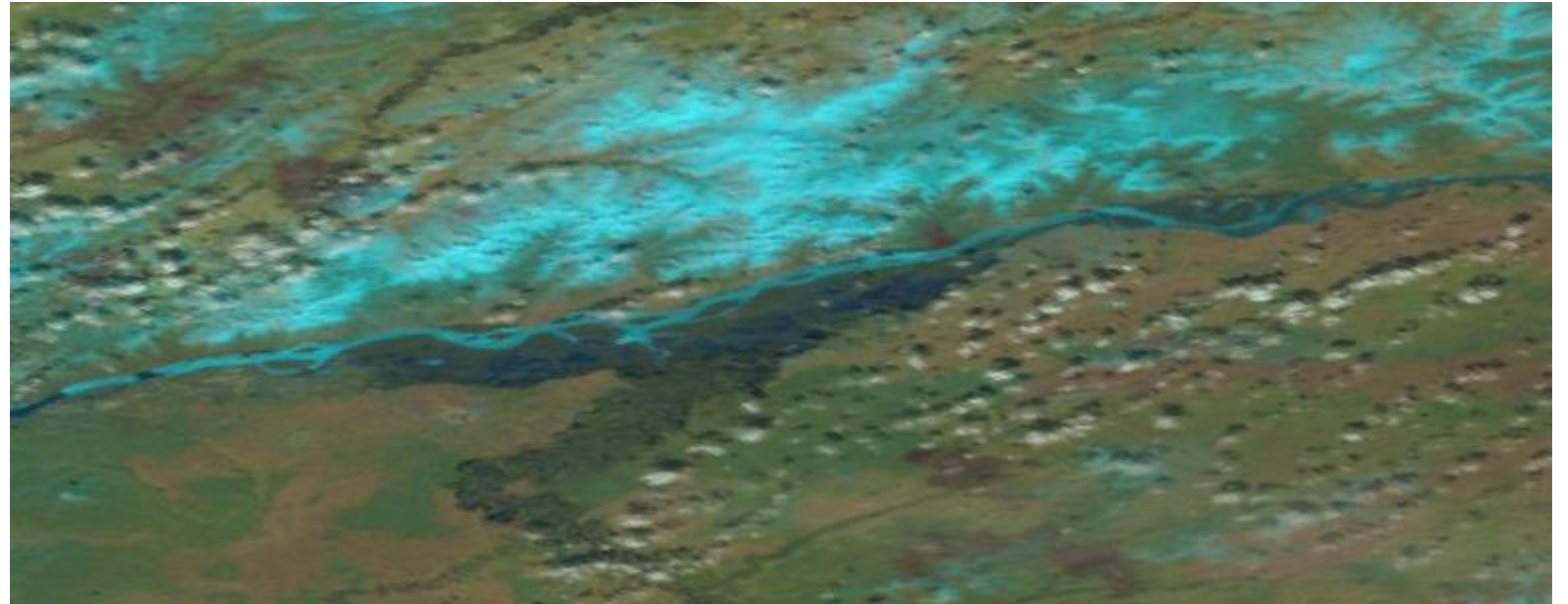
NOAA-21/VIIRS false-color image on May 18, 2023 21:37 (UTC)



NOAA-21/VIIRS flood map on May 18, 2023 21:37 (UTC)

