Office of Satellite and Product Operations
Environmental Satellite and Product Services

VIIRS Surface Reflectance (SR) External Users Manual (EUM)

Version 1.1
November 02, 2023

Prepared by: ERT Inc.

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
Office of Satellite Products and Operations

Approval Page

Environmental Satellite and Products Services

The Regional Advanced Baseline Imager and Visible Infrared Imaging Radiometer Suite Emissions (RAVE)

GROUP: ESPC Date Hanjun Ding (OSPO), SR Product Area Lead	GROUP: OMS Date Nageswarrao Gopanapalli, Project Manager
GROUP: Date	

Changes/Revisions Record

This document is changed as required to reflect system, operational, or organizational changes. Modifications made to this document are recorded in the Changes/Revisions Record below. This record will be maintained throughout the life of the document.

DOCUMENT TITLE: VIIRS Surface Reflectance External User's Manual			
DOCUMENT CHANGE HISTORY			
Revision No.	**Date**	**Revision Originator Project Group**	**CCR Approval # and Date**
1.0	July 2023	CCAP initial version	N/A
1.1	11/02/2023	NCCF Implement Updates	NCCFPVPM-5

LIST OF CHANGES

Significant alterations made to this document are annotated in the List of Changes table.

DOCUMENT TITLE: VIIRS Surface Reflectance External User's Manual					
LIST OF CHANGE-AFFECTED PAGES/SECTIONS/APPENDICES					
Version Number	**Date**	**Changed By**	**Page**	**Section**	**Description of Change(s)**
1.1	11/02/2023	H. Ding Y. Zhu		ALL	NCCF Implementation updates

TABLE OF CONTENTS

Page

LIST OF TABLES AND FIGURES

Page

1. PRODUCTS

This is an external user's manual document describing the Visible Infrared Imaging Radiometer Suite (VIIRS) algorithm for Surface Reflectance. The VIIRS Surface Reflectance algorithm was developed at Goddard Space Flight Center (GSFC) as part of the original National Polar-orbiting Operational Environmental Satellite System (NPOESS) – now Suomi National Polar-orbiting Partnership (NPP) - Interface Data Processing Segment (IDPS). This algorithm has been modified for the NCCF (NESDIS Common Cloud Framework) environment through assistance from the OSGS (Office of Satellite Ground Services). After preliminary testing, the algorithm will be delivered to the Office of Systems Development (OSD) to be run operationally.

The intended users of the External User's Manual (EUM) are end users of the output products and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and product testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system, i.e. are outside of OSD. The output files are defined as those for public use.

1.1 Product Overview

1.1.1 Product Requirements

All of the VIIRS Surface Reflectance requirements are available through the VIIRS Surface Reflectance Requirements Allocation Document (RAD). These requirements identify the users and their needs with respect to file content, format, latency, and quality. This document is available upon request from the Surface Reflectance Product Area Lead (PAL), current as of this document in the table below.

Table 1-1 - Product Team Members

Team Member	Organization	Role	Contact Information
Hanjun Ding	OSPO	PAL (Product Area Lead)	hanjun.ding@noaa.gov
Walter Wolf	OSGS	Product Portfolio Management Lead	walter.wolf@noaa.gov
Shanna Sampson	OSGS	ASSISTT Solutions Architect	shanna.sampson@noaa.gov

Priyanka Roy	OSGS	Quality Assurance Lead, Deputy Project Manager	Priyanka.roy@noaa.gov
Tracey Dorian	OSGS	QA Deputy	tracey.dorian@noaa.gov
Edrees Wardak	OSGS	ASSISTT Quality Assurance	edrees.wardak@noaa.gov
Yunhui Zhao	OSGS	ASSISTT CM Lead & Special Projects	yunhui.zhao@noaa.gov
Yunyue Yu	STAR	Science Team	yunyue.yu@noaa.gov
Heshun Wang	STAR	Science Team	heshun.wang@noaa.gov
Eric Vermote	NASA	Science Team	eric.f.vermote@nasa.gov
Mike Wilson	OSGS	ASSISTT GitLab Merge Lead	michael.wilson@noaa.gov
Douglas March	OSGS	ASSISTT Integration Team	douglas.march@noaa.gov
Letitia Soulliard	OSGS	ASSISTT Standalone Integration Team Lead	letitia.soulliard@noaa.gov
Hua Xie	OSGS	ASSISTT Science QA Lead	hua.xie@noaa.gov
John Lindeman	OSGS	ASSISTT Technical Writer	john.lindeman@noaa.gov
Brandon Laufer	OSGS	Python Developer	brandon.laufer@noaa.gov
Eric Buzan	OSGS	ASSISTT R2O & Processing	eric.buzan@noaa.gov
Ramaswamy Tiruchirapalli	OSGS	ASSISTT Framework Integration Team	Ramaswamy.Tiruchirapalli@noaa.gov
Edward Borders	OSGS	ASSISTT Python Developer Team Lead	Edward.borders@noaa.gov
Yufeng Zhu	OSPO	OSPO Team Member	Yufeng.zhu@noaa.gov

