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Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Sea Ice Concentration (SIC) Intermediate Product (IP) 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 Sea Ice Concentration (SIC) Intermediate Product (IP) Software JPSS Electronic Signature Page

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Preface

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

Any questions should be addressed to:

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Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	06/03/2011	This version incorporates **474-CCR-11-0109** which converts D42820, Operational Algorithm Description Document for VIIRS Sea Ice Concentration (SIC) Intermediate Product (IP), Rev C dated 05/19/2010 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-11-0252:** This version baselines 474-00094, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Sea Ice Concentration (SIC) Intermediate Product (IP) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	05/14/2013	**474-CCR-13-0948:** This version authorizes 474-00094, JPSS OAD Document for VIIRS SIC IP, for the Mx 7.0 IDPS release. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SEA ICE CONCENTRATION (SIC) INTERMEDIATE PRODUCT (IP)

SDRL No. S141
SYSTEM SPECIFICATION SS22-0096

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

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

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SEA ICE CONCENTRATION (SIC) INTERMEDIATE PRODUCT (IP)

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

CAGE NO. 11982

Operational Algorithm Description Document
for the VIIRS Sea Ice Concentration Intermediate Product (IP) Software

Document Date: Sep 19, 2011

Document Number: D42820
Revision: D2

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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. **Space Technology** One Space Park Redondo Beach, CA 90278	NORTHROP GRUMMAN Raytheon

Revision/Change Record

Document Number D42820

Revision	Document Date	Revision/Change Description	Pages Affected
---	5-6-05	Initial PCIM Release - Reference ECR A049	All
A1	6-20-06	11Oct05 - Reflects Raytheon-Omaha's Science To Operational Code Conversion 19Jan06 – Made minor edits to address 12Jan06 IPO CUTPR comments. 16Feb06 – Renumbering problem to fix Figure and Table references. Some got removed from original generic VIIRS-SeaIceCharacterization-IP-OAD (Pg 5 ref to Table 32, Pg 9 ref to Fig 16, Pg 10 ref to Fig 16-18, Pg 14 ref to Table 18 and 23 and 27 and Fig 19, Pg 17 ref to Table 32. 17May06 – Made minor edits to address 17May06 OPT CUT & CC PR comments. 20June06 – Final edits. 20June06 – Changed Document ID From D39593-IDP-002, to D41873 with approval from NGST DM	All
A2	5-17-07	Updated document for TM : NP-EMD.2005.510.0038. Modified Section 2.2.3.1 added verbiage describing code changes for cross granule processing.	All
A3	6-22-07	Updates in response to SIC spl XGnl FO CCPR comments. – Change will to present tense where possible.	All
A4	10-5-07	Updated with correct values for I_VIIRS_SDR_ROWS and I_VIIRS_SDR_COLS values. Implemented TMs NP-EMD.2006.510.0067, NP-EMD.2006.510.0048, & NP-EMD.2006.510.0072.	All
A5	10-17-07	Renamed OAD from D41873 to D42820. Prepared for NGST delivery. Delivered to NGST for approval under ECR A-TBD.	All
A6	3-11-08	Updated document for TM# NP-EMD.2007.510.0046.	All
A7	6-9-08	Reformatted to conform to template document D41851. Updated graceful degradation and data quality monitoring sections	All
A8	10-20-08	Incorporated OAD updates from TM NP-EMD.2008.510.0018 and TIM comments. Prepared for delivery to NGST.	All
A	12-10-08	Addressed TIM comments. ECR A-182.	All
B1	1-19-10	Updated based on TM NP-EMD-2009.510.0049	All
B2	2-24-10	Updated for TIM	All
B	3-17-10	Incorporated TIM comments and prepared for ARB/ACCB.	All
C1	3-31-10	Incorporated TM 2010.510.0005.Rev-C	Tables 1 & 2
C	5-19-10	Prepared for TIM/ARB/ACCB	All
D1	10-18-10	Updated due to document convergence to include tech memo 2010.510.0011	All
D2	09-19-11	Updated for PCR027383.	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(s) required to create the VIIRS Sea Ice Concentration IP. The theoretical basis for this algorithm is described in Section 3.3 of the VIIRS Sea Ice Characterization Algorithm Theoretical Basis Document (ATBD), 474-00047.

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 Ice Concentration Unit Level Detailed Design Document	Y3235 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
VIIRS Sea Ice Characterization Algorithm Theoretical Basis Document (ATBD)	474-00047	Latest
JPSS Environmental Data Record (EDR) Production Report (PR) for NPP	474-00012	Latest

Document Title	Document Number/Revision	Revision Date
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
JPSS Common Data Format Control Book - External - – Block 1.2.2 (All Volumes)	474-00001-01-B0122 CDFCB-X Vol I 474-00001-02-B0122 CDFCB-X Vol II 474-00001-03-B0122 CDFCB-X Vol III 474-00001-04-01-B0122 CDFCB-X Vol IV Part 1 474-00001-04-02-B0122 CDFCB-X Vol IV Part 2 474-00001-04-03-B0122 CDFCB-X Vol IV Part 3 474-00001-04-04-B0122 CDFCB-X Vol IV Part 4 474-00001-05-B0122 CDFCB-X Vol V 474-00001-06-B0122 CDFCB-X Vol VI 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 474-00001-02-B0123 CDFCB-X Vol II 474-00001-03-B0123 CDFCB-X Vol III 474-00001-04-01-B0123 CDFCB-X Vol IV Part 1 474-00001-04-02-B0123 CDFCB-X Vol IV Part 2 474-00001-04-03-B0123 CDFCB-X Vol IV Part 3 474-00001-04-04-B0123 CDFCB-X Vol IV Part 4 474-00001-05-B0123 CDFCB-X Vol V 474-00001-06-B0123 CDFCB-X Vol VI 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
JPSS Data Format Control Book - Internal Volume III – Retained Intermediate Product Formats (IDFCB) – Block 1.2.3	474-00020-03-B0123 IDFCB Vol III	Latest
JPSS Program Lexicon	474-00175	Latest
IDPS Processing SI Common IO Design	DD60822-IDP-011 Rev. A	21 Jun 2007
NGST/SE technical memo –Cross-granule Processing Memo	NP-EMD.2005.510.0038	07 Mar 2005

Document Title	Document Number/Revision	Revision Date
NGST/SE technical memo – MS_EngMemo_STIP_codefix_SPCR982_971	NP-EMD.2006.510.0004	03 Mar 2006
NGST/SE technical memo – NPP_VIIRS_IceConc_logical_expression_fixes_067	NP-EMD.2006.510.0067	12 Sep 2006
NGST/SE technical memo – NPP_VIIRS_SeaIce_Concentration_STIP_Quality	NP-EMD.2006.510.0048	03 Jul 2006
NGST/SE technical memo – NPP_VIIRS_IceConc_precision_fix	NP-EMD.2006.510.0072	18 Oct 2006
NGST/SE technical memo – NPP_VIIRS_SeaIce_v3.4.4_delta_delivery_OAD_updates	NP-EMD.2007.510.0046	08 Aug 2007
NGST/SE technical memo – NPP_VIIRS_SeaIce_v3.4.5_delta_delivery_OAD_updates	NP-EMD.2008.510.0018	14 Apr 2008
NGAS/SE technical memo – SeaIceConc_v4.17_OAD_Update	NP-EMD.2009.510.0049	24 Nov 2009
NGAS/SE technical memo –_Granule-Level Summary Exclusion Flag Definition Rev C	NP-EMD.2010.510.0005.Rev-C	02 Mar 2010
NGST/SE technical memos: LUT_OAD_Drop History_Corrections	NPOESS GJM-2010.510.0011	21 Sep 2010
Operational Algorithm Description Document for VIIRS Sea Ice Quality (SIQ) Intermediate Product (IP) and Surface Temperature (ST) IP	474-00095	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 SeaIceCharacterization science-grade software (original reference source) (ECR-A049)	ISTN_VIIRS_NGST_3.4 (OAD Rev. ---)	05 May 2005
VIIRS SeaIceCharacterization (SIC) operational software	B1.4 (OAD Rev. A1)	20 Jun 2006
VIIRS SeaIceCharacterization science-grade software (ECR-A066)(Sea Ice Age) Includes Tech Memo: NP-EMD.2005.510.0115	ISTN_VIIRS_NGST_3.4.1	29 Sep 2005
VIIRS SeaIceCharacterization science-grade software (ECR-A073)(Sea Ice Quality) Includes Tech Memo: NP-EMD.2005.510.0137	ISTN_VIIRS_NGST_3.4.2	14 Nov 2005
VIIRS SeaIceCharacterization science-grade software (ECR-A073 & A108)(Sea Ice Age)	ISTN_VIIRS_NGST_3.4.3 Data	18 Dec 2006
VIIRS SeaIceCharacterization science-grade software (ECR-A127A)(Sea Ice Age) Includes Tech Memo: NP-EMD.2007.510.0046	ISTN_VIIRS_NGST_3.4.4 Data	11 Sep 2007
Implemented Tech Memos: 2006.510 0048, 2006.510 0067, 2006.510 0072	B1.5 (OAD Rev. A4)	17 Aug 2007
VIIRS SeaIceCharacterization science-grade software (Sea Ice Characterization) Includes OAD update Tech Memo: NP-EMD.2008.510.0018	ISTN_VIIRS_NGST_3.4.5 (OAD updated by TM)	14 May 2008
VIIRS SeaIceCharacterization (SIC) operational software includes Tech Memo 2008.510.0018	B1.5x1 (OAD Rev. A8)	24 Oct 2008
ACCB (no code updates)	OAD Rev A	10 Dec 2008

