Precipitation Processing System (PPS)

Algorithm Theoretical Basis Document (ATBD)

NASA GPM Level 1C Algorithms

Version 1.0

Prepared By:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
Code 610.2/PPS
Greenbelt, Maryland 20771

and
GPM Intercalibration (X-CAL) Working Group

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

TABLE OF CONTENTS

Page

1. INTRODUCTION 1
1.1 Objective 1
1.2 L1C Algorithms Overview 1
1.3 L1C Input Data Description 1
1.4 L1C Products Description 2
2. ORBITIZATION 2
2.1 Orbit Boundary Derivation 2
2.1.1 Two-Line Element (TLE) 2
2.1.2 SGP4 4
2.1.3 Daily Orbit Start/Stop Times Generation 4
2.2 Data Reorbitization 4
3. SATELLITE INTERCALIBRATION ALGORITHMS 5
4. QUALITY CONTROL 5
5. ANCILLARY DATA CALCULATIONS 6
6. LEVEL 1C PROCESSING 6
6.1 Orbit Boundaries Derivation Processing 6
6.1.1 Activation 6
6.1.2 Execution 8
6.1.3 Termination 9
6.2 Data Reorbitization Processing 9
6.2.1 Activation 9
6.2.2 Execution 10
6.2.3 Termination 11
6.3 Intercalibration Processing 12
6.3.1 Activation 12
6.3.2 Execution 12
6.3.3 Termination 14
6.3.4 Static Data Files 14
7. REFERENCES 14
APPENDIX A. L1C GMI 15
A.1 Introduction 15

A.1.1 .. L1C GMI Input Data Description......15
A.1.2 .. L1C GMI Product Description......15

A.2.. Orbitization 15

A.3.. Satellite Intercalibration 16

A.3.1 .. Ta to Tb Conversion......16
A.3.2 .. Satellite Intercalibration 16

A.4.. Quality Control 16

A.5.. Static Data Files......17

A.6.. References......17

APPENDIX B. L1C TMI......18

B.1.. Introduction......18

B.1.1 .. L1C TMI Input Data Description......18
B.1.2 .. L1C Product Description......18

B.2.. Orbitization 19

B.3.. Satellite Intercalibration 19

B.3.1... Ta to Tb Conversion......19
B.3.2 .. Satellite Intercalibration 19

B.4.. Quality Control 19

B.5.. Static Data Files......20

B.6.. References......20

APPENDIX C. L1C SSMI......21

C.1.. Introduction......21

C.1.1 .. L1C SSMI Input Data Description......21
C.1.2 .. L1C SSMI Product Description 21

C.2.. Orbitization 22

C.3.. Satellite Intercalibration 22

C.3.1 .. Cross-Track Bias Correction......22
C.3.2 .. Ta to Tb Conversion......23
C.3.3 .. Satellite Intercalibration 23

C.4.. Quality Control 25

C.5.. Static Data Files......266

C.6.. References......26

APPENDIX D. L1C SSMI/S 27

D.1.. Introduction......27

D.1.1 .. L1C SSMI/S Input Data Description 27
D.1.2 .. L1C SSMI/S Product Description 27
D.2 .. Orbitization 28
D.3 .. Satellite Intercalibration 28
D.4 .. Quality Control 28
D.5 .. Static Data Files 28
D.6 .. References 28
APPENDIX E. L1C AMSR-E 29
E.1 .. Introduction 29
E.1.1 ... L1C AMSR-E Input Data Description 29
E.1.2 ... L1C AMSR-E Product Description 29
E.2 .. Orbitization 30
E.3 .. Satellite Intercalibration 30
E.4 .. Quality Control 30
E.5 .. Static Data Files 31
E.6 .. References 31
APPENDIX F. L1C WINDSAT 32
F.1 .. Introduction 32
F.1.1 ... L1C WindSat Input Data Description 32
F.1.2 ... L1C WindSat Product Description 32
F.2 .. Orbitization 32
F.3 .. Satellite Intercalibration 33
F.4 .. Quality Control 33
F.5 .. Static Data Files 33
F.6 .. References 33
ACRONYMS USED IN THIS DOCUMENT AND ITS APPENDICES 34

LIST OF FIGURES

Figure 1. Flow Chart for Executing the ostFinderTLE Program……………………………………...8
Figure 2. Flow Chart for Executing the L1CBASE Program………………………………..………10
Figure 3. Flow Chart for Executing the L1CBASE File-by-File, Scan-by-Scan Processing…...11
Figure 4. Flow Chart for Executing the L1CXCAL Program…………….…..…………………...13
Figure B-1. Relation Between Swaths for L1C TMI..…………………………………………......19
Figure C-1. Relation Between Swaths for L1C SSMI…………………………………………...…..22
Figure C-2. Crossover Matches Between the TRMM TMI and SSMI Sensors………………...24
Figure D-1. Relation Between Swaths for L1C SSMI/S.……………………………………….....28
Figure E-1. Relation Between Swaths for L1C AMSR-E..……………………………………….30

LIST OF TABLES

Table A-1. List of Static Data Files for L1C GMI.………………………………………………..17
Table B-1. List of Static Data Files for L1C TMI..………………………………………………..20
Table C-1. Offset Calibration Values for L1C SSMI.……………………………………………..25
Table C-2. List of Static Data Files for L1C SSMI……………………………………………..26

1. INTRODUCTION

Level 1C (L1C) algorithms are a collection of algorithms that produce common calibrated brightness temperature products for the Global Precipitation Measurement (GPM) Core and Constellation satellites.

1.1 OBJECTIVE

This document describes the GPM Level 1C algorithms. It consists of physical and mathematical bases for orbitization, satellite intercalibration, and quality control, as well as the software architecture and implementation for the Level 1C algorithms.

1.2 L1C ALGORITHMS OVERVIEW

The Level 1C algorithms transform equivalent Level 1B radiance data into Level 1C products. The input source data are geolocated and radiometric calibrated antenna temperature (Ta) or brightness temperature (Tb). The output Level 1C products are common intercalibrated brightness temperature (Tc) products using the GPM Microwave Imager (GMI) as the reference standard.

The Level 1C algorithms contain the following major components:

- Orbitization.
- Satellite intercalibration.
- Quality control.
- Ancillary data calculations.

The detail of L1C algorithms and implementation depends on the details of each sensor. In this document, the Level 1C algorithms are described in a general sense. Individual sensor-specific details are provided separately for each of the six sensors in Appendices A through F: A) GMI, B) Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), C) Special Sensor Microwave Imager (SSMI), D) Special Sensor Microwave Imager/Sounder (SSMI/S), E) Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E), and F) WindSat.

1.3 L1C INPUT DATA DESCRIPTION

The input data to the Level 1C process are equivalent Level 1B radiance data. The input source to the L1C process is different for each sensor. Input data are geolocated, and radiometric calibrated antenna temperature (Ta) or brightness temperature (Tb) depends on the data availability from each sensor. An input data file could be an orbit with an arbitrary starting point or a half orbit. The input data format could be in binary, Network Common Data Form (NetCDF), or Hierarchical Data Format (HDF), etc.

Detailed information on the L1C input data description for each sensor is included in the Appendices.

