

**GSFC JPSS CMO**  
**April 6, 2017**  
**Released**

**Joint Polar Satellite System (JPSS) Ground Project**  
**Code 474**  
**474-00057**

**Joint Polar Satellite System (JPSS)**  
**Operational Algorithm Description**  
**(OAD)**  
**Document for Atmospheric Correction**  
**Over Ocean / Ocean Color**  
**Chlorophyll (ACO/OCC)**  
**Environmental Data Record (EDR)**  
**Software**

**For Public Release**

The information provided herein does not contain technical data as defined in the International Traffic in Arms Regulations (ITAR) 22 CFC 120.10. This document has been approved For Public Release to the NOAA Comprehensive Large Array-data Stewardship System (CLASS).



**Goddard Space Flight Center**  
**Greenbelt, Maryland**

National Aeronautics and  
Space Administration

**Joint Polar Satellite System (JPSS)  
Operational Algorithm Description (OAD) Document for  
Atmospheric Correction Over Ocean / Ocean Color  
Chlorophyll (ACO/OCC) Environmental Data Record  
(EDR) 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.

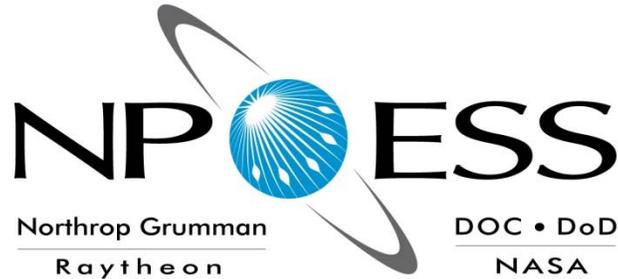
Any questions should be addressed to:

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## Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	05/20/2011	<b>474-CCR-11-0075:</b> This version baselines D36813, Operational Algorithm Description (OAD) Document for Atmospheric Correction Over Ocean / Ocean Color Chlorophyll (ACO/OCC), Rev A, dated 02/11/09, as a JPSS document, version Rev -. This is the version that was approved for NPP launch. Per NPOESS CDFCB - External, Volume V – Metadata, doc number D34862-05, this has been approved for Public Release into CLASS. This CCR was approved by the JPSS Algorithm ERB on May 20, 2011.
Revision A	01/18/2012	<b>474-CCR-11-0253:</b> This version baselines 474-00057, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for Atmospheric Correction Over Ocean / Ocean Color Chlorophyll (ACO/OCC) Environmental Data Record (EDR) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	10/09/2012	<b>474-CCR-12-0627:</b> This version authorizes 474-00057, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for Atmospheric Correction Over Ocean / Ocean Color Chlorophyll (ACO/OCC) Environmental Data Record (EDR) Software, for the Mx 6.1 – 6.3 IDPS releases. Includes <b>ECR-ALG-0035</b> which contains Raytheon PCR031656, OAD: Implement 474-CCR-11-0219 (OCV3 Revised RSR Look Up Table Update) (ADR 4395), updated in Table 15.
Revision C	02/20/2013	<b>474-CCR-13-0835:</b> This version authorizes 474-00057, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for Atmospheric Correction Over Ocean / Ocean Color Chlorophyll (ACO/OCC) Environmental Data Record (EDR) Software, for the Mx 6.6 IDPS release. Includes <b>ECR-ALG-0036</b> which contains Raytheon PCR032887; OAD: Implement 474-CCR-12-0685 (OCC Updates to Increase Retrievals for Mx 6.5) (ADRs 4869, 4877, 4898), on pages 6, 18, 19, 22, 24, 31, 32, & 35. Also includes <b>ECR-ALG-0038</b> , which contains PCR033853; OAD: Update OCC OAD per direction from AERB (474-AI-0018), updates section 2.1.2.9 (this update supersedes the changes found in CCR-0685 for this section only).
Revision D	05/14/2013	<b>474-CCR-13-0948:</b> This version authorizes 474-00057, JPSS OAD Document for ACO/OCC EDR Software, for

		the Mx 7.0 IDPS release. Includes <b>ECR-ALG-0037</b> which contains Raytheon PCRs: PCR028974; OCC OAD needs update for QF descriptions, in Section 2.1.1.2.; PCR029386; OAD: PRO: OCC OAD updates for 4 QF descriptions, in Section 2.1.1.2.; PCR030137; OAD: Implement 474-CCR-12-0349 (VIIRS-OCC-EDR-AC Update), in Section 2.1.2.9. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.
Revision E	07/10/2013	<b>474-CCR-13-1101:</b> This version authorizes 474-00057, JPSS OAD Document for ACO/OCC EDR Software, for the Mx 7.1 IDPS release. Includes Raytheon <b>ECR-ALG-0039/PCR033577:</b> ACO/OCC OAD update to clarify wind direction, in Table 4.
Revision F	03/13/2017	<b>474-CCR-17-3243 (ECR-CGS-0740):</b> This version authorizes 474-00057, JPSS OAD Document for ACO/OCC EDR 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 ATMOSPHERIC  
CORRECTION OVER OCEAN / OCEAN  
COLOR CHLOROPHYLL (ACO/OCC)**

**SDRL No. S141  
SYSTEM SPECIFICATION SS22-0096**

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

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**Engineering & Manufacturing Development (EMD) Phase  
Acquisition & Operations Contract**

**CAGE NO. 11982**

**Operational Algorithm Description Document  
Atmospheric Correction Over Ocean (ACO) for Production of Remote  
Sensing Reflectance (RSR) Intermediate Product and the Ocean Color  
/ Chlorophyll (OCC) EDR**

**Document Date: Nov 05, 2011**

**Document Number: D36813  
Revision: B10**

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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. <b>Space Technology</b> One Space Park Redondo Beach, CA 90278		 	
<b>Revision/Change Record</b>		<b>Document Number D36813</b>	
Revision	Document Date	Revision/Change Description	Pages Affected
---	3-31-03	Initial Release.	All
A1	7-22-03	Updated to combine ACO, OCC algorithms and IDPS changes.	All
A2	2-5-04	Updated to list units in input and output tables, ERB updates.	All
A3	5-4-05	Reflects NGST comment corrections plus inserted new logo and updated upper right header date, title/signature page dates, Revision/Change Record.	All
A4	7-13-05	Reflects dCUTPR comment corrections. Removed export markings per 26May05 official policy change and under section 1.3.2, Source Code 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	5-19-06	15Dec05 – Reflects corrections based on reviewer comments from the 15Dec05 Follow-on I-P-O dDDPR. 20Dec05 – Inserted new Figure 2 per Tim Gardner's comment. 09Mar06 – Updated per comments from follow-on I-P-O CUTPR. Inserted latest Unit Test (03/07/06); removed section 5.2 Summary of Differences (same data is in Unit Test); renumbered all tables due to removal of Table 1, 3, and 4 plus fixed all table references within the text; updated Table of Contents, List of Tables, and List of Figure page numbers. 17Apr06 – added aerocoef to Table 2, added ylog & y2 to Table 3, added thetav and updated parameter dimension, removed note in 2.3.8.1. 21Apr06 – updated OAD per Tech Memo NP-EMD.2005.510.xxxx. 08May06 – updated Fig2, table data, added main inputs dimensional parameter table. 16May06 – Inserted a 19May06 date in doc's upper right header and next to Raytheon electronic signatures in preparation for official delivery on that date. Inserted Raytheon electronic signatures. Made other edits in preparation for delivery. 19May06 – Fixed Omaha QA's suggested changes.	All

Northrop Grumman Space & Mission Systems Corp. <b>Space Technology</b> One Space Park Redondo Beach, CA 90278		 	
<b>Revision/Change Record</b>			<b>Document Number D36813</b>
Revision	Document Date	Revision/Change Description	Pages Affected
A6	9-25-06	Updated Document ID number from D36813-IDP-002 to D36813 per NGST DM.	All
A7	6-15-07	Logo, cleanup updates. Delivered to NGST.	All
A8	12-13-07	ECR A-103, EDRPR 1.8 CP 3 updates -Format changes for CDFCB-X compliance- removed Table 2.2.3-3. Granule Level Quality Bit Flags for the VIIRS OCC EDR.	All
A9	2-14-08	ECR A-132 updates for Drop 4.1.2 delivery.	All
A10	9-4-08	Updated Graceful Degradation.	27, TOCs
A11	10-15-08	Updated for NP-EMD.2008.510.0020, NP-EMD-2008.510.0008. Prepared for NGST delivery.	All
A12	12-4-08	Addressed NGST SDRL comments.	All
A13	1-21-09	Updated based on comments from TIM (CDA RFA Nos. 278 & 282	6, 14, 19 & 30
A	2-11-09	Rev rolled for ACCB Delivery	All
B1	4-1-09	Updated table 4 (Main Inputs) and section 2.1.2.2 to correct the units of total column ozone from Dobson units to atm-cm	8, 16
B2	11-4-09	Incorporated RFA Nos. 277, 279, 280, 281& 546; implemented the OAD portion of PCR21639 (Table 15); updated for SDRL	All
B3	2-10-2010	Implemented TM NP-EMD.2009.510.0057_NPP_RevA_OC_QualityFlagUpdates	All
B4	5-10-10	Replaced reference from ETOPO30 to SRTM30+, updated the SCN, logo, and copyright no.	4, cover pages
B5	07-08-10	Prepared for OAD Giver UID 35077	All
B6	09-23-10	Incorporated Drop 4.24 and prepared for SDRL	All
B7	10-12-10	Updated due to document convergence, to include tech memos 2010.510.0011, 2010.510.0012, 2010.510.0013, 2010.510.0014, 2010.510.0015, 2010.510.0016,	All
B8	03-01-11	Changes for OCC Drop 4.24.2: TM NP-EMD.2010.510.0101, NP-EMD.2010.510.0102, and NP-EMD.2010.510.0103 (PCR026155)	ALL
B9	09-26-11	Updated for PCR026650.	ALL
B10	11-05-11	Updated for PCR026447	Table 18



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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.

**1.2 Scope**

The scope of this document is limited to the description of the core operational algorithm(s) required to create the VIIRS RSR IP and the VIIRS OCC EDR. The theoretical basis for this algorithm is described in Section 3.3 of the VIIRS Atmospheric Correction Over Ocean Algorithm Theoretical Basis Document ATBD, D0001-M01-S01-029 and VIIRS Ocean Color/Chlorophyll Algorithm Theoretical Basis Document ATBD, D0001-M01-S01-009.

**1.3 References**

The primary software detailed design documents listed here include science software documents; JPSS program documents; plus source code and test data references.

**1.3.1 Document References**

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 Atmospheric Correction Over Ocean Algorithm Theoretical Basis Document ATBD	D0001-M01-S01-029	Latest
VIIRS Ocean Color/Chlorophyll Algorithm Theoretical Basis Document ATBD	D0001-M01-S01-009	Latest
MODIS Case 2 Chlorophyll a ATBD	ATBD 19 Version 7	30 Jan 2003