VIIRS SeaIceCharacterization science-grade software (Sea Ice Characterization) Includes OAD update Tech Memos: NP-EMD.2009.510.0049 & NP-EMD.20098.510.0068	ISTN_VIIRS_NGST_4.17 (OAD updated by TM)	16 Dec 2009
VIIRS SeaIceCharacterization (SIC) operational software (PCRs 21984-SIQ & 21983-SIC)	Sensor Characterization (Build SC-6) (OAD Rev B1)	19 Jan 2010
ACCB (no code updates)	OAD Rev B	17 Mar 2010
Implemented TM 2009.510.0049	(OAD Rev B1)	19 Jan 2010
PCR021630	Sensor Characterization (Build SC-8) (OAD Rev C1)	31 Mar 2010
ACCB	OAD Rev C	19 May 2010
Convergence Update (No code updates)	(OAD Rev D1)	18 Oct 2010
PCR027383	(OAD Rev D2)	19 Sep 2011
OAD transitioned to JPSS Program – this table is no longer updated.		

2.0 ALGORITHM OVERVIEW

The Sea Ice Concentration algorithm is the second executable in the Sea Ice Characterization chain. It utilizes VIIRS 375m Sensor Data Record (SDR) files, Intermediate Product (IP) files from the VIIRS Ice Quality algorithm, and two Sea Ice Look-Up-Table files as input to produce the Sea Ice Concentration IP files. The Ice Concentration processing chain is shown in Figure 1.

The Ice Concentration Unit generates two IP files:

- Ice Concentration IP
- Ice Reflectance/Temperature IP

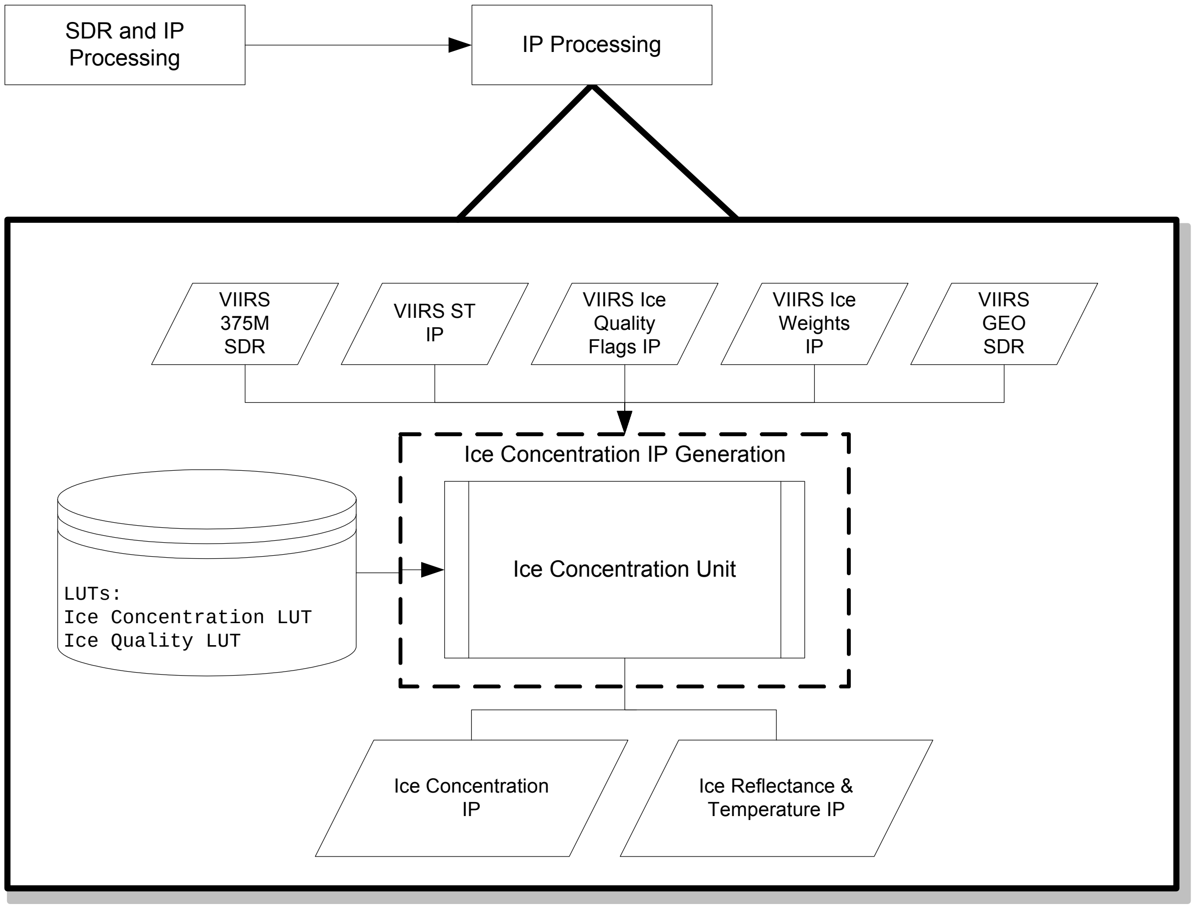

Figure 1. Ice Concentration Processing Chain

2.1 Sea Ice Concentration Intermediate Product Description

The Sea Ice Characterization EDR retrieval algorithm and the theoretical basis are described in detail in the VIIRS Sea Ice Characterization ATBD, 474-00047. That document also gives the theoretical basis for the Ice Concentration algorithm in Section 3.3.3.

2.1.1 Interfaces

Refer to the CDFCB-X, D34862, for a detailed description of the inputs. Some inputs (ex. VIIRS Ice Quality Flags IP and Ice Weights IP) are described in the IDFCB, 474-00020-03-B0123 IDFCB Vol III, Sections 3.3.15 and 3.3.17, respectively.

2.1.1.1 Inputs

The Sea Ice Concentration Unit requires input files specified in Table 6. It should be noted that several practical considerations related to the VIIRS Surface Temperature IP (STIP) input are required and discussed in Section 4.1. A description of the contents of the STIP and details regarding the quality flags associated with it are described in the Operational Algorithm Description Document for VIIRS Sea Ice Quality (SIQ) Intermediate Product (IP) and Surface Temperature (ST) IP, 474-00095. It should be noted that the value of the parameter max_wsize defined in Table 5 acts as a switch to allow the algorithm to be run using adjustable search window mode or with fixed sized search windows. The adjustable window mode should be the operational default run mode until the optimal window size is determined during Calibration/Validation. Table 3 shows the global attributes for Ice Concentration and Table 4 shows the main inputs for Ice Concentration.

