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Code 474
474-00068

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Type (STYPE) Environmental Data Records (EDR) Software

For Public Release

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

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Type (STYPE) Environmental Data Records (EDR) Software
JPSS Electronic Signature Page

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Preface

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

Any questions should be addressed to:

JPSS Configuration Management Office
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Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	05/20/11	**474-CCR-11-0074:** This version baselines D38696, Operational Algorithm Description Document for VIIRS Surface Type (STYPE) EDR, Rev B, dated 03/17/2010, as a JPSS document, version Rev –. This is the version that was approved for NPP launch. Per NPOESS CDFCB - External, Volume V – Metadata, doc number D34862-05, this has been approved for Public Release into CLASS. This CCR was approved by the JPSS Algorithm ERB on May 20, 2011.
Revision A	01/18/2012	**474-CCR-11-0259:** This version baselines 474-00068, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Surface Type (STYPE) Environmental Data Records (EDR) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	05/14/2013	**474-CCR-13-0948:** This version authorizes 474-00068, JPSS OAD Document for VIIRS SType EDR Software, for the Mx 7.0 IDPS release. Includes Raytheon PCR032720; CCR-474-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.
Revision C	04/30/2014	**474-CCR-14-1702:** This version authorizes 474-00068, JPSS OAD Document for VIIRS SType EDR Software, for the Mx 8.4 IDPS release. Includes Raytheon PCR037581; CHILD: PRO: OAD: 474-CCR-13-1264: VIIRS Surface Type Use of Snow Flag and VCM Input (DRs 7090, 7329), in sections 2.1.1.1.2, 2.1.1.1.6, & 2.1.2.6 and Tables 3, 4, 6, 16 & 20.
Revision D	09/03/2015	**474-CCR-15-2591:** This version authorizes 474-00068, JPSS OAD Document for VIIRS SType EDR Software, for the Mx 8.11 IDPS release. Includes Raytheon PCR049391; Child: PRO OAD: 474-CCR-15-2375: Update Documents - QST Update Not Quarterly/Remove QSTIP As EDR (DR4459)-SType EDR OAD, in section 2.0.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SURFACE TYPE (STYP) EDR

SDRL No. S141
SYSTEM SPECIFICATION SS22-0096

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

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

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS SURFACE TYPE (STYP) EDR

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

CAGE NO. 11982

Operational Algorithm Description Document for VIIRS Surface Type EDR

Document Number: D38696
Revision: C4
Document Date: Sep 27, 2011

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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.

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Revision/Change Record

Document Number D38696

Revision	Document Date	Revision/Change Description	Pages Affected
---	6-30-04	New Release.	All
A1	10-27-04	Reflects Science To Operational Code Conversion.	All
A2	4-20-05	Inserted new logo and updated upper right header date, title/signature page dates, Revision/Change Record.	All
A3	6-15-05	Reflects additional comments posted on 19-20 Apr 05 to the eRoom “Post-Sci2Ops OAD Review Comments” site.	All
A4	6-23-05	Incorporates two of Alain Sei’s 20Apr05, 12:00pm eRoom Comments about Vegetation Fraction and Top of Canopy NDVI.	Pg 15
A5	7-01-05	Under Section 1.3.3, Source Code and Test Data References, inserted a more detailed table listing paths to find applicable source code within the ClearCase configuration management tool.	Pg 2
A6	7-12-05	Per Dan Antzoulatos’ request, changed the wording of information added by the 01 Jul 2005 Revision/Change Record line.	Pg 2
A7	10-30-06	Grammar, etc. updates for EDR Code PR.	All
A8	6-06-07	Logo, cleanup updates. Delivered to NGST.	All
A9	12-10-07	ECR A-103, EDRPR 1.8 CP 3 updates –Format changes for CDFCB-X compliance – Remove Table 2.2-16. Data Available	All
A10	6-16-08	Reformatted to conform to template D41851. Updated data quality monitoring section. Updated Graceful Degradation.	All
A11	9-15-08	New cover sheet, update references, acronym list, prepare for peer review. Delivered to NGST.	All
A12	10-1-08	Prepare for TIM/ACCB.	All
A	10-29-08	ECR A-170. Incorporated interim changes and addressed TIM comments.	All
B1	1-21-09	Changed range of values for Solar Zenith Angle Exclusion Flag as described in PCR019337.	All
B2	2-19-09	Changed surface type water value from 0 to 17 per TM NP-EMD-2008.510.0070	9
B3	11-04-09	Incorporated RFA Nos.316 & 317, PCR 21537 (Table 16) and updated for SDRL.	All
B4	1-20-10	Updated for TIM/ARB and new SCN.	All
B5	3-10-10	Incorporated changes from PCR 22725	Table 14
B	3-17-10	Incorporated TIM comments and prepared for ACCB	All
C1	8-18-10	Updated Table 1 & 2 due to omission of TM 2010.510.0005.Rev-C	Table 1 & 2