Document Title	Document Number/Revision	Revision Date
Joint Polar Satellite System (JPSS) Algorithm Specification Part 24	474-00448-01-24_JPSS-SRS-Vol-I-Part-24 474-00448-02-24_JPSS-DD-Vol-II-Part-24 474-00448-03-24_JPSS-OAD-Vol-III-Part-24 474-00448-04-24_JPSS-SRSPF-Vol-IV-Part-24	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 06	474-00448-02-06_JPSS-DD-Vol-II-Part-06	Latest
Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM EDR)	474-00062	Latest
Operational Algorithm Description Document for VIIRS Sea Surface Temperature (SST) Environmental Data Records (EDR)	474-00061	Latest
Operational Algorithm Description Document for the Granulate Ancillary Software	474-00089	Latest
JPSS Program Lexicon	470-00041	Latest
Applied Optics	Vol. 33, Issue 3	Jan1994
Applied Optics	Vol. 40	2001
<u>Gordon's Atmospheric correction of ocean color imagery in the Earth Observing System era, JGR</u>	Vol 102	1997
MS Engineering Memo_ACO-OCC OAD Update	NP-EMD.2005.510.0108	28 Aug 2005
NPP_VIIRS_ACO-OCC_BugsFix_20061106	NP-EMD.2006.510.0082	06 Nov 2006
NPP_Bright_Pixel_Flag_for_OceanColor	NP-EMD.2007.510.0051	04 Sep 2007
NPP_GracefulDegradation_for_OceanColor_Branching	NP-EMD.2007.510.0052	04 Sep 2007
NPP_ACO_CodeFixes_CT&Xtalk	NP-EMD.2007.510.0053	04 Sep 2007
NPP_OceanColor_OAD_Updates	NP-EMD.2007.510.0054	04 Sep 2007
VIIRS ACO Code Modifications and No Double Precision Implementation	NP-EMD.2008.510.0008 Rev. A	07 Feb 2008
VIIRS Ocean Color Science Code Updates	NP-EMD.2008.510.0020	15 Apr 2008
NPP_OceanColor_QualityFlagUpdate	NP-EMD.2009.510.0025	18 May 2009
NPP_RevA_OC_QualityFlagUpdates	NP-EMD.2009.510.0057	18 Jan 2010
VIIRS Ocean Color Science Code Updates Drop 4.24	NP-EMD.2010.510.0048	08 Jun 2010
NPP_OceanColor_InlandWater_Coastal_NoRetreval	NP-EMD.2010.510.0054	30 Jun 2010
NPP_OceanColor_GlintCorr&NegativeNLWUpdates	NP-EMD.2010.510.0062_RevB	24 Aug 2010
NGST/SE technical memos: LUT_OAD_Drop_History_Corrections LUT_Format_Corrections PC_OAD_Last_Drop_Corrections PC_Format_Corrections SAD_OAD_Last_Drop_Corrections SAD_Formatand Usage_Corrections	NPOESS GJM-2010.510.0011 NPOESS GJM-2010.510.0012 NPOESS GJM-2010.510.0013 NPOESS GJM-2010.510.0014 NPOESS GJM-2010.510.0015 NPOESS GJM-2010.510.0016	21 Sep 2010 21 Sep 2010 22 Sep 2010 22 Sep 2010 22 Sep 2010 22 Sep 2010
Joint Polar Satellite System (JPSS) Common Ground System (CGS) IDPS PRO Software User's Manual Part 2	UG60917-IDP-1005	Latest
NGST/SE technical memos: ACO Science Algorithm and LUT Updates Based on the VIIRS Fused RSR	NP-EMD.2010.510.0101	22 Dec 2010
NGST/SE technical memos: OC3V Regression Coefficient Update Based on the A&DP Global Synthetic Data using the VIIRS Fused RSR	NP-EMD.2010.510.0102	22 Dec 2010

Document Title	Document Number/Revision	Revision Date
NGST/SE technical memos: Ocean Color OAD Update	NP-EMD.2010.510.0103	22 Dec 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.

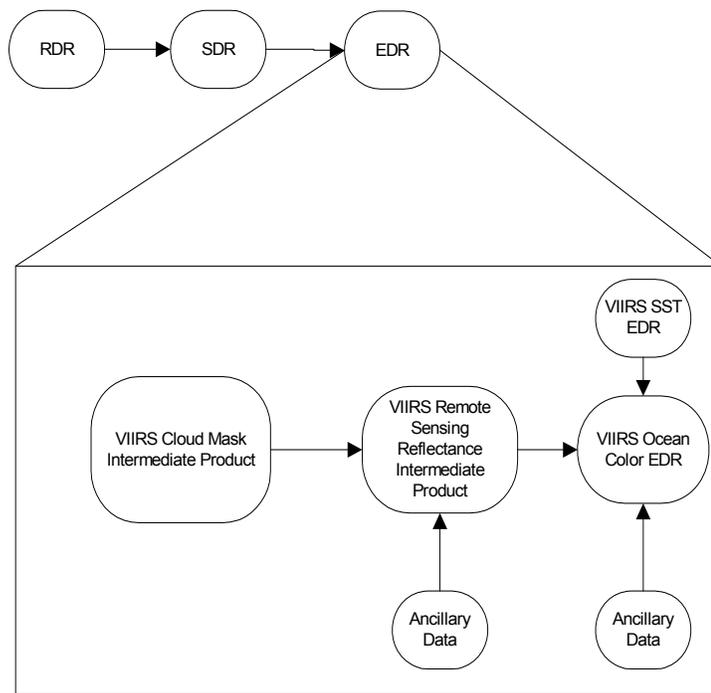
**Table 2. Source Code References**

Reference Title	Reference Tag/Revision	Revision Date
VIIRS ACO science-grade software	ISTN_VIIRS_NGST_1.0	31 Mar 2003
VIIRS OCC science-grade software	ISTN_VIIRS_NGST_1.0	31 Mar 2003
VIIRS ACO_OCC operational software	B1.4 (OAD Rev A4)	13 Jul 2005
VIIRS OCC science-grade software	ISTN_VIIRS_NGST_4.1 (ECR A-064A)	22 Sep 2005
Instruction for Updating the ACO-OCC OAD at the IDPS named 050504 SDRL S141 D36813-IDPS-002 VIIRS ACO OCC-OAD	NP-EMD.2005.510.0108	15 Sep 2005
VIIRS ACO_OCC operational software	B1.4 Follow-on (OAD Rev A5)	20 Apr 2006
VIIRS OCC science-grade software includes Tech Memo NP-EMD.2006.510.0082	ISTN_VIIRS_NGST_4.1.1_Data (ECR A-110C)	19 Dec 2006
VIIRS ACO_OCC operational software	B1.5 (OAD Rev A7)	15 Jun 2007
VIIRS OCC science-grade software includes Tech Memos NP-EMD.2007.510.0051 & NP-EMD.2007.510.0052	ISTN_VIIRS_NGST_4.1.2_Data (ECR -A132A)	26 Nov 2007
NPP_OceanColor_OAD_Updates	NP-EMD.2007.510.0054	04 Sep 2007
VIIRS OCC science-grade software	ISTN_VIIRS_NGST_4.1.3 (ECR A-139A)	12 Mar 2008
VIIRS OCC science-grade software includes Tech Memo NP-EMD.2008.510.0020	ISTN_VIIRS_NGST_4.1.4 (Data Only)	15 Apr 2008
VIIRS ACO/OCC Science software	ISTN_VIIRS_NGST_4.12	21 Oct 2008
VIIRS ACO/OCC operational software	B1.5.X.1 (OAD Rev A11)	15 Oct 2008
ACCB Approval	OAD Rev A	11 Feb 2009
SDRL	(OAD Rev B2)	04 Nov 2009
NPP_RevA_OC_QualityFlagUpdates NP-EMD.2009.510.0057 (PCR021792)	Sensor Characterization Build SC-14 (OAD Rev B3)	10 Feb 2010
VIIRS ACO/OCC Science software Includes Tech Memos: NPP_OceanColor_InlandWater_Coastal_NoRetrieval NP-EMD.2010.510.0054 (PCR024328) and NPP_OceanColor_GlintCorr&NegativeNLWUpdates NP-EMD.2010.510.0062_RevB (PCR024614)	ISTN_VIIRS_NGST_4.24 and ISTN_VIIRS_NGST_4.24.1_DATA Sensor Characterization Build SC-14 (ECR A-295) (OAD Rev B6)	23 Sep 2010
Convergence Updates (No code updates)	(OAD Rev B7)	12 Oct 2010
Changes for OCC Drop 4.24.2 (PCR026155) TM NP-EMD.2010.510.0101, NP-EMD.2010.510.0102, and NP-EMD.2010.510.0103	(OAD Rev B8)	11 Mar 2011
PCR026650 (OAD update for ADL)	(OAD Rev B9)	26 Sep 2011
PCR026447 (x-ref PCR026444) and PCR026155	(OAD Rev B10)	05 Nov 2011

Reference Title	Reference Tag/Revision	Revision Date
OAD transitioned to JPSS Program – this table is no longer updated.		

## 2.0 ALGORITHM OVERVIEW

This document details an operational algorithm description of the ACO and OCC units of the VIIRS Ocean Module algorithms. These algorithms produce the RSR IP and OCC EDR respectively. Most of the signal (about 90%) reaching a satellite-based visible-wavelength detector above the ocean is of atmospheric origin or reflected light from the sea surface. In order to obtain information like chlorophyll concentration just beneath the ocean surface, atmospheric and surface reflection components must be removed from the signal. Removing the atmospheric effects from the signals and creating the RSR IP is the purpose of the ACO algorithm. This RSR IP then becomes the input to the OCC algorithm in producing the OCC EDR.



**Figure 1. Processing Chain to Create VIIRS RSR IP and OCC EDR.**

Inputs to the algorithms are measured Top-Of-Atmosphere (TOA) VIIRS reflectances in the visible and near-infrared bands, VCM EDR, VIIRS Sea Surface Temperature (SST) EDR, SRTM30+ global bathymetric data and MODIS Nitrate Temperature Depletion (NDT) data interpolated to VIIRS granule resolutions, sea surface wind speed (SSWS), surface atmospheric pressure, and total column ozone. The ACO algorithm uses a sun glint flag, obtained from the VCM EDR to mask the sun glint exclusion. Bathymetric data is used to distinguish shallow water from deep water. Corrections are made for ozone absorption, whitecaps, and the sensitivity of the VIIRS instrument to radiation polarization. The algorithm then subtracts contributions of molecular and aerosol scattering in the atmosphere, as well as reflection from the air-sea interface from the corrected VIIRS reflectances.

For the OCC algorithm, the Case 2 Chlorophyll-*a* algorithm [ATBD 19] for use on the initial Moderate Resolution Imaging Spectroradiometer (MODIS) data is employed. This algorithm is based on the Carder semi-analytical, bio-optical model of remote sensing reflectance,  $R_{rs}(\lambda)$ , where remote sensing reflectance is defined as the normalized water-leaving radiance divided

by the downwelling irradiance just above the sea surface. The model has two free parameters—the absorption coefficient due to phytoplankton at 675-nm,  $a_{ph}(675)$ , and the absorption coefficient due to gelbstoff at 400-nm,  $a_g(400)$ . This model has many other parameters that are fixed or specified based on region and season of the scene. The initial MODIS strategy (MODIS ATBD 19, January 2003) using SST and NDT is employed to set variable packaging parameters.  $R_{rs}(\lambda)$  is modeled in the VIIRS visible bands.  $R_{rs}(\lambda)$  values at 412, 445, 488, 555, and 672 nm wavelengths are retrieved from the atmospheric correction algorithm and put into the model. The model is inverted and  $a_{ph}(675)$  and  $a_g(400)$  are computed. Chlorophyll-a concentration is then derived simply from the  $a_{ph}(675)$  value. This algorithm also outputs inherent optical properties (IOP) for both back-scattering and total absorption at the VIIRS visible wavelengths and the derived normalized water-leaving radiance at the five VIIRS visible bands. Additional inputs include the VIIRS retrieved SST and seasonal global NDT map. In highly turbid waters, an empirical  $R_{rs}(488)/R_{rs}(555)$  ratio algorithm is used instead of the bio-optics model to estimate chlorophyll concentration.

The ACO algorithm is performed only under clear-sky daytime conditions. Major sources of uncertainty in the retrieved normalized water-leaving radiance include: (1) possibility that the candidate aerosol models are not representative of some regions or selected aerosol models are not sufficiently accurate; (2) assumption of zero water-leaving radiance in two near-infrared bands are not valid for regions with high chlorophyll or coccolithophore concentration or turbid water; (3) uncertainty in whitecap reflectance; (4) uncertainty in VIIRS radiometric calibration, polarization sensitivity, and sensor noise. It should be pointed out that the signal to noise ratio is a key factor affecting selection of the aerosol model and calculation of the diffuse transmittance for conversion of the normalized water-leaving reflectance to remote sensing reflectance.

## 2.1 Atmospheric Correction Over Ocean/Ocean Color Chlorophyll Algorithm Description

### 2.1.1 Interfaces

To begin data processing, the ACO/OCC algorithm is initiated by the IDPS Infrastructure (INF) subsystem Software Item (SI). The INF SI provides tasking information to the algorithm indicating which granule to process. 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

All the required input data for the ACO-OCC algorithms are found in JPSS-SRS-Vol-1. Some of the input data can originate from multiple sources. For these situations, a hierarchy is established for order of preference (see Section 2.1.3, Graceful Degradation, for additional information). Refer to 474-00448-01-24\_JPSS-SRS-Vol-I-Part-24, for a description of the inputs.

