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

For Public Release

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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

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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:

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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 for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	05/14/2013	**474-CCR-13-0948:** This version authorizes 474-00069, JPSS OAD Document for VIIRS SR IP Software, for the Mx 7.0 IDPS release. Includes **ECR-ALG-0037** which contains Raytheon PCR028892; OAD: Surf Refl OAD needs update, on Table 18. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.
Revision C	11/06/2013	**474-CCR-13-1288:** This version authorizes 474-00069, JPSS OAD Document for VIIRS SR IP Software, for the Mx 8.0 IDPS release. Includes administrative changes authorized by interoffice memo and Raytheon PCR033831; OAD: Update SR IP OAD for NOGAPS to NAVGEM (FNMOC) change, in Tables 3 & 22.
Revision D	03/05/2014	**474-CCR-14-1590:** This version authorizes 474-00069, JPSS OAD Document for VIIRS SR IP Software, for the Mx 8.3 IDPS release. Includes Raytheon PCR035976; Child: PRO: OAD: 474-CCR-13-1078: VIIRS Land SR IP and SR GIP Changes for DRs 4488_7141_7142_7008_7016, in Tables 7, 18 & 22 and sections 2.1.2 and 2.1.2.1, and Figures 2 & 3.
Revision E	03/13/2017	**474-CCR-17-3243 (ECR-CGS-0734):** This version authorizes 474-00069, JPSS OAD Document for VIIRS SR IP Software, for the Block 2.0 IDPS release. Includes Raytheon PCR045678**:** Block 2.0: PRO: OAD: CCR: 474-CCR-15-2444: General OAD Clean-up CCR/PCR, affects all 35/37 OADs. All sections and tables may be affected.

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

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

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

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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.

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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

Northrop Grumman Space & Mission Systems Corp. **Space Technology** One Space Park Redondo Beach, CA 90278	NORTHROP GRUMMAN Raytheon
Revision/Change Record	**Document Number D38697**

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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
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

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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 Joint Polar Satellite System (JPSS) 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 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, D0001-M01-S01-026.

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 Algorithm Theoretical Basis Document ATBD	D0001-M01-S01-026	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 15	474-00448-01-15_JPSS-SRS-Vol-I-Part-15	Latest

Document Title	Document Number/Revision	Revision Date
	474-00448-02-15_JPSS-DD-Vol-II-Part-15 474-00448-03-15_JPSS-OAD-Vol-III-Part-15 474-00448-04-15_JPSS-SRSPF-Vol-IV-Part-15	
Joint Polar Satellite System (JPSS) Program Lexicon	470-00041	Latest
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 Jul 2007
NGST/SE technical memo – NPP_Surface_Reflectance_IP_Coefficient_Update	NP-EDM.2008.510.0005	18 Jan 2008
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_Updates	NP-EMD.2008.510.0061	12 Nov 2008
Operational Algorithm Description Document for the Granulate Ancillary Software	474-00089	Latest
NGST/SE technical memo – Update_of_gaseous_transmittance_coefficients_for_the VIIRS_surface_reflectance_code	NP-EMD.2010.510.0014	15 Apr 2010
NGST/SE technical memo – Update_to_the_solar_zenith_angle_threshold_parameter_for_surface_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

Reference Title	Identification Label/Version	Revision Date
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
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)
OAD transitioned to JPSS Program – this table is no longer updated.		

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 in the Daily Surface Reflectance Tile and SR-BT-VI Tile gran to grid updating. 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.