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Revision/Change Record

Document Number **D38696**

Revision	Document Date	Revision/Change Description	Pages Affected
C2	9-13-10	ECR1061/PCR024068 Corrected max Veg Fraction in table 14	Table 14
C3	10-13-2010	Updated due to document convergence	All
C4	09-27-2011	Updated OAD for PCR026672.	All

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1.0 INTRODUCTION

1.1 Objective

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

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

The purpose of an OAD is two-fold:

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

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

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm required to create the VIIRS Surface Type (SType or STYPE) EDR. The theoretical basis for this algorithm is described in Section 3.3 of the Operational Algorithm Description Document for VIIRS Surface Type Algorithm Theoretical Basis Document ATBD, 474-00037.

1.3 References

1.3.1 Document References

The science and system engineering documents relevant to the algorithm described in this OAD are listed in Table 1.

Table 1. Reference Documents

Document Title	Document Number/Revision	Revision Date
VIIRS Land Surface Type EDR Detailed Design Document	Y2500 Ver. 5 Rev. 3	30 Jan 2004
Operational Algorithm Description Document For VIIRS Surface Type Algorithm Theoretical Basis Document ATBD	474-00037	Latest
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module Interface Control Document	Y3279 Ver. 5 Rev. 6	27 May 2004
JPSS Environmental Data Record (EDR) Production Report (PR) for NPP	474-00012	Latest
JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP	474-00007	Latest

Document Title	Document Number/Revision	Revision Date
NPP Mission Data Format Control Book and App A (MDFCB)	429-05-02-42-02_MDFCB	Latest
JPSS Common Data Format Control Book - External - Block 1.2.4 (All Volumes)	474-00001-01-B0124 CDFCB-X Vol I 474-00001-02-B0124 CDFCB-X Vol II 474-00001-03-B0124 CDFCB-X Vol III 474-00001-04-01-B0124 CDFCB-X Vol IV Part 1 474-00001-04-02-B0124 CDFCB-X Vol IV Part 2 474-00001-04-03-B0124 CDFCB-X Vol IV Part 3 474-00001-04-04-B0124 CDFCB-X Vol IV Part 4 474-00001-05-B0124 CDFCB-X Vol V 474-00001-06-B0124 CDFCB-X Vol VI 474-00001-08-B0124 CDFCB-X Vol VIII	Latest
NPP Command and Telemetry (C&T) Handbook	D568423 Rev. C	30 Sep 2008
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module Software Architecture Document	Y2474 Ver. 5 Rev. 9	27 May 2004
Visible/Infrared/Imager/ Radiometer Suite (VIIRS) Land Module Data Dictionary	Y0010883 Ver. 5 Rev. 4	09 Feb 2004
JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I – IV	IC60917-IDP-002	Latest
IDPS Processing SI Common IO Design	DD60822-IDP-011 Rev. A	21 Jun 2007
Joint Polar Satellite System (JPSS) Program Lexicon	470-00041	Latest
Operational Algorithm Description Document for VIIRS Surface Reflectance Intermediate Product (IP) Software	474-00069	Latest
Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM IP)	474-00062	Latest
NGST/SE technical memo – NPP_Land_Surface_Type_EDR_Coding_error_Update	NP-EMD.2007.510.0043	17 Jul 2007
NGAS/A&DP technical memo – NPP_Surface_Type_Indexing_Update	TM NP-EMD-2008.510.0070	05 Dec 2008
NGST/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev. C.doc	NP.EMD.2010.510.0005.Rev-C	02 Mar 2010
Joint Polar Satellite System (Jpss) Common Ground System (CGS) IDPS PRO Software User's Manual Part 2	UG60917-IDP-026	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
Land Surface Type EDR Visible Infrared Imager/Radiometer Suite Science Grade Software Unit Test Document (Doc # D38711)	D38711	30 Jun 2004 Initial release
VIIRS Surface Type (STYP) science-grade software	ISTN_VIIRS_NGST_2.8	30 Jun 2004
VIIRS Surface Type (STYP) operational software	I1.3.0.14	28 Jun 2005
NPP_Land_Surface_Type_EDR_Coding_error_Update	NP-EMD.2007.510.0043	17 July 2007
VIIRS Surface Type (STYP) operational software (PCR019337)	Build X.1.J.2 (OAD Rev B1)	20 Jan 2009
NGAS/A&DP technical memo – NPP_Surface_Type_Indexing_Update, TM NP-EMD-2008.510.0070	(OAD Rev B2)	19 Feb 2009
SDRL	(OAD Rev B3)	04 Nov 2009
PCR022725	Sensor Characterization (SC-9) (OAD Rev B5)	10 Mar 2010
ACCB	OAD Rev B	17 Mar 2010
PCR 22882 [TM 2010.510.0005.Rev-C]	Build Sensor Characterization SC-09 (OAD Rev C1)	12 Apr 2010
PCR024168 (ECR 1061) (No code updates)	(OAD Rev C2)	13 Sep 2010
Convergence Update (No code updates)	(OAD Rev C3)	13 Oct 2010
PCR026672 (OAD update for ADL)	(OAD Rev C4)	27 Sep 2011
OAD transitioned to JPSS Program – this table is no longer updated.		