Feedback, comments, criticisms, and/or suggestions are welcome and should be sent to:

Name	Email
Hanjun Ding	Hanjun.ding@noaa.gov
Ramaswamy Tiruchirapalli	ramaswamy.tiruchirapalli@noaa.gov
Brandon Laufer	brandon.laufer@noaa.gov
Eric Buzan	eric.buzan@noaa.gov
Ed Borders	edward.borders@noaa.gov
Tracey Dorian	tracey.dorian@noaa.gov
Eddy Wardak	edrees.wardak@noaa.gov
Priyanka Roy	priyanka.roy@noaa.gov

1.1.2 Product Description

The VIIRS Surface Reflectance product is generated from a combination of the VIIRS SDR and geolocations data, and Global Forecast System (GFS), aerosol, cloud mask, and cloud height products. The output products include surface reflectance for channels I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, and M11. Output additionally includes seven bytes of quality flags (QF1, QF2, QF3, QF4, QF5, QF6, QF7), which are each bitmasks representing various properties of both inputs and outputs. Statistical quality information is also included in the output file. All products are output in netCDF-4. For information on the science algorithms, see the VIIRS Surface Reflectance Algorithm Theoretical Basic Document (ATBD). This document can be obtained from the Product Area Lead (PAL) identified in the Product Team table in section 1.1.1.

The Surface Reflectance NetCDF4 product files will contain surface reflectance data for each M-band and I-band used as input to the algorithm package. For the M-bands, the resolution will be 750 meters. For the I-bands, the resolution will be375 meters. The amount of data within the I-Band product files will be roughly four times larger than the amount of data within the M-Band product files as the I-Bands have a higher swath resolution.

1.1.3 Product History

The VIIRS Surface Reflectance product originally existed as a product in the IDPS. The original system used the VIIRS SDR and geolocation, VIIRS Cloud Mask, Aerosol Optical Depth Product, and internal NCEP files for surface pressure, precipitable water, and total column ozone. All of these inputs were available internally in the IDPS system. The output was generated in HDF-EOS2 format. This delivery is a final CCAP delivery to NCCF, and is the first version of the algorithm to be run at NCCF.

1.1.4 Product Access

Table 1-2 lists the single output file from the VIIRS Surface Reflectance algorithm, along with a description and approximate size. Table 1-3 details the contents of the output file.

Table 1-2 – VIIRS Surface Reflectance Output File

File	Description	Format	Size/file
SurfRefl_v#r#_<sat>_sYYYYMMDDhhmmsss_eYYYYMMDDhhmmsss_cYYYYMMDDhhmmsss.nc	The SR (Surface Reflectance) file contains surface reflectances for I-bands 1,2,3 and for M-bands 1,2,3,4,5,7,8,10,11. This file also includes five bitmapped quality flags.	NetCDF-4	~209 MB/file 288 files/day

Where:

SurfRefl – Surface Reflectance Products
v#r# – version number, revision number (eg. v1r2)
<SAT> - the type of satellite used (eg. j01, n21, npp)
YYYY – 4-digit Year
MM – 2-digit Month
DD – 2-difit Day of Month
hh – 2-digit Hour
mm – 2-digit Minute
sss – 3-digit Second (3rd digit 10ths of a second)

