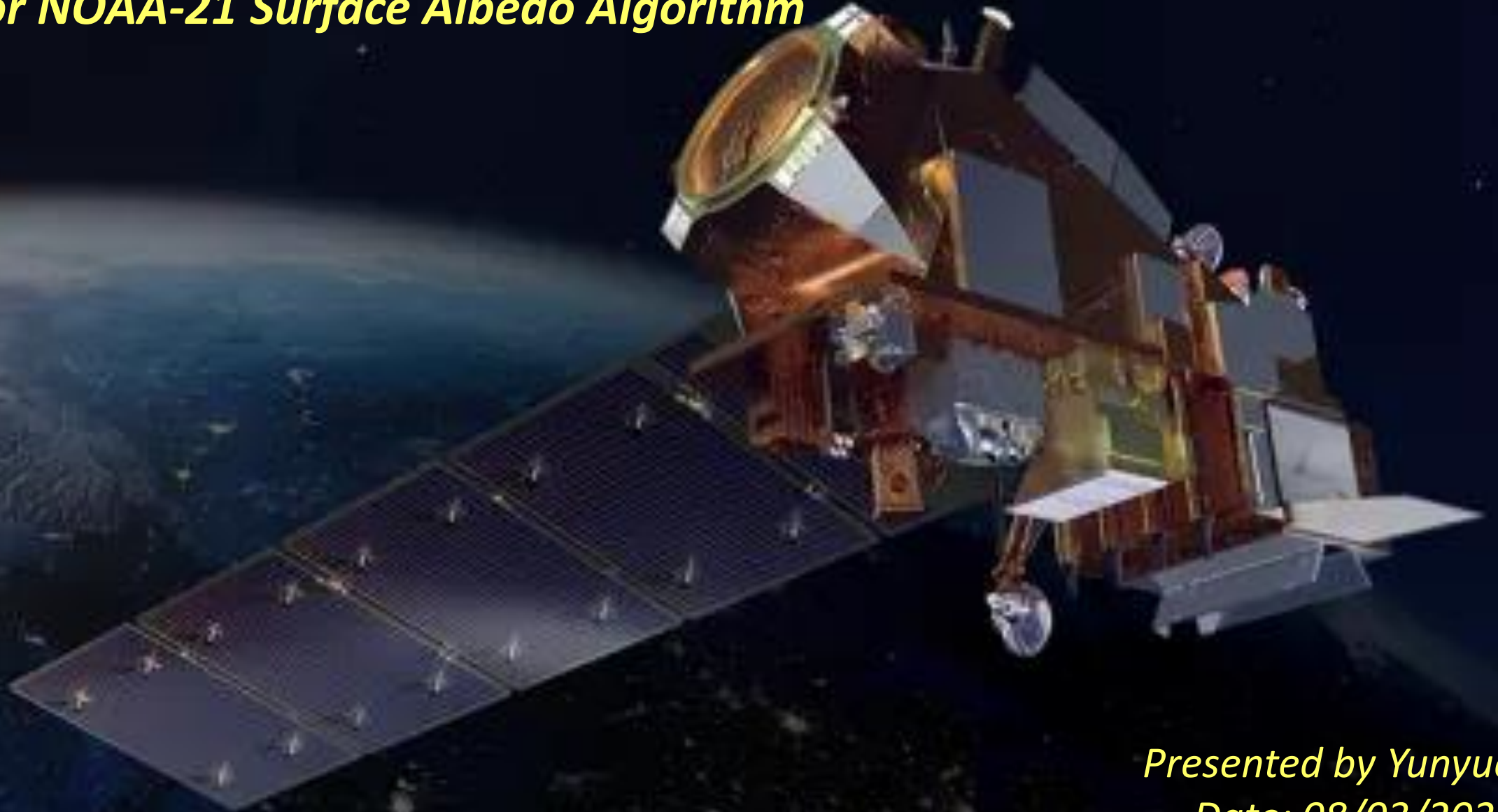**Beta Maturity Science Review**
For NOAA-21 Surface Albedo Algorithm

Presented by Yunyue Yu
Date: 08/03/2023

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.

BETA MATURITY REVIEW MATERIAL

- Surface Albedo 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

NOAA-21 Surface Albedo Algorithm Cal/Val Team

Algorithm Cal/Val Team Members

	Name	Organization	Major Task
STAR/EMB	Land Lead: Ivan Csiszar	NOAA/NESDIS/STAR	Project Management
	EDR Lead: Yunyue Yu	NOAA/NESDIS/STAR	Team management, algorithm development, validation advises
	Jingjing Peng	NOAA Affiliate, UMD/CISESS	product monitoring and validation; algorithm development/improvement
	Dongdong Wang	UMD/CISESS	algorithm development/improvement
	Lei Ji	UMD/CISESS	product monitoring and validation; software improvement
	Peng Yu	UMD/CISESS	product monitoring and illustration
JSTAR ASSIST	Michael Butler	NOAA/NESDIS/STAR	STAR ASSIST Lead
	Mingming Yao	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Algorithm System integration
	Eric Buzan	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Algorithm System integration
	Wilson, Michael	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Algorithm System integration
NOAA/EMC	Michael Barlage	NOAA/EMC/NCEP	user readiness
	Fanglin Yang	NOAA/EMC/NCEP	user readiness
	Weizhong Zheng	NOAA Affiliate	user readiness
	Helin Wei	NOAA Affiliate	user readiness
NOAA/OSPO	Hanjun Ding	NOAA/NESDIS/OSPO	NDE operational Land Lead
	Yufeng Zhu	NOAA Affiliate	NDE operational

- Product Overview

  ▸ Surface Albedo (SURFALB), defined as the ratio between solar radiation reflected by Earth's surface and solar radiation incident at the surface, is a function of both solar illumination and the surface reflective properties.

  ▸ The **L2** VIIRS enterprise surface albedo is retrieved with a direct estimation method, which directly links surface broadband albedo with clear-sky VIIRS TOA reflectance through statistical modeling. The algorithm also includes an offline component to generate cloudy-sky albedo from historical data filtering.

  ▸ The L2 albedo product is further processed into a grid-based **L3** albedo product, since the form of granule product may present challenges for users since the pixels have different sizes and varying latitude and longitude coordinates.

We built the spectral regression relationship between single TOA reflectance and the daily mean blue-sky-albedo. The regression coefficients vary with each angle combination $(\theta, \vartheta, \phi)$, for specific latitude on specific day of year.
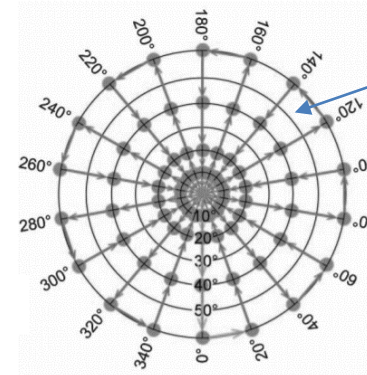
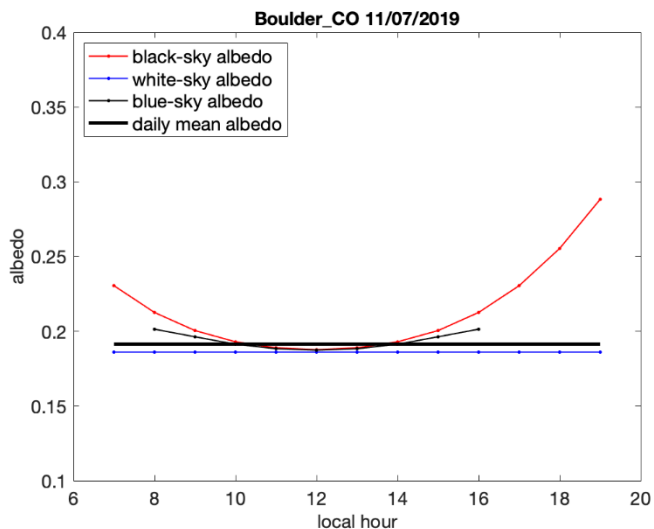One angular bin (The actual grid size is finer).

$$a^{daily} = \boxed{c_0} + \sum_{\Lambda=1}^{bands} R(\theta, \vartheta, \phi, \Lambda) \cdot \boxed{c_\Lambda}$$ ⟵ LUT

c_0 is the constant item, and

c_Λ is the channel-related coefficients

Daily mean albedo definition

$$\alpha^{daily} = \frac{E_u^{daily}}{E_d^{daily}} = \frac{\int\limits_{daytime} \alpha(t)I_d(t)dt}{\int\limits_{daytime} I_d(t)dt}$$

Boulder_CO 11/07/2019

- black-sky albedo
- white-sky albedo
- blue-sky albedo
- daily mean albedo

The daily mean albedo α^{daily} is the ratio between daily upward shortwave radiation E_u^{daily} and daily downward shortwave radiation E_d^{daily} at the surface.