2.0 ALGORITHM OVERVIEW

The algorithm is developed around a global1km VIIRS gridded surface type (GST) map generated externally, converted to IDPS format and delivered as static Quarterly Surface Type Gridded Intermediate Product ("QST GIP") data tiles. Though the nomenclature in the code and documentation indicates the ancillary surface type update is quarterly (as was originally envisioned), the updates are anticipated to be more or less annually. The surface type EDR code produces land surface types, surface type quality flags (QF), and vegetation fractions for each VIIRS pixel based on the annual GST, but these inputs are still referred to as quarterly ("QST") in IDPS Surface Type, Surface Temperature, Cloud Mask, and Active Fire EDRs.

The Surface Type EDR algorithm consists of:

- Updating Surface type according to the snow mask and fire masks and
- Computing the Green Vegetation Fraction based on internally computed NDVI value, maximum ($NDVI_{\infty}$), and minimum ($NDVI_0$).

The algorithm processing code contains four main modules:

- Main driver for the processing portion of the EDR algorithm (calcSurfType),
- Subroutine to calculate NDVI from surface reflectance inputs (Calculate_NDVI),
- Subroutine to compute vegetation fractions (Compute_Veg_Fraction),
- Subroutine to compute surface type Flags (Set_SurfType_Flags).

2.1 Surface Type Environmental Data Record Description

See the Operational Algorithm Description Document for VIIRS Surface Type Algorithm Theoretical Basis Document ATBD, 474-00037, Section 3.3, to get a detailed description of the science within the STYPE retrieval algorithm. This section only addresses the near real time portion of surface type ATBD.

2.1.1 Interfaces

To begin data processing, the Infrastructure (INF) Subsystem Software Item (SI) initiates the STYP algorithm. The INF SI provides tasking information to the algorithm indicating which granule to process. The Data Management Subsystem (DMS) SI provides data storage and retrieval capability. A library of C++ classes is used to implement the SI interfaces. More information regarding these topics is found in document UG60917-IDP-026 with reference in particular to sections regarding PRO Common (CMN) processing and the IPO Model.

2.1.1.1 Inputs

Table 3 lists STYPE EDR inputs. Refer to the CDFCB-X, 474-00001, for a detailed description of the inputs.

The input data items are retrieved from DMS by ProEdrViirsSurfType::setupDataItems. These data items may contain fill values which would affect algorithm calculations. In order to prevent division by zero errors or division by near zero (epsilon), a check is performed in Calculate_NDVI against the constant ERR_FLOAT32_FILL. Tables 3 through 5 describe the algorithm inputs and identify the Operational Algorithm Documents that contain the methodology for setting fill values for each input data item.

Table 3. STYPE EDR Inputs

Input	Type	Description	Units / Valid Range
VIIRS Geolocation SDR	Float32	Geolocation information and basic SDR information. The input is used to read the number of scans for the current granule.	radians
VIIRS Snow Cover EDR	Float32	The snow fraction field is threshold to determine a mask indicating pixels with snow cover.	Unitless/ 0.0 ≤ FractionFromBinaryMap ≤ 1.0
VIIRS Active Fires EDR	UInt8	A fire mask indicating pixels with active fires.	Unitless
VIIRS Surface Reflectance IP	Float32	Directional surface reflectance in VIIRS bands M1, M2, M3, M4, M5, M7, M8, M10, and M11, along with associated pixel-level Quality Flags. Only bands M5 and M7 are used to compute the current pixel's NDVI.	Unitless 0.0 - 1.6
VIIRS Cloud Mask IP	UInt8	Includes information about whether the view of the surface is obstructed by clouds and specifies the processing path the algorithm took. Cloud phase data is also included as well as spatial uniformity, aerosol, shadow, and fire detection data.	Unitless
Annual TOC NDVI	Float32	Maximum and minimum for Top of Canopy NDVI from previous years of data. This is the granulated version of the gridded product annual max/min NDVI which is produced by the quarterly surface type IP.	Unitless -1.0 - + 1.0
VIIRS Quarterly Surface Type IP	UInt8	Most recent quarterly surface types product with full IGBP classes regridded to swath. This is the granulated version of the gridded Quarterly Surface Type IP.	Unitless 1-16
IVSIC	UInt8	Granulation of the Gridded VIIRS Snow Ice Cover Rolling Tile	Unitless
Surface Type Processing Coefficients	Float32, Float32, Int32	Modifiable coefficients necessary to the execution of the Surface Type EDR algorithm.	Unitless
ST DQTT	Float32	Data quality Threshold Table.	Unitless

