Effective Date: January 18, 2012
Revision A

GSFC JPSS CMO
January 25, 2012
Released

Joint Polar Satellite System (JPSS) Ground Project
Code 474
474-00069

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Reflectance (SR) Intermediate Product (IP) Software Software

For Public Release

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

This page intentionally left blank.

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Reflectance (SR) Intermediate Product (IP) Software Software

JPSS Electronic Signature Page

Prepared By:

Neal Baker
JPSS Data Products and Algorithms, Senior Engineering Advisor
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm)

Approved By:

Heather Kilcoyne
DPA Manager
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm)

Goddard Space Flight Center
Greenbelt, Maryland

This page intentionally left blank.

Preface

This document is under JPSS Ground Algorithm ERB configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

JPSS Configuration Management Office
NASA/GSFC
Code 474
Greenbelt, MD 20771

This page intentionally left blank.

Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	06/03/2011	This version incorporates **474-CCR-11-0086** which converts D38697, Operational Algorithm Description (OAD) Document for VIIRS Surface Reflectance IP Software, Rev B, dated 03/07/2010 to a JPSS document, Rev -. This was approved by the JPSS Ground Algorithm ERB on June 3, 2011.
Revision A	01/18/2012	**474-CCR-11-0272:** This version baselines 474-00069, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Reflectance (SR) Intermediate Product (IP) Software Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.

This page intentionally left blank.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SURFACE REFLECTANCE (SR) IP

SDRL No. S141
SYSTEM SPECIFICATION SS22-0096

RAYTHEON COMPANY
INTELLIGENCE AND INFORMATION SYSTEMS (IIS)
NPOESS PROGRAM
OMAHA, NEBRASKA

IAW DFAR 252.227-7036, Raytheon hereby declares that, to the best of its knowledge and belief, the technical data delivered under Subcontract No. 7600002744 is complete, accurate, and complies with all requirements of the Subcontract.

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SURFACE REFLECTANCE (SR) IP

APPROVAL SIGNATURES:

____

Stephen E. Ellefson Date
ING/PRO Lead

____

Gabriela A. Ostler Date
Mission Assurance and Enterprise Effectiveness (MAEE)

Northrop Grumman Space & Mission Systems Corp.
Space Technology
One Space Park
Redondo Beach, CA 90278

Engineering & Manufacturing Development (EMD) Phase
Acquisitions &Operations Contract

CAGE NO. 11982

Operational Algorithm Description Document for VIIRS Surface Reflectance (SR) IP Software

Document Number: D38697
Document Date: Jun 29, 2011
Revision: C5

PREPARED BY:

Alain Sei *AM&S Surface Reflectance IP Lead*	*Date*	Paul D. Siebels *IDPS PRO SW Manager*	*Date*

ELECTRONIC APPROVAL SIGNATURES:

Roy Tsugawa *SEIT Lead & ACCB Chair*	*Date*	Stephen E. Ellefson *IDPS Processing SI Lead*	*Date*
Bob Hughes *Data Product System Engineering Lead*	*Date*		

Prepared by
Northrop Grumman Space Technology
One Space Park
Redondo Beach, CA 90278

Prepared for
Department of the Air Force
NPOESS Integrated Program Office
C/O SMC/CIK
2420 Vela Way, Suite 1467-A8
Los Angeles AFB, CA 90245-4659

Under
Contract No. F04701-02-C-0502

This document has been identified per the NPOESS Common Data Format Control Book – External Volume 5 Metadata, D34862-05, Appendix B as a document to be provided to the NOAA Comprehensive Large Array-data Stewardship System (CLASS) via the delivery of NPOESS Document Release Packages to CLASS.

Northrop Grumman Space & Mission Systems Corp. **Space Technology** One Space Park Redondo Beach, CA 90278	NORTHROP GRUMMAN Raytheon

Revision/Change Record

Document Number D38697

Revision	Document Date	Revision/Change Description	Pages Affected
---	6-30-04	New Release.	All
A1	11-30-04	Reflects Science To Operational Code Conversion.	All
A2	3-17-05	Test Procedure and Results inserted into Section 5.1.	Pgs 37-47
A3	4-27-05	corrections plus updated upper right header date, title/signature Reflects NGST comment page dates, Revision/Change Record.	All
A4	7-13-05	Removed export markings per 26May05 official policy change and under Section 1.3.3, Source Code and Test Data References, inserted a more detailed table listing paths to find applicable source code within the ClearCase configuration management tool to include Dan Antzoulatos' 11Jul05 email with rewording comments.	All
A5	6-15-07	Logo, cleanup updates. Delivered to NGST.	All
A6	8-23-07	Updated Surface Reflectance Coefficients table.	16
A7	12-13-07	Implemented NGST comment responses to June 2007 delivery and revisions based on NP-EMD.2007.510.0042 and NP-EDM.2005.510.0026.	All
A8	1-25-08	Reformat in accordance to new template. Delivered to NGST.	All
A9	1-30-08	Updated Surface Reflectance Coefficients table re. AI.	13
A10	2-14-08	Surface pressure input units now hPa (mb) instead of Pa.	5. 11, 17
A11	8-13-08	New cover sheet, update references, acronym list, prepare for peer review.	All
A12	9-4-08	Updated Graceful Degradation.	27
A13	10-28-08	Changed land to not ocean in describing exclusions. Updated fintexp equations to match the operational code implementation	15, 26
A14	10-29-08	Prepare for TIM/ACCB.	All
A	12-10-08	Addressed TIM comments. ECR A-178.	All
B1	4-1-09	Removed text from section 2.1.2.1 that stated that the code converts total column ozone from Dobson Units to atm-cm and converts precipitable water from mm to cm because neither of these conversions are performed by the code any more. (Those conversions are performed upstream of this algorithm.) This was done as part of PCR 020153	16
B2	11-4-09	Incorporated RFA Nos. 318, 319, 320 & 550 and updated for SDRL	All
B3	1-20-10	Updated for TIM/ARB and new SCN.	All
B	3-17-10	Incorporated TIM comments (sect. 2.1.1.1.6) and prepared for ACCB	All

Northrop Grumman Space & Mission Systems Corp. **Space Technology** One Space Park Redondo Beach, CA 90278	NORTHROP GRUMMAN Raytheon

Revision/Change Record	**Document Number D38697**

Revision	Document Date	Revision/Change Description	Pages Affected
C1	6-16-10	Added changes associated with NP-EMD.2010.510.0014, NP-EMD.2010.510.0015 and ECR A-281A.	All
C2	7-08-10	Prepared for SDRL	All
C3	9-07-10	Implemented NP-EMD.2010.510.0038 Roujean kernel correction for the VIIRS gridded surface albedo IP	All
C4	10-14-10	Updated due to document convergence to include tech memo 2010.510.0013	All
C5	06-29-11	Updated due to ECR-ALG-0012 VIIRS Surface Reflectance IP_Drop 2.5.9 and TM 2010.510.0092	All

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

1.1 Objective

The purpose of the Operational Algorithm Description (OAD) document is to express, in computer-science terms, the remote sensing algorithms that produce the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

The science basis of an algorithm is described in a corresponding Algorithm Theoretical Basis Document (ATBD). The OAD provides a software description of that science as implemented in the operational ground system -- the Data Processing Element (DPE).

The purpose of an OAD is two-fold:

1. Provide initial implementation design guidance to the operational software developer.
2. Capture the “as-built” operational implementation of the algorithm reflecting any changes needed to meet operational performance/design requirements.

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents. This particular document describes operational software implementation for the Visible/Infrared Imager/Radiometer Suite (VIIRS) Surface Reflectance Intermediate Product (IP).

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm implementation required to create the VIIRS Surface Reflectance IP. It provides a general overview and is intended to supplement in-line software documentation and interface control documentation for maintenance of the operational software. The theoretical basis for this algorithm is described in Section 3.4 of the VIIRS Surface Reflectance Algorithm Theoretical Basis Document ATBD, 474-00034.

1.3 References

1.3.1 Reference Documents

The science and system engineering documents relevant to the algorithms described in this OAD are listed in Table 1.

Table 1. Reference Documents

Document Title	Document Number/Revision	Revision Date
VIIRS Surface Reflectance IP Detailed Design Document	Y2498 Ver. 5 Rev. 5	9 Apr 2004
VIIRS Surface Reflectance Algorithm Theoretical Basis Document ATBD	474-00034	22 Apr 2011
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module Interface Control Document	Y3279 Ver. 5 Rev. 3	May 2002
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module	Y2474 Ver. 5 Rev. 7	May 2002

Document Title	Document Number/Revision	Revision Date
Software Architecture Document		
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module Data Dictionary	Y0010883 Ver. 5 Rev. 4	9 Feb 2004
JPSS Environmental Data Record (EDR) Production Report for NPP	474-00012 Rev. A	09 Feb 2011
JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP	474-0007 Rev. A	09 Feb 2011
NPP Mission Data Format Control Book and App A (MDFCB)	472-REF-00057	06 Jan 2011
JPSS Internal Data Format Control Book Volume III – Retained Intermediate Product Formats (IDFCB)	474-00020-03, Rev -	18 Feb 2011
JPSS Common Data Format Control Book - External - Volume I - Overview	474-00001-01, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume II - RDR Formats	474-00001-02, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume III - SDR/TDR Formats	474-00001-03, Rev-	16-Feb-11
JPSS Common Data Format Control Book - External - Volume IV - Part I - IPs, ARPs, and Geolocation Data	474-00001-04-01, Rev-	10-Dec-10
JPSS CDFCB - External - Volume IV - Part II - Imagery, Atmospheric, and Cloud EDRs	474-00001-04-02, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume IV - Part III - Land and Ocean/Water EDRs	474-00001-04-03, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume IV - Part IV - Earth Radiation Budget and Space EDRs	474-00001-04-04, Rev-	18-Feb-11
JPSS Common Data Format Control Book - External - Volume V - Metadata	474-00001-05, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VI - Ancillary Data, Auxiliary Data, Messages, and Reports	474-00001-06, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume VII - Part I - JPSS Downlink Data Formats	474-00001-07-01, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 2 - JPSS Downlink Data Formats - CrIS	474-00001-07-02, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 3 - JPSS Downlink Data Formats - OMPS	474-00001-07-03, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 4 - JPSS Downlink Data Formats - ATMS	474-00001-07-04, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 5 - JPSS Downlink Data Formats - VIIRS	474-00001-07-05, Rev-	16-Feb-11
JPSS Common Data Format Control Book - External - Volume VIII - Look Up Table Formats	474-00001-08, Rev-	10-Dec-10
NPP Command and Telemetry (C&T) Handbook	D568423 Rev. C	30 Sep 2008
JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I – IV	IC60917-IDP-002, Rev C	29-Sep-11
JPSS CGS Acronyms and Glossary	LI60917-GND-005, Rev -	17-Oct-11
IDPS Processing SI Common IO Design Document	DD60822-IDP-011 Rev. A	21 June 2007
NGST/SE technical memo – NPP_Surface_Reflectance_Quality_Flag _Update	NP-EDM.2005.510.0026	22 Feb 2005
NGST/SE technical memo – NPP_Surface_Reflectance_IP_Coding_Error_Update	NP-EMD.2007.510.0042	16 July 2007
NGST/SE technical memo –	NP-EDM.2008.510.0005	18 Jan 2008