Table 1-3 – VIIRS EDR File Content Description

Variable	Type	Description	Dim	Units	Range

375m Surface Reflectance Band I1	Short	Surface Reflectance for I1 Band, stored as value * 10000.	1536 x 6400	N/A	-0.01-1.6
375m Surface Reflectance Band I2	Short	Surface Reflectance for I2 Band, stored as value * 10000.	1536 x 6400	N/A	-0.01-1.6
375m Surface Reflectance Band I3	Short	Surface Reflectance for I3 Band, stored as value * 10000.	1536 x 6400	N/A	-0.01-1.6
750m Surface Reflectance Band M1	Short	Surface Reflectance for M1 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M2	Short	Surface Reflectance for M2 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M3	Short	Surface Reflectance for M3 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M4	Short	Surface Reflectance for M4 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M5	Short	Surface Reflectance for M5 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M7	Short	Surface Reflectance for M7 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M8	Short	Surface Reflectance for M8 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M10	Short	Surface Reflectance for M10 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
750m Surface Reflectance Band M11	Short	Surface Reflectance for M11 Band, stored as value * 10000.	768 x 3200	N/A	-0.01-1.6
Latitude_at_375m _resolution	Float	Latitude at 375 meter resolution to match up with the I-Band Surface Reflectances	1536 x 6400	Degrees	-90-90
Longitude_at_375m _resolution	Float	Longitude at 375 meter resolution to match up with the I-Band Surface Reflectances	1536 x 6400	Degrees	-180-180

Latitude_at_750m_resolution	Float	Latitude at 750 meter resolution to match up with the M-Band Surface Reflectances	768 x 3200	Degrees	-90-90
Longitude_at_750m_resolution	Float	Longitude at 750 meter resolution to match up with the M-Band Surface Reflectances	768 x 3200	Degrees	-180-180
QF1 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-2	768 x 3200	N/A	0-255
QF2 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-3	768 x 3200	N/A	0-255
QF3 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-4	768 x 3200	N/A	0-255
QF4 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-5	768 x 3200	N/A	0-255
QF5 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-6	768 x 3200	N/A	0-255
QF6 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-7	768 x 3200	N/A	0-255
QF7 Surface Reflectance	Byte	Bitmasks for Surface Reflectance – see Table 3-8	768 x 3200	N/A	0-255
quality_information	String	QI Statistics – see section 3.3	N/A	N/A	N/A

Quality Flag information for the QF1-QF7 Surface Reflectance variables can be found in Table 3-2 to Table 3-8. Details about the quality_information variable can be found in section 3.3.

Metadata included with each output file is shown in Table 1-4.

Table 1-4 - Surface Reflectance Metadata

Attribute	Description	Type	Array Size
AncillaryInputPointer	Names of the ancillary input files	String	1

Conventions	Conventions used here	String	1
InputPointer	Names of the input files	String	1
PGE_Name	Name of the PGE	String	Scalar
_NCProperties	NetCDF and HDF version numbers, will be automatically generated	String	Scalar
ascend_descend_data_flag	Flag indicate whether satellite ascending or descending	Integer	Scalar
cdm_data_type	States the geographic category the product represents	String	Scalar
creator_email	Email for the algorithm development team	String	Scalar
creator_name	Indicates the line office and algorithm team responsible for product development	String	Scalar
creator_url	Website for end users	String	Scalar
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	String	Scalar
day_night_data_flag	Indicates whether the output product is in the daytime, nighttime, or both	String	Scalar
end_orbit_number	This attribute is a sequential whole number set by the	String	Scalar

	S-NPP/JPSS Ground System in the xDR metadata.		
geospatial_bounds	Describes the shape and bounding corner locations of the domain	string	1
geospatial_first_scanline_first_fov_lat	The first latitude at the first scanline	float	scalar
geospatial_first_scanline_first_fov_lon	The first longitude at the first scanline	float	scalar
geospatial_first_scanline_last_fov_lat	The last latitude at the first scanline	float	scalar
geospatial_first_scanline_last_fov_lon	The last longitude at the first scanline	float	scalar
geospatial_last_scanline_first_fov_lat	The first latitude at the last scanline	float	scalar
geospatial_last_scanline_first_fov_lon	The first longitude at the last scanline	float	scalar
geospatial_last_scanline_last_fov_lat	The last latitude at the last scanline	float	scalar
geospatial_last_scanline_last_fov_lon	The last longitude at the last scanline	float	scalar
geospatial_lat_units	Indicates unit associated with geospatial latitude	String	Scalar
geospatial_lon_units	Indicates unit associated with geospatial longitude	String	Scalar
history	Indicates algorithm name and version responsible for creating the file	String	Scalar
id	Unique identifier for the product	String	Scalar
institution	Indicates institution responsible for product file	String	Scalar
instrument	Indicates the instrument(s) used	String	Scalar