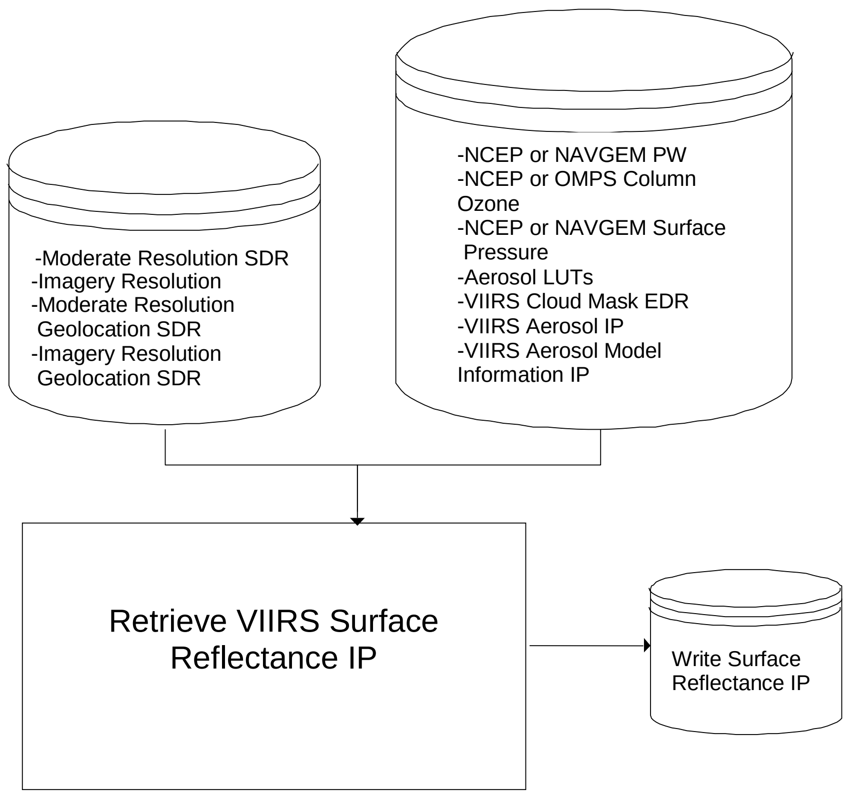

Figure 1. Processing Chain

See the VIIRS Surface Reflectance ATBD, D0001-M01-S01-026, 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

To begin processing the data, the Infrastructure (INF) Software Item (SI) initiates the VIIRS Surface Reflectance IP algorithm. The INF SI provides tasking information to the algorithm indicating which granule is processed. The Data Management Subsystem (DMS) SI provides data storage and retrieval capability. A library of C++ classes is used to implement the SI interfaces. More information regarding these topics is found in document UG60917-IDP-1005 with reference in particular to sections regarding PRO Common (CMN) processing and the IPO Model.

2.1.1.1 Inputs

In order to compute the Surface Reflectance IP several types of data are required, as summarized in 474-00448-01-15_JPSS-SRS-Vol-I-Part-15, Table 3-1. 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. Listed below is a detailed list of the inputs and a reference to the description of the inputs.

Table 3. Inputs

Input	Description	Reference Documents
VIIRS Moderate Resolution SDR	TOA Reflectance for bands M1, M2, M3, M4, M5, M7, M8, M10, and M11 stored in VIIRS Moderate Resolution SDR	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Moderate Resolution Geolocation	Solar Zenith angle, View Zenith angle, Solar Azimuth angle and View Azimuth angle stored in the Moderate Geolocation structure	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Imagery Resolution SDR	Top of Atmosphere (TOA) Reflectance for bands I1, I2, and I3	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Cloud Mask EDR	Moderate resolution pixels that include 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.	474-00448-02-11_JPSS-DD-Vol-II-Part-11
VIIRS Aerosol Optical Thickness (AOT) EDR	Array indicating the value of the Aerosol Optical Thickness for each VIIRS moderate resolution pixel for each band.	474-00448-02-12_JPSS-DD-Vol-II-Part-12
VIIRS Aerosol Model Information IP	The Aerosol Model Information IP used for the AOT Determination for each VIIRS moderate resolution pixel	474-00448-02-12_JPSS-DD-Vol-II-Part-12
Ancillary Data	Precipitable Water, Column Ozone and Surface Pressure NCEP Granulated Ancillary data	Refer to Section 2.1.1.1.1 for a detailed description of the input Ancillary Data
Surface Reflectance LUTs	Lookup tables (LUTs) that used by the Surface Reflectance code.	Refer to Section 2.1.1.1.2 for a detailed description of the input LUTs
Surface Reflectance Coefficients	Surface Reflectance tunable parameters	474-00448-02-15_JPSS-DD-Vol-II-Part-15

2.1.1.1.1 Ancillary Data

The Surface Reflectance processing also requires ancillary datasets from National Center for Environmental Prediction (NCEP), or the alternatives to the NCEP data. 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.