Document Title	Document Number/Revision	Revision Date
NPP_Surface_Reflectance_IP_Coefficient_Update		
NGST/SE technical memo – NPP_Surface_Reflectance_LUT_Ingest_Coding_Error	NP-EDM.2008.510.0010	22 Mar 2008
NGST/SE technical memo- NPP_Surface_Reflectance_Processing_Quality_Flags_Update s	NP-EMD.2008.510.0061	12 Nov 2008
Operational Algorithm Description Document for the Granulate Ancillary Software	474-00089	02 Dec 2011
NGST/SE technical memo – Update_of_gaseous_transmittance_coefficients_for_the VIIRS_surface_reflectance_code	NP-EMD.2010.510.0014	15 April 2010
NGST/SE technical memo – Update_to_the_solar_zenith_angle_threshold_parameter_for_s urface_reflectance	NP-EMD.2010.510.0015	10 May 2010
NGST/SE technical memo: PC_OAD_Last_Drop_Corrections	NPOESS GJM-2010.510.0013	22 Sep 2010
NGST/SE technical memo: Update_of_gaseous_transmittance_coefficients_for_the VIIRS_surface_reflectance_IP	NP-EMD.2010.510.0092	30 Nov 2010

1.3.2 Source Code References

The science and operational code and associated documentation relevant to the algorithms described in this OAD are listed in Table 2.

Table 2. Source Code References

Reference Title	Identification Label/Version	Revision Date
VIIRS SurfRefl science-grade software	ISTN_VIIRS_NGST_1.0	31 Mar 2003
VIIRS Science Algorithms 2.5 Delivery to IDPS	(OAD Rev ---)	30 Jun 2004
VIIRS SurfRefl operational-grade software	B1.3 (OAD Rev ---)	
NGST/SE technical memo – NPP_Surface_Reflectance_Coding Error Update	NP-EMD.2007.510.0042	16 Jul 2007
VIIRS SurfRefl operational-grade software	B1.5 (OAD Rev A5)	15 Jun 2007
VIIRS Science Algorithms 2.5.4 Delivery to IDPS	Data Only	17 Apr 2008
NGST/SE technical memo – NPP_Surface_Reflectance_IP_Coefficient_Update	NP-EDM.2008.510.0005	18 Jan 2008
VIIRS SurfRefl operational-grade software	B1.5.x.1 (OAD Rev A8)	15 Jan 2008
NGST/SE technical memo – NPP_Surface_Reflectance_LUT_Ingest_Coding_Error	NP-EDM.2008.510.0010	22 Mar 2008
VIIRS Science Algorithms 2.5.7 Data Delivery to IDPS	(ECR-A176)	09 Sep 2008
ACCB	OAD Rev A	10 Dec 2008
VIIRS Science Algorithms 2.5.7 Data Delivery to IDPS Rev A	(ECR-A176A)	29 Jan 2009
VIIRS SurfRefl operational-grade software (PCR20153)	Build POST_X-D (OAD Rev B1)	08 Apr 2009
VIIRS SurfRefl operational-grade software (PCR19019- NPP_Surface_Reflectance_Processing_Quality_Flags_Updates: NP-EMD.2008.510.0061)	Build POST_X-G (No OAD updates)	02 Jun 2009
SDRL	(OAD Rev B2)	04 Nov 2009
ACCB (no code changes)	OAD Rev B	17 Mar 2010

Reference Title	Identification Label/Version	Revision Date
VIIRS Science Algorithms 2.5.8 Data Delivery to IDPS (Drop includes NP-EMD.2010.510.0014) and additional TM NP-EMD.2010.510.0015	(ECR-A281A)	04 May 2010
VIIRS SurfRefl operational-grade software (includes PCRs: 22724, 22973, 23464, 23775)	Build Sensor Characterization SC-11 (OAD Rev C1)	16 Jun 2010
SDRL	(OAD Rev C2)	08 Jul 2010
Convergence Update (No code updates)	(OAD Rev C3)	14 Oct 2010
VIIRS SurfRefl science-grade software includes TM 2010.510.0092	ISTN_VIIRS_NGST_2.5.9	17 Jan 2011
VIIRS SurfRefl operational-grade software (PCRs 025931 & 026170)	ECR-A0012 Maintenance Build 1.5.05.E (OAD Rev C5)	09 Mar 2011 & 29 Jun 2011 (OAD)

2.0 ALGORITHM OVERVIEW

This document details the operational algorithm description of the VIIRS Surface Reflectance IP retrieval algorithm. Its products are necessary to process other products such as the VIIRS Surface Type EDR and VIIRS Vegetation Index EDR and are also used after gridding in Quarterly Surface Type and Albedo IP. The VIIRS Surface Reflectance code produces surface reflectance values for moderate and imagery resolution pixels and the land quality flags (LQF). The algorithm processing code contains three main modules:

Main driver for the processing portion of the IP algorithm (Generate_SurfReflect_IP),

Subroutine to compute land quality flags (Generate_QC_Flags),

Subroutine to calculate Surface Reflectance from inputs (Calc_Lamb).

Figure 1 depicts the processing chain to create VIIRS Surface Reflectance IP product.

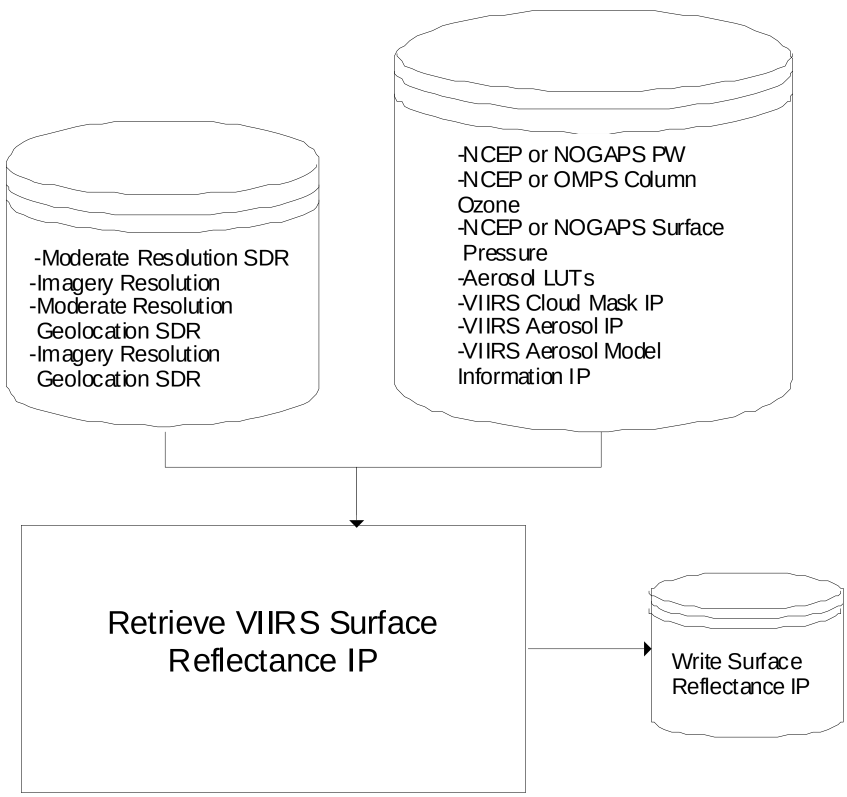

Figure 1. Processing Chain

See the VIIRS Surface Reflectance ATBD, 474-00034, Section 3.3, to obtain a detailed description of the science within the Surface Reflectance retrieval algorithm. Note that the operational algorithm differs from the ATBD in that no thin cirrus correction is performed. Also, the operational code does not perform any correction for adjacency affects.

2.1 Surface Reflectance Intermediate Product Description

2.1.1 Interfaces

2.1.1.1 Inputs

In order to compute the Surface Reflectance IP several types of data are required, as summarized in Table 3. Some input data have more than one possible source. For these situations, establishing a hierarchy order of preference is done. See Section 2.1.3, Graceful Degradation, for additional information on the order of preference for data sources. Refer to the CDFCB-X, D34862, for a detailed description of the inputs.

Table 3. VIIRS Surface Reflectance IP Input File Specifications

Input	Description	Original Source
VIIRS 375-m Earth View (Imagery Resolution) SDR for bands I1, I2, and I3	VIIRS calibrated top of the atmosphere (TOA) reflectance (unitless)	VIIRS Imagery Resolution SDR Processing
VIIRS 750-m Earth View (Moderate Resolution) SDR for bands M1, M2, M3, M4, M5, M7, M8, M10, and M11	VIIRS calibrated top of the atmosphere (TOA) reflectance (unitless)	VIIRS Moderate Resolution SDR Processing
VIIRS Geolocation SDR (Moderate Resolution)	Terrain corrected Geolocation information,	VIIRS Moderate Resolution SDR Processing
VIIRS Geolocation SDR (Imagery Resolution)	Terrain corrected Geolocation information,	VIIRS Imagery Resolution SDR Processing
VCM	Pixel level flags indicating a variety of conditions that may effect processing paths as well as output data quality	VCM Algorithm Processing
VIIRS AOT IP (550nm and Product Quality Flags)	Aerosol Optical Thickness	VIIRS AOT IP Algorithm Processing
VIIRS Aerosol Model Information IP	Aerosol Model Information IP	VIIRS Aerosol Model Information IP Algorithm Processing
NCEP PW NOGAPS PW	Total column precipitable water (cm)	1. NCEP Ancillary Data Processing 2. NOGAPS Data Processing
OMPS Column Ozone, or NCEP Column Ozone	Total Column Ozone amount (atm.cm)	1. OMPS Column Ozone Algorithm Processing 2. NCEP Ancillary Data Processing
NCEP Surface Pressure, or NOGAPS Surface Pressure	Surface pressure (hPa)	1. NCEP Ancillary Data Processing 2. NOGAPS Data Processing
AOT Values LUT	Aerosol optical thickness values	6SV1.1
Solar Zenith Angles LUT	Solar angles	6SV1.1
Satellite Zenith Angles LUT	Satellite angles	6SV1.1
Incremental Scattering Angle LUT	Incremental scattering angle	6SV1.1
Scattering Angle Dimensions LUT	Scattering angle dimensions	6SV1.1
Downward Transmittance LUT	Downward transmittance	6SV1.1
Spherical Albedo LUT	Spherical albedo	6SV1.1
Atmospheric Reflectance LUT	Atmosphere reflectance	6SV1.1
Surface Reflectance Coefficients	Configurable coefficients	VIIRS SR Coefficients LUT

2.1.1.1.1 VIIRS Imagery Resolution SDR

Table 4 describes the parameters extracted for VIIRS imagery resolution bands I1, I2, and I3.