	in the creation of the product		
keywords	Look-up words/phrases associated with this product	String	1
Metadata_Conventions	Conventions used in the creation of the metadata	String	Scalar
metadata_link	Contains a URL where detailed metadata or a product information page is located	String	Scalar
naming_authority	Organization responsible for providing the “id” attribute	String	Scalar
ncei_template_version	NCEI template used for processing	String	Scalar
platform	Indicates the satellite(s) used to create the product	String	1
processing_level	Level of processing associated with product file	String	Scalar
production_environment	Processing string responsible for generating the product	String	Scalar
production_site	Processing site for the product	String	Scalar
project	Indicates the name(s) of the project(s) responsible for generating the original data used as input to the processing system	String	Scalar

publisher_email	Provides an email that can be used to contact the person or entity who is responsible for publishing the output files to the proper end users	String	Scalar
publisher_name	Provides the name of the organization responsible for the product's publication	String	Scalar
publisher_url	Provides URL of publisher's website	String	Scalar
source	Provides a list of all significant input files into the product system as a comma separated list	String	Scalar
standard_name_vocabulary	Provides the name and corresponding version number of the controlled vocabulary used	String	Scalar
start_orbit_number	This attribute is a sequential whole number set by the S-NPP/JPSS Ground System in the xDR metadata. Orbits are incremented on the northward equatorial node.	String	Scalar
summary	Provides a brief summary of the product	String	Scalar
time_coverage_end	Indicates the end time of the observation associated with the file in 4-digit year,	String	Scalar

	2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second format		
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	String	Scalar
title	Provides the short name for the product	String	Scalar

2. ALGORITHM

2.1 Algorithm Overview

The Surface Reflectance EDR (Environmental Data Record) algorithm is designed to contain four main subroutines: Extract inputs, Quality Flags, Surface Reflectance Retrieval and Write Surface Reflectance EDR. The Surface Reflectance Retrieval subroutine is the main subroutine since it performs the lambertian approximation (atmospheric correction), the adjacency adjustment, and the bidirectional reflectance distribution function (BRDF) coupling adjustment.

The Surface Reflectance Retrieval routine corrects for the effects of gaseous absorption, molecular and aerosol scattering, thin cirrus contamination, glare from surrounding surface pixels (adjacency adjustment), and the coupling of the atmosphere and the surface bidirectional reflectance as a function of the viewing and solar geometries, elevation of the target and spectral band. The atmospheric adjustment (within the ‘Surface Reflectance Retrieval’ routine) includes updating the correction coefficients with ‘in-view’ total column water vapor, ozone, and aerosol optical thickness data input fields. The aerosol information required for surface reflectance retrieval comes from the VIIRS Aerosol Optical Thickness (AOT) EDR and the Aerosol Model Information IP, complemented by total column water vapor, total column ozone, and surface pressure from National Centers for Environmental Prediction (NCEP) feeds. Backups for these inputs include total column ozone from the Ozone Mapping Profiling Suite (OMPS). The atmospherically corrected surface reflectance values derived using the Lambertian approximation are subsequently adjusted for adjacency and bi-directional reflectance distribution function (BRDF) effects. The BRDF-coupling adjustment is presently designed after the MODIS approach with a slight modification making the isotropic shape parameter a function of the normalized difference vegetation index, NDVI, an approximation due to operational constraints, and the developmental maturity of the MODIS BRDF-coupling adjustment routine. The surface reflectance values after each adjustment are included as data layers in the surface reflectance EDR along with the Land Quality Flags. The atmospheric inputs are available elsewhere, and the solar and viewing geometries are kept as part of the SDR.

Thin cirrus effects are removed by implementing an empirically based correction using VIIRS band M9 (1.38 µm). The quality control (QC) flags generated from the Build SDR module and the cloud and aerosol quality flag inputs are fused into a single Land Quality Flag (LQF) structure that applies to the Surface Reflectance EDR, the Surface Albedo EDR, the Vegetation Index EDR, the Surface Type EDR. The LQF output is appended to the Surface Reflectance EDR. Then the heart of the surface reflectance retrieval process begins, by converting the cirrus effects adjusted satellite reflectance values into surface reflectance values assuming the surface is Lambertian. The earth's surface is generally not Lambertian, and as a result a further correction is applied. The conversion of the at-satellite-reflectance values to surface reflectance requires (i) the use of a set of conversion equations that also account for first order atmospheric multiple scattering effects, and (ii) inputs from pre- generated look up tables (LUTs) and analytic equations for gaseous or molecular effect.