2.1.1.1.1.1 Precipitable Water

Table 4 describes the fields extracted from the Precipitable Water NCEP Granulated Ancillary data for use in the Surface Reflectance IP.

Table 4. NCEP Precipitable Water

Field Name	Description
"Precipitable Water"	NCEP Precipitable Water Ancillary data product.

2.1.1.1.1.2 Column Ozone

Table 5 describes the fields extracted from the Column Ozone NCEP Granulated Ancillary data for use in the Surface Reflectance IP.

Table 5. NCEP Column Ozone

Field Name	Description
"Column Ozone"	NCEP Column Ozone Ancillary data product.

2.1.1.1.1.3 Surface Pressure

Table 6 describes the fields extracted from the Surface Pressure NCEP Granulated Ancillary data for use in the Surface Reflectance IP.

Table 6. NCEP Surface Pressure

Field Name	Description
"Surface_Pressure"	NCEP Surface Pressure Ancillary data product.

2.1.1.1.2 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: JPSS-DD-Vol-II-Part-15, Section 7.1.1.3
Spherical Albedo: JPSS-DD-Vol-II-Part-15, Section 7.1.1.8

Atmosphere Reflectance: JPSS-DD-Vol-II-Part-15, Section 7.1.1.2
Aero-Optical-Depth/Tau: JPSS-DD-Vol-II-Part-15, Section 7.1.1.1
Solar Zenith Angle: JPSS-DD-Vol-II-Part-15, Section 7.1.1.5
Satellite Zenith Angle: JPSS-DD-Vol-II-Part-15, Section 7.1.1.7
Incremental Scattering Angle: JPSS-DD-Vol-II-Part-15, Section 7.1.1.4
Scattering Angle: (see JPSS-DD-Vol-II-Part-15, Section 7.1.1.6)

2.1.1.2 Outputs

474-00448-01-15_JPSS-SRS-Vol-I-Part-15, Table 3-1describes the VIIRS Surface Reflectance IP output files. Refer to 474-00448-02-15_JPSS-DD-Vol-II-Part-15, Section 4.1.1 for a detailed description of the outputs.

Table 7. Outputs

Output	Description	Reference Documents
VIIRS Surface Reflectance IP	The VIIRS Surface Reflectance IP consists of surface reflectance values for VIIRS spectral bands I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, and M11. It also includes associated land quality flags.	474-00448-02-15_JPSS-DD-Vol-II-Part-15

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 day and not ocean by the Land Quality Flags. If the pixel is flagged, it contains a fill value, (NA_FLOAT32_FILL).