Table 3. Global Attributes (Ice Concentration)

Input	Type	Description/Source	Units/Valid Range
VIIRS_RDR_SCANS	Int32	Number of RDR scans	Unitless/ VIIRS_RDR_SCANS > 0 ***(Currently set to 48)***
I_DETECTORS	Int32	Number of Image detectors	Unitless/ I_DETECTORS > 0 ***(Currently set to 32)***
I_VIIRS_SDR_ROWS	Int32	Number of image Viirs rows	Unitless/ VIIRS_RDR_SCANS * I_DETECTORS
I_VIIRS_SDR_COLS	Int32	Number of image Viirs columns	Unitless/ I_VIIRS_SDR_COLS > 0 ***(Currently set to 6400)***
IC_BANDS	Int32	Number of bands, extracted from the Ice Quality Flags IP, now represent band I1, I2, and surface temperature (not I5 brightness temperature values)	Unitless/ IC_BANDS > 0 ***(Currently set to 3 => I1,I2,STIP)***

Table 4. Main Inputs (Ice Concentration)

Input	Data Type/Size	Description/Source	Units/Valid Range
Reflectance_Img	float*32 x I_VIIRS_SDR_COLS X I_VIIRS_SDR_ROWS	I1 and I2 Reflectances, from the IMG SDR	Unitless/ Reflectance_Img > 0
Pixel Quality Img	Uint*8 x I_VIIRS_SDR_COLS X I_VIIRS_SDR_ROWS	I1 and I2 pixel level quality, from the IMG SDR	Unitless/ Pixel Quality Img ≥ 0
Actual Scans	Int*32	Number of scans in the granule, from the IMG Geolocation SDR	Unitless/ Actual Scans > 0
ST	float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Surface Temperature IP (STIP) @ Imagery resolution	Kelvin/ ST ≥ 0
ST Quality	Uint*8 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Surface Temperature IP Quality Flags @ Imagery resolution See Ice Quality OAD, 474-00095	See Table 20 in the Sea Ice Quality IP and STIP OAD, 474-00095

Input	Data Type/Size	Description/Source	Units/Valid Range
Ice Weights	float*32 x IC_BANDS (I1,I2, STIP) x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Ice Weights for Imagery Bands (I1, I2) and STIP, from the Ice Weights IP	Unitless/ 0.0 ≤ Ice Weights ≤ 1.0
Sea Ice Range Flag	Uint*8	Granule not in sea ice range flag, from the Ice Quality IP	Unitless/ 0 = No 1 = Yes
Freshwater Ice Range Flag	Uint*8	Granule not in freshwater ice range flag, from the Ice Quality IP	Unitless/ 0 = No 1 = Yes
Ice Concentration LUT	See Table 5	See Table 5	See Table 5
Ice Quality LUT	See Ice Quality OAD, 474-00095	See Ice Quality OAD, 474-00095	See Ice Quality OAD, 474-00095

Table 5. Ice Concentration LUT

Input	Data Type/Size	Description/Source	Units/Valid Range
hmin	float*32 x IC_BANDS	Minimum range of histogram, by band. If hmin = hmax then code must derive hmin.	[Unitless, Kelvin]/ hmin = [0.0, 0.0, 0.0]
hmax	float*32 x IC_BANDS	Maximum range of histogram, by band. If hmax = hmin then code must derive hmax.	[Unitless, Kelvin]/ hmax = [0.0, 0.0, 0.0]
max_wsize	int*8	Maximum local window search size in pixels.	Unitless/ max_wsize ≥ 0 ***(Currently set to 15)***
min_pix_win	int*8	Minimum number of “good” ice pixels, in a search window, required for a reliable histogram	Unitless/ min_pix_win ≥ 0 ***(Currently set to 200)***
min_wsize	int*8	Minimum local window search size in pixels	Unitless/ min_wsize ≥ 0 ***(Currently set to 8)***
wat_wsize	int*8	Size of search window for local *water* tie points	Unitless/ wat_wsize ≥ 0 ***(Currently set to 15)***
min_pix_wat	int*8	Minimum number of “good” water pixels, in a search window, required for a reliable histogram	Unitless/ min_pix_wat ≥ 0 ***(Currently set to 50)***
nbig	int*8	Number of bins in the reflectance or temperature histograms (global)	Unitless/ nbig > 0 ***(Currently set to 100)***
nbin	int*8	Number of bins in the reflectance or temperature histograms (local)	Unitless/ nbin > 0 ***(Currently set to 50)***
ning	int*8	Number of bins for boxcar smoothing of global histograms	Unitless/ ning > 0 ***(Currently set to 5)***
nint	int*8	Number of bins for boxcar smoothing of local histograms	Unitless/ nint ≥ 0 ***(Currently set to 10)***
thre_def	float*32 x IC_BANDS	Default ice/water thresholds by band	[Unitless, Kelvin]/ thre_def = [0.2, 0.17, 269.0]
thre_max	float*32 x IC_BANDS	Maximum ice/water thresholds by band	[Unitless, Kelvin]/ thre_max = [0.25, 0.22, 270.0]
thre_min	float*32 x IC_BANDS	Minimum ice/water threshold by band	[Unitless, Kelvin]/ thre_min = [0.15, 0.13, 268.0]

Input	Data Type/Size	Description/Source	Units/Valid Range
wat_def	float*32 x IC_BANDS	Default water tie points	[Unitless, Kelvin]/ wat_def = [0.08, 0.07, 271.4]
wat_max	float*32 x IC_BANDS	Default maximum water tie point	[Unitless, Kelvin]/ wat_max = [0.1, 0.08, 278.0]
wat_min	float*32 x IC_BANDS	Default minimum water tie point	[Unitless, Kelvin]/ wat_min = [0.04, 0.03, 270.0]
ice_tiept_adj_thinice _thresh	float*32 x IC_BANDS	Ice tie point adjustment thresholds for thin ice. See note on -999.00 switch value	[Unitless, Kelvin]/ ice_tiept_adj_thinice_thresh = [0.2, 0.17, 269.0] -999.00 value defined for any of the three elements invokes switch (iswitch_adj = 0) that turns off the tie point adjustment computation
ice_tiept_adj_thresh T	float*32	Ice tie point adjustment temperature threshold Ice tie point adjustment not applied to pixels with surface temperatures greater than the threshold value	Kelvin ice_tiept_adj_threshT = 270.00

Table 6. Ice Concentration IP Input File Specifications

Input	Object/Format	Original Source
VIIRS Earth View 375-meter I1 & I2 SDRs	IDPS Binary	VIIRS SDR Module
VIIRS 375-meter Geolocation SDR	IDPS Binary	VIIRS SDR Module
VIIRS Ice Weights IP	IDPS Binary	VIIRS Ice Quality IP Module
VIIRS Ice Quality Flags IP	IDPS Binary	VIIRS Ice Quality IP Module
VIIRS Surface Temperature IP	IDPS Binary	VIIRS Surface Temperature IP Module
Ice Concentration LUT	IDPS Binary	Lookup Table
Ice Quality LUT	IDPS Binary	Lookup Table

2.1.1.1.1 Requirements for Input

The Ice Concentration algorithm is reliant on VIIRS SDR and IP products. The processing approach developed for the Sea Ice Concentration algorithm is based on sliding windows that slide along the pixel row counting/averaging neighboring pixels surrounding each product pixel using these values as a basis for processing decisions. The sliding windows used by subroutines: IC_tie_point, IC_tie_point_plus and IC_local_water_tie_point include pixel information from both neighboring rows and neighboring columns. As a result, the first and last scan lines of the granule require that the pixel information from the preceding and succeeding granules be available. To accomplish this, the last scan of the previous granule and the first scan of the next granule is read and passed to the algorithm as extended data that gets processed along with the current granule.

2.1.1.2 Outputs

The Ice Concentration Unit produces outputs for two IP products:

- Ice Concentration IP
- Ice Reflectance/Temperature IP

The two IP files produced are "retained Cal/Val" IP files. Note: the Ice Concentration Application Related Product (ARP) described in the Sea Ice Characterization ATBD, 474-00047, is not required and is no longer generated as a product file by the code. The Ice Concentration ARP is therefore not described in this OAD.

Each of the retained IP files (Ice Concentration, Ice Reflectance and Temperature) contains parameters and attributes/metadata that are detailed in Table 7 through Table 9.