2.2 Input Satellite Data

2.2.1 Satellite Instrument Overview

The VIIRS instrument is a scanning radiometer aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite, on Joint Polar Satellite System -1 and -2 (JPSS-1/N20/J01 and JPSS-2/N21/J02), and planned for inclusion on future JPSS missions. VIIRS is a scanning radiometer that gathers radiances spanning from visible wavelengths through longwave infrared wavelengths. Radiances and/or reflectances are reported as Sensor Data Records (SDRs) through five imagery bands at 375-meter resolution, sixteen moderate resolution bands at 750-meter resolution, and one day-night band for low light at 750-meter resolution. Data is reported in granules containing approximately 85 seconds worth of retrievals. This is the equivalent of aerial coverage of approximately 3040 km by 570 km per granule. VIIRS also produces geolocation files for both the I-bands and M-bands for ellipsoid or terrain projections as well as Environmental Data Records (EDRs) that remap and reproject the data.

The S-NPP satellite was launched on October 28, 2011 and establishes a bridge between NASA's Earth Observing System (EOS) satellites and the current line of JPSS satellites. The S-NPP satellite contains VIIRS as well as four other instruments measuring the ultraviolet, visible, infrared, and microwave spectra. S-NPP exists in a sun-synchronous orbit with an ascending node equator crossing time of approximately 1330 UTC. JPSS-1 was launched on November 18, 2017 and follows the same orbit path as S-NPP but is 50 minutes separated from S-NPP. During this time, the earth rotates underneath the orbit, which results in the geolocated center of each swath falling in the gaps left by the other satellite thereby improving coverage. JPSS-2 was launched on November 10, 2022, and follows a similar trajectory as the other two satellites.

2.2.2 Satellite Data Preprocessing Overview

The raw VIIRS data is dumped every orbit (~101 minutes) at Svalbard, Norway. These raw data records (RDRs) are recalibrated and geolocated into VIIRS SDR (and EDR) data in the IDPS system. The VIIRS SDR data is then ported from the IDPS to the AWS (Amazon Web Services) system for use by the Surface Reflectance algorithm.

The Enterprise Cloud Mask, the Cloud Height product, and the Aerosol Optical Thickness product are all derived from the VIIRS instrument data. The GFS fields are NUP (NOAA Unique Product) files which provide numerical model data.

The Surface Reflectance algorithm will create swath data that matches the input VIIRS SDR data. Distribution of the final product will occur via the Product Distribution Area (PDA) in near-real time. More details about the processing sequence can be found within the VIIRS Surface Reflectance System Maintenance Manual (SMM), available from the Surface Reflectance PAL.

2.2.3 Input Satellite Data Description

The VIIRS instrument is the sole instrument providing data for processing. The VIIRS Surface Reflectance algorithm requires the VIIRS SDR for each band where surface reflectance is calculated (M1-M5, M7, M8, M10, M11, I1-3), the geolocation for the moderate and imagery bands (GMTCO/GITCO). Table 2-1 lists the naming convention and examples of the VIIRS satellite data input files.

Table 2-1 - Satellite Data Input Files

PDA ShortName and Item	Description	Product FileName

<table>
<tr><td>VIIRS-I[1-3]-SDR
VIIRS Imagery Band SDR</td><td>Sensor Data Records</td><td>SVI0[1-3]_<SAT>_d<DATE>_t<TIME>_e<TIME>_b<ORBIT>_c<DATE/TIME>_naoc_ops.h5</td></tr>
<tr><td colspan="3">Example:
SVI01_j01_d20200817_t2317203_e2318448_b14239_c20200817233309432386_noac_ops.h5</td></tr>
<tr><td>VIIRS-M[1-5/7-8/10-11]-SDR
VIIRS Moderate Resolution Band SDR</td><td>Sensor Data Records</td><td>SVM[01-05/07-08/10-11]_<SAT>_d<DATE>_t<TIME>_e<TIME>_b<ORBIT>_c<DATE/TIME>_naoc_ops.h5</td></tr>
<tr><td colspan="3">Example:
SVM01_j01_d20200817_t2317203_e2318448_b14239_c20200817233313298861_noac_ops.h5</td></tr>
<tr><td>VIIRS-MOD-GEO-TC
Moderate Resolution Band SDR Terrain Corrected Geolocation</td><td>Sensor Data Records</td><td>GMTCO_<SAT>_d<DATE>_t<TIME>_e<TIME>_b<ORBIT>_c<DATE/TIME>_naoc_ops.h5</td></tr>
<tr><td colspan="3">Example:
GMTCO_j01_d20200817_t2317203_e2318448_b14239_c20200817233209765218_noac_ops.h5</td></tr>
<tr><td>VIIRS-IMG-GEO-TC
Imagery Band SDR Terrain Corrected Geolocation</td><td>Sensor Data Records</td><td>GITCO_<SAT>_d<DATE>_t<TIME>_e<TIME>_b<ORBIT>_c<DATE/TIME>_naoc_ops.h5</td></tr>
<tr><td colspan="3">Example:
GITCO_j01_d20200817_t2317203_e2318448_b14239_c20200817233209708558_noac_ops.h5</td></tr>
</table>

