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# Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Perform Parallax Correction (PPC) 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 Perform Parallax Correction (PPC) 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-11-0103** which converts D40382, Operational Algorithm Description Document for VIIRS Perform Parallax Correction (PPC) Software, Rev B dated 03/17/2010 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-11-0277:** This version baselines 474-00088, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Perform Parallax Correction (PPC) 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 474-00088, JPSS OAD Document for VIIRS PPC IP Software, 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. |
| Revision C | 03/13/2017 | **474-CCR-17-3243 (ECR-CGS-0734):** This version authorizes 474-00088, JPSS OAD Document for VIIRS PPC IP Software for the Block 2.0 IDPS release. Includes Raytheon PCR045678**:** Block 2.0: PRO: OAD: CCR: 474-CCR-15-2444: General OAD Clean-up CCR/PCR, affects all 35/37 OADs. All sections and tables may be affected. |

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

# OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS CLOUD PERFORM PARALLAX CORRECTION (PPC)

## SDRL No. 141
## 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 CLOUD PERFORM PARALLAX CORRECTION (PPC)

APPROVAL SIGNATURES:

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

**CAGE NO. 11982**

# Operational Algorithm Description Document for the VIIRS Perform Parallax Correction (PPC) Software

**Document Number: D40382**

**Document Date: Oct 12, 2010** **Revision: C2**

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

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|---|---|

| Revision/Change Record | Document Number | D40382 |
|---|---|---|

| Revision | Document Date | Revision/Change Description | Pages Affected |
|---|---|---|---|
| --- | 1-21-05 | Initial PCIM Release. ECR A046. | All |
| A1 | 6-11-05 | Discussion of quality flags per SPCR ALG 629. | 4-9 |
| A2 | 9-22-05 | –Reflects Raytheon-Omaha's initial edits for Science To Operational (Sci2Ops) Code Conversion Process, adding Raytheon coversheet, title/signature page, etc. | All |
| A3 | 3-21-06 | Section 2.3.1.1 – Restore of original science version of algorithm, Section 5.1 – Addition of test procedures. Inserted a new 3-21-06 Unit Test plus minor edits. | 11-14, 18-25 |
| A4 | 3-28-06 | Made edits to start working off Omaha QA comments from I-P-O CUTPR held 3-23-06. Fixed copyright year on coversheet, removed extra blank rows in some tables, removed Table 2 titled "PPC Module Constants" per PRO SW engineer's suggestion, renumbered then updated List of Tables to correct for changes made, inserted a new TBD01 on Page 13 then updated TBD/TBR table, fixed Unit Test problems in "Pass/Fail" column. | All |
| A5 | 9-8-06 | List of OAD TBD/TBR table – deleted TBD04, TBD06,<br>Updated Section 4.4 Quality Assessment and Diagnostics,<br>Updated Section 4.2 Error Handling,<br>Updated Figures 1 and 3,<br>Added information regarding satellite position vector. | v<br>11<br>16<br>17<br>19 |
| A6 | 9-25-06 | Deleted TB02,<br>Updated Tables 1-4,Updated Sections 2.2.3.1, 2.2.3.2, 2.3.2, 5.1, 6.1<br>Updated reference Table 1.3.2. | v<br>12, 13, 16, 21, 22, 25, 32<br>10 |
| A7 | 9-29-06 | Updated unit test and results. | 25, 26, 32 |
| A8 | 11-13-06 | Updated Table 1: Global Attributes. | 12 |
| A9 | 11-27-06 | Replaced Section 1.5 Unit test. | 25-29 |
| A10 | 12-18-06 | Incorporated changes per Optimization Code Completion Peer Review; reformatted OAD to new document template D41951. | All |
| A11 | 3-30-07 | Incorporated changes per customer responses to Dec 2006 delivery. | All |
| A12 | 6-19-07 | Added bit-level quality flag information per customer responses to Dec 2006 delivery, updated Section 2.1, updated Figure 2. | 5-15, 21 |
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|---|---|---|---|
| A14 | 10-24-07 | Delivered to NGST. | All |
| A15 | 7-23-08 | Prepared for delivery to ACCB. Updated Acronym list and references. Implemented new cover sheet from NGST. | All |
| A | 9-2-08 | ECR A-119. Incorporated interim changes and addressed TIM comments. | All |
| B1 | 06-03-09 | Updated per PCR020530 to process new COP quality flag byte as a results of NP-EMD-2008.510.0067, Rev A | 8,13-15 |
| B2 | 07-07-09 | Updated for NP-EMD.2008.510.0050 | All |
| B3 | 10-16-09 | Updated Table 9 with CM IP Quality Flags based on the VIIRS Cloud Mask 4.13.delivery. | Table 9 |
| B4 | 11-4-09 | Updated for SDRL | All |
| B5 | 01-13-10 | Synced up GEO pixel quality flags. | Table 7 |
| B6 | 1-20-10 | Updated for TIM/ARB | All |
| B | 3-17-10 | Submitted to ACCB | Cover pages |
| C1 | 10-12-10 | Updated due to document convergence | All |

## Table of Contents

## List of Figures



## List of Tables

# 1.0 INTRODUCTION

## 1.1 Objective

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

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

The purpose of an OAD is two-fold:

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

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

## 1.2 Scope

The scope of this document is limited to the description of the core operational algorithm(s) required to create the VIIRS Parallax Corrected Cloud Mask (CM) IP, VIIRS Parallax Corrected Cloud Optical Properties (COP) IP, and VIIRS Parallax Corrected Cloud Top Parameters (CTP) IP. The theoretical basis for this algorithm is described in Section 4.1 of VIIRS Cloud Cover/Layers Algorithm Theoretical Basis Document (ATBD), D0001-M01-S01-014.