- Surface Albedo (SURFALB), defined as the ratio between solar radiation reflected by Earth's surface and solar radiation incident at the surface, is a function of both solar illumination and the surface reflective properties.
- The daily mean albedo is essential for studying how surface changes affect global climate. The daily mean albedo can be calculated from instantaneous albedo $a(t)$ weighted by the instantaneous downward flux.
- Blue-sky-albedo is a combination of two conceptual values, the white-sky albedo (α_{ws}) and the black-sky albedo (α_{bs}), which are weighted by scattered skylight fraction.

$$a(\Omega_i) = \{1 - S(\theta_i)\}a_{bs}(\theta_i) + S(\theta_i)a_{ws}$$

- The instantaneous black-sky-albedo and white-sky-albedo are calculated as the summation of the angular integration of each kernel. f_x is the kernel parameter. $K_x(\Omega_v, \Omega_i)$ can be calculated from the kernel equations. Here, Ω_i refers to the incident geometry and Ω_v the view geometry. $N(\Omega_i)$ is the normalized sky radiance.

Product Requirements

Attribute	JPSS VIIRS LSA Threshold	Objective
Geographic coverage	The Surface Albedo product shall provide the broad-band earth surface albedo, from 0.4 to 4.0 microns, globally over land and ice, in daytime, in clear conditions, at the refresh rates of the instrument.	The same as threshold
Measurement Range	0 to 1.0 (albedo units)	0 to 1.0
Measurement Accuracy	0.08 (albedo units)	0.02
Measurement Precision	0.05 (albedo units)	0.0125

Joint Polar Satellite System (JPSS) Ground Segment Data Product Specification (GSegDPS)
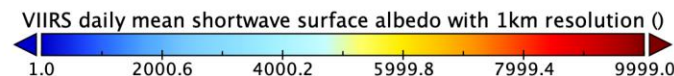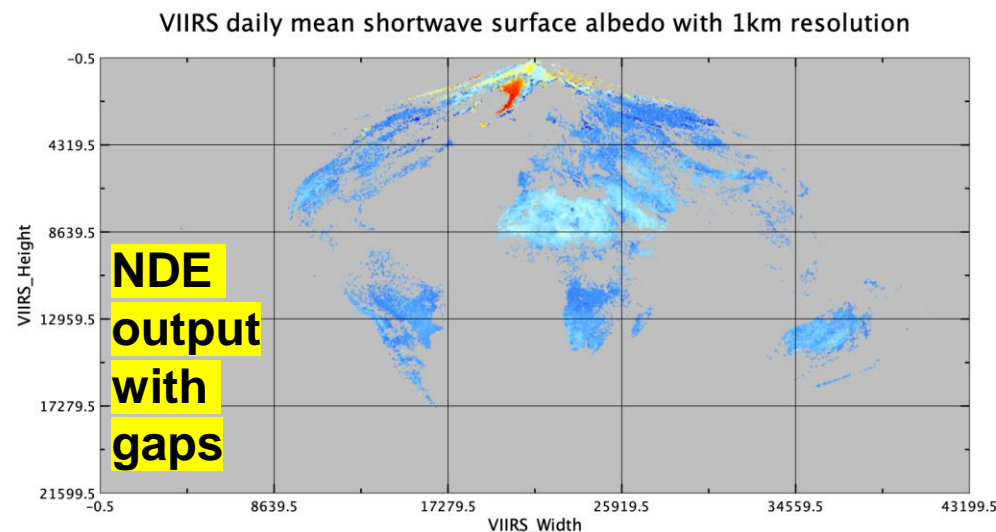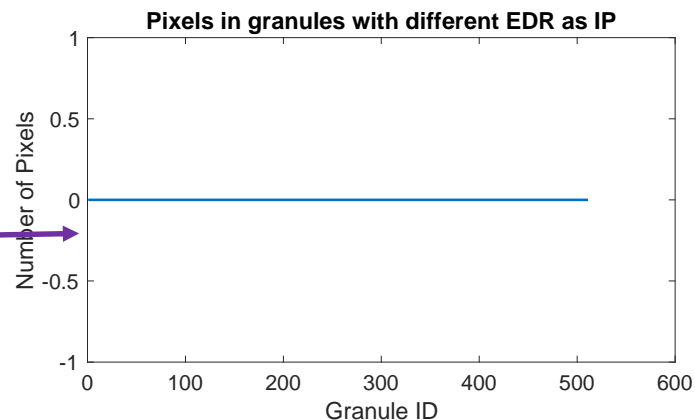
- Description of processing environment and algorithms used to achieve the maturity stage:
  - Algorithm version
    - v2r2
  - Version of LUTs used
    - NOAA-21 LUT v1
  - Version of PCTs used
    - v2r2
  - Effective date
    - Aug 2, 2023

| IT Item	OSPO (NCCF Operations)
Operating Systems	Redhat Linux
Programming languages/compilers	Intel & GNU Compiler (C/C++/Fortran)
Scripting languages	Python (version 2.7)
Graphical/Imaging programs, COTS S/W, other tools, etc	NetCDF4, HDFEOS, HDF5
Helpdesk Monitoring Tool	Tidal monitoring tool NCCF Dash Board
Other platforms needed for monitoring/imaging/graphics	IDL, (Python) NCCF Product trending and product visualization (PMPV)
Other	Cloudwatch NetCDF library, Python library
How often does system run (granule time, orbital, daily); event or schedule driven?	Daily
Memory used at run time	132 GB
Communication Requirements/Protocol	ftps

- ## Findings/Issues in Beta Review

  o **Issue:** unexpected data gaps in VIIRS albedo
  - **Actions in Science Team:** Requested the log files from NDE and identified the reason
  - **Progress:** Science team has identified a potential cause for the failure, which appears to be related to the script expecting a different key name in the PCF file, specifically the word preceding the '=' sign. The PCF is the script generated by ASSISTT . We have maintained communication with the NDE team to inquire about their progress in resolving this issue.
  - **Mitigations:** The NDE team is expected to fix the script and provide the updated version to and coordinate with ASSIST.

VIIRS daily mean shortwave surface albedo with 1km resolution

NDE output with gaps

VIIRS daily mean shortwave surface albedo with 1km resolution ()

NOAA-20 VIIRS Global Albedo v2r2 (Daily Composite): Jul 06, 2023

Expected output

EDR LSA is the gap filled product and is expected to be different from the IP LSA (before gap-filling), which is not the case as shown in the figure.