Where:

<VERSION> - version of file as <v?r?>
<SAT> - the type of satellite used (e.g., j01, j02, npp)
<DATE> - format of <YYYYmmdd>

<TIME> - format of <HHMMsss>
<DATE/TIME> - format of <YYYYmmddHHMMsss>
<ORBIT> - Orbit number, a five-digit number continuously increasing over time

For the above format definitions, YYYY is the 4-digit year, mm is the 2-digit month, dd is the 2-digit day, HH is the 2-digit hour, MM is the 2-digit minute, and sss is the 3 digit second (the third ‘s’ is 10^{ths} of a second).

2.3 Input Ancillary Data

The main algorithm ingests several dynamic files and static lookup tables. The static files are provided with the delivery. The enterprise cloud mask, cloud height file, aerosol optical depth file, and GFS files at the pixel level are dynamic ancillary data files. **Table 2-2** contains the file names and a brief description of the dynamic files, and the static files are presented in **Table 2-3.**

Table 2-2 - Dynamic Ancillary Data Files

PDA ShortName and Item	Description	Product FileName
JRR-AOD Aerosol Optical Depth	NUPS	JRR-AOD_<VERSION>_<SAT>_s<DATE/TIME>_e<DATE/TIME>_c<DATE/TIME>.nc
Example: JRR-AOD_v2r3_j01_s202008172317203_e202008172318448_c202008172343240.nc		
JRR-CloudHeight Cloud Height Product	NUPs	JRR-CloudHeight_<VERSION>_<SAT>_s<DATE/TIME>_e<DATE/TIME>_c<DATE/TIME>.nc
Example: JRR-CloudHeight_v2r3_j01_s202008172317203_e202008172318448_c202008172340120.nc		
JRR-CloudMask Enterprise Cloud Mask	NUPs	JRR-CloudMask_<VERSION>_<SAT>_s<DATE/TIME>_e<DATE/TIME>_c<DATE/TIME>.nc

Example: JRR-CloudMask_v2r3_j01_s202008172317203_e202008172318448_c202008172340050.nc		
NWP_GFS GFS Data	NUPs	NWP_GFS_<VERSION>_<SAT>_s<DATE/TIME>_e<DATE/TIME>_c<DATE/TIME>.nc
Example: NWP_GFS_v2r3_j01_s202008172317203_e202008172318448_c202008172343040.nc		

Where:

<VERSION> - version of file as <v?r?>
<SAT> - the type of satellite used (e.g., j01, j02, npp)
<DATE> - format of <YYYYmmdd>
<TIME> - format of <HHMMsss>
<DATE/TIME> - format of <YYYYmmddHHMMsss>
<YYYY> - Year

For the above format definitions, YYYY is the 4-digit year, mm is the 2-digit month, dd is the 2-digit day, HH is the 2-digit hour, MM is the 2-digit minute, and sss is the 3 digit second (the third ‘s’ is 10^{ths} of a second).

Table 2-3 – Static Ancillary Data Files

File Name	File Description
aot	Table of 20 aerosol optical thicknesses
vzen	Table of 40 viewing angles
szen	Table of 38 solar zenith angles
reflec	Table of reflectivities, one value each for combinations of: - 4 aerosol models - 20 AOT values - 9 M-bands - 5527 scattering angle combinations
trans	Table of transmittances, one value each for combinations of: - 4 aerosol models - 20 AOT values - 9 M-bands

	- 15 solar zenith angle bins
albedo	Table of albedos, one value each for combinations of - 4 aerosol models - 20 AOT values - 9 M-bands
VIIRS-SR-IncScatAngles-LUT_v1.5.06.02_LP	Scattering Angle Increment
VIIRS-SR-ScatAngDims-LUT_v1.5.06.02_LP	Location of the first (maximum) scattering angle corresponding to a pair of solar/sensor zenith angles
VIIRS-SR-IP-AC-INT_v1.5.06.02_LP	- Min/Max for Retrieved Surface Reflectance - Min/Max for Aerosol Optical Depth - Minimum value for GFS water vapor, ozone, surface pressure - Aerosol Min/Max Model Values - Rayleigh Optical Depth - Ozone (1 value), water vapor (3 values), and other gas (6 values) transmittance coefficients.