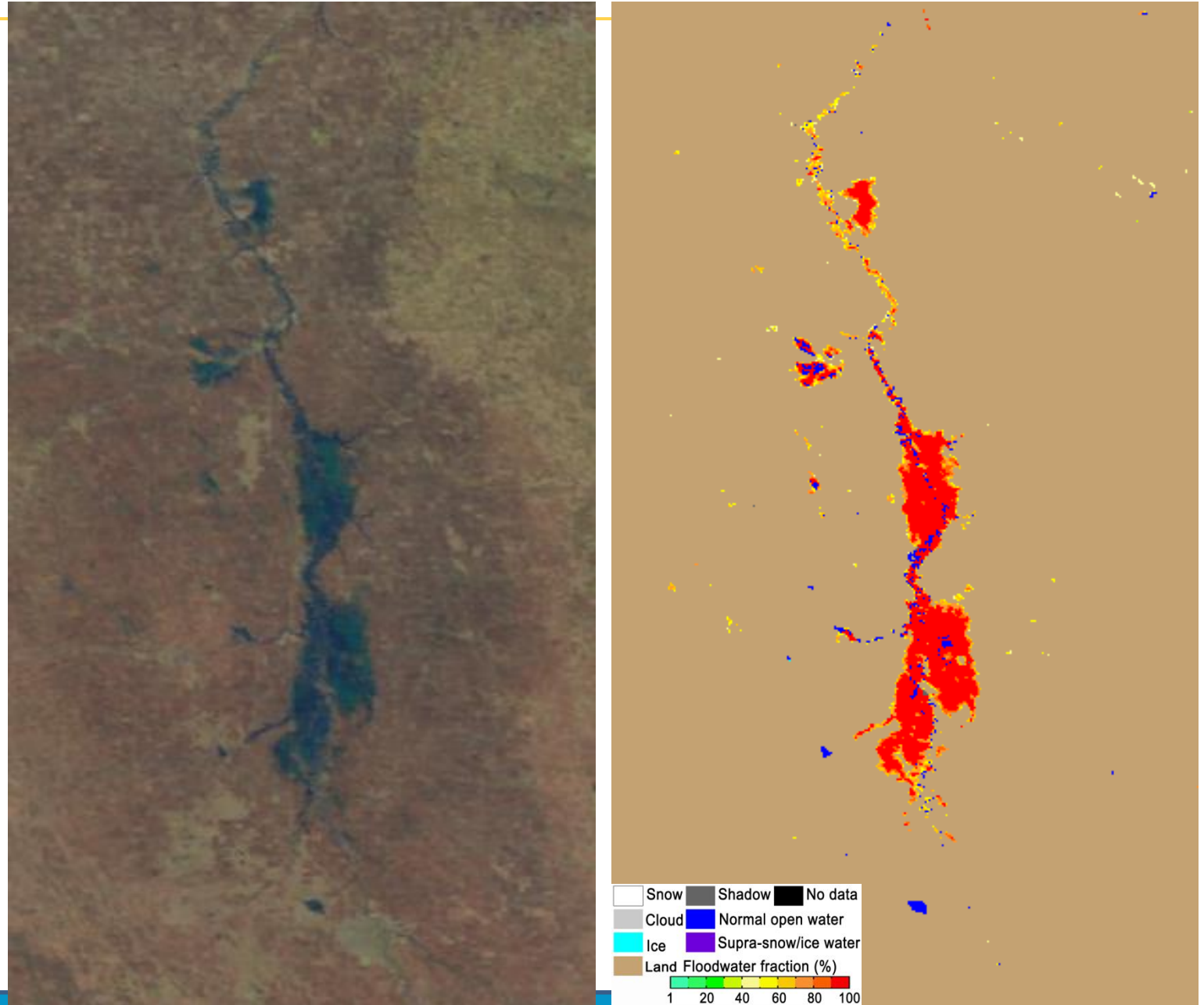
- VIIRS flood maps are visually inspected with the VIIRS false-color images one by one.

NOAA-21 false-color image
(top) and flood map (bottom)
on May 18, 2023 21:37 (UTC)