## 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 Cloud Cover/Layers Algorithm Theoretical Basis Document (ATBD) | D0001-M01-S01-014 | Latest |
| Department of Defense World Geodetic System 1984 – Its Definition and Relationship with Local Geodetic Systems | N/A | (NIMA 1997) |
| Joint Polar Satellite System (JPSS) Algorithm Specification Part 16 | 474-00448-01-16_JPSS-SRS-Vol-I-Part-16<br>474-00448-02-16_JPSS-DD-Vol-2-Part-16<br>474-00448-03-16_JPSS-OAD-Vol-III-Part-16<br>474-00448-04-16_JPSS-SRSPF-Vol-IV-Part-16 | Latest |
| Joint Polar Satellite System (JPSS) Algorithm Specification Part 06 | 474-00448-02-16_JPSS-DD-Vol-2-Part-06 | Latest |
| Joint Polar Satellite System (JPSS) Algorithm Specification Part 08 | 474-00448-02-16_JPSS-DD-Vol-2-Part-08 | Latest |
| Joint Polar Satellite System (JPSS) Algorithm Specification Part 11 | 474-00448-02-16_JPSS-DD-Vol-2-Part-11 | Latest |
| Operational Algorithm Description Document for VIIRS Cloud Optical Properties (COP) Software | 474-00074 | Latest |
| Operational Algorithm Description Document for VIIRS Cloud Mask EDR (VCM EDR) | 474-00062 | Latest |
| Operational Algorithm Description Document for VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (CAL) SDR | 474-00090 | Latest |
| Operational Algorithm Description Document for Common Geolocation | 474-00091 | Latest |
| Operational Algorithm Description Document for VIIRS Cloud Cover/Layers (CCL) and Generate Cloud EDR (GCE) Software | 474-00085 | Latest |
| VIIRS Geolocation Algorithm Theoretical Basis Document (ATBD) | D0001-M01-S01-004 | Latest |
| Joint Polar Satellite System (JPSS) Program Lexicon | 470-00041 | Latest |
| NGST/SE technical memo – VIIRS Cloud Mask (VCM) OAD Update | NP-EMD.2004.510.0050 | 03 Dec 2004 |
| NGST/SE technical memo – MS Engineering Memo_PPC OAD Update | NP-EMD.2005.510.0076 | 07 Jul 2005 |
| NGST/SE technical memo – NPP_VIIRS_PPC_FIX_BACKFILL_DETR_XTRASCAN | NP-EMD.2006.510.0092 | 05 Dec 2006 |
| NGST/SE technical memo – VIIRS GEO EVtimesUPdates | NP-EMD.2008.510.0050 | 29 Oct 2008 |
| NGST/SE technical memo – NPP_VIIRS_PPC_bug_fix_backfil | NP-EMD.2008.510.0022 | 11 Apr 2008 |
| NGAS/SE technical memo – VIIRS Geo Quality Flags Logic Updates | NP-EMD.2009.510.0048 Rev A | 12 Oct 2009 |
| JPSS Algorithm Specification Volume II Data Dictionary for the Spacecraft Diary RDR- Block 2.0.0 | 474-00448-02-08 | Latest |
| JPSS Algorithm Specification Volume II Data Dictionary for the VIIRS RDR/SDR- Block 2.0.0 | 474-00448-02-06 | Latest |

| Document Title | Document Number/Revision | Revision Date |
|---|---|---|
| JPSS Algorithm Specification Volume II Data Dictionary for the VIIRS Cloud Mask- Block 2.0.0 | 474-00448-02-11 | Latest |
| JPSS Algorithm Specification Volume II Data Dictionary for the VIIRS Cloud Physical Properties-Block 2.0.0 | 474-00448-02-16 | 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 Perform Parallax Correction --- science-grade software | 20050812_ISTN_VIIRS_NGST_3.5 | 12 Aug 2005 |
| VIIRS Perform Parallax Correction --- operational software | /PRO/EDR/VIIRS/clouds/ppc/ B1.5, Vers. D.1.1.6 (OAD Rev A10) | 28 Nov 2006 |
| NGST/SE technical memo – VIIRS GEO EVtimesUPdates | NP-EMD.2008.510.0050 (OAD Rev B2) | 29 Oct 2008 |
| SDRL | (OAD Rev B4) | 04 Nov 2009 |
| OAD update only—no code changes | (OAD Rev B5) | 13 Jan 2010 |
| ACCB (no code changes) | OAD Rev B | 17 Mar 2010 |
| Convergence Update (No code changes) | (OAD Rev C1) | 12 Oct 2010 |
| OAD transitioned to JPSS Program – this table is no longer updated. | | |

## 2.0 ALGORITHM OVERVIEW

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

The Perform Parallax Correction (PPC) algorithm is implemented during IP/EDR processing and requires RDR, SDR, IP and LUT inputs to produce IP outputs. A top-level diagram for the PPC algorithm is shown in Figure 1.

PPC consists of derived and core algorithm modules. The derived algorithm module ProEdrViirsPpc (represented by the shaded portion in Figure 1) functions as a wrapper for the core algorithm module and handles the I-O stages in the I-P-O architecture. ProEdrViirsPpc initiates the core algorithm module PerformParallaxCorrection which makes up the P stage.