1.4 L1C PRODUCTS DESCRIPTION

The standard Level 1C products are the intercalibrated microwave brightness temperatures. All L1C products have a common format and are in HDF. The format is designed to be simple and generic. One or more swaths are included in a product; a swath is defined as scan time, latitude, longitude, and data that match the latitude and longitude (lat/lon). Each swath includes scan time, latitude, longitude, scan status, quality, incidence angle, sun glint angle, and the intercalibrated brightness temperature (Tc). The granule size is one orbit, which begins and ends at the southernmost point. Overlap scans from the previous and next granule are included in L1C products. However, the number of overlap scans maybe different for each sensor.

A more detailed L1C product description for each sensor is included in the Appendices.

2. ORBITIZATION

The orbitization process reorbitizes and reformats multiple input files into an intermediate base file. The base file is a GPM standard orbital file that begins and ends at the southernmost point. It is written in a base format that preserves all of the information from the input but is written out in HDF.

The purpose of orbitization is to prepare a standard orbital file in the same format for the succeeding L1C intercalibration process. The use of the base file allows the Intercalibration Working Group (X-CAL) to experiment with different intercalibration algorithms without having to read the inputs in several different formats and without having to reorbitize the data.

The orbitization process is needed only when the input files do not conform to the GPM standard orbit format. L1C GMI and L1C TMI processes do not need the orbitization process because their input source files (GMIBASE and TMIBASE, respectively) are already GPM standard orbital files. The major components in the orbitization process include orbit boundary derivation and data reorbitization.

2.1 ORBIT BOUNDARY DERIVATION

The orbit start (and end) point is the instant in time when the satellite reaches the southernmost point in its orbit, independent of where each instrument happens to be pointing at that instant. The southernmost point in orbit was chosen to avoid the undesirable granule boundaries in the tropics, over Japan, and over ground validation (GV) sites (most of which are in the northern hemisphere). The North American Aerospace Defense Command (NORAD) two-line element (TLE) and simplified general perturbations satellite orbit model 4 (SGP4) orbital model was used in the L1C process to derive the orbit boundaries [Hoots and Roehrich, 1980].

2.1.1 Two-Line Element (TLE)

A two-line element set is a set of orbital elements that describe the orbit of an earth satellite. The TLE is in a format specified by NORAD and used by NORAD and the National Aeronautics and

Space Administration (NASA). The TLE can be used directly by the SGP4 model to compute the precise position of a satellite at a particular time.

The following is an example of a TLE:

```
1 25544U 98067A   08264.51782528 -.00002182  00000-0 -11606-4 0  2927
2 25544  51.6416 247.4627 0006703 130.5360 325.0288 15.72125391563537
```

The meaning of these data is as follows:

LINE 1

Field	Columns	Content	Example
1	01-01	Line number	1
2	03-07	Satellite number	25544
3	08-08	Classification (U=Unclassified)	U
4	10-11	International designator (last two digits of launch year)	98
5	12-14	International designator (launch number of the year)	067
6	15-17	International designator (piece of the launch)	A
7	19-20	Epoch year (last two digits of the year)	08
8	21-32	Epoch (day of the year and fractional portion of the day)	264.51782528
9	34-43	First time derivative of the mean motion divided by two	-.00002182
10	45-52	Second time derivative of mean motion divided by six (decimal point assumed)	00000-0
11	54-61	B-Star drag term (decimal point assumed)	-11606-4
12	63-63	The number 0 (originally this should have been “ephemeris type”)	0
13	65-68	Element number	292
14	69-69	Checksum (Modulo 10)	7

LINE 2

Field	Columns	Content	Example
1	01-01	Line number	2
2	03-07	Satellite number	25544
3	09-16	Inclination (degrees)	51.6416
4	18-25	Right ascension of the ascending node (degrees)	247.4627
5	27-33	Eccentricity (decimal point assumed)	0006703
6	35-42	Argument of perigee (degrees)	130.5360
7	44-51	Mean anomaly (degrees)	325.0288
8	53-63	Mean motion (revolutions per day)	15.72125391
9	64-68	Revolution number at epoch (revolutions)	56353
10	69-69	Checksum (Modulo 10)	7

2.1.2 SGP4

The simplified general perturbations satellite orbit model 4 (SGP4) is a NASA/NORAD algorithm that calculates the orbital state vectors of near-earth satellites relative to the Earth Centered Inertial coordinate system. Any satellite with an orbital time of less than 225 minutes should use this algorithm. Satellites with orbital times greater than 225 minutes should use the simplified drag perturbations satellite orbit model 4 (SDP4) or SDP8 algorithms. The significance of choosing 225 minutes for selecting the propagation model (near-earth or deep-space) appears somewhat arbitrary, but it relates to the original range of the NORAD tracking radar system. TLE data should be used as the input for the SGP4 algorithm. The accuracy of SGP4 is typically about 1 km in position. More details about TLE and SGP4 can be found in Spacetrack Report No. 3 [Hoots and Roehrich, 1980].

2.1.3 Daily Orbit Start/Stop Times Generation

Each day, TLEs for satellites of interest (e.g., AQUA, F15, F16, Coriolis, etc.) are obtained automatically from the Spacetrack site, and the TLE data are stored in the PPS database. The ostFinderTLE algorithm, which utilizes the SGP4 model, then is run using these TLE data. The algorithm computes the satellite positions throughout the day and identifies the orbit start/stop times (orbit definition) by searching the times when the satellite reaches the lowest position (in Z component). It then outputs these orbit start/stop times and orbit numbers to an orbit definition file for each orbit identified during the day. These orbit definition data are then registered in the database and can be used in the succeeding data reorbitization process.

The very first orbit definition is created manually by assigning an initial orbit number. After that, the ostFinderTLE will automatically increment the orbit number by one from the previous orbit definition. This process is done only once per day. Once the orbit definition data are created during the initial processing, they will not change during the reprocessing.

2.2 DATA REORBITIZATION

In most cases, it takes two or three input files to create one GPM standard orbit file. This process is done by the L1CBASE algorithms. The inputs to L1CBASE are: Input filenames, orbitNumber, orbitStartDate, orbitStartTime, orbitStopDate, and orbitStopTime. The output is a standard base file; it is standard in the sense that it has been reorbitized to a GPM standard orbit and reformatted into a common HDF format. The base file preserves all information from the input and is used as the input to the succeeding L1C intercalibration algorithms.

The L1CBASE algorithms read multiple input files. For each sensor, the input is in a specific format (binary, NetCDF, HDF, etc.), and therefore different code applying to each format is used to read the input files. The code that reads the input data is provided by each data source and is used in each L1CBASE algorithm. The scan time is used to check whether the current scan data fall within the desired L1C orbit boundary and determine whether it should be written to the output file. The algorithm also checks for missing scans and fills in missing data if found. Overlap scans from the previous and next granule are also included in the output file. An empty granule is generated if no scan was extracted from the input files. Scan data are reformatted into the base file format and written to the output base file using the PPS Science Algorithm Input/Output Toolkit (TKIO).

A minimum of processing, other than reorbitizing and reformatting, is done in the L1CBASE algorithm. This algorithm simply preserves all information from the input data and creates a uniform, standard base file for further L1C processing. The base file is intended to be created once and not need to be reprocessed.

3. SATELLITE INTERCALIBRATION ALGORITHMS

Producing intercalibrated brightness temperature data from different satellites depends on the details of each sensor. The GPM L1C implementation uses GMI as the reference standard.

The physical and mathematical bases of satellite intercalibration are provided separately for each individual sensor in the Appendices by the X-CAL Working Group.

4. QUALITY CONTROL

To ensure the consistency among all L1C algorithms, all data are checked and quality flags are assigned according to the following definition. The following quality flags are set for data of questionable quality. The corresponding brightness temperatures are retained; however, it is advised to use caution with these values.