Table 7. Ice Reflectance/Temperature IP

Output	Data Type/Size	Description	Units/Valid Range
IceTiePoints	float*32 x IC_BANDS x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Ice Tie Points computed for the two reflectance bands and the STIP	Kelvin/ IceTiePoints > 0.0 Unitless/ 0.0≤IceTiePoints≤1.0
SearchWinQual	int*8 x IC_BANDS x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Search Window Quality determined for the two reflectance bands and the STIP	Unitless/ SearchWinQual = 0 = Good Search Window 1 = Bad Search Window
LocalWaterTiePoints	float*32 x IC_BANDS x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Local Water Tie points computed for the two reflectance bands and the STIP	Kelvin/ LocalWaterTiePoints > 0.0 Unitless/ 0.0≤LocalWaterTiePoints≤1.0
WaterSearchWindowQual	int*8 x IC_BANDS x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Water Search Window Quality determined for the two reflectance bands and the STIP	Unitless/ SearchWinQual = 0 = Good Search Window 1 = Bad Search Window
BandQual	int*8 x IC_BANDS x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Quality of the two reflectance bands and the STIP	Unitless/ BandQual = 0 = Green 1 = Red 2 = Yellow

Table 8. Ice Reflectance/Temperature IP Attributes/Metadata

Attribute	Data Type/Size	Description
GlobalWaterTiePoints	float*32 x IC_BANDS	Global Water Tie points for bands I1, I2, and Surface Temperature
IceWaterThreshold	float*32 x IC_BANDS	Ice Water Thresholds for bands I1, I2 and Surface Temperature

Table 9. Ice Concentration (Fraction) IP

Output	Data Type/Size	Description	Units/Valid Range
IceFraction	float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Ice Fraction	Unitless/ 0.0 ≤ IceFraction ≤ 1.0
ConcWgt	float*32 x I_VIIRS_SDR_COLS x I_VIIRS_SDR_ROWS	Ice Concentration Weights	Unitless/ 0.0 ≤ ConcWgt ≤ 1.0

2.1.2 Algorithm Processing

The Sea Ice Characterization EDR algorithm consists of four individual independent modules, which produce IP and EDR products. The arrow flows shown in Figure 2 below reflects the call sequence of the software units.

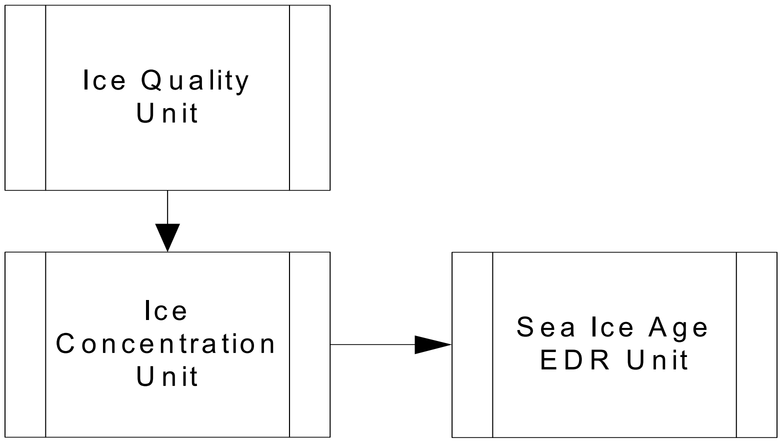

Figure 2. Call Sequence of the Sea Ice Characterization Algorithm Units

2.1.2.1 Main Module - Ice Concentration

This module reports ice concentration as a band weighted ice fraction for each imagery pixel. Module outputs are detailed in Section 2.1.1.2. The ice fraction is retrieved using a tie point method. Tie points, determined for ice and water pixels, are derived from the input reflectances (I1, I2) and surface temperature (ST) values, and are reported as reflectance values for I1 and I2 and as temperature values for surface temperature. A top-level flow of this Ice Concentration module is shown in Figure 3. This algorithm only processes if the granule is within the specified range of latitude.

The ice and water tie-points correspond to “peaks”, or histogram maximums, of Reflectance and Surface Temperature distributions over a single granule. These histograms are constructed using band specific parameters (I1, I2, and STIP values) and pre-determined LUT values that legislate histogram dimensions. To derive the ice/water tie-points, the algorithm must extrapolate from the band specific parameters histograms, the scene-specific ice/water threshold. The ice/water threshold corresponds to the local minimum of the band parameter distribution. For example, an ice/water threshold for the I1 reflectance band would correspond to a region of the parameter distribution that contains the least number of pixels. The histogram is “smoothed” out by using a running boxcar filter, producing a sliding integral of the parameter distribution. The boxcar filter window can either be fixed or self-adjusting. Each boxcar filter representing a portion of the histogram contains the summed up contribution of pixels within that region of the distribution. Each of these window filters are compared to other running filters within the histogram. The window containing the least number of pixels denotes the ice/water threshold region. The center of this region becomes the ice/water threshold point.

On either side of the threshold band specific water and ice tie points are computed for each imagery pixel. Water tie points are selected as maximums in a probability density distribution corresponding to the maximum of the sliding integral over water reflectance values (STIP). Ice tie points are derived locally for each imagery pixel for parameter values on the ice side of the ice/water threshold. For each pixel, the ice tie point is selected as the maximum value from a sliding integral over a localized parameter distribution. For more details on the tie point selection process refer to the Sea Ice Characterization ATBD, 474-00047, Section 3.3.3. Logic flow diagrams for the ice/water threshold and tie point determination are shown in Figures 4 through 6.

The tie point determination follows a similar algorithm as the ice/water threshold logic. For the case of local ice tie points, input data is filtered by the quality of the Ice Weights, computed in the Ice Quality IP module. An ice histogram is constructed and a running box filter produces a sliding integral, which "smoothes" out the distribution. Within a pre-determined local search window size a local maximum corresponds to a local ice tie point. Similarly, the water histogram is constructed from water pixels of good quality. The constructed distribution of water depends upon the tie point calculation in question. For global water tie points, the histogram makes use of all good quality water pixels. Local water tie points follow a similar localized search window recipe as the ice tie point computation. If there are not enough good pixels to compute a local water tie point, the local water tie point takes on the global water tie point as a default (see Table 10). Note: These tie point computations can implore a fixed or self-adjusting search window algorithm; the LUT parameters "max_wsize" and "min_wsize" determine which algorithm the Ice Concentration module utilizes. If max_wsize <= min_wsize, the self-adjusting algorithm is chosen.

Table 10. Ice Tie Point Logic Branches Not Shown in Flow Charts

Test	Logic	Result
Global tie point within LUT defined boundaries	IF (global_water_tie_point(band) < wat_min(band) || global_water_tie_point(band) > wat_max(band))	global_water_tie_point(band) = water_def(band)
Enough good water pixels in local search window	IF (not enough good water pixels in local search window)	local_water_ti_point(band) = global_water_tie_point(band)