**Table 3. ACO/OCC Inputs**

Input Data	Description	Reference Document
VIIRS MOD SDR	Reflectance, pixel quality, etc (for bands M1-M7) from VIIRS SDR data	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS MOD Geolocation	Sensor angles , Solar angles etc from Terrain Corrected VIIRS Geolocation data	474-00448-02-06_JPSS-DD-Vol-II-Part-06

Input Data	Description	Reference Document
VIIRS Cloud Mask EDR	VIIRS Cloud Mask	474-00448-02-11_JPSS-DD-Vol-II-Part-11
VIIRS OBC IP	Half Angle Mirror Side from VIIRS On-board Calibrator IP	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS SST EDR	VIIRS Sea Surface Temperature EDR	474-00448-02-25_JPSS-DD-Vol-II-Part-25
Granulated Ancillary Data	Granulated Bathymetry, Nitrate Depletion, Precipitable Water, Wind Speed, Wind Direction, Column Ozone, Surface Pressure data	474-00448-02-07_JPSS-DD-Vol-II-Part-07
ACO/OCC LUTs	Several ACO/OCC Look Up Tables	Refer to Section 2.1.1.1.1 for a detailed description of the input ACO/OCC LUTs
VIIRS ACO/OCC Coefficients	ACO/OCC tunable parameters	474-00448-02-24_JPSS-DD-Vol-II-Part-24

**2.1.1.1.1 ACO/OCC LUT Description**

**2.1.1.1.1.1 Aerosol LUTs**

The Aerosol LUT, provided by Dr. Menghua Wang of the NPP Science team (NOAA), consists of aerosol parameters pertaining to 12 different aerosol models. These models are enumerated as follows:

1. Oceanic (Relative Humidity (RH) of 99%) – (1)
2. Maritime (RH = 50%, 70%, 90%, 99%) – (2-5)
3. Coastal (RH = 50%, 70%, 90%, 99%) – (6-9)
4. Troposphere (RH = 50%, 90%, 99%) – (10-12)

Where the indices enclosed by the parentheses, symbolically represent each aerosol model in the ACO algorithm. Each of these contains parameters which are described in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.2, Aerosol Coefficients. NOTE: The configurable parameter **thetav** (containing preset sensor viewing angle range and increments) was previously hard coded but has now been added to the Aerosol Coefficients LUT. There also exists another LUT which contains additional aerosol parameters that correspond to each of the 12 models just described; these values are detailed in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.3, Aerosol Properties. The computation of the ACO parameter  $\epsilon_{model}$  (“Epsilon”) for each of the aerosol models requires the values from the Aerosol Properties LUT. Parameter dimensions for the LUTs called out above can be found in the Comments column in each of the tables listed above.

**2.1.1.1.1.2 Rayleigh LUTs**

The ACO code requires Rayleigh Scattering LUT VIIRS ACO/OCC Diffuse Transmittance LUT, 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.5-1 values to compute the Rayleigh Component of the TOA reflectance. Parameter dimensions for the Rayleigh Scattering LUT can be found in the Comments column in Table 7.1.1.5-1.

### 2.1.1.1.1.3 Diffuse Transmittance LUTs

The subroutine **diffuse\_t\_viirs()** computes the diffuse transmittance values for the ocean-atmosphere system at VIIRS bands M1 to M7, using LUT coefficients **tt\_coeff\_a** and **tt\_coeff\_b**, along with the aerosol optical thickness computed in the aerosol correction subroutine **aerosol\_rads()**. The VIIRS ACO/OCC Diffuse Transmittance LUT coefficients are found in VIIRS ACO/OCC Diffuse Transmittance LUT, 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.4-1. Parameter dimensions for the Diffuse Transmittance LUT can be found in the Comments column in Table 7.1.1.4-1.

### 2.1.1.1.1.4 Polarization LUT

The subroutine **aco\_pol\_corr()** computes the instrumental polarization sensitivity correction using the Instrumental Polarization Sensitivity LUT found in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.6-1, with the VIIRS TVAC sensor characterization data. Parameter dimensions for the Instrumental Polarization Sensitivity LUT can be found in the Comments column in Table 7.1.1.6-1.

### 2.1.1.1.1.5 Detector-Dependent Rayleigh Correction Adjustment Factors LUT

The VIIRS Detector-Dependent Rayleigh Correction Adjustment LUT can be found in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.1-1. Parameter dimensions for the Detector-Dependent Rayleigh Correction Adjustment LUT can be found in the Comments column in Table 7.1.1.1-1.

Detector-Dependent Rayleigh Correction Adjustment Factors are to Address Detector-to-Detector Variations in Implementing the TOA Rayleigh Radiance Correction. The Detectors are in engineering order which is the reverse of the Product Order.

### 2.1.1.1.1.6 Bright Pixel Flag Threshold LUT

The VIIRS Bright Pixel Flag Threshold LUT can be found in 474-00448-02-06\_JPSS-DD-Vol-II-Part-06, Table 7.1.26-1. Parameter dimensions for the Bright Pixel Flag Threshold LUT can be found in the Comments column in Table 7.1.26-1.

### 2.1.1.1.1.7 Program Parameters for continuous monitoring

Configurable parameters used in the operational code for the VIIRS ACO OCC algorithm are listed in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.2.2.2-1.

## 2.1.1.2 Outputs

The ACO/OCC unit produces an output OCC EDR with five fields, described in detailed in 474-00448-01-24\_JPSS-DD-Vol-I-Part-24, Table 3-1. The output is further defined in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 5.1.1-1. The Quality Flag (QF) Data Fields in the OCC EDR contain the ocean color QFs for each moderate resolution pixel and for the granule stored as bit fields within 8-bit unsigned integers. Bit structure of the OCC pixel level QFs is described in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 5.1.1-1 and Product Profile, Table 5.1.2-1.

**Table 4. ACO/OCC Outputs**

Output Data	Description	Reference Document
VIIRS OCC EDR	VIIRS Ocean Color Chlorophyll Product	474-00448-02-24_JPSS-DD-Vol-II-Part-24

A brief description of OCC QFs (not defined elsewhere):

Chlorophyll a Concentration Quality (indicates pixel level chlorophyll a concentration quality). This flag is set to “Poor” if:

- 1) The Chlorophyll-a is out of the system spec range OR
- 2) Any band’s IOP-a or IOP-s value is outside the system spec range OR
- 3) Coccolithophores are present OR
- 4) The M5-Band RSR values indicate Turbid Water OR
- 5) Atmospheric correction failed OR
- 6) Optional input Bright Pixel IP is not present

Five separate QFs (per band):

Ocean Color Quality at <wavelength> (indicates pixel level Normalized Water-Leaving Radiance quality at <band>). This flag is set to “Poor” if

- 1) The <wavelength> (<band>) nLw is out of the system spec range OR
- 2) Any <wavelength> (<band>) nLw is less than or equal to 0 OR
- 3) The M5-Band RSR values indicate Turbid Water OR
- 4) Coccolithophores are present OR
- 5) SDR for given band is out of the range 0.0 – 1.0 OR
- 6) Epsilon is out of range OR
- 7) Atmospheric correction failed OR
- 8) Sun glint is present OR
- 9) HRI exclusion exists OR
- 10) Shallow water is present OR
- 11) Probably clear or probably cloudy conditions exist OR
- 12) Adjacent pixel is cloudy OR
- 13) Cirrus is detected OR
- 14) Cloud shadow exists OR
- 15) Heavy aerosol obstruction exists OR
- 16) Strongly absorbing aerosol exists OR
- 17) AOT exclusion exists OR
- 18) Optional input Bright Pixel IP is not present.

Five separate QFs (per band):

IOP\_a Quality at <wavelength> (indicates pixel level IOP-a quality at <band>). This flag is set to “Poor” if

- 1) The M5-Band RSR values indicate Turbid Water OR
- 2) The <wavelength> (<band>) IOP-a is out of the system spec range OR
- 3) Coccolithophores are present OR

- 4) Optional input Bright Pixel IP is not present.

Five separate QFs (per band):

IOP\_s Quality at <wavelength> (indicates pixel level IOP-a quality at <band>). This flag is set to "Poor" if

- 1) The M5-Band RSR values indicate Turbid Water OR
- 2) The <wavelength> (<band>) IOP-s is out of the system spec range OR
- 3) Coccolithophores are present OR
- 4) Optional input Bright Pixel IP is not present.

Ocean Color values (any band) out of range (indicates if any of the ocean color values are out of range). This flag is set to "Out of range" if:

- 1) Ocean color (water leaving radiance) in any band is out of range OR
- 2) Chlorophyll-a is fill.

IOP-a values (any band) out of range (indicates if any of the IOP-a (Inherent Optical Properties-Absorption) are out of range). This flag is set to "Out of range" if:

- 1) IOP-a in any band is out of range OR
- 2) Chlorophyll-a is fill.

IOP-s values (any band) out of range (indicates if any of the IOP-s (Inherent Optical Properties-Scattering) values are out of range). This flag is set to "Out of range" if:

- 1) IOP-s in any band is out of range OR
- 2) Chlorophyll-a is fill.

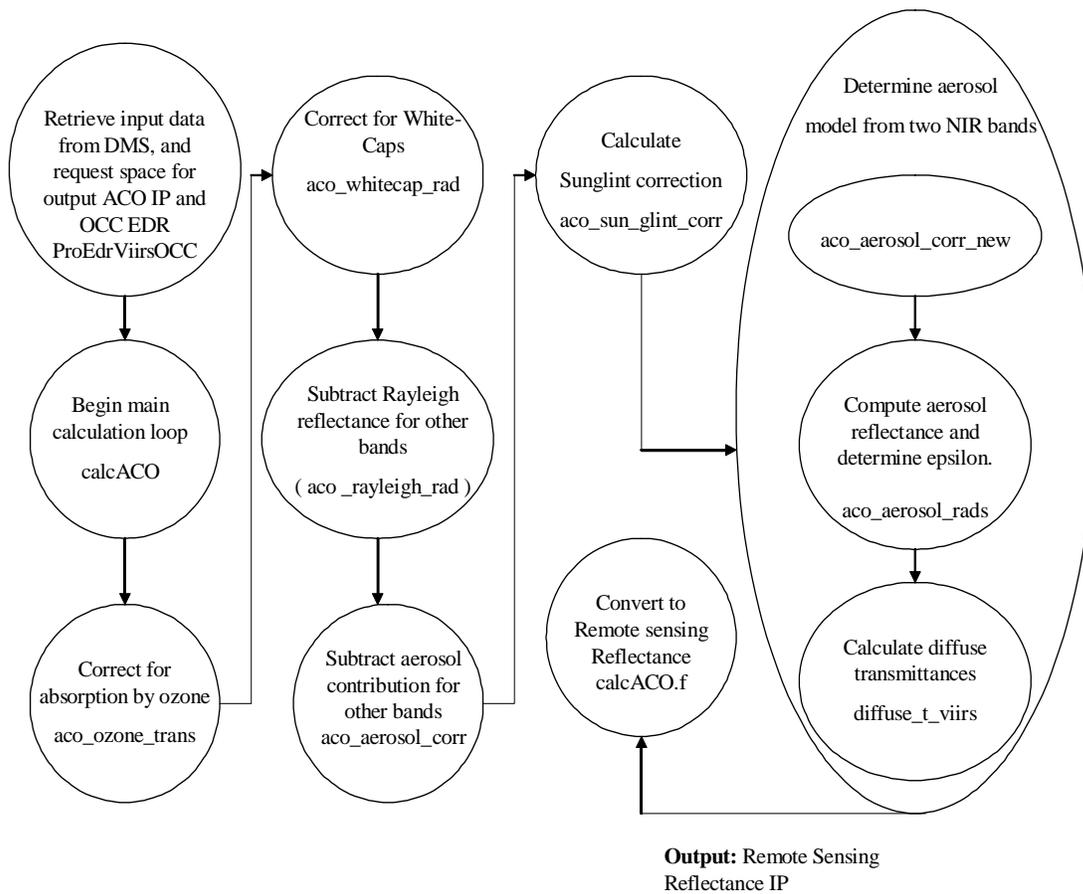
Excl - DOM Absorption > 2m<sup>-1</sup> (indicates dissolved organic matter absorption a(410) > 2/m). This flag is set to "Exclusion" if:

- 1) Inherent optical properties – absorption (IOP-a) at 410 nm > 2/m OR
- 2) Chlorophyll-a is fill.