0 Good.
1 Possible sun glint.
2 Climatology check warning; values near cutoff!

The following quality flags are set for failing catastrophic tests. As a result, in each of these cases the resulting brightness temperatures are set to missing values.

10 Data are missing from file or are unreadable.
20 Geolocation check flagged scan as bad.
30 Climatology check flagged scan as bad.
40 Distance between pixels is nonphysical.
50 Antenna temperatures are < 50K or > 325K.
60 Lat/lon values are out of range.
70 Adjacent/cross-polarized pixel flagged as bad.

The missing values used in L1C algorithms are as follows:

MISSING_FLOAT	-9999.9
MISSING_DOUBLE	-9999.9
MISSING_INT	-9999
MISSING_SHORT	-9999
MISSING_BYTE	-99

Detailed quality control procedures provided by the X-CAL Working Group for each radiometer are discussed in the Appendices.

5. ANCILLARY DATA CALCULATIONS

Various geometric ancillary data such as solar beta angle, earth incidence angle, and sun glint angle are calculated during the L1C process if the input source does not contain such data. The details can be obtained from the PPS GPM Geolocation Toolkit Algorithm Theoretical Basis Document (ATBD).

6. LEVEL 1C PROCESSING

This section documents the software architecture overview and details for Level 1C processing. Level 1C processing is further divided into three steps: 1) orbit boundaries derivation, 2) data reorbitization, and 3) satellite intercalibration.

Not all sensors require all three steps in their L1C processing. For sensors such as GMI and TMI, the input file is already in GPM standard orbital base file format; therefore, processing steps one and two can be omitted.

6.1 ORBIT BOUNDARIES DERIVATION PROCESSING

Orbit boundaries derivation processing processes the ostFinderTLE algorithm. It generates the orbit definition files (also called orbit start/stop times [OST] files) for a given date and satellite. Each orbit definition file contains the start time, stop time, and orbit number for one orbit. Orbit definition data are then registered in the database and to be used in succeeding data reorbitization processing. This processing is done only once per day for each satellite of interest.

6.1.1 Activation

The scheduler spawns the ostFinderTLE executable once per day for each of the satellites.

Command line usage:

ostFinderTLE jobName inputParameterFile

jobName – A given string assigned to this job.
inputParameterFile – A text file that lists all the input parameters using “key=value” format.

The following is an example of the inputParameterFile:

```
satID=AQUA
date=2010-05-12
TLE1= 1 27424U 02022A   10132.81341700 +.00000131 +00000-0 +39133-4 0 0637
TLE2= 2 27424 098.1870 074.7138 0001078 121.1285 239.0040 14.5711775142676
preOrbitNumber=42664
```

```
preOrbitStartDate=2010-05-11
preOrbitStartTime=21:41:04
preOrbitStopDate=2010-05-11
preOrbitStopTime=23:19:57
outputDir=/someDirectory/ost/aqua/
maxDays=5
```

Input parameters:

satID – Satellite ID.
Date – Date in YYYY-MM-DD format.
TLE1 – Line 1 of the nearest TLE.
TLE2 – Line 2 of the nearest TLE.
preOrbitNumber – Previous orbit number.
preOrbitStartDate – Start date of previous orbit in YYYY-MM-DD format.
preOrbitStartTime – Start time of previous orbit in HH:MM:SS format.
preOrbitStopDate – Stop date of previous orbit in YYYY-MM-DD format.
preOrbitStopTime – Stop time of previous orbit in HH:MM:SS format.
outputDir – Directory path for the output orbit definition files.
maxDays – The number of days allowed for missing payloads.

Output files:

The outputs of ostFinderTLE are orbit definition files for all of the orbits found during the given date. Orbit definition files are in Extensible Markup Language (XML) format and are to be used for registering orbit information in the database. The following is an example of orbit definition file (ost.aqua.20100512.dat):


```
<ost:orbitStartTimes
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="OST.xsd">

    <dBData>
        <dBChange>
            <dBTable>OrbitInfo</dBTable>
            <dBAction>insert</dBAction>
            <dBKey>
                <dBField>SeqNo</dBField>
                <dBValue>42665</dBValue>
            </dBKey>
            <dBKey>
                <dBField>Platform</dBField>
                <dBValue>AQUA</dBValue>
            </dBKey>
            <dBEntry>
                <dBField>StartTime</dBField>
```

```
            <dBValue>2010-05-11 23:19:58</dBValue>
        </dBEntry>
        <dBEntry>
            <dBField>StopTime</dBField>
            <dBValue>2010-05-12 00:58:50</dBValue>
        </dBEntry>
        <dBEntry>
            <dBField>LongOfMaxLat</dBField>
            <dBValue>-39.959433</dBValue>
        </dBEntry>
    </dBChange>
    <dBChange>
       :  (for next orbit)
    </dBChange>
     :
  </dBData>
</ost:orbitStartTimes>
```

6.1.2 Execution

The flow chart for executing the ostFinderTLE program is shown in Figure 1.

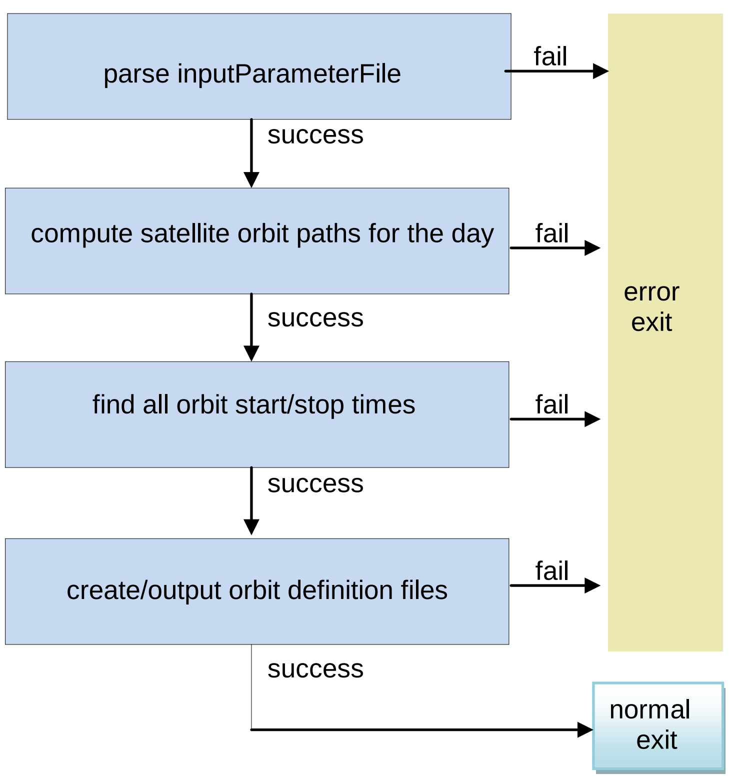

Figure 1. Flow Chart for Executing the ostFinderTLE Program

6.1.3 Termination

When ostFinderTLE finishes execution, successfully or otherwise, it passes a return code to the scheduler and stops. The return code tells the scheduler the reason for termination. The following return states are defined:

- 1 Problem reading input (i.e., no orbit definition file created).
- 2 Problem creating output (i.e., no orbit definition file created).
- 0 Normal termination (i.e., orbit definition files created).

