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# Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Snow Cover Environmental Data Record (EDR) Software

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

National Aeronautics and Space Administration

# Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Snow Cover 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:

JPSS Configuration Management Office
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# Change History Log

| Revision | Effective Date | **Description of Changes** (Reference the CCR & CCB/ERB Approve Date) |
|---|---|---|
| Original | 06/03/2011 | This version incorporates **474-CCR-11-0101** which converts D39592, Operational Algorithm Description Document for VIIRS Snow Cover Environmental Data Record (EDR), Rev C dated 07/07/2010 to a JPSS document, Rev -. This was approved by the JPSS Ground Algorithm ERB on June 3, 2011. |
| Revision A | 01/18/2012 | **474-CCR-11-0267:** This version baselines, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Snow Cover 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 | 05/14/2013 | **474-CCR-13-0948:** This version authorizes, JPSS OAD Document for VIIRS Snow Cover EDR Software, for the Mx 7.0 IDPS release. Includes **ECR-ALG-0037** which contains Raytheon PCR031559; OAD: Implemented 474-CCR-12-0480 (Increase SZA Threshold in VIIRS-SCD-SNOW-COVER-QUAL-LUT from 60 to 85 degrees) (ADR 4787) on Tables 11 & 12. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release. |
| Revision C | 11/06/2013 | **474-CCR-13-1288:** This version authorizes 474-00086, JPSS OAD Document for VIIRS Snow Cover EDR Software, for the Mx 8.0 IDPS release. Includes administrative changes authorized by interoffice memo and Raytheon PCR034979; VIIRS-Snow-Cover-EDR OAD (474-00086) definition of NDVI Quality flag is incorrect, in section 2.1.2.6.. |
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# NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

# OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SNOW COVER ENVIRONMENTAL DATA RECORD (EDR)

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

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

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

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SNOW COVER ENVIRONMENTAL DATA RECORD (EDR)

APPROVAL SIGNATURES:

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

**CAGE NO. 11982**

# Operational Algorithm Description Document for the VIIRS Snow Cover EDR Software

**Document Date: Sep 21, 2011**

**Document Number: D39592**
**Revision: D5**

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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.<br>**Space Technology**<br>One Space Park<br>Redondo Beach, CA 90278 | NORTHROP GRUMMAN<br>Raytheon |

## Revision/Change Record

**Document Number** **D39592**

| Revision | Document Date | Revision/Change Description | Pages Affected |
|---|---|---|---|
| -- | 4-29-05 | Initial PCIM Release - Reference ECR A048. | All |
| A1 | 5-4-05 | Revision A – Replace ITAR marking with Commerce Destination Control Statement. | Title Page |
| A2 | 11-3-05 | Reflects Raytheon-Omaha's Science To Operational Code Conversion including insertion of Fig 2 titled "IPO Model Interface to INF and DMS plus renumbering the original Figures 2 thru 5. Also includes insertion of the 31-page Tech Memo addressing quality flags. | All |
| A3 | 1-16-06 | Inserted new Figure 2 (IPO Model Interface to INF and DMS) for shell granules info per comments from EH/DQ DDPR held on 11Jan06. Per the same PR, Greg Richardson added info to Section 4.2 Error Handling and Section 2.2.2.2 Data Quality Notification. | 4,17,27 |
| A4 | 11-13-06 | Clean up TBDs, typos, grammar. | All |
| A5 | 2-22-07 | Placed OAD information into new template. | All |
| A6 | 2-28-07 | Delivered to NGST. | All |
| A7 | 5-14-07 | Implemented revisions based on NP-EMD.2007.510.0021 for Fresh Water Lake Processing. | All |
| A8 | 6-6-07 | Implemented NGST comment responses to Feb 2007 delivery. Delivered to NGST. | All |
| A9 | 10-24-07 | Implemented NGST comment responses to June 2007 delivery. Implemented revisions based on NP-EMD.2006.510.0075 for AOT table entry. Delivered to NGST. | All |
| A10 | 12-11-07 | Replaced Figures 4 and 6 with more legible figures from NGST. | All |
| A11 | 9-6-08 | Updated Graceful Degradation. | 25 |
| A12 | 10-1-08 | Prepared for delivery to TIM/ACCB. | All |
| A | 1-15-09 | Incorporated interim changes and addressed TIM/ACCB comments. ECR A-170 Rev A. Corrected Reference Source Error, editorial comment, and hidden link issues. | All |
| B | 03-01-10 | Rev Rolled for Public Release. | All |
| C1 | 12-01-09 | Updated for RFA No. 632 and updated Subcontract Number. | Title pg. |
| C2 | 5-26-10 | Incorporated TIM comments | All |
| C | 7-07-10 | Prepared for second TIM, then ARB/ACCB | All |
| D1 | 8-16-10 | Updated Table 1 and 2 due to an omission | Table 1 & 2 |
| D2 | 9-29-10 | Updated for Algorithm Development Library | Figure 2 |
| D3 | 10-13-10 | Updated due to document convergence actions | All |
| D4 | 10-28-10 | Updated Solar Zenith angle range in Table 4 & 5 (FPV comment) | Tables 4 & 5 |
| D5 | 09-21-11 | Updated due to PCR026168 (Drop 3.3.5 and TM 2010.510.0097) | Table 9 |

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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 National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

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

The purpose of an OAD is two-fold:

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

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents.

## 1.2 Scope

The scope of this document is limited to the description of the core operational algorithm required to create the VIIRS Snow Cover EDR. The theoretical basis for this algorithm is described in Section 3.3 of the VIIRS Snow Cover Algorithm Theoretical Basis Document ATBD, 474-00038.

## 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 |
|---|---|---|
| VIIRS Snow Cover Algorithm Theoretical Basis Document ATBD | 474-00038 | Latest |
| Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM IP) | 474-00062 | Latest |
| JPSS Environmental Data Record (EDR) Production Report (PR) for NPP | 474-00012 | Latest |
| JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP | 474-00007 | Latest |
| NPP Mission Data Format Control Book and App A (MDFCB) | 429-05-02-42_MDFCB | Latest |

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| JPSS Common Data Format Control Book - External - – Block 1.2.2 (All Volumes) | 474-00001-01-B0122 CDFCB-X Vol I<br>474-00001-02-B0122 CDFCB-X Vol II<br>474-00001-03-B0122 CDFCB-X Vol III<br>474-00001-04-01-B0122 CDFCB-X Vol IV Part 1<br>474-00001-04-02-B0122 CDFCB-X Vol IV Part 2<br>474-00001-04-03-B0122 CDFCB-X Vol IV Part 3<br>474-00001-04-04-B0122 CDFCB-X Vol IV Part 4<br>474-00001-05-B0122 CDFCB-X Vol V<br>474-00001-06-B0122 CDFCB-X Vol VI<br>474-00001-08-B0122 CDFCB-X Vol VIII | Latest |
| JPSS Common Data Format Control Book - External - Block 1.2.3 (All Volumes) | 474-00001-01-B0123 CDFCB-X Vol I<br>474-00001-02-B0123 CDFCB-X Vol II<br>474-00001-03-B0123 CDFCB-X Vol III<br>474-00001-04-01-B0123 CDFCB-X Vol IV Part 1<br>474-00001-04-02-B0123 CDFCB-X Vol IV Part 2<br>474-00001-04-03-B0123 CDFCB-X Vol IV Part 3<br>474-00001-04-04-B0123 CDFCB-X Vol IV Part 4<br>474-00001-05-B0123 CDFCB-X Vol V<br>474-00001-06-B0123 CDFCB-X Vol VI<br>474-00001-08-B0123 CDFCB-X Vol VIII | Latest |
| NPP Command and Telemetry (C&T) Handbook | D568423 Rev. C | 30 Sep 2008 |
| JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I – IV | IC60917-IDP-002 | Latest |
| VIIRS Snow Cover Unit Detailed Design Document | Y3234 Ver. 5 Rev. 5 | 21 Mar 2005 |
| VIIRS Snow/Ice Module Interface Control Document | Y0011650 Ver. 5 Rev. 5 | 21 Mar 2005 |
| VIIRS Snow/Ice Module Software Architecture Document | Y2477 Ver. 5 Rev. 6 | 21 Mar 2005 |
| VIIRS Snow/Ice Module Data Dictionary | Y2482 Ver. 5 Rev. 5 | 21 Mar 2005 |
| NGST/SE technical memo – Snow Cover Algorithm Ocean Fill Value Fix | NP-EMD.2007.510.0028 | 19 Apr 2007 |
| NGST/SE technical memo – Snow Cover Algorithm OAD Updates for Fresh Water Lake Processing Drop | NP-EMD.2007.510.0021 | 23 Feb 2007 |
| NGST/SE technical memo – NPP_VIIRS_SnowCover_550nmAOT_OAD_update | NP-EMD.2006.510.0075 | 15 Oct 2006 |
| NGST/SE technical memo – MS_Engineering_Memo_SnowCover_OAD_Update | NP-EMD.2005.510.0129 | 14 Nov 2005 |