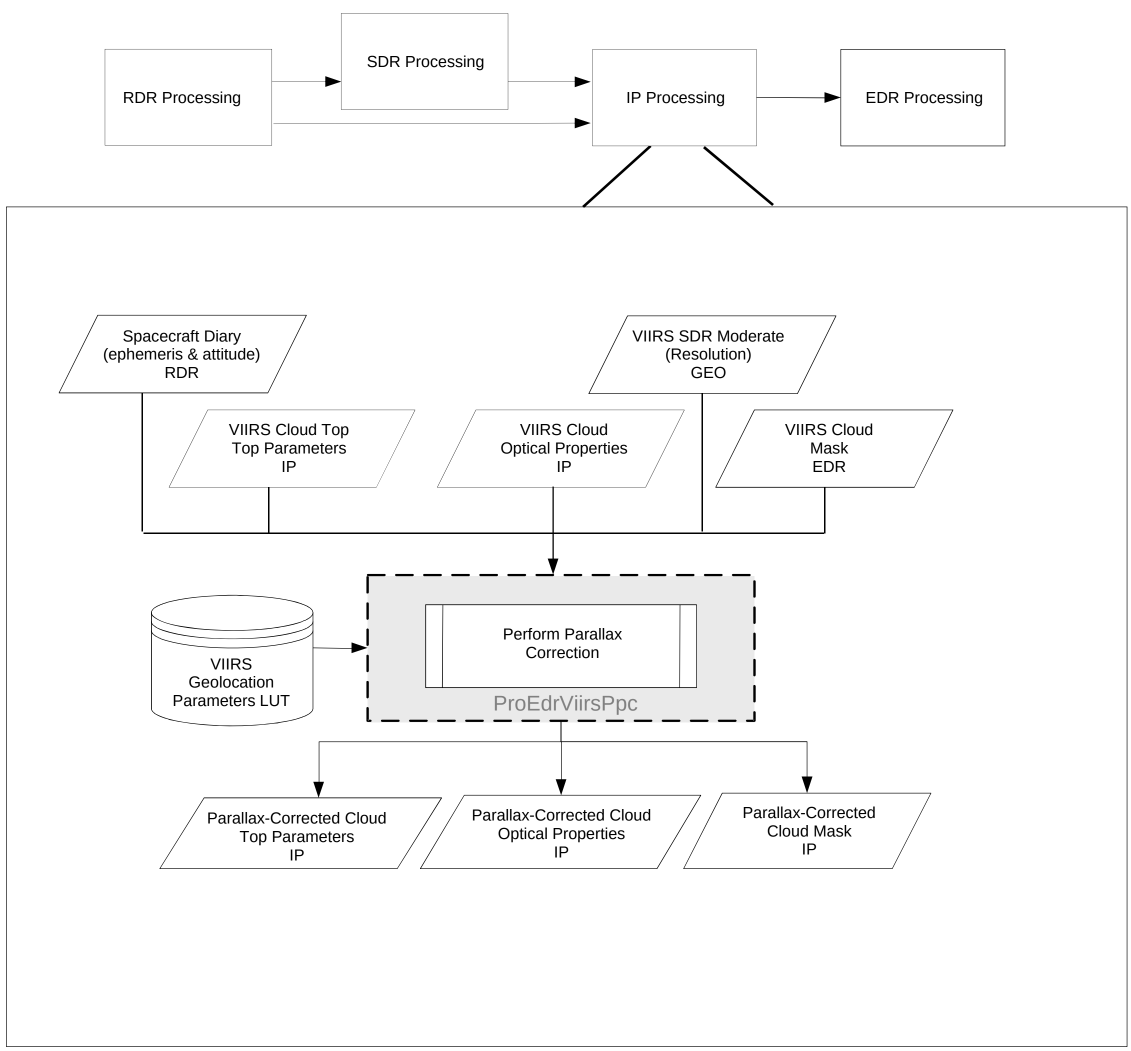



**Figure 1. Algorithm Overview**

## 2.1 VIIRS Cloud Perform Parallax Correction Description

The PPC Module is part of the Cloud IP processing chain. Its purpose is to determine the geolocation on the surface of the Earth where a locally vertical line intercepts the cloud. Since the cloud is viewed from a slant path, the "parallax corrected" geolocation depends on the cloud top height and the viewing scan angle. The PPC Module therefore determines the "corrected" geolocation due to slant path effects so that geolocation for the cloud Environmental Data Records (EDRs) is reported at the local vertical.

A dataflow diagram for the VIIRS Cloud Module, of which the VIIRS Cloud PPC Module is a member, is shown in Figure 2. Each circle represents a stand-alone unit of the VIIRS Cloud Module. Processing order is indicated by the number in each circle. The VIIRS Cloud PPC Module is "shadowed" in the diagram.

