Effective Date: June 3, 2011
Revision -

GSFC JPSS CMO
December 6, 2011
Released

Joint Polar Satellite System (JPSS) Ground Project
Code 474
474-00084

Joint Polar Satellite System (JPSS) Operational Algorithm Description Document for VIIRS Cloud

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.

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Check the JPSS MIS Server at https://jpssmis.gsfc.nasa.gov/frontmenu_dsp.cfm to verify that this is the correct version prior to use.

This page intentionally left blank.

Joint Polar Satellite System (JPSS) Operational Algorithm Description Document for VIIRS Cloud

JPSS Electronic Signature Page

Prepared By:

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

Approved By:

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

Goddard Space Flight Center
Greenbelt, Maryland

This page intentionally left blank.

Preface

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

Any questions should be addressed to:

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

This page intentionally left blank.

Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	06/03/2011	**474-CCR-11-0099**: This version baselines D39589, Operational Algorithm Description Document for VIIRS Cloud, Rev A dated 09/02/2008 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 June 3. 2011.

This page intentionally left blank.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS CLOUD (D39589 Rev A)

CDRL No. A032

Northrop Grumman Space & Mission Systems Corporation
One Space Park
Redondo Beach, California 90278

Copyright © 2004-2009
Northrop Grumman Corporation and Raytheon Company
Unpublished Work
ALL RIGHTS RESERVED

Portions of this work are the copyrighted work of Northrop Grumman and Raytheon. However, other entities may own copyrights in this work.

This documentation/technical data was developed pursuant to Contract Number F04701-02-C-0502 with the US Government. The US Government's rights in and to this copyrighted data are as specified in DFAR 252.227-7013, which was made part of the above contract.

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.

The information provided herein does not contain technical data as defined in the International Traffic in Arms Regulations (ITAR) 22 CFR 120.10.

This document has been approved by the Unites States Government for public release in accordance with NOAA NPOESS Integrated Program Office.

Distribution: Statement A: Approved for public release; distribution is unlimited.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS CLOUD (D39589 Rev A)

PREPARED BY:
Eric Wong, AM&S Algorithm Lead
Paul D. Siebels, IDPS PRO SW Manager

ELECTRONIC APPROVAL SIGNATURES:

_____

Roy Tsugawa Date
Algorithm & Data Processing IPT Lead &
Algorithm Change Control Board Chairperson

_____

Gerald J. Mulvey Date
Senior Systems Engineer

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Revision/Change Record

Document Number	D39589

Revision	Document Date	Revision/Change Description	Pages Affected
---	1-21-05	Initial PCIM Release, ECR A046.	All
A1	9-21-05	Reflects Raytheon-Omaha's initial edits for Science To Operational (Sci2Ops) Code Conversion Process, adding Raytheon coversheet, title/signature page, etc.	All
A2	2-23-07	Update per EH DQ OPT GD design peer review.	15,17
A3	3-4-07	Update per EH DQ OPT GD design peer review.	All
A4	3-10-07	Update per EH DQ OPT GD CUT CC peer review.	5
A5	3-26-07	Convert OAD to new template.	All
A6	4-27-07	Reflects updates pertaining to Tech Memo NP-EMD.2005.510.0080. Delivered to NGST.	All
A7	8-9-07	TM EMD.2007.510.0038 is implemented in B1.5.	All
A8	10-24-07	Minor update to Figure 1 per NGST. Delivered to NGST.	All
A9	7-23-08	Prepared for delivery to ACCB. Updated Acronym list and references. Implemented new cover sheet from NGST.	All
A	9-2-08	ECR A-166. Incorporated interim changes and addressed TIM comments. Approved for Public Release per Contracts letter 090618-01.	All

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Table Of Contents

1.0 INTRODUCTION 1
1.1 Objective 1
1.2 Scope 1
1.3 References 1
1.3.1 Document References 1
1.3.2 Source Code References 2
2.0 ALGORITHM OVERVIEW 4
2.1 VIIRS Cloud Module Description 4
2.1.1 Interfaces 5
2.1.1.1 Inputs 7
2.1.1.2 Outputs 9
2.1.2 Algorithm Processing 9
2.1.2.1 Main Module – CBH_main() 10
2.1.2.2 Submodule CalculateCbh() 10
2.1.2.3 Submodule CalculateWaterCbh() 11
2.1.2.4 Submodule CalculateMixedCbh() 13
2.1.3 Graceful Degradation 14
2.1.4 Exception Handling 14
2.1.5 Data Quality Monitoring 15
2.1.6 Computational Precision Requirements 15
2.1.7 Algorithm Support Considerations 15
2.1.8 Assumptions and Limitations 15
3.0 GLOSSARY/ACRONYM LIST 16
3.1 Glossary 16
3.2 Acronyms 18
4.0 OPEN ISSUES 20

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

List of Figures

Figure 1. CBH Algorithm Overview 4
Figure 2. Cloud Module Data Flow 5
Figure 3. Cloud Base Height Overall Flow Diagram 6
Figure 4. CalculateCbh() Logic Flow 11
Figure 5. CalculateWaterCbh() Logic Flow 12
Figure 6. CalculateMixedCbh() Logic Flow 14

List of Tables

Table 1. Reference Documents 1
Table 2. Source Code References 2
Table 3. Fill Values 6
Table 4. CBH Input: VIIRS Parallax Corrected Cloud Mask IP 7
Table 5. CBH Input: VIIRS Parallax Corrected Cloud Optical Properties IP 7
Table 6. CBH Input: VIIRS Parallax Corrected Cloud Top Parameters IP 7
Table 7. CBH Input: VIIRS Cloud Cover IP 8
Table 8. CBH Input: VIIRS SDR Moderate Resolution GEO Data 8
Table 9. VIIRS Granulated Ancillary Terrain Height Data Ancillary Data Inputs 8
Table 10. VIIRS CBH Liquid Water Content LUT 8
Table 11. CBH Tunable Parameters and Processing Coefficients 8
Table 12. CBH Output: VIIRS Cloud Base Height IP 9
Table 13. Glossary 16
Table 14. Acronyms 18
Table 15. TBXs 20

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

1.0 INTRODUCTION

1.1 Objective

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

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

The purpose of an OAD is two-fold:

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

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATDB 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 CBH IP. The theoretical basis for these algorithms is described in Section 3.3 of the Cloud Base Height ATBD, D43316.