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| IDPS Processing SI Common IO Design Document | DD60822-IDP-011 Rev. A | 21 Jun 2007 |
| Joint Polar Satellite System (JPSS) Program Lexicon | 470-00041 | Latest |
| NGST/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev. C | NP-EMD.2010.510.0005.Rev-C | 02 Mar 2010 |
| NGST/SE technical memo – Snow Cover OAD Update for btmax thermal threshold | NP-EMD.2010.510.0097 | 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 Snow Cover -- science-grade software | ISTN_VIIRS_NGST_3.3 (ECR A-048 (OAD Rev ---) | 29 Apr 2005 |
| VIIRS Snow Cover -- operational software | Build 1.4 (OAD Rev A1) | 04 May 2005 |
| VIIRS Snow Cover -- science-grade software | ISTN_VIIRS_NGST_3.3.1 (ECR A-074) (OAD: see TM 2005.510.0129) | 14 Nov 2005 |
| VIIRS Snow Cover -- operational software | Build 1.4 Follow-on (OAD Rev A3) | 16 Jan 2006 |
| VIIRS Snow Cover -- science-grade software | ISTN_VIIRS_NGST_3.3.3 (ECR A-121A) (OAD: see TM 2007.510.0021) | 04 Apr 2007 |
| VIIRS Snow Cover -- operational software | Build 1.5 (OAD Rev A7 ) | May 2007 |
| VIIRS Snow Cover -- science-grade software | ISTN_VIIRS_NGST_3.3.4 (No OAD dropped by NG) | 26 Apr 2007 |
| VIIRS Snow Cover -- operational software | Build 1.5 Follow-on (OAD Rev A9) | 24 Oct 2007 |
| ACCB (No code updates) | OAD Rev A | 15 Jan 2009 |
| RFA Update (No code updates) | (OAD Rev C1) | 01 Dec 2009 |
| Implement TIM comments | (OAD Rev C2) | 25 May 2010 |
| PCR20629 (TM 2010.510.00005.Rev-C) | Sensor Characterization Build SC-09 (No OAD Update) | 22 Apr 2010 |
| ACCB (no code update) | OAD Rev C | 07 Jul 2010 |
| VIIRS Snow Cover - Algorithm Development Library | Mx1.5.4.00 (OAD Rev D2) | 29 Sep 2010 |
| Convergence Update (No code updates) | Mx1.5.4.00 (OAD Rev D3) | 13 Oct 2010 |
| PCR023893 | Mx1.5.5_A (OAD Rev D4) | 28 Oct 2010 |
| VIIRS Snow Cover -- science-grade software (includes TM 2010.510.0097) | ISTN_VIIRS_NGST_3.3.5 | 14 Jan 2011 |
| VIIRS Snow Cover -- operational software (PCR025927) | Mx1.5.6_B (OAD not updated) | 10 May 2011 |
| PCR026168 (OAD Update for 3.3.5/TM 2010.510.0097) | (OAD Rev D5) | 21 Sep 2011 |
| OAD transitioned to JPSS Program – this table is no longer updated. | | |

## 2.0 ALGORITHM OVERVIEW

The purpose of the Snow Cover EDR algorithm is to produce the following products:

- Snow Cover Binary Map (@ 375M resolution)
- Snow Fraction (@ 750M resolution).

The Snow Cover algorithm requires SDR, IP, and LUT input to produce the EDR output. This algorithm is heavily reliant on lookup tables (LUTs) which are described in Section 2.1.1.1. The overall processing chain is shown in Figure 1.

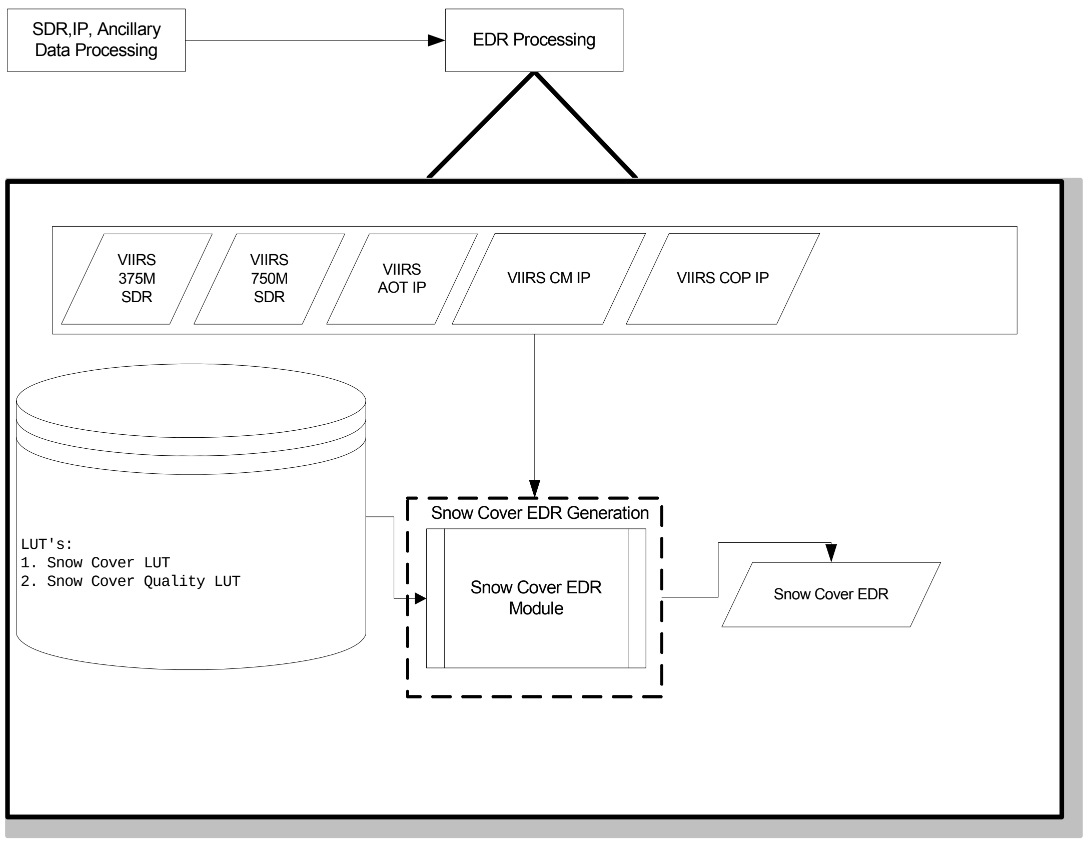


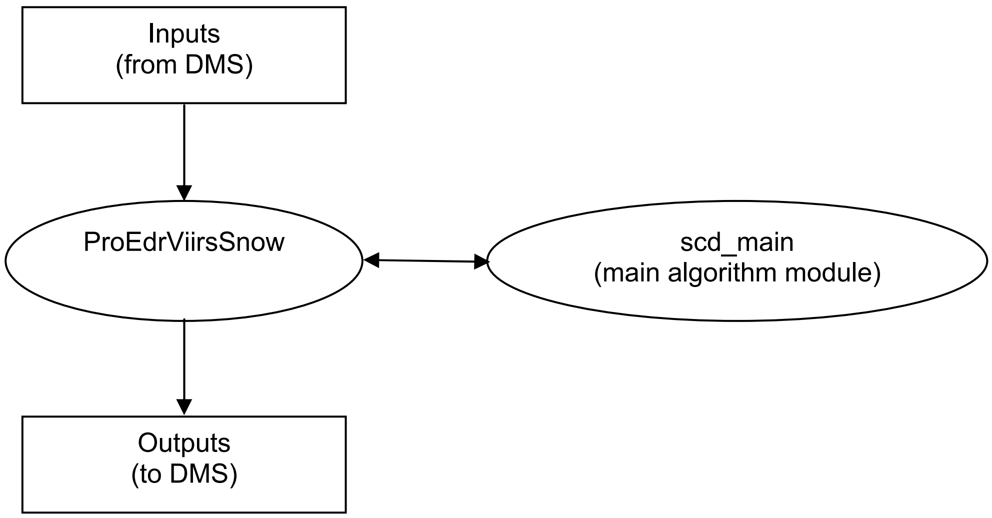

**Figure 1. Snow Cover EDR Processing Overview**

### 2.1 VIIRS Snow Cover EDR Description

The Snow Cover EDR retrieval algorithm and the theoretical basis are described in detail in the VIIRS Snow Cover Algorithm Theoretical Basis Document ATBD, 474-00038, Section 3.3.

#### 2.1.1 Interfaces

The main interfaces to the operational Snow Cover EDR algorithm are shown in Figure 2 below. The Snow Cover EDR algorithm receives all the required input data from DMS. The derived algorithm (ProEdrViirsSnow) retrieves input and output data buffers from DMS and supplies them to the algorithm. When all the input data needed for processing is available, the main module (scd_main) is called to produce the Snow Binary Map EDR output data and the Snow Fraction EDR output data.




**ProEdrViirsSnow Description**

This is the derived class from ProCmnAlgorithm that contains the overridden method doProcessing. Method ProCmnAlgorithm::setupDataItems instantiates input and output data items which represent data buffers from DMS, which are used by the algorithm. The doProcessing method invokes the algorithm processing module, where the processing of the algorithm input data and generation of the output data is done. For more information see the Processing SI Common IO Design, DD60822-IDP-011.

**Figure 2. Snow Cover Interfaces**

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. The following fill values apply: NA_UINT8_FILL for UInt8 datatypes, -1 for Int8 datatypes, NA_FLOAT32_FILL for Float32 datatypes, 0 for quality flags.
- For detailed descriptions of the quality flags in Tables 6 through 8, refer to the applicable I-P-O algorithm OAD (AOT, CM, or COP).
- Table 3 shows global attributes used in the input/output descriptions.

#### 2.1.1.1 Inputs

Tables 4 through 11 describe the inputs for the Snow Cover algorithm. Table 3 describes global attributes used in the array dimensions.

All fields italicized and flagged with an asterisk are related to the legacy Multiple End-member Spectral Mixture Analysis (MESMA) algorithm. It should be noted that NGST has commented out branches that allow invoking the MESMA method in the delivered science code so that it may be implemented at a later time if deemed necessary. Therefore, the spectral mixture method is not implemented operationally at the current time.