Table 4. VIIRS Surface Reflectance Science Code – Imagery Resolution SDR Inputs

Field Name	Type	Description/Source	Units
Reflectance_Img	Float32	Top of Atmosphere (TOA) Reflectance for bands I1, I2, and I3	Unitless

2.1.1.1.2 VIIRS Moderate Resolution SDR

The contents of Table 5 are extracted for VIIRS imagery resolution bands I1, I2, and I3.

Table 5. VIIRS Surface Reflectance Science Code – Moderate Resolution SDR Inputs

Field Name	Type	Description/Source	Units
Reflectance_Mod	Float32	TOA Reflectance for bands M1, M2, M3, M4, M5, M7, M8, M10, and M11 stored in VIIRS Moderate Resolution SDR	Unitless
SolarZenith_Mod	Float32	Solar Zenith angle stored in the Moderate Geolocation structure	Radian
ViewZenith_Mod	Float32	View Zenith angle stored in the Moderate Geolocation structure	Radian
SolarAzimuth_Mod	Float32	Solar Azimuth angle stored in the Moderate Geolocation structure	Radian
ViewAzimuth_Mod	Float32	View Azimuth angle stored in the Moderate Geolocation structure	Radian

2.1.1.1.3 VCM

The dimensions that correspond to the VCM are as follows:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>
VCM = 6

Table 6 describes the VCM IP field.

Table 6. VCM IP Field

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>“VIIRS Cloud Mask IP”</td><td>Uint8</td><td>(VCM, ROWS, COLS)</td></tr>
<tr><td colspan="3">Description:

A 48-bit word (6 bytes) for each moderate resolution pixel that includes information about whether the view of the surface is obstructed by clouds and specifies the processing path the algorithm took. Cloud phase data is also included as well as spatial uniformity, aerosol, shadow, and fire detection data. See Table 7 for a detailed bits/bytes description.

Field Attributes:
units= none (dimensionless)
fill_value= 255
valid_range= 0, 1</td></tr>
</table>

Table 7. VCM Quality Flag (LQF) Bits and Descriptions

Byte	Bit	Flag Description Key	Result
0	0-1	Cloud Mask Quality	00=Poor, 01=Low, 10=Medium, 11=High
	2-3	Cloud Detection Result & Confidence Indicator	11=Confident Cloudy 10=Probably Cloudy 00=Confident Clear 01=Probably Clear
	4	Day / Night	0 = Night 1 = Day
	5	Snow / Ice Surface	1 = Snow/Ice 0 = No Snow/Ice
	6-7	Sun Glint	00 = None 01 = Geometry Based 10 = Wind Speed Based 11 = Geometry & Wind
1	0-2	Land / Water Background	000 = Land & Desert 001 = Land no Desert 010 = Inland Water 011 = Sea Water 101 = Coastal
	3	Shadow Detected	1 = Yes 0 = No
	4	Non Cloud Obstruction (Heavy Aerosol)	1 = Yes 0 = No
	5	Fire Detected	1 = Yes 0 = No
	6	Cirrus Detection (Solar) (Reflective) (RM9)	1 = Cloud 0 = No Cloud
	7	Cirrus Detection (IR) (Emissive) (BTM15-BTM16)	1 = Cloud 0 = No Cloud
2	0	IR Threshold Cloud Test (BTM15)	1 = Cloud 0 = No Cloud
	1	High Cloud (BTM12 - BTM16) Test	1 = Cloud 0 = No Cloud
	2	IR Temperature Difference Test (BTM14 - BTM15 & BTM15 - BTM16)	1 = Cloud 0 = No Cloud
	3	Temperature Difference Test (BTM15 - BTM12)	1 = Cloud 0 = No Cloud
	4	Temperature Difference Test (BTM12 – BTM13)	1 = Cloud 0 = No Cloud
	5	Visible Reflectance Test (RM5)	1 = Cloud 0 = No Cloud
	6	Visible Reflectance Test (RM7), also Visible Reflectance Test (RM1)	1 = Cloud 0 = No Cloud
	7	Visible Ratio Test (RM7/RM5)	1 = Cloud 0 = No Cloud
3	0-1	Adjacent Pixel Cloud Confident Value	11 = Confident Cloudy 10 = Probably Cloudy 00 = Confident Clear 01 = Probably Clear
	2	Conifer Boreal Forest	1 = Yes 0 = No
	3	Spatial Uniformity	1 = Yes 0 = No
	4	Dust candidate	1 = Yes 0 = No
	5	Smoke candidate	1 = Yes 0 = No
	6	Dust/Volcanic Ash	1 = Yes 0 = No
	7	SPARE	
4	0-7	SPARE	
5	0-2	Cloud Phase	000 = Not Executed 001 = Clear 010 = Partly Cloudy 011 = Water Cloud 100 = Supercooled Water/Mixed 101 = Opaque Ice Cloud 110 = Cirrus Cloud 111 = Cloud Overlap
	3	Thin Cirrus Flag (Supplemental)	1 = Yes 0 = No
	4	Ephemeral Water Flag	1 = Yes 0 = No
	5-7	SPARE	

2.1.1.1.4 VIIRS AOT

The AOT IP is detailed in Table 8. The IP is comprised of a number of fields. Dimensions associated with this IP are:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>

Table 8. AOT Description

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>“faot550”</td><td>Float32</td><td>(ROWS,COLS)</td></tr>
<tr><td colspan="3">Description:
32-bit floating point array indicating the value of the Aerosol Optical Thickness for each VIIRS moderate resolution pixel for each band.

Field Attributes:
Units: “None”
Valid Range: [0.0, 2.0]
Fill Value: NA_FLOAT32_FILL</td></tr>
<tr><td>“aotqf”</td><td>Uint8</td><td>(ROWS,COLS)</td></tr>
<tr><td colspan="3">Description:
8-bit unsigned integer array indicating the Overall AOT product quality for each VIIRS moderate resolution pixel.

Field Attributes:
Units: “None”
Valid Range: [0.0, 1.0]</td></tr>
</table>

2.1.1.1.5 VIIRS Aerosol Model Information IP

The Aerosol Model Information parameter is in the Aerosol Model Information IP file. The dimensions of this IP are:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>

Table 9 describes the Aerosol Model information IP.

Table 9. Aerosol Model Information IP

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>“Aerosol_Model”</td><td>Uint8</td><td>(ROWS,COLS)</td></tr>
<tr><td colspan="3">Description:
8-bit unsigned integer array indicating the Aerosol Model Information IP used for the AOT Determination for each VIIRS moderate resolution pixel. (See Table 10.)

Field Attributes:</td></tr>
</table>

Units: “None” Valid Range: [0, 4] Fill Value: 255

Table 10. Aerosol Model Information IP Key

Array Value	Model Name
0	Dust
1	Smoke High Density
2	Smoke Low Density
3	Urban High Density
4	Urban Low Density

2.1.1.1.6 Ancillary Data

The Surface Reflectance processing also requires ancillary datasets from National Center for Environmental Prediction (NCEP), or the alternatives to the NCEP data, which are listed in Table 3. Each of these components is passed into the Surface Reflectance IP. For a better understanding of how NCEP data is used, granulated and/or converted, refer to Operational Algorithm Description Document for the Granulate Ancillary Software, 474-00089. The following three sections describe the ancillary data formats.

2.1.1.1.6.1 PW

See Table 11 for a description of the NCEP PW product data field. Dimensions that correspond to this product are as follows:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>

Table 11. NCEP PW

Field Name	Data Type	Dimension Names
“Precipitable Water”	Float32	ROWS,COLS
Description: NCEP Precipitable Water Ancillary data product. **Field Attributes:** Units: mm Valid Range: Positive Fill Value: N/A		

2.1.1.1.6.2 Column Ozone

See Table 12 for details of the NCEP Column Ozone product data field. Dimensions that correspond to this product are as follows:

ROWS = <Defined by granule size>

COLS = <Defined by granule size>

Table 12. NCEP Column Ozone

Field Name	Data Type	Dimension Names
"Column Ozone"	Float32	ROWS,COLS
Description: NCEP Column Ozone Ancillary data product. **Field Attributes:** Units: atm.cm Valid Range: Positive Fill Value: N/A		

2.1.1.1.6.3 Surface Pressure

See Table 13 for a description of the NCEP Surface Pressure Product. Dimensions that correspond to this product are as follows:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>

Table 13. NCEP Surface Pressure

Field Name	Data Type	Dimension Names
"Surface_Pressure"	Float32	ROWS,COLS
Description: NCEP Surface Pressure Ancillary data product. **Field Attributes:** Units: hPa Valid Range: Positive Fill Value: N/A		

2.1.1.1.7 Look-up Tables (LUTs)

The Surface Reflectance retrieval algorithm consists of aerosol lookup tables (LUTs) that are populated by the 6S radiative transfer model (RTM). The LUTs are used for the Lambertian correction portion of the Surface Reflectance code. The LUTs are generated using 6SV1.1. The data sets are:

- downward transmittance
- spherical albedo

- atmosphere reflectance
- Aero-optical-depth/tau

Dimensions of these data sets are described as:

- int32 AERO_MODEL_DIM = 5;
- int32 AOT_DIM = 15;
- int32 BAND_DIM = 10;
- int32 SOL_ZEN_DIM = 21;
- int32 ANG_DIM = 5527;

For "downward transmittance" dimensions:

- AERO_MODEL_DIM, AOT_DIM, BAND_DIM, SOL_ZEN_DIM

For "spherical albedo" dimensions:

- AERO_MODEL_DIM, AOT_DIM, BAND_DIM

For "atmosphere reflectance" dimensions:

- AERO_MODEL_DIM, AOT_DIM, BAND_DIM, ANG_DIM

For "Aero-optical-depth/tau", which corresponds to the ratio of the optical depth at the given band to the optical depth at 550 nm, the dimensions of this field are:

- AERO_MODEL_DIM, AOT_DIM, BAND_DIM

In addition, there are LUTs for users to retrieve other useful information. They are self-explanatory except for the dimension of angles, **ANG_DIM**. Dimensions for the Solar and Satellite Zenith Angle LUTs are, respectively,

- int32 SOL_ZEN_DIM = 21 (domain: 0.0 – 80.0 degree)
- int32 SAT_ZEN_DIM = 20 (domain: 0.0 – 70.0 degree)

The scattering angle dimension varies with different solar and satellite zenith angles. But the total number of all possible solar, satellite, and scattering angle combinations is a constant equal to **ANG_DIM**. When given Solar and Satellite zenith angles (in radians), the maximum and minimum scattering angles are defined as:

scatt_max = 180. – fabs(SolZen – SatZen)
scatt_min = 180. – (SolZen + SatZen)

If the corresponding scattering angle dimension is larger than 1, then

scatt_ang [0] = scatt_max
scatt_ang [1] = scatt_max - step_length

and so forth. Currently, the incremental scattering angle (step_length) is set to 4.0 (in degrees) and the scattering angles dimension is SOL_ZEN_DIM*SAT_ZEN_DIM. It must be pointed out that the range of (**scatt_max – scatt_min**) is NOT always divisible by the incremental scattering angle. The 6S RTM takes the minimum scattering angle as **scatt_min**; that is, the last scattering angle increment could be larger than 4.0, but less than 8.0 degrees.