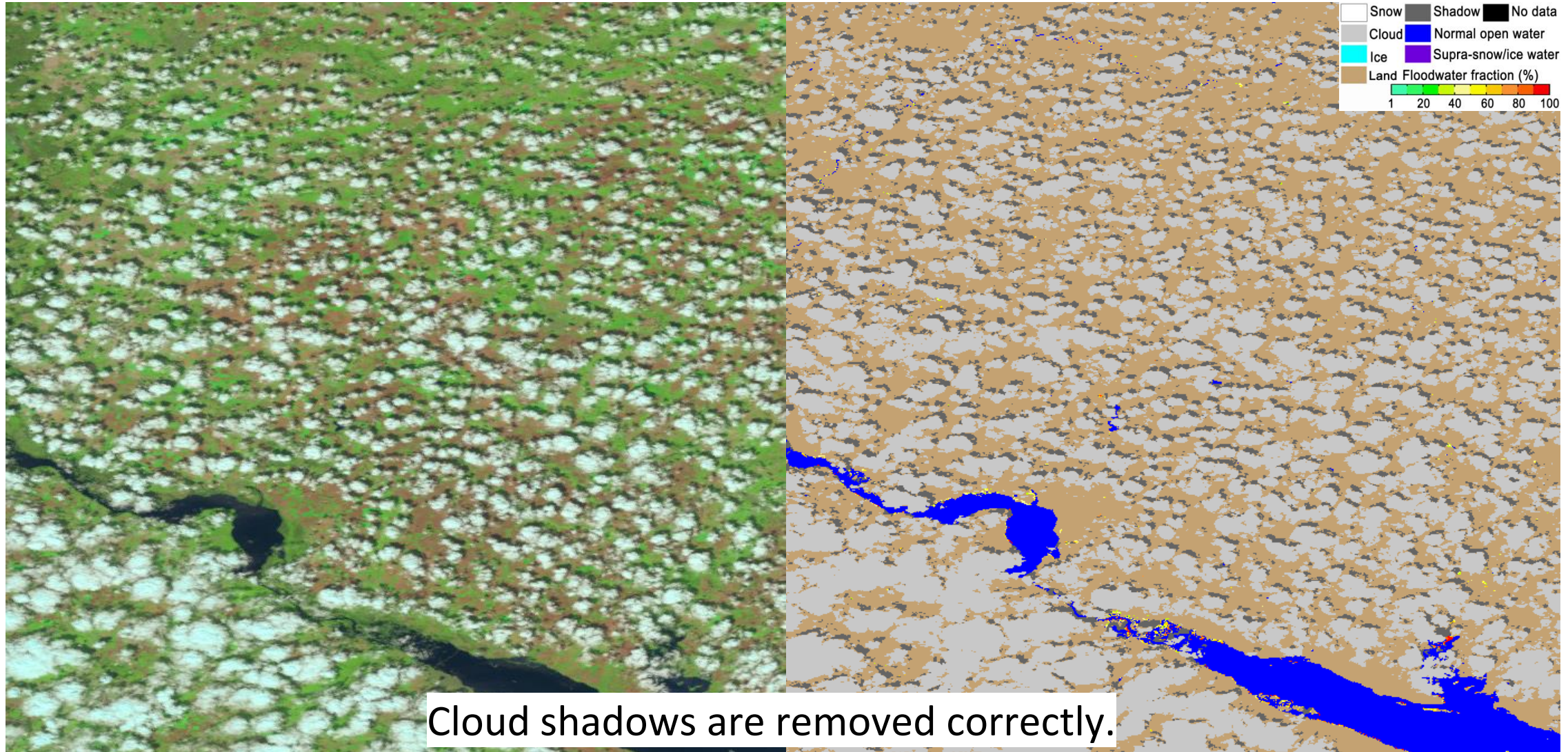


Algorithm Performance – Visual Inspection

NOAA-21 false-color image (left) and flood map (right) on May 02, 2023 18:09 (UTC)



