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

For Public Release

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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**

Prepared By:

Ray Godin
JPSS Data Products and Algorithms EDR Lead
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm))

Approved By:

Gilberto Vicente
JPSS Ground Project Algorithm Integration Team (AIT) Manager
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm))

**Goddard Space Flight Center
Greenbelt, Maryland**

Preface

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

Any questions should be addressed to:

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

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Revision D	03/13/2017	474-CCR-17-3243 (ECR-CGS-0727): This version authorizes 474-00086, JPSS OAD Document for VIIRS Snow Cover EDR Software, for the Block 2.0 IDPS release. Includes Raytheon PCR045678; Block 2.0: PRO: OAD: CCR: 474-CCR-15-2444: General OAD Clean-up CCR/PCR, affects all 35/37 OADs. All sections and tables may be affected.



**NATIONAL POLAR-ORBITING
OPERATIONAL ENVIRONMENTAL
SATELLITE SYSTEM (NPOESS)**

**OPERATIONAL ALGORITHM DESCRIPTION
DOCUMENT FOR 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**

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



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PREPARED BY:

Robert Mahoney *Date*
AM&S VIIRS Snow Cover EDR Lead

Paul D. Siebels *Date*
IDPS PRO SW Manager

ELECTRONIC APPROVAL SIGNATURES:

Roy Tsugawa *Date*
A&DP Lead & ACCB Chair

Stephen E. Ellefson *Date*
IDPS Processing SI Lead

Bob Hughes *Date*
A&DP Deputy & ARB Chair

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

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

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

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1.0 INTRODUCTION

1.1 Objective

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

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

The purpose of an OAD is two-fold:

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

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

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm 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, D0001-M01-S01-017.

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	D0001-M01-S01-017	Latest
Operational Algorithm Description (OAD) Document for VIIRS Cloud Mask (VCM) EDR	474-00062	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

Document Title	Document Number/Revision	Revision Date
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
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
Joint Polar Satellite System (JPSS) Algorithm Specification	474-00448-02-01_JPSS-DD-Vol-II-Part-1 474-00448-02-06_JPSS-DD-Vol-II-Part-06 474-00448-02-11_JPSS-DD-Vol-II-Part-11 474-00448-02-12_JPSS-DD-Vol-II-Part-12 474-00448-02-16_JPSS-DD-Vol-II-Part-16 474-00448-02-29_JPSS-DD-Vol-II-Part-29	Latest

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

Reference Title	Reference Tag/Revision	Revision Date
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.