For a block of data with given solar and satellite zenith angle indices, say, indx_sol and indx_sat, one can obtain the following scattering angle index:

indx_scatt = indx_sol * SAT_ZEN_DIM + indx_sat

Then, the Scattering angle LUT (defined here as **ScattAngDim** for brevity) contains:

ScattAngDim[indx_scatt] = scattering angle dimension

This determines how many scattering angles correspond to the given solar and satellite zenith angles. The sum of all the values in **ScattAngDim** should be equal to **ANG_DIM**.

The starting position (called **indx**) of this block of data in the range 0 – (**ANG_DIM** –1) can be calculated by:

```
int32 indx = 0;
for( i = 0; i < indx_scatt; ++i ) {
indx += ScattAngDim[ i ];
}
```

The index of this block of data is obtained in the range:

indx <= i < indx + ScattAngDim[indx_scatt]

2.1.1.1.8 Configurable Coefficients (LUT)

See Table 14 below for a description of the configurable coefficients used:

Table 14. Surface Reflectance Coefficients

Coefficient Name	Coefficient Description
min_SR	Minimum value for surface reflectance
max_SR	Maximum value for surface reflectance
min_AOT	Minimum value for AOT
max_AOT	Maximum value for AOT
min_ANC	Minimum value for ancillary data
max_SDR	Maximum value for SDR data
min_AMDL	Minimum value for AMDL
max_AMDL	Maximum value for AMDL
heavy_AOT	Heavy aerosol limit
tauray[12]	Rayleigh optical thickness
oztransa[12]	Ozone transmittance coefficients
wvtransa[12]	Water vapor transmittance coefficients
wvtransb[12]	Water vapor transmittance coefficients
wvtransc[12]	Water vapor transmittance coefficients
ogtransa0[12]	Other gases transmittance coefficients
ogtransa1[12]	Other gases transmittance coefficients
ogtransb0[12]	Other gases transmittance coefficients
ogtransb1[12]	Other gases transmittance coefficients
ogtransc0[12]	Other gases transmittance coefficients

Coefficient Name	Coefficient Description
ogtransc1[12]	Other gases transmittance coefficients

2.1.1.2 Outputs

Table 15 describes the VIIRS Surface Reflectance IP output file datasets. Refer to the CDFCB-X, D34862, for a detailed description of the outputs.

Table 15. VIIRS Surface Reflectance IP Output File Datasets

Output	Description
Surface Reflectance IP	Directional Surface Reflectance in VIIRS bands I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, and M11 (unitless)
Land Quality Flags	Moderate resolution 48-bit unsigned integer array (unitless)

2.1.1.2.1 Imagery Resolution Output Description

Table 16 provides a detailed description of all output parameters of the Surface Reflectance IP. Dimensions corresponding to this output are:

ROWS = <Defined by granule size>
COLS = <Defined by granule size>

Band_SurfReflect = 3 (corresponding to the three VIIRS imagery resolution bands)

Table 16. Surface Reflectance Data Field in the Imagery Resolution Surface Reflectance IP

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>“SurfReflect_Img”</td><td>Float32</td><td>(ROWS,COLS,Band_SurfReflect)</td></tr>
<tr><td colspan="3">Description:
Atmospherically corrected surface reflectance values for bands I1, I2, and I3 at each imagery resolution pixel, stored as 32-bit floats.

Field Attributes:
Band Names: [“I1”, “I2”, “I3”]
Units: ”Dimensionless”
Scale: none
Offset: 0.0
Valid Range: [0,1.5]
Fill Value : NA_FLOAT32_FILL</td></tr>
</table>

2.1.1.2.2 Moderate Resolution Output Description

This section details the Moderate Resolution outputs to the Surface Reflectance IP. The dimensions for these sets are as follows:

ROWS= <Defined by granule size>,
COLS = <Defined by granule size>,
NumBytes_LQF = <Defined by granule size>,
Band_SurfReflect = 9 (corresponding to the nine VIIRS Moderate-resolution bands for which Surface Reflectance is calculated)

Table 17 shows the Surface Reflectance data field in the moderate resolution Surface Reflectance IP and Table 18 shows the land quality data field in the moderate resolution Surface Reflectance IP.

Table 17. Surface Reflectance Data Field in the Moderate Resolution Surface Reflectance IP

Field Name	Data Type	Dimension Names
“SurfReflect_Mod”	Float32	(ROWS,COLS,Band_SurfReflect)
Description: Atmospherically corrected surface reflectance values for VIIRS bands M1, M2, M3, M4, M5, M7, M8, M10, and M11 at each moderate resolution pixel, stored as 32-bit floats. **Field Attributes:** Band Names: [“M1”, “M2”, “M3”, “M4”, “M5”, “M7”, “M8”, “M10”, “M11”] Units: ”Dimensionless” Scale: none Offset: 0.0 Valid Range: [0,1.5] Fill Value : NA_FLOAT32_FILL		

Table 18. Land Quality Flag Data Field in the Moderate Resolution Surface Reflectance IP

Field Name	Data Type	Dimension Names
“Land_Quality_Flags”	UInt64	(ROWS,COLS, NumBytes_LQF)
Description: Land quality flags for each moderate resolution pixel stored as bit fields within 48-bit unsigned integers. Bits are indexed as reported in the most current version of the CDFCB (the masks associated with these flags are configurable parameters). **Field Attributes:** Units: ”Dimensionless” Valid Range: [0,1] First two bytes of quality flags are as follows: Byte 0, bit 0: Cloud mask quality (See Table 7, Byte0 for Cloud mask quality bit definitions) Byte 0, bit 1: Cloud mask quality Byte 0, bit 2: Cloud confidence (See Table 7, Byte0 for Cloud Confidence bit definitions) Byte 0, bit 3: Cloud confidence Byte 0, bit 4: Day/night Byte 0, bit 5: Low sun mask Byte 0, bit 6: Sun glint masks (geometry, wind speed) (See Table 7, Byte0 for Sun glint bit definitions) Byte 0, bit 7: Sun glint masks (geometry, wind speed) Byte 1, bit 0: Land/water mask (See Table 7, Byte1 for Land/water mask bit definitions) Byte 1, bit 1: Land/water mask Byte 1, bit 2: Land/water mask Byte 1, bit 3: Shadow mask Byte 1, bit 4: Heavy aerosol mask Byte 1, bit 5: Unused Byte 1, bit 6: Thin cirrus reflective Byte 1, bit 7: Thin cirrus emissive Byte 2, bit 0: Bad M1 SDR data Byte 2, bit 1: Bad M2 SDR data Byte 2, bit 2: Bad M3 SDR data Byte 2, bit 3: Bad M4 SDR data Byte 2, bit 4: Bad M5 SDR data Byte 2, bit 5: Bad M7 SDR data Byte 2, bit 6: Bad M8 SDR data		

Field Name	Data Type	Dimension Names
Byte 2, bit 7: Bad M10 SDR data Byte 3, bit 0: Bad M11 SDR data Byte 3, bit 1: Bad I1 SDR data Byte 3, bit 2: Bad I2 SDR data Byte 3, bit 3: Bad I3 SDR data Byte 3, bit 4: Overall quality of AOT Byte 3, bit 5: Missing AOT input data Byte 3, bit 6: Invalid land AMI Byte 3, bit 7: Missing PW input data Byte 4, bit 0: Missing OZ input data Byte 4, bit 1: Missing SP input data Byte 4, bit 2: Overall quality M1 SR data Byte 4, bit 3: Overall quality M2 SR data Byte 4, bit 4: Overall quality M3 SR data Byte 4, bit 5: Overall quality M4 SR data Byte 4, bit 6: Overall quality M5 SR data Byte 4, bit 7: Overall quality M7 SR data Byte 5, bit 0: Overall quality M8 SR data Byte 5, bit 1: Overall quality M10 SR data Byte 5, bit 2: Overall quality M11 SR data Byte 5, bit 3: Overall quality I1 SR data Byte 5, bit 4: Overall quality I2 SR data Byte 5, bit 5: Overall quality I3 SR data Byte 5, bit 6: Unused Byte 5, bit 7: Unused		

2.1.2 Algorithm Processing

The Surface Reflectance IP code is written in C and FORTRAN. It uses a C++ compiler to facilitate interfaces with the IDPS Infrastructure (INF) and Data Management Subsystems (DMS). Figure 2 depicts overall data flow of this operational code. The code determines a surface reflectance value for each pixel flagged as not confidently cloudy, day, not ocean, and no thin cirrus by the Land Quality Flags. If the pixel is flagged, it contains a fill value, (NA_FLOAT32_FILL).