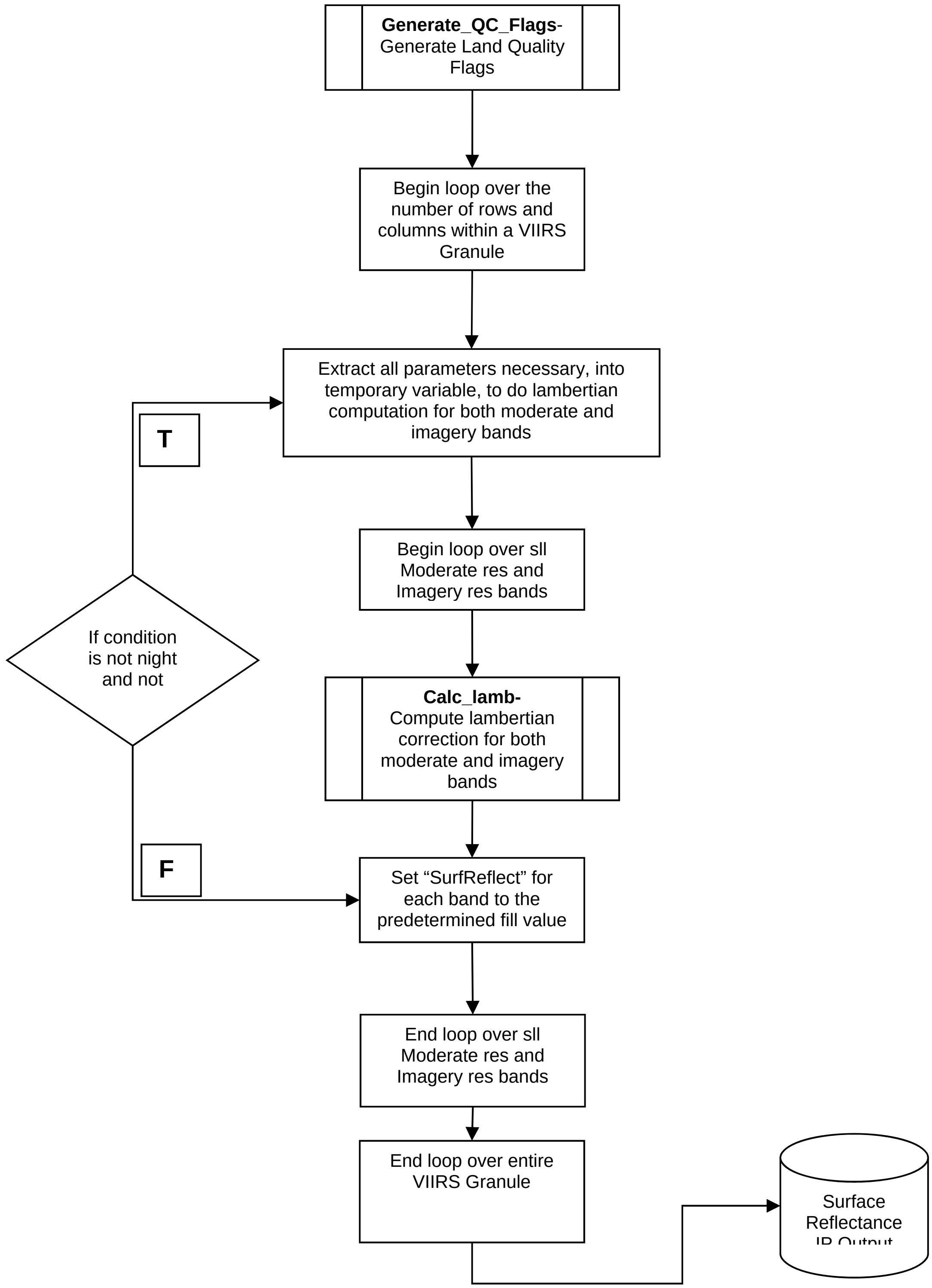

Figure 2. Flow of Generate_SurfReflect_IP

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 8. This function requires inclusion of the “SurfReflect.h” include file. It subsequently calls the following functions to produce the final IP:[DCC1]

1. Generate_QC_Flags – This function produces the Quality Flags (QF) used to characterize the quality of the Surface Reflectance retrieval.
2. 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 Ocean
- Not Night

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 8. Generate_SurfReflect_IP.cpp Arguments

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

2.1.2.1.1 [DCC2]Generate_QC_Flags.cpp

This is a function for generating Surface ReflectanceQFs. The QFs are used for retrieval logic and to provide information and guidance to the end users. VCM and the VIIRS AOT IPs, as well as the SR IP retrieval are used to generate these flags. Arguments for this function are shown in Table 9. The flow of this function is shown in Figure 3.