Pixels in granules with different EDR as IP
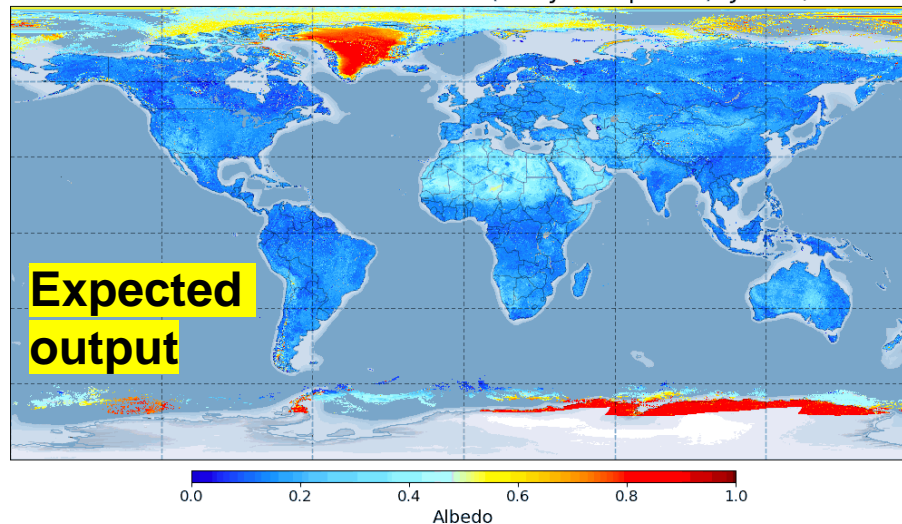
- *Improvements since last version*
  - **Algorithm Improvements**
    1. L2-online code update

       Snow mask and ice concentration input data has been switched to IMS snow/ice mask
    2. L2-offline code update

       1) Snow/Snow-free observations separation in offline temporal filtering
          - -- Mark snow/snow-free flags for each L2 albedo layers within the filtering window
          - -- Use snow (snow-free) only observations in temporal filtering for snow (snow-free) pixels in the current day
          - -- If there is no historical snow (snow-free) observations when the current day is snow (snow-free), use all valid observations within the filtering window to do temporal filtering, which is the same as the original algorithm

       2) Handling the updated netCDF format climatology
    3. L3 code update

       Handling the netCDF version gridding index (tiles_info)
  - **LUT / PCT updates**
    - The LUT has been updated according to the spectral response function of NOAA-21
    - NAN values in the previous NPP and J01 LUTs are filled
    - Climatology updated to Version 5 with upgraded quality, and netCDF format to replace the previous binary (.img) format
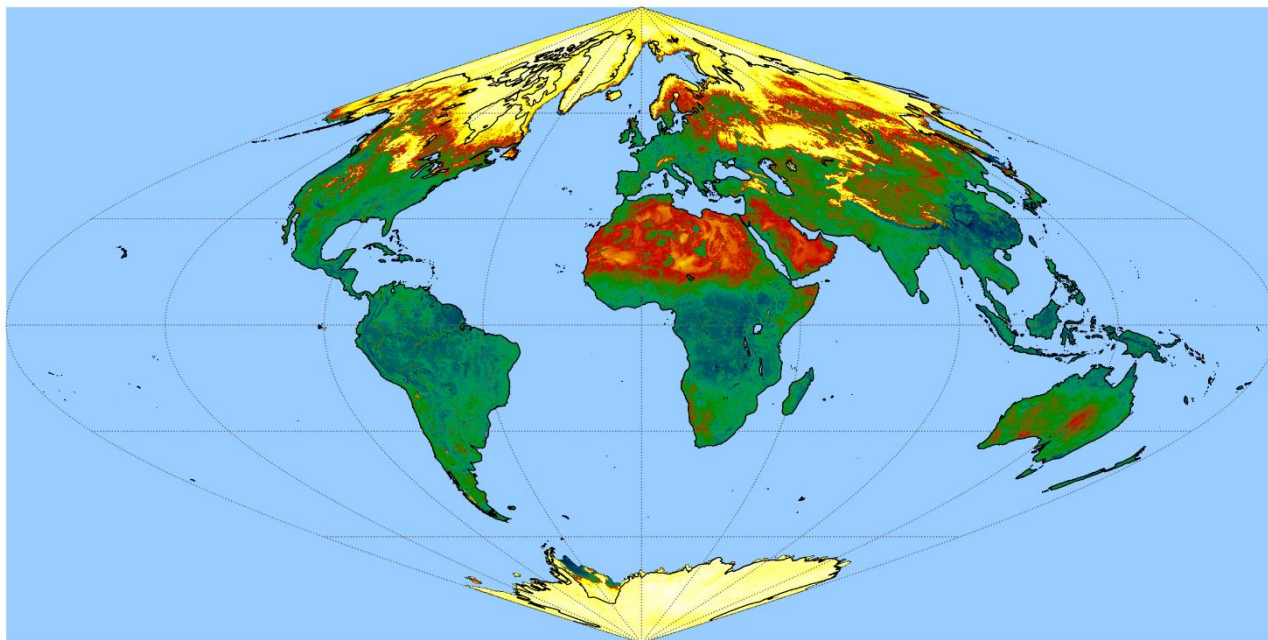 - **LTM adaptation**
    - The local LTM (Long-term-monitoring) system has been adapted to J2 surface albedo product

If there are no historical snow (or snow-free) observations on a current day that is classified snow (or snow-free), the temporal filtering process will utilize all valid observations within the filtering window, following the same approach as in the original algorithm
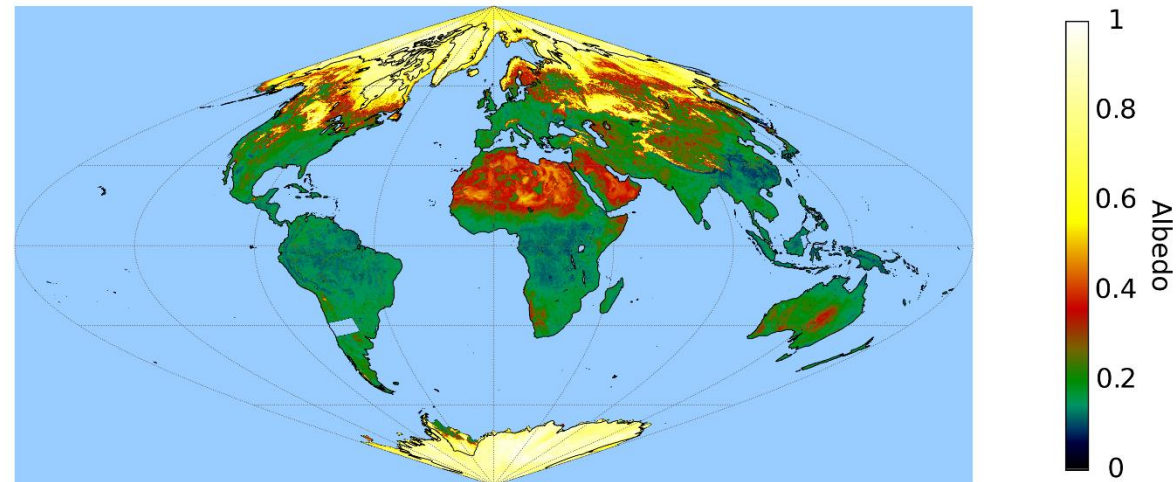
- ***Algorithm performance evaluation***
  - Visual Inspection
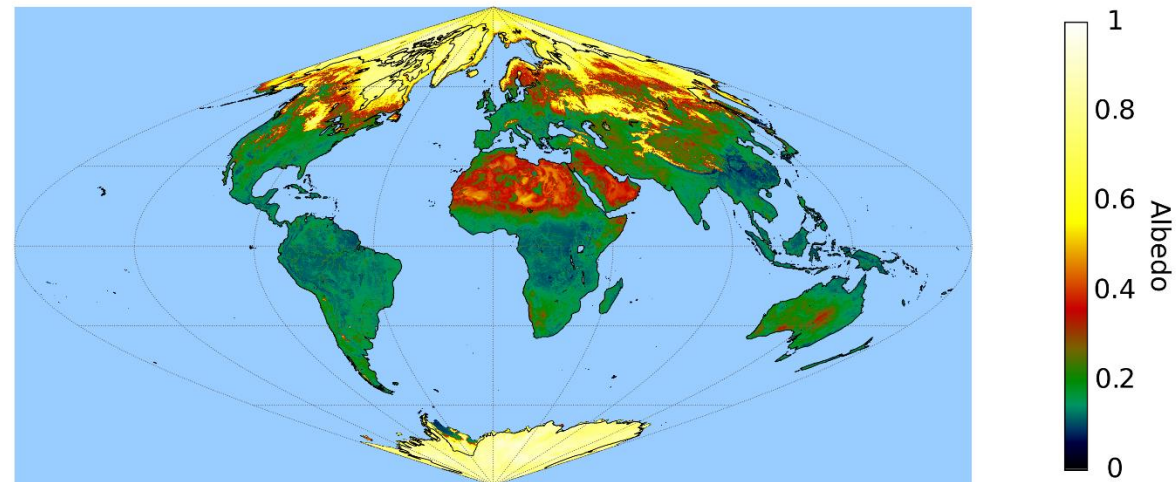
SNPP VIIRS v2r2 SURFALB Albedo Mar 20 2023

NOAA21 VIIRS v2r2 SURFALB Albedo Mar 20 2023

NOAA20 VIIRS v2r2 SURFALB Albedo Mar 20 2023

The NOAA21 VIIRS albedo has similar distribution as that from NOAA20 and SNPP.