3. PERFORMANCE

3.1 Product Testing

3.1.1 Test Data Description

Test cases will be provided with each delivery of the processing system to ensure product verification can occur before the system becomes operational. Each test case will provide satellite input data, static ancillary data, dynamic ancillary data, and any additional resulting product datasets. All requirements listed in the Requirements Allocation Document (RAD) associated with each science algorithm within the processing system must be met during testing. Once end users of the products are satisfied that all requirements have been sufficiently met, the products will be transitioned into operations.

3.1.2 Unit Test Plans

Testing of all products produced by the processing system will occur with each update of the system. The science team(s) develop, test the accuracy of, and validate each of the products. The Office of Satellite Ground Services (OSGS) is responsible for testing each algorithm and script to ensure all RAD requirements are met. Before each product becomes operational, the products must be tested to ensure they run successfully on the intended system. If there are any issues that arise during testing procedures, all relevant groups must work together to “iron-out” these issues.

3.2 Product Accuracy

The Surface Reflectance products must meet accuracy standards set forth by the science team and can be found in the RAD document.

3.2.1 Test Results

The Algorithm Theoretical Basis Document (ATBD) associated with the Surface Reflectance algorithms contain the results of the science team’s algorithm validation tests. Please note that each science algorithm will have its own separate ATBD.

3.2.2 Product Accuracy

VIIRS Surface Reflectance products have been validated against observations. The accuracy and precision of these products fall well within the accuracy and precision specifications. For more information concerning any product’s accuracy, please contact the appropriate Product Area Lead (PAL) at OSPO. The product accuracy specifications are shown in Table 3-1.

Table 3-1 – Summary of VIIRS Surface Reflectance Product Performance

Products/Retrievals	Precision	Accuracy	Accuracy Specs
Surface Reflectance	No specific threshold or objective.	Threshold: 0.01+0.1r Objective: 0.005+0.05r	where r denotes the retrieved surface reflectance.

3.3 Product Quality Output

There are seven quality flags in the VIIRS Surface Reflectance file, listed as QF1 through QF7. These fields are bit-mapped quality fields for the inputs and outputs of the algorithm. These are listed in Table 3-2 through Table 3-8. Tables are ordered from the most significant bit (7) to the least significant bit (0).

Table 3-2 - QF1 Surface Reflectance

Bit #	Meaning
7	(Empty)
6	Sun Glint 0: no sun glint detected 1: sun glint detected
5	Low Sun Mask 0: high 1: low
4	Day/Night Flag 0: day 1: night
2-3	Cloud Detection and Confidence 00: confident clear 01: probably clear 10: probably cloudy 11: confidence cloudy
0-1	Cloud Mask Quality (currently undefined) 00: poor 01: low 10: medium 11: high

Table 3-3 - QF2 Surface Reflectance

Bit #	Meaning
7	Thin Cirrus Detected – Emissive Test 0: no cloud 1: cloud
6	Thin Cirrus Detected – Reflective Test 0: no cloud 1: cloud
5	Snow/Ice Flag 0: no snow/ice 1: snow or ice
4	Heavy Aerosol Mask 0: no heavy aerosol 1: heavy aerosol
3	Cloud Shadow Mask 0: no cloud shadow 1: shadow

0-2	Land/Water Background 001: deep ocean 010: shallow water 011: land 100: snow 101: arctic 110: Antarctic and Greenland 111: desert

Table 3-4 - QF3 Surface Reflectance

Bit #	Meaning
7	Bad M10 SDR data 0: no 1: yes
6	Bad M8 SDR data 0: no 1: yes
5	Bad M7 SDR data 0: no 1: yes
4	Bad M5 SDR data 0: no 1: yes
3	Bad M4 SDR data 0: no 1: yes
2	Bad M3 SDR data 0: no 1: yes
1	Bad M2 SDR data 0: no 1: yes
0	Bad M1 SDR data 0: no 1: yes