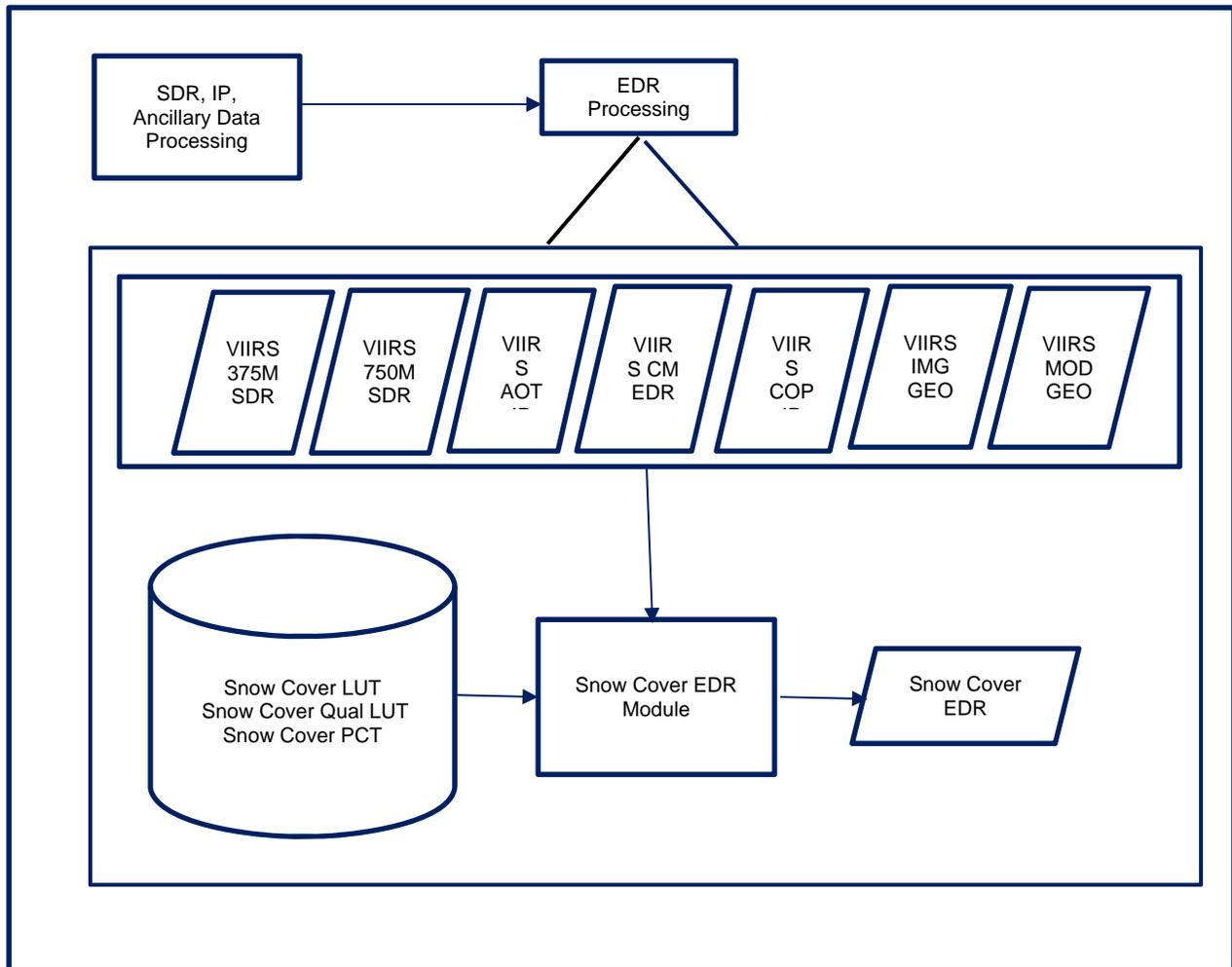


Figure 1. Snow Cover EDR Processing Overview

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, D0001-M01-S01-017, 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.