- ***Algorithm performance evaluation***
  - Validation data sets
    - Ground measurements from SURFRAD, BSRN, ARM-SGP, NEON from Feb 22 to Jul 18, 2023
  - Validation strategies / methods
    - Direct comparison
  - Validation results
    - The N21 accuracy and bias has met the requirements
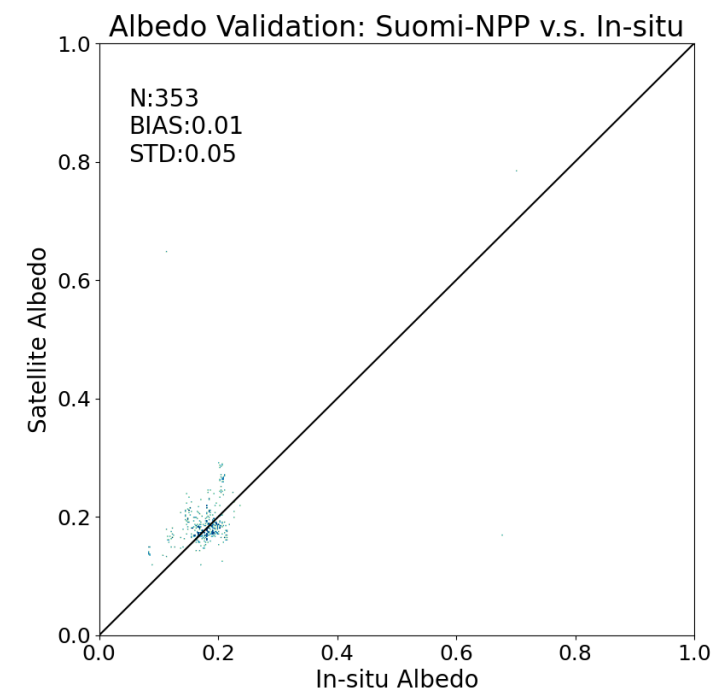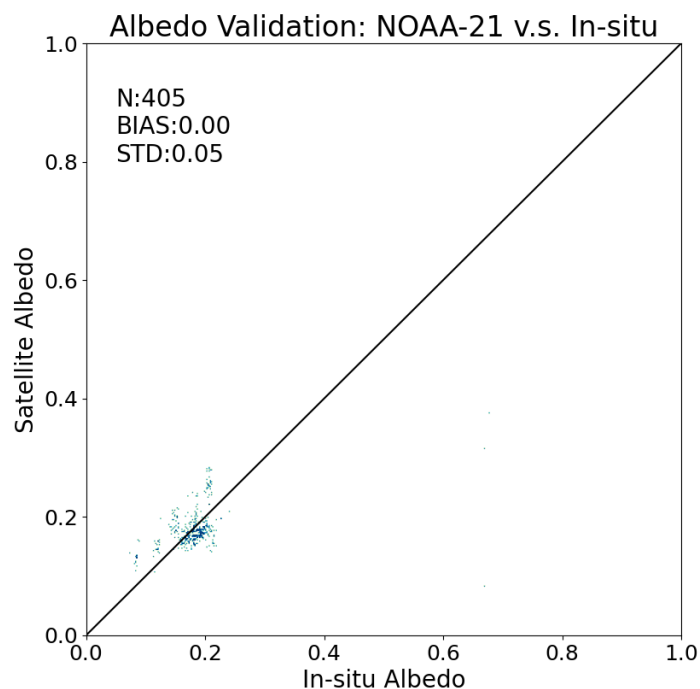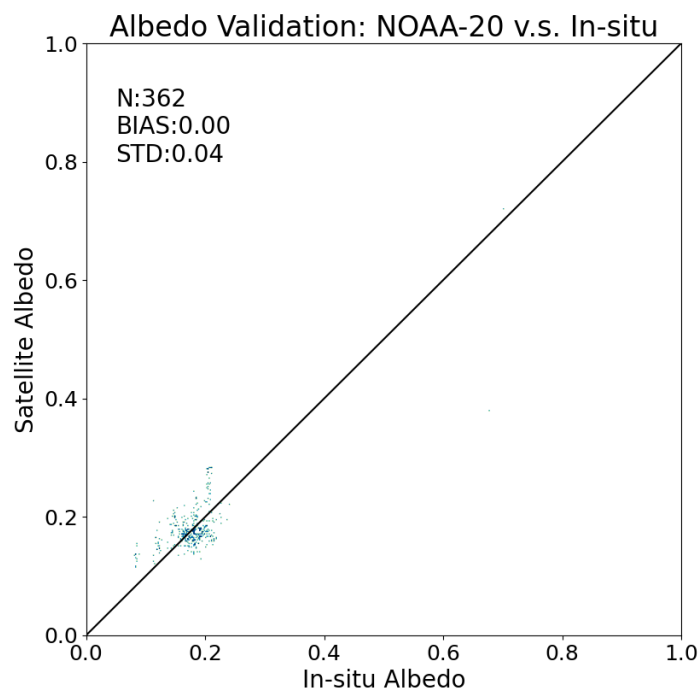
- ## Inter-sensor comparison

  - Compare with S-NPP and NOAA-20 over the globe and different retrieval paths
  - The algorithm version of the data source was the same v2r2 before May 10, and then S-NPP and NOAA-20 went back to v1r4 due to resource allocation and NOAA-21 uses v2r2
 - Results suggest NOAA-21 LSA is similar with S-NPP and NOAA-20 under the same version
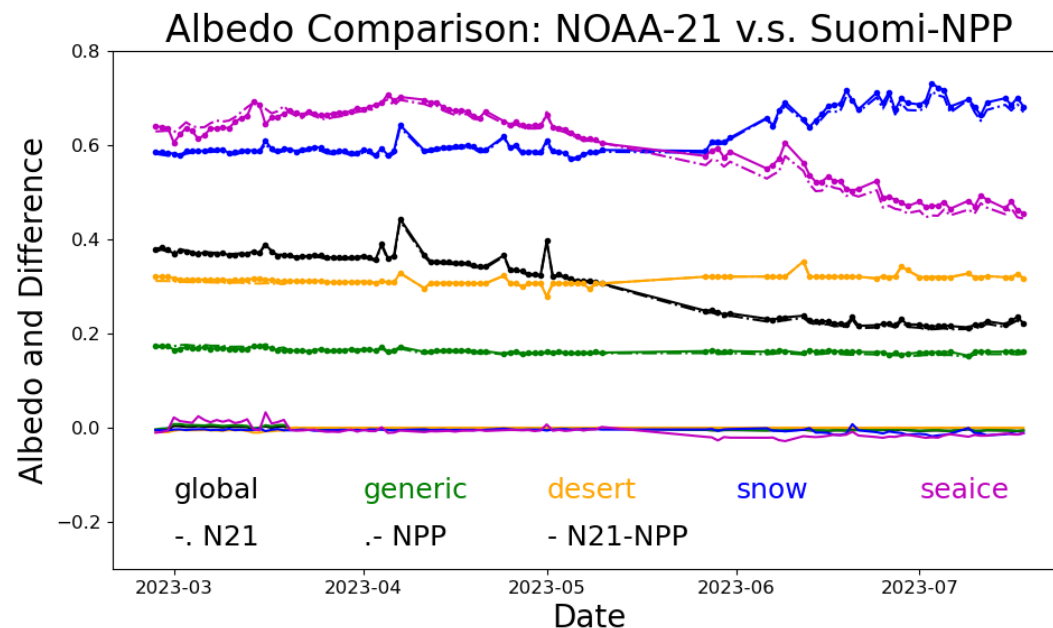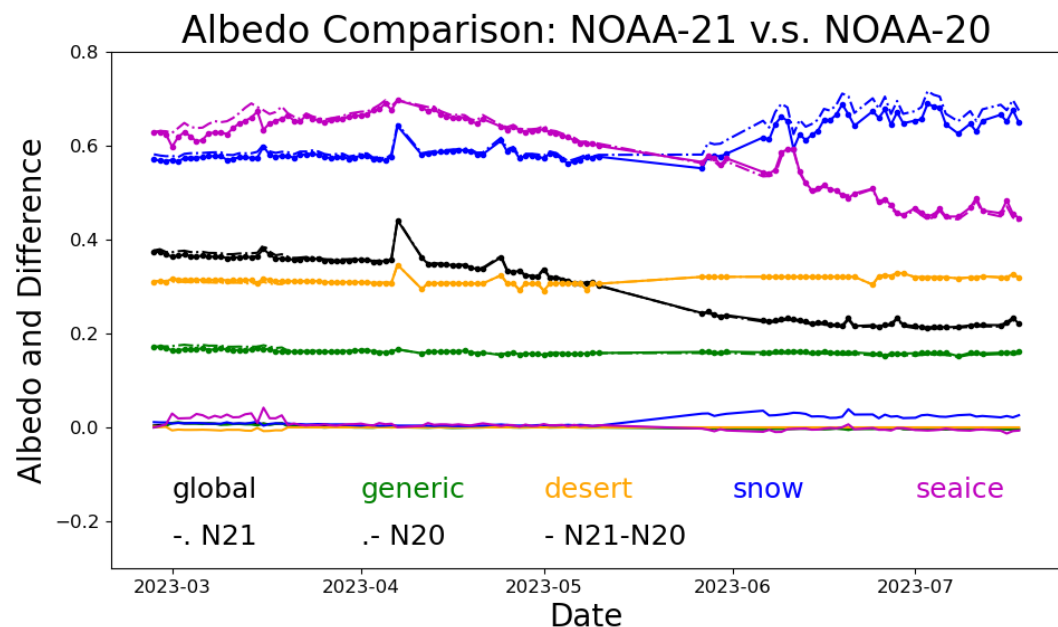
The NOAA-20 LSA and S-NPP LSA before May 10 used the same version (v2r2) with NOAA-21, meaning they use the same snow/ice mask, leading to a better consistency. After May 10, the difference over snow and ice albedo are larger due to the difference between VIIRS snow mask/ice concentration and IMS snow/ice mask.