1.3 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
Cloud Base Height, Visible/Infrared Imager/Radiometer Suite Algorithm Theoretical Basis Document (ATBD)	D43316 Rev. A	28 Nov 2007
NPP EDR Production Report	D37005 Rev. C	16 Mar 2007
EDR Interdependency Report	D36385 Rev. C	7 Nov 2007
CDFCB-X Volume I - Overview	D34862-01 Rev. B	27 Aug 2007
CDFCB-X Volume II – RDR Formats	D34862-02 Rev. B	27 Aug 2007
CDFCB-X Volume III – SDR/TDR Formats	D34862-03 Rev. A	27 Aug 2007
CDFCB-X Volume IV Part 1 – IP/ARP/GEO Formats	D34862-04-01 Rev. A	10 Sep 2007
CDFCB-X Volume IV Part 2 – Atmospheric, Clouds, and Imagery EDRs	D34862-04-02 Rev. A	10 Sep 2007
CDFCB-X Volume IV Part 3 – Land and Ocean/Water EDRs	D34862-04-03 Rev. A	10 Sep 2007
CDFCB-X Volume IV Part 4 – Earth Radiation Budget	D34862-04-04 Rev. A	10 Sep 2007

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Document Title	Document Number/Revision	Revision Date
EDRs		
CDFCB-X Volume V - Metadata	D34862-05 Rev. B	27 Aug 2007
CDFCB-X Volume VI – Ancillary Data, Auxiliary Data, Reports, and Messages	D34862-06 Rev. C	10 Sep 2007
CDFCB-X Volume VII – Application Packets	D34862-07 Rev. ---	10 Sep 2007
NPP Mission Data Format Control Book (MDFCB)	GSFC 429-05-02-42 R1	14 Apr 2006
NPP Command and Telemetry (C&T) Handbook	568423 Rev. A	5 Apr 2005
VIIRS Cloud Base Height Unit Level Detailed Design	Y2495-VIIRS-CBH-SW-DDD-028 Ver. 5 Rev. 7	Jan 2005
NPOESS System Specification	SY15-0007 Ver. E	1 Aug 2002
Data Processor Inter-subsystem Interface Control Document (DPIS ICD)	D35850 Rev. U	23 Jan 2008
Processing SI Common IO Design Document	DD60822-IDP-011 Rev. A	21 June 2007
D35836_E_NPOESS_Glossary	D35836_E Rev. E	23 May 2005
D35838_E_NPOESS_Acronyms	D35838_E Rev. E	23 May 2005
VIIRS Cloud Module-Level Software Architecture	Y2472 Ver. 5 Rev. 12	Jan 2005
VIIRS Cloud Module Level Interface Control Document	Y3278 Ver. 5 Rev. 9	Oct 2004
VIIRS Cloud Module Data Dictionary	Y0010871 Ver. 5 Rev. 11	Jan 2005
Operational Algorithm Description Document for the VIIRS Cloud Optical Properties (COP) Software	D39298 Rev. A5	19 June 2008
Operational Algorithm Description Document for the VIIRS Cloud Top Parameters (CTP) EDR Software	D39568 Rev. B6	19 June 2008
Operational Algorithm Description Document for the VIIRS Cloud Mask Intermediate Product (VCM IP) Software	D36816 Rev. A	12 Apr 2006
Operational Algorithm Description Document for VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (Cal) SDR Software	D41868 Rev. A11	22 Feb 2008
Operational Algorithm Description Document for the VIIRS Cloud Cover Layers (CCL) and Generate Cloud EDR (GCE) Software	D39590 Rev. A	02 Sep 2008
Operational Algorithm Description Document for the VIIRS Perform Parallax Correction (PPC) Software	D40382 Rev. A	02 Sep 2008
NGST/SE technical memo – MS Engineering Memo_CBH OAD Update	NP-EMD.2006.510.0080	07 July 2005
NGST/SE technical memo – NPP_VIIRS_CBH_bug_fixes_RevA	NP-EMD.2007.510.0038 Rev. A	08 June 2007
NGST/SE technical memo – VIIRS Cloud Mask (VCM) OAD Update	NP-EMD.2004.510.0050	3 Dec 2004
VIIRS Cloud Base Height (CBH) IP Science Grade Software Unit Test Document	NP-EMD.2005.510-0007 Rev. ---	21 Jan 2005

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 Cloud Base Height --- science grade software	20050812_ISTN_VIIRS_NGST_3.5	12 Aug 2005

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Reference Title	Reference Tag/Revision	Revision Date
VIIRS Cloud Base Height --- operational software	/PRO/EDR/VIIRS/clouds/cbh/ B1.5, Vers. D.1.1.6	06 Apr 2007

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

2.0 ALGORITHM OVERVIEW

For this section, the definition of an algorithm is a logical grouping of operational algorithm modules for which there is a single Input-Processing-Output (I-P-O) architecture with a single defined set of external inputs and outputs (e.g., IPs or xDRs).

The Cloud Base Height (CBH) algorithm is executed during IP/EDR processing and requires SDR, IP, Ancillary (ANC), and Look-Up Table (LUT) inputs to produce an IP output. A top-level diagram for the CBH algorithm is shown in Figure 1.