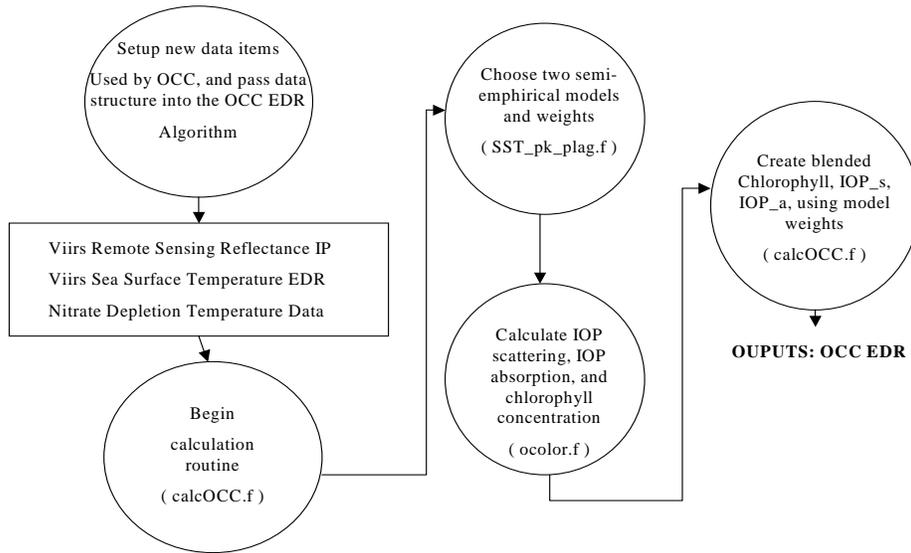
### 2.1.2 Algorithm Processing

The VIIRS Remote Sensing Reflectance Intermediate Product (RSR IP) is produced by the Atmospheric Correction Over Ocean (ACO) algorithm through removal of atmospheric and surface reflection components from signals received by the satellite-based visible-wavelength detectors. The VIIRS OCC EDR contains ocean color (normalized water-leaving radiance) and inherent optical properties for scattering and absorption at the five visible wavelength bands, chlorophyll concentration, and a 7-byte quality flag is produced by the Ocean Color/Chlorophyll (OCC) algorithm. Inputs to the ACO and OCC algorithms include measured TOA VIIRS reflectances in the visible and near-infrared bands M1 to M7, Bright Pixel IP bands M1 to M7, VCM EDR, VIIRS SST EDR, granulated bathymetric data and NDT data, SSWS, surface atmospheric pressure, total precipitable water, and total column ozone. The ACO algorithm utilizes the sun glint flag and the snow/ice flag obtained from the VCM EDR for setting the sun glint and ice ocean exclusion, bathymetric data for setting the shallow water flag. The algorithm

first applies corrections for atmospheric gaseous absorption for ozone, water vapor, and other constant species as total transmittance and whitecaps. Then the algorithm computes the Rayleigh reflectance due to molecular scattering and adjusts for detector-to-detector variation of the RSR and corrects for scan angle, HAM side, and detector dependent residual instrumental polarization. The algorithm then correct for sun glint and subtracts the contributions of aerosol scattering in the atmosphere, and reflection from the air-sea interface, from the corrected VIIRS reflectances. The OCC algorithm starts with the RSR IP retrieved by the ACO algorithm and utilizes SST and NDT to select the branching algorithm and the corresponding model parameters to produce the ocean color EDR. A derived class of the ProCmnAlgorithm class, two algorithm drivers, and fourteen FORTRAN 90 functions are discussed below, including descriptions of the algorithms used. Data flow for producing the RSR IP is shown in Figure 2. Data flow for producing the OCC EDR is shown in Figure 3.



**Figure 2. Processing Steps for calcACO.f to Produce the RSR IP**



**Figure 3. Processing Steps for calcOCC.f to Produce the OCC EDR**

**2.1.2.1 Main Module - OO Controller/Interface for ACO/OCC (ProEdrViirsOCC.cpp)**

This object is the ACO/OCC derived class of ProCmnAlgorithm.cpp responsible for controlling the calculation of both the RSR IP and OCC EDR. The routine obtains from DMS both VIIRS and non-VIIRS input data then assigns output data locations within DMS. This object has methods that are responsible for obtaining input data items required to perform the algorithm, calling the FORTRAN90 science code responsible for operation of the algorithms, and outputting the generated IP and EDR as well as any associated metadata.

**2.1.2.2 Atmospheric Correction Over Ocean subroutine driver (calcACO.f)**

This routine loops through VIIRS moderate-resolution pixels calling the subroutines for each component of the atmospheric correction for every pixel. Each of the correction functions are called sequentially in the following order:

1. Gaseous absorption
2. Whitecap
3. Rayleigh
4. Polarization
5. Sun glint
6. Aerosol.

As these corrections are computed they are applied to the incoming TOA reflectance. The corrections are designated as the following parameters:

1. *t\_ozone*

2. *Lwc* ( Section 2.1.2.3 )
3. *Lray* ( Section 2.1.2.4 )
4. *Lpol\_corr* ( Section 2.1.2.6.1 )
5. *Lsg\_corr*, and
6. *Laer* ( Section 2.1.2.6.3).

The code also computes the diffuse transmittance (*t\_diffuse*) summarized in Section 2.1.2.6.4.

The code does not retrieve the remote sensing reflectance (RSR) for pixels flagged as land, confidently cloudy, snow/ice, or night. If any of the SDRs visible/IR bands (M1 to M7) is not available (i.e. a fill value) or flagged as saturated, the code will not retrieve the RSR.

The interpolated total column ozone from OMPS or NCEP, *OZ\_interp*, and the total column ozone (*oz*) used in the code is in atm-cm. The interpolated total precipitable water from NCEP TPW interp is in cm.

The subsequent atmospheric corrections are computed as follows:

- $Lcorr\_gas(\lambda) = Lin(\lambda)/t\_gas(\lambda) \rightarrow$  Gaseous Absorption Correction
- $Lcorr\_wc(\lambda) = Lcorr\_oz(\lambda) - Lwc(\lambda) \rightarrow$  Whitecap Correction
- $Lcorr\_ray(\lambda) = Lcorr\_wc(\lambda) - Lray(\lambda) \cdot pol\_corr(\lambda) \rightarrow$  Rayleigh and Polarization Correction
- $Lcorr\_sg(\lambda) = Lcorr\_ray(\lambda) - Lsg(\lambda) \rightarrow$  Sun-glnt Correction
- $Lcorr\_aer(\lambda) = Lcorr\_sgl(\lambda) - Laer(\lambda) \rightarrow$  Aerosol Correction
- $RSR(\lambda_{visible}) = (1/\pi)Lcorr\_aer(\lambda)/t\_diffuse(\lambda_{visible}), \rightarrow$  RSR Computation

where *Lcorr\_gas*, *Lcorr\_wc*, *Lcorr\_ray*, *Lcorr\_sg*, and *Lcorr\_aer* are the corrected TOA reflectances after the ozone, whitecap, Rayleigh, polarization, sun glint correction, and aerosol corrections respectively; *t\_diffuse* is the diffuse transmittance. All of these parameters are a function of wavelength ( $\lambda$ ) which represent VIIRS VISIR bands M1 to M7. RSR is the normalized remote sensing reflectance in sr<sup>-1</sup> where the normalization factor is the 1/π multiplier; the RSR is a function of bands M1 to M5 ( $\lambda_{visible}$ ).

### 2.1.2.3 Atmospheric Gaseous Absorption (aco\_ozone\_trans.f)

The 2-way total gaseous transmittance for VIIRS bands M1 to M7 is given as  $t_{gas} = t_{oz} t_{h2o} t_{og}$ . The subroutine *aco\_ozone\_trans()* is used to compute the ozone transmittance for bands M1 to M7 given the viewing geometry, total ozone column, and the ozone absorption coefficients for each band. The ozone transmittance for bands M1 to M7 is given by

$$t_{oz}(\lambda) = e^{-Z \cdot k_{oz}(\lambda) \cdot \left( \frac{1}{\mu} + \frac{1}{\mu_0} \right)}$$

where, *Z* is the total column ozone concentration in atmospheres-cm (converted from Dobsons by dividing by 1000), *k<sub>oz</sub>(λ)* is the ozone absorption coefficient,  $\mu$  is the cosine of the viewing zenith angle,  $\mu_0$  is cosine of the solar zenith angle.

The subroutine *aco\_water\_trans()* is used to compute the water vapor transmittance. The 2-way water vapor transmittance for each ocean band is given by

$$t_{H2O}(\lambda) = e^{a(\lambda) \cdot x + b(\lambda) \cdot \log(x) + c(\lambda) \cdot x \cdot \log(x)}$$

$$x = U \left[ \frac{1}{\mu} + \frac{1}{\mu_0} \right]$$

where,  $U$  is the total precipitable water,  $a$ ,  $b$ , and  $c$  are the band dependent water vapor absorption coefficients.

Similarly, the subroutine `aco_other_trans()` is used to compute the transmittance for other constant species gas. The total transmittance for other constant species is given as:

$$t_{OG}(\lambda) = \exp[m \cdot (a_0 P + a_1 \log P)] \cdot \exp[(b_0 P + b_1 \log P) \cdot \log(m)] \cdot \exp[(c_0 P + c_1 \log P) \cdot m \log(m)]$$

$$m = \frac{1}{\mu} + \frac{1}{\mu_0}$$

where  $P$  is the surface pressure,  $a_0$ ,  $a_1$ ,  $b_0$ ,  $b_1$ ,  $c_0$ , and  $c_1$  are the band dependent absorption coefficients. The gaseous absorption corrected reflectance  $\rho_{gas\ corr}(\lambda)$  is then computed as  $\rho_{gas\ corr}(\lambda) = \rho_N(\lambda) / t_{gas}(\lambda)$ .

#### 2.1.2.4 Calculate Reflectance Due To Whitecaps (`aco_whitecap_rad.f`)

This subroutine calculates whitecap reflectance corrections for each band. If the surface wind speed is zero then the reflectance due to whitecaps is zero, otherwise the whitecap reflectance is a function of the wind speed. The white foam reflectance is given by

$$white = 0.25 * 6.49x10^{-7} * (winds^{3.52})$$

where “winds” is the wind speed in m/s. The whitecap reflectance,  $Lwc$ , for each band is

$$Lwc(nl) = white * t\_rho$$

where  $nl$  are the M1 to M7 band indices (1-7) and  $t\_rho$  is a set of band dependent whitecap coefficients inherited from the MODIS ACO algorithm/data package ( $t\_rho$  is declared in `aco_geom_phys.f`). Both  $Lwc$  and  $t\_rho$  are unitless.

#### 2.1.2.5 Calculate Reflectance Due to Atmospheric Rayleigh Scattering (`aco_rayleigh_rad.f`)

The Rayleigh scattering radiance components “I”, “Q”, and “U” are extracted from the Rayleigh LUTs detailed in Section 2.1.1.1.2. These LUT values are then interpolated with respect to the viewing geometry (solar zenith ( $\theta_0$ ) and sensor zenith angles ( $\theta$ )). In addition to interpolating with respect to the viewing geometry, the code also interpolates the radiance with respect to wind speed; these are denoted  $ray\_i\_lut$ ,  $ray\_q\_lut$ , and  $ray\_u\_lut$  for the I, Q, and U Stokes components. After computing the interpolated radiance values a correction factor  $fac$  is computed as follows:

$$fac = \frac{1 - e^{-cc\tau_r(\lambda)\left(\frac{1}{\cos(\theta)} + \frac{1}{\cos(\theta_0)}\right)}}{1 - e^{-cc\tau_r(\lambda)\left(\frac{1}{\cos(\theta)} + \frac{1}{\cos(\theta_0)}\right)}}$$

Where:  $\frac{1}{\cos(\theta)} + \frac{1}{\cos(\theta_0)}$  (cosines of the sensor zenith and solar zenith angles respectively) is the air mass,  $\tau_r(\lambda) = \tau_r(\lambda)P_0$ , and  $\tau_r(\lambda)$  is defined as the Rayleigh optical depth for bands M1 to M7, and **cc** is the coefficient that accounts for atmospheric variations and is computed as follows:

$$cc = (0.6543 - 1.608\tau_r) + (0.8192 - 1.2541\tau_r)\log\left(\frac{1}{\cos(\theta)} + \frac{1}{\cos(\theta_0)}\right).$$

$P_0$  accounts for the surface pressure variations by taking the ratio of the measured surface pressure *pres* (NCEP data) and the standard pressure *pres0* at 1013.25mb.

The final Rayleigh reflectance is computed as such:

$$\begin{aligned} ray\_i(\lambda) &= ray\_i\_lut(\lambda) \cdot fac \cdot \pi / \cos(\theta_0) \\ ray\_q(\lambda) &= ray\_q\_lut(\lambda) \cdot fac \cdot \pi / \cos(\theta_0) \\ ray\_u(\lambda) &= ray\_u\_lut(\lambda) \cdot fac \cdot \pi / \cos(\theta_0) \end{aligned}$$

where the  $\pi/\cos(\theta_0)$  factor converts the Rayleigh radiance, normalized with solar-irradiance  $F_0=1$ , into reflectance. The parameter  $ray\_i(\lambda)$  is the  $L_{ray}(\lambda)$  parameter.