- Required Algorithm Inputs
  - Primary Sensor Data
    - The L1 SDR data has passed the Beta review already
  - Ancillary Data
    - The albedo climatology data has been published in a peer review journal
  - Upstream algorithms
    - The VIIRS Cloud mask, IMS snow/ice mask, and VIIRS surface type data could meet the albedo algorithm needs
  - LUTs / PCTs
    - The NOAA-21 LUTs could generate continuous albedo retrievals with qualified performance

NOAA-20 vs. NOAA-21 Compared in L3 LSA and QC (20230308)	Percentage
NOAA20 vs. NOAA21: different cloud mask	**4.22%**
Cloud difference: N20==0 & N21==1	0.33%
Cloud difference: N20==0 & N21==2	0.17%
Cloud difference: N20==0 & N21==3	0.87%
Cloud difference: N20==1 & N21==0	0.28%
Cloud difference: N20==1 & N21==2	0.11%
Cloud difference: N20==1 & N21==3	0.32%
Cloud difference: N20==2 & N21==0	0.16%
Cloud difference: N20==2 & N21==1	0.1%
Cloud difference: N20==2 & N21==3	0.37%
Cloud difference: N20==3 & N21==0	0.84%
Cloud difference: N20==3 & N21==1	0.3%
Cloud difference: N20==3 & N21==2	0.36%
NOAA20 & NOAA21: different retrieval path	**0.12%**
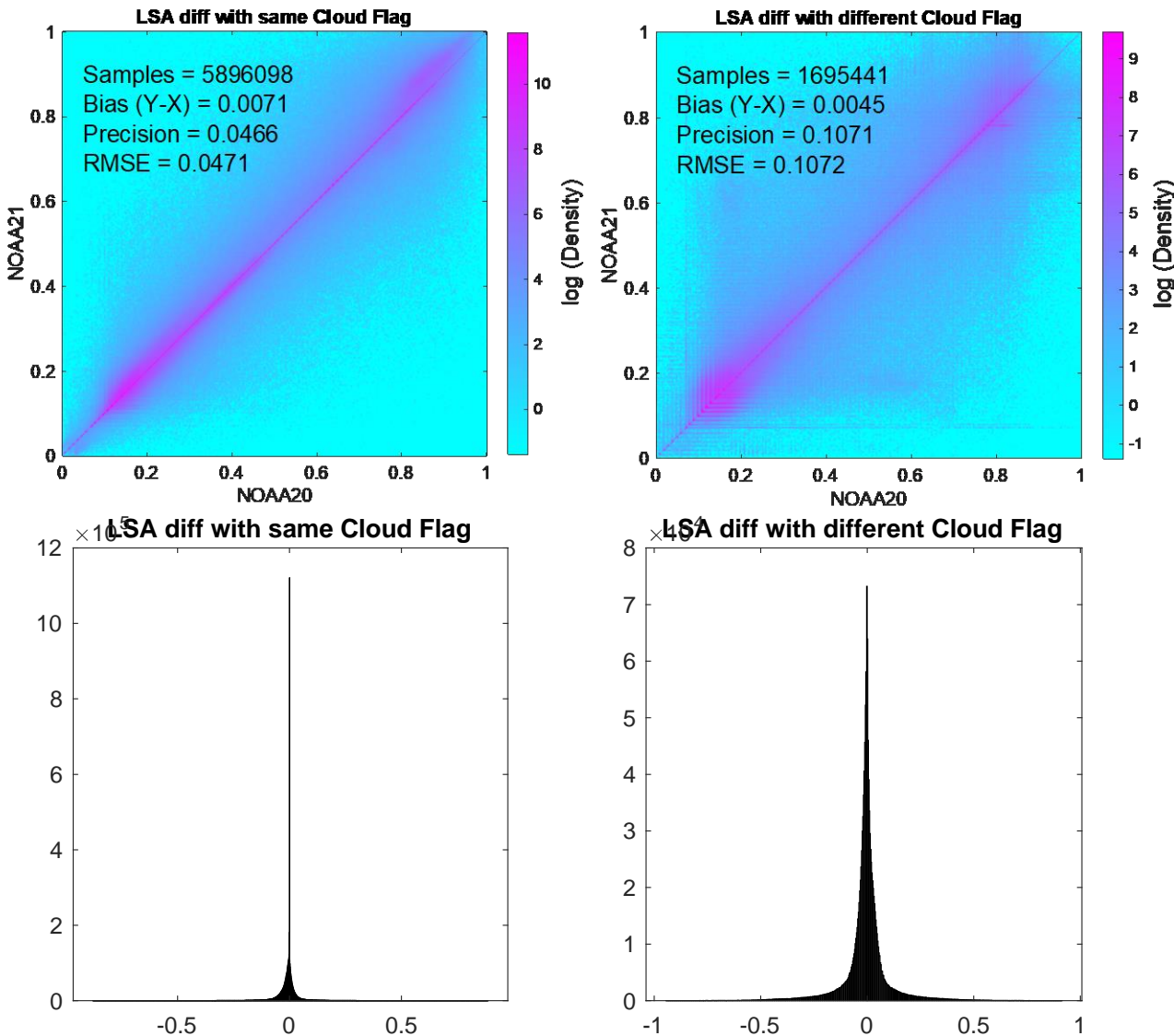
The figures show an influence of cloud mask difference (listed in the table) on LSA between NOAA-20 and NOAA-21. Their cloud mask show difference while they do have pass time difference. When cloud mask is different, the LSA retrieval would have larger bias.