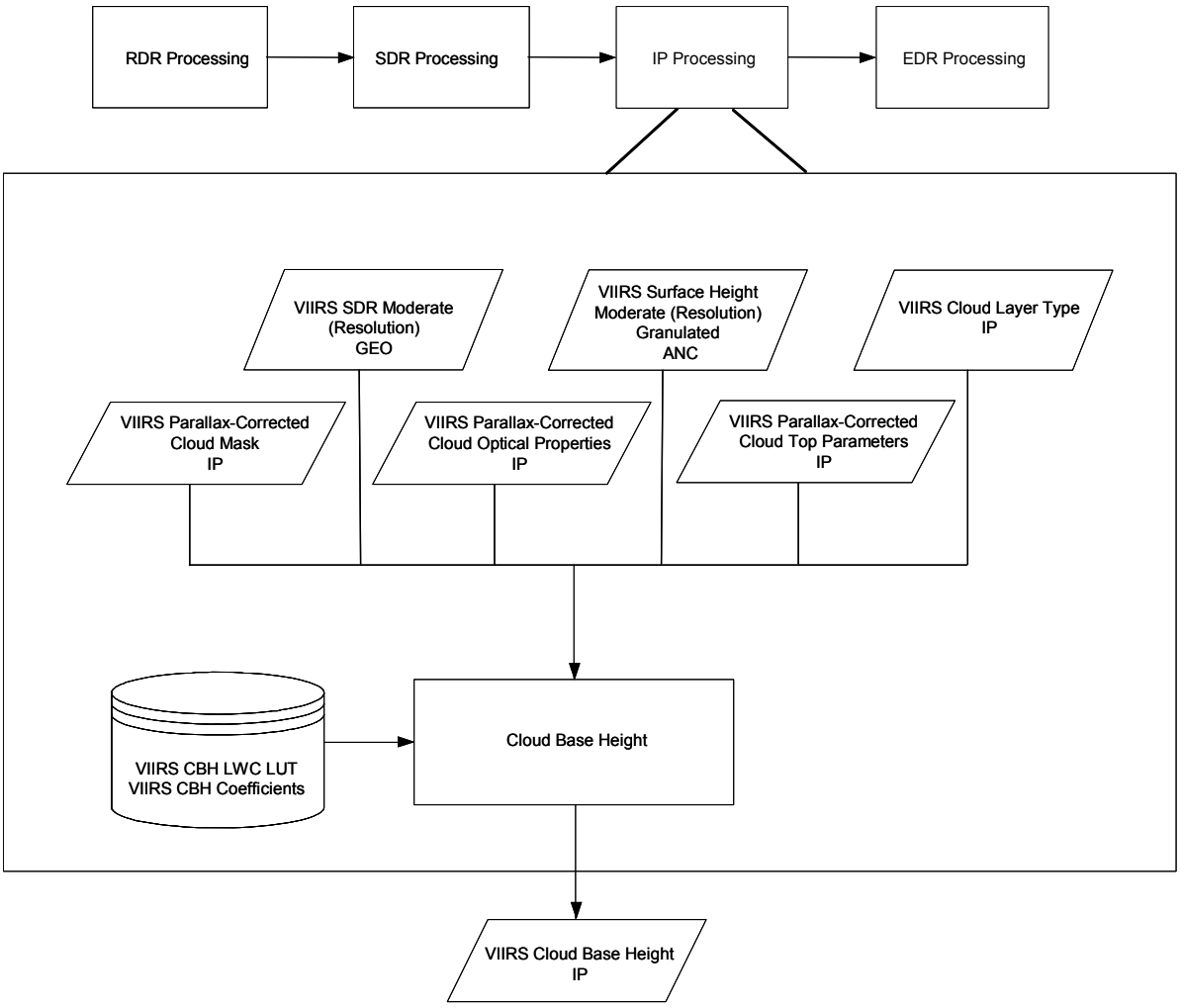


Figure 1. CBH Algorithm Overview

2.1 VIIRS Cloud Module Description

A dataflow diagram for the VIIRS Clouds Module, of which the CBH Module is a member, is shown in Figure 2. Each circle represents a stand-alone unit of the VIIRS Cloud Module. Processing order is indicated by the number in each circle. The CBH algorithm produces the CBH IP which is used by the GCE algorithm to produce the CBH EDR.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