Cloud Shadow Check



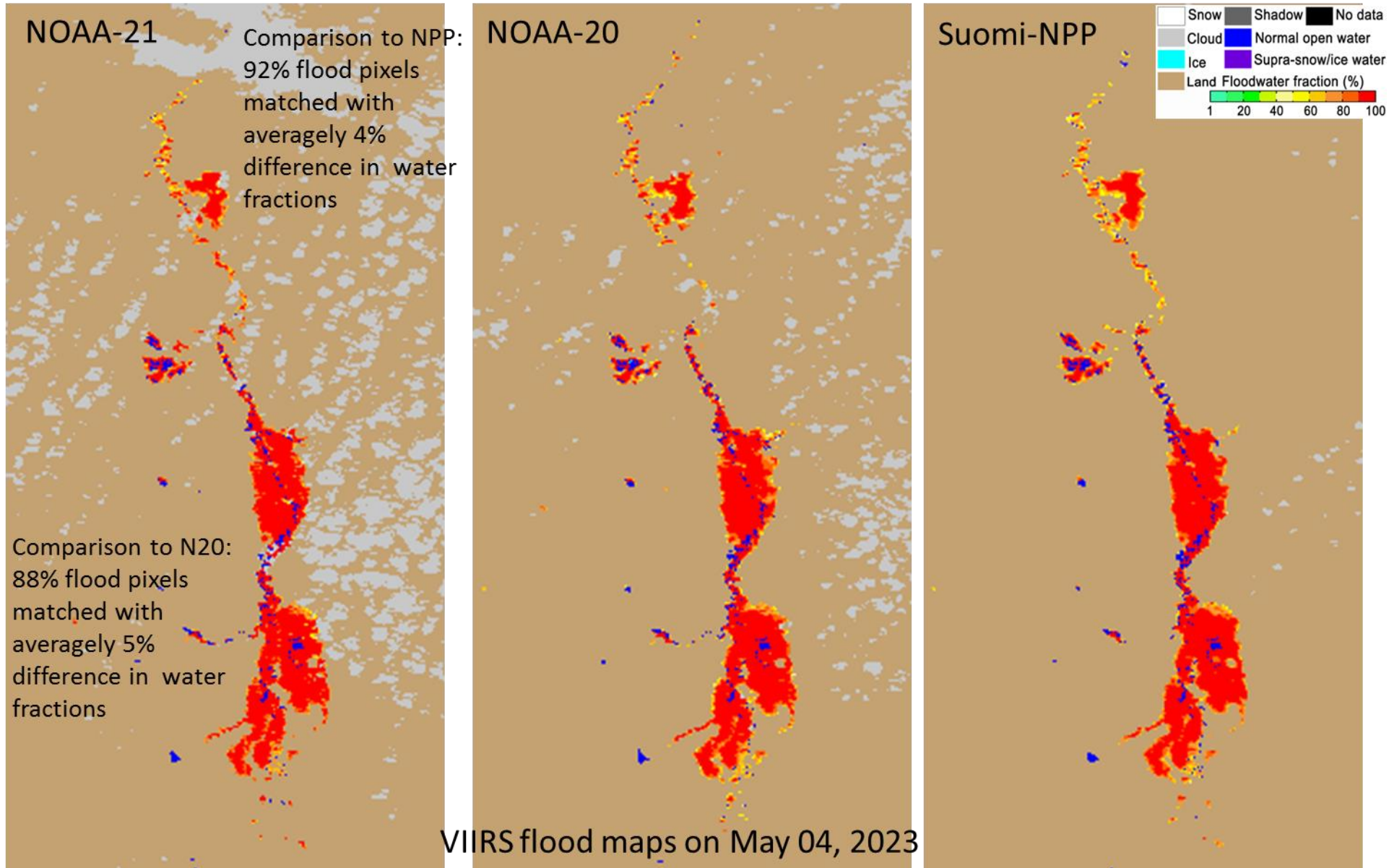
NOAA-21 false-color image (left) and flood map (right) on June 06, 2023 10:26 (UTC)