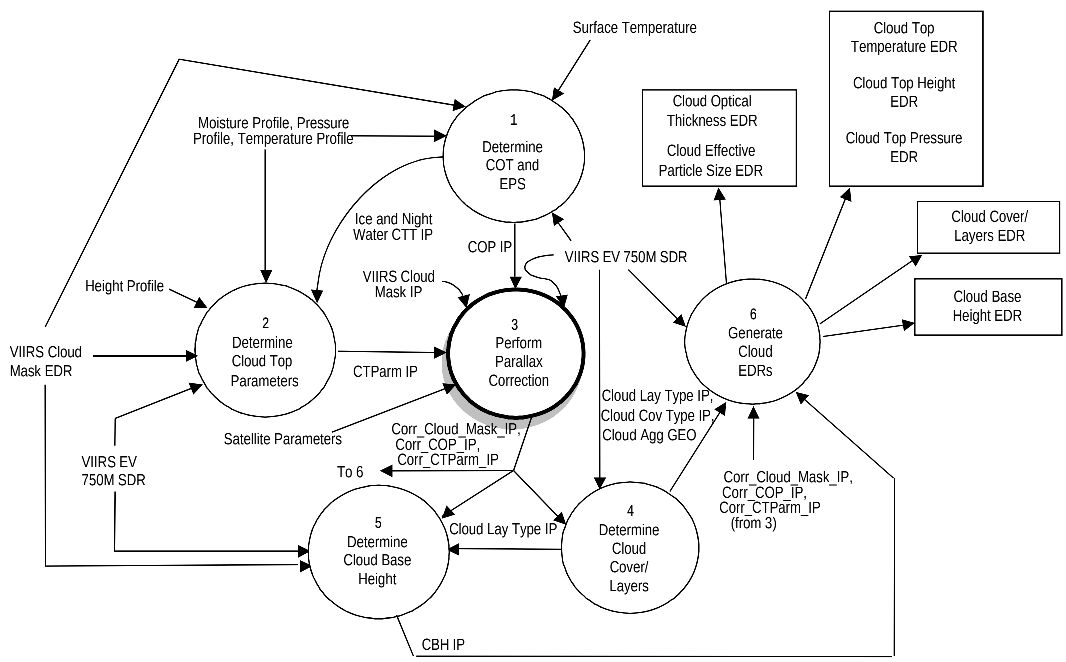
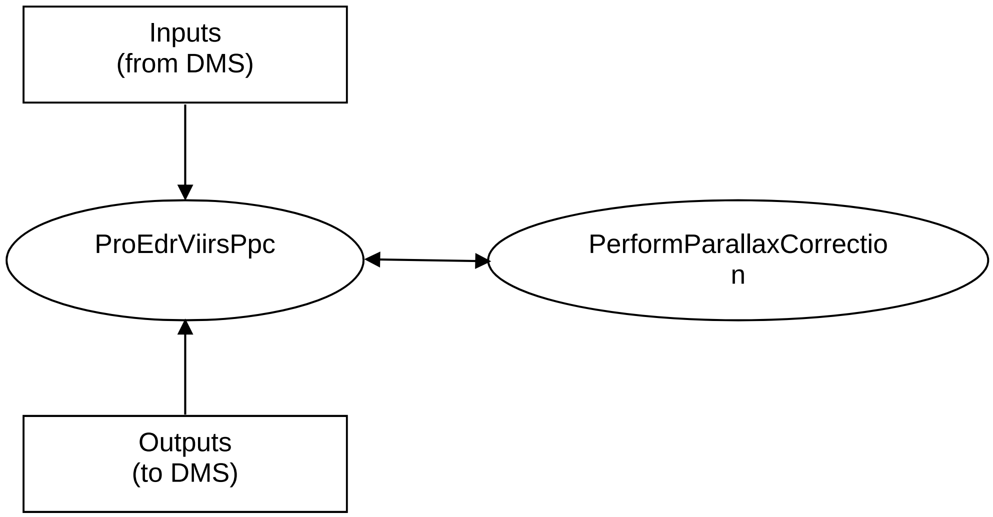



**Figure 2. Cloud Module Data Flow**

### 2.1.1 Interfaces

The main flow of the operational PPC algorithm is shown in Figure 3 below. The PPC algorithm receives all the required input data from DMS. The first step is to use the verified RDR routine to unpack and byte-align the Space Craft Diary RDR. Then the algorithm uses a Common Geolocation (CMN GEO) library of functions to set up the ephemeris and attitude data. When all the input data needed for processing is available, the main module (PerformParallaxCorrection) is called to produce Corrected Cloud Mask, Corrected COP and Corrected CTP.




**ProEdrViirsPpc Description**

This is the derived class from ProCmnAlgorithm that contains overridden methods setupDataItems and doProcessing. Method setupDataItems instantiates input and output data items which represent data buffers to be used by the algorithm. DoProcessing is the method where processing of the algorithm input data and output data is done. For more information see the Processing SI Common IO Design, UG60917-IDP-1005, Pt 2, Appx A.

**Figure 3. Perform Parallax Correction Overall Flow Diagram**

The PPC Module requires Spacecraft Diary RDR, VIIRS Moderate Geolocation (GEO), VIIRS CM EDR, VIIRS COP IP, VIIRS CTP IP, and VIIRS SDR Moderate Geolocation Parameters Look-Up Table (LUT) as inputs to produce the following outputs: VIIRS Parallax Corrected CM IP; VIIRS Parallax Corrected COP IP; VIIRS Parallax Corrected CTP IP. A detailed itemization of the inputs and outputs for the PPC Module is provided below.

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

- Fill values corresponding to the individual pixels in each product that do not contain valid data are dictated by the datatype. The following fill values apply: NA_UINT8_FILL for UInt8 datatypes, NA_FLOAT32_FILL for Float32 datatypes, zero for quality flags.
- For detailed descriptions of the quality flags in the tables below, refer to the applicable I-P-O algorithm OAD (CM, COP, or CTP).
- M_VIIRS_SDR_ROWS = NUMBER of SCANS PER GRANULE X NUMBER of MODERATE DETECTORS
- M_VIIRS_SDR_COLS = 3200

#### 2.1.1.1 Inputs

PPC algorithm inputs are found in 474-00448-01-16_JPSS-SRS-Vol-I-Part-16, Table 3-1 (rows 12 – 8 from the bottom of the table). Detailed descriptions of the inputs and LUTs are referenced below.

**Table 3. PPC Inputs**

| Input | Description | Referece Documents |
|---|---|---|
| Spacecraft Diary RDR | Information from Spacecraft Diary like S/C position | 474-00448-02-08_JPSS-DD-Vol-II-Part-08, Section 4.0 |
| VIIRS SDR Moderate Geolocation | Latitude, Longitude, Solar and Satellite angles and other data from geoloaction | 474-00448-02-06_JPSS-DD-Vol-II-Part-06, Section 6.2.66 |
| VIIRS Cloud Mask | Quality flags from Cloud Mask output | 474-00448-02-11_JPSS-DD-Vol-II-Part-11, Section 4.7 |
| VIIRS Cloud Optical Properties | Cloud optical thickness, cloud effective particle size and quality flags | 474-00448-02-16_JPSS-DD-Vol-II-Part-16, Section 4.6 |
| VIIRS Cloud Top Parameters | Cloud Top Temperature, Height , Pressure values and quality flags | 474-00448-02-16_JPSS-DD-Vol-II-Part-16, Section 4.4 |
| VIIRS SDR Moderate Geolocation Parameters LUT | Several geolocation Parameters from VIIRS-SDR-GEO-MOD-PARAM-LUT | 474-00448-02-06_JPSS-DD-Vol-II-Part-06, Section 7.1.27 |

### 2.1.1.2 Outputs

PPC algorithm outputs are found in 474-00448-01-16_JPSS-SRS-Vol-I-Part-16, Table 3-1 (next to last row of table) and are defined (along with QFs) in 474-00448-02-16_JPSS-DD-Vol-II-Part-16, Sections 4.5 – 4.7.