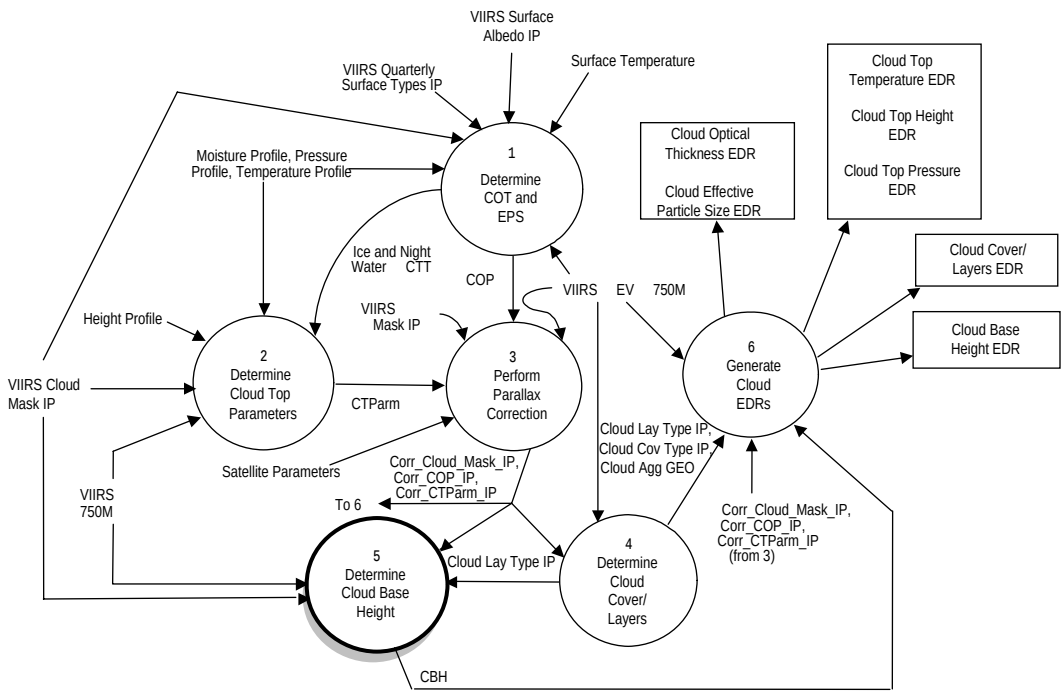


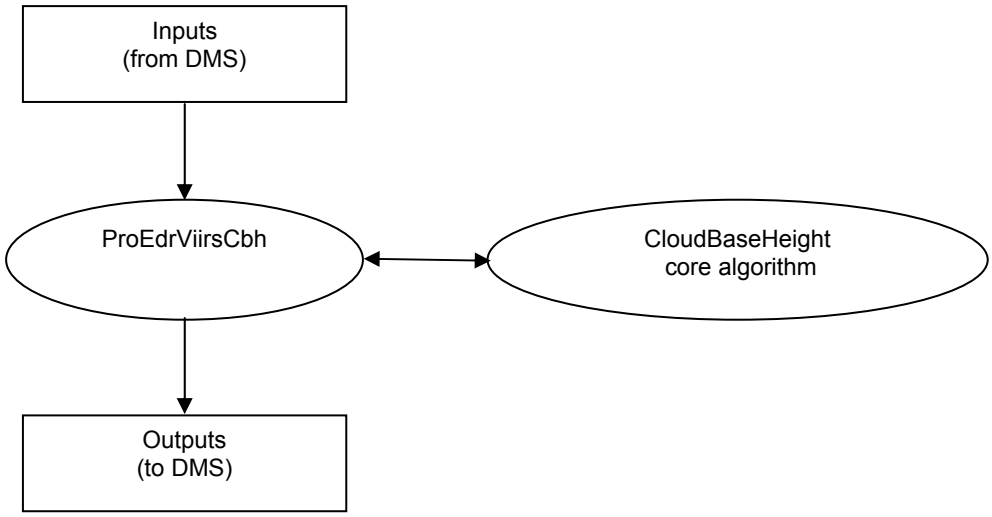
Figure 2. Cloud Module Data Flow

2.1.1 Interfaces

CBH consists of derived and core algorithm modules. The derived algorithm module ProEdrViirsCbh functions as a wrapper for the core algorithm module and handles the I-O stages in the I-P-O architecture. ProEdrViirsCbh initiates the core algorithm module Cloud Base Height which makes up the P stage.

The main flow of the operational CBH algorithm is shown in Figure 3 below. The CBH algorithm gets all required input data from the Data Management System (DMS). When all input data needed for processing is available, the core algorithm CloudBaseHeight is called to determine cloud base height. All inputs from and outputs to DMS are in binary format.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO



ProEdrViirsCbh Description

This is the derived class from ProCmnAlgorithm that contains overridden methods setupDataItems and doProcessing. Method setupDataItems instantiates input and output data items which represent data buffers to be used by the algorithm. doProcessing is the method where processing of the algorithm input data and generation of the output data by the algorithm is done. For more information see the Process Common IO Design Document and Users Guide, DD60822-IDP-011.

Figure 3. Cloud Base Height Overall Flow Diagram

The CBH Module requires VIIRS Moderate Geolocation (GEO), VIIRS Moderate Surface Height Granulated ANC, VIIRS Parallax Corrected Cloud Mask (CM) IP, VIIRS Parallax Corrected Cloud Optical Properties (COP) IP, VIIRS Cloud Layer Type IP, VIIRS CBH Liquid Water Content (LWC) LUT, and VIIRS CBH IP Algorithm Coefficients as inputs to produce the VIIRS CBH IP. A detailed itemization of the inputs and outputs for the CBH Module is provided below.

Note: For Sections 2.1.1.1 and 2.1.1.2 below, the following applies:

- Fill values corresponding to the individual pixels in each product that do not contain valid data are dictated by the datatype (see Table 3). Exception: bitwise flags (i.e. cloud mask data, quality flags) are filled with zeros.
- For detailed descriptions of the quality flags in the tables below, refer to the applicable I-P-O algorithm OAD (CM, COP, or CTP).
- M_VIIRS_SDR_ROWS = NUMBER of SCANS PER GRANULE X NUMBER of MODERATE DETECTORS
- M_VIIRS_SDR_COLS = 3200

Table 3. Fill Values

Input	Type	Description	Units/Valid Range
NA_FLOAT32_FILL	Float32	Float32 not applicable fill value	Unitless / -999.9
MISS_FLOAT32_FILL	Float32	Float32 missing fill value	Unitless / -999.8
ONBOARD_PT_FLOAT32_FILL	Float32	Float32 onboard pixel trim fill value	Unitless / -999.7
ONGROUND_PT_FLOAT32_FILL	Float32	Float32 on ground pixel trim fill value	Unitless / -999.6
ERR_FLOAT32_FILL	Float32	Float32 error fill value	Unitless / -999.5

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Input	Type	Description	Units/Valid Range
NA_UINT8_FILL	UInt8	UInt8 not applicable fill value	Unitless / 255
MISS_ UINT8_FILL	UInt8	UInt8 missing fill value	Unitless / 254
ONBOARD_PT_ UINT8_FILL	UInt8	UInt8 onboard pixel trim fill value	Unitless / 253
ONGROUND_PT_ UINT8_FILL	UInt8	UInt8 on ground pixel trim fill value	Unitless / 252
ERR_ UINT8_FILL	UInt8	UInt8 error fill value	Unitless/ 251

2.1.1.1 Inputs

Tables 4 through 11 describe CBH algorithm inputs. Note that none of the inputs are scaled and that all input files must be spatially and temporally consistent with each other.

Table 4. CBH Input: VIIRS Parallax Corrected Cloud Mask IP

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
Cloud confidence	2-bit unsigned field	Cloud Detection Result & Confidence Indicator	0 - Confidently clear 1 - Probably clear 2 - Probably cloudy 3 - Confidently cloudy
Sun glint	2-bit unsigned field	Sun glint	0 - No sun glint 1 - Geometry Based 2 - Wind Speed Based 3 - Geometry & Wind
Cloud phase	3-bit unsigned field	Cloud phase	0 - Not Executed 1 - Clear 2 - Partly Cloudy 3 - Water 4 - Mixed 5 - Opaque Ice 6 - Cirrus 7 - Overlap

Table 5. CBH Input: VIIRS Parallax Corrected Cloud Optical Properties IP

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
Cot	Float32[M_VIIRS_SDR_ROW][M_VIIRS_SDR_COLS]	Unscaled cloud optical thickness	Unitless / 0.1 to 64
Eps	Float32[M_VIIRS_SDR_ROW][M_VIIRS_SDR_COLS]	Unscaled cloud effective particle radius	Microns / 1 to 50

Table 6. CBH Input: VIIRS Parallax Corrected Cloud Top Parameters IP

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
Ctt	Float32[M_VIIRS_SDR_ROW][M_VIIRS_SDR_COLS]	Unscaled Cloud Top Temperature	Kelvin / 175 to 310

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Input	Type	Description	Units/Valid Range
Cth	Float32[M_VIIRS_SDR_ROW][M_VIIRS_SDR_COLS]	Unscaled Cloud Top Height	Kilometers / 0 to 20