**Table 3. Snow Cover Global Attributes**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Global attributes for Data Items*** | | | |
| I_VIIRS_SDR_COLS | int*32 | Number of imagery resolution pixels in scan direction (VIIRS scan dimension) | Unitless/ I_VIIRS_SDR_COLS > 0 ***(Currently set to 6400)*** |
| I_VIIRS_SDR_ROWS | int*32 | Number of imagery resolution along-track lines in a VIIRS granule (VIIRS along-track dimension) | Unitless/ I_VIIRS_SDR_ROWS> 0 ***(Currently set to 1536)*** |
| M_VIIRS_SDR_COLS | int*32 | Number of moderate resolution pixels in scan direction (VIIRS scan dimension) | Unitless/ M_VIIRS_SDR_COLS > 0 ***(Currently set to 3200)*** |
| M_VIIRS_SDR_ROWS | int*32 | Number of moderate resolution along-track lines in a VIIRS granule (VIIRS along-track dimension) | Unitless/ M_VIIRS_SDR_ROWS> 0 ***(Currently set to 768)*** |
| nbands_m | int*32 | Number of Moderate Resolution Bands | Unitless/ nbands_m > 0 ***(Currently set to 9)*** |
| nbands_i | int*32 | Number of Imagery Resolution Bands | Unitless/ nbands_i > 0 ***(Currently set to 3)*** |
| *ntypes** | int*32 | Number of Snow Types<br>24 snow types = 6 grain sizes (50, 100, 250, 500, 750, 1000 micron radius)<br>x 4 impurity levels (0, 1, 10, 100ppmw) | Unitless/ 1 ≤ ntypes ≤ 24 ***(Currently set to 24)*** |
| *n_ami** | int*32 | Number of Aerosol Models | Unitless/ 1 ≤ n_ami ≤ 9 ***(Currently using 2 models, "Continental" and "Marine")*** |

* *Fields that are related to the legacy MESMA algorithm.*

**Table 4. Snow Cover Input: VIIRS SDR Moderate Resolution**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Pixel-Level Data Items*** | | | |
| BrightTemp_M15<br>bt15_m | float*32 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | Band M15 Brightness Temperatures | Units: Kelvin<br>Range: bt15_m ≥ 0.0 |

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| BrightTemp_M16 bt16_m | float*32 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | Band M16 Brightness Temperatures | Units: Kelvin Range: bt16_m ≥ 0.0 |
| SolZenAng_Mod sza_m | float*32 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | Solar Zenith Angle @ Moderate Resolution (from Geolocation) | Units: Degrees Range: 0 ≤ sza_m≤ 180 |

**Table 5. Snow Cover Input: VIIRS SDR Imagery Resolution**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Pixel-Level Data Items*** | | | |
| Reflectance_I1 toa_refl_i(:,:,1) | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | TOA Reflectances for band I1 | Units: Unitless Range: toa_refl_i ≥ 0.0 |
| Reflectance_I2 toa_refl_i(:,:,2) | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | TOA Reflectances for band I2 | Units: Unitless Range: toa_refl_i ≥ 0.0 |
| Reflectance_I3 toa_refl_i(:,:,3) | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | TOA Reflectances for band I3 | Units: Unitless Range: toa_refl_i ≥ 0.0 |
| BrightTemp_I5 bt5_i | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | Band I5 Brightness Temperatures | Units: Kelvin Range: bt5_i ≥ 0.0 |
| SolZenAng_Img sza_i | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | Solar Zenith Angle @ Imagery Resolution Resolution (from Geolocation) | Units: Degrees Range: 0 ≤ sza_i ≤ 180 |
| SenZenAng_Img vza_i | float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | Sensor Zenith Angle @ Imagery Resolution Resolution (from Geolocation) | Units: Degrees Range: -90 ≤ vza_i ≤ 90 |

**Table 6. Snow Cover Input: AOT IP**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Pixel-Level Data Items*** | | | |
| AOT aot_m | float*32 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | Aerosol Optical Thickness (550 nm) @ 750m | Units: Unitless aot_m >= 0.0 |

**Table 7. Snow Cover Input: Cloud Mask IP**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Granule-Level Data Items*** | | | |
| GranuleAllOcean | uint*8 | Flag indicating the granule is all ocean | Bitwise flags |

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Pixel-Level Data Items*** | | | |
| Vcm0 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 0 | Bitwise flags |
| Vcm1 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 1 | Bitwise flags |
| Vcm2 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 2 | Bitwise flags |
| Vcm3 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 3 | Bitwise flags |
| Vcm4 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 4 | Bitwise flags |
| Vcm5 | uint*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | VIIRS Cloud Mask IP byte 5 | Bitwise flags |

**Table 8. Snow Cover Input: COP IP**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| ***Pixel-Level Data Items*** | | | |
| COP IP<br>cot_m | float*32 x M_VIIRS_SDR_ROW x M_VIIRS_SDR_COLS | Cloud Optical Thickness @ 750m resolution | Units: Unitless<br>Range: cot_m ≥ 0.0 |

**Table 9. Snow Cover Input: Snow Cover LUT**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| *nbands_m* * | int*32 | Number of moderate resolution bands | Unitless/<br>nbands > 0<br>***(Currently set to 9)*** |
| *band_m* * | int*32 x nbands_m | Band Numbers (nbands_m in size) | Unitless/<br>[1,2,3,4,5,7,8,10,11] |
| num_r_water | int*32 | Number of water reflectance thresholds (For I1 and I2) | Unitless/<br>num_r_water > 0<br>***(Currently set to 2)*** |

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| r_water | float*32 x num_r_water | Water Reflectance Thresholds (For I1 and I2) | Unitless/<br>0.0 ≤ r_water ≤ 1.0<br>r_water = [0.11, 0.11] |
| ndsi_thre1 | float*32 | First NDSI Threshold | Unitless/<br><br>(***Currently set to 0.4***) |
| ndsi_thre2 | float*32 | Second NDSI Threshold | Unitless<br><br>(***Currently set to 0.1***) |
| n_max_coeff | int*32 | Number of NDVI Maximum Coefficients | Unitless<br>n_max_coeff > 0<br>(***Currently set to 4***) |
| ndvi_max_coeff | float*32 x n_max_coeff | NDVI Maximum Coefficients | Unitless<br>ndvi_max_coeff = [-0.28,6.4,-12.0,10.0] |
| n_min_coeff | int*32 | Number of NDVI Minimum Coefficients | Unitless<br>n_min_coeff > 0<br>(***Currently set to 2***) |
| ndvi_min_coeff | float*32 x n_min_coeff | NDVI Minimum Coefficients | Unitless/<br>ndvi_min_coeff = [0.32,-0.70] |
| btmax | float*32 | Brightness Temperature Threshold | Kelvin/<br>(***Currently set to 281.0***) |
| *ntypes* * | int*32 | Number of Snow Types (6 grain size * 4 impurities = 24 types) | Unitless/<br>1 ≤ ntypes ≤ 24<br>(***Currently set to 24***) |
| frac_option | int*32 | Flag which determines which snow fraction algorithm to run | Unitless/<br>0 = Spectral Mixing Algorithm<br>1 = Binary Snow Map Aggregation<br>2 = Both<br>***(Currently set to 1)*** |

** Fields that are related to the legacy MESMA algorithm.*

**Table 10. Snow Cover Input: Algorithm Processing Coefficients**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| cot_switch | int*32 | Switch to flag use of VIIRS Cloud Mask or Cloud Optical Thickness for determining cloud confidence | Unitless/<br>0 = Use VCM<br>1 = Use COT<br>***(Currently set to 0*** |

**Table 11. Snow Cover Input: Snow Cover Quality LUT**

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| nbands_i | int*32 | Number of Imagery Resolution Bands | Unitless/<br>nbands_i > 0<br>***(Currently set to 3)*** |
| *nbands_m* * | int*32 | Number of Moderate Resolution Bands | Unitless/<br>nbands_m > 0<br>***(Currently set to 9)*** |
| *band_wgt* * | float*32 x nbands_m | Default Moderate Resolution Band Weights | Unitless/<br>0.0 ≤ band_wgt ≤ 1.0<br>band_wgt =<br>[1.0,1.0,1.0,<br>1.0,1.0,1.0,<br>1.0,1.0,1.0] |
| num_aot_bins | int*32 | Number of AOT bins, corresponding to the number of AOT values used for thresholding (aot_bin, this table) | Unitless/<br>num_aot_bins > 0<br>***(Currently set to 4)*** |
| aot_bins | float*32 x num_aot_bins | AOT Bin Boundary Values | Unitless/<br>0.0 ≤ aot_bin ≤ 1.0<br>aot_bin =<br>[0.0,0.15,0.5,1.0] |
| num_thresh | int*32 | Number of Solar Zenith Angle Thresholds | Unitless<br>num_thresh > 0<br>***(Currently set to 2)*** |
| *q_aot_sza* ** | float*32 x (nbands_i + nbands_m) x num_aot_bins x num_thresh | Solar Zenith Angle values that correspond to the Solar Zenith Angle quality regimes (G/Y = "Green/Yellow", Y/R = "Yellow/Red", this corresponds to the "2" in the "Data Types/Size" column) and to the "aot_bin" values (**(1) -> 0.0, (2) -> 0.15, (3) -> 0.5, (4) -> 1.0**). The order for each num_aot_bin x num_thresh matrix of angles is: I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, and M11<br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians/<br>-π/2 ≤ sza_bin ≤π/2<br>(**I1,I2,I3**,*M1,M2,M3, M4,M5,M7,M8,M10, M11*)<br>**(G/Y) (Y/R)**<br>[85.0, 88.0;**(1)**<br>85.0, 88.0;**(2)**<br>85.0, 88.0;**(3)**<br>85.0, 88.0]**(4)**<br>(Order of bands follows the scheme showed above) |
| cot_switch | int*32 | Switch to flag use of VIIRS Cloud Mask or Cloud Optical Thickness for determining cloud confidence<br>cot_switch is used in the code, but not from this field in this table. The cot_switch used in the code has been placed in the VIIRS Snow Cover/Depth Ephemeral PC | Unitless/<br>0 = Use VCM<br>1 = Use COT<br>***(Currently set to 0)*** |
| num_cloud_types | int*32 | Number of Cloud Types | Unitless/<br>num_cloud_types > 0<br>***(Currently set to 7)*** |