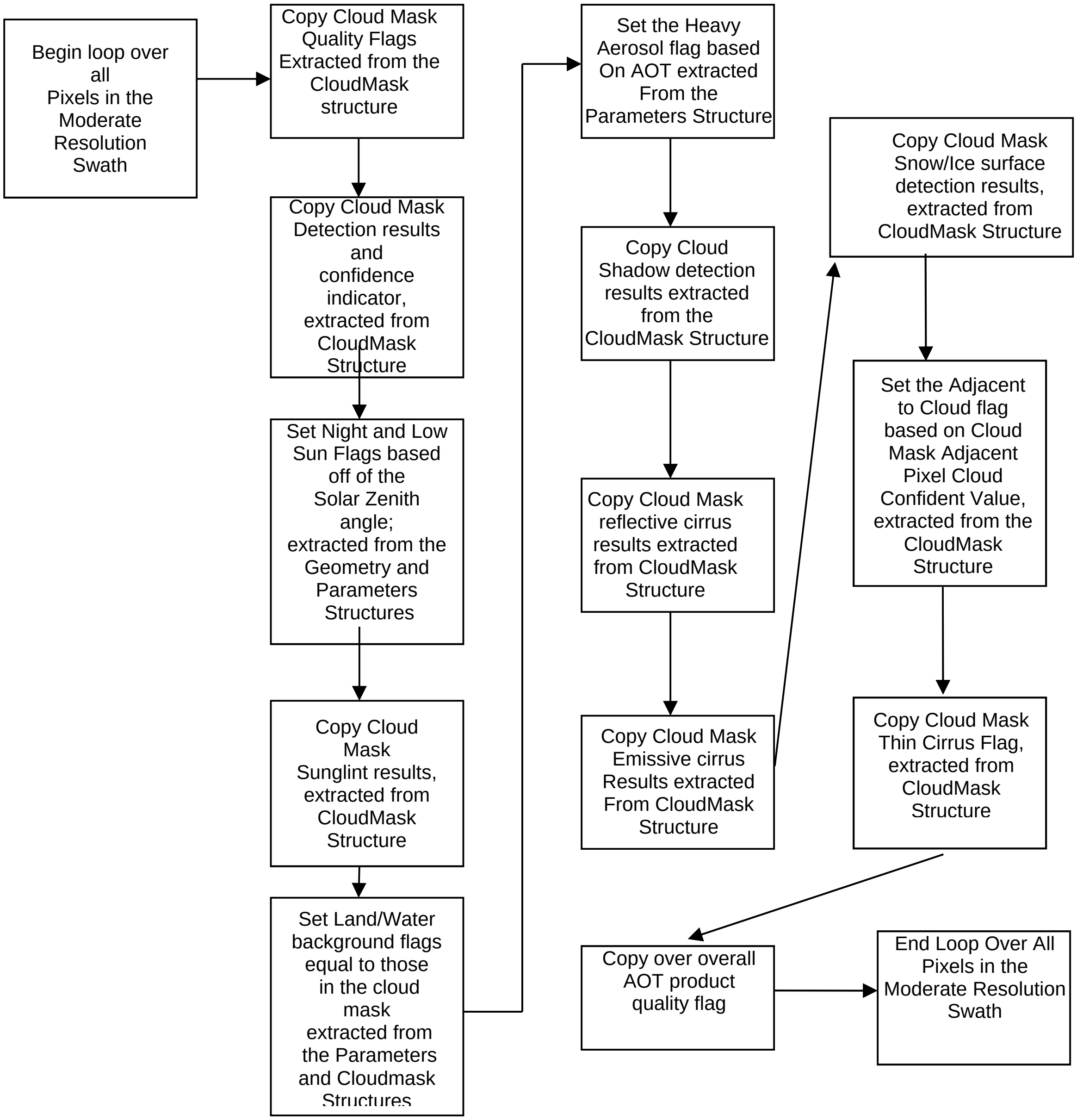

Figure 3. Flow of "Generate_QC_Flags"