Table 7. CBH Input: VIIRS Cloud Cover IP

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
Cloud_Layer	UInt8[M_VIIRS_SDR_ROWS][M_VIIRS_SDR_COLS]	Pixel-level cloud layer identification (up to 4 layers)	Unitless / 0 to 3
Cloud_Type	UInt8[M_VIIRS_SDR_ROWS][M_VIIRS_SDR_COLS]	Pixel-level cloud type identification	Unitless / 1 to 5 1-Stratus 2-Alto Cumulus 3-Cumulus 4-Cirrus 5-CirrusCumulus

Table 8. CBH Input: VIIRS SDR Moderate Resolution GEO Data

Input	Type	Description	Units/Valid Range
Granule-Level Data Items			
Actual scans	Int32	Actual number of sdr scans in a granule	Unitless / 1 to VIIRS_RDR_SCANS

Table 9. VIIRS Granulated Ancillary Terrain Height Data Ancillary Data Inputs

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
Terrain height	UInt16[M_VIIRS_SDR_ROWS][M_VIIRS_SDR_COLS]	Terrain Height with respect to mean sea level (msl)	Meters / -1000 to 9000

Table 10. VIIRS CBH Liquid Water Content LUT

Input	Type	Description	Units/Valid Range
Lwc	Float32[MAX_VIIRS_CBH_LWC]	Cloud liquid water concentration (LWC) lookup table values for cloud type	g/m^3 / 0.000: no cloud 0.293: stratus 0.455: altocumulus or altostratus 0.580 : cumulus 0.010 : cirrus 0.010 : cirrocumulus

Table 11. CBH Tunable Parameters and Processing Coefficients

Input	Type	Description	Units/Valid Range
minCbh	Float32	Minimum cloud base height	Kilometers / 0
maxCbh	Float32	Maximum cloud base height	Kilometers / 20
c_0	Float32	Ice water path (IWP) constants in equation IWP = Cot / [c0 + (c1 / 2reff)]	m^2/g / – 0.006656
c_1	Float32	Ice water path (IWP) constant in equation IWP = Cot / [c0 + (c1 / 2reff)]	m^2 µm/g / 3.686
c_2	Float32	Ice water concentration (IWC) constant	Celsius / 20.0

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Input	Type	Description	Units/Valid Range
c_3	Float32	Ice water concentration (IWC) constant	Unitless / 2.455
c_4	Float32	Ice water concentration (IWC) constant	Unitless / – 0.2443
c_5	Float32	Ice water concentration (IWC) constant	Unitless / 0.001
c_6	Float32	Ice water concentration (IWC) constant	Unitless / – 7.6
c_7	Float32	Ice water concentration (IWC) constant	Unitless / 4.0
d_0	Float32	Cloud liquid water path (LWP) constant in equation LWP = (d0 * Cot * reff) / d3	gm/m^2 / 2.0
d_3	Float32	Cloud liquid water path (LWP) constants in equation LWP = (d0 * Cot * reff) / d3	Microns / 3.0
minCtt	Float32	Minimum cloud top temperature	Celcius / -60.0
maxCtt	Float32	Maximum cloud top temperature	Celcius / -20.0

2.1.1.2 Outputs

Table 12 describes CBH algorithm outputs.

Table 12. CBH Output: VIIRS Cloud Base Height IP

Input	Type	Description	Units/Valid Range
Pixel-Level Data Items			
cbh	Float32 [M_VIIRS_SDR_ROWS][M_VIIRS_SDR_COLS]	Cloud base height	Kilometers / 0 to 20
cbhQf	UInt8 [M_VIIRS_SDR_ROWS][M_VIIRS_SDR_COLS]	Bitwise cloud base height quality flags 0 Out of Range — 0-Not, 1-Out of range 1 Cloud Confidence — 0-Not, 1-Prob/Conf clear 2 Sun glint — 0-None, 1-Sun glint 3-7 Spare	

2.1.2 Algorithm Processing

The purpose of the CBH IP algorithm is to retrieve cloud base heights for each confidently cloudy pixel in a VIIRS moderate resolution (750 m) granule. CBH, defined as the height above sea level where cloud bases occur, is calculated by determining the cloud thickness and subtracting it from cloud top height (CTH). Since CTH is obtained from a parallax-corrected version of the CTH IP, the processing focuses on the calculation of the cloud thickness. Briefly, cloud thickness is calculated by dividing the liquid (or ice) water path with liquid (or ice) water content. Both liquid water path and ice water path are determined based on a correlation equation in terms of cloud optical depth and effective particle size (EPS). Ice water content is also determined from a parameterization equation in terms of cloud top temperature (CTT). For liquid water content, however, constant values are used for each water cloud type.

Cloud thickness must be calculated and is dependent on cloud-phase. The CBH retrieval is performed by one of two algorithms:

1) a liquid-water algorithm for water-phase clouds,
2) a mixed-phase algorithm for opaque ice-phase, cirrus-phase, mixed-phase, or overlap-phase clouds.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

The retrieval is performed for confidently cloudy pixels only.

Quality assessment flags for each pixel are stored in the CBH Quality Flag (QF) output.

2.1.2.1 Main Module – CBH_main()

The CBH_main() module performs four main tasks: 1) initialize output buffers, 2) associate pointers returned from DMS with local variables, 3) perform basic error handling, and 4) call CalculateCbh().

The CBH algorithm outputs two pieces of data: cloud base height and quality flags. CBH is initialized to ONGROUND_PT_FLOAT32_FILL and quality flags are initialized to zero.

Pointers to CBH inputs retrieved from DMS in ProEdrViirsCbh() are assigned to a class variable (a structure) that is passed throughout the CBH algorithm.

A small amount of error handling is performed in CBH_main() at the granule level to ensure there are valid scans to process and that selected coefficients (used later as divisors) do not cause divide-by-0 errors.

CBH_main() calls CalculateCbh() which in turn calculates CBH and quality flags for the entire granule.

2.1.2.2 Submodule CalculateCbh()

The logic flow of the CBH IP retrieval algorithm is provided in Figures 4 through 6. Duties of the module CalculateCbh() are: 1) establish whether or not a pixel should be processed, 2) determine the retrieval quality, 3) determine the retrieval algorithm for pixels that are processed, and 4) adjust for terrain height if necessary.