Upon examination of the individual detector RSRs for each band, it was determined that there is sufficient detector-to-detector variation (especially for band M1) to warrant implementing a simple detector-dependent adjustment to the TOA Rayleigh radiance correction, which is currently determined from the Rayleigh LUT based solely on detector-averaged RSRs. The detector-dependent adjustment multiplies the normalized radiance obtained from the Rayleigh Radiance LUT by the ratio of the band-averaged Rayleigh Optical Thickness computed from each detector RSR to that produced from the detector-averaged RSR. This approach is based on the approximation for the band-averaged Rayleigh radiance from Gordon [2], where:

$$\begin{aligned} \langle L_r(\lambda) \rangle_{S_i} &\cong G(\theta_0, \theta_V, \phi) \int_{\lambda} \tau_r(\lambda) F_0(\lambda) S_i(\lambda) d\lambda \\ \text{so that } \langle \hat{L}_r(\lambda) \rangle_{S_i} &\cong \frac{\langle L_r(\lambda) \rangle_{S_i}}{\langle F_0(\lambda) \rangle_{S_i}} \cong G(\theta_0, \theta_V, \phi) \frac{\int_{\lambda} \tau_r(\lambda) F_0(\lambda) S_i(\lambda) d\lambda}{\int_{\lambda} F_0(\lambda) S_i(\lambda) d\lambda} = G(\theta_0, \theta_V, \phi) \langle \tau_r(\lambda) \rangle_{S_i} \end{aligned}$$

Based on the above relation, the normalized band-averaged Rayleigh radiance for each detector,  $\langle L_r(\lambda) \rangle_{S\_Det}$ , can be easily determined using the normalized band-averaged radiance from the Rayleigh LUT,  $\langle L_r(\lambda) \rangle_{S\_Avg}$  and the ratio of the Rayleigh Optical Thicknesses,

$$\langle \widehat{L}_r(\lambda) \rangle_{S-Det} = \langle \widehat{L}_r(\lambda) \rangle_{S-Avg} \frac{\langle \tau_r(\lambda) \rangle_{S-Det}}{\langle \tau_r(\lambda) \rangle_{S-Avg}}.$$

The above ratio of Rayleigh Optical Thicknesses has been pre-computed for each detector and is provided as a detector-dependent Rayleigh correction factor LUT, shown in the VIIRS Detector-Dependent Rayleigh Correction Adjustment LUT found in 474-00448-02-24\_JPSS-DD-Vol-II-Part-24, Table 7.1.1.1-1,.

### 2.1.2.6 Instrumental Polarization Correction (aco\_pol\_corr.f)

#### Instrumental Polarization Correction

The detailed description of the polarization is given in Section 3.3.2 of the VIIRS ACO ATBD (D0001-M01-S01-029). In summary, Rayleigh polarization correction, PolCor, is

$$[1 + P_{in} P_{pol} \cos 2(\alpha - \phi - \chi_{in})]$$

where,

$P_{in}$  = Instrument polarization sensitivity

$\chi_{in}$  = Instrument polarization phase angle

$$P_{pol} = \text{Degree of polarization at TOA} \equiv \frac{\sqrt{Q_{TOA}^2 + U_{TOA}^2}}{L_{TOA}}$$

$$\phi = \text{Polarization phase angle at TOA} \equiv \frac{1}{2} \tan^{-1} \left( \frac{U_{TOA}}{Q_{TOA}} \right)$$

The residual reflectance at each ocean band after correction to Rayleigh (including detector-dependent adjustment) and polarization are:

$$\rho_{ay\_corr}(\lambda) = \rho_m - \rho_r(\lambda) \cdot [1 + P_{pol} \cdot P_{in} \cos 2(\alpha - \phi - \chi_{in})]$$

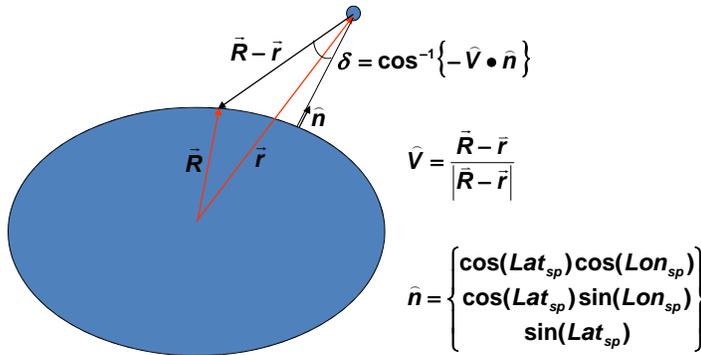
where,  $\rho_{pol\_corr}$  is the reflectance corrected for instrument polarization and Rayleigh scattering with detector dependent adjustment,  $\rho_m$  is the measured reflectance after applying subsequent atmospheric corrections (e.g., gaseous absorption and whitecap).

#### Approach for Computing the Scan Angle used in the Polarization Correction

The VIIRS scan angle is needed for implementing the polarization correction in the ACO code. Since the scan angle is not a saved variable in the VIIRS SDR, EDRs or any of the IPs, it needs to be computed from information that is contained in these outputted products. Using information that is readily available in the SDR and GEO IP products, a formally exact method for computing the sensor scan angle has been developed. The approach, illustrated in the figure below, uses the Cartesian coordinates of the satellite position in the ECEF frame (which is available from the GEO IP) together with the geodetic latitude and longitude of the center in-track pixel (either pixel 8 or 9) from the SDR to accurately determine the magnitude of the scan angle. In general, we first use the satellite ECEF position,  $\vec{r}$ , and the pixel ECEF position,  $\vec{R}$ , to form the line-of-sight (LOS) unit vector from the satellite to the pixel location,

$\widehat{V} = (\vec{R} - \vec{r}) / |\vec{R} - \vec{r}|$ . We then compute the normal,  $\widehat{n}$ , to the WGS84 Earth Reference Ellipsoid at the sub-satellite point. This normal is along the direction of the z-axis of the satellite for a

geodetic pointing satellite like NPOESS. The scan angle,  $\delta$ , is then obviously given by  $\delta = \cos^{-1}\{-\hat{V} \cdot \hat{n}\}$ .



**Figure 4. Illustration of the approach for computing the sensor scan angle**

The detailed steps of the algorithm described above are as follows:

- Obtain satellite ECEF position,  $\vec{r} = \{x_{sat}, y_{sat}, z_{sat}\}$ , from the VIIRS GEO IP
- Obtain the latitude and longitude of in-track pixel 8 for each along-scan frame from the SDR and convert them into Cartesian coordinates in the ECEF frame. The relations for this are:

$$\vec{R} = \begin{Bmatrix} N \cos(lat_p) \cos(lon_p) \\ N \cos(lat_p) \sin(lon_p) \\ (1 - e^2) N \sin(lat_p) \end{Bmatrix},$$

where,

$$N = R_E / [1 - e^2 \sin^2(lat_p)]$$

$$e^2 = 2f - f^2$$

$$f = 1/298.257223563$$

$$R_E = 6,378,137 \text{ meters}$$

- Compute geodetic latitude and longitude of the sub-satellite point, at which the normal to the WGS84 Earth Reference Ellipsoid will be determined. The latitude and longitude are given by:

$$lon_{sp} = \tan^{-1}(y_{sat}, x_{sat}), \text{ where } lon_{sp} = \text{mod}(lon_{sp}, 2\pi)$$

$$lat_{sp} = \tan^{-1}(z_{sat} + ep^2 b \sin^3 \theta, p - e^2 R_E \cos^3 \theta)$$

where,

$$b = \sqrt{R_E^2(1 - e^2)}$$

$$ep = \sqrt{(R_E^2 - b^2) / b^2}$$

$$\rho = \sqrt{x_{sat}^2 + y_{sat}^2}$$

$$\theta = \tan^{-1}(R_E z_{sat} / bp)$$

- Compute the normal to the Earth Reference Ellipsoid at the sub-satellite point. Since we're using the geodetic latitude and longitude, the normal at the sub-satellite point is simply

$$\hat{n} = \begin{Bmatrix} \cos(lat_{sp}) \cos(lon_{sp}) \\ \cos(lat_{sp}) \sin(lon_{sp}) \\ \sin(lat_{sp}) \end{Bmatrix}.$$

- Compute the LOS vector from the satellite to the pixel location

$$\vec{V} = \vec{R} - \vec{r}.$$

- Finally, compute the magnitude of the scan angle,  $\delta$ , from

$$\delta = \cos^{-1} \left\{ \frac{-\vec{V}}{|\vec{V}|} \cdot \hat{n} \right\}.$$

Only the magnitude of the scan angle is computed from the above algorithm, not its sign. The only way to obtain the sign of the scan angle is to have prior knowledge of the scan direction (i.e., minus-to-plus or plus-to-minus) and to use the frame number (i.e., frame numbers greater or less than 1600 of 3200 moderate-resolution frames). It should also be noted that any attitude variation of the satellite from geodetic nadir will give rise to an error in the scan angle. Since the nominal attitude variations of the satellite will be less than ~45 arc-seconds, the error in scan angle should be negligible.

To assess the performance of the scan angle computation, several 48 scan VIIRS proxy granules taken at the equator, mid-latitude, and pole were used.

### 2.1.2.7 Sun Glint Correction (aco\_glint\_corr.f)

The sun glint correction is performed using the same formulation described in Wang and Bailey (Correction of sun glint contamination on the SeaWiFS ocean and atmosphere products, *Applied Optics*, 40, 4790-4798, 2001). The correction is implemented according to the procedure outlined in the Wang and Bailey article and the SeaDAS software Version 2.8. The majority of the source code for sun glint correction was either provided by Dr. Minghua Wang or extracted from the SeaDAS processing software provided by NASA. The source code has been modified by NGST in order to be integrated into the VIIRS ACO science code.

ACO\_GLINT\_CORR.f contains the following subroutines:

**glint\_refl** (num\_iter, nband, glint\_coef, mu0, mu, taur, taua, La, TLg) is used to compute the sun glint reflectance given the solar and viewing geometry, the glitter radiance from the Cox and Munk model, aerosol optical thickness, and aerosol reflectance.

`glitter_refl (glintOn,x1,x2,x3,x4,x5,x6)` is used to calculate the glitter reflectance according to the Cox and Munk model.

The sun glint correction is performed just before the aerosol correction. It is done using a two-step iterative scheme, in which the first call to subroutine `glint_refl()` is to use the climatological averaged aerosol optical thickness of 0.1 to obtain an estimate of sun glint reflectance, then an estimated aerosol reflectance is computed using the estimated sun glint reflectance. The subroutine `glint_refl()` is called a second time to obtain a better estimate of the sun glint reflectance.

**2.1.2.8 Obtain Aerosol Transmittance and Reflectance Correction (aco\_aerosol\_corr.f)**

The aerosol correction mainly takes place in the `aerosol_rads()` function. The purpose of the function is to compute the aerosol contribution to the TOA reflectance. The aerosol correction algorithm employs the single-scattering epsilon method laid out by Menghua Wang and Howard Gordon’s Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: A Preliminary algorithm, *Applied Optics*, 33, 443-452 (1994) and Gordon’s Atmospheric correction of ocean color imagery in the Earth Observing System era, *JGR*, 102, 17081-17106 (1997). Section 2.1.2.6.1 summarizes the aerosol correction process.