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| *cloud_wgts*** | float*32 x num_cloud_types x nbands | Cloud weights corresponding to the 3 imagery bands + 9 moderate bands and the 7 cloud properties – 4 phases = Default (1), Water (2), Ice (3), Mixed (4), and 3 types = cirrus (5), shadow (6), adjacency (7); the parenthetical values correspond to the rows of the matrix shown in the "Units/Range" cell, the column represent the bands I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, and M11 in this order. | Unitless/<br><br>0.0≤ cloud_wgts ≤ 1.0<br><br>cloud_wgts = (**I1,I2,I3,**M1,M2,M3, M4,M5,M7,M8,M10, M11)<br>[0.5;**(1)**<br>0.5;**(2)**<br>0.5;**(3)**<br>0.5;**(4)**<br>0.6;**(5)**<br>0.3;**(6)**<br>0.8]**(7)** |
| cot_gy | float*32 x (nbands_i + nbands_m) x num_cloud_types | Cloud Optical Thickness "GREEN/YELLOW" quality threshold values | Unitless/<br>cot_gy = 0.2 |
| cot_yr | float*32 x (nbands_i + nbands_m) x num_cloud_types | Cloud Optical Thickness "YELLOW/RED" quality threshold values | Unitless/<br>cot_yr = 0.5 |
| qwgt_r | float*32 x (nbands_i + nbands_m) | Solar Zenith Angle boundaries "RED" | Unitless/<br>qwgt_r = 0.3 |
| qwgt_y | float*32 x (nbands_i + nbands_m) | Solar Zenith Angle boundaries "YELLOW" | Unitless/<br>qwgt_y = 0.5 |
| qwgt_g | float*32 x (nbands_i + nbands_m) | Solar Zenith Angle boundaries "GREEN" | Unitless/<br>qwgt_g = 0.7 |
| frac_wgt_yr | float*32 | Fractional Weight "YELLOW/RED" Threshold | Unitless/<br>***(Currently frac_wgt_yr = 0.4)*** |
| fract_wgt_gy | float*32 | Fractional Weight "GREEN/YELLOW" Threshold | Unitless/<br>***(Currently frac_wgt_gy = 0.6)*** |
| sfrac_bmap_excl_thresh1 | float*32 | Tunable snow fraction threshold lower limit for binary map performance exclusion<br>(0.2 < snow fraction < 0.7)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Unitless<br>sfrac_bmap_excl_thresh1 = 0.2 |
| sfrac_bmap_excl_thresh2 | float*32 | Tunable snow fraction threshold upper limit for binary map performance exclusion<br>(0.2 < snow fraction < 0.7)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Unitless<br>sfrac_bmap_excl_thresh2 = 0.7 |
| sza_sfrac_degrad_thresh1 | float*32 | Tunable solar zenith angle threshold lower limit for degraded snow fraction condition<br>(70 deg <=sza<=85 deg)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians<br>sza_sfrac_degrad_thresh1 = 70 * DEG2RAD |

| Input | Type | Description | Units/Valid Range |
|---|---|---|---|
| sza_sfrac_degrad_thresh2 | float*32 | Tunable solar zenith angle threshold upper limit for degraded snow fraction condition (70 deg <=sza<=85 deg)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians sza_sfrac_excl_thresh2 = 85 * DEG2RAD |
| sza_bmap_excl_thresh | float*32 | Tunable solar zenith angle threshold for binary map performance exclusion (sza > 85 deg)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians sza_bmap_excl_thresh = 85 * DEG2RAD |
| sza_sfrac_excl_thresh | float*32 | Tunable solar zenith angle threshold for snow fraction performance exclusion (sza > 85 deg)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians sza_sfrac_excl_thresh = 85 * DEG2RAD |
| aot_excl_thresh | float*32 | Tunable aerosol optical thickness exclusion threshold (aot>1.0)<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Unitless aot_excl_thresh = 1.0 |
| sza_daynight_thresh | float*32 | Tunable Ssolar zenith angle threshold for setting night fill values.<br><br>(defined in VIIRS-SCD-SNOW-COVER-QUAL-LUT) | Radians sza_daynight_thresh = 85 * DEG2RAD |

* *Fields that are related to the legacy MESMA algorithm.*

** *q_aot_sza and cloud_wgts arrays contain imagery band weights and legacy MESMA algorithm weight values.*

#### 2.1.1.2 Outputs

Tables 12 and 13 describe the outputs of the Snow Cover algorithm.

The Snow Cover Algorithm produces a Snow Binary Map EDR output file and a Snow Fraction EDR output File. Setting frac_option to one or two produces a Snow Fraction EDR based on 2x2 aggregation of the binary snow cover map. In the science code, setting frac_option to zero produces a Snow Fraction EDR based on the spectral mixture method and setting frac_option to two produces both the Snow Binary Map EDR and the Snow Fraction EDR based on the spectral mixing method. NGST commented out branches that allow invoking the spectral mixture method in the delivered code so that the spectral mixture method may be implemented at a later time if deemed necessary. This code is not implemented operationally at this time.

The Snow Cover Binary Map EDR file is a binary format output file consisting of four imagery resolution layers. The contents of this file are shown in Table 12. The binary map quality (BinaryMapQual) is a data field consisting of three bytes of quality flags per pixel.

**Table 12. Snow Cover Output: Snow Cover Binary Map EDR**

| Input | Type/Size | Description | | | Units/Valid Range |
|---|---|---|---|---|---|
| ***Granule-Level Data Items*** | | | | | |
| Binary Map Quality (Metadata) | int*8 | Percent of pixels with high quality | | | Percent / 0-100 |
| Exclusion Summary (Metadata) | int*8 | Percent of pixels with excluded conditions | | | Percent / 0-100 |
| ***Pixel-Level Data Items*** | | | | | |
| BinaryMap | int*8 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | Snow Binary Map | | | Unitless/<br>0 = No Snow<br>1 = Snow<br>*FILL_VALUE = (See* CDFCB-X Vol IV part 3 (D34862-04-03), Table 5.4.5.2.1.2-1 for fill values) |
| BinaryMapQual (quality bit flags) | int*8 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS | **0** | 0-1 | Overall Pixel Quality | 00 = GREEN (high)<br>01 = YELLOW (medium)<br>10 = RED (bad)<br>11 = FILL (no retrieval) |
| | | | 2 | Input SDR Quality (bands I1, I2, I3) | 0 = Good<br>1 = Bad |
| | | | 3-4 | Cloud Confidence | 00 = confidently clear<br>01 = probably clear<br>10 = probably cloudy<br>11 = confidently cloudy |
| | | | 5 | Solar Zenith Angle Exclusion (based on a tunable solar zenith angle exclusion threshold) | 0 = No (no exclusion)<br>1 = Yes (exclusion condition: sza > sza_bmap_excl_thresh |
| | | | 6 | Aerosol Optical Thickness Exclusion (based on a tunable aerosol optical thickness exclusion threshold) | 0 = No (no exclusion)<br>1 = Yes (exclusion condition: aot > 1.0; based on slant path AOT) |
| | | | 7 | Snow Fraction Exclusion (based on tunable snow fraction exclusion thresholds) | 0 = No (no exclusion)<br>1 = Yes (exclusion condition: snow fraction between 0.2 and 0.7) |
| | | **1** | 0 | Thin Cirrus | 0 = No<br>1 = Yes (thin cirrus detected; based on VCM thin cirrus quality flag) |
| | | | 1 | Cloud Shadow | 0 = No<br>1 = Yes |

| Input | Type/Size | Description | | | Units/Valid Range |
|---|---|---|---|---|---|
| | | | 2-3 | Cloud Phase | 00 = Clear<br>01 = Water<br>10 = Ice<br>11 = Mixed |
| | | | 4 | Forest | 0 = No<br>1 = Yes |
| | | | 5-6 | Land/Water | 00 = Land<br>01 = Coastal<br>10 = Inland Water<br>11 = Ocean |
| | | | 7 | Sun Glint | 0 = No<br>1 = Yes |
| | | **2** | 0 | Thermal Threshold Exceeded (based on a tunable temperature threshold) | 0 = No<br>1 = Yes |
| | | | 1 | NDSI Quality | 0 = Good<br>1 = Bad |
| | | | 2 | NDVI Quality | 0 = Good<br>1 = Bad |
| | | | 3 | Fire | 0 = No<br>1 = Yes |
| | | | 4-7 | Spare | Spare |

The Snow Fraction Binary Snow Map is a binary file consisting of five moderate resolution layers. The contents of this file are shown in Table 13. The snow fraction quality (FractionQual) is a data field consisting of three bytes of quality flags per pixel.

**Table 13. Snow Cover Output: Aggregated Snow Fraction Binary Snow Map EDR**

| Input | Type/Size | Description | Units/Valid Range |
|---|---|---|---|
| ***Granule-Level Data Items*** | | | |
| Snow Fraction Quality (Metadata) | int*8 | Percent of pixels with high quality | Percent / 0-100 |
| Degradation Summary (Metadata) | int*8 | Percent of pixels with degraded conditions | Percent / 0-100 |
| Exclusion Summary (Metadata) | int*8 | Percent of pixels with excluded conditions | Percent / 0-100 |
| ***Pixel-Level Data Items*** | | | |
| FractionFromBinary Map | float*32 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_COLS | Snow Fraction reported at Moderate Resolution | Unitless/<br>0.0 ≤ FractionFromBinary Map ≤ 1.0<br>*FILL_VALUE = (See* CDFCB-X Vol IV part 3 (474-00001), Table 5.4.5.2.2.2-1for fill values) |