**Table 4. PPC Outputs**

| Output | Description | Reference Document |
|---|---|---|
| VIIRS Parallax Corrected Cloud Mask IP | VIIRS-Parx-Corr-CM-IP contains Parallax corrected values from Cloud Mask EDR | 474-00448-02-16_JPSS-DD-Vol-II-Part-16 |
| VIIRS Parallax Corrected Cloud Optical Properties | VIIRS-Parx-Corr-Cd-Opt-Prop-IP contains parallax corrected values from COP IP ( like Cot , Eps and quality flags) | 474-00448-02-16_JPSS-DD-Vol-II-Part-16 |
| VIIRS Parallax Corrected Cloud Top Parameters | VIIRS-Parx-Corr-Cd-Top-Parm-IP contains parallax corrected values from CTP IP ( like Ctt , Cth , Ctp and quality flags) | 474-00448-02-16_JPSS-DD-Vol-II-Part-16 |

### 2.1.2 Algorithm Processing

The approach for parallax correction is to find the vector that intersects the sensor line-of-sight (LOS) at the altitude of the cloud top height (CTH). The sensor LOS is determined from the pixel position vector and the satellite position vector at the given pixel time. The vector intersecting the sensor LOS at the CTH is the position vector of the cloud. After transforming the cloud position vector into geodetic coordinates, the cloud latitude/longitude is compared with that of pixels along the sensor scan line. The pixel latitude/longitude closest to the cloud latitude/longitude is taken as the cloud's new pixel location.

Parallax correction is not performed for pixels that have filled CTH values.

For operational software, the parallax correction module uses non terrain-corrected geolocation data.

#### 2.1.2.1 Main Module - PerformParallaxCorr()

The logic flow of the PPC Module retrieval algorithm is shown in Figure 4.

PerformParallaxCorr copies original IP data (inputs) to corrected IP data (outputs) thereby maintaining original IP data for pixels that are not relocated (parallax corrected).

CMN GEO method GEO_determine_sample_time_offsets() is called to determine the scan sample time offsets (discussed in VIIRS Geolocation (GEO) SDR OAD, 474-00091) and scan start times are retrieved from the VIIRS SDR MOD GEO. Scan start times and sample time offsets are used in ComputeParallaxCorrection() to calculate pixel time.

For each pixel with cloud data present, the cloud top height is converted from geopotential to geometric height by Height_Conversion(). ComputeParallaxCorrection() determines the cloud parallax corrected latitude and longitude, then FindNewPixel() determines the pixel that corresponds to the cloud parallax corrected latitude and longitude. Original cloud IP data at the original pixel is then copied to corrected cloud IP data at the new pixel. Note: For quality flags, only cloud related quality flags are copied to the new pixel, all non-cloud related quality flags (for example: sun glint, day/night) are not copied (refer to CM, COP, and CTP OADs for quality flag information). The original pixel is then backfilled to clear the data.