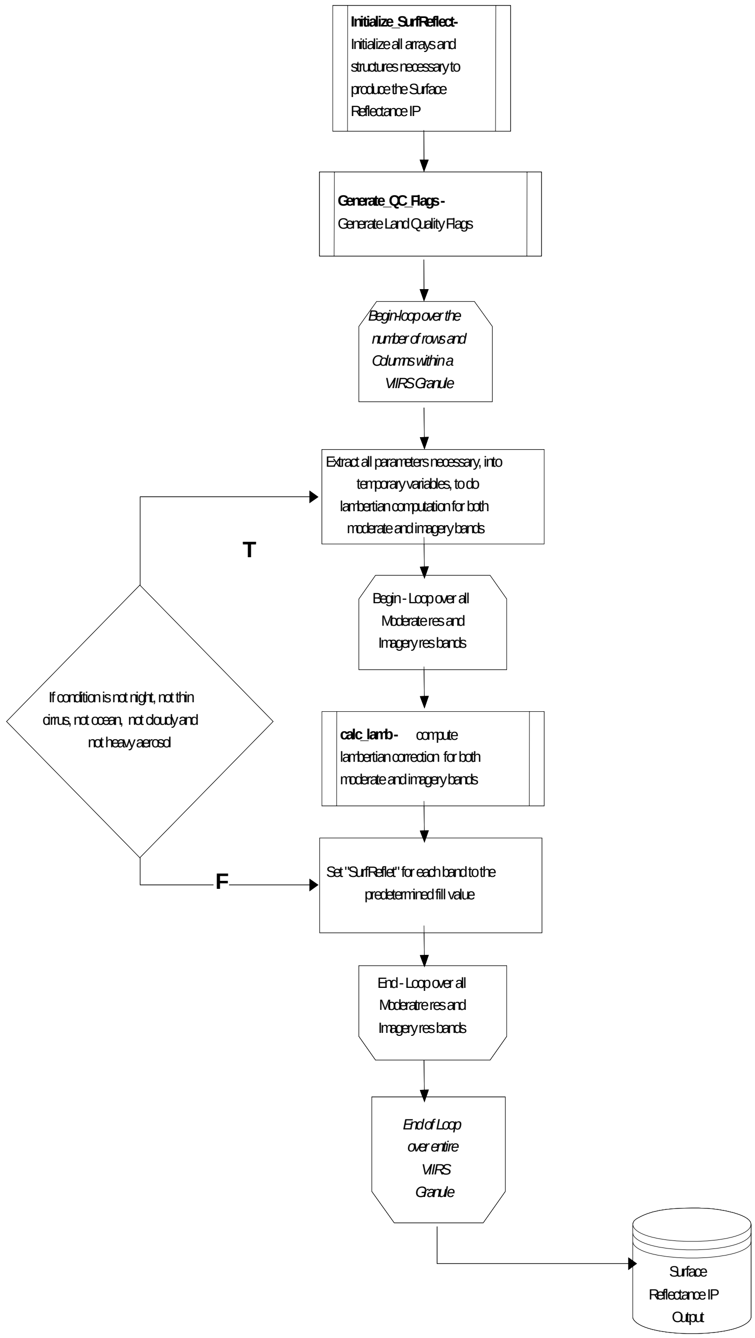

Figure 2. Flow of Generate_SurfReflect_IP

2.1.2.1 Main Module - Generate_SurfReflect_IP.cpp

This function serves as the main driver of the Surface Reflectance IP unit. It takes input arguments of the structure that contains all DMS input and outputs, and the stop pointer. Function arguments are shown in Table 19. This function requires inclusion of the "SurfReflect.h" include file. It subsequently calls the following functions to produce the final IP:

1. Initialize_SurfReflect – This module performs several initialization tasks (configuration of processing parameters, array initialization, etc.). This module is called only once.
2. Generate_QC_Flags – This function produces the Land Quality Flags (LQF) used to characterize the quality of all downstream land products.
3. calc_lamb - This function computes surface reflectance values in each band using RT expressions, RT-based LUTs, and the extracted and processed input data. The output of this routine is the Lambertian-corrected Surface Reflectance.

Between the functional calls a section of the code saves the TOA reflectance values for each band to the variable “rotoa.” This variable, along with a variety of other temporary variables, gets passed into the function “calc_lamb”. A unit conversion is also performed to convert surface pressure from hPa (millibars) to atmospheres.

NOTE: The function “calc_lamb” only gets called if the LQFs that indicate pixel conditions are:

- Not Confidently Cloudy
- Not Ocean
- Not Night
- Neither Reflective nor Emissive Thin Cirrus Detected

Also “calc_lamb” is called for an entire VIIRS granule for each VIIRS band. The Adjacency Adjustment on the reflectance values and the BRDF correction are not being implemented at this time.

Table 19. Generate_SurfReflect_IP.cpp Arguments

Name	Type	Description
ioData	Struct	Structure for holding: • All SDR, IP inputs for Surface Reflectance • LUTs • Output structure for Surface Reflectance
StopPtr	Int32	Pointer to check for stop callback

2.1.2.1.1 Initialize_SurfReflect .cpp

This function initializes array values for the purposes of generating the NPOESS/VIIRS Surface Reflectance IP.

This function requires the “SurfReflect.h” include file as input. Various input arguments are passed in through these include files. Arguments for this function are shown in Table 20.

Table 20. Initialize_SurfReflect.cpp Arguments

Name	Type	Description
ioData	Struct	Structure for holding: • All SDR,IP inputs for Surface Reflectance • LUTs • Output structure for Surface Reflectance

2.1.2.1.2 Generate_QC_Flags.cpp

This is a function for generating VIIRS LQFs, which are placed in a multi-byte-per-pixel array. The LQFs are used for retrieval logic and to provide information and guidance to the end users. VCM and the VIIRS AOT IPs are used to generate these flags. Arguments for this function are shown in Table 21. The flow of this function is shown in Figure 3. Note: Additional LQFs are defined as part of EDRPR implementation.

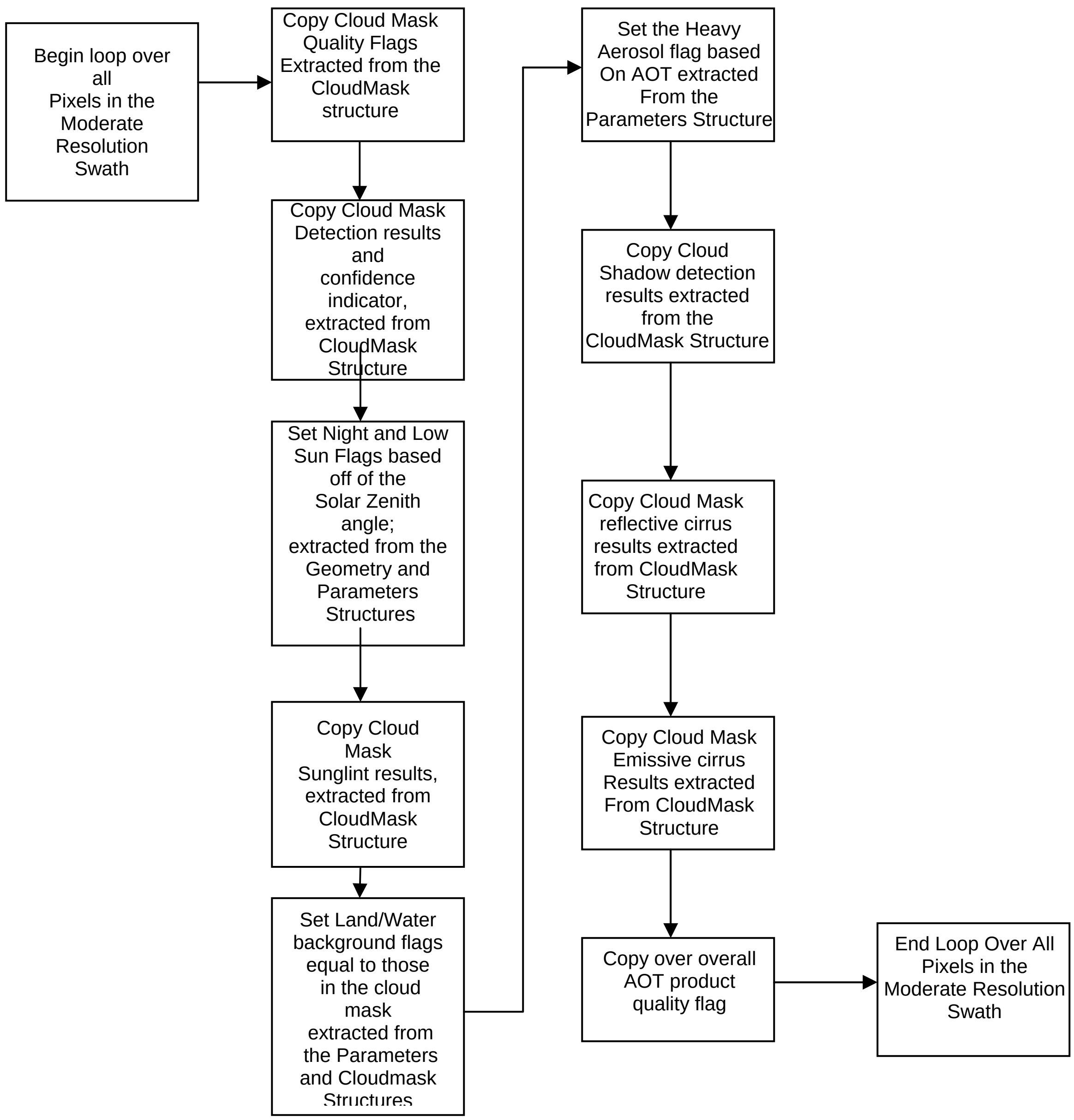

Figure 3. Flow of "Generate_QC_Flags"

Table 21. Generate_QC_Flags.cpp Arguments

Name	Type	Description
ioData	Struct	Structure for holding: • All SDR,IP inputs for Surface Reflectance • LUTs • Output structure for Surface Reflectance

2.1.2.1.3 Calc_Lamb.f

This Fortran90 function converts TOA reflectance to atmospherically corrected surface reflectance values, assuming a Lambertian surface.