Table 4. STYPE EDR Processing Coefficients

Value	Description	Data Type	Valid Range
Vegetation Threshold	Threshold value for determining what Vegetation Fraction values should cause an update of the Vegetation Flag for the Surface Type EDR	Float32	0-1
Snow Threshold	Threshold value for determining what Snow Cover values should cause an update of the Snow Flag for the Surface Type EDR	Float32	0-1
Vegetation Fraction Scale	The scale value for the Vegetation Fraction	Int32	1-255
Solar Zenith Angle Threshold	Zenith threshold for determining quality flag status	Float32	$1-\pi/2$
Solar Zenith Angle Snow Ice Threshold	Zenith threshold for determining quality flag status	Float32	$1-\pi/2$
Snow Fraction Quality Threshold	Threshold value for determining whether the Snow Cover data from VSCDO is in good quality (if not, IVSIC's snow cover will be used to replace VSCDO in that pixel) (CDFCB-X-Vol-IV-Part-3, Table 5.4.5.2.1.2-2)	Int32	0-3

2.1.1.1.1 Surface Reflectance IP Input data

The input consists of the nine VIIRS moderate resolution bands (M1, M2, M3, M4, M5, M7, M8, M10, and M11). For a complete description of this item, see the OAD document for VIIRS Surface Reflectance IP, 474-00069.

Table 5. Surface Reflectance Data Field in the Moderate Resolution Surface Reflectance IP

Field Name	Data Type	Dimension Names
“SurfReflect_Mod”	Float32	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: Atmospherically corrected surface reflectances for bands M1, M2, M3, M4, M5, M7, M8, M10, and M11 at each moderate resolution pixel **Field Attributes:** Band Names: [“M1”, “M2”, “M3”, “M4”, “M5”, “M7”, “M8”, “M10”, “M11”] Units: dimensionless Valid Range: [0,1.5] Fill Value : NA_FLOAT32_FILL		

2.1.1.1.2 Snow Cover/Depth Inputs

Tables 6 through 8 details the Snow Cover/Depth EDR input into the Surface Type EDR module.

Note: The information listed in the tables was extracted from the VIIRS Snow Cover Unit Level Detailed Design, Y3234.

Table 6. Snow Cover Granulated IP from Gridded Snow/Ice Rolling Tiles (IVSIC)

Field Name	Data Type	Dimensions
“snowIcecover”	UInt8	VIIRS-MOD-ROWS, VIIRS-MOD-COLS
Description: 8-bit byte array containing “1” for each pixel classified as “snow” and “0” for each pixel classified as “no snow”. **FIELD Attributes:** Long Name: "VIIRS-GridIP-VIIRS-Snow-Ice-Cover-Mod-Gran_All" Units: unitless Valid Range: 0 or 1 Fill Value: 255		

Table 7. Snow Cover EDR Snow Fraction Field

Field Name	Data Type	Dimension Names
“Fraction”	Float32	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: 32-bit Floating-point array containing the snow fraction for each pixel in the granule. **FIELD Attributes:** Long Name: "VIIRS Snow Cover EDR Snow Fraction" Units: unitless Valid Range: 0.0 to 1.0 Fill Value: < -999.0		

Table 8. Snow Cover EDR Snow Fraction Weight Field

Field Name	Data Type	Dimension Names

Field Name	Data Type	Dimension Names
“FractionWeight”	Float32	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: 32-bit Floating-point array containing the snow fraction weight of each pixel in the granule. **FIELD Attributes:** Long Name: "VIIRS Snow Cover EDR Snow Fraction Weight" Units: unitless Valid Range: 0.0 to 9.0 Fill Value: < -999.0		

2.1.1.1.3 Annual Maximum and Minimum NDVI Gridded IP Description

This section details the Annual Maximum and Minimum NDVI IP input into the Surface Type EDR algorithm. Table 9 describes the dimensions associated with this product.

Table 9. Science Data Field of the Annual Maximum and Minimum NDVI IP

Field Name	Data Type	Dimension Names
“maxNDVI”	Float32	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: This field is a 32-bit floating point array. **Attributes:** Long_Name: ”maxNDVI” Units: dimensionless Valid Range: -1.0, 1.0		
“minNDVI”	Float32	VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: This field is a 32-bit floating point array. **Attributes:** Long_Name: ”minNDVI” Units: dimensionless Valid Range: -1.0, 1.0		

2.1.1.1.4 Fire Mask IP Input

Table 10 describes the details of the Fire Mask IP input data into the Surface Type EDR algorithm.