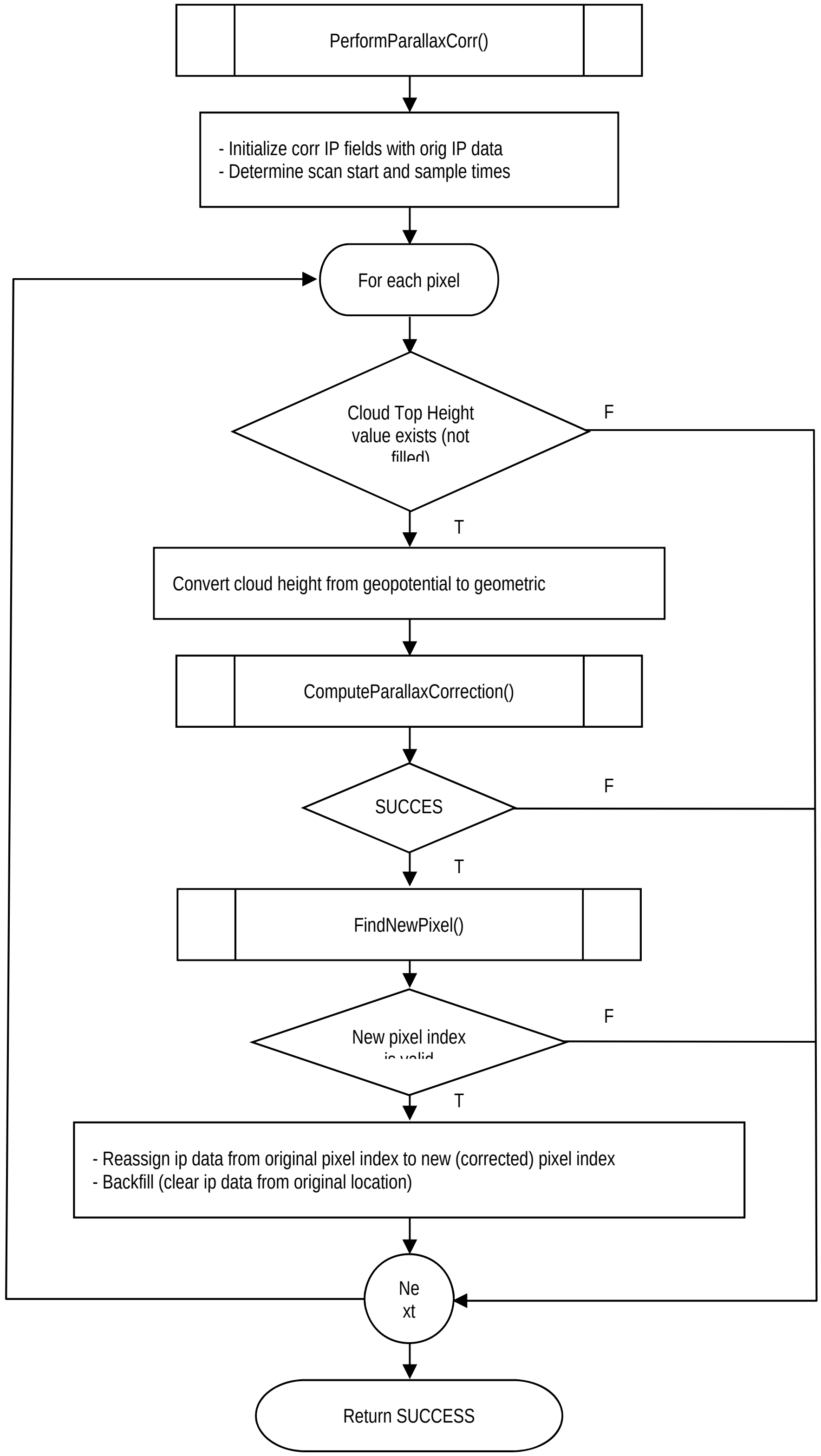



**Figure 4. PerformParallaxCorrection() Logic Flow**

#### 2.1.2.2 ComputeParallaxCorrection()

This function computes the true geodetic coordinates of the observed cloud. To compute the parallax correction, the following steps are required:

1. Transform the pixel position vector from geodetic to Earth Centered Earth Fixed (ECEF) coordinates.
2. Retrieve the satellite position vector for the time of the pixel and perform vector subtraction to obtain the sensor LOS vector.
3. Solve for the intersection of the sensor LOS vector and the reference ellipsoid plus the cloud top height. This is the cloud position vector in ECEF coordinates (see PPC_ellipIntersect())
4. Transform the cloud position vector from ECEF to geodetic coordinates (see PPC_ellipIntersect()).

The following mathematical description of the steps listed above has been derived from the equations in the VIIRS Geolocation ATBD, D0001-M01-S01-004, Section 3.3.1.3, ECEF to Geodetic, and Section 3.3.2.2, Basic Earth Ellipsoid Intersection Algorithm. Steps 3 and 4 are performed in the operational algorithm by PPC_elllipIntersect(). To complete the correction, a new pixel index must be determined by the FindNewPixel() function, as discussed below.

**Step 1:** Transform the pixel position vector from geodetic to ECEF coordinates.

The relationship between ECEF and geodetic coordinates can be expressed simply in its direct form as discussed in Department of Defense World Geodetic System 1984 – Its Definition and Relationship with Local Geodetic Systems, (NIMA 1997):

$$
\begin{aligned}
x &= (N + h_{terrain})\cos(lat)\cos(lon) \\
y &= (N + h_{terrain})\cos(lat)\sin(lon) \\
z &= \left(N(1-e^2) + h_{terrain}\right)\sin(lat) \\
N &= a / \left(1 - e^2 \sin^2(lat)\right)^{\frac{1}{2}} \\
e^2 &= 1 - \frac{b^2}{a^2}
\end{aligned}
$$

where:

| | | |
|---|---|---|
| $(x,\ y,\ z)$ | - | ECEF coordinates |
| $(lat,\ lon,\ h_{terrain})$ | - | Geodetic coordinates |
| $N$ | - | Ellipsoid radius of curvature in the prime vertical |
| $e$ | - | Ellipsoid eccentricity |
| $a$ | - | Earth equatorial radius (ellipsoid semi-major axis) |
| $b$ | - | Earth polar radius (ellipsoid semi-minor axis) |

The geodetic coordinates, $lat$ and $lon$, are inputs from the GEO data. Geolocation data used by the cloud module is non terrain-corrected, therefore $h_{terrain}$ = 0. Parameters $e$, $a$ and $b$ are well known physical constants. Note that constants $e$ and $N$ are calculated from $a$ and $b$.

**Step 2:** In the operational code, pixel time is calculated by adding scan start time and sample time offset. Pixel time is used by CMN GEO method satPosAtt() to interpolate the satellite position for the exact time of interest (pixel time). A description of satPosAtt() can be found in the VIIRS Common Geolocation OAD, 474-00091. Vector subtraction is then performed to obtain the sensor LOS.

$$\vec{u}_{\text{ecef}} = \vec{g}_{\text{ecef}} - \vec{p}_{\text{ecef}}$$

where:

$\vec{u}_{\text{ecef}}$ - LOS unit vector in ECEF

$\vec{g}_{\text{ecef}}$ - pixel position vector in ECEF

$\vec{p}_{\text{ecef}}$ - spacecraft position vector in ECEF

#### 2.1.2.3 PPC_ellipIntersect()

Function PPC_ellipIntersect(), (a modification of CMN GEO ellipIntersect() to include cloud height in calculations), solves for the intersection of the sensor LOS vector and the reference ellipsoid plus the cloud top height. This is the cloud position vector in ECEF coordinates. It then transforms the cloud position vector from ECEF to geodetic coordinates and returns the parallax corrected latitude and longitude.

**Step 3:** (Continued from above) Solve for the intersection of the sensor LOS vector and the reference ellipsoid plus the cloud top height (as depicted in Figure 5).