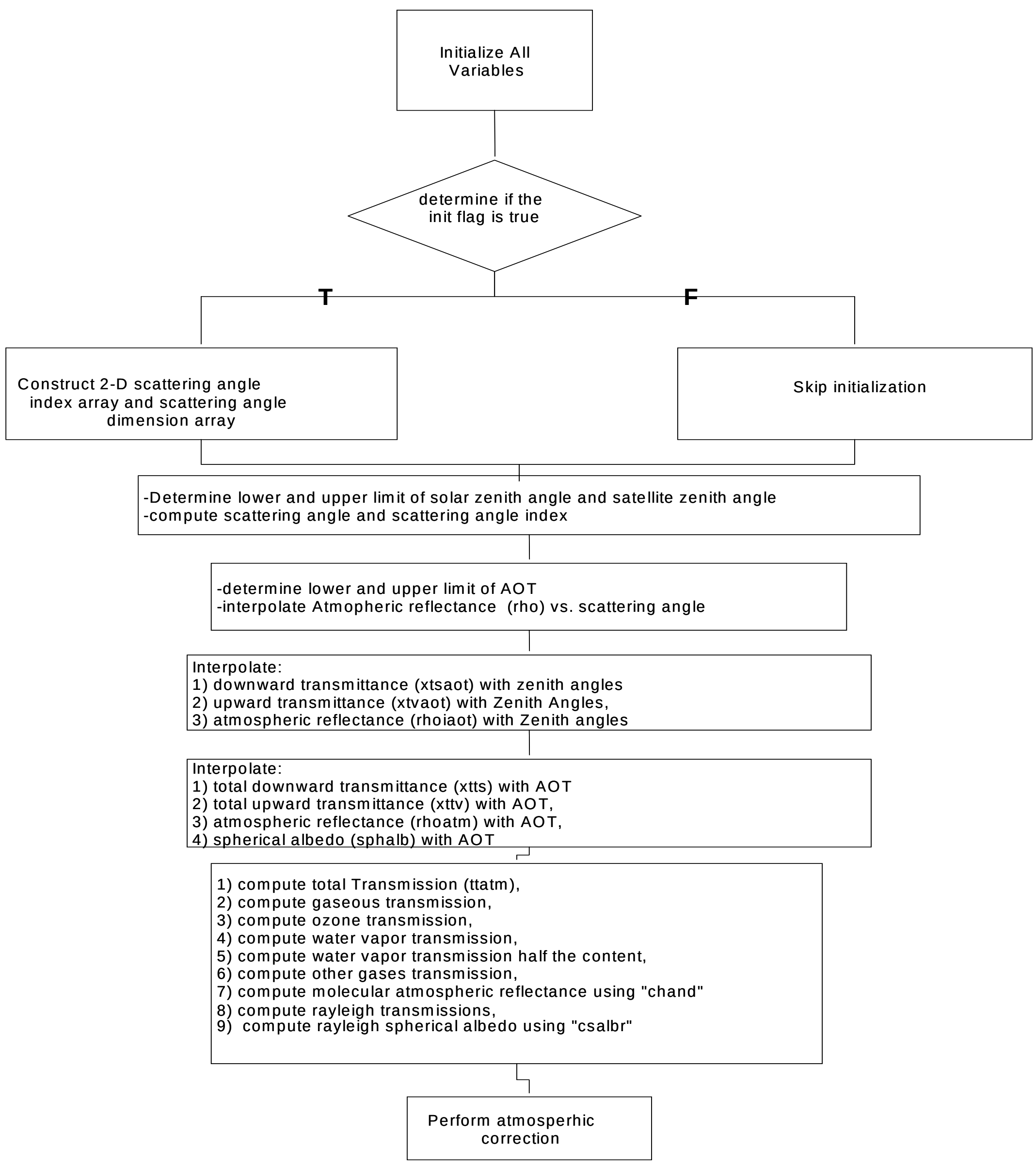

Figure 4. Flow of calc_lamb

To get a more theoretical description of the Lambertian correction computation, see Section 3.4.2 of the VIIRS Surface Reflectance Algorithm Theoretical Basis Document ATBD, 474-00034.

Arguments for this function are shown in Table 22. Internal variables for this function are detailed in Table 23. The flow of this function is shown in Figure 4.

The function “calc_lamb” is called for each of the 12 VIIRS bands (nine moderate resolution bands and three imagery bands), for each VIIRS pixel. For each pixel, the scattering angle (**scaa**) must be computed. For any given pair of solar zenith (soz) and satellite zenith angles (sez), there is a number of possible scattering angles that correspond to the (soz, sez) pair. (See Section 2.1.1.1.7 for a description of all LUT dimensions and attributes in the Aerosol LUT.)

The atmospheric reflectance is a function of scattering angle, band number, and AOT dimensions. In order to extract the proper atmospheric reflectance value from the LUT, the corresponding scattering angle values must be computed. Scattering angle values are a function of solar zenith and view zenith angles. Therefore the atmospheric reflectance needs to be interpolated in scattering angle, solar and view zenith angles as well as AOT.

The input scattering angle, Θ, computation uses the following formula:

$$\cos(\Theta) = -\cos(\theta_v)\cos(\theta_s)(\cos(\phi)+1) + \cos(\phi)\cos(\theta_v + \theta_s)$$

where θ_v, θ_s, and ϕ correspond to the view zenith, solar zenith, and relative azimuth angles respectively. Since the atmospheric reflectance may not be defined at this angle, Θ, the correct scattering angle corresponding to the atmospheric reflectance needs to be calculated.

The first step is to find the nearest four solar and view zenith pairs, from among the LUT sun/sensor zenith angle vertices, that correspond to the input (θ_s, θ_v) pair. For each of these four pairs, compute the maximum scattering angle and minimum scattering angle using the following formula respectively:

$maxscat_i = 180 - abs(soz_i - sez_i)$
$minscat_i = 180 - (soz_i + sez_i)$

where i= 1…4, **soz_i**= ith solar zenith entry from the LUT, and **sez_i** = the ith view zenith entry from the LUT. From these four pairs of maximum and minimum scattering angles, compute the four scattering angles (**scaalut**) that come closest to the input scattering angle Θ. These four scattering angles can now be used to interpolate atmospheric reflectance. NOTE: The scattering angle indices for these four angles are also saved into the array **iscat**.

Now the code computes the lower and upper limit for AOT. The code must determine which LUT value of AOT (**aot550nm**) is nearest the input value of AOT (**raot550nm**). After extracting the correct LUT angle (actually the index of the correct angle is extracted and is saved into **iaot1**), atmospheric reflectance is interpolated against scattering angle. The interpolation breaks into two branches: 1) if the number of scattering angle dimensions equals one, and 2) if the number of scattering angle dimensions is not one. If the number of dimensions, **nscat,** is one, then take the atmospheric reflectance values (from the atmospheric reflectance LUT) that correspond to the scattering angle indices in **iscat**. If the number of scattering angle dimensions is greater than one, then it is necessary to interpolate the atmospheric reflectance against scattering angle. This is done using the following linear interpolation scheme:

$$\rho = \frac{\rho_{\inf} + (\rho_{\sup} - \rho_{\inf})(\Theta - scaalut(j) + \delta)}{\delta}$$

where ρ is the interpolated atmospheric reflectance value, ρ_{sup} is the atmospheric reflectance value at the jth index, ρ_{inf} is the atmospheric reflectance at the j+1 index, and δ is either the scattering angle increment or the difference between the jth scattering angle and the jth minimum scattering angle, where j = 1…4.

Since atmospheric reflectance is a function of scattering angle, solar zenith, view zenith, and AOT, the code interpolates atmospheric reflectance with these four parameters. The code uses bilinear interpolation in the following form (with the solar zenith and view zenith parameters):

$$\rho_{\text{int}} = \rho_1(s)(v) + \rho_2(1-s)(v) + \rho_3(s)(1-v) + \rho_4(1-s)(1-v)$$

where ρ_k (k = 1…4) are the four atmospheric reflectance values that were interpolated against scattering angle, **s** is the interpolated solar zenith angle, and **v** is the interpolated view zenith angle. Note: Atmospheric reflectance is interpolated against solar and view zenith simultaneously.

The upward transmittance (**xtvaot**) and downward transmittance (**xtsaot**) are also interpolated against solar and view zenith angles. It is important to note the downward and upward transmittance parameters are a function of θ_s and θ_v (the solar and view zenith angles) respectively (in reality the transmittance values use interpolated solar and view zenith values as opposed to θ_s and θ_v which have already been defined as the input solar and view zenith angles, respectively). However, since the upward transmittance parameter (in the LUT) has the same dimensions as the downward transmittance, then the upward transmittance view zenith angles must be mapped to the solar zenith angle dimension. Finding the index within the solar zenith angle attribute, which corresponds to the angle closest to the input view zenith angle, does this. This angle (call it **tts**) which corresponds to the found index (call it **itvt**), with adjacent values in the LUT and the input view zenith angle, should be interpolated to compute the correct upward transmittance value (using the view zenith angle mapped into the solar zenith angle dimension in the LUT). The upward and downward transmittance values are computed using linear interpolation schemes.

After interpolating against solar and view zenith angles, the atmospheric reflectance, upward and downward transmittance must be interpolated against AOT. Using the index **iaot1** compute:

deltaaot = aot550nm(iaot1+1) - aot550nm(iaot1)

Using this value, compute the following:

1. Interpolated spherical albedo (**satm**),
2. Interpolated downward transmittance (**xtts**),
3. Interpolated upward transmittance (**xttv**), and
4. Interpolated atmospheric reflectance (**roatm**).

All of these use the same linear interpolation scheme as is used for the interpolation of atmospheric reflectance against scattering angle.

After doing all the necessary interpolations, the following parameters are computed:

1. Full transmittance - The product of the downward and upward transmittance values (**ttatm = xtts*xttv**)

$$Tr^i_{atm}(\theta_s, \theta_v, P, Aer^i) = T^i_{atm}(\theta_s, P, Aer^i) T^i_{atm}(\theta_v, P, Aer^i)$$

2. Air Mass

$$m = \frac{1}{\cos(\theta_v)} + \frac{1}{\cos(\theta_s)}$$

3. Ozone transmittance (see Section 2.1.2.1.3.1)
4. Water Vapor and Half Water Vapor transmittance (see Section 2.1.2.1.3.2)
5. Other Gas transmittance (see Section 2.1.2.1.3.3)
6. Molecular atmospheric reflectance at standard pressure (see Section 2.1.2.1.3.4)
7. Molecular atmospheric reflectance at actual pressure (see Section 2.1.2.1.3.4)
8. Rayleigh Spherical Albedo at actual pressure (see Section 2.1.2.1.3.5)
9. Total (upward and downward) Molecular (Rayleigh) transmission at standard pressure
10. Total (upward and downward) Molecular (Rayleigh transmission at actual pressure
11. Atmospheric Spherical Albedo – the actual computation of this parameter is done in this module, but the description is in Section 2.1.2.1.3.5
12. The final atmospheric reflectance at the TOA

The final atmospheric reflectances do not have their own functions and are detailed in the following paragraphs.