**2.1.2.8.1 Aerosol Correction ( aerosol\_rads.f )**

In order to utilize the single-scattering epsilon method to compute the aerosol correction, the “epsilon” value must be computed for the incoming sensor/viewing geometry. The retrieved epsilon value is defined as:

$$\epsilon_{retrieved} = \frac{\sum_{i=1}^M \rho_{as}^{(i)}(\lambda_s)}{M}$$

where  $\Sigma$  over  $i = 1, \dots, M$  is the sum over all possible aerosol models; in this algorithm  $M = 12$  (see Section 2.1.1.1.1 for details). The ratio of  $\rho_{as}^{(i)}(\lambda_s) / \rho_{as}^{(i)}(\lambda_l)$  is the ratio of the single scattering aerosol values at the VIIRS shortwave and long-wave IR bands  $\lambda_s=M6$  and  $\lambda_l=M7$  over all 12 aerosol models.  $\lambda_s$  and  $\lambda_l$  are wavelengths at 746 and 865 nm respectively. Thus, the retrieved epsilon function is the average of the ratio of the single scattering aerosol parameter over all aerosol models. In order to compute  $\rho_{as}$  for any band, the algorithm must solve the following quadratic equation:

$$\rho_{pol\_corr}^{(i)}(\lambda) = a^{(i)}(\lambda) + b^{(i)}(\lambda)\rho_{as} + c^{(i)}(\lambda)\rho_{as}^2 + d^{(i)}(\lambda)\rho_{as}^3 + e^{(i)}(\lambda)\rho_{as}^4$$

where  $i$ , again, represents the “ith” aerosol model;  $a, b, c, d, e$  are the fitting coefficients extracted from the binary aerosol LUTs with `nir_s = 6` (standard ACO mode; see Section 2.1.1.1.1 and Table 5);  $\rho_{pol\_corr}^{(i)}$  is the TOA reflectance, corrected for ozone, whitecaps, Rayleigh, and polarization; and  $\lambda$ , again, is the VIIRS shortwave/long-wave IR bands at 746nm and 865nm respectively. This only works for these bands because the water-leaving radiance can be ignored in the IR regime. Solving the quartic equation computationally is not trivial. Fortunately the LUTs coefficients can reverse fit the above equation making it trivial to compute  $\rho_{as}^{(i)}$ :

$$\rho_{as}^{(i)}(\lambda) = a^{(i)}(\lambda) + b^{(i)}(\lambda)\rho_{pol\_corr} + c^{(i)}(\lambda)\rho_{pol\_corr}^2 + d^{(i)}(\lambda)\rho_{pol\_corr}^3 + e^{(i)}(\lambda)\rho_{pol\_corr}^4$$

where the coefficients  $a, b, c, d, e$  are the fitting coefficients extracted from the binary aerosol LUTs. One thing to note is that  $\rho_{pol\_corr}^{(i)}$  contains the aerosol reflectance due to multiple scattering and single scattering. After computing  $\epsilon_{retrieved}$  the epsilon of the models  $\epsilon_{model}$  must be computed. The model “epsilons” can be constructed from the Aerosol Properties LUT values detailed in Section 2.1.1.1.1. This value is computed using the following equations:

$$\epsilon_{model}(\lambda) = \frac{\omega_a(\lambda)c(\lambda)p_a(\theta, \phi; \theta_0, \phi_0; \lambda)}{\omega_a(865)c(865)p_a(\theta, \phi; \theta_0, \phi_0; 865)}$$

$$p_a(\theta, \phi; \theta_0, \phi_0; \lambda) = P_a(\theta_-, \lambda) + (r(\theta) + r(\theta_0))P_a(\theta_+, \lambda)$$

$$\cos \theta_{\pm} = \pm \cos \theta_0 \cos \theta - \sin \theta_0 \sin \theta \cos(\Delta\phi)$$

where  $\omega_a(\lambda)$ ,  $P_a(\theta, \lambda)$ , and  $c(\lambda)$  are the single-scattering Albedo (omega0 in Table 6), aerosol scattering phase function (s11 in Table 6) for a scattering phase angle  $\theta$ , and aerosol extinction coefficient (extinct in Table 6) for all 12 aerosol models; and  $\lambda$  are wavelengths of M1 to M7. Parameter  $r(\theta)$  is the Fresnel reflectance of the interface of the incident angle  $\theta$ . The angles  $\theta_0$  and  $\phi_0$  are the zenith and azimuth angles respectively of a vector from the point on the sea surface under consideration to the Sun, and likewise  $\theta$  and  $\phi$  are the zenith and azimuth angles respectively of a vector from the pixel to the sensor, and  $\Delta\phi = \phi_0 - \phi$  is the relative azimuth angle.

After computing both  $\epsilon_{retrieved}$  and  $\epsilon_{model}$  the code determines the two closest models by comparing the retrieved to the set of model epsilons; only  $\epsilon_{model}(746, 865)$  is used for the comparison. From this point on  $\epsilon_{model}$  will be denoted as  $\epsilon$ . This process involves iteratively refining  $\epsilon_{retrieved}$  until the code reaches the two closest aerosol models and a newly refined value for  $\epsilon_{meas} = \epsilon_{retrieved}$ ; in other words, this condition must be reached

$$\epsilon^{(m1)}(746, 865) < \epsilon_{meas}(746, 865) < \epsilon^{(m2)}(746, 865).$$

Once the two models, m1 and m2, are determined, the code computes a weighting factor using  $\epsilon^{(m1)}$  and  $\epsilon^{(m2)}$  in the following manner:

$$w = \frac{\epsilon_{meas}(765, 865) - \epsilon^{(m1)}(765, 865)}{\epsilon^{(m2)}(765, 865) - \epsilon^{(m1)}(765, 865)}.$$

This weighting factor is used to linearly interpolate subsequent calculations of aerosol optical thickness, aerosol reflectance (single scattering and multiple-scattering), and diffuse transmittance.

### 2.1.2.8.2 Aerosol Optical Thickness ( AOT Calculation )

The aerosol optical thickness (AOT) is computed in three steps. The first step is to compute the AOT at 865nm using the following expression:

$$\tau_a^{(i)}(865) = \frac{\rho_{as}^{(i)}(865)}{p_a^{(i)}(\theta, \phi; \theta_0, \phi_0; \lambda)}$$

where  $i$  are the indices for aerosol models m1 and m2. The second step is to linearly extrapolate the AOT of bands M1 to M6 using  $\tau_a^{(i)}(865)$  as an anchor by doing the following:

$$\tau_a^{(i)}(\lambda) = \tau_a^{(i)}(865) \sum_{\lambda=1}^7 \frac{c(\lambda)}{c(865)}.$$

The final step is to linearly interpolate between the AOTs for m1 and m2 to get the final set of AOTs for bands M1 to M7:

$$\tau_a(\lambda) = (1 - w)\tau_a^{(m1)}(\lambda) + w\tau_a^{(m2)}(\lambda).$$

### 2.1.2.8.3 Aerosol Reflectance

In order to compute the aerosol reflectance (Laer) for aerosol models m1 and m2, the code extracts the fitting coefficients  $a, b, c, d, e$  with nir\_s = 8 (see Section 2.1.1.1.1), computes  $\rho_{as}$ , (the single scattering aerosol reflectance), for bands M1 to M5, then uses the original quartic equation to get the following:

$$\rho_{Laer}^{(m1,m2)}(\lambda) = a^{(m1,m2)}(\lambda) + b^{(m1,m2)}(\lambda)\rho_{as} + c^{(m1,m2)}(\lambda)\rho_{as}^2 + d^{(m1,m2)}(\lambda)\rho_{as}^3 + e^{(m1,m2)}(\lambda)\rho_{as}^4$$

where  $\lambda = M1, M2, M3, \dots, M7$ . Note: The code only computed  $\rho_{as}$  for bands M1 to M5 because  $\rho_{as}$  for M6 and M7 has already been calculated. To compute the final aerosol reflectance array, the code linearly interpolates between Laer for both models:

$$\rho_{Laer}(\lambda) = (1 - w)\rho_{Laer}^{(m1)}(\lambda) + w\rho_{Laer}^{(m2)}(\lambda).$$

This is the aerosol component to the TOA reflectance.

### 2.1.2.8.4 Diffuse Transmittance (diffuse\_t\_viirs.f)

The diffuse transmittance (t\_diffuse) is computed in a few steps.

1. Fitting LUT values,  $a$  and  $b$ , described in Section 2.1.1.1.3 and the AOT (for aerosol models m1 and m2) output from **aerosol\_rads( )** to the equation:
- 2.

$$yfit(i, \lambda) = a(i) \cdot e^{-b(i) \cdot \tau_a(\lambda)}$$

where  $i = 1, 2$ ,  $yfit(i)$  are the diffuse transmittance values at sensor angles, defined by the LUT, that straddle the incoming sensor geometry.

3. Linearly interpolate  $yfit$  with the slant path  $xfit(i) = 1/\cos(\theta_i)$  where  $\theta_i$  are the LUT derived viewing angles. The diffuse transmittance, thus, is
- 4.

$$t\_diffuse(\lambda) = yfit(1) + \frac{yfit(2) - yfit(1)}{xfit(2) - xfit(1)} \cdot (xbar - xfit(1))$$

where  $xbar = 1/\cos(\theta)$  ( $\theta$  is the sensor zenith angle). This computation is done for both aerosol models. Then the two transmittance values are linearly interpolated in the same fashion as the AOT and Laer from `aerosol_rads( )`.

### 2.1.2.9 Ocean Color/Chlorophyll subroutine driver (`calcOCC.f`)

This process is the driver program that calculates the OCC EDR from RSR for bands M1, M2, M3, M4, and M5, VIIRS SST EDR, and ancillary data. This routine loops over VIIRS moderate-resolution pixels to calculate the water-leaving reflectance and inherent optical properties for each band plus chlorophyll concentration for each pixel. It then fills the output data arrays. In order for the OCC algorithm to retrieve Chlorophyll-a, Water Leaving Radiance, Inherent Optical Properties (IOP-a and IOP-b), the following conditions must be true:

1. The pixel is daytime.
2. The pixel is designated as confidently clear, probably clear, or probably cloudy. For probably clear or probably cloudy, the pixel is retrieved, but flagged as degraded.
3. The pixel is designated as ocean, inland water, or coastal.
4. The pixel has an SDR input with no saturation for bands M1 to M7.

The water-leaving radiance ( $L_w$ ) in units of  $W\ m^{-2}\ \mu m^{-1}\ sr^{-1}$  is calculated from the RSR (in units of  $sr^{-1}$ ) by

$$L_w(k) = RSR(k) * \pi / esol(k)$$

where  $k = 1..5$  is the band index for bands M1 to M5 and  $esol(k)$  is the solar constant by band in units of  $W\ m^{-2}\ \mu m^{-1}$ . Extra-terrestrial Solar Irradiance values are based on the MODTRAN Solar Spectrum and the VIIRS Fused RSR. The chlorophyll concentration can be calculated either by using the OC3V or the Carder algorithm. If the Carder algorithm is used, the subroutine `SST_PK_FLAG` is called to determine the two models to be used to calculate the chlorophyll concentration and the inherent optical properties and their relative weight (`weit`). The subroutine `ocolor` is then called twice, once for each model to be used in the calculation, and a blended value is determined for the chlorophyll concentration (Chlorophyll) by

$$\text{Chlorophyll} = \text{tchlo\_a}(\text{pktran}(1)) * (1 - \text{weit}) + \text{tchlo\_a}(\text{pktran}(2)) * \text{weit}$$

where `pktran` is a two element array holding the flag that indicates which model is used in the calculation and `tchlor_a` is the chlorophyll concentration returned for each subroutine call. Chlorophyll, `tchlor_a`, and `weit` are unitless. The absorption (IOP\_a) and back-scattering (IOP\_s) inherent optical properties are given similarly by

$$\begin{aligned} \text{IOP\_a} &= \text{tIOPa}(\text{pktran}(1)) * (1 - \text{weit}) + \text{tIOPa}(\text{pktran}(2)) * \text{weit} \\ \text{IOP\_s} &= \text{tIOPs}(\text{pktran}(1)) * (1 - \text{weit}) + \text{tIOPs}(\text{pktran}(2)) * \text{weit} \end{aligned}$$

where `tIOPa` and `tIOPs` are the absorption and back-scattering IOP values returned for each subroutine call. `IOP_a`, `IOP_s`, `tIOPa`, and `tIOPs` are in units of  $m^{-1}$ .

The Bright Pixel IP will be read in for band M1 to M7. If pixel data is greater than or equal to a pre-defined 4-bit configurable threshold, the bright pixel quality flag will be set. Processing will continue as normal.

**2.1.2.10 Determine semi-empirical model using SST (sst\_pk\_flag.f)**

This subroutine determines which two models are used in calculating chlorophyll concentration based on SST (sst) relative to NDT (ndt) for the pixel of interest. The sst and ndt are both given in K. Models include the global empirical model, unpackaged phytoplankton model, packaged phytoplankton semi-analytic model, or the fully packaged (or hipackaged) phytoplankton semi-analytic model. Model indicator values are returned in the 2-element integer array pktran. The weighting value (weit) is unitless and is a function of SST. Table 5 shows the various models used and weighting factors as a function of the relation between SST and NDT.