6.2 DATA REORBITIZATION PROCESSING

Data reorbitization processing processes the L1CBASE algorithms. It reorbitizes and reformats multiple input files into one standard GPM base file for each radiometer of interest in the GPM Constellation. Each radiometer has a different executable for the reorbitization processing. Current L1CBASE algorithms include L1CBASEssmi, L1CBASEamsre, L1CBASEssmis, and L1CBASEwind. More will be added when more satellites join the constellation. However, all L1CBASE algorithms follow the same procedure and have the same command line usage.

6.2.1 Activation

The scheduler spawns the L1CBASE program, for example L1CBASEssmi for SSMI, as an autonomous process upon the availability of input granules. The scheduler passes it several input parameters as follows:

- Job name assigned by scheduler.
- Granule IDs of the input files.
- Granule ID of the L1CBASE granule that is to contain the output data.
- Orbit number for the output granule.
- Orbit start date in YYYY-MM-DD format.
- Orbit start time in HH:MM:SS format.
- Orbit stop date in YYYY-MM-DD format.
- Orbit stop time in HH:MM:SS format.

6.2.2 Execution

The flow chart for executing the L1CBASE program is shown in Figure 2.

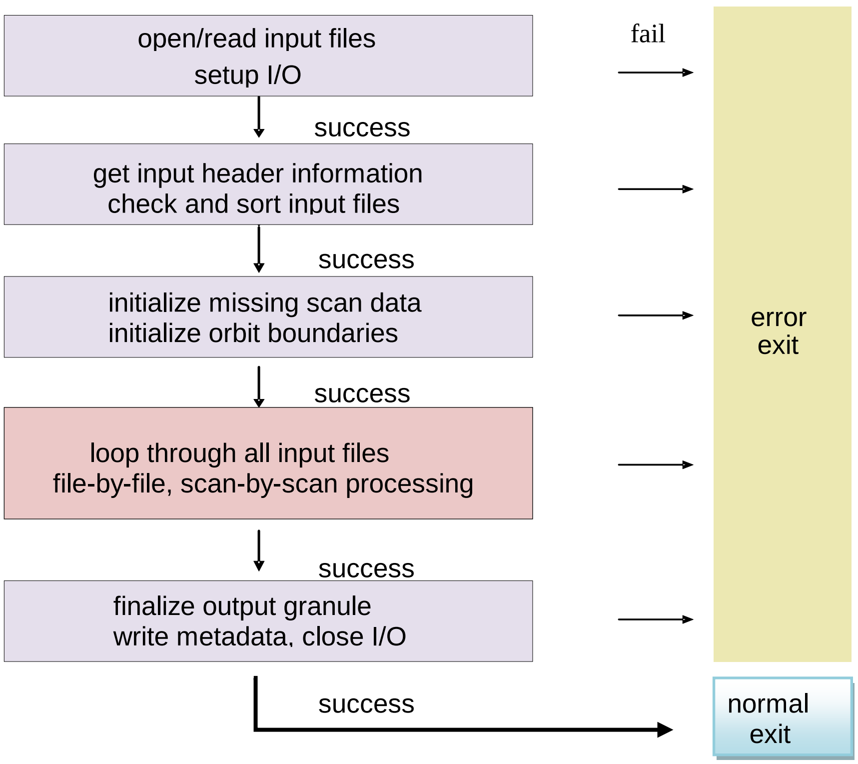

Figure 2. Flow Chart for Executing the L1CBASE Program

The flow chart for executing the file-by-file, scan-by-scan process is shown in Figure 3. If unsuccessful, the program exits with an error report.

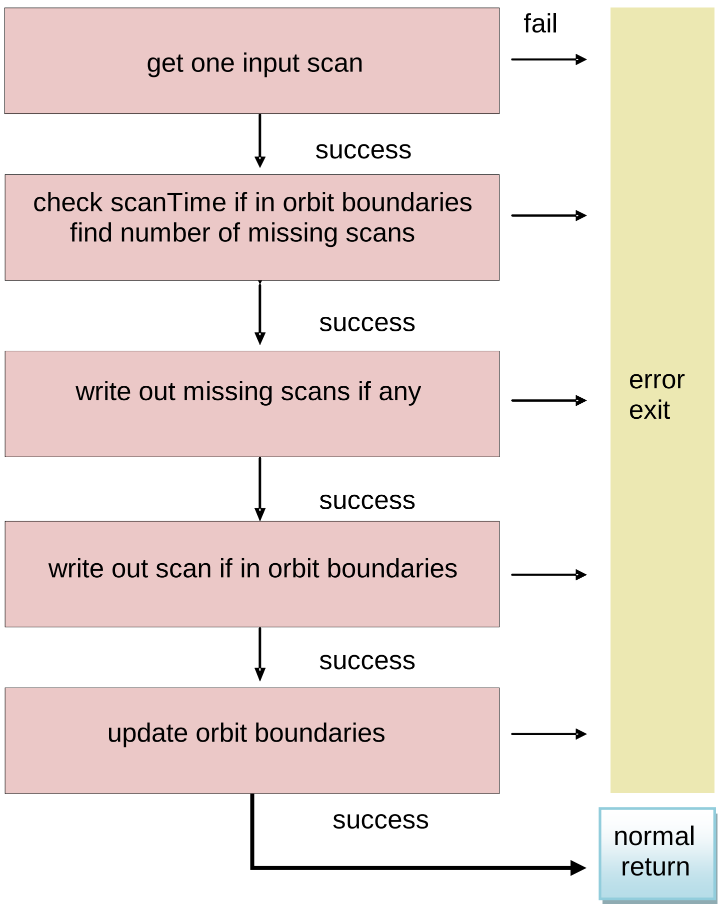

Figure 3. Flow Chart for Executing the L1CBASE File-by-File, Scan-by-Scan Processing

6.2.3 Termination

When L1CBASE finishes execution, successfully or otherwise, it passes a return code to the scheduler and stops. The return code tells the scheduler the reason for termination. The following return states are defined as follows:

- 1 Problem reading input (i.e., no L1CBASE created).
- 2 Problem creating output (i.e., no L1CBASE created).
- 9 Empty granule created (i.e., L1CBASE created, but it is an empty granule).
- 0 Normal termination (i.e., L1CBASE created).

6.3 INTERCALIBRATION PROCESSING

Intercalibration processing processes the L1CXCAL algorithms. It performs satellite intercalibration and quality control and creates the L1C products for the GPM Core and Constellation satellites. Each sensor has a different executable for the L1C intercalibration processing. Current L1C includes L1CXCALgmi, L1CXCALtmi, L1CXCALssmi, L1CXCALamsre, L1CXCALssmis, and L1CXCALwind. However, all L1CXCAL algorithms follow the same procedure and have the same command usage.

6.3.1 Activation

The scheduler spawns the L1CXCAL program, for example L1CXCALgmi for GMI, as an autonomous process upon the availability of the input GMIBASE granule. The scheduler passes it several parameters as follows:

- Job name assigned by scheduler.
- Granule ID of the input base granule.
- Granule ID of the L1C granule that is to contain the output data.
- Optional directory path to the static data files needed during processing.

6.3.2 Execution

The flow chart for executing the L1CXCAL program is shown in Figure 4.