| Input | Type/Size | Description | | | Units/Valid Range |
|---|---|---|---|---|---|
| NumAggPix | int*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | Number of Imagery Pixels Aggregated | | | Unitless/<br>0≤ NumAggPix ≤ 4<br>*FILL_VALUE = (See* CDFCB-X Vol IV part 3 (474-00001), Table 5.4.5.2.2.2-1for fill values) |
| FractionQual | int*8 x M_VIIRS_SDR_COLS x M_VIIRS_SDR_ROWS | **0** | 0-1 | Overall Pixel Quality | 00 = GREEN (high)<br>01 = YELLOW (medium)<br>10 = RED (bad)<br>11 = FILL (no retrieval) |
| | | | 2 | Input SDR quality (bands I1, I2, I3) | 0 = Good<br>1 = Bad |
| | | | 3-4 | Cloud Confidence | 00 = confidently clear<br>01 = probably clear<br>10 = probably cloudy<br>11 = confidently cloudy |
| | | | 5 | Solar Zenith Angle Degradation | 0 = No (no degradation)<br>1 = Yes (degradation condition: sza between 70 and 85 deg) |
| | | | 6 | Forest Exclusion | 0 = No<br>1 = Yes |
| | | | 7 | Solar Zenith Angle Exclusion | 0 = No (no exclusion)<br>1 = Yes (exclusion condition: sza > 85 deg) |
| | | **1** | 0 | Aerosol Optical Thickness Exclusion | 0 = No (no exclusion)<br>1 = Yes (exclusion condition aot > 1.0; based on slant path AOT) |
| | | | 1 | Thin Cirrus | 0 = No<br>1 = Yes (thin cirrus detected; based on VCM thin cirrus quality flag) |
| | | | 2 | Cloud Shadow | 0 = No<br>1 = Yes |
| | | | 3-4 | Cloud Phase | 00 = Clear<br>01 = Water<br>10 = Ice<br>11 = Mixed |
| | | | 5-6 | Land/Water | 00 = Land<br>01 = Coastal<br>10 = Inland Water<br>11 = Ocean |
| | | | 7 | Sun Glint | 0 = No<br>1 = Yes |
| | | **2** | 0 | Snow Reflectance (place holder) | 0 = Good<br>1 = Bad |

| Input | Type/Size | Description | | | Units/Valid Range |
|---|---|---|---|---|---|
| | | | 1 | Non-snow Reflectance (place holder) | 0 = Good<br>1 = Bad |
| | | | 2 | Snow Fraction Out of Valid Range (place holder) | 0 = No<br>1 = Yes |
| | | | 3 | Fire | 0 = No<br>1 = Yes |
| | | | 4-7 | Spare | Spare |

The aerosol optical thickness exclusion is based on a slant path AOT. A vertical column AOT is also utilized in the Snow Cover algorithm for all Lookup table applications such as the input interpolation coordinate for computing pixel quality weights (AOT/SZA quality LUT) and spectral mixture method computations (spectral mixture method not implemented operationally).

### 2.1.2 Algorithm Processing

The Snow Cover EDR algorithm calculates two datasets: a snow cover binary map (375M) and snow fraction (750M). The algorithms that produce the snow cover binary map and the snow fraction are encapsulated in one large Fortran 90 routine (scd_main). The binary map algorithm only requires a few LUT table parameters, various VCM bits, and the quality of the imagery reflectance bands I1, I2, and I3. The brightness temperature in the I5 band is also utilized for performing thermal threshold screening. The brightness temperatures in the M15 and M16 bands are utilized for the thermal threshold screening for graceful degradation in the event that the I5 band quality is bad. The binary map logic and computation are described in Section 2.1.2.4. The Snow Cover EDR algorithm subroutine calls are shown in Figure 3.

#### 2.1.2.1 Main module – scd_main

The main module is a driver routine that calls four subroutines in order to produce the binary map and snow fraction. First, SN_extract_data1 is called to extract SDR, IP and LUT data to be used by the algorithm. Next, SN_make_pixel_masks is called to create the moderate and imagery resolution pixel masks for use in determining the binary snow map quality and snow fraction quality. SN_binary_map is then called to create the snow cover binary map. Lastly, the SN_write_edr subroutine is called. This routine generates the snow fraction values and writes the snow cover EDR data to output buffers. It calls routines to set the snow cover binary map quality flags and the snow fraction quality flags. The sequence of subroutine calls is shown in Figure 3.

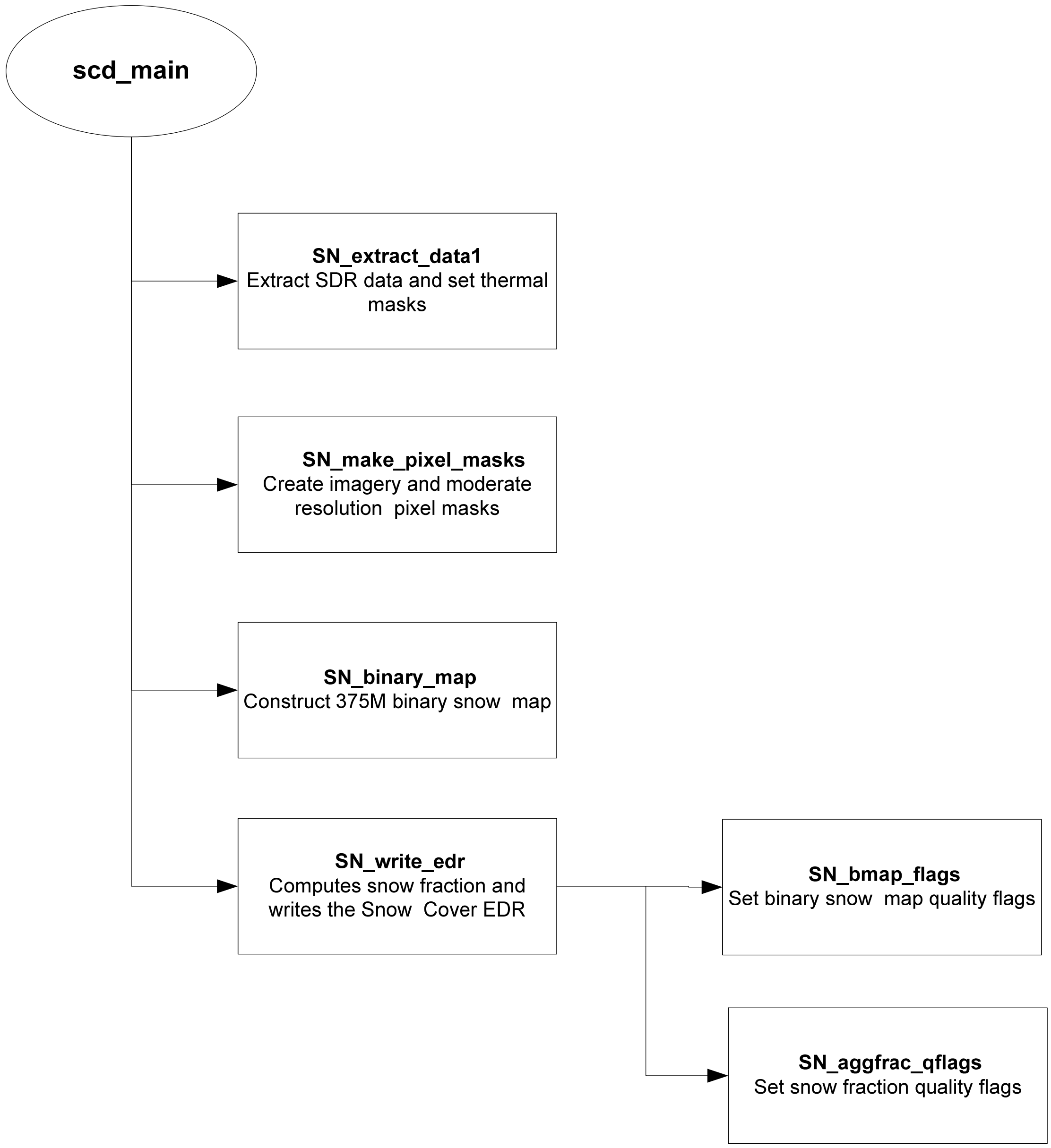



**Figure 3. Snow Cover Algorithm Flow**

#### 2.1.2.2 SN_extract_data1

This routine extracts data from the moderate and imagery resolution SDR data for later use in creating the moderate and imagery resolution pixel masks. Imagery and Moderate resolution thermal masks are also created here from brightness temperatures for I5, M15, and M16. A brightness temperature threshold is read from the Snow Cover Quality LUT. The thermal mask is set for each pixel. If the threshold is exceeded for at least one band, then the mask value is set to zero. If all bands exceed the threshold, then the mask is set to -1. Otherwise the mask is set to one. The imagery resolution thermal mask is used in setting the thermal mask quality bit in SN_bmap_qflags. If the thermal mask value is set to one for a pixel, then the binary snow cover map will be set to zero (no snow) for that pixel in routine SN_binary_map.

#### 2.1.2.3 SN_make_pixel_masks

This routine performs pixel masking and pixel weighting, using information in the VIIRS moderate and imagery resolution SDR, VIIRS Aerosol Optical Thickness IP, VIIRS Cloud Optical Thickness IP (if COT switch is set to use COT), VIIRS Cloud Mask IP, and the Snow Quality LUT.

Pixel weights are determined for each band and for both imagery resolution and moderate resolution. The weights are obtained by reducing an initialized band weight ($w_0$) by various weight reduction factors:

$$w(\text{band, pixel}) = w_0(\text{band}) * w_{cloud} * w_{aerosol}$$

where:

$w_0$ is the initial default value for a band
$w_{cloud}$ is the weight reduction factor for cloud contamination
$w_{aerosol}$ is the weight reduction factor for aerosols

The moderate resolution weights are first initialized with default values from Snow Cover Quality LUT and the imagery resolution weights are initialized to 1.0.