Table 10. Fire Mask IP Input

Field Name	Data Type	Dimension Names
Fire Mask	UINT8	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)

Description:
Unsigned 8-bit integer pixel map for identifying detected fires.
0 = missing input data
1 = not processed (obsolete)
2 = not processed(obsolete)
3 = water
4 = cloud
5 = non-fire
6 = unknown
7 = fire (low confidence)
8 = fire (nominal confidence)
9 = fire (high confidence)

FIELD Attributes:
Long_Name: "Fire Mask Intermediate Product"
Units: dimensionless
Valid Range = 0, 255

2.1.1.1.5 VIIRS Quarterly Surface Type IP

Table 11 details the VIIRS Quarterly Surface Type IP input into the Surface Type EDR algorithm.

Table 11. The Type Science Data Field of the Quarterly Surface Type IP

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>"Type"</td><td>UINT8</td><td>(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)</td></tr>
<tr><td colspan="3">Description:
This field is an 8-bit unsigned integer array.

FIELD Attributes:
Long_Name: " Type"
Units: dimensionless
Valid Range: 0, 255
Values are:
1 evergreen needleleaf forest
2 evergreen broadleaf forest
3 deciduous needleleaf forest
4 deciduous broadleaf forest
5 mixed forests
6 closed shrubland
7 open shrublands
8 woody savannas
9 savannas
10 grasslands
11 permanent wetlands
12 croplands
13 urban and built-up
14 cropland/natural vegetation mosaic
15 snow and ice
16 barren or sparsely vegetated
17 water body

30 unclassified
31 fill value</td></tr>
<tr><td>"confidence"</td><td>UINT8</td><td>VIIRS-MOD-ROWS, VIIRS-MOD-COLS)</td></tr>
<tr><td colspan="3">Description:
Confidence associated with IGBP Surface Type classification value in percentage

Attributes:</td></tr>
</table>

Long_Name: ”confidence”
Units: Unitless
Valid Range: 0, 100

2.1.1.1.6 VIIRS Cloud Mask IP Input

Cloud Mask Flags, detailed in Table 12, is a 48-bit word (6 bytes) for each moderate resolution pixel that includes information about whether the view of the surface is obstructed by clouds and specifies the processing path the VCM algorithm took. See the Operational Algorithm Description Document for VIIRS Cloud Mask Intermediate Product (VCM IP), 474-00062, for complete details on this item. Information from the VCM IP is required as input for determination of land/water and calculation of granule level surface type exclusion metadata..

Table 12. VCM IP Summary Table

Field Name	Data Type	Dimension Names
Cloud Mask Flags	Boolean	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: Boolean flags packed into a 6 byte structure indicating cloud mask conditions. The Surface Type EDR algorithm is concerned with the following conditions. Day/Night Thin Cirrus Cloud Confidence Land/Water **FIELD Attributes:** Long Name: "VIIRS Cloud Mask Intermediate Product" Units: unitless Valid Range: 0 to 1 Fill Value: NA		

2.1.1.1.7 VIIRS Surface Type Data Quality Threshold Table

This item contains the data quality threshold table, Table 13, used by the algorithm.

Table 13. VIIRS Surface Type Data Quality Threshold Table Contents

Field Name	Data Type	Dimension Names
DQTT	Float32	NA
Description: FLOAT32_FILL_TEST, NA_FLOAT32_FILL, MISS_FLOAT32_FILL, ONBOARD_PT_FLOAT32_FILL, ONGROUND_PT_FLOAT32_FILL, ERR_FLOAT32_FILL **FIELD Attributes:** NA		

2.1.1.2 Outputs

Table 14 lists SType EDR output contents. Refer to the CDFCB-X, 474-00001, for a detailed description of the outputs.

Table 14. STYPE EDR Output Contents

Output	Type Dimensions	Description	Range of Values
Surface Type Flags	UInt8 / VIIRS-MOD-ROWS, VIIRS-MOD-COLS	Two-dimensional array containing the current surface type in the IGBP classification scheme for each moderate resolution pixel.	0-255
Vegetation Fraction	UInt8/ VIIRS-MOD-ROWS, VIIRS-MOD-COLS	Two-dimensional Current Vegetation Fraction (%) scaled to unsigned 8-bit integers (8-bit integer scale and offset factors are stored as calibration attributes).	0-1.00, Values outside of this range, reflect fill values.
Surface Type Quality Flags	UInt8 * 3 / VIIRS-MOD-ROWS, VIIRS-MOD-COLS	Pixel level quality flags for Surface Type EDR. See Table 16 for a detailed description.	N/A
Vegetation scale	Float32	The scale value for the vegetation fraction.	100 (This value is modifiable as it is retrieved from the processing Coefficients)
Vegetation Offset	Float32	The offset from zero of the minimum value for Vegetation Fraction.	0

Table 15 describes the SType Flags.