Re-scale the viewing vector and satellite vector using the ellipsoid of interest semi-major *a'* and semi-minor *b'* axis dimensions (*a', a', b'*):

$$\mathbf{u}' = \begin{bmatrix} u_1 / a' \\ u_2 / a' \\ u_3 / b' \end{bmatrix} \qquad \mathbf{p}' = \begin{bmatrix} p_1 / a' \\ p_2 / a' \\ p_3 / b' \end{bmatrix}$$

where:

$a' = a + h_{cloud}$ and $b' = b + h_{cloud}$

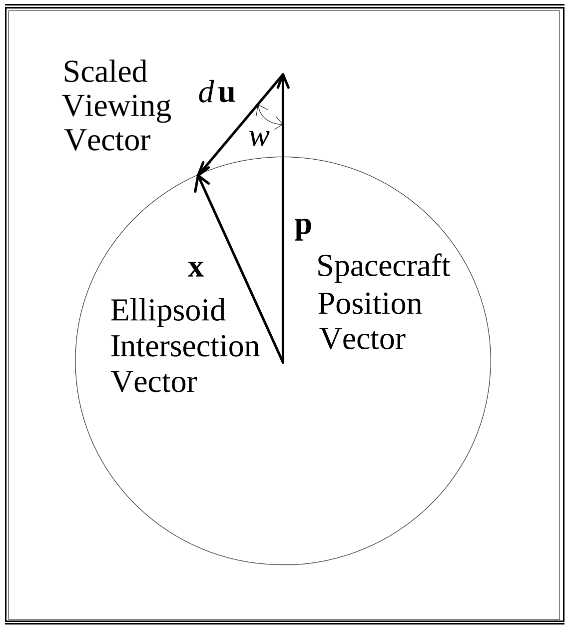



**Figure 5. Ellipsoidal Viewing Vector Intersection**

Note:

$$\mathbf{x}' = \begin{bmatrix} x_1 / a' \\ x_2 / a' \\ x_3 / b' \end{bmatrix}$$ - the unknown cloud position vector (re-scaled)

Solve for the scaling *d* of $\mathbf{u}'$ which intersects the unit sphere:

From the law of cosines:

$$|\mathbf{x}'|^2 = |d\,\mathbf{u}'|^2 + |\mathbf{p}'|^2 - 2\,|d\,\mathbf{u}'|\,|\mathbf{p}'|\cos(w)$$

Using the dot-product, the cosine of the acute angle *w* between $\mathbf{u}'$ and $-\mathbf{p}'$ is:

$$\cos(w) = -(\mathbf{u}' \cdot \mathbf{p}') / (|\mathbf{u}'||\mathbf{p}'|)$$

By definition $|\mathbf{x}'| = 1$ so:

$$1 = d^2 |\mathbf{u}'|^2 + |\mathbf{p}'|^2 + 2d|\mathbf{u}'||\mathbf{p}'|(\mathbf{u}' \cdot \mathbf{p}') / (|\mathbf{u}'||\mathbf{p}'|)$$

Simplifying and rearranging:

$$d^2 |\mathbf{u}'|^2 + 2d(\mathbf{u}' \cdot \mathbf{p}') + |\mathbf{p}'|^2 - 1 = 0$$

This can be solved for *d* using the quadratic formula:

$$d = \frac{-(\mathbf{u}'\cdot\mathbf{p}') - \sqrt{(\mathbf{u}'\cdot\mathbf{p}')^2 - |\mathbf{u}'|^2\left(|\mathbf{p}'|^2 - 1\right)}}{|\mathbf{u}'|^2}$$

This is the smaller of the two solutions for *d*, the intersection closest to the satellite. If the solution is not real, then there is no intersection.

Use *d* to compute $\mathbf{x}'$ and $\mathbf{x}$:

$$\mathbf{x}' = \mathbf{p}' + d\,\mathbf{u}'$$

$$\mathbf{x} = \begin{bmatrix} x'_1\, a' \\ x'_2\, a' \\ x'_3\, b' \end{bmatrix} = \begin{bmatrix} (p'_1 + d\,u'_1)a' \\ (p'_2 + d\,u'_2)a' \\ (p'_3 + d\,u'_3)b' \end{bmatrix} = \begin{bmatrix} p'_1\, a' + d\,u'_1\, a' \\ p'_2\, a' + d\,u'_2\, a' \\ p'_3\, b' + d\,u'_3\, b' \end{bmatrix}$$

$$\mathbf{x} = \mathbf{p} + d\,\mathbf{u}$$

**Step 4:** Transform the cloud position vector from ECEF to geodetic coordinates. Convert the ECR ellipsoid pierce point to geodetic coordinates (special case direct solution).

$$lon = \tan^{-1}\left(\frac{x_2}{x_1}\right)$$

$$lat = \tan^{-1}\left(\frac{x_3 / (1 - e^2)}{\sqrt{x_1^2 + x_2^2}}\right)$$

$$h_{terrain} = 0$$

### 2.1.2.4 FindNewPixel()

Function FindNewPixel() compares the parallax corrected (cloud) latitude and cloud longitude to the nearest pixels along the same scan line. The pixel whose latitude and longitude is closest to the cloud latitude and longitude is taken as the cloudy pixel's new location. The linear position of that pixel is stored in *newPixIndex*.

The algorithm to find the pixel in the current scanline with the closest geolocation to the cloud is as follows:

1. Initialize minimum distance, *range*, to a large value.
2. Initialize *newPixIndex* to original pixel index.
3. Calculate scan pixel number.
   *pixel_number = original pixel index % n_pixels*
4. Compute arc length on ellipsoid from current pixel lat/lon to cloud lat/lon using spherical ellipsoid approximation.
   $$new\_range =$$
   $$\arccos(\sin(lat_{pixel})\sin(lat_{cloud}) + \cos(lat_{pixel})\cos(lat_{cloud})\cos(lon_{cloud} - lon_{pixel}))$$
5. Compare arc length to minimum distance.
   If *new_range* < *range*; set *range* = *new_range*; otherwise go to step 8.