Table 3-5 - QF4 Surface Reflectance

Bit #	Meaning

7	Missing Precipitable Water data 0: no 1: yes
6	Invalid Land AM input data 0: valid 1: invalid or over ocean
5	Missing AOT input data 0: no 1: yes
4	Overall Quality of AOT 0: good 1: bad
3	Bad I3 SDR data 0: no 1: yes
2	Bad I2 SDR data 0: no 1: yes
1	Bad I1 SDR data 0: no 1: yes
0	Bad M11 SDR data 0: no 1: yes

Table 3-6 - QF5 Surface Reflectance

Bit #	Meaning
7	Overall Quality of M7 Surface Reflectance Data 0: good 1: bad
6	Overall Quality of M5 Surface Reflectance Data 0: good 1: bad
5	Overall Quality of M4 Surface Reflectance Data 0: good 1: bad
4	Overall Quality of M3 Surface Reflectance Data 0: good 1: bad
3	Overall Quality of M2 Surface Reflectance Data 0: good

	1: bad
2	Overall Quality of M1 Surface Reflectance Data 0: good 1: bad
1	Missing Surface Pressure input data 0: no 1: yes
0	Missing total column ozone input data 0: no 1: yes

Table 3-7 - QF6 Surface Reflectance

Bit #	Meaning
7	Unused
6	Unused
5	Overall Quality of I3 Surface Reflectance Data 0: good 1: bad
4	Overall Quality of I2 Surface Reflectance Data 0: good 1: bad
3	Overall Quality of I1 Surface Reflectance Data 0: good 1: bad
2	Overall Quality of M11 Surface Reflectance Data 0: good 1: bad
1	Overall Quality of M10 Surface Reflectance Data 0: good 1: bad
0	Overall Quality of M8 Surface Reflectance Data 0: good 1: bad

Table 3-8 - QF7 Surface Reflectance

Bit #	Meaning
7	Unused

6	Unused
5	Unused
4	Thin Cirrus Flag 0: no 1: yes
2-3	Aerosol Quantity 00: climatology 01: low 10: average 11: high
1	Adjacent to Cloud (currently undefined) 0: no 1: yes
0	Snow Present 0: no 1: yes

Details regarding statistical quality information NetCDF variable (quality_information) are as follows:

PercentCloud
PercentLand
PercentWater
long_name (includes the metadata: total number of retrievals, percentage of optimal retrievals, percentage of bad retrievals)
percent_cloud_shadow
percent_low_sun
percent_missing_for_band_I1
percent_missing_for_band_I2
percent_missing_for_band_I3
percent_missing_for_band_M1
percent_missing_for_band_M10
percent_missing_for_band_M11
percent_missing_for_band_M2
percent_missing_for_band_M3
percent_missing_for_band_M4
percent_missing_for_band_M5
percent_missing_for_band_M7
percent_missing_for_band_M8
percent_poor_retrieval_for_I1
percent_poor_retrieval_for_I2
percent_poor_retrieval_for_I3
percent_poor_retrieval_for_M1
percent_poor_retrieval_for_M10

percent_poor_retrieval_for_M11
percent_poor_retrieval_for_M2
percent_poor_retrieval_for_M3
percent_poor_retrieval_for_M4
percent_poor_retrieval_for_M5
percent_poor_retrieval_for_M7
percent_poor_retrieval_for_M8
percentage_bad_retrievals
percentage_optimal_retrievals
total_number_retrievals

3.4 External Product Tools

No external product tools are supplied. The Surface Reflectance output file is in netCDF4 format. External users can choose their own tools to display and analyze these output files with any publicly available netCDF tools.

4. PRODUCT STATUS

4.1 Operations Documentation

NESDIS/OSPO (2023), VIIRS Surface Reflectance System Maintenance Manual (SMM)

NESDIS/OSPO (2019), Surface Reflectance Requirements Allocation Document (RAD)

NESDIS/STAR (2023), VIIRS Surface Reflectance Delivery (CCAP) Documents (Readme file, PCF-PSF document, Production Rules, and the Delivery Memo)

NOAA/CIRA (2018): Surface Reflectance Algorithm Theoretical Basis Document (ATBD)

4.2 Maintenance History

Please see the VIIRS Surface Reflectance System Maintenance Manual,
Section 5 “Monitoring and Maintenance” for detailed information about monitoring and maintenance support.

END OF DOCUMENT