The Molecular (Rayleigh) transmission (downward) can be written as:

$$T^i_R(\theta_s, P_0) = \frac{\left[\frac{2}{3} + \cos(\theta_s)\right] + \left[\frac{2}{3} - \cos(\theta_s)\right] \exp\left(-\tau_R / \cos(\theta_s)\right)}{\frac{4}{3} + \tau_R}$$

The upward transmission can be computed by replacing θ_s with θ_v, the view zenith angle. The total Molecular (Rayleigh) transmission (**traytotp***traytotp0**) is thus

$$T^i_R(\theta, P_0) = T^i_R(\theta_s, P_0) T^i_R(\theta_v, P_0)$$

where the generic θ represents the dependency on θ_s and θ_v. Computing the total Molecular (Rayleigh) transmission at actual pressure only requires the replacement of τ_R with $\tau_R P$, where P is the actual surface pressure. The total atmospheric transmission (atmospheric and Rayleigh, **ttatm*traytotp/traytotp0**) at actual pressure can be written as:

$$T^i_{atm}(\theta, P, Aer^i) = T^i_{atm}(\theta, P_0, Aer^i) \frac{T^i_R(\theta, P)}{T^i_R(\theta, P_0)}$$

where Aer^i are the aerosol components (aerosol model and AOT). Also, update the parameter ρ_{atm} by taking the water vapor (half content) effects, and the molecular atmospheric reflectance at standard pressure (ρ_R) and actual pressure (ρ'_R) which yields

$$\rho_{atm} = \rho'_R(\theta_s,\theta_v,\phi,P) + \left(\rho_{\text{int}}(\theta_s,\theta_v,\phi,Aer^i) - \rho_R(\theta_s,\theta_v,\phi,P_0)\right)Tg^i_{H_20}(m,\frac{U_{H_20}}{2})$$

Taking this parameter and the outputs of ozone gaseous transmittance (tgoz), water vapor transmittance (tgwv), water vapor half content transmittance (tgwvhalf), transmittance due to other gases (tgog), the molecular atmospheric reflectance values at both standard and actual pressure (), interpolated atmospheric reflectance values ($\rho_{\text{int}}(\theta_s,\theta_v,\phi,Aer^i)$), spherical albedo (satm), and original input TOA reflectance value, the corrected atmospheric reflectance value is:

$$\rho_s = \frac{\gamma}{1+\gamma\left[S^i_{atm}(P,Aer^i)\right]}$$

where

$$\gamma = \left(\frac{1}{Tg^i_{H_20}(m,U_{H_20})Tr^i_{atm}(\theta_s,\theta_v,P,Aer^i)}\right)\left[\begin{array}{l}\rho_{TOA}(\theta_s,\theta_v,P,Aer^i,U_{H_20}U_{O_3})\left(\frac{1}{Tg^i_{O_3}(m,U_{O_3})Tg^i_{OG}(m,P)}\right) - \\ \left(\rho_{int}(\theta_s,\theta_v,\phi,P,Aer^i) - \rho_R(\theta_s,\theta_v,\phi,P_0)\right)Tg^i_{H_20}(m,\frac{U_{H_20}}{2}) - \\ \rho'_R(\theta_s,\theta_v,\phi,P)\end{array}\right]$$

Table 22. Calc_Lamb.f Arguments

Name	Type	Description	Units
xts	REAL*4	Solar Zenith Angle	Degree
xtv	REAL*4	Sensor View Zenith Angle	Degree
xfi	REAL*4	Relative Azimuth Angle	Degree
raot550nm	REAL*4	AOT at 550nm	Unitless
imod	INTEGER*1	Aerosol Model Information IP	N/A
uwv	REAL*4	NCEP or NOGAPS PW	cm
uoz	REAL*4	OMPS or NCEP Column Ozone	Atm-cm
pres	REAL*4	NCEP or NOGAPS Surface Pressure	Atmosphere
ib	INTEGER*4	VIIRS band number: 1 = M1, 2 = M2, 3 = M3, 4 = M4, 5 = I1, 6 = M5, 7 = I2, 8 = M7, 9 = M8, 10 = I3, 11 = M10, 12 = M11	N/A
rotoa	REAL*4	TOA Reflectance	Unitless
roslamb	REAL*4	Lambertian Surface Reflectance	Unitless
cxfi	REAL*4	Cosine Relative Azimuth	Unitless
cxfi2	REAL*4	Cosine 2*Relative Azimuth	Unitless
xmuv	REAL*4	Cosine Solar Zenith	Unitless
xmus	REAL*4	Cosine Sensor Zenith	Unitless
xsum	REAL*4	Cosine (Solar + Sensor Zenith)	Unitless
ptrs	SURFREFLECT_PTRS	Pointers to input and output data for Surface Reflectance	Unitless

Table 23. Calc_Lamb.f Internal Variables

Name	Type	Description	Units
trans	Real*4	Downward Transmittance LUT	Unitless
sphalb	Real*4	Sperical Albedo LUT	Unitless
rolut	Real*4	Atmospheric reflectance LUT	Unitless
aot550nm	Real*4	AOT Attribute from the LUT	Unitless
tts	Real*8	Solar Zenith Angles Attribute from the LUT	Degree
ttv	Real*8	View Zenith Angles Attribute from the LUT	Degree
dscat	Real*4	Incremental scattering angle	N/A
numscat	Integer*4	Scattering angle dimensions	N/A
tauray	Real	Rayleigh Optical Depth array for each VIIRS band	Unitless

2.1.2.1.3.1 O3_trans (calc_Lamb.f)

This subroutine computes the ozone transmittance (**tgoz**) using the following formulation:

$$Tg^i_{O_3}(m,U_{O_3}) = e^{-a^i_{O_3} m U_{O_3}}$$

where m is the mass of air, U_{O_3} is the integrated columnar ozone content, and $a^i{}_{O_3}$ is the “ith” band “a-coefficient” value for Ozone. The mass of air is computed in item number 2 in the above listing of parameters. The “a-coefficients” for ozone, which represent the ozone transmittance LUT, are hard-coded within this function. Arguments for this function are shown in Table 24. Internal variables for this function are detailed in Table 25.

Table 24. O3_trans (calc_Lamb.f) Arguments

Name	Type	Description	Units
m	Real	Gaseous Transmission	Unitless
uoz	Real	Integrated columnar ozone content	Atm.cm
ib	Real	Band number	N/A
toz	Real	Ozone transmittance	Unitless

Table 25. O3_trans (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
oztransa	Real	12 element table of “a-coefficients” for ozone	Unitless

2.1.2.1.3.2 H2O_trans (calc_Lamb.f)

This function computes the water vapor gaseous transmittance (**tgwv** and **tgwvhalf**) using the following equation:

$$Tg^i_{H_2O}(m,U_{H_2O}) = e^{a^i_{H_2O} m U_{H_2O} + b^i_{H_2O}\log(mU_{H_2O}) + c^i_{H_2O} m U_{H_2O}\log(mU_{H_2O})}$$

where $a^i_{H_2O}$ is the ith band “a-coefficient” value for water, $b^i_{H_2O}$ is the ith band “b-coefficient” value for water, $c^i_{H_2O}$ is the ith band “c-coefficient value” for water, U_{H_2O} is the total PW, and m is the air mass. The a, b, and c coefficients, which represent the Water Vapor Transmittance LUT, are hard-coded in this subroutine. This is also done for $U_{H_2O}/2$. Arguments for this function are shown in Table 26. Internal variables for this function are detailed in Table 27.

One more thing to note is that if the product of the air mass and PW is less than or equal to $1x10^{-6}$, then the water vapor gaseous transmittance is set to 1.

Table 26. H2O_trans (calc_Lamb.f) Arguments

Name	Type	Description	Units
m	Real	Gaseous Transmission	Unitless
uwv	Real	Total PW	cm
ib	Real	Band number	N/A
th2o	Real	Water vapor gaseous transmittance	Unitless

Table 27. H2O_trans (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
wvtransa	Real	12 element table of “a-coefficients” for H2O	Unitless
wvtransb	Real	12 element table of “b-coefficients” for H2O	Unitless
wvtransc	Real	12 element table of “c-coefficients” for H2O	Unitless

2.1.2.1.3.3 OG_trans (calc_Lamb.f)

This function computes the gaseous transmittance of gases (**tgog**) other than water and ozone. The equation is as follows:

$$Tg_{OG}^{i}(m,P) = \exp\begin{bmatrix} m\left(a_0^i P + a_1^i \log(P)\right) + \log(m)\left(b_0^i P + b_1^i \log(P)\right) + \\ m\log(m)\left(c_0^i P + c_1^i \log(P)\right) \end{bmatrix}$$

where P is the input surface pressure, m is the air mass, a_0^i, a_1^i, b_0^i, b_1^i, c_0^i, and c_1^i represent coefficients in the “Other Gases” LUT, which are hard-coded in this subroutine. Arguments for this function are shown in Table 28. Internal variables for this function are detailed in Table 29.

Table 28. OG_trans (calc_Lamb.f) Arguments

Name	Type	Description	Units
m	Real	Gaseous Transmission	Unitless
p	Real	Surface Pressure	Atmospheres
ib	Real	Band number	N/A
tgo	Real	Other gaseous transmittance	Unitless

Table 29. OG_trans (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
ogtransa0	Real	12 element table of “a0-coefficients” for Other gaseous transmission	Unitless
ogtransa1	Real	12 element table of “a1-coefficients” for Other gaseous transmission	Unitless
ogtransb0	Real	12 element table of “b0-coefficients” for Other gaseous transmission	Unitless
ogtransb1	Real	12 element table of “b1-coefficients” for Other gaseous transmission	Unitless

Name	Type	Description	Units
ogtransc0	Real	12 element table of “c0-coefficients” for Other gaseous transmission	Unitless
ogtransc1	Real	12 element table of “c1-coefficients” for Other gaseous transmission	Unitless

2.1.2.1.3.4 chand (calc_Lamb.f)

This function computes the molecular atmospheric reflectance at standard pressure $\rho_R(\theta_s,\theta_v,\phi,P_0)$ and actual pressure $\rho'_R(\theta_s,\theta_v,\phi,P)$. If computing the atmospheric reflectance at standard pressure P_0, the molecular optical depth is just the molecular optical depth value extracted from the band specific Rayleigh Optical Depth LUT, that is currently hard-coded in the function “calc_lamb.” To compute the atmospheric reflectance at actual pressure P, simply multiply the molecular optical depth by P, that is $\tau_R(P)=\tau_R P$, where τ_R is the molecular optical value extracted from the LUT “tauray” defined in the function “calc_lamb.” Arguments for this function are shown in Table 30. Internal variables for this function are detailed in Table 31.