Table 9. Generate_QC_Flags.cpp Arguments

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

2.1.2.1.2 Calc_Lamb.f

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

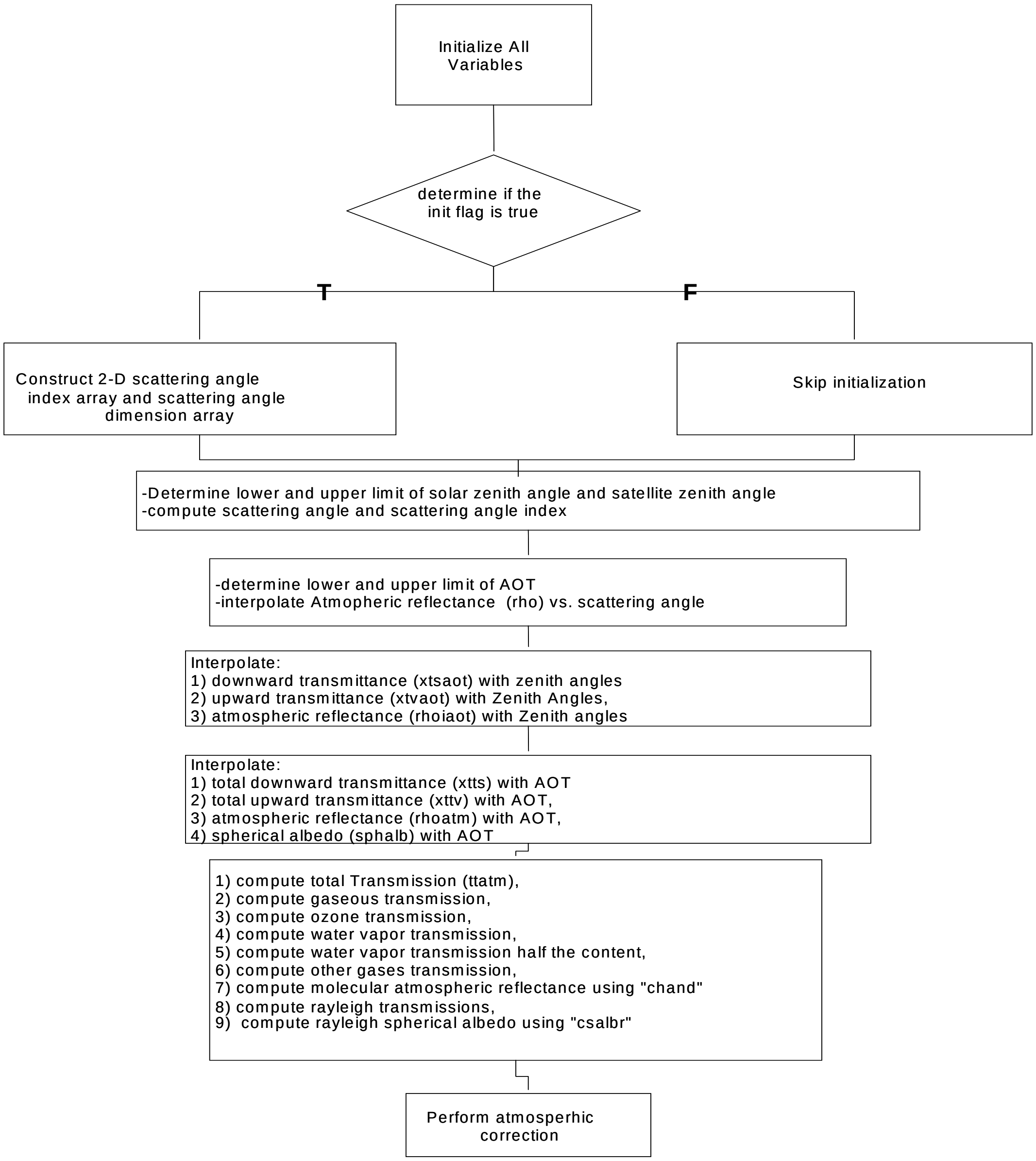

Figure 4. Flow of calc_lamb

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, D0001-M01-S01-026.