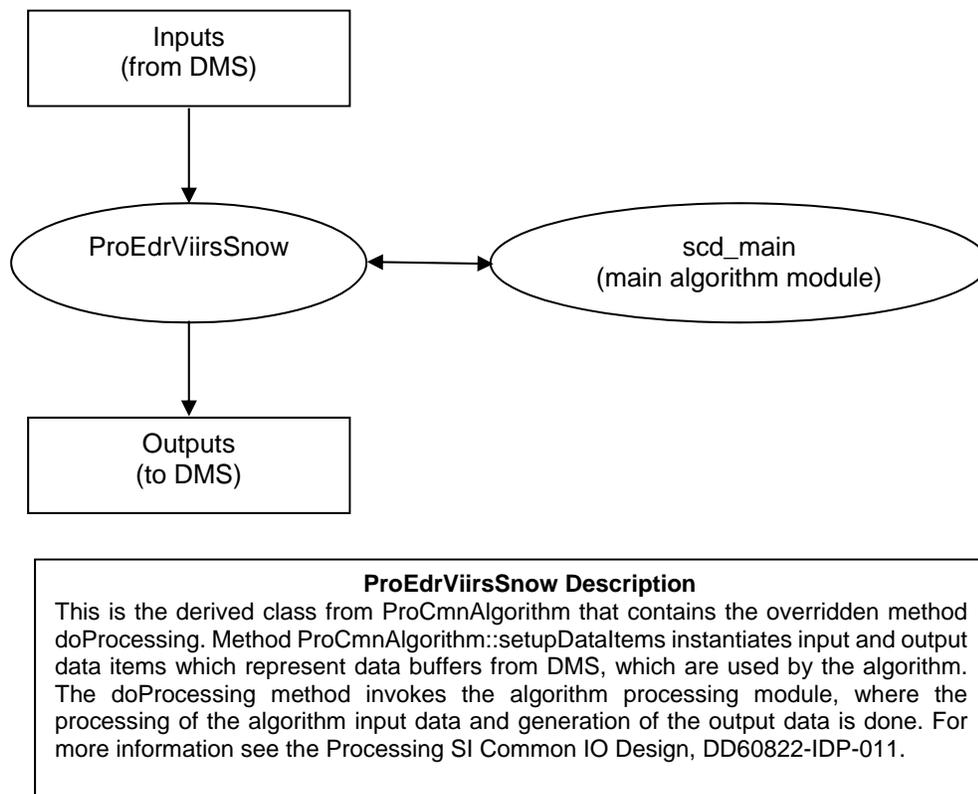


Figure 2. Snow Cover Interfaces

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

Table 3 describes the inputs for the Snow Cover algorithm.

Table 3. VIIRS Snow Cover EDR Inputs

Input	Description	Reference Document
VIIRS I1, I2, I3 and I5 Imagery Band SDRs	Band I1 - radiance & reflectance at nominal center wavelength 640 nm. Band I2 - radiance & reflectance at nominal center wavelength 865 nm. Band I3 - radiance & reflectance at nominal center wavelength 1610 nm. Band I5 - radiance & reflectance at nominal center wavelength 11450 nm	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS M15 and M16 Moderate Band SDRs	Band M15 - radiance & emittance at nominal center wavelength 10763 nm. Band M16 - radiance & emittance at nominal center wavelength 12013 nm.	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Img Geo	VIIRS Imagery Band SDR Geolocation	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Mod Geo	VIIRS Moderate Band SDR Geolocation	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS AOT IP	The VIIRS Aerosol Optical Thickness RIP contains thickness values at assorted spectral bands over land and water as well as associated quality flags	474-00448-02-12_JPSS-DD-Vol-II-Part-12
VIIRS COP IP	Parallax Corrected Cloud Optical Properties Data	474-00448-02-16_JPSS-DD-Vol-II-Part-16
VIIRS Cloud Mask EDR	The VIIRS Cloud Mask (VCM) technique incorporates a number of cloud detection tests that determine whether a cloud obstructs a cell. If a cloud is detected, the VCM indicates whether its phase is water, ice, or mixed. Additionally, the VCM specifies whether aerosols, fire, or shadows are detected within the cell field of view (FOV). A spatial uniformity test is also performed on the scene.	474-00448-02-11_JPSS-DD-Vol-II-Part-11
VIIRS Snow Cover Depth PC	The VIIRS Snow Cover/Depth EDR Ephemeral PC provides tunable processing coefficients for use by the algorithm during execution	474-00448-02-29_JPSS-DD-Vol-II-Part-29
VIIRS Snow Cover Depth Quality LUT	The VIIRS SCD Snow Cover Quality LUT file contains weight reduction factors for cloud contamination and degradation/exclusion threshold limits.	474-00448-02-29_JPSS-DD-Vol-II-Part-29

Input	Description	Reference Document
VIIRS Snow Cover Depth LUT	The VIIRS SCD Snow Cover LUT file contains thresholds, switches, and coefficients used to derive TOA reflectance for each of the nine moderate resolution bands used for snow fraction.	474-00448-02-29_JPSS-DD-Vol-II-Part-29

2.1.1.2 Outputs

Table 4 describes 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.

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 4. VIIRS Snow Cover EDR Outputs

Output	Description	Reference Document
VIIRS Snow Cover Depth Binary Snow Fraction EDR	The VIIRS Snow Cover Fraction EDR is output at the VIIRS moderate resolution. The snow cover fraction is based off of the VIIRS Snow Cover Binary Map and is calculated using a 2x2 pixel aggregation of the Snow Binary Map.	474-00448-02-29_JPSS-DD-Vol-II-Part-29
VIIRS Snow Cover Depth Binary Snow Map EDR	The Snow Cover Binary Map EDR is a snow/no snow binary map which classifies a pixel as snow or no snow from its values of Normalized Difference Snow Index (NDSI) and Normalized Difference Vegetation Index (NDVI).	474-00448-02-29_JPSS-DD-Vol-II-Part-29
VIIRS Snow Cover Depth Binary Snow Fraction EDR DQN	Data Quality Notification	474-00448-02-01_JPSS-DD-Vol-II-Part-1
VIIRS Snow Cover Depth Binary Snow Map EDR DQN	Data Quality Notification	474-00448-02-01_JPSS-DD-Vol-II-Part-1

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.