Quality flag analysis/validation
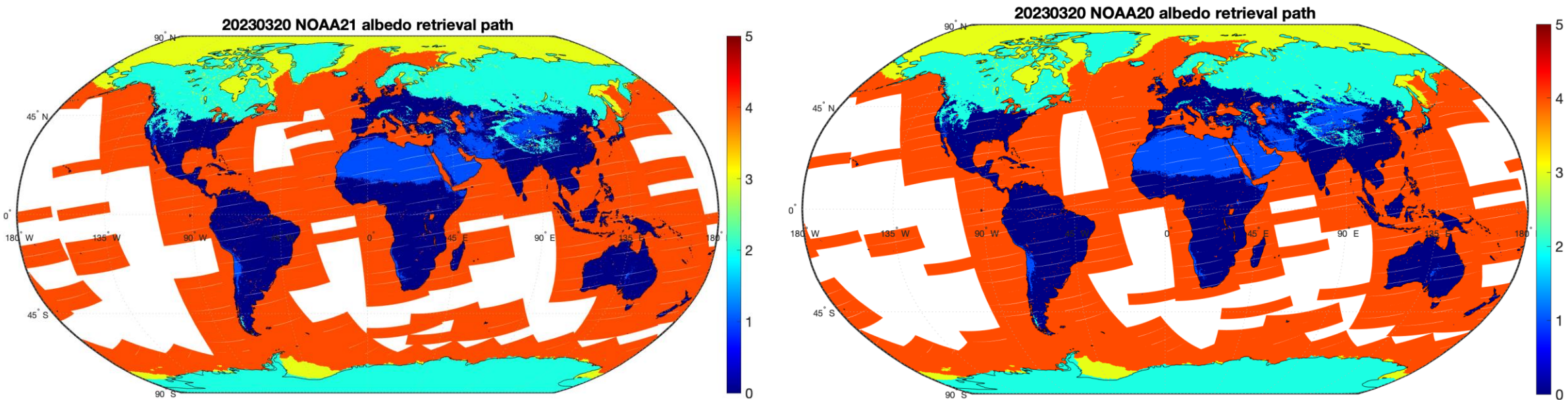
- ## Defined Quality Flags

L2 Product Quality Information

Byte	Bit	Flag	Source	Description
0	0-1	Overall quality	LSA	00: high-quality retrieval, 01: retrieval, 10:no retrieval (Same as DQF)
	2-3	Cloud condition	Cloud mask	00=confidently clear, 01=probably clear,10=probably cloudy,11=confidently cloudy
	4	SDR quality	SDR	0 = normal , 1 = bad data
	5	Solar zenith angle flag	SDR	0: favorable SZA, 1: very large SZA (>60)
	6	View zenith angle flag	SDR	0: favorable VZA, 1: very large VZA (>60)
	7	Spare		
1	0-2	Retrieval Path	LSA	000: generic, 001: desert, 010: snow, 011: seaice, 100: no retrieval
	3-4	Temporal filter quality flag	LSA	00: high-quality retrieval, 01: degraded retrieval, 10:no retrieval
	5	Online filter flag	Online filter	0: no filter, 1: filtered
	6-7	Spare		

L3 Product Quality Information

Byte	Bit	Flag	Source	Description
0	0-1	Overall Quality	Refer to the composition criteria	00: high quality retrieval 01: medium quality retrieval 10: low quality retrieval 11: no retrieval
	2-3	Cloud Confidence	Level-2 LSA	00: confidently clear 01: probably clear 10: probably cloudy 11: confidently cloudy
	4-6	Retrieval Path	Level-2 LSA	000: generic 001: desert 010: snow 011: sea-ice 100: no retrieval path
	7	Spare		

- Defined Quality Flags

20230320 NOAA21 albedo retrieval path
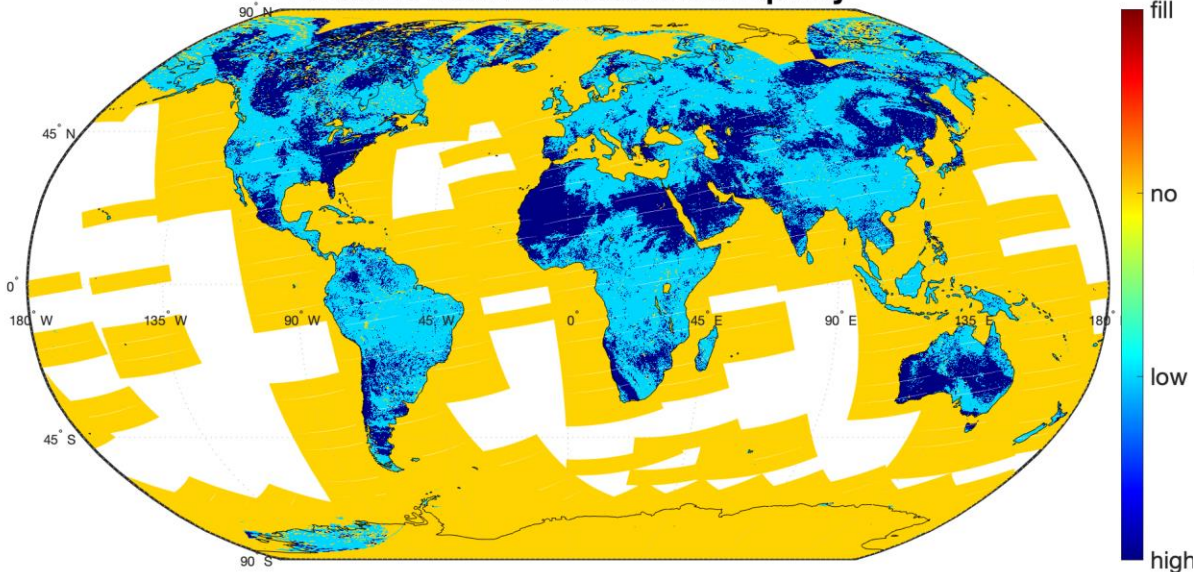
20230320 NOAA20 albedo retrieval path

- The retrieval path information was obtained by extracting the first three bits in Byte 2 of the QC flag.
- Comparison between NOAA21 and NOAA20 retrieval path flag suggests they are consistent.

- Defined Quality Flags
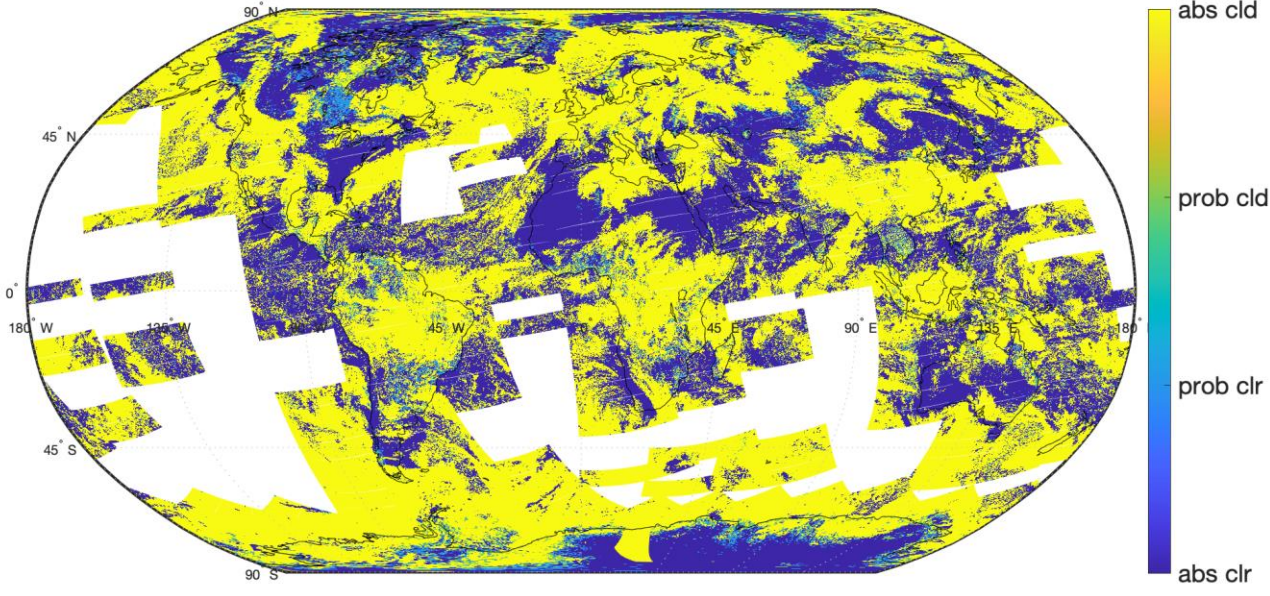
- The overall quality flag is largely determined by the cloudy condition.
- The overall quality flag and the cloud flag are consistent, and their distribution look reasonable