Table 30. chand (calc_Lamb.f) Arguments

Name	Type	Description	Units
xcosf2	Real*4	Cosine PI - Relative Azimuth Angle	Degree
cxfi2	Real*4	Cosine 2PI - Relative Azimuth Angle	Degree
xmus	Real*4	Cosine of the Solar Zenith Angle	Degree
xmuv	Real*4	Cosine of the View Zenith Angle	Degree
xlntau	Real*4	Log Molecular Optical Depth	Unitless
xrray	Real*4	Molecular Atmospheric Reflectance at standard pressure or actual pressure	Unitless
emus	Real*4	Exponential Molecular Optical Depth/Cosine Solar Zenith	Unitless
emuv	Real*4	Exponential Molecular Optical Depth/Cosine Sensor Zenith	Unitless
xsum	Real*4	Cosine (Solar + Sensor Zenith)	Unitless

Table 31. chand (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
xdep	Real*4	Depolarization factor = 0.0279	Unitless
xbeta2	Real*4	Constant with value 0.5	Unitless
as0	Real	10 element data array	Unitless
as1	Real	2 element data array	Unitless
as2	Real	2 element data array	Unitless

2.1.2.1.3.5 csalbr (calc_Lamb.f)

This function computes the Atmospheric (Rayleigh) Spherical Albedo (**satm**) at standard pressure and at actual surface pressure. As is with the function “calc_lamb”, this module also requires the molecular optical depth at standard pressure P_0 (normalized to 1) and actual pressure P, which correspond to molecular optical depths of τ_R and $\tau_R P$ respectively.

The analytical form for the atmospheric spherical albedo at actual pressure is described as:

$$S^i_{atm}(P, Aer^i) = \int_0^{\pi/2}\int_0^{\pi/2}\int_0^{2\pi}\rho^i_{atm}(\theta_s,\theta_v,\phi,P,Aer^i)\sin(\theta_s)\cos(\theta_v)d\theta_s d\theta_v d\phi$$

where θ_s is the solar zenith angle, θ_v is the view zenith angle, ϕ is the relative azimuth angle, P is the surface pressure, and Aer^i is the aerosol components (aerosol model and AOT, both extracted from the Aerosol LUT briefly described in Section 2.2.1.7). By ignoring the water vapor dependence on the atmospheric intrinsic reflectance, this integral can be simplified into an expression that looks like this:

$$S^i_{atm}(P, Aer^i) = \left(S^i_{atm}(P_0, Aer^i) - S^i_R(P_0)\right) + S^i_R(P)$$

where $S^i_{atm}(P_0, Aer^i)$ are the pre-computed spherical albedo values extracted from the Aerosol LUT; these spherical albedo values are a function of aerosol model, AOT and band number. The parameters $S^i_R(P_0)$ and $S^i_R(P)$ represent the Rayleigh spherical albedo at standard pressure and actual pressure respectively. These values are computed by this module in conjunction with “fintexp3” (Section 2.1.2.1.3.6) and “fintexp1” (Section 2.1.2.1.3.7).

The Rayleigh spherical albedo formula is as follows:

$$S^i_R(P) = \frac{3\tau_R - \mathrm{A}(\tau_R)(4 + 2\tau_R) + 2\exp(-\tau_R)}{4 + 3\tau_R}$$

where τ_R is the molecular optical depth passed in from the function “calc_lamb” from a pre-defined LUT, which is currently hard-coded into the function, and $\mathrm{A}(\tau_R)$ corresponds to the output of the function “fintexp3.” Arguments for this function are shown in Table 32. Internal variables for this function are detailed in Table 33.

Table 32. csalbr (calc_Lamb.f) Arguments

Name	Type	Description	Units
xtau	Real	Molecular Optical depth at standard or actual pressure	Unitless
xlntau	Real	Log Molecular Optical depth at standard or actual pressure	Unitless
xalb	Real	Atmospheric (Rayleigh) Spherical Albedo	Unitless

Table 33. csalbr (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
fintexp3	Real	Evaluated $\mathrm{A}(\tau_R)$	Unitless

2.1.2.1.3.6 fintexp3 (calc_Lamb.f)

This function computes the parameter $\mathrm{A}(\tau_R)$ necessary to compute Rayleigh spherical albedo for standard and actual pressure; this formula is as follows:

$$\mathrm{A}(\tau_R) = \frac{\exp(-\tau_R)(1 - \tau_R) + \tau_R^{\,2}(EXPI(\tau_R) - \ln(\tau_R))}{2}$$

where EXPI (τ_R) is the summation portion of the exponential integral function. The module "fintexp1" evaluates this summation portion of the integral function. Arguments for this function are shown in Table 34. Internal variables for this function are detailed in Table 35.

Table 34. fintexp3 (calc_Lamb.f) Arguments

Name	Type	Description	Units
xtau	Real*4	Molecular Optical Depth	Unitless
extau	Real*4	Exponential - Molecular Optical Depth	Unitless

Table 35. fintexp3 (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
fintexp1	Real	Evaluated Exponential Integral Function	Unitless
fintexp3	Real	Evaluated $A(\tau_R)$	Unitless
a	Real	Interpolation coefficients	Unitless

2.1.2.1.3.7 fintexp1 (calc_Lamb.f)

This function evaluates summation portion of the exponential integral function:

$$EXPI(\tau_R) = \sum_{i=0}^{4} a_i \tau_R{}^i$$

where a_i are the interpolation coefficients for the exponential function (defined within the parameter "a" in this module). Arguments for this function are shown in Table 36. Internal variables for this function are detailed in Table 37.

Table 36. fintexp1 (calc_Lamb.f) Arguments

Name	Type	Description	Units
xtau	Real*4	Molecular Optical Depth	Unitless

Table 37. fintexp1 (calc_Lamb.f) Internal Variables

Name	Type	Description	Units
fintexp1	Real	Evaluated Exponential Integral Function	Unitless
a	Real	Interpolation coefficients	Unitless

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There are two cases where graceful degradation is indicated for the Surface Reflectance IP.

1. The primary input denoted in the algorithm configuration guide cannot be successfully retrieved but an alternate input can be retrieved.

2. An input retrieved for the algorithm had its N_Graceful_Degradation metadata field set to YES (propagation).

Table 38 details the instances of these cases for the Surface Reflectance IP. Note that the shades cells indicate that graceful degradation was done upstream at product production.

Table 38. Surface Reflectance Graceful Degradation

Input Data Description	Baseline Data Source	Primary Backup Data Source	Secondary Backup Data Source	Tertiary Backup Data Source	Graceful Degradation Done Upstream
Total Column Ozone	VIIRS_GD_09.4.1 NCEP	VIIRS_GD_09.4.1 NCEP (Extended Forecast)	N/A	N/A	Yes
Total Column Precipitable Water	VIIRS_GD_09.4.11 NCEP	VIIRS_GD_09.4.11 NCEP (Extended Forecast)	N/A	N/A	Yes
Adjusted Surface Pressure	VIIRS_GD_28.4.1 NCEP	VIIRS_GD_28.4.1 NCEP (Extended Forecast)	N/A	N/A	Yes
Aerosol Optical Thickness	VIIRS_GD_15.4.1 NCEP	VIIRS_GD_25.4.1 NAAPS	VIIRS_GD_15.4.1 Climatology	N/A	Yes, backup only

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

The VIIRS Surface Reflectance Unit software is designed to handle a wide variety of processing problems, including bad and missing data and fatal errors. Any exceptions or errors are reported to IDPS using the appropriate INF Application Program Interface (API). All input is assumed to be available with the graceful degradation plan implemented.

Since quality of SDR data is accessed before processing, if missing or out of range pixels are detected in any of the input data then a fill value for Surface Reflectance is set to NA_FLOAT32_FILL.

VIIRS Surface Reflectance algorithm does not produce reflectance under all circumstances. If the pixel is night, thin cirrus, ocean, or confident cloudy then a fill value for floating point real values is set to NA_FLOAT32_FILL to indicate that a value was not computed if the value is out of range.

Since the Surface Reflectance outputs a floating-point number, range checking is implemented for Image and Moderate resolution. A fill value for floating point real values is set to NA_FLOAT32_FILL to indicate that a value was not computed.

Science exceptions were implemented to check for divide by zero and on invalid molecular depth. If either is detected, a failure message is sent to INF and processing does not complete.

2.1.5 Data Quality Monitoring

No Data Quality tests or notifications are required for Surface Reflectance.

2.1.6 Computational Precision Requirements

None

2.1.7 Algorithm Support Considerations

INF and DMS must be running before the Surface Reflectance algorithm is executed.

2.1.8 Assumptions and Limitations

2.1.8.1 Assumptions

The Surface Reflectance algorithm assumes all input data are available before processing.

2.1.8.2 Limitations

None

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

The current glossary for the NPOESS program, D35836_H_NPOESS_Glossary, can be found on eRooms. Table 39 contains those terms most applicable for this OAD.

Table 39. Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of: 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Configuration Control Board (ACCB)	Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations.
Ancillary Data	Any data which is not produced by the NPOESS System, but which is acquired from external providers and used by the NPOESS system in the production of NPOESS data products.
Auxiliary Data	Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the NPOESS system, and used to produce the NPOESS deliverable data products.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.). *[Supplementary Definition]* An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT.

Term	Description
Operational-Grade Software	Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code.
Raw Data Record (RDR)	*[IORD Definition]* Full resolution digital sensor data, time referenced and earth located, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression. *[Supplementary Definition]* A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use.
Retrieval Algorithm	A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing.
Science Algorithm	The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade".
Science Algorithm Provider	Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.
Science-Grade Software	Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure.
SDR/TDR Algorithm	Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Sensor Data Record (SDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data. *[Supplementary Definition]* A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data.

Term	Description
Temperature Data Record (TDR)	*[IORD Definition]* Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. *[Supplementary Definition]* A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.

3.2 Acronyms

The current acronym list for the NPOESS program, D35838_H_NPOESS_Acronyms, can be found on eRooms. Table 40 contains those terms most applicable for this OAD.

Table 40. Acronyms

Acronym	Description
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
CDFCB-X	Common Data Format Control Book - External
DMS	Data Management Subsystem
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
DQTT	Data Quality Test Table
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LQF	Land Quality Flag
LUT	Look-Up Table
MDFCB	Mission Data Format Control Book
QF	Quality Flag
RTM	Radiative Transfer Model
SATM	Atmospheric (Rayleigh) Spherical Albedo
SDR	Sensor Data Record
SEZ	Satellite Zenith
SI	International System of Units
SOZ	Solar Zenith
TBD	To Be Determined
TBR	To Be Resolved
TGOG	Gaseous Transmittance of Gases
TGOZ	Ozone Gaseous Transmittance
TGWV	Water Vapor Transmittance
TGWVHALF	Water Vapor Half Content Transmittance
TOA	Top of the Atmosphere
VCM	VIIRS Cloud Mask

4.0 OPEN ISSUES

Table 41. TBXs

TBX ID	Title/Description	Resolution Date
None		