CBH is not retrieved if any of the following conditions occur:

- The pixel is not confidently cloudy (as specified by the VIIRS CM).
- Cloud phase is specified as something other than water-phase, opaque-ice-phase, cirrus-phase, mixed-phase, or overlap-phase.
- Cloud type is outside the CBH definition range of stratus, altocumulus/altostratus, cumulus, cirrus, or cirrocumulus.
- Cloud layer is outside a defined range.
- The pixel is determined to be in an area affected by the VIIRS “bow tie” effect.
- COT, EPS, or CTH contains Fill values.

Further retrieval restrictions apply for ice-phase (opaque-ice, cirrus), mixed-phase, or overlap-phase clouds:

- CTT contains Fill values.

For pixels that are processed, CBH is retrieved by either a water-phase algorithm for water-phase clouds or by a mixed-phase algorithm for ice-phase, mixed-phase, or overlap-phase clouds. A false retrieval occurs if cloud base height for a given pixel is greater than the pixel’s CTH. In this scenario, the CBH is filled with ERR_FLOAT32_FILL.

For valid CBH retrievals where CBH is less than the terrain height, CBH is adjusted to terrain height.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

CBH retrieval quality is checked and flagged for sun glint, cloud confidence of probably or confidently clear, and out-of range values.

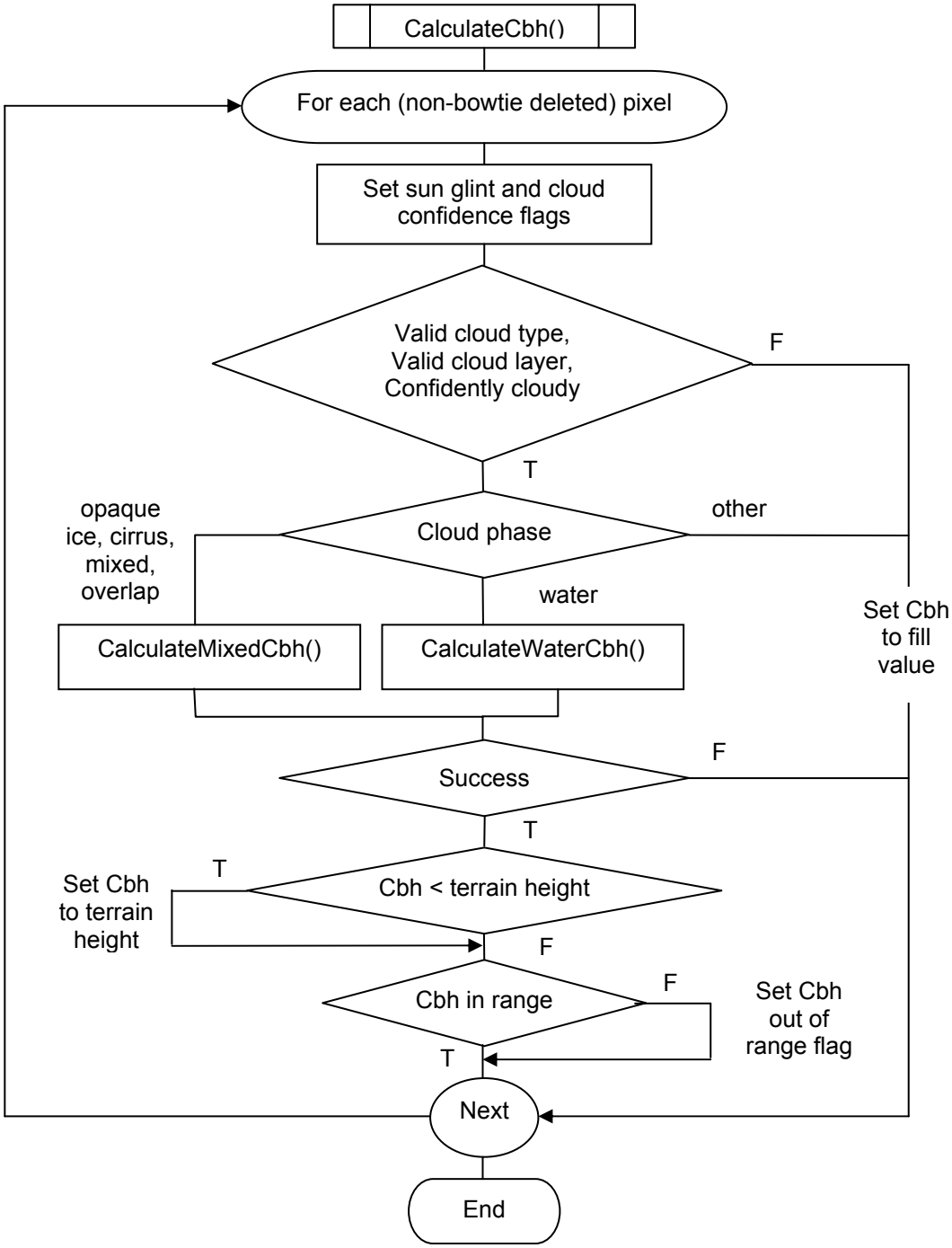


Figure 4. CalculateCbh() Logic Flow

2.1.2.3 Submodule CalculateWaterCbh()

For water-phase clouds, CBH is calculated according to the following algorithm (see Figure 5 for logic flow):

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Calculate Liquid Water Path (LWP).

$$LWP = \frac{d_0 \cdot Cot \cdot r_{eff}}{d_3}$$

where

LWP is in g/m^2,
d_0 and d_3 are cloud LWP constants,
Cot is the unitless COT, and
r_{eff} is the effective particle radius in □m, (also denoted by variable Eps).

Calculate CBH, Cbh in m and convert to km.

$$Cbh = Cth - cloud\ thickness = Cth - \left(\frac{LWP}{LWC_{Ct}}\right) \cdot METERS_TO_KM$$

where

Cth is the CTH in km,
LWC_{Ct} is the liquid water concentration lookup value in g/m^3 for a specified cloud type, Ct, and
METERS_TO_KM is the conversion from m to km.

Note that all calculations are carried out in floating point arithmetic. The theoretical basis of this algorithm is presented in Section 3.3.2 of the Cloud Base Height ATBD, D43316.