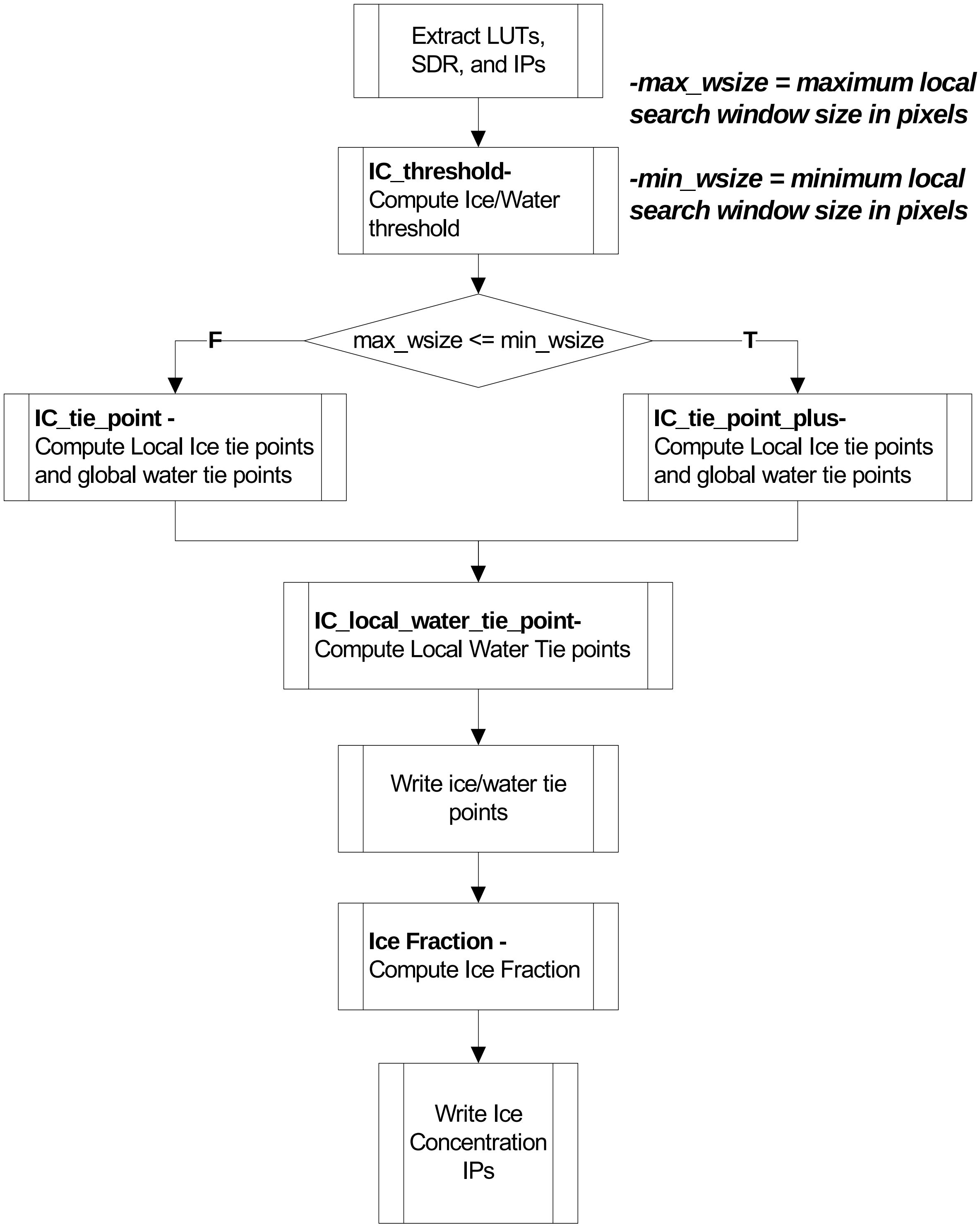

Figure 3. Ice Concentration Unit Top Level Flow

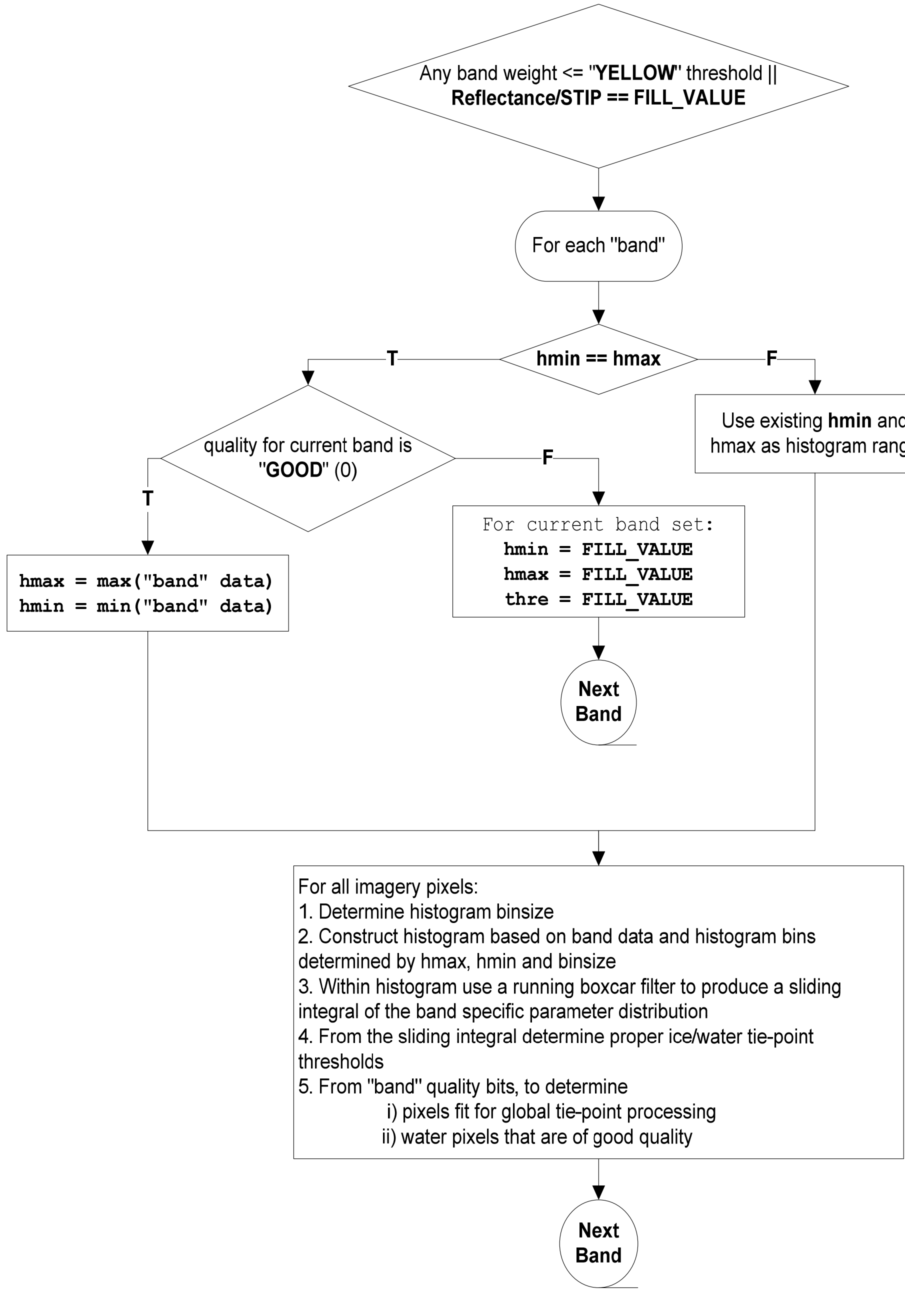

Figure 4. Logic Flow of `IC_threshold ()`

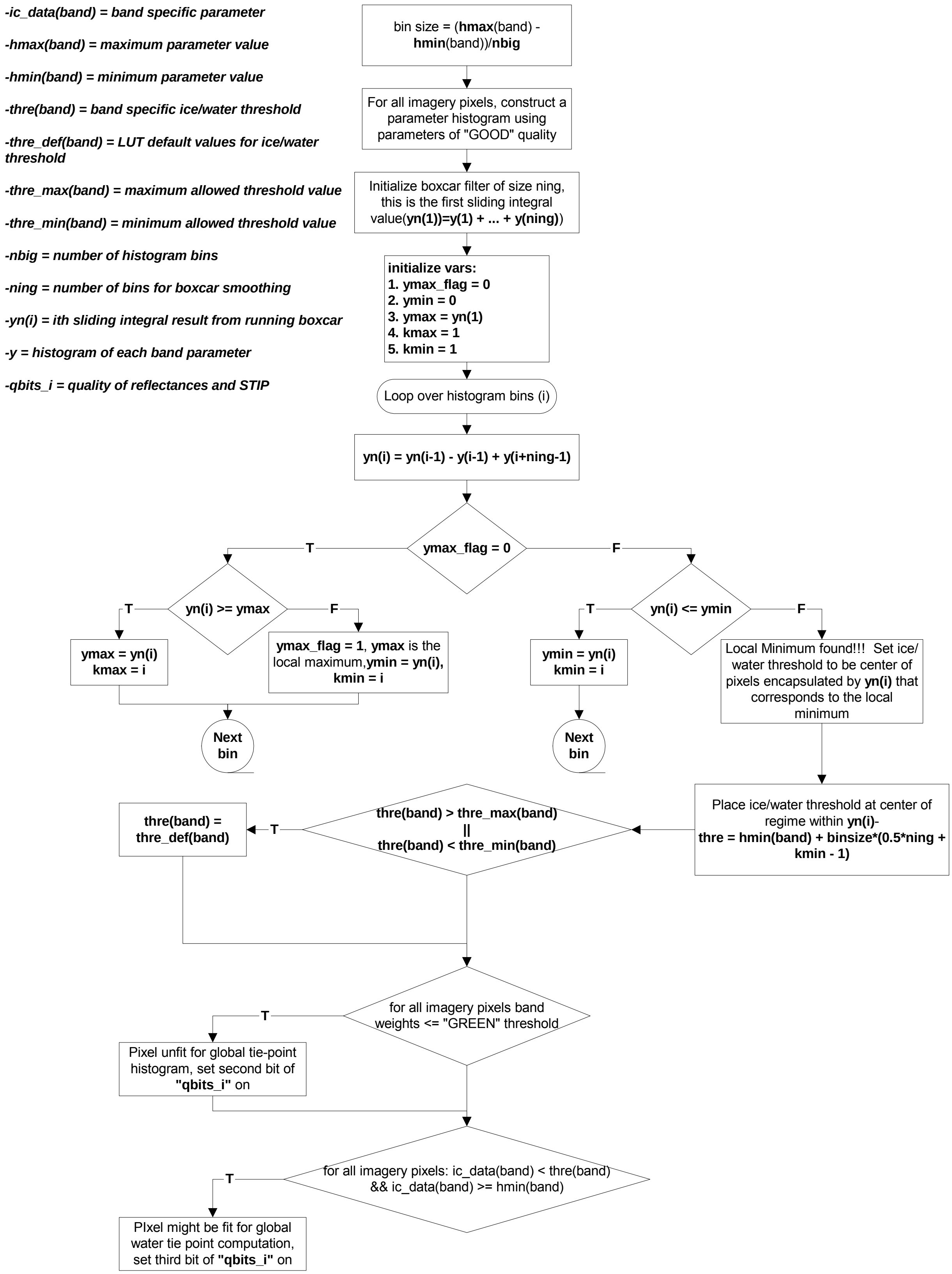

Figure 5. Detailed Diagram of Ice/Water Tie-Point Threshold Computation (`IC_threshold()`)