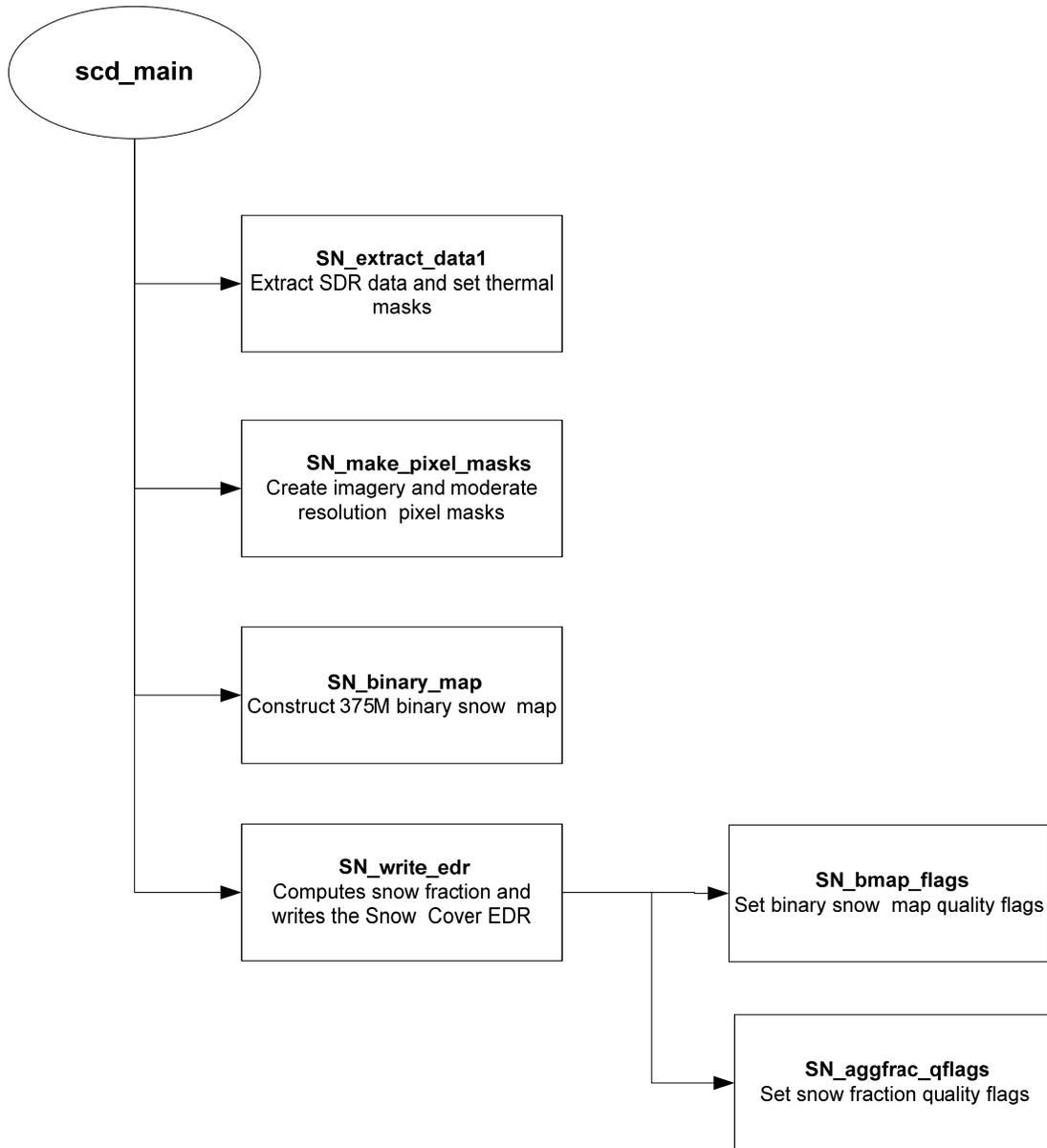


Figure 3. Snow Cover Algorithm Flow

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:

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

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:

$$W_{\text{cloud}} = (\text{COT_YR}(\text{band}) - \text{COT}(\text{pixel})) / (\text{COY_YR}(\text{band}) - \text{COT_GY}(\text{band}))$$

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:

$$W_{\text{aerosol}} = (\text{SZA_YR}(\text{band}) - \text{SZA}(\text{pixel})) / (\text{SZA_YR}(\text{band}) - \text{SZA_GY}(\text{band}))$$

Pixel quality masks are determined for both imagery resolution (Table 5) 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 5. Description of VCM and Band Quality Bits (mask_i)

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

Table 6. Description of VCM and Band Quality Bits (mask_m)

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

BYTE	Bit	Flag Description Key	Result
	5-6	Overall M5 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
	7	Overall M7 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
4	0	Overall M7 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
	1-2	Overall M8 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
	3-4	Overall M10 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
	5-6	Overall M11 Quality *	00 = GREEN (GOOD) 01 = GREEN/YELLOW 10 = YELLOW/RED 11 = RED (POOR)
	7	Overall Quality	0 = GREEN (GOOD) 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 EDR(VCM EDR, 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 7 describes variables used in constructing the map.

Table 7. 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, D0001-M01-S01-017.

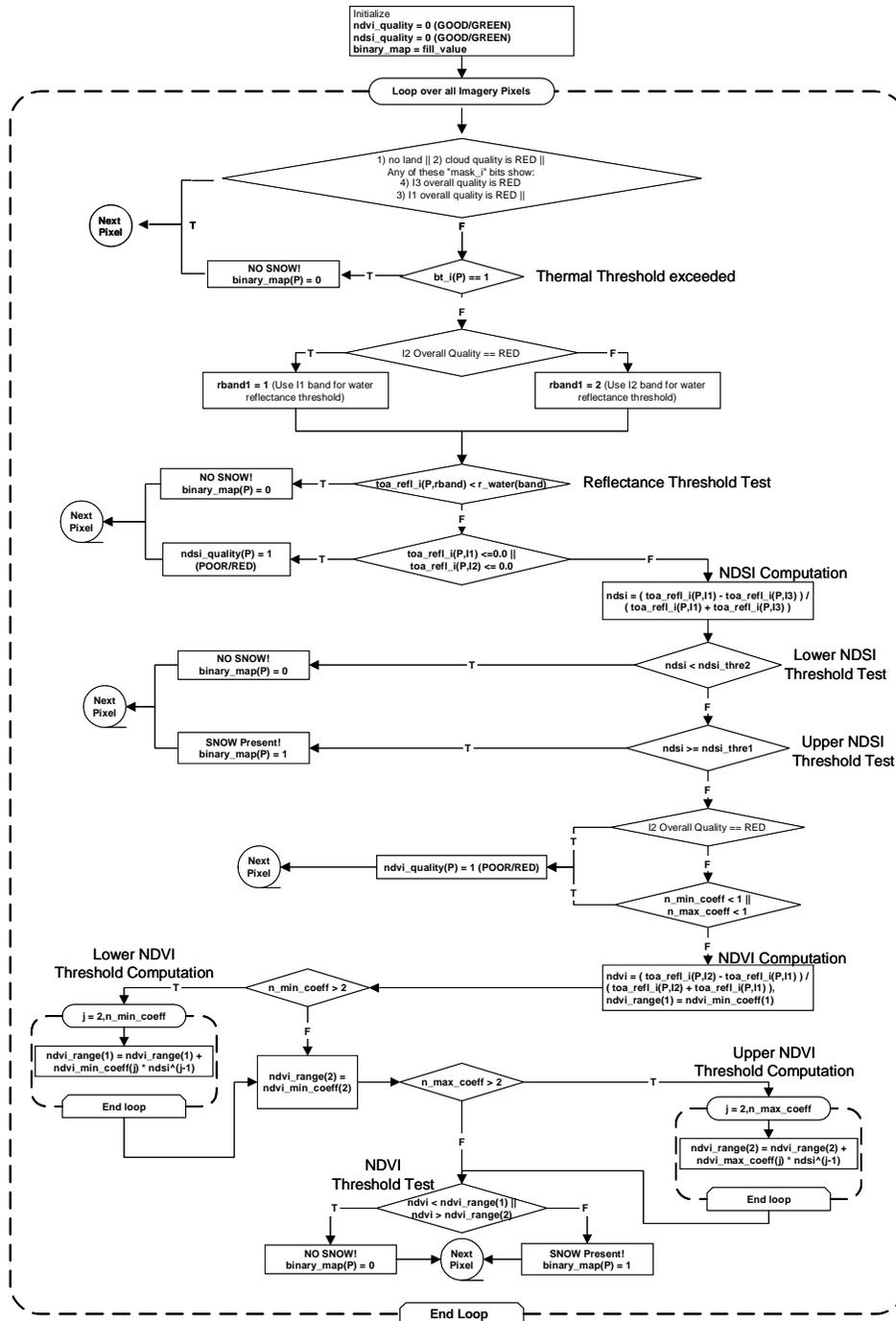


Figure 4. Logic flow for the Snow Cover Binary Map Algorithm

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.