Weight reduction factors for cloud contamination are obtained from the Snow Cover Quality LUT. The LUT includes factors for various cloud types (water, ice, and mixed), thin cirrus, cloud shadow, and cloud adjacency. The algorithm allows for the option of determining cloud weight reduction factors from cloud optical thickness (COT), obtained from the VIIRS Cloud Optical Properties IP. This option is controlled by the COT usage switch which is the only processing coefficient currently used by this algorithm. The COT-dependent weight reduction factor is determined from the COT thresholds obtained from the Snow Quality LUT. These include “Red/Yellow” and “Yellow/Green” thresholds. If the pixel COT is greater than the “Red/Yellow” threshold for a given band, the pixel/band weight is set to zero. If the pixel COT is less than the “Yellow/Green” threshold for a given band, the pixel/band weight is unaffected. For a pixel COT in the range between the two thresholds, the pixel/band weight is reduced by a factor computed by linear interpolation of COT between the two thresholds:

$$w_{cloud} = (\text{COT\_YR(band)} - \text{COT(pixel)}) / (\text{COY\_YR(band)} - \text{COT\_GY(band)})$$

Weight reduction factors for aerosols are determined in combination with the solar zenith angle (SZA), to allow for greater aerosol degradation at higher SZA. Band-dependent threshold values of SZA for a set of aerosol optical thickness (AOT) nodes are obtained from the Snow Quality LUT. These include “Red/Yellow” and “Yellow/Green” thresholds. If the pixel SZA is greater than the “Red/Yellow” threshold for a given band, the pixel/band weight is set to zero. If the pixel SZA is less than the “Yellow/Green” threshold for a given band, the pixel/band weight is unaffected. For a pixel SZA in the range between the two thresholds, the pixel/band weight is reduced by a factor computed by linear interpolation of SZA between the two thresholds:

$$w_{aerosol} = (\text{SZA\_YR(band)} - \text{SZA(pixel)}) / (\text{SZA\_YR(band)} - \text{SZA\_GY(band)})$$

Pixel quality masks are determined for both imagery resolution (Table 14) and moderate resolution (Table 15) pixels. This routine takes the VCM and constructs quality bits, stored in the variables “mask_i” and “mask_m”, for the purpose of determining the binary snow map quality and snow fraction quality respectively.

**Table 14. Description of VCM and Band Quality Bits (mask_i)**

| BYTE | Bit | Flag Description Key | Result |
|---|---|---|---|
| 0 | 0 | Land/Ocean Background | 0 = Land<br>1 = Ocean |
| | 1 | Forest | 0 = No<br>1 = Yes |
| | 2 | Coastline | 0 = No<br>1 = Yes |
| | 3-4 | Cloud Quality | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED( (POOR)<br>(Result of VCM cloud confidence and cloud quality, adjacency, thin cirrus or cot mode COT threshold tests) |
| | 5 | Thin Cirrus | 0 = No<br>1 = Yes (from VCM Thin Cirrus Quality Flag) |
| | 6 | Cirrus (VCM Solar or IR Tests) | 0 = No<br>1 = Yes (if either VCM solar or IR cirrus test quality flag is positive) |
| | 7 | Cloud Shadow | 0 = No<br>1 = Yes |
| 1 | 0-1 | Cloud Phase | 00 = Clear<br>01 = Water<br>10 = Ice<br>11 = Mixed |
| | 2 | Fire | 0 = No<br>1 = Yes |
| | 3 | Sun Glint | 0 = No<br>1 = Yes |
| | 4 | Imagery Band Quality (I1) | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 5 | Imagery Band Quality (I2) | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 6 | Imagery Band Quality (I3) | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 7 | Spare | Spare |
| 2 | 0-1 | I1 Overall Quality | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 2-3 | I2 Overall Quality | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 4-5 | I3 Overall Quality | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 6 | Solar Zenith Angle Exclusion | 0 = No<br>1 = Yes |
| | 7 | Aerosol Optical Thickness Exclusion | 0 = No<br>1 = Yes (based on slant path AOT) |

**Table 15. Description of VCM and Band Quality Bits (mask_m)**

| BYTE | Bit | Flag Description Key | Result |
|---|---|---|---|
| 0 | 0 | Land/Ocean Background | 0 = Land<br>1 = Ocean |
| | 1 | Forest | 0 = No<br>1 = Yes |
| | 2 | Coastline | 0 = No<br>1 = Yes |
| | 3-4 | Cloud Quality | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED( (POOR)<br>(Result of VCM cloud confidence and cloud quality, adjacency, thin cirrus or cot mode COT threshold tests) |
| | 5 | Thin Cirrus (Solar) | 0 = No<br>1 = Yes (from VCM Thin Cirrus Quality Flag) |
| | 6 | (VCM Solar or IR Tests) | 0 = No<br>1 = Yes (if either VCM solar or IR cirrus test quality flag is positive) |
| | 7 | Cloud Shadow | 0 = No<br>1 = Yes |
| 1 | 0-1 | Cloud Phase | 00 = Clear<br>01 = Water<br>10 = Ice<br>11 = Mixed |
| | 2 | Fire | 0 = No<br>1 = Yes |
| | 3 | Sun Glint | 0 = No<br>1 = Yes |
| | 4 | Moderate Band Quality (M1)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 5 | Moderate Band Quality (M2)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 6 | Moderate Band Quality (M3)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 7 | Moderate Band Quality (M4)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| 2 | 0 | Moderate Band Quality (M5)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 1 | Moderate Band Quality (M7)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 2 | Moderate Band Quality (M8)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 3 | Moderate Band Quality (M10)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 4 | Moderate Band Quality (M11)* | 0 = GREEN (GOOD)<br>1 = RED (POOR) |
| | 5-6 | Overall M1 Quality* | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 7 | Overall M2 Quality* | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| 3 | 0 | Overall M2 Quality* | |
| | 1-2 | Overall M3 Quality* | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 3-4 | Overall M4 Quality* | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |

| BYTE | Bit | Flag Description Key | Result |
|---|---|---|---|
| | 5-6 | *Overall M5 Quality* * | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 7 | *Overall M7 Quality* * | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| 4 | 0 | *Overall M7 Quality* * | |
| | 1-2 | *Overall M8 Quality* * | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 3-4 | *Overall M10 Quality* * | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 5-6 | *Overall M11 Quality* * | 00 = GREEN (GOOD)<br>01 = GREEN/YELLOW<br>10 = YELLOW/RED<br>11 = RED (POOR) |
| | 7 | Overall Quality | 0 = GREEN (GOOD)<br>1 = RED (POOR) |

* *Fields that are related to the legacy MESMA algorithm.*

### 2.1.2.4 SN_binary_map

This routine generates the binary snow map. The binary map calculation requires inputs from the VCM bits (described in the Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM IP, 474-00062) and LUTs (described in Table 9, Table 10, and Table 11). Furthermore, the code requires the quality of each imagery reflectance band. The band quality and VCM bits are stored in a variable "mask_i" in a total of three bytes; Table 14 gives the bit description of "mask_i."

Using the bit description and the LUT parameters, a snow binary map is constructed. Table 16 describes variables used in constructing the map.

**Table 16. Relevant Parameters in SN_binary_map**

| Parameter | Description |
|---|---|
| toa_refl_i | TOA Reflectance for Imagery Bands I1, I2, and I3 |
| P | Current Pixel |
| binary_map | Binary Snow Map |
| Ndvi | Normalized Difference Vegetation Index (NDVI) |
| Ndsi | Normalized Difference Snow Index (NDSI) |
| ndvi_quality | NDVI Quality (0 = GOOD/GREEN, 1 = POOR/RED) |
| ndsi_quality | NDSI Quality (0 = GOOD/GREEN, 1 = POOR/RED) |

The quality of each binary map pixel is determined and written out in the SN_write_edr routine, detailed in Section 2.2.1.5. The binary map quality segment of SN_write_edr could be moved to the SN_binary_map routine without affecting the output contents.

The logic flow for the snow cover binary map algorithm is shown in Figure 4. Definitions of equations used in the algorithm can be found in the ATBD, 474-00038.