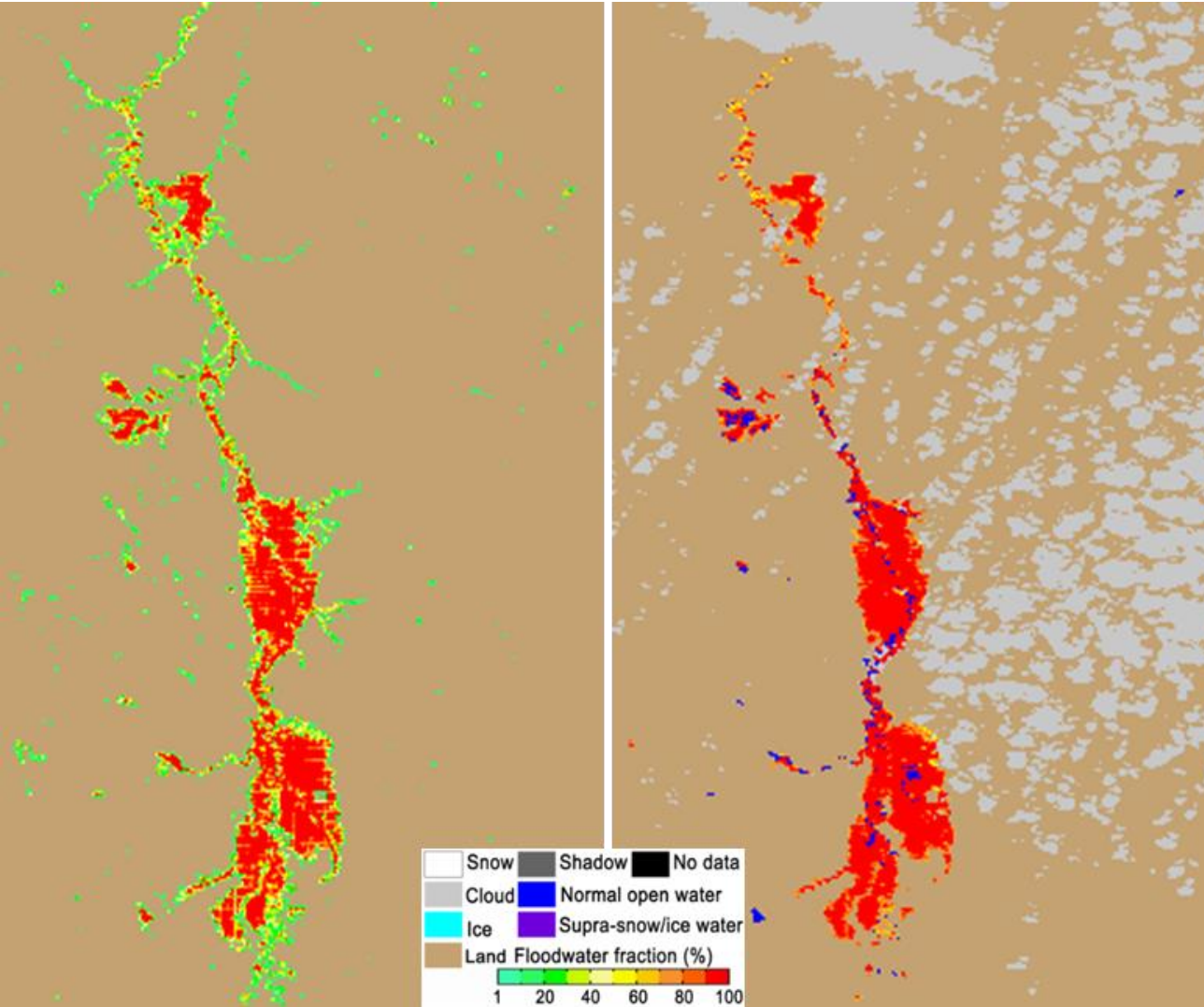
Granules in polar regions are projected correctly with reliable flood detection results.

NOAA-21/VIIRS flood map in northern Alaska (polar regions) on May 18, 2023 16:38 (UTC)