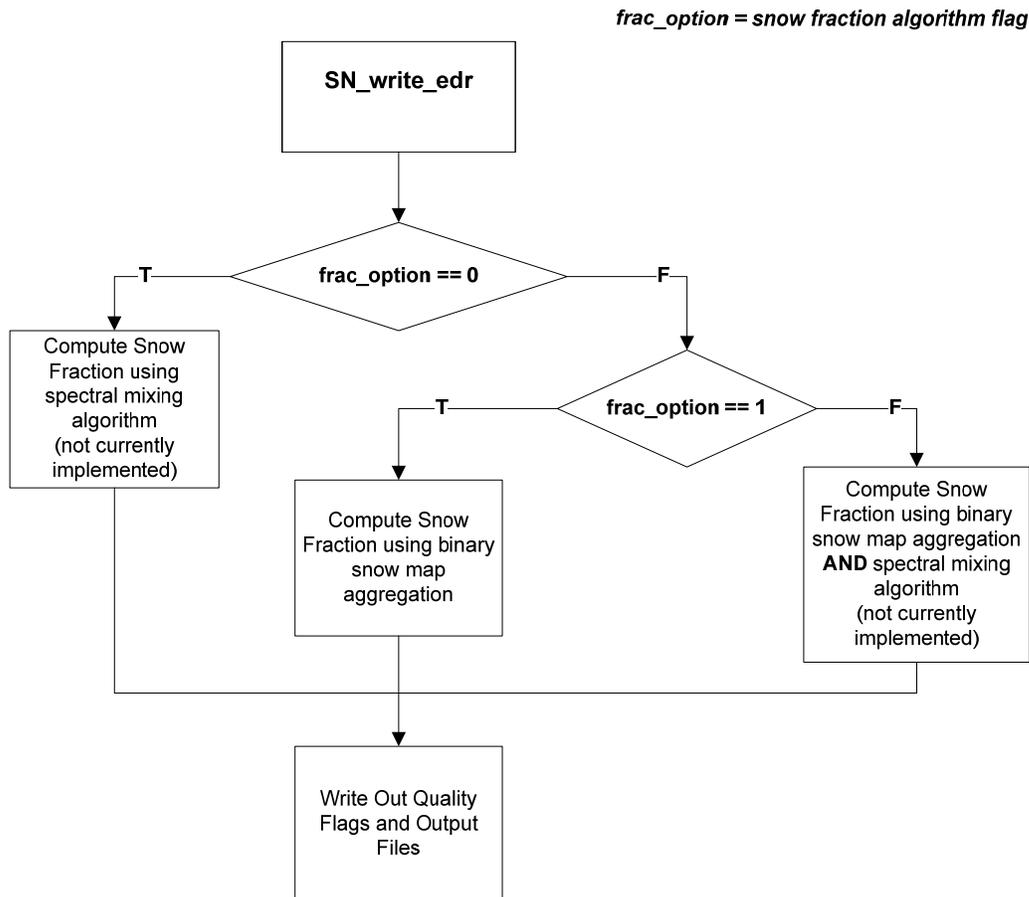


Figure 5. Logic flow of SN_write_edr

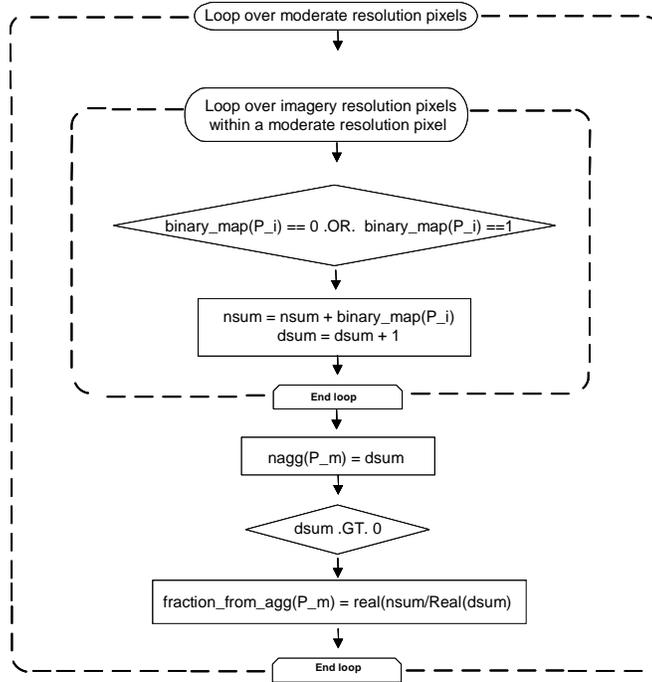


Figure 6. Logic Flow for the Snow Fraction Aggregation

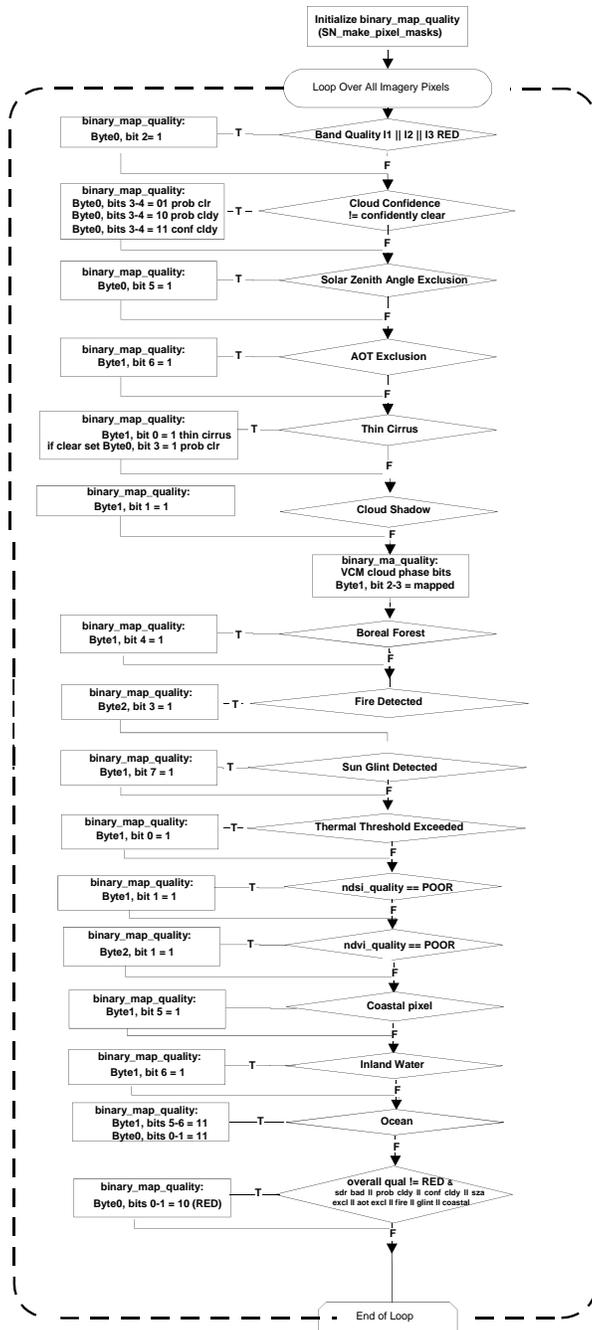


Figure 7. Logic Flow for SN_bmap_qflags to set Binary Map Quality Flags

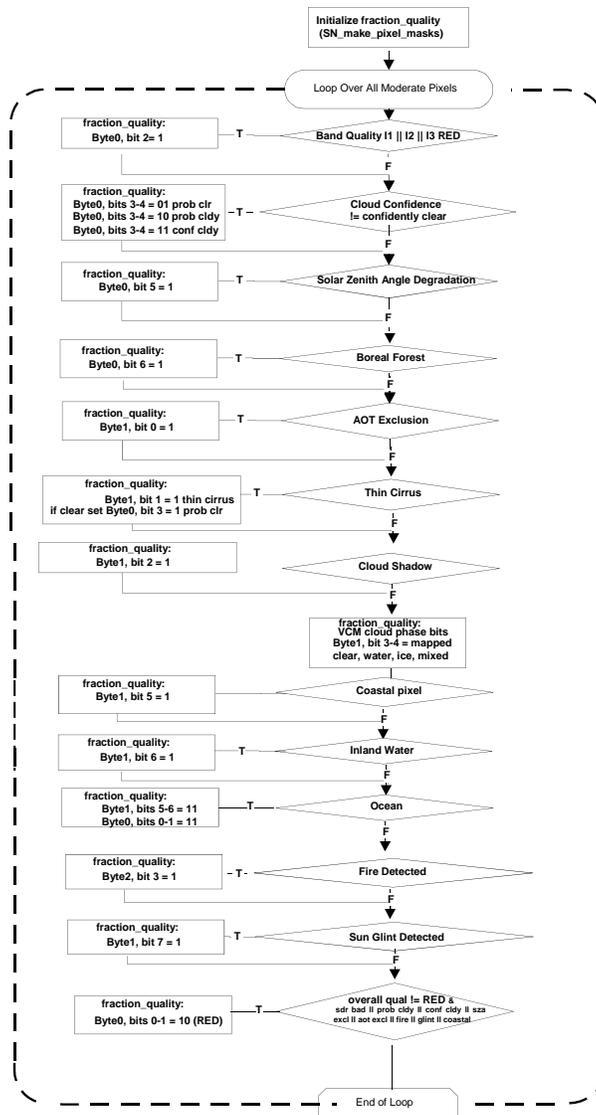


Figure 8. Logic Flow for Snow Fraction Quality Portion of SN_write_edr()

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 8 references the data quality monitoring tests document 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.

Snow Binary Map and Snow Fraction Data Quality Thresholds Tables (DQTTs) are optional inputs that contain the data quality monitoring tests. If at least one of these tests fails, a Data Quality Notification (DQN) will be generated. See 474-00448-02-01_JPSS-DD-Vol-II-Part-1 and 474-00448-02-29_JPSS-DD-Vol-II-Part-29 for more details.

Table 8. Data Quality Threshold Table Tests

Input	Description	Reference Document
VIIRS Snow Cover DQTT	Data Quality Test Table	474-00448-02-29_JPSS-DD-Vol-II-Part-29

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 9 contains terms most applicable for this OAD.

Table 9. Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On JPSS an algorithm consists of: <ol style="list-style-type: none"> 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Engineering Review Board (AERB)	Interdisciplinary board of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Data Process Algorithm Lead, members include representatives from STAR, DPES, IDPS, and Raytheon.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the 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 JPSS System, but which is acquired from external providers and used by the JPSS system in the production of JPSS data products.
Auxiliary Data	Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the JPSS system, and used to produce the JPSS deliverable data products.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	<p><i>[IORD Definition]</i> Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.).</p> <p><i>[Supplementary Definition]</i> An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more JPSS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.</p>
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [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.
Operational-Grade Software	Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code.

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

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

3.2 Acronyms

Table 10 contains acronyms most applicable for this OAD.

Table 10. Acronyms

Term	Expansion
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
COT	Cloud Optical Thickness
DMS	Data Management Subsystem
DQTT	Data Quality Test Table
IIS	Intelligence and Information Systems
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LUT	Look-Up Table
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 11. TBXs

TBX ID	Title/Description	Resolution Date
None		