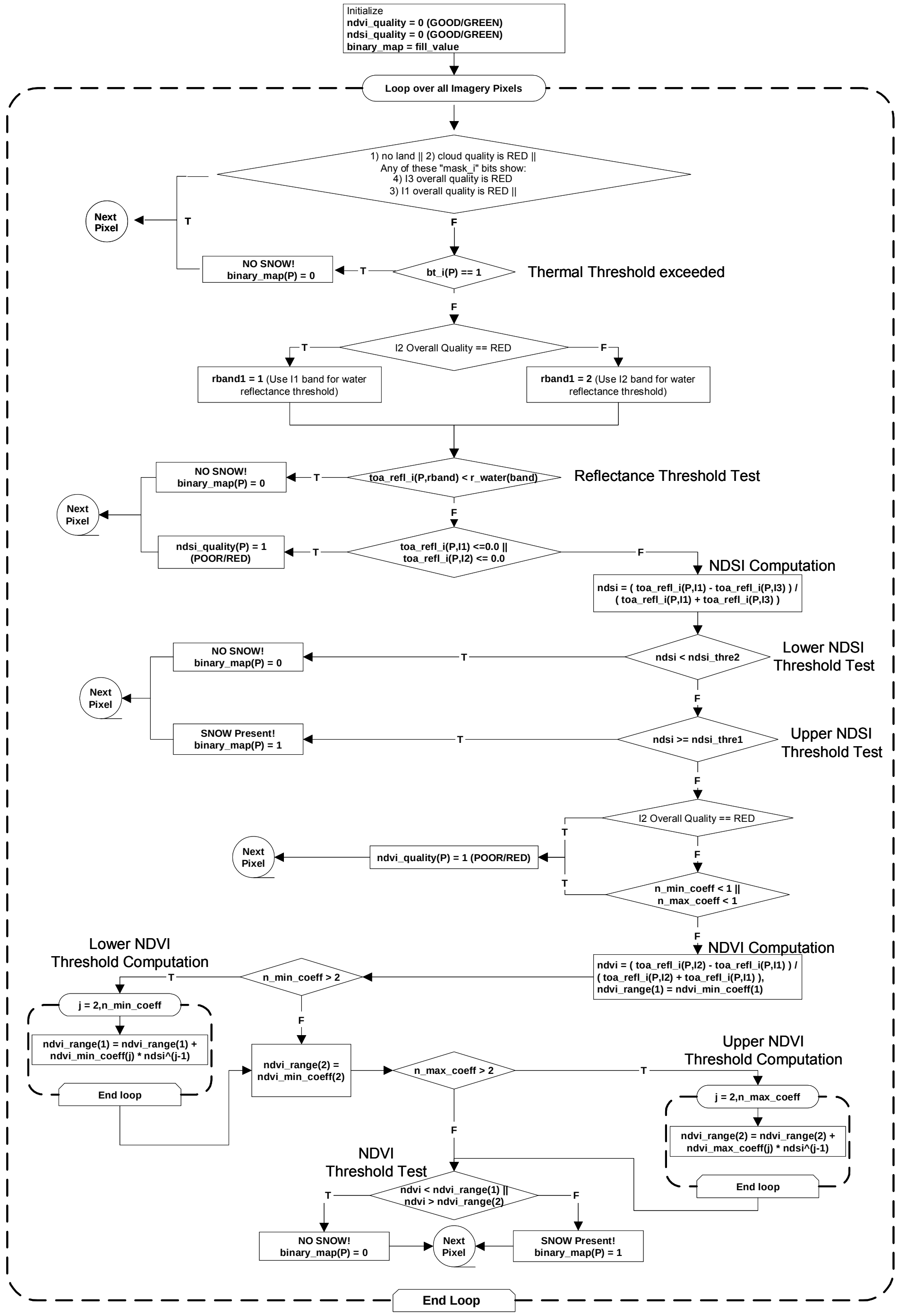



**Figure 4. Logic flow for the Snow Cover Binary Map Algorithm**

### 2.1.2.5 SN_write_edr

This routine computes a fractional snow cover and produces the quality flag parameters for both the snow binary map and snow fraction EDRs. The fractional snow cover is computed by performing a 2x2 aggregation of the imagery resolution snow binary map. The snow fraction measurement uncertainty using this technique will be 25%. Aggregation is performed by counting the number of snow filled pixels within each 2x2 pixel aggregation window of the imagery resolution snow map, and dividing by the total number of pixels. Snow fraction (at moderate resolution) is determined to 25% measurement uncertainty. The “frac_option” flag (last entry of the snow_cover.lut configuration file), set to a value of one, selects this branch of the Snow Cover algorithm.

Subroutine SN_bmap_qflags is called to generate the snow binary map quality flags, but they are stored to the Snow Cover Binary Map EDR buffer in this routine. Also granule quality metadata, derived from the pixel level quality flags, is calculated and stored to the Snow Cover Binary Map EDR in this routine. The quality flags are documented in Table 12.

Subroutine SN_aggfrac_qflags is called to calculate the aggregated snow fraction quality flags, but they are stored to the Aggregated Snow Fraction Binary Snow Map EDR buffer in this routine. Also granule quality metadata, derived from the pixel level quality flags, is calculated and stored to the Aggregated Snow Fraction Binary Snow Map EDR buffer in this routine. The quality flags are documented in Table 13.

In the current operational algorithm, computation of the snow fraction using the spectral mixing algorithm is not implemented, so choosing frac_option = 0 will result in the Snow Fraction Binary Snow Map EDR data containing fill values. The logic flow in the SN_write_edr routine is shown in Figure 5. The logic flow for the snow fraction aggregation is shown in Figure 6. The logic flow for SN_bmap_qflags to set binary map quality flags is shown in Figure 7. The logic flow for the snow fraction quality portion of SN_write_edr() is shown in Figure 8.