- Defined Quality Flags
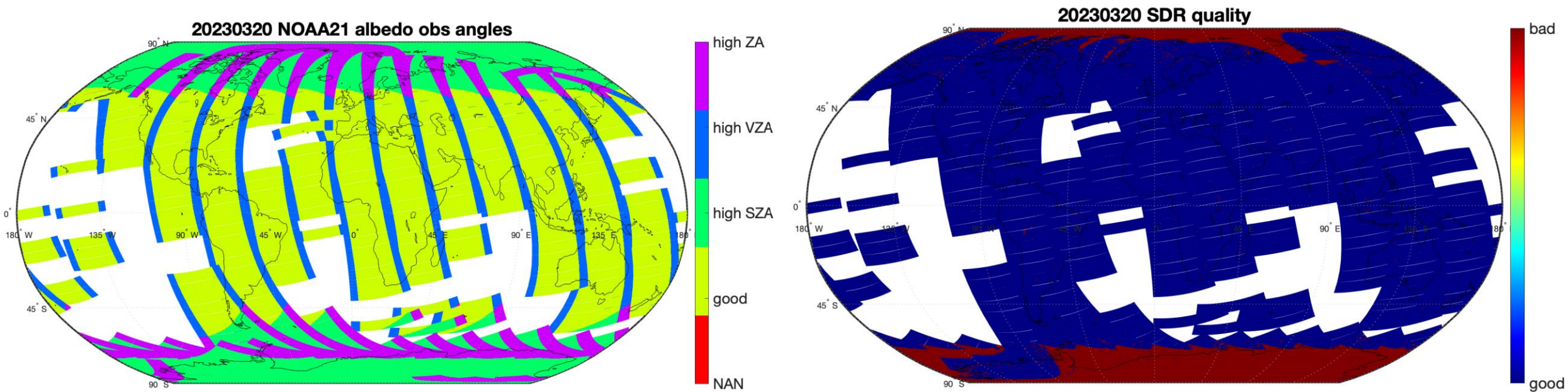
- The angle distribution and the SDR quality flags are as expected

Checking the metadata about LSA statistics

The values of the metadata variables about LSA value and quality look reasonable and distribute in the valid range.

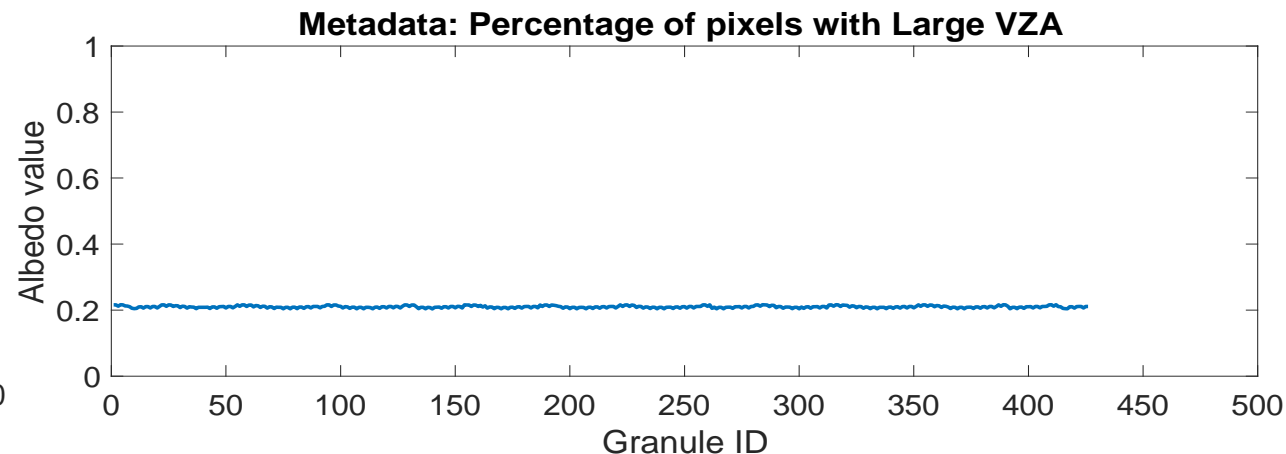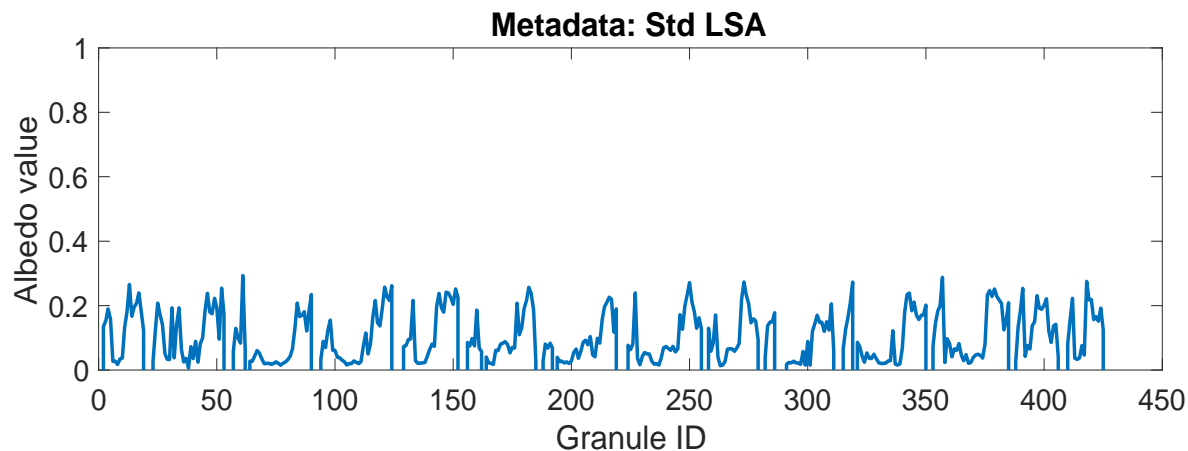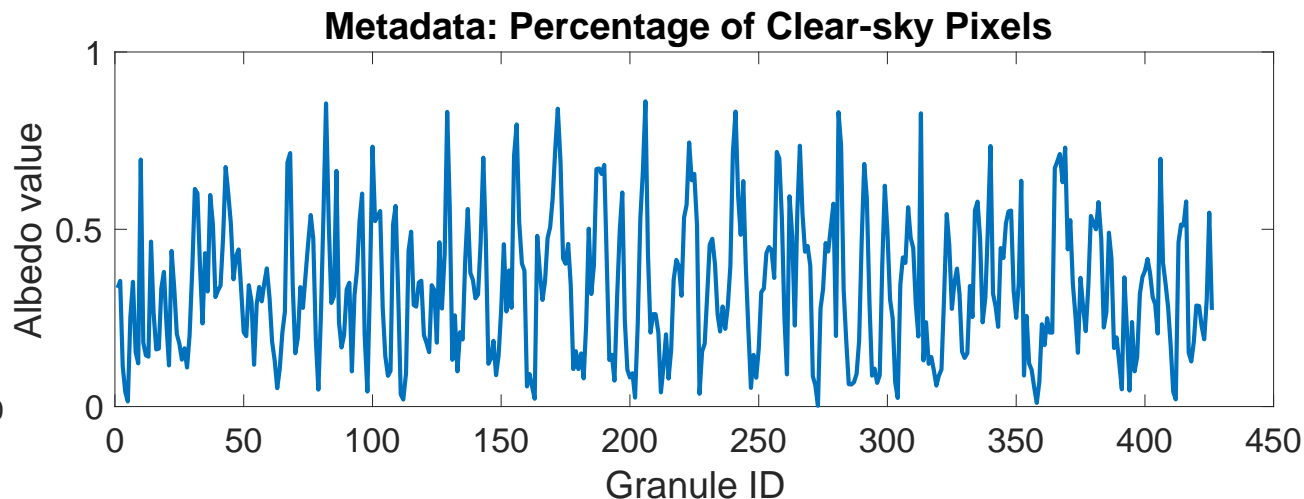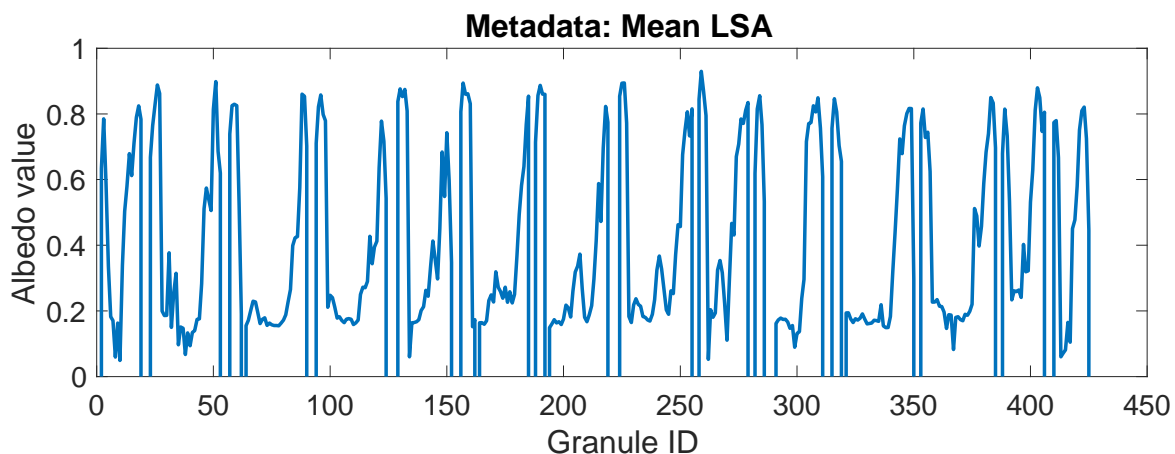| Attribute	Description	Sample Value
Conventions	Conventions used here	CF-1.6
Metadata_Conventions	Metadata conventions used here	CF-1.6, Unidata Dataset Discovery v1.0
Metadata_Link	Contains a URL where detailed metadata or a product information page is located	SURFALB_v2r2_j01_s202211121237152_e202211121238397_c202211121301508.nc
ascend_descend_data_flag	Flag indicate whether satellite ascending or descending	0
cdm_data_type	States the geographic category the product represents	swath
date_created	UTC time the product file was created in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second format	2022-11-12T13:01:50Z
day_night_data_flag	flag which indicates whether it is day or night	day
end_orbit_number	The ending number of the satellite orbit	25824
geospatial_bounds	Describes the shape and bounding corner locations of the domain	POLYGON((23.4534912 17.8855019, -4.35899878 13.6890326, -5.92952919 18.6223907, 22.7109413 22.9405155,23.4534912 17.8855019))
geospatial_first_scanline_first_fov_lat	The first latitude at the first scanline	17.885502
geospatial_first_scanline_first_fov_lon	The first longitude at the first scanline	23.453491
geospatial_first_scanline_last_fov_lat	The last latitude at the first scanline	22.940516
geospatial_first_scanline_last_fov_lon	The last longitude at the first scanline	22.710941
geospatial_last_scanline_first_fov_lat	The first latitude at the last scanline	13.689033
geospatial_last_scanline_first_fov_lon	The first longitude at the last scanline	-4.358999
geospatial_last_scanline_last_fov_lat	The last latitude at the last scanline	18.62239
geospatial_last_scanline_last_fov_lon	The last longitude at the last scanline	-5.929529
geospatial_lat_units	Indicates unit associated with geospatial latitude	degrees_north
geospatial_lon_units	Indicates unit associated with geospatial longitude	degrees_east
history	Indicates algorithm name and version responsible for creating the file	Delivery Package v2r2
history_package	The delivery package version number	
id	Unique identifier for the product	05748cf3-be9c-4eb7-b25a-18ee00f6bbd3
institution	Indicates institution responsible for product file	DOC/NOAA/NESDIS/NDE > S-NPP Data Exploitation, NESDIS, NOAA, U.S. Department of Commerce
instrument_name	Name of the relevant satellite instrument	VIIRS
naming_authority	Organization responsible for providing the "id" attribute	gov.noaa.nesdis.nde
processing_level	Level of processing associated with product file	NOAA Level 2
production_environment	Processing string responsible for generating the product	ITE
production_site	Processing site for the product	NSOF
project	Indicates the name(s) of the project(s) responsible for generating the original data used as input to the processing system	S-NPP VIIRS Land Surface Temperature/ Surface Albedo: Land Surface Albedo (LSA) Product
references	Contact info	
resolution	horizontal resolution	750M
satellite_name	Name of the satellite	NOAA-20
sensor_band_central_radiation_wavelength	Central wavelength of the satellite instrument	0.412um,0.445um,0.488um,0.555um,0.672um,0.865um,1.240um,1.610um,2.250um
sensor_band_identifier	Band number of the satellite instrument	M1,M2,M3,M4,M5,M7,M8,M10,M11
standard_name_vocabulary	Provides the name and corresponding version number of the controlled vocabulary used	CF Standard Name Table v76
start_orbit_number	The starting number of the satellite orbit	25824
summary	Provides a brief summary of the product	Enterprise Land Surface Albedo Product
time_coverage_end	Indicates the end time of the observation associated with the file in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second format	2022-11-12T12:38:39Z
time_coverage_start	Indicates the start time of the observation associated with the file in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second format	2022-11-12T12:37:15Z
title	Provides the short name for the product	SURFALB