Cross comparison among NPP, N20 and N21

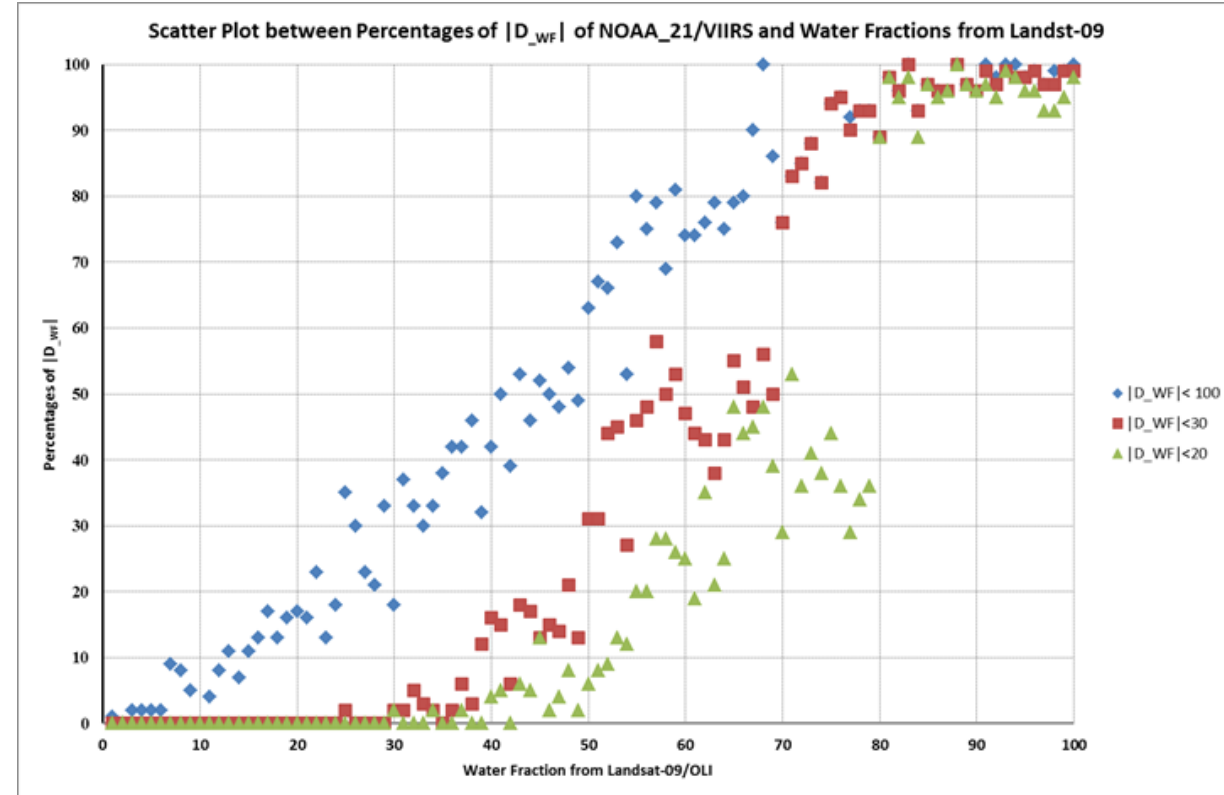


Comparison with Landsat-09/OLI



Landsat-09/OLI 375m
water fraction map
on May 04, 2023

NOAA-21/VIIRS 375
water fraction map
on May 04, 2023



- $|D_{WF}|$, defined as the absolute water fraction difference between VIIRS and Landsat-09, is used to evaluate the results by calculating the percentage of flood pixel with $|D_{WF}|$ in different range:
 - $P_{|D_{WF}| \leq 100}$: Percentage of flood pixels both detected in VIIRS and Landsat-09 image ignoring the water fraction difference
 - $P_{|D_{WF}| \leq 20}$: Percentage of flood pixels both detected in VIIRS and Landsat-09 images with $|D_{WF}|$ less than 20%
 - $P_{|D_{WF}| \leq 30}$: Percentage of flood pixels both detected in VIIRS and Landsat-09 images with $|D_{WF}|$ less than 30%

- Defined Quality Flags
 - **Low quality flag (2):** If a pixel is detected as cloud, but in the VIIRS enterprise cloud mask, it is shown as clear-sky land, then this pixel is with low quality flag. If a pixel is detected as non-cloud, but in the VIIRS enterprise cloud mask, it is shown as cloud, then this pixel is with low quality flag. All the cloud shadow pixels on the granule edges with their clouds in other granules are with low quality flag.
 - **Moderate quality flag (1):** Pixels that are detected as vegetation, bare land or water with the DT algorithm, but are re-detected as a different type during the post analysis are with moderate quality flag.
 - **High quality flag (0):** The rest pixels that are not with any of the above three quality flags are with high quality flags.
 - **Fill value (255):** All the pixels with fill value from the detection results are with fill-value quality flag.