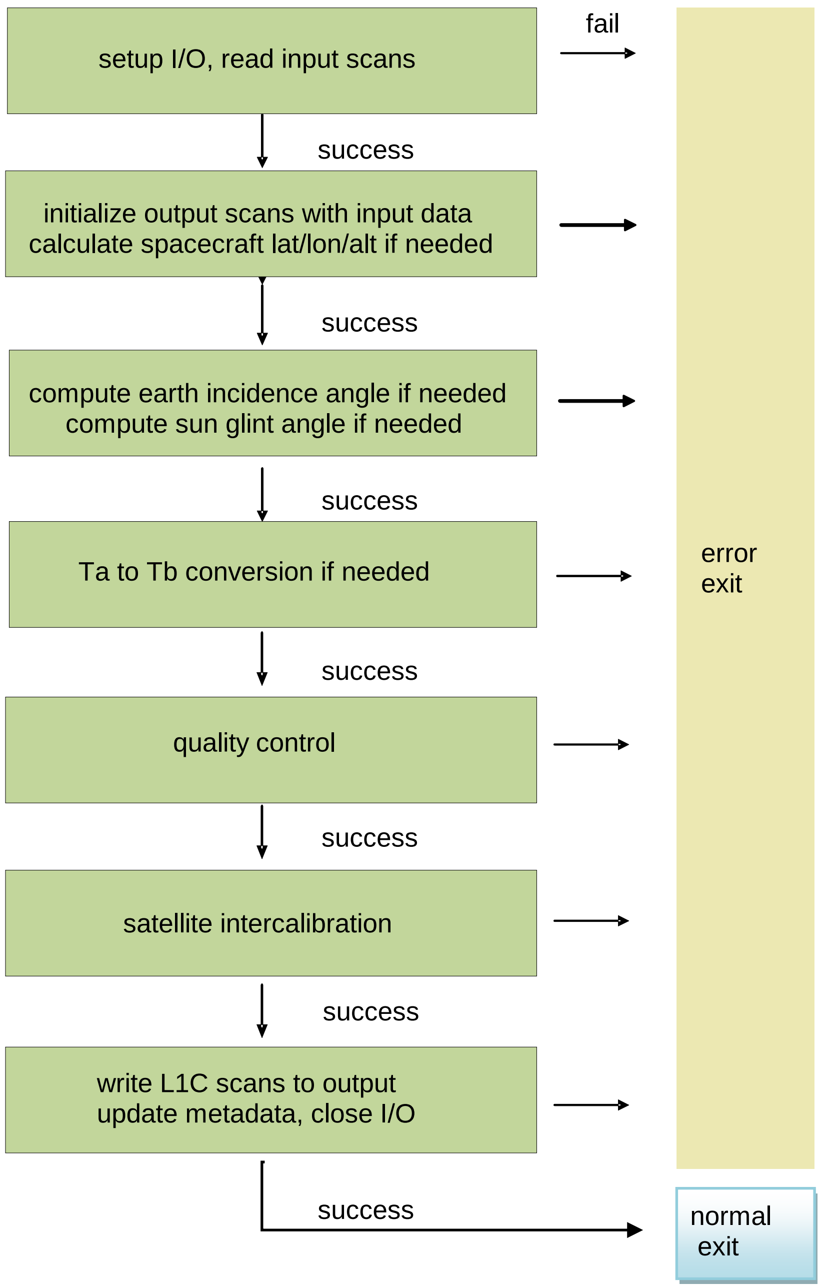

Figure 4. Flow Chart for Executing the L1CXCAL Program

6.3.3 Termination

When L1CXCAL finishes execution, successfully or otherwise, it passes a return code to the scheduler and stops (ceasing to exist as a spawned process). The return code specifies the reason for termination to the scheduler. The following return states are defined:

- 1 Problem reading input (i.e., no L1C created).
- 2 Problem creating output (i.e., no L1C created).
- 9 Empty granule created (i.e., L1C created, but it is an empty granule).
- 0 Normal termination (i.e., L1C created).

6.3.4 Static Data Files

Various algorithms within the Level 1C intercalibration processing require a handful of parameters. The values are set manually to some initial values (during prelaunch software development) and will possibly be changed by scientists throughout the mission depending on observation of the algorithm performance and external physical changes. A list of these static data files can be obtained in the Appendices for each sensor.

7. REFERENCES

1. Hoots, F. R., and Roehrich, R. L., 1980: Spacetrack Report No. 3: Models for Propagation of NORAD Element Sets, December 1980.

APPENDIX A. L1C GMI

A.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C GMI algorithm.

A.1.1 L1C GMI Input Data Description

The GPM Microwave Imager L1C product is derived from GPM GMIBASE data. GMIBASE contains GMI antenna temperatures (Ta) and is in HDF format. Details about the data content and format can be obtained from the GPM PPS GMIBASE File Specification Document.

A.1.2 L1C GMI Product Description

1CGMI contains common calibrated brightness temperatures from the GMI passive microwave instrument flown on the GPM satellite. 1CGMI has two swaths and 50 overlapping scans before and after the granule.

Swath S1 has nine channels that are similar to TRMM TMI (10V 10H 19V 19H 23V 37V 37H 89V 89H). Swath S2 has four channels similar to the Advanced Microwave Sounding Unit – B (AMSU-B) (165V 165H 183+/-3V 183+/-8V). Data for both swaths are observed in the same revolution of the instrument.

Earth observations are taken during a segment of the rotation when GMI is looking in the +x direction of the GPM satellite. Since the spacecraft turns around every few weeks, +x may be forward or aft. We define the spacecraft axis v, used in the definition of the variable SCorientation, at the center of this segment and the same as the +x direction.

32rpm * 1min/60s * 5538s/orbit = 2954 scans/orbit.

Relation between the swaths: Swath S2 has the same number of scans and the same number of pixels as swath S1. Each S1 scan contains nine channels sampled 202 times along the scan. Each S2 scan contains four channels sampled 202 times along the scan. Since the incidence angle of swath S1 is different than swath S2, the geolocations of the pixel centers are different.

Details about the data content and format can be obtained from the GPM PPS 1CGMI File Specification Document.

A.2 ORBITIZATION

No orbitization process was done to the input source (GMIBASE) since it is already a GPM orbital base file.

A.3 SATELLITE INTERCALIBRATION

A.3.1 Ta to Tb Conversion

Corrections of the calibrated antenna temperatures are performed to transform calibrated antenna temperature to brightness temperature. The antenna temperature of each pixel is corrected for the co-polarization, cross-polarization, and spillover effects of the antenna. The brightness temperature (Tb) will be derived from Equation:

$$\mathbf{T_b = C_n T_a + D_n T_a^* + E_n}$$

$\mathbf{T_a^*}$: Antenna temperature of cross-polarized channel of the $\mathbf{T_a}$

$\mathbf{C_n}$, $\mathbf{D_n}$, and $\mathbf{E_n}$: Antenna pattern correction (APC) coefficients are derived from in-flight simulation using radiative transfer models with antenna patterns as well as a global database. The APC coefficients will be provided by Ball Aerospace or the GPM Intercalibration Working Group (X-CAL).

The above correction procedures are identical to the procedures used in the GMI L1B algorithm.

A.3.2 Satellite Intercalibration

The GPM GMI brightness temperatures have been defined as the calibration reference for the GPM constellation. As a result, no changes were made to the GMI brightness temperature (Tb).

A.4 QUALITY CONTROL

The following quality control procedures were implemented for GMI.

1. Scan check for missing scan: Missing scans are flagged and all pixel values are set to missing.
2. Scan check for bad geolocation quality: Scans with dataQuality != 0 are flagged and all pixel values are set to missing.
3. Pixel check for nonphysical values: Checks that individual brightness temperature values are within physical limits (currently 50K to 325K), and lat/lon values are within range (-90 to 90 and -180 to 180). Pixels outside range are flagged accordingly and set to missing.
4. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

A.5 STATIC DATA FILES

Table A-1 summarizes the current list of static data files used in the L1CXCALgmi algorithm.