Table 15. STYPE Flags

<table>
<tr><th>Field Name</th><th>Data Type</th><th>Dimension Names</th></tr>
<tr><td>Surface Type Flags</td><td>UInt8</td><td>(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)</td></tr>
<tr><td colspan="3">Description:
Unsigned 8-bit Integer Array consisting of a 5-bit land type indicator.
<table>
<tr><th>Bit</th><th>Description</th><th>Result</th></tr>
<tr><td>0-4</td><td>The IGBP Surface Type from the Quarterly Surface Type Input</td><td>1-17 = one of the 17 identified IGBP Surface Types</td></tr>
<tr><td>5-7</td><td>Spare</td><td></td></tr>
</table>
FIELD Attributes:
Long Name: "Surface Type Flags"
Units: unitless
Valid Range: 0 to 255
Fill Value: NA</td></tr>
</table>

Table 16. STYPE Quality Flags

Field Name	Data Type	Dimension Names
Quality Flags	UInt8	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)

Description:
Unsigned 8-bit Integer Array consisting of packed bits indicating quality of a corresponding pixel.

Byte 0

Bit	Description	Result
0	Fire Detection in pixel	1 = Fire 0 = No Fire
1	Snow/ice in pixel	1 = Snow 0 = No Snow
2	Vegetation in pixel	1 = vegetation 0 = no vegetation
3-4	cloud confidence indicatior	11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confident Clear
5	Excl – Sun Glint	1 = In Sun Glint 0 = Not In Sun Glint
6	Input Data Quality	1 = Degraded/Bad 0 = Good
7	Spare Bit	Initialized to 0

Byte 1

Bit	Description	Result
0	Excl – AOT > 1.0	1 = AOT > 1.0 0 = AOT <= 1.0
1	Vegetation fraction out of range	1 = Frac < 0.0 or Frac > 1.0 0 = 0.0 <= Frac <= 1.0
2 - 3	SZA Exclusion	00 = SZA < 70 01 = 70 <=SZA >= 85 10 = SZA > 85
4	Use IVSIC	1 = Yes 0 = No
5-7	Spare Bits	Initialized to 0

Byte 2

Bit	Description	Result
0 - 7	QST IP Pixel Confidence*****	0 – 100%

FIELD Attributes:
Units: unitless
Valid Range: 0 to 255
Fill Value: NA

***** - QST IP Pixel Confidence field is a direct copy from the Quarterly Surface Type Granulated IP product (required input for VIIRS Surface Type EDR).

Table 17 describes the STYPE Vegetation Fraction.

Table 17. STYPE Vegetation Fraction

Field Name	Data Type	Dimension Names
Vegetation Fraction	UInt8	(VIIRS-MOD-ROWS, VIIRS-MOD-COLS)
Description: Unsigned 8-bit Integer Array containing scaled Vegetation Fraction values. **FIELD Attributes:** Units: unitless Scale: 100 Offset: 0 Valid Range: 0 to 200 Fill Value: 255		

2.1.2 Algorithm Processing

Figure 1 describes the EDR data flow.