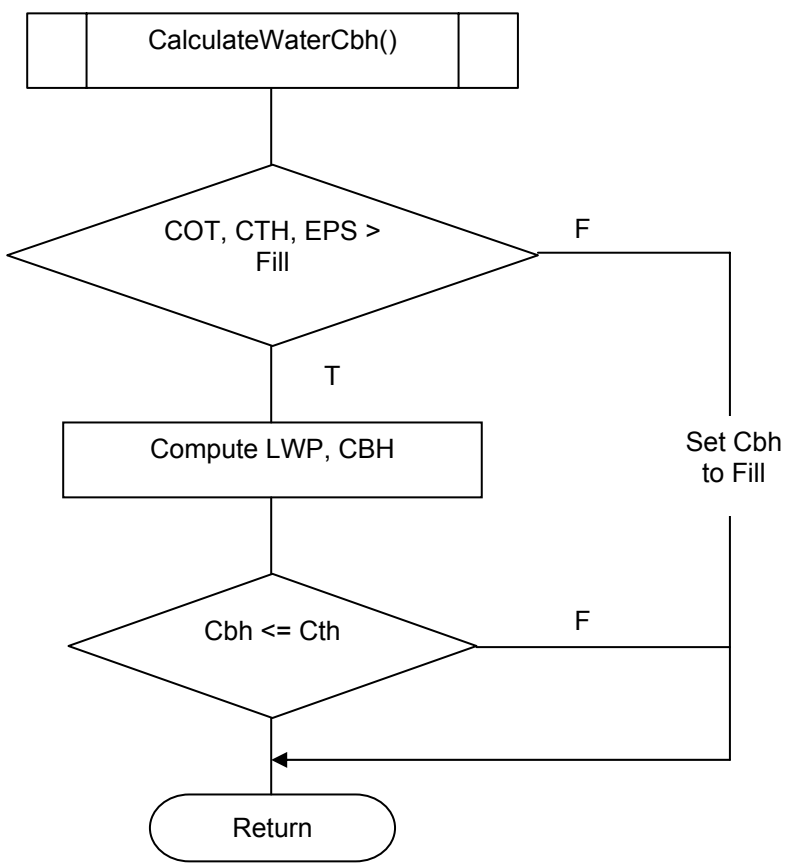


Figure 5. CalculateWaterCbh() Logic Flow

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

2.1.2.4 Submodule CalculateMixedCbh()

For ice-phase and mixed-phase clouds, CBH is calculated according to the following algorithm (see Figure 6 for logic flow):

Calculate Ice Water Path (IWP).

$$IWP = \frac{Cot}{c_0 + \frac{c_1}{2r_{eff}}}$$

where

IWP is in g/m^2,
c_0 and c_1 are cloud IWP constants,
Cot is the unitless COT, and
r_{eff} is the effective particle radius in □m, (also denoted by variable Eps).

Calculate Cloud Mean Temperature (CMT), from CTT, Ctt

- Convert CTT, Ctt from Kelvin to Centigrade
  $$Ctt = Ctt - 273.15$$
- Reset temperature to –60° C if it is below –60° C.
  Add delta temperature correction (Cot * 20.0/6.0).
  Reset temperature to –20°C if it is warmer than –20°C
  $$\mathrm{CMT} = \min(\,(\max(-60, \mathrm{Ctt}) + (20.0/6.0) * \mathrm{Cot}\,), -20\,)\,.$$

Calculate Ice Water Path, IWC.

- Since IWP equation is valid for |CMT| > 20 ° C, ensure that this condition is met.
  $$\mathrm{absCMT} = \max(|\mathrm{CMT}|, 20.000001)$$
- Use absCMT to calculate IWC.
  $$\ln(IWC) = c_6 + c_7 \cdot e^{term}$$
  $$term = c_4 \cdot c_5 \cdot (absCMT - c_2)^{c_3}$$
  where

  IWC is the Ice Water Path in g/m^3, and
  c_2 to c_7 are the IWC constants.

Calculate CBH, Cbh in m and convert to km.

$$Cbh = Cth - cloud\ thickness = Cth - \left(\frac{IWP}{IWC}\right) \cdot METERS_TO_KM$$

where

Cth is the CTH in km, and
METERS_TO_KM is the conversion from m to km.

Note that all calculations are carried out in floating point arithmetic. The theoretical basis of this algorithm is presented in Section 3.3.2 of the Cloud Base Height ATBD, D43316.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