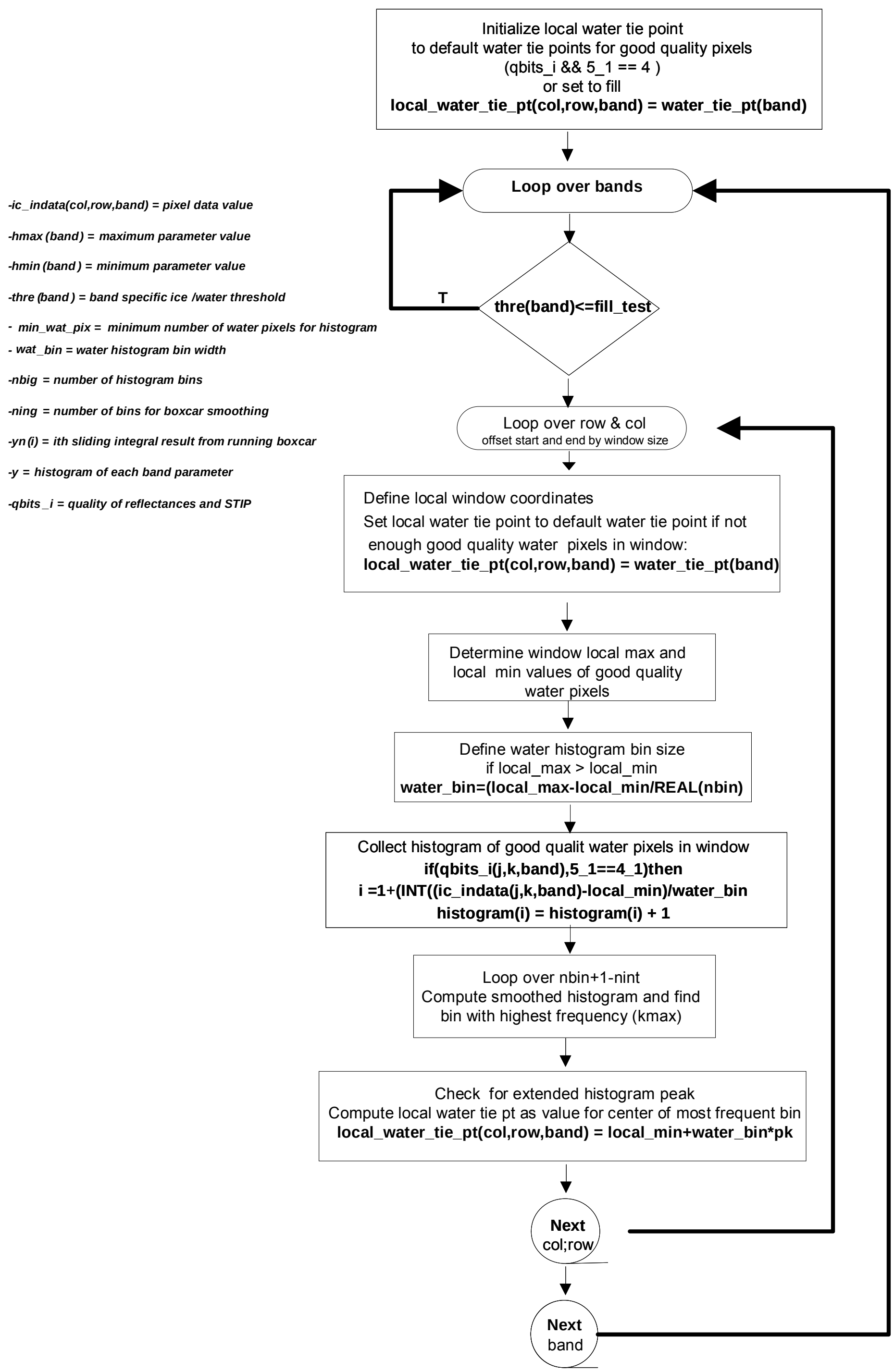

Figure 6. Detailed Diagram of Local Water Tie-Point Computation (`IC_local_water_tie_point()`)

-ic_indata(col,row,band) = pixel data value

-hmax (band) = maximum parameter value

-hmin (band) = minimum parameter value

-thre (band) = band specific ice /water threshold

- wat_def(band) = default water tie point thresholds

- wat_max(band) = maximum water tie point thresholds

- wat_min(band) = minimum water tie point thresholds

-nbig = number of histogram bins

-ning = number of bins for boxcar smoothing

-yn (i) = ith sliding integral result from running boxcar

-y = histogram of each band parameter

-qbits_i = quality of reflectances and STIP

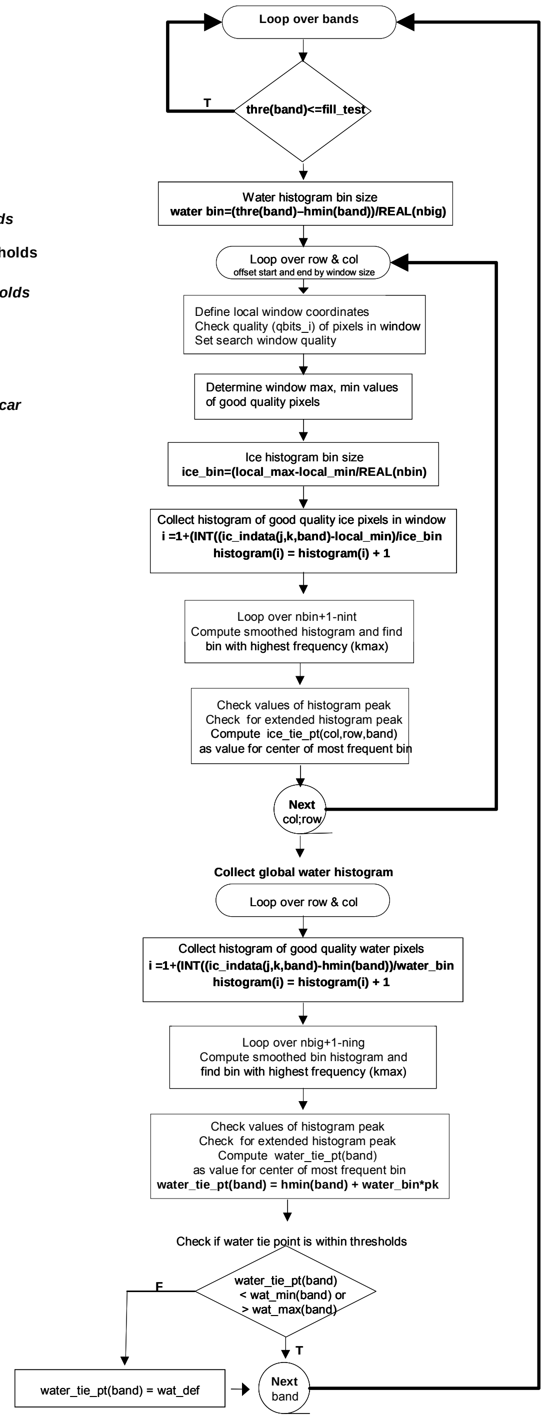

Figure 7. Detailed Diagram of Ice Tie-Point and Global Water Tie Point Computation (`IC_tie_point()`)