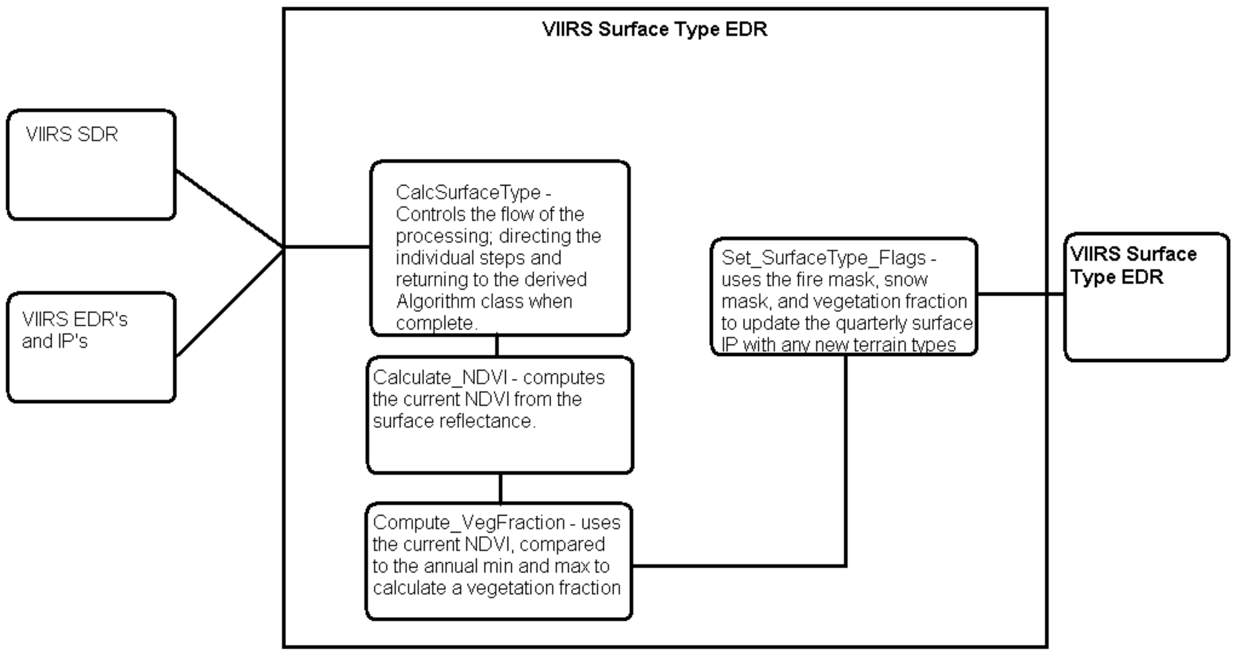

Figure 1. EDR Data Flow

2.1.2.1 Main Module - ProEdrViirsSurfType.cpp

This is the derived algorithm for the STYPE algorithm and is a subclass of the ProCmnAlgorithm class. The derived algorithm class creates a list of input data items read from DMS and passes required data into the algorithm. An output data item is written to DMS once the algorithm finishes processing this data.

2.1.2.2 Main Driver for Surface Type (calcSurfaceType.cpp)

This is the main driver for the processing portion of the STYPE algorithm. It calls the other routines associated with the algorithm.

2.1.2.3 Calculate_NDVI.cpp

This function calculates the NDVI used in the Compute_VegFraction using the following equation:

$$NDVI = \frac{\rho_{M7} - \rho_{M5}}{\rho_{M7} + \rho_{M5}},$$

where ρ_{M7} and ρ_{M5} are the surface reflectance values for the VIIRS moderate resolution bands "M7" and "M5" respectively. If there are no values for the surface reflectance values, a pre-determined fill value is used for the "NDVI".

This function makes calls to the external class ProCmnViirsTrimTable. For a detailed description of this class and its methods, see the Processing SI Common IO Design, DD60822-IDP-011.

2.1.2.4 Compute_VegFraction (../src/land/SurfType/Compute_VegFraction.c)

This function computes the fraction of green vegetation cover within VIIRS pixels. The following algorithm is used to compute vegetation fraction

$$f_g = \frac{NDVI - NDVI_0}{NDVI_\infty - NDVI_0}$$

where f_g is the fractional green vegetation cover within a specific VIIRS cell. $NDVI_\infty$ represents the Maximum NDVI for the area of concern over the past year, $NDVI_0$ represents the annual minimum NDVI for the area of concern over the past year, and $NDVI$ is the current top of canopy NDVI value for the pixel. The parameter f_g is constrained to values between 0-1.

This function makes calls to two external classes: ProCmnViirsTrimTable and ProCmnVCMExtractor. For a detailed description of these classes and their methods see the Processing SI Common IO Design, DD60822-IDP-011.

The variable NDVI over certain land types (conifer forests, e.g.) causes a max and min value that are very close together. The area function used in the quarterly surface type algorithm to produce the min and max gridded NDVI products is a sliding window of 5 km by 5 km.

2.1.2.5 Set_Pre_SurfType_Flags(../src/land/SurfType/SetSurfType_Flags.c)

This function computes the quality flags that can be computed prior to entering the portion of the code that does the bulk of the processing.

Currently, this function sets the following flags:

Solar zenith angle - If the input SDR solar zenith angle is greater than 70 degrees, this flag is set to true. The 70 degree value is specified by the EDRPR and, in the code, is controlled by a constant defined in ProEdrViirsSurfTypeGbl.h.

2.1.2.6 Set_SurfType_Flags(../src/land/SurfType/SetSurfType_Flags.c)

This function is for flagging VIIRS pixels with the following flags:

Surface type – which of 17 IGBP surface types corresponds to the current VIIRS pixel.

Snow cover flag (SnowFraction) – snow or no snow present. This flag is set based on the VIIRS Snow Cover/Depth EDR with a quality flag value of 0 (good) or 1 (medium). When the VIIRS Snow Cover/Depth EDR does not exist (e.g., during night time), or its quality flag is poor (> 1), the IVSIC product is used as fallback for identification of snow/ice. The IVSIC product is the granulation of the gridded snow/ice rolling tiles (IVGSC). Bit 4 of byte 1 of the Surface Type Quality flags is set to a value of "1" to indicate that the IVSIC has been used instead of the VIIRS Snow EDR (Table 16) for determining snow/ice.

Vegetation flag (VegFraction) – vegetation or no vegetation present.

Fire flag (FireFlags) – fire or no fire present.

This function also does a check for "Night", "Cloudy", "ThinCirrus", and "Ocean" flags. In these conditions the Surface type is set, but the Snow cover flag and Vegetation flag are not set. If the QF indicates "Water" not "Ocean", then it assigns IGBP type 0 to the STYPE structure. Otherwise, it assigns any of the other 16 IGBP land types. The function determines snow based on Snow Cover values exceeding an update threshold provided in the processing coefficients input; vegetation growth based on calculated NDVI vs annual NDVI exceeding a threshold value provided in the processing coefficients input; and fire based on firemask 'Fire' or 'burnscar' indicators. For each of these conditions, a bit is set in the surface type flags output.