Arguments for this function are shown in Table 10. Internal variables for this function are detailed in Table 11. 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 2.1.1.1.2 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, $\mathbf{soz_i}$= ith solar zenith entry from the LUT, and $\mathbf{sez_i}$ = 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:

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

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 2.1.2.1.2.1)
4. Water Vapor and Half Water Vapor transmittance (see Section 2.1.2.1.2.2)
5. Other Gas transmittance (see Section 2.1.2.1.2.3)
6. Molecular atmospheric reflectance at standard pressure (see Section 2.1.2.1.2.4)
7. Molecular atmospheric reflectance at actual pressure (see Section 2.1.2.1.2.4)
8. Rayleigh Spherical Albedo at actual pressure (see Section 2.1.2.1.2.5)
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 2.1.2.1.2.5
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 τ_RP, 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 10. Calc_Lamb.f Arguments

Name	Description
xts	Solar Zenith Angle
xtv	Sensor View Zenith Angle
xfi	Relative Azimuth Angle
raot550nm	AOT at 550nm
imod	Aerosol Model Information IP
uwv	NCEP or FNMOC PW
uoz	OMPS or NCEP Column Ozone
pres	NCEP or FNMOC Surface Pressure
ib	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
rotoa	TOA Reflectance
roslamb	Lambertian Surface Reflectance
roatm	Interpolated Atmospheric Reflectance
xrorayp	Molecular Atmospheric Reflectance at actual pressure
cxfi	Cosine Relative Azimuth
cxfi2	Cosine 2*Relative Azimuth
xmuv	Cosine Solar Zenith
xmus	Cosine Sensor Zenith
xsum	Cosine (Solar + Sensor Zenith)

Name	Description
ptrs	Pointers to input and output data for Surface Reflectance

Table 11. Calc_Lamb.f Internal Variables

Name	Description
trans	Downward Transmittance LUT
sphalb	Sperical Albedo LUT
rolut	Atmospheric reflectance LUT
aot550nm	AOT Attribute from the LUT
xtts	Solar Zenith Angles Attribute from the LUT
ttv	View Zenith Angles Attribute from the LUT
dscatt	Incremental scattering angle
numscat	Scattering angle dimensions
tauray	Rayleigh Optical Depth array for each VIIRS band

2.1.2.1.2.1 O3_trans (calc_Lamb.f)

This subroutine computes the ozone transmittance (**toz**) 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 12. Internal variables for this function are detailed in Table 13.

Table 12. O3_trans (calc_Lamb.f) Arguments

Name	Description
m	Gaseous Transmission
uoz	Integrated columnar ozone content
ib	Band number
toz	Ozone transmittance

Table 13. O3_trans (calc_Lamb.f) Internal Variables

Name	Description
oztransa	12 element table of “a-coefficients” for ozone

2.1.2.1.2.2 H2O_trans (calc_Lamb.f)

This function computes the water vapor gaseous transmittance (th2ousing the following equation:

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

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 14. Internal variables for this function are detailed in Table 15.

One more thing to note is that if the product of the air mass and PW is less than or equal to $1\text{x}10^{-6}$, then the water vapor gaseous transmittance is set to 1.

Table 14. H2O_trans (calc_Lamb.f) Arguments

Name	Description
m	Gaseous Transmission
uwv	Total PW
ib	Band number
th2o	Water vapor gaseous transmittance

Table 15. H2O_trans (calc_Lamb.f) Internal Variables

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

2.1.2.1.2.3 OG_trans (calc_Lamb.f)

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

$$Tg^{\,i}_{OG}(m,P) = \exp\begin{bmatrix} m\left(a^i_0 P + a^i_1 \log(P)\right) + \log(m)\left(b^i_0 P + b^i_1 \log(P)\right) + \\ m\log(m)\left(c^i_0 P + c^i_1 \log(P)\right) \end{bmatrix}$$

where P is the input surface pressure, m is the air mass, a^i_0, a^i_1, b^i_0, b^i_1, c^i_0, and c^i_1 represent coefficients in the “Other Gases” LUT, which are hard-coded in this subroutine. Arguments for this function are shown in Table 16. Internal variables for this function are detailed in Table 17.