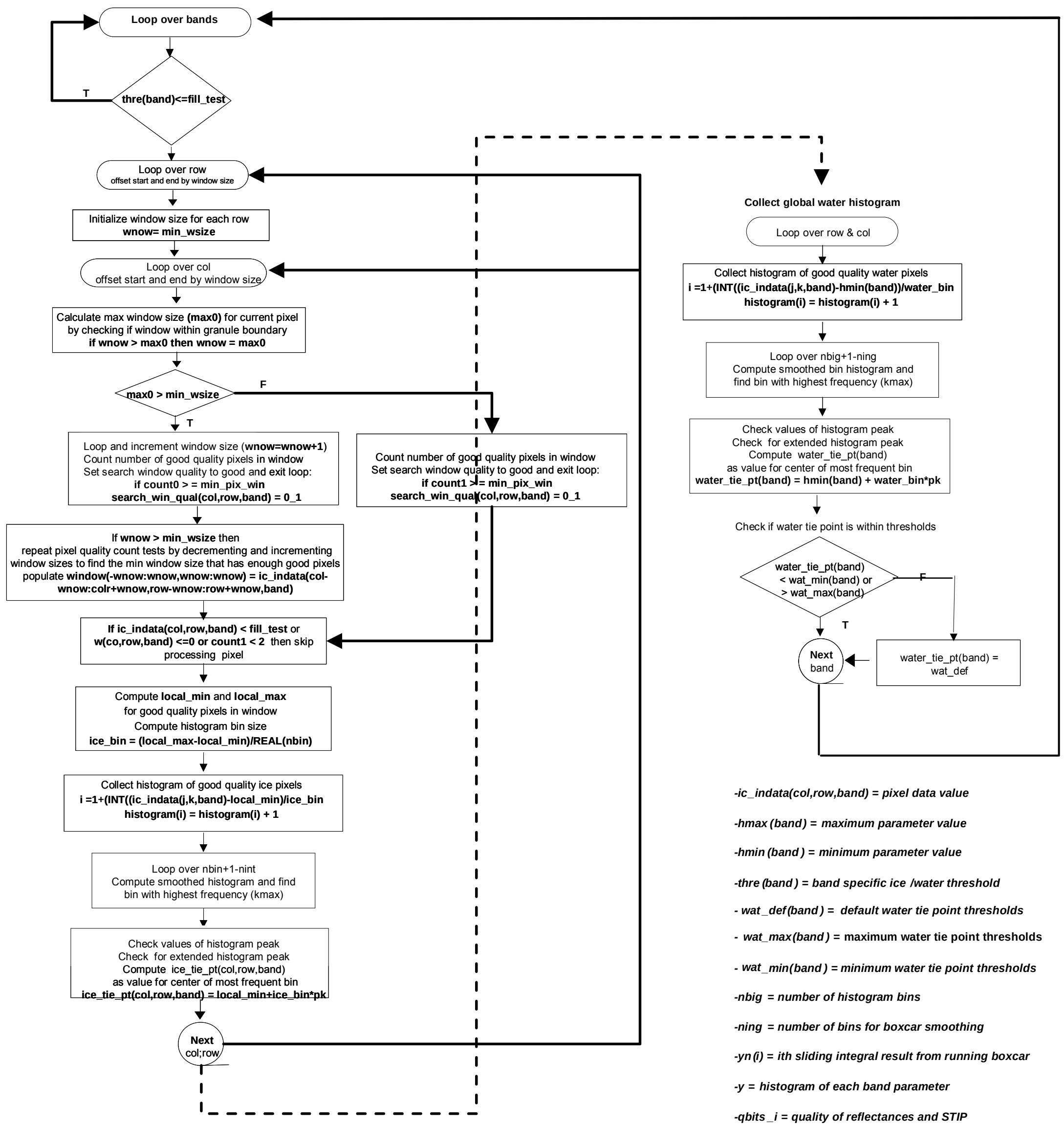

Figure 8. Detailed Diagram of Adjustable Window Ice Tie-Point Computation (`IC_tie_point_plus()`)

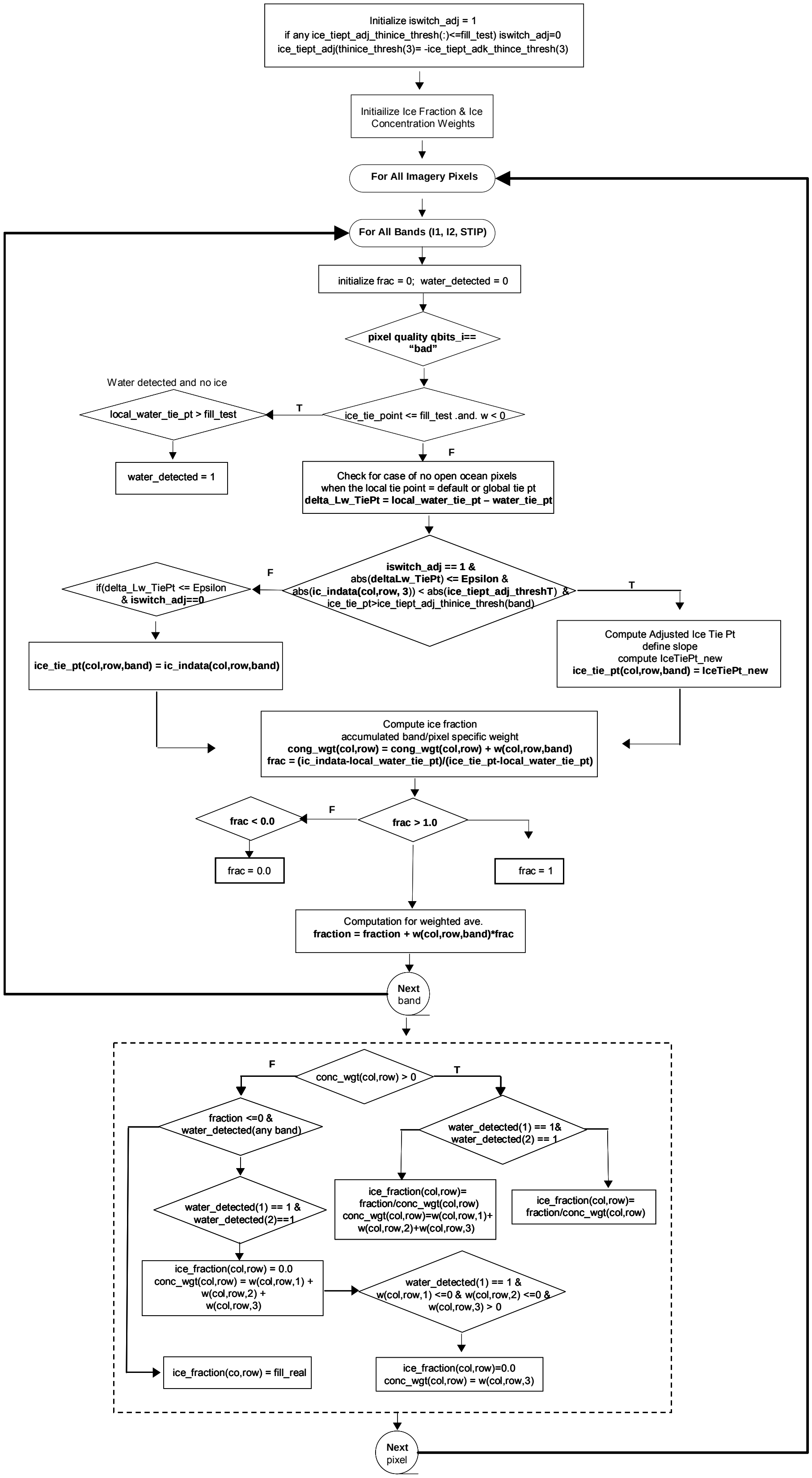

Figure 9. Detailed Diagram of Ice Fraction Computation Logic (IC_fraction())

After tie points are computed, band specific ice concentration weights are computed from the tie points. These weights are derived from the Ice Weights IP. The algorithm then uses the band weights to compute an ice fraction for each imagery pixel (Figure 9). The ice fraction, along with the band weights, becomes the output of the Ice Concentration IP (Table 9). Note that for the case of pixels where no open water pixels are found in the associated search window an ice tie point adjustment computation is invoked. This computation is triggered by an internally set switch "iswitch_adj =1" set by the algorithm. The recommended default operational configuration is to invoke the ice tie point adjustment scheme. The ice tie point adjustment however, may be optionally disabled by specification of -999.0 for any value of the tunable parameter ice_tiept_adj_thinice_thresh (algorithm internally sets iswitch_adj = 0).