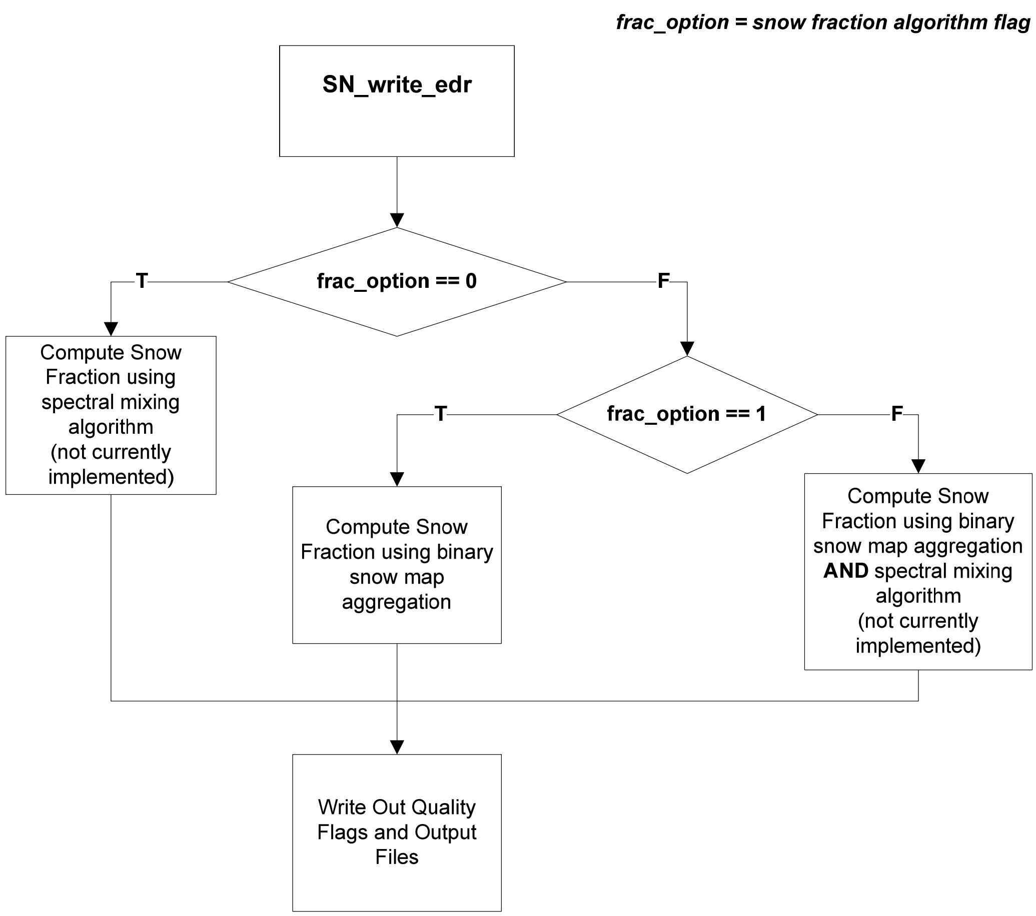


**Figure 5. Logic flow of SN_write_edr**

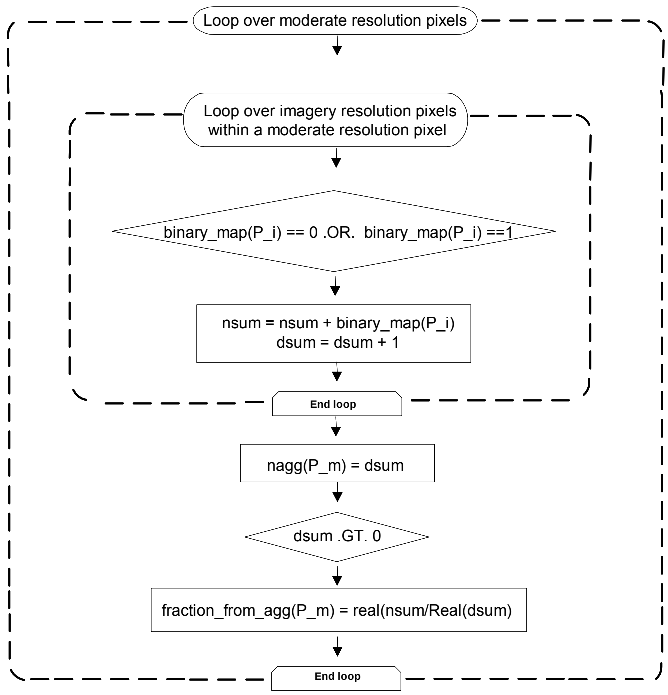



**Figure 6. Logic Flow for the Snow Fraction Aggregation**

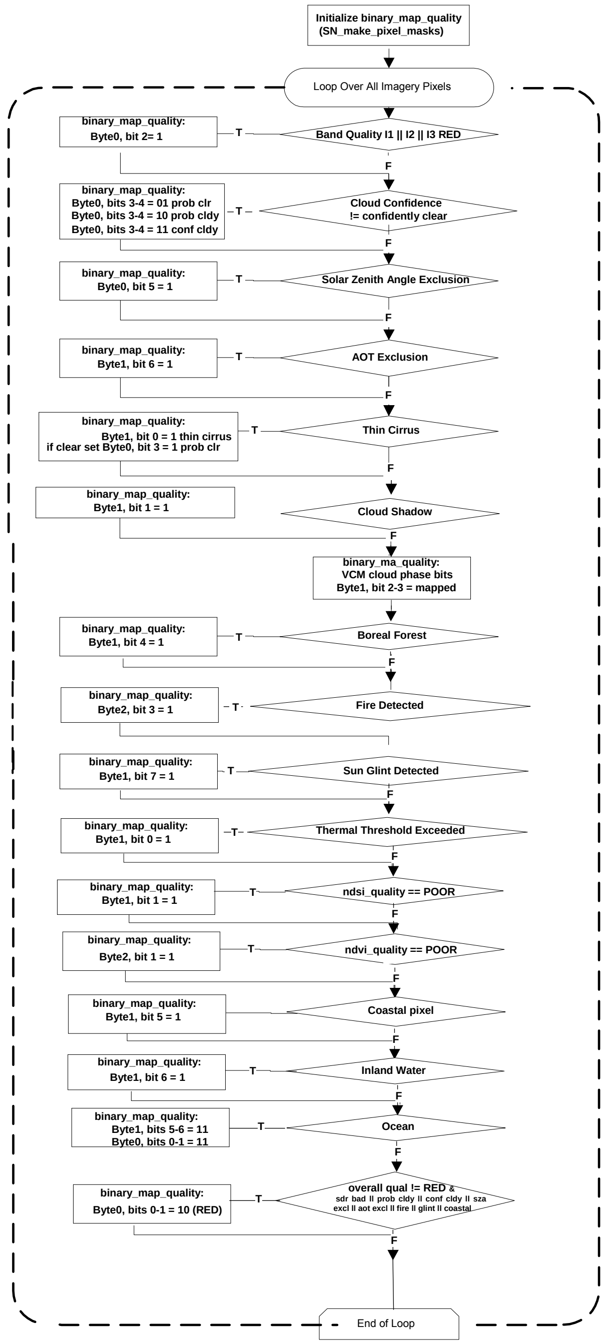



**Figure 7. Logic Flow for SN_bmap_qflags to set Binary Map Quality Flags**

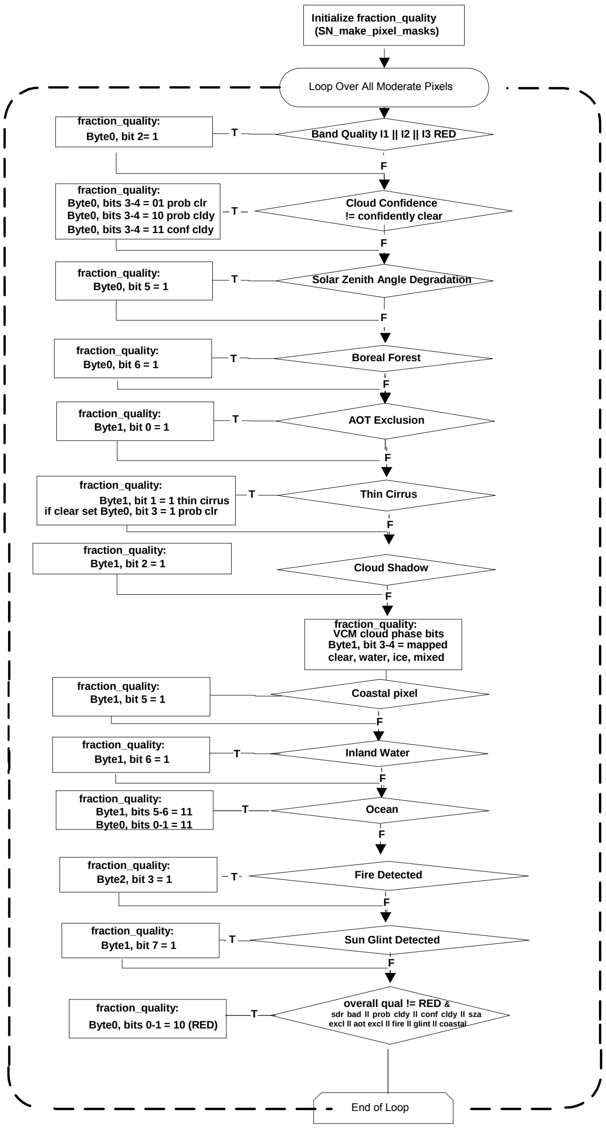



**Figure 8. Logic Flow for Snow Fraction Quality Portion of SN_write_edr()**

### 2.1.2.6 SN_bmap_qflags

This routine generates the Snow Cover Binary Map EDR quality flags. These quality flags are documented in Table 12. Almost all tests determining the binary map quality are set using the quality bits of "mask_i" (see Table 14). The exceptions are:

- the thermal mask is used to set the thermal mask quality flag
- the NDVI quality is used to set the NDVI quality flag (flag set if I1 or I2 quality is bad or no NDVI coefficients available)
- the NDSI quality is used to set the NDSI quality flag (flag is set if I1 or I3 reflectance is bad)
- the overall quality can be set to FILL if the binary snow map contains a fill value

The Snow Binary Map Quality flags are written to the Binary Snow Cover Map EDR buffer in SN_write_edr.

#### 2.1.2.7 SN_aggfrac_qflags

This routine generates the Aggregated Snow Fraction Binary Snow Map EDR quality flags. These quality flags are documented in Table 13. Almost all tests determining the binary map quality are derived from the Snow Cover Binary Map EDR quality flags and the "mask_m" (documented in Table 15) quality bits. The exceptions are:

- the SZA degradation flag is set if any of the imagery resolution SZAs are within the degradation
- the SZA exclusion flag is set if any of the imagery resolution SZAs exceed the exclusion threshold
- the AOT exclusion flag is set if the AOT value exceeds the aot exclusion threshold
- the fraction quality is set to FILL if the snow fraction binary snow map value is fill

The exclusion and degradation thresholds are defined in the Snow Quality LUT table (Table 9).

### 2.1.3 Graceful Degradation

#### 2.1.3.1 Graceful Degradation Inputs

There is one case where input graceful degradation is indicated in the Snow Cover EDR.

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

#### 2.1.3.2 Graceful Degradation Processing

None.

#### 2.1.3.3 Graceful Degradation Outputs

None.

### 2.1.4 Exception Handling

There are no optional inputs (with the exception of DQTT threshold tables). A failure to get input data from DMS or store output data to DMS during the Input/Output (I/O) stages of the algorithm are reported and result in process termination. No output products are produced.

Errors extracting VCM values result in an error message and process termination with no output products produced.

If AOT values are out of range or fill, the pixel weight is set to zero and a quality flag is set.

If solar zenith angles are out of range or fill, the pixel weight is set to zero and a quality flag is set.

There are currently no conditions which result in returning a PRO_FAIL status from the algorithm main module (scd_main).

### 2.1.5 Data Quality Monitoring

Table 17 lists the data quality monitoring tests which are defined in the Snow Binary Map and Snow Fraction EDR Data Quality Threshold Tables. If any of these tests fail, a Data Quality Notification will be sent to DQM.

**Table 17. Data Quality Threshold Table Tests**

| Test Description | Test Type | Text | Value | Test Parameters | Action |
|---|---|---|---|---|---|
| Check for Binary Map Quality in Binary Map EDR | Threshold – less than | scdBinaryMapQuality is below 91 percent | Logical / Boolean | Min = 91% | Send DQN if flag is below threshold |
| Check for Exclusion Summary in Binary Map EDR | Threshold – greater than | scdExclusionSummary exceeds 89 percent | Logical / Boolean | Max = 89% | Send DQN if flag exceeds threshold |
| Check for Snow Fraction Quality in Aggregated Fraction EDR | Threshold – less than | scdSnowFractionQuality is below 91 percent | Logical / Boolean | Min = 91% | Send DQN if flag is below threshold |
| Check for Degradation Summary in Aggregated Fraction EDR | Threshold – greater than | scdDegradationSummary exceeds 89 percent | Logical / Boolean | Max = 89% | Send DQN if flag exceeds threshold |
| Check for Exclusion Summary in Aggregated Fraction EDR | Threshold – greater than | scdExclusionSummary exceeds 89 percent | Logical / Boolean | Max = 89% | Send DQN if flag exceeds threshold |

### 2.1.6 Computational Precision Requirements

Single precision floating point computations are required by the Snow Cover algorithm.

### 2.1.7 Algorithm Support Considerations

The Snow Cover algorithm uses tunable parameters contained in the Snow Cover LUT (Table 9) and the Snow Cover Quality LUT (Table 11). These LUTs contain thresholds used by the algorithm. They are generated by offline processes and may be updated when needed, but do not require periodic updating.

### 2.1.8 Assumptions and Limitations

Retrievals are not performed under nighttime conditions. This is defined as instances where the solar zenith angle exceeds 85 degrees.

Retrievals are not performed under confidently cloudy conditions.

Retrievals are not performed over ocean.

Retrievals over inland water are performed but are not required to meet performance specification.

Retrievals of the binary snow map and snow fraction are questionable under conditions of extreme aerosol loading, such as events associated with volcanic eruptions or biomass-burning. The results are not guaranteed to meet the performance specification for these circumstances.

# 3.0 GLOSSARY/ACRONYM LIST

## 3.1 Glossary

Table 18 contains terms most applicable for this OAD.

**Table 18. 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:<br>1. A theoretical description (i.e., science/mathematical basis)<br>2. A computer implementation description (i.e., method of solution)<br>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]*<br>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.).<br>*[Supplementary Definition]*<br>An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality. |
| Model Validation | The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management] |
| Model Verification | The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management] |
| Operational Code | Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT. |

| Term | Description |
|---|---|
| Operational-Grade Software | Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code. |
| Raw Data Record (RDR) | *[IORD Definition]*<br>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.<br>*[Supplementary Definition]*<br>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]*<br>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.<br>*[Supplementary Definition]*<br>A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data. |

| Term | Description |
|---|---|
| Temperature Data Record (TDR) | *[IORD Definition]*<br>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.<br>*[Supplementary Definition]*<br>A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction. |

## 3.2 Acronyms

Table 19 contains acronyms most applicable for this OAD.

**Table 19. Acronyms**

| Term | Expansion |
|---|---|
| AM&S | Algorithms, Models & Simulations |
| API | Application Programming Interfaces |
| ARP | Application Related Product |
| CDFCB-X | Common Data Format Control Book - External |
| COT | Cloud Optical Thickness |
| DMS | Data Management Subsystem |
| DPIS ICD | Data Processor Inter-subsystem Interface Control Document |
| DQTT | Data Quality Test Table |
| IIS | Intelligence and Information Systems |
| INF | Infrastructure |
| ING | Ingest |
| IP | Intermediate Product |
| LUT | Look-Up Table |
| MDFCB | Mission Data Format Control Book |
| NDSI | Normalized Difference Snow Index |
| PRO | Processing |
| QF | Quality Flag |
| SDR | Sensor Data Records |
| SI | Software Item or International System of Units |
| TBD | To Be Determined |
| TBR | To Be Resolved |
| TOA | Top of the Atmosphere |
| VCM | VIIRS Cloud Mask |

# 4.0 OPEN ISSUES

**Table 20. TBXs**

| TBX ID | Title/Description | Resolution Date |
| --- | --- | --- |
| None | | |