Table 16. OG_trans (calc_Lamb.f) Arguments

Name	Description
m	Gaseous Transmission
p	Surface Pressure
ib	Band number
tog	Other gaseous transmittance

Table 17. OG_trans (calc_Lamb.f) Internal Variables

Name	Description
ogtransa0	12 element table of “a0-coefficients” for Other gaseous transmission

Name	Description
ogtransa1	12 element table of “a1-coefficients” for Other gaseous transmission
ogtransb0	12 element table of “b0-coefficients” for Other gaseous transmission
ogtransb1	12 element table of “b1-coefficients” for Other gaseous transmission
ogtransc0	12 element table of “c0-coefficients” for Other gaseous transmission
ogtransc1	12 element table of “c1-coefficients” for Other gaseous transmission

2.1.2.1.2.4 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 18. Internal variables for this function are detailed in Table 19.

Table 18. chand (calc_Lamb.f) Arguments

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

Table 19. chand (calc_Lamb.f) Internal Variables

Name	Description
xdep	Depolarization factor = 0.0279
xbeta2	Constant with value 0.5
as0	10 element data array
as1	2 element data array
as2	2 element data array

2.1.2.1.2.5 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). 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 2.1.2.1.2.6) and “fintexp1” (Section 2.1.2.1.2.7).

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 20. Internal variables for this function are detailed in Table 21.

Table 20. csalbr (calc_Lamb.f) Arguments

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

Table 21. csalbr (calc_Lamb.f) Internal Variables

Name	Description
fintexp3	Evaluated $\mathrm{A}(\tau_R)$

2.1.2.1.2.6 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 22. Internal variables for this function are detailed in Table 23.

Table 22. fintexp3 (calc_Lamb.f) Arguments

Name	Description
xtau	Molecular Optical Depth
xlntau	Log Molecular Optical depth at standard or actual pressure
extau	Exponential - Molecular Optical Depth

Table 23. fintexp3 (calc_Lamb.f) Internal Variables

Name	Description
fintexp1	Evaluated Exponential Integral Function
fintexp3	Evaluated $A(\tau_R)$

2.1.2.1.2.7 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 24. Internal variables for this function are detailed in Table 25.

Table 24. fintexp1 (calc_Lamb.f) Arguments

Name	Description
xtau	Molecular Optical Depth

Table 25. fintexp1 (calc_Lamb.f) Internal Variables

Name	Description
fintexp1	Evaluated Exponential Integral Function
a	Interpolation coefficients

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 26 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 26. 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

Table 26 contains those terms most applicable for this OAD.

Table 27. 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 JPSS, 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 Engineering Review Board (AERB)	Interdisciplinary board of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Data Process Algorithm Lead, members include representatives from STAR, DPES, IDPS, and Raytheon..
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 GRAVITE facility. Delivered code is executed on compatible GRAVITE 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 JPSS System, but which is acquired from external providers and used by the JPSS system in the production of JPSS 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 JPSS system, and used to produce the JPSS 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 JPSS 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 the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model.
Operational Code	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications.
Operational-Grade Software	Verified science-grade software, delivered by an algorithm provider and verified by GRAVITE, is developed into operational-grade code by the IDPS IPT.

Term	Description
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 JPSS (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/JPSS 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

Table 28 contains terms most applicable for this OAD.

Table 28. Acronyms

Acronym	Description
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
DMS	Data Management Subsystem
DQTT	Data Quality Test Table
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LQF	Land Quality Flag
LUT	Look-Up Table
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 29. TBXs

TBX ID	Title/Description	Resolution Date
None		