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		80% under clear-sky conditions	N/A	Share similar accuracy with Suomi-NPP&NOAA-20/VIIRS flood products according to the current validation results. More validation is required before it is confirmed.	Averagely about 80% in water detection and water fraction retrieval depending on water fractions. Larger water-fraction pixels are with better accuracy.	Averagely about 80% in water detection and water fraction retrieval depending on water fractions. Larger water-fraction pixels are with better accuracy.	Yes	
Precision								
Uncertainty								

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
Need more user reviews of data	While the NOAA-21 VIIRS FIM has been provided since March 2023, user feedback has not been provided. This is because N21 AWIPS files are not on Ops string, which is what is what is being distributed to NWS	Unable to ensure NWS acceptance and prepared to use of NOAA21 VFM products	Working with TOWR-S to see when N21 files will be distributed via LDM to WFOs. Will be working with NWS, CIMSS Proving Ground, and RFCs to complete user evaluation of the data prior to full maturity.
EUM and SMM not updated for N21	ATBD has been updated, but EUM and SMM have not been.	Users unprepared for N21. outdated documentation.	Complete before final review
New algorithm needs to be tested on JPSS and N20	New algorithm needs to be tested for impacts on all sensors to provide new user performance metrics.	Unknown accuracy of new algorithm.	Conduct updated testing of new algorithm on legacy satellites.

Downstream Product Feedback

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts

No Downstream products at this time

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
	FEMA	Assessment of flooded areas to assist in recovery after flood events	Uses the daily, 5-day composites from VIIRS as well as daily Joint ABI/VIIRS products (currently being operationalized). Excellent usage in various events
	NWS WFOs (various)	Assessment of flooded areas to assist in aiding DSS support for issuing/scaling back warnings and situational awareness	Currently using the mosaics for NPP and N20. Waiting for NCCF ops to assess N21. But no issues expected
	APRFC	Assessment of flooded areas to assist in aiding DSS support for issuing warnings and situational awareness during ice break up season	Currently using the mosaics for NPP and N20. Waiting for provisional to assess N21.
	International stakeholders	Assessment of flooded areas to assist in recovery after flood events	Uses the daily, 5-day composites from VIIRS. No issues expected, but will be assessing after ops NCCF transition

Documentations (Check List, 1 slide)

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	NEEDS N21 Updating
System Maintenance Manual (for ESPC products)	NEEDS N21 Updating
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 - Beta Maturity

Beta Maturity End State	Assessment
<p>Product is minimally validated, and may still contain significant identified and unidentified errors</p>	<p>Successful</p>
<p>Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose</p>	<p>Successful</p>
<p>Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists</p>	<p>Successful, but needs minor updating to include N21 for EUM and SMM</p>

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
<p>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.</p>	<p>Successful</p>
<p>Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).</p>	<p>Successful</p>
<p>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.</p>	<p>Successful, though validation will continue.</p>
<p>Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.</p>	<p>Successful, but needs minor updating to include N21 for EUM and SMM</p>

- Cal/Val results summary:
 - Team recommends algorithm Beta/Provisional maturity
 - The vision inspection, SNPP and NOAA-20 comparisons give us confidence the VFM algorithm is meeting specifications with the limited validation dataset included in this Beta/Provisional review. Current quantitative review is meeting requirements, but more review will be conducted to ensure conclusive review.
 - **The science team recommends Provisional status upon Sept 2023 delivery of V1.1 algorithm.**

- Lessons learned for NOAA-21 Cal/Val:
 - Some ancillary datasets such as water reference map, land/sea mask need to be updated in time for reliable quality of the product.
- Planned algorithm improvements
 - Better discrimination between wet soil and floodwater during snow-melting season
 - Improve the quality of salt-like water detection against melting snow surface
 - Improve the quality of water fraction retrieval on flood pixels with minor sun-glint contamination
 - Improve the quality of water detection over regions with permanent water bodies in the water reference map
- Future Cal/Val activities / milestones
 - More cross comparison with Suomi-NPP&NOAA-20/VIIRS flood products for consistent water detection among different sensors
 - More quantitative analysis using Landsat-8&9/OLI images
 - Work with users for evaluation and feedback
 - Update documentation