**Table 5. Chlorophyll Concentration Models and Weighting for SST vs. NDT**

SST Test	Model	Pktran	weit
ndt + 3.0 < sst	unpackaged	1	1.0
	unpackaged	1	
ndt + 1.4 ≤ sst < ndt + 3.0	global	0	(sst - (ndt + 1.4) / 1.6
	unpackaged	1	
ndt - 0.1 ≤ sst < ndt + 1.4	packaged	2	(sst - (ndt - 0.1) / 1.5
	global	0	
ndt - 2.0 ≤ sst < ndt - 0.1	fully packaged	3	(sst - (ndt - 2.0) / 1.9
	packaged	2	
sst < ndt - 2.0	fully packaged	3	1.0
	fully packaged	3	

**2.1.2.11 Calculate Chlorophyll a Concentration (ocolor.f)**

This subprogram calculates ratio of the RSR (rrs(band), band=1..5) and absorption coefficient due to phytoplankton at 672-nm (aph675) plus absorption coefficient due to gelbstoff at 400-nm (ag400) algebraically from R<sub>rs</sub> model equations [ATBD 19]. Chlorophyll concentration is then calculated from aph675 and either a semi-analytical or empirical model. The subroutine has parameters for three different semi-analytical models: unpackaged, packaged, or fully packaged pigments. A flag (pk) is passed to the subroutine to determine which model is used in the calculation. A default value for the chlorophyll concentration (chl\_def) is calculated using the current model parameters and is given by

$$chl\_def = 10^{c0+c1*abr35+c2*abr35^2+c3*abr35^3}$$

where abr35 = log(rrs(3)/rrs(4)), c0, c1, c2, and c3 are model dependent coefficients. The parameters c0, c1, c2, and c3 and the variables abr35 and chl\_def are unitless.

Alternatively, the empirical algorithm, OC3V equivalent to the MODIS OC3M has been implemented as the primary default option. Currently, the OC3V is to replace the Carder default (Equation 14a) as the default algorithm for chlorophyll retrieval. The form of the OC3V algorithm is:

$$\log(C) = \alpha_0 + \alpha_1 x + \alpha_2 x^2 + \alpha_3 x^3 + \alpha_4 x^4$$

$$x = \log \left[ \frac{\max(R_{rs}(445), R_{rs}(488))}{R_{rs}(555)} \right]$$

and the initial coefficients are the MODIS OC3M coefficients,  $\alpha_0 = 0.283$ ,  $\alpha_1 = -2.753$ ,  $\alpha_2 = 1.457$ ,  $\alpha_3 = 0.659$ , and  $\alpha_4 = -1.403$ . These are the coefficients used for MODIS processing in SeaDAS and may be updated using either global synthetic data or MODIS matchup data like the NOMAD dataset before launch. In the current implementation with the OC3V as the default chlorophyll retrieval algorithm, the OC3V calculation is performed in calcOCC.f. The chlorophyll concentration is computed whenever  $R_{rs}$  at M4 is valid ( $>1e-8$ ) and either  $R_{rs}$  at M2 or M3 is valid ( $>1e-8$ ). In the option for using the Carder algorithm with OC3V default,  $R_{rs}$  at M1 to M4 have to be valid for processing to occur.

A control switch has been installed in the software for allowing the different algorithm branching for chlorophyll retrievals. The control switch can be 0, or 1, or 2. It is set to (1) 0 for using the Carder chlorophyll algorithm with the Carder default; (2) 1 for using the Carder chlorophyll algorithm with the OC3V default; (3) 2 for using the OC3V algorithm.

The default values of ag400 (ag\_def) and aph675 (aph\_def) are also calculated using the current model parameters. They are given by

$$ag\_def = 1.5 \times 10^{-1.147-1.963*abr15-1.01*abr15^2+0.856*abr25+1.702*abr25^2}$$

$$aph\_def = (10^{-0.919+1.037*abr25-0.407*abr25^2-3.531*abr35+1.579*abr35^2}-0.008)/3.05$$

where  $abr15 = \log(rrs(1)/rrs(4))$  and  $abr25 = \log(rrs(2)/rrs(4))$ . These variables, ag\_def, aph\_def, abr15, and abr25 are unitless.

The inherent optical properties for back-scattering ( $IOP\_S(\text{band})$ ,  $\text{band} = 1..5$ ,  $IOP\_s$  is in  $m^{-1}$ ) is given by

$$IOP\_s(\text{band}) = bbw(\text{band}) + X*[555/lam(\text{band})]^Y$$

where  $bbw(\text{band})$  is the measured backscatter due to water for each band in  $m^{-1}$ ,  $lam(\text{band})$  is the wavelength of each band in nm, and X and Y are empirically determined functions for the back-scattering due to particles at 555-nm. The equation for X is given by

$$X = x_0 + x_1*rrs(4)$$

where  $x_0 = -0.00182 m^{-1}$  and  $x_1 = 2.058 sr m^{-1}$  are empirically determined regression coefficients. The equation for Y is given by

$$Y = y_0 + y_1*rrs(2)/rrs(3)$$

where  $y_0 = -1.13$  and  $y_1 = 2.57$  are empirically determined regression coefficients. X is in  $m^{-1}$  while Y is unitless.

For the semi-analytic models, aph675 is found by finding the root of the following function:

$$\text{function}(aph675) = f_0 + f_1*aph(1,aph675) + f_2*aph(2,aph675) + f_3*aph(2,aph675) + f_4*aph(4,aph675)$$

where

$$f_0 = g_{12}*(aw(4) + IOP\_s(4) - r_{34}*(aw(2)+IOP\_s(2))) - g_{34}*(aw(2) + IOP\_s(2) - r_{12}*(aw(1)+IOP\_s(1))) \text{ if } bb\_denom = 1 \text{ or}$$

$$= g12*(aw(4) + IOP\_s(4) - r34*(aw(2)+IOP\_s(2))) - g34*(aw(2) + IOP\_s(2) - r12*aw(1)) \quad \text{otherwise}$$

$$\begin{aligned} f1 &= g34*r12 \\ f2 &= -g34 \\ f3 &= -g12*r34 \\ f4 &= g12. \end{aligned}$$

The absorption due to water is given by aw (band) in m<sup>-1</sup> for each band. The coefficients r12, r34, g12, and g34 are given by

$$\begin{aligned} r12 &= (rrs(1) / IOP\_s(1)) / (rrs(2) / IOP\_s(2)) \\ r34 &= (rrs(2) / IOP\_s(2)) / (rrs(4) / IOP\_s(4)) \\ g12 &= r12 * \exp(-s*(lam(1) - 400) - \exp(-s*(lam(2) - 400) \\ g34 &= r34 * \exp(-s*(lam(2) - 400) - \exp(-s*(lam(4) - 400) \end{aligned}$$

where s = 0.0225 nm<sup>-1</sup> is the spectral slope for absorption coefficient due to gelbstoff as a function of wavelength (ag(lam)). The coefficients r12, r34, g12, and g34 are unitless. The normalized pigment absorption (aph(band, aph675)) is provided by the function call aph(band,aph675,a0,a1,a2,a3). The coefficients a0, a1, a2, and a3 depend on the model being evaluated. The coefficients a0, a1, and a2 are unitless, while a3 is in m<sup>-1</sup>. In order to facilitate the determination of the root of function (aph675) by filling an array (tx) of NX + 1 (NX = 32) test values for aph675 where the values are logarithmically spaced between a minimum value (aph\_lo = 0.0001 m<sup>-1</sup>) and a maximum value (aph\_hi = 0.030 m<sup>-1</sup>) of aph675, i.e.

$$tx(i) = 10^{\log(aph\_lo) - (\log(-ph\_hi) - \log(aph\_lo)) * (i-1) / NX}, \quad i = 1..NX+1.$$

The root (aph\_mod in m<sup>-1</sup>) of function (aph675) is found via bisection, with the search being iterated N\_ITER = 5 times. After the last iteration the bi-linear interpolation between the bracketing values tx(xlo+1) and tx(xhi+1), is

$$aph\_mod = tx(xlo+1) + (tx(xhi+1) - tx(xlo+1)) * flo / (flo - fhi)$$

where flo = f0 + f1 \* aph(1,tx(xlo+1)) + f2 \* aph(2,tx(xlo+1)) + f3 \* aph(2,tx(xlo+1)) + f4 \* aph(4,tx(xlo+1)) and  
 fhi = f0 + f1 \* aph(1,tx(xhi+1)) + f2 \* aph(2,tx(xhi+1)) + f3 \* aph(2,tx(xhi+1)) + f4 \* aph(4,tx(xhi+1)).

The corresponding model value for ag400 (ag\_mod in m<sup>-1</sup>) is then given by

$$ag\_mod = wph / g34$$

where wph = aw(4) + aph(4,aph\_mod) + IOP\_s(4) - r34 \* (aw(2) + aph(2,aph\_mod) + IOP\_s(2)) if bb\_denom = 1 or  
 wph = aw(4) + aph(4-aph\_mod) - r34 \* (aw(2) + aph(2,aph\_mod)) otherwise.

The chlorophyll concentration is then given by

$$chl\_mod = 10^{p0 + p1 * \log(aph\_mod) + p2 * \log^2(aph\_mod)}$$

where p0, p1, and p2 are model dependent and are unitless.

If  $aph_{hi}/2 < aph_{mod} < aph_{hi}$ , then the semi-analytical model is blended with the default empirical model. The weight (wt) for the blending is given by

$$wt = -(aph_{hi} - aph_{mod}) / -(aph_{hi} - aph_{hi}/2.)$$

where wt is unitless. The blended values for chlorophyll, aph675, and ag400 are

$$\begin{aligned} chl_{mod} &= wt * chl_{mod} + (1 - wt) * chl_{def}, \\ ag_{mod} &= wt * ag_{mod} + (1 - wt) * ag_{def}, \text{ and} \\ aph_{mod} &= wt * aph_{mod} + (1 - wt) * aph_{def}. \end{aligned}$$

If there was no root between  $aph_{lo}$  and  $aph_{hi}$ , i.e.  $aph_{mod} > aph_{hi}$ , then the default model is used giving

$$\begin{aligned} chl_{mod} &= chl_{def}, \\ aph_{mod} &= aph_{def}, \text{ and} \\ ag_{mod} &= ag_{def}. \end{aligned}$$

The inherent optical properties absorption coefficient ( $IOP_a(\text{band})$  in  $m^{-1}$  for band = 2–4) including absorption from pure water, phytoplankton pigments, and dissolved organic matter is given by

$$IOP_a(\text{band}) = aw(\text{band}) + aph(\text{band}, aph_{mod}) + ag_{mod} * \exp(-s*(-am(\text{band}) - 400)).$$

For band M1 a phaeophytin term is added, then the  $IOP_a(1)$  is given by

$$\begin{aligned} IOP_a(1) &= aw(1) + aph(1, aph_{mod}) + ag_{mod} * \exp(-s*(lam(1)-400.0)) \\ &+ ag_{mod} * \exp(-s*(lam(2)-400.0)) \\ &* (\exp(sphae*(lam(2)-412.0)) - \exp(s*(lam(2)-412.0))) \end{aligned}$$

where  $sphae = 0.0225 \text{ nm}^{-1}$ .

The  $IOP_a$  for band M5 is given by

$$IOP_a(5) = aw(5) + aph_{mod} + ag_{mod} * \exp(-s*(lam(5)-400.0)).$$

In the current implementation,  $IOP$  at M1 to M4 are retrieved with valid  $R_{rs}$  ( $>1e-8$ ) at M1 to M4 regardless the quality of  $R_{rs}$  at M5. Band wavelengths and model independent coefficients are shown in Table 6. The same a1 and a2 model coefficients are used for the global, unpackaged, and packaged semi-analytical models. Table 7 shows model dependent coefficients of the phytoplankton absorption function  $aph$  for the global, unpackaged, and packaged semi-analytical model. Fully packaged semi-analytical model coefficients for the phytoplankton absorption function  $aph$  are shown in Table 8. Table 9 shows model dependent coefficients for the global, unpackaged, packaged, and fully packaged semi-analytical models used in calculating chlorophyll concentrations.