Table A-1. List of Static Data Files for L1C GMI

File Name	Description
APC-Coef.dat	Antenna pattern correction coefficients

A.6 REFERENCES

1. PPS GPM GMIBASE File Specification.
2. PPS GPM 1CGMI File Specification.
3. PPS GPM GMI L1B Algorithm Theoretical Basis Document (ATBD).

APPENDIX B. L1C TMI

B.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C TMI algorithm.

B.1.1 L1C TMI Input Data Description

The TMI L1C product is derived from the TRMM TMIBASE data. TMIBASE contains TMI radiometric calibrated antenna temperatures (Ta) and is in HDF format. Details about the data content and format can be obtained from the GPM PPS TMIBASE File Specification Document.

B.1.2 L1C Product Description

1CTMI contains common calibrated brightness temperatures from the TMI passive microwave instrument flown on the TRMM satellite. 1CTMI has two swaths and 50 overlapping scans before and after the granule.

Swath S1 has seven low-resolution channels (10V 10H 19V 19H 21V 37 37H). Swath S2 has two high-resolution channels (85V 85H). Data for both swaths are observed in the same revolution of the instrument. Earth observations are taken during a segment of the rotation when TMI is looking in the + × direction of the TRMM satellite. Since the spacecraft turns around every few weeks, + × may be forward or aft. We define the spacecraft axis v, used in the definition of the variable SCorientation, at the center of this segment and the same as the + × direction.

Relation between the swaths: Swath S2 has the same number of scans but twice as many pixels as swath S1. Each S1 scan contains low-frequency channels sampled 104 times along the scan. Each S2 scan contains high-frequency channels sampled 208 times along the scan. S1 and S2 scans are repeated every 1.9s. Along an S1 scan, every other center of an S2 pixel coincides with the center of an S1 pixel. L1CTMI has 50 overlapping scans before and after the granule.

Figure B-1 shows the locations of the centers of pixels of scans 1 and 2 for both swaths in mid-scan. The shaded circles represent the centers of low-frequency pixels of swath S1. The black dots represent the centers of high-frequency pixels of swath S2.

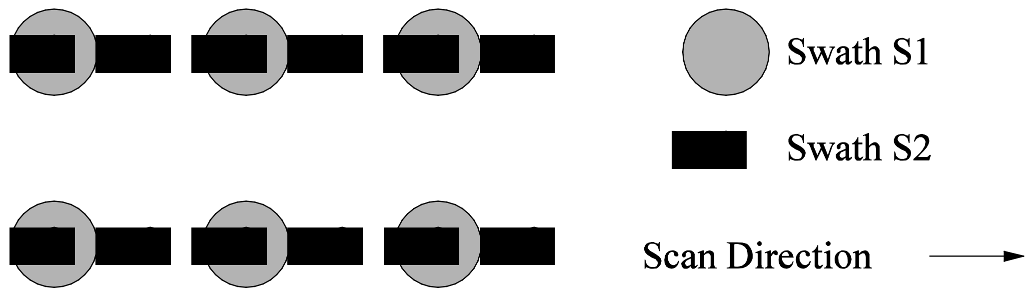

Figure B-1. Relation Between Swaths for L1C TMI

Details about the data content and format can be obtained from the GPM PPS 1CTMI File Specification Document.

B.2 ORBITIZATION

No orbitization process was done to the input source (TMIBASE) since it is already a GPM orbital base file.

B.3 SATELLITE INTERCALIBRATION

B.3.1 Ta to Tb Conversion

The procedures to transform calibrated TMI antenna temperature to brightness temperature are identical to the procedures used in the TRMM V7 TMI L1B algorithm. For details, please refer to the TRMM TMI L1B Algorithm Theoretical Basis Document (ATBD).

B.3.2 Satellite Intercalibration

The TRMM TMI brightness temperatures have been defined as the calibration reference for the current L1C prototype. As a result, no changes were made to the TMI brightness temperatures (Tb).

B.4 QUALITY CONTROL

The following quality control procedures were implemented for TMI.

1. Scan check for missing scan: Missing scans are flagged and all pixel values are set to missing.
2. Scan check for bad geolocation quality: Scans with dataQuality != 0 are flagged and all pixel values are set to missing.
3. Pixel check for nonphysical values: Checks that individual brightness temperature values are within physical limits (currently 50K to 325K), and lat/lon values are within range (-90 to 90 and -180 to 180). Pixels outside range are flagged accordingly and set to missing.

4. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

B.5 STATIC DATA FILES

Table B-1 summarizes the current list of static data files used in L1CXCALtmi algorithm.

Table B-1. List of Static Data Files for L1C TMI

File Name	Description
Tmi_tuning.dat	TMI tuning parameters, antenna correction coefficients
table_yaw0_standard.txt	Solar beta angle correction coefficients
table_yaw180_standard.txt	Solar beta angle correction coefficients

B.6 REFERENCES

1. PPS GPM TMIBASE File Specification.
2. PPS GPM 1CTMI File Specification.
3. PPS TRMM TMI L1B Algorithm Theoretical Basis Document (ATBD).

APPENDIX C. L1C SSMI

C.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C SSMI algorithm.

C.1.1 L1C SSMI Input Data Description

The source for the Special Sensor Microwave Imager (SSMI) L1C product is the Temperature Data Record (TDR) data produced by the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC). The TDR data are archived and publicly available from the National Oceanic and Atmospheric Administration's (NOAA's) Comprehensive Large Array-Data Stewardship System (CLASS). The TDR data contain antenna temperatures and are in binary format. Details about the data content and format can be obtained from the Special Sensor Microwave Imager (SSM/I) Data Requirements Document DRD for FNOC.

C.1.2 L1C SSMI Product Description

1CSSMI contains common calibrated brightness temperature from the SSMI passive microwave instruments flown on the Defense Meteorological Satellite Program (DMSP) satellites. The 1CSSMI product has two swaths and 10 overlapping scans before and after the granule.

Swath S1 has five low-frequency channels (19V 19H 22V 37V 37H). Swath S2 has two high-frequency channels (85V 85H). Earth observations for both swaths are taken during a 102.4° segment of the instrument rotation when SSMI is looking in the aft direction from satellite F8 or the forward direction from satellites F10 – F15. We define the spacecraft vector (v) at the center of this segment. "v" is used in the definition of the variable SCorientation.

Relation between the swaths: Each S1 scan contains low-frequency channels sampled 64 times along the scan. Each S2 scan contains high-frequency channels sampled 128 times along the scan. Swath S2 has exactly twice as many scans as swath S1. S1 scans 1, 2, 3, ... coincide with S2 scans 1, 3, 5, ... S1 scans are repeated every 3.8s; S2 scans are repeated every 1.9s. Along an S1 scan, every other center of an S2 sample coincides with the center of an S1 sample.

Figure C-1 shows the locations of the centers of the first few samples of swath S1 scans 1-2 and swath S2 scans 1-4. The shaded circles represent the centers of low-frequency samples of swath S1. The black dots represent the centers of high-frequency samples of swath S2.

Details about the product content and data format can be obtained from the GPM PPS 1CSSMI File Specification Document.