Are all correct

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-376	0.08	NA	0	0	0.01	Yes	NA
Precision	DPS-377	0.05	NA	0.04	0.04	0.05	Yes	NA

User Feedback

Name	Organization	Application	User Feedback - **User readiness dates for ingest of data and bringing data to operations**
Michael Barlage	NCEP/EMC	EMC NWP Models	Soil albedo dataset and albedo diurnal variation from VIIRS albedo could be applied in the Noah-MP model
CLASS	NOAA	Archive	VIIRS L2 and L3 surface albedo data are archived in the NOAA CLASS system, where they are available to the public
Barry Baker	NOAA ARL	Fengsha Dust Model	The VIIRS BRDF climatology and future NRT BRDF could improve the dust prediction ability

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
Production error in NDE	Unexpected data gap in VIIRS albedo	No valid value over cloudy pixels (pixels other than absolutely clear)	Actions in Science Team: Requested the log files from NDE and identified the reason Progress: Science team has identified a potential cause for the failure, which appears to be related to the script expecting a different key name in the PCF file, specifically the word preceding the '=' sign. The PCF is the script generated by ASSISTT . We have maintained communication with the NDE team to inquire about their progress in resolving this issue. Mitigations: The NDE team is expected to fix the script and provide the updated version to and coordinate with ASSISTT. Schedule pending on the NDE response.

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	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 - Beta Maturity

Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	Yes. The product has been validated using four months of ground data, demonstrating the accuracy and precision are satisfied. However, the system production still has some issue, causing the cloudy pixels to have gaps.
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	Yes. The validation basically demonstrates a large probability that the product is qualified, referring to the consistency between NOAA-21 and the NOAA-20, SNPP counterparts which are both qualified.
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	Yes. This document has recorded the performance of the product in both albedo values and quality.

Conclusion

➤ NOAA-21 Surface Albedo Product has been verified and preliminarily validated. The product is suggested being released as beta maturity version.

➤ Some issues and problems are found that will be solved or improved for the provisional release:

- No valid value over cloudy pixels, because the offline output is not correctly organized in the system script

Path Forward

- Future Cal/Val activities
  - Over more seasons including Autumn and Winter
  - Implement the LTM adaptations with routine NOAA-21 albedo data
  - Routine cross-comparisons
- Future Cal/Val activities
  - Provisional Maturity Review
  - Validated maturity Review
  - Climatology update
- Application in NOAA climate models
- Improved albedo products
  - Blended Albedo product with S-NPP and NOAA-20 VIIRS Albedo
  - Apply NOAA-21 data into BRDF/BSA/WSA/NBAR algorithm

Backup

- Inter-sensor comparison
  - Sample number in comparison with S-NPP and NOAA-20