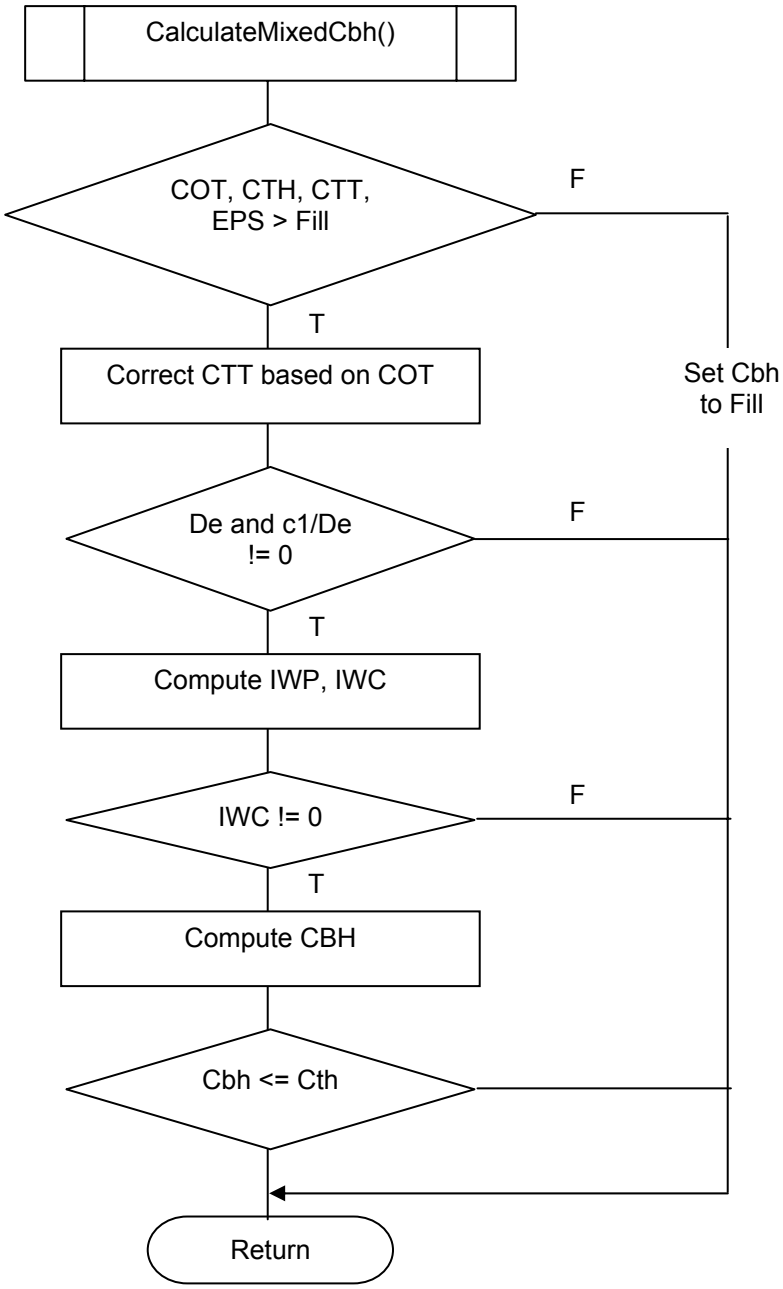


Figure 6. CalculateMixedCbh() Logic Flow

2.1.3 Graceful Degradation

None.

2.1.4 Exception Handling

A mechanism for external termination of the algorithm, called a stop callback, has been implemented. If a stop callback is issued, processing is terminated and no outputs are produced.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Error-handling in the Input (I) and Output (O) stages of the I-P-O algorithm addresses errors associated with reading/writing of databases. If an error occurs, the error is reported, the process is terminated and no outputs are produced.

Error-handling in the Processing (P) stage involves granule level and pixel level errors. For granule level errors, i.e. bad LUT values or an invalid number of scans, the error is reported, the process is terminated and no outputs are produced.

At initialization, cbh outputs are set to ONGROUND_PT_FLOAT32_FILL (i.e. pixel-trim fill) so they are already set for bow tie deletion and quality flag outputs are set to zero. Only pixels that are not in the bow-tie deletion region are processed. During processing, pixel level errors (i.e. divide by zero, cbh > cth), are reported, the pixels are filled with ERR_FLOAT32_FILL, and processing continues with the next pixel. Pixels not applicable for cloud base height processing (i.e. invalid cloud layer or type; not water, ice, mixed, or overlap phase; filled COT, CTH, CTT, or EPS) are filled with NA_FLOAT32_FILL and processing continues with the next pixel.

2.1.5 Data Quality Monitoring

CBH quality assessments consist of quality flags for sun glint, cloud confidence (confidently/probably clear), and out-of-range (see Table 12) in the output IP.

Any Data Quality Threshold Tables (DQTTs) or Data Quality Notifications (DQNs) relevant to CBH are handled downstream during EDR processing by the Generate Cloud EDRs (GCE) module.

2.1.6 Computational Precision Requirements

Floating-point calculations are carried out in single-precision and double-precision arithmetic.

2.1.7 Algorithm Support Considerations

Sufficient research observations have been made to characterize cloud optical properties (e.g., LWC and IWC), and these values are relatively constant over global conditions.

2.1.8 Assumptions and Limitations

Assumptions and limitations based on theory are contained in the VIIRS Cloud Base Height ATBD, D43316.

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

The current glossary for the NPOESS program, D35836_E_NPOESS_Glossary, can be found on eRooms. Table 13 contains those terms most applicable for this OAD.

Table 13. Glossary

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

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

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

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Term	Description
Temperature Data Record (TDR)	*[IORD Definition]* Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. *[Supplementary Definition]* A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]

3.2 Acronyms

The current acronym list for the NPOESS program, D35838_E_NPOESS_Acronyms, can be found on eRooms. Table 14 contains those terms most applicable for this OAD.

Table 14. Acronyms

Acronym	Description
ACO	Atmospheric Correction over Ocean
ADCS	Advanced Data Collection System
AFM	Airborne Fluxes and Meteorology Group
AOS	Acquisition of Signal
CBH	Cloud Base Height
CCL	Cloud Cover\Layers
CDA	Command and Data Acquisition
CDR	Climate Data Records
CI	Configured Item
CM	Cloud Mask
CMT	Cloud Mean Temperature
COMSAT	Communications Satellite
COP	Cloud Optical Properties
COT	Cloud Optical Thickness
CTH	Cloud Top Height
CTP	Cloud Top Parameters
CTT	Cloud Top Temperature
DES	Digital Encryption System
DHN	Data Handling Node
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
EOS	Earth Observing System
EPS	Effective Particle Size
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
GSE	Ground Support Equipment

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

Acronym	Description
HRD	High Rate Data
IGS	International GPS Service
IJPS	Initial Joint Polar System
IOC	Initial Operational Capability
IP	Intermediate Product
IWP	Ice Water Path
LEO&A	Launch, Early Orbit, & Anomaly Resolution
LOS	Loss of Signal
LRD	Low Rate Data
LST	Local Solar Time
LUT	Look-Up Table or Local User Terminal
LWP	Liquid Water Path
Metop	Meteorological Operational Program
MSS	Mission System Simulator
NA	Non-Applicable
NCA	National Command Authority
NDT	Nitrate-Depletion Temperature
OC/C	Ocean Color/Chlorophyll
PIP	Program Implementation Plan
PMT	Portable Mission Terminal
POD	Precise Orbit Determination
QF	Quality Flag
RSR	Remote Sensing Reflectance
S&R	Search and Rescue
SCA	Satellite Control Authority
SDE	Selective Data Encryption
SDP	Software Development Plan
SDR	Sensor Data Records
SDS	Science Data Segment
SGI®	Silicon Graphics, Inc.
SI	International System of Units
SN	NASA Space Network
SOC	Satellite Operations Center
SRD	Sensor Requirements Documents
SS	Space Segment
SST	Sea Surface Temperature
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
USB	Unified S-band
UTC	Universal Time Coordinated

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO

4.0 OPEN ISSUES

Table 15. TBXs

TBX ID	Title/Description	Resolution Date
None		

D39589, A. PDMO Released: 2009-08-27 (VERIFY REVISION STATUS)
PDMO