6. Determine direction toward scan nadir.
   If *pixel_number <= n_pixels/2*, increase *newPixIndex*
   If *pixel_number > n_pixels/2*, decrease *newPixIndex*
7. Repeat steps 4 through 6 until minimum distance is found.
8. Move one pixel towards nadir.
   If *pixel_number > n_pixels/2*, increase *newPixIndex*
   If *pixel_number <= n_pixels/2*, decrease *newPixIndex*

Note that this algorithm is based on the assumption that the pixel nearest the sub-cloud location is on the same scan line as the pixel where the cloud was observed.

##### 2.1.2.5 Height_conversion()

Function height_conversion() converts geopotential height to geometric height above the ellipsoid (refer to Section 4.3.1 of the Cloud Cover/Layers ATBD, D0001-M01-S01-014).

##### 2.1.2.6 Backfill()

Function backfill() fills the corrected IP outputs (COP, CTP) with FILL values for the pixel location given and sets the quality flags and corrected IP output CM to zero.

### 2.1.3 Graceful Degradation

None.

### 2.1.4 Exception Handling

Errors that occur during the Input/Output (I/O) stages of the algorithm are reported and result in process termination. No outputs are produced.

In the processing stage of the algorithm, the PPC Module checks for a valid number of scans before any pixels are processed.

- If the number of scans is invalid, the error is reported, processing terminates and no outputs are produced.
- If the number of scans is valid but less than the expected number of scans, the pixels for the valid scans are processed, the missing scans are backfilled with FILL values, and outputs are produced.
- If the number of scans is valid, the pixels are processed. If an error occurs during pixel level processing, the error is reported, the pixel data remains at its original index, and processing continues with the next pixel. The following pixel level errors are handled: divide by zero; invalid satellite position; no ellipsoid intersection; invalid pixel index. Pixel level errors do not prevent PPC from producing outputs.

### 2.1.5 Data Quality Monitoring

None. (There are no Data Quality Threshold Tables (DQTTs) or Data Quality Notifications (DQNs) defined for PPC.)

### 2.1.6 Computational Precision Requirements

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

### 2.1.7 Algorithm Support Considerations

None.

### 2.1.8 Assumptions and Limitations

To determine the parallax-corrected pixel, the assumption is made that the pixel nearest the sub-cloud location is on the same scan line as the pixel where the cloud was observed.

# 3.0 GLOSSARY/ACRONYM LIST

## 3.1 Glossary

Table 5 contains terms most applicable for this OAD.

**Table 5. Glossary**

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

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

## 3.2 Acronyms

Table 6 contains terms most applicable for this OAD.

**Table 6. Acronyms**

| Acronym | Description |
|---|---|
| ACO | Atmospheric Correction over Ocean |
| ADCS | Advanced Data Collection System |
| AFM | Airborne Fluxes and Meteorology Group |
| AOS | Acquisition of Signal |
| CDA | Command and Data Acquisition |
| CDR | Climate Data Records |
| CI | Configured Item |
| CM | Cloud Mask |
| COMSAT | Communications Satellite |
| COP | Cloud Optical Properties |
| CTH | Cloud Top Height |
| CTP | Cloud Top Parameters |
| DES | Digital Encryption System |
| DHN | Data Handling Node |
| ECEF | Earth Centered Earth Fixed |
| ECR | Earth Centered Rotating |
| EOS | Earth Observing System |
| ERBS | Earth Radiation Budget Suite |
| ESD | Electrostatic Discharge |
| EUMETSAT | European Organization for the Exploitation of Meteorological Satellites |
| FMH | Federal Meteorological Handbook |
| GEO | Geolocation |
| GPS | Global Positioning System |
| GSE | Ground Support Equipment |
| HRD | High Rate Data |
| IGS | International GPS Service |
| IJPS | Initial Joint Polar System |
| IOC | Initial Operational Capability |
| IP | Intermediate Product |

| Acronym | Description |
|---|---|
| LEO&A | Launch, Early Orbit, & Anomaly Resolution |
| LOS | Line Of Sight |
| LRD | Low Rate Data |
| LST | Local Solar Time |
| LUT | Look-Up Table or Local User Terminal |
| Metop | Meteorological Operational Program |
| MSS | Mission System Simulator |
| NA | Non-Applicable |
| NCA | National Command Authority |
| NDT | Nitrate-Depletion Temperature |
| OAD | Operational Algorithm description Document |
| OC/C | Ocean Color/Chlorophyll |
| PIP | Program Implementation Plan |
| PMT | Portable Mission Terminal |
| POD | Precise Orbit Determination |
| PPC | Perform Parallax Correction |
| QF | Quality Flag |
| RSR | Remote Sensing Reflectance |
| S&R | Search and Rescue |
| SCA | Satellite Control Authority |
| SDE | Selective Data Encryption |
| SDP | Science Data Production |
| SDR | Sensor Data Records |
| SDS | Science Data Segment |
| SGI® | Silicon Graphics, Inc. |
| SI | International System of Units |
| SN | NASA Space Network |
| SOC | Satellite Operations Center |
| SRD | Sensor Requirements Documents |
| SS | Space Segment |
| SST | Sea Surface Temperature |
| TBD | To Be Determined |
| TBR | To Be Resolved |
| TBS | To Be Supplied |
| TEMPEST | Telecommunications Electronics Material Protected from Emanating Spurious Transmissions |
| TOA | Top of the Atmosphere |
| USB | Unified S-band |
| UTC | Universal Time Coordinated |

# 4.0 OPEN ISSUES

**Table 7. TBXs**

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