The tunable parameter ice_tiept_adj_threshT allows the adjustment scheme to be applied to pixels that are below a threshold temperature. The default operational value settings for tunable parameters ice_tiept_adj_thinice_thresh and ice_tiept_adj_threshT are defined in table 12. The operational default settings invoke the ice tie point adjustment scheme and apply the adjustment to pixels (for the special case described above) that have surface temperatures below the ice_tiept_adj_threshT threshold. Pixels with surface temperatures above the temperature threshold and all other ice pixels will have ice fractions computed using the predominant ice tie point computed by subroutine IC_tie_point or IC_tie_point_plus. Defining lower reflectance values for ice_tiept_adj_thinice_thresh or a higher value for temperature will result in higher ice fraction values for non-predominant thin ice pixels. Bypassing the ice tie point adjustment scheme may be performed by setting any of the values of the ice_tiept_adj_thinice_thresh array to -999.0 and will result in Ice fractions will be set to 1.0 and the ice tie point is set to the observed reflectance or brightness temperature of the center pixel of the search window for the special case described.

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There is one case where graceful degradation is indicated in the Sea Ice Concentration IP.

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

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

When processing granules outside the defined sea ice range, data fields in the output IPs are set to the "not applicable" (NA) fill value and the IPs are stored in DMS. When required input data is not available, the software logs the error(s) and exits gracefully. When processing night granules, the I1 and I2 band SDRs exist as empty shells, so only STIP data used during processing. Internal buffers representing the SDRs are set to fill values and skipped during processing. The code contains checks to insure "divide-by-zero" operations do not occur. If such a divide operation occurs, the software logs the error and exits gracefully.

2.1.5 Data Quality Monitoring

Each algorithm uses specific criteria contained in a Data Quality Threshold Table (DQTT) to determine when a Data Quality Notification (DQN) is produced. The DQTT contains the threshold used to trigger the DQN as well as the text contained in the DQN. If a threshold is met, the algorithm stores a DQN in DMS indicating the test(s) that failed and the value of the DQN attribute. For more algorithm specific detail refer to the CDFCB-X, 474-00001.

2.1.6 Computational Precision Requirements

Single precision 32-bit floating point computations are required.

2.1.7 Algorithm Support Considerations

The Sea Ice Concentration checks the one byte VIIRS Surface Temperature IP (STIP) retrieval quality flag word and performs retrievals for all pixels with STIP quality indicating non-fill. It should be noted that the value of the parameter max_wsize defined in Table 5 acts as a switch to allow the algorithm to be run using adjustable search window mode or with fixed sized search windows. A value of max_wsize = 0 will result in the algorithm running with a fixed search window size for computation of tie points. It is recommended that the algorithm be run using the adjustable search window mode until the optimal fixed window size is determined during calibration/validation.

Table 11 contains the tunable algorithm parameters that may need adjustment throughout the SNPP and NPOESS program.

Table 11. List of Tunable Algorithm Parameters

Algorithm Parameter Name	Description	Parameter Location	Assigned Value
hmin	Minimum range of histogram, by band	Ice Concentration LUT	[0.0, 0.0, 0.0]
hmax	Maximum range of histogram, by band	Ice Concentration LUT	[0.0, 0.0, 0.0]
max_wsize	Maximum local window search size in pixels	Ice Concentration LUT	15
min_pix_win	Minimum number of "good" ice pixels, in a search window, required for a reliable histogram	Ice Concentration LUT	200
min_wsize	Minimum local window search size in pixels	Ice Concentration LUT	8
wat_wsize	Size of search window for local *water* tie points	Ice Concentration LUT	15
min_pix_wat	Minimum number of "good" water pixels, in a search window, required for a reliable histogram	Ice Concentration LUT	50
nbig	Number of bins in the reflectance or temperature histograms (global)	Ice Concentration LUT	100
nbin	Number of bins in the reflectance or temperature histograms (local)	Ice Concentration LUT	50
ning	Number of bins for boxcar smoothing of global histograms	Ice Concentration LUT	5
nint	Number of bins for boxcar	Ice Concentration LUT	10

Algorithm Parameter Name	Description	Parameter Location	Assigned Value
	smoothing of local histograms		
thre_def	Default ice/water thresholds by band	Ice Concentration LUT	[0.20,0.17,269.0]
thre_max	Maximum ice/water thresholds by band	Ice Concentration LUT	[0.25,0.22,270.0]
thre_min	Minimum ice/water threshold by band	Ice Concentration LUT	[0.15,0.13,268.0]
wat_def	Default water tie points	Ice Concentration LUT	[0.08,0.07,271.4]
wat_max	Default maximum water tie point	Ice Concentration LUT	[0.10,0.08,278.0]
wat_min	Default minimum water tie point	Ice Concentration LUT	[0.04,0.03,270.0]
ice_tiept_adj_thinice_thresh	Ice tie point adjustment thresholds for thin ice. Note -999.00 invokes a switch to disable the ice tie point adjustment computation	Ice Concentration LUT	[0.2, 0.17, 269.0]
ice_tiept_adj_threshT	Ice tie point adjustment temperature threshold Ice tie point adjustment not applied to pixels with surface temperatures greater than the threshold value	Ice Concentration LUT	270.00

The tunable parameters described and defined in table 11 consist of two categories: 1) empirical and 2) physical. Empirical parameters control the histogram binning, smoothing and quality for the local water and ice tie point search windows. The recommended values listed in table 11 are empirically based on testing with MODIS proxy scenes. Physical parameters are those related to temperature and reflectance thresholds for water and ice. The physical ice and water thresholds are the expected (default) values and the minimum and maximum values of the expected that the values are expected to range. These thresholds are determined based on inspection of the MODIS proxy scenes tested and are close to the reflectance for thin ice (B.P Briegleb and B. Light, NCAR Technical Note TN-472+STR, Feb. 2007), thin ice surface temperature (G. Riggs, D. Hall, A. REMOTE SENS. ENVIRON. 68:152-163, 1999) and the sea water freezing temperature (Y. Yu and D. Rothrock JGR, Vol. 101, no C10, p25, 753-25, 766, Nov.15, 1996). The ice tie point adjustment thresholds are similarly based. Optimal values are to be determined during calibration/validation.

2.1.8 Assumptions and Limitations

2.1.8.1 Assumptions

None

2.1.8.2 Limitations

None

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

Table 12 contains terms most applicable for this OAD.

Table 12. Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of: 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Configuration Control Board (ACCB)	Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations.
Ancillary Data	Any data which is not produced by the NPOESS System, but which is acquired from external providers and used by the NPOESS system in the production of NPOESS data products.
Auxiliary Data	Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the NPOESS system, and used to produce the NPOESS deliverable data products.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.). *[Supplementary Definition]* An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.
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]* Full resolution digital sensor data, time referenced and earth located, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression. *[Supplementary Definition]* A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use.
Retrieval Algorithm	A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing.
Science Algorithm	The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade".
Science Algorithm Provider	Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.
Science-Grade Software	Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure.
SDR/TDR Algorithm	Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Sensor Data Record (SDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data. *[Supplementary Definition]* A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data.

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

3.2 Acronyms

Table 13 contains terms most applicable for this OAD.

Table 13. Acronyms

Acronym	Description
ACO	Atmospheric Correction over Ocean
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
CDFCB-X	Common Data Format Control Book - External
CDR	Climate Data Records
CI	Configured Item
COT	Cloud Optical Thickness
DMS	Data Management Subsystem
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
DQN	Data Quality Notification
IET	IDPS Epoch Time
IIS	Intelligence and Information Systems
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LUT	Look-Up Table
MDFCB	Mission Data Format Control Book
PRO	Processing
PW	Precipitable Water
QF	Quality Flag
RTM	Radiative Transfer Model
SDR	Sensor Data Records
SI	Software Item or International System of Units
SST	Sea Surface Temperature
ST	Surface Temperature
SWS	Surface Wind Speed
TBD	To Be Determined
TBR	To Be Resolved
TOA	Top of the Atmosphere
VCM	VIIRS Cloud Mask

4.0 OPEN ISSUES

Table 14. TBXs

TBX ID	Title/Description	Resolution Date
None		