**Table 6. Model Independent Coefficients**

Band	lam	bbw	aw	a1	a2
M1	412	0.003341	0.00480	0.59	-0.48

Band	lam	bbw	aw	a1	a2
M2	445	0.002406	0.00742	0.69	-0.48
M3	488	0.001563	0.01632	0.54	-0.48
M4	555	0.000929	0.05910	-0.18	-0.48
M5	672	0.000388	0.43538	0.00	-0.48

**Table 7. Model Dependent Coefficients for Phytoplankton Absorption Function aph**

Model	Global		Unpackaged		Packaged	
Band	a0	a3	a0	a3	a0	a3
M1	1.82	0.014	2.20	0.0112	1.46778	0.017276
M2	3.05	0.014	3.59	0.0112	2.53786	0.017276
M3	1.94	0.014	2.27	0.0112	1.62954	0.017276
M4	0.39	0.014	0.42	0.0112	0.355520	0.017276
M5	1.00	0.014	1.00	0.0112	1.00	0.017276

**Table 8. Fully Packaged Model Coefficients for Phytoplankton Absorption Function aph**

Band	a0	a1	a2	a3
M1	1.019	0.26	-0.45	0.021
M2	1.893	0.45	-0.45	0.021
M3	1.237	0.42	-0.45	0.021
M4	0.316	-0.08	-0.45	0.021
M5	1.000	0.00	-0.45	0.021

**Table 9. Model Dependent Coefficients for Default and Model Chlorophyll Concentrations**

Coefficient	Global	Unpackaged	Packaged	Fully Packaged
c0	0.354824	0.281800	0.423284	0.5100
c1	-2.64124	-2.78300	-2.50834	-2.340
c2	1.13884	1.86300	0.45994	0.400
c3	-1.62316	-2.38700	-0.90706	0.0
p0	1.7454	1.7150	1.7739	1.9000
p1	1.000	1.000	1.000	1.000
p2	0.0	0.0	0.0	0.0

**2.1.2.11.1 Calculate Normalized Pigment Absorption (aph)**

This function returns the absorption coefficient due to phytoplankton (aph) at a given waveband as a function of the absorption coefficient due to phytoplankton at 672-nm (aph675). The absorption coefficient is given by

$$aph = a0(\text{band}) * \exp(a1(\text{band}) * \tanh(a2(\text{band}) * \log(aph675/a3(\text{band})))) * aph675$$

where a0, a1, a2, and a3 are the fitting coefficients for each band = M1, M2, M3, and M4. The coefficients a0, a1, and a2 are unitless, while a3 is in m<sup>-1</sup>. The function is contained in ocolor.f.

**2.1.3 Graceful Degradation**

**2.1.3.1 Graceful Degradation Inputs**

There is one case where input graceful degradation is indicated in the OCC.

1. An input retrieved for the algorithm had its N\_Graceful\_Degradation metadata field set to YES (propagation).

Table 10 details the instance of this one case. Note that the shaded cells indicate that the graceful degradation was done upstream at product production.

**Table 10. Graceful Degradation**

Input Data Description	Baseline Data Source	Primary Backup Data Source	Secondary Backup Data Source	Tertiary Backup Data Source	Graceful Degradation Done Upstream
Digital Bathymetry Database*	VIIRS_GD_12.4.1 SRTM30_PLUS	N/A	N/A	N/A	N/A
Surface Pressure	VIIRS_GD_09.4.9 NCEP	VIIRS_GD_09.4.9 NCEP (Extended Forecast)	N/A	N/A	Yes
Total Column Ozone	VIIRS_GD_09.4.1 NCEP	VIIRS_GD_09.4.1 NCEP (Extended Forecast)	N/A	N/A	Yes
Sea Surface Wind Speed and Direction	VIIRS_GD_09.4.2 NCEP	VIIRS_GD_09.4.2 NCEP (Extended Forecast)	N/A	N/A	Yes
Nitrate Depletion Temperatures*	VIIRS_GD_13.4.1 Univ. of Florida (Kendal Carder) database	N/A	N/A	N/A	N/A

**2.1.3.2 Graceful Degradation Processing**

None

**2.1.3.3 Graceful Degradation Outputs**

None

**2.1.4 Exception Handling**

VIIRS ACO algorithm produces remote sensing reflectances (RSR) under all circumstances. If the pixel is not over ocean, is indicated as “confidently cloudy” by the cloud mask, includes sun glint, heavy aerosol or shadow, or is observed at night, a null value for the RSR IP is produced. The OCC is retrieved under all conditions except confidently cloudy and is flagged as “degraded” during probably clear and probably cloudy conditions.

Chlorophyll retrievals are performed only if the atmospheric correction algorithm provides positive values of water-leaving radiances in the VIIRS visible bands at 412, 445, 488, and 555-nm. If the algorithm results in chlorophyll concentrations above a predetermined maximum value, algorithm outputs will be set to -999.9.

### **2.1.5 Data Quality Monitoring**

Each algorithm uses specific criteria contained in a Data Quality Threshold Table (DQTT) to determine when a Data Quality Notification (DQN) is produced. The DQTT contains the threshold used to trigger the DQN as well as the text contained in the DQN. If a threshold is met, the algorithm stores a DQN in DMS indicating the test(s) that failed and the value of the DQN attribute. For more algorithm specific detail refer to the 474-00448-02-24\_JPSS-DD-Vol-II-Part-24.

### **2.1.6 Computational Precision Requirements**

The ACO/OCC algorithm requires input items to be 32-bit floating-point precision. All computations within the algorithm are done in 32-bit floating-point precision. Output values of the algorithm (see Section 2.1.1.2) are also all 32-bit floating-point precision, except QFs which are 8-bit integers.

### **2.1.7 Algorithm Support Considerations**

#### **2.1.7.1 Numerical Computation Considerations**

The magnitude of the output of the ACO algorithm is much less than the input values and the correction values calculated at each step in the routine. Small differences in inputs or subsequent correction values lead to significant changes in output values.

Both ACO and OCC use modeled data. They analyze current conditions and select an atmospheric model based on those conditions. In a situation where an analysis falls near a decision point between two possible models, machine error can lead to different models being picked on the same input data. The differing model could result in very different output data.

In the OCC routine, the output field Inherent Optical Properties Absorption is much greater than any other output value or any intermediary calculated value, with a large dynamic range. Small differences in input values and in processing calculations could lead to significant changes in output.

Both of these algorithms are very sensitive to calculation precision and rounding error.

#### **2.1.7.2 Software Environment Considerations**

Both a Fortran-90 and a C++ compiler are necessary to compile the ACO / OCC source code.

INF and DMS must be running before the ACO / OCC algorithm is executed.

#### **2.1.7.3 (Deleted) Science Enhancement Opportunities**

Section deleted by JPSS Change Order 10.

## 2.1.8 Assumptions and Limitations

### 2.1.8.1 Assumptions

- ACO receives an image of VIIRS geolocated pixels and calibrated TOA reflectances in the bands used by the ACO in internal IDPS SDR format.
- A cloud mask file, including cloud confidence, ocean/land flags, sun glint flags, a heavy aerosol flag, and a shadow flag for each VIIRS pixel, is provided to match the VIIRS data granule. The cloud mask is in the expected VIIRS cloud mask format.
- An SST EDR is provided to match the RSR granule.
- Ancillary and auxiliary data are provided and interpolated to provide values at each VIIRS pixel.
- Ancillary and auxiliary data will be provided by processing systems of other JPSS instruments, by a VIIRS module that will run before the ACO/OCC Unit, or from an analysis such as NCEP.
- The aerosol models used are representative of aerosols present over the ocean.
- Water-leaving reflectance is zero in the two near-infrared wavelength bands (M6 and M7).
- The formulation of whitecap reflectance as a function of wind speed and electromagnetic wavelength is valid.
- The two-layer plane-parallel model atmosphere adopted for radiative transfer calculations is valid.
- Water-leaving reflectance is described as a function of the ratio of the total back-scattering coefficient to the total absorption coefficient.
- The spectral slope of the DOM absorption coefficient is empirically determined.
- Parameters of the SPM back-scattering coefficient are empirically correlated to the remote-sensing reflectance.

### 2.1.8.2 Limitations

- The ACO is only performed under daytime conditions. This correction is not performed for a pixel if the cloud mask indicates confidently cloudy, sun glint, heavy aerosols, or shadow. The OCC is retrieved under all conditions except confidently cloudy and is flagged as “degraded” during probably clear and probably cloudy conditions. If the presence of cloud at an adjacent pixel is possible, or if a pertinent cloud mask test was not performed, the ACO is performed, but the product quality flag is set.
- The presence of an absorbing aerosol will cause the aerosol correction to fail, so the atmospheric correction will not be completed if absorbing aerosol is present.
- In the ACO algorithm, the water-leaving reflectance is assumed negligible in the two near-infrared wavelength bands (M6 and M7). This is not true in turbid coastal waters or in coccolithophore blooms. Techniques for adjusting the atmospheric correction under these conditions are under investigation. Currently, the atmospheric correction over turbid and shallow water is not performed.
- Further studies of the spectral dependence of whitecap reflectance and the variation in its contribution to the TOA reflectance with wind speed should be made.

### 3.0 GLOSSARY/ACRONYM LIST

#### 3.1 Glossary

Table 11 contains terms most applicable for this OAD.

**Table 11. 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: <ol style="list-style-type: none"> <li>1. A theoretical description (i.e., science/mathematical basis)</li> <li>2. A computer implementation description (i.e., method of solution)</li> <li>3. A computer implementation (i.e., code)</li> </ol>
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)	<p><i>[IORD Definition]</i>                      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.).</p> <p><i>[Supplementary Definition]</i>                      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.</p>
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.
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications.
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by GRAVITE, is developed into operational-grade code by the IDPS IPT.
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.

Term	Description
Raw Data Record (RDR)	<p><i>[IORD Definition]</i>                      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.</p> <p><i>[Supplementary Definition]</i>                      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.</p>
Retrieval Algorithm	<p>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.</p>
Science Algorithm	<p>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".</p>
Science Algorithm Provider	<p>Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.</p>
Science-Grade Software	<p>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.</p>
SDR/TDR Algorithm	<p>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.</p>
Sensor Data Record (SDR)	<p><i>[IORD Definition]</i>                      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.</p> <p><i>[Supplementary Definition]</i>                      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.</p>

Term	Description
Temperature Data Record (TDR)	<p><i>[IORD Definition]</i>                      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.</p> <p><i>[Supplementary Definition]</i>                      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.</p>

### 3.2 Acronyms

Table 12 contains acronyms most applicable for this OAD.

**Table 12. Acronyms**

Term	Expansion
ACO	Atmospheric Correction over Ocean
AFM	Airborne Fluxes and Meteorology Group
AM&S	Algorithms, Models & Simulations
AOS	Acquisition of Signal
API	Application Programming Interfaces
ARP	Application Related Product
BT	Brightness Temperature
BTD	Brightness Temperature Difference
CDA	Command and Data Acquisition
CDR	Climate Data Records
CI	Configured Item
CLAVR	Cloud Advanced Very High Resolution Radiometer
COMSAT	Communications Satellite
DES	Digital Encryption System
DHN	Data Handling Node
DMS	Data Management Subsystem
DQTT	Data Quality Test Table
EDC	Environmental Data Center
EOS	Earth Observing System
ERBS	Earth Radiation Budget Suite
ESD	Electrostatic Discharge
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMH	Federal Meteorological Handbook
GPS	Global Positioning System
GPSOS	GPS Occultation Suite
GSE	Ground Support Equipment
HRD	High Rate Data
I	Imagery
IGS	International GPS Service
IJPS	Initial Joint Polar System
INF	Infrastructure
IOC	Initial Operational Capability
ING	Ingest
IP	Intermediate Product
LEO&A	Launch, Early Orbit, & Anomaly Resolution
LOS	Loss of Signal
LRD	Low Rate Data
LST	Local Solar Time
LUT	Look-Up Table
M	Moderate
MDFCB	Mission Data Format Control Book
METOP	Meteorological Operational Program
MSS	Mission System Simulator
NA	Non-Applicable
NCA	National Command Authority
NPP	NPOESS Preparatory Program

Term	Expansion
PIP	Program Implementation Plan
PMT	Portable Mission Terminal
POD	Precise Orbit Determination
QF	Quality Flag
R	Reflectance
S&R	Search and Rescue
SCA	Satellite Control Authority
SDE	Selective Data Encryption
SDR	Sensor Data Records
SDS	Science Data Segment
SI	International System of Units
SN	NASA Space Network
SOC	Satellite Operations Center
SRD	Sensor Requirements Documents
SS	Space Segment
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
TEMPEST	Telecommunications Electronics Material Protected from Emanating Spurious Transmissions
TOA	Top of the Atmosphere
TOC NDVI	Top of the Canopy Normalized Difference Vegetation Index
TPIWV	Total Path Integrated Water Vapor
TPW	Total Precipitable Water
USB	Unified S-band
UTC	Universal Time Coordinated

**4.0 OPEN ISSUES**

**Table 13. TBXs**

TBX ID	Title/Description	Resolution Date
None		