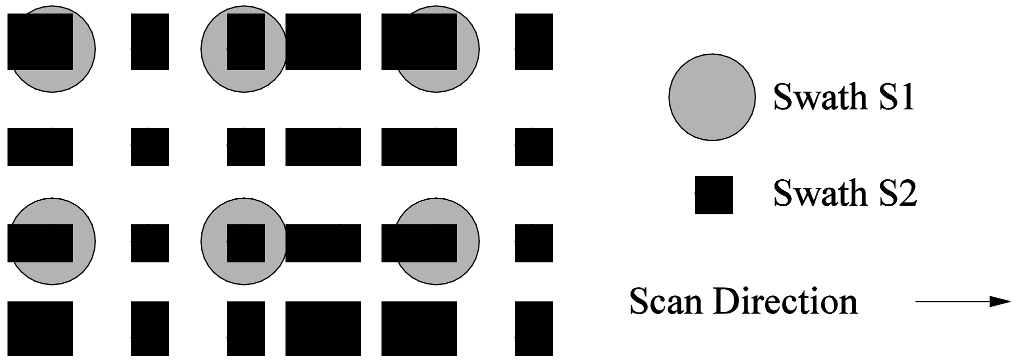

Figure C-1. Relation Between Swaths for L1C SSMI

C.2 ORBITIZATION

Orbitization processing was first done to the input SSMI TDR files to reorbitize and reformat them into the GPM standard orbital base file (SSMIBASE). The resulting SSMIBASE file is then used as input to the satellite intercalibration process.

C.3 SATELLITE INTERCALIBRATION

The following sections describe the physic basis of SSMI intercalibration. All information was provided by Christian Kummerow and Wesley Berg of the Colorado State University.

C.3.1 Cross-Track Bias Correction

It has been determined that the glare suppression system-B (GSS-B) scatters cosmic background energy into the SSMI field-of-view (FOV) [Colton and Poe, 1999]. While this primarily affects those FOVs towards the end of the scan, the impact is significant, resulting in a falloff of up to several Kelvin. Colton and Poe [1999] also note that there is a possible falloff at the beginning of the scan due to side-lobe energy from the reflective spacecraft surface. Colton and Poe [1999] suggest that this energy loss towards the end of the scan can be corrected for by multiplying the antenna pattern correction coefficients by a pixel-dependent factor, defined as unity plus the ratio of the deviations at each beam position normalized to the average brightness temperature of the central uncontaminated beam positions.

Mean cross-track bias correction coefficients were computed for each satellite using a full 2 years of data. In computing the bias coefficients, a liberal land mask was applied to the data to remove any land influence, and the data poleward of 60 degrees were eliminated. This was done to avoid the impact of sea ice, as well as a latitudinal bias on one end of the scan as the sensor passed near the poles. It was decided to compute the cross-track bias values based on the antenna temperatures.

C.3.2 Ta to Tb Conversion

The antenna pattern correction procedure described by Colton and Poe [1999] was used to convert the antenna temperatures to brightness temperatures. There is a modification to the coefficients provided by Colton and Poe [1999]; however, the coefficients for F13 also have been used for F14 and F15. This was done to maintain compatibility with the FNMOC processing. As a result, the brightness temperatures have been verified to exactly match those in the FNMOC Sensor Data Record (SDR) files. The rationale for the change in the F14 and F15 coefficients was provided by Gene Poe. The coefficients are stored in apc.dat file.

C.3.3 Satellite Intercalibration

The analysis of SSMI intersatellite differences by Colton and Poe [1999] revealed relatively small differences in antenna temperatures, but differences in the brightness temperatures of more than a Kelvin for some channels. Because the Goddard profiling (GPROF) retrieval algorithm is sensitive to differences in brightness temperatures, we attempt to remove these intersatellite biases by calibrating the SSMI brightness temperatures to TMI.

To accomplish this, we created a database of crossover matches between the TRMM TMI and SSMI sensors (including F11, F13, F14, and F15) during the period from January 1998 through June 2001. This range mostly covers the period between the TRMM launch and the boost of the satellite to a higher orbit, which occurred in July 2001. While this provided a total of 42 months of matches for F13 and F14, F11 died in May 2000, and data from F15 were not available until February 2000. This resulted in a total of 29 coincident months for F11 and 17 months for F15, which still provided a substantial number of matches. Using only crossovers occurring within 10 minutes resulted in a large number of samples (F11-3672, F13-6747, F14-6628, and F15-2563). Next, a 350 km radius from the intersection between the two swaths was used to define the matchup region. Within this region, the closest TMI pixel was found for each SSMI pixel, resulting in nearly 500 pixel matches for a single crossover. Only open ocean pixels were used. A liberal land mask was used to avoid the influence of land/coastlines. Figure C-2 shows an example of a crossover between the two satellites with TMI pixels indicated in red and the lower resolution SSMI pixels indicated in blue.

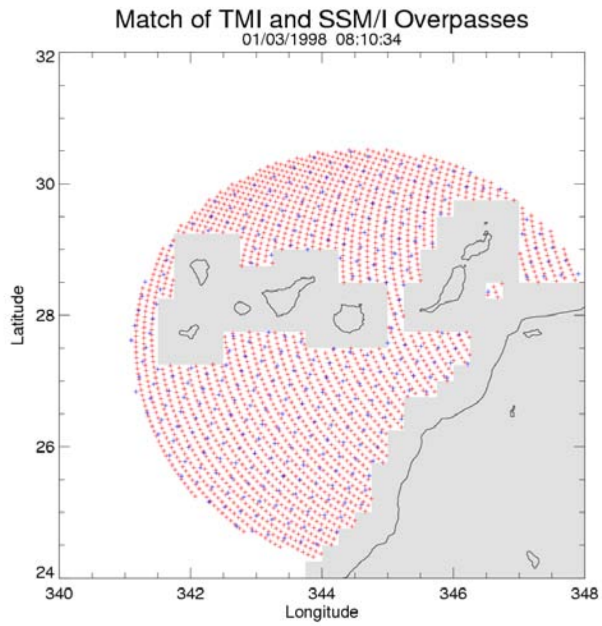

Figure C-2. Crossover Matches Between the TRMM TMI and SSMI Sensors

Mean brightness temperatures were computed from the TMI and SSMI matches and binned into 2-degree bins based on the TMI brightness temperatures. In addition, 3x3 and 5x5 pixel TMI averages were computed to determine the impact of beam filling differences on the larger SSMI footprint. Although slight differences in aspects such as the geolocation, center of the TMI and SSMI pixels, and viewing geometry impact the matches, the large number of pixel matches reduces the impact of random variations such as these to negligible values.

Although the TMI sensor is very similar to the SSMI sensors, differences in the earth incidence angle, the spatial resolution, and the frequency of the water vapor channel (i.e., 22.235 GHz for SSMI vs. 21.3 GHz for TMI) mean that properly calibrated sensors will still produce slightly different brightness temperatures, especially for the water vapor channel. To address this, radiative transfer simulations from the two sensors were computed using clear-sky retrievals and hydrometeor profiles derived from the TRMM precipitation radar (PR). Different values were computed for each of the SSMI sensors due to slight variations in the mean earth incidence angle, which are the result of slight altitude variations as well as slight differences in the spacecraft attitude. The following values for the mean earth incidence angle were obtained from Colton and Poe [1999], except for the F15 value, which was provided by Gene Poe [personal communication].