The STYPE product essentially gets created during this processing phase.

This function makes calls to two external classes: ProCmnViirsTrimTable and ProCmnVCMExtractor. For a detailed description of these classes and their methods see the Processing SI Common IO Design, DD60822-IDP-011.

2.1.2.7 Quality Flags

The VIIRS Surface Type algorithm has the capability to continue to process with missing data:

Surface Reflectance, the Vegetation Fraction output of the Surface Type EDR is left entirely as Fill values, and a quality indicator is updated to indicate the missing data. In addition the Vegetation Flag defaults to 'NoVegetation'.

Snow Cover, the snow flag of the Surface Type EDR defaults to 'No Snow' and a quality bit is set to indicate the absence of the input item.

Active Fire, the fire flag of the Surface Type EDR defaults to 'No Fire' and a quality bit is set to indicate the absence of the input item.

Cloud Mask, the Vegetation Fraction output of the Surface Type EDR is left entirely as FILL. The fire, snow, and vegetation flags are defaulted to 'Not Present', and a quality bit is set to indicate the absence of the input item. The Surface type is set according to the QSType IP.

Annual NDVI, the Vegetation Fraction output of the Surface Type EDR is left entirely as FILL. The vegetation flag defaults to 'No Vegetation', and a quality bit is set to indicate the absence of the input item.

The Vegetation fraction performance for sun glint times may result in values that are not reasonable during portions of the week where the retrieval falls into sun glint zones. The sun glint flag is included in the cloud mask, and retrievals that are affected by glint result in cloud mask data quality notifications. The vegetation fraction can be affected when a cloud shadow is detected. The shadow information is also part of the cloud mask.

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There is one case where input graceful degradation is indicated in the VIIRS Surface Type.

An input retrieved for the algorithm had its N_Graceful_Degradation metadata field set to YES (propagation). See Table 18 for Graceful Degradation details.

Table 18. Graceful Degradation

Input Data Description	Baseline Data Source	Primary Backup Data Source	Secondary Backup Data Source	Tertiary Backup Data Source	Graceful Degradation Done Upstream
Snow Cover	VIIRS_SN_01.4.1 VIIRS	N/A	N/A	N/A	N/A
Quarterly Surface Type IP	VIIRS_GD_08.4.3 VIIRS	N/A	N/A	N/A	N/A
Annual Max/Min Vegetation Index IP	VIIRS_GD_08.4.4 VIIRS	N/A	N/A	N/A	N/A

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

Very few operations in the algorithm (beyond address references) have the potential to cause exceptions. Two notable divide operations in the Compute_VegFraction routine and the Calculate_NDVI routine have the divisor compared to an epsilon prior to the operation.

The constant Float32 EPSILON is defined in the header file SurfType.h and set to 1^{e-10} (.0000000001). It is used to prevent division by zero or near zero errors. Because two floating point values cannot be compared for equality, epsilon is used to compare against a value that, for practical purposes, is equivalent to zero.

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

All non-Boolean numerical computations are performed using 32-bit floating point values. The vegetation fraction is initially calculated as a value ranging from 0 to 1.0. This value is then scaled by 100 and rounded to the nearest integer--i.e. the vegetation fraction is reported as an unsigned integer (UInt8) with values from 0 to 100. The loss of precision in the scaling of vegetation fraction is acceptable (there are no precision requirements for this attribute).Algorithm Support Considerations.

The DMS and INF must be running before the algorithm is executed. A C++ compiler is needed to compile the Surface Type EDR algorithm.

2.1.7 Assumptions and Limitations

2.1.7.1 Assumptions

All necessary data is available and provided within the necessary time constraints.

2.1.7.2 Limitations

None.

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

Table 19 contains terms most applicable for this OAD.

Table 19. 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.
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)	*[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 20 contains terms most applicable for this OAD.

Table 20. Acronyms

Acronym	Description
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
CDFCB-X	Common Data Format Control Book - External
DMS	Data Management Subsystem
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
DQTT	Data Quality Test Table
GMASI	Global Multi-sensor Automated Snow/Ice product
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
NCC	Near Constant Contrast
PDL	Program Design Language
PRO	Processing
QF	Quality Flag
SDR	Sensor Data Records
SI	Software Item or International System of Units
SOM	Space Oblique Mercator (a conformal nearly equal area map)
STYP or STYPE or SType	Surface Type
TBD	To Be Determined
TBR	To Be Resolved
TOA	Top of the Atmosphere

4.0 OPEN ISSUES

Table 21. TBXs

TBX ID	Description	Resolution Date
None		