F11	F13	F14	F15
53.29	52.94	53.25	53.00

Table C-1 contains the offset calibration values for each of the four SSMI sensors and each of the seven channels used in the Level 1C data product. Note that these calibration values are added to the SSMI brightness temperatures after the QC, cross-track bias correction, and antenna pattern correction (Ta to Tb) have been applied. As a result, it is possible for the user to remove the bias correction. Based on the following table, a calibration of all the SSMI sensors to F15, for example, would be relatively easy to implement.

Table C-1. Offset Calibration Values for L1C SSMI

Sat	**19V**	**19H**	**22V**	**37V**	**37H**	**85V**	**85H**
F11	-0.8	-2.1	-1.5	-0.3	-1.5	-1.4	-2.8
F13	-1.3	-2.1	-1.9	-1.2	-2.2	-0.8	-1.3
F14	-1.2	-1.7	-1.8	-1.8	-2.0	-0.9	-1.3
F15	-0.1	-1.9	-1.2	-0.9	-1.8	-0.1	-0.8

C.4 QUALITY CONTROL

There are significant issues with the TDR data resulting in nonphysical antenna temperatures, mislocated scans, and geolocation problems. Unless these bad data are eliminated, they can result in significant errors in the rainfall estimates. To address this issue, a number of quality control procedures were implemented.

1. Pixel check for nonphysical values: Checks that individual antenna temperature values are within physical limits (currently 50K to 325K), that lat/lon values are within range (-90 to 90 and -180 to 180), and that the distance between pixels along a scan is reasonable (10 km to 30 km).
2. Scan check for nonphysical separation: Checks that the distance between adjacent scans (nadir point) is between 20 km and 30 km. Scans outside of this range are flagged and are currently eliminated (set to missing value).
3. Scan check for deviations from climatology: Compares the antenna temperatures for each channel along the scan to climatological values. If more than 30% of the pixels along a given scan are greater outside the range of the mean climatological Ta +/- 3 sigma, and this represents a change of 30% or more from the prior scan, the scan is flagged and eliminated (set to missing value).
4. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

C.5 STATIC DATA FILES

Table C-2 summarizes the current list of static data files used in L1CXCALssmi algorithm.

Table C-2. List of Static Data Files for L1C SSMI

File Name	Description
CLIM01.grd	Tb climatology file for Jan
CLIM02.grd	Tb climatology file for Feb
CLIM03.grd	Tb climatology file for Mar
CLIM04.grd	Tb climatology file for Apr
CLIM05.grd	Tb climatology file for May
CLIM06.grd	Tb climatology file for June
CLIM07.grd	Tb climatology file for July
CLIM08.grd	Tb climatology file for Aug
CLIM09.grd	Tb climatology file for Sep
CLIM10.grd	Tb climatology file for Oct
CLIM11.grd	Tb climatology file for Nov
CLIM12.grd	Tb climatology file for Dec
apc.dat	Antenna pattern correction coefficients
cal.dat	Tb calibration coefficients
f10_ctb.dat	Cross-track bias correction coefficients for F10
f11_ctb.dat	Cross-track bias correction coefficients for F11
f13_ctb.dat	Cross-track bias correction coefficients for F13
f14_ctb.dat	Cross-track bias correction coefficients for F14
f15_22v_radcal.dat	Radcal adjustment coefficients for F15 22V
f15_85h_radcal.dat	Radcal adjustment coefficients for F15 85H
f15_ctb.dat	Cross-track bias correction coefficients for F15

C.6 REFERENCES

1. Colton, M. C., and Poe, G. A., 1999: Intersensor Calibration of DMSP SSMIs: F8 to F-14, 1987-1997, IEEE Trans. Geosci. Rem. Sens., 37, 418-439.
2. Hollinger, J., DMSP Special Sensor Microwave/Imager Calibration/Validation, Naval Research Laboratory, Washington, D.C., Vol. 2, May 20, 1991.
3. Hollinger, J., Lo, R., and Poe, G., Special Sensor Microwave/Imager User's Guide, Naval Research Laboratory, Washington, D.C., Sep. 14, 1987.
4. Hollinger, J., DMSP Special Sensor Microwave/Imager Calibration/Validation, Naval Research Laboratory, Washington, D.C., Vol. 1, July 20, 1989.
5. Special Sensor Microwave Imager (SSM/I) Data Requirements Document (DRD) for FNOC.
6. PPS GPM SSMIBASE File Specification.
7. PPS GPM 1CSSMI File Specification.

APPENDIX D. L1C SSMI/S

D.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C SSMI/S algorithm.

D.1.1 L1C SSMI/S Input Data Description

The source for the Special Sensor Microwave Imager/Sounder (SSMI/S) L1C data is the Sensor Data Record (SDR) data produced by the Navy's FNMOC. The SDR data are archived and publicly available from NOAA's Comprehensive Large Array-Data Stewardship System (CLASS). The SDR data contain brightness temperatures and are in binary format. Details about the data content and format can be obtained from the Interface Design Document for the Special Sensor Microwave Imager/Sounder (SSMI/S) Ground Processing Software.

D.1.2 L1C SSMI/S Product Description

L1CSSMIS contains common calibrated brightness temperature from the SSMI/S passive microwave instruments flown on the DMSP satellites. L1CSSMIS has two swaths and 20 overlapping scans before and after the granule.

Swath S1 has five low-frequency channels (19V 19H 22V 37V 37H). Swath S2 has six high-frequency channels (91V 91H 150H 183+/-1H 183+/-3H 183+/-7H). All of the above frequencies are in GHz. Earth observations for both swaths are taken during a 144° segment of the instrument rotation when SSMI/S scans in the direction of forward satellite motion. We define the spacecraft vector (v) at the center of this segment; "v" is used in the definition of the variable SCorientation.

Relation between the swaths: Each S1 scan contains low-frequency channels sampled 90 times along the scan. Each S2 scan contains high-frequency channels sampled 180 times along the scan. Swath S2 has exactly the same number of scans as swath S1. Both S1 and S2 scans repeat every 1.9s. S1 and S2 alternate in earth position along the satellite track. The locations of the S1 pixels do not match the locations of the S2 pixels.

Figure D-1 shows the locations of the centers of the first few samples of swath S1 scans 1-2 and swath S2 scans 1-2. The shaded circles represent the centers of low-frequency samples of swath S1. The black dots represent the centers of high-frequency samples of swath S2.

Details about the product content and data format can be obtained from the GPM PPS 1CSSMIS File Specification Document.

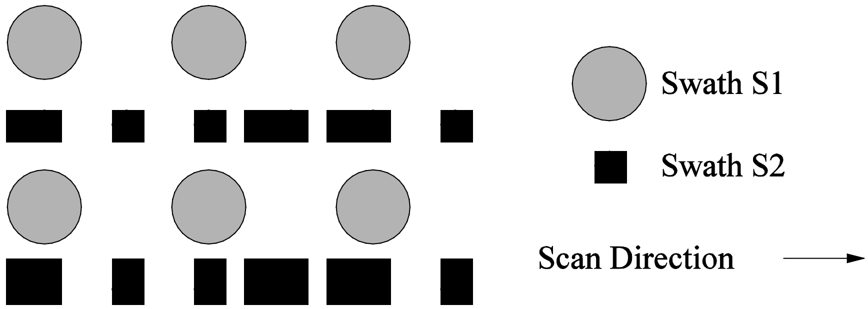

Figure D-1. Relation Between Swaths for L1C SSMI/S

D.2 ORBITIZATION

Orbitization processing was first done to the input SSMI/S SDR files to reorbitize and reformat them into the GPM standard orbital base file (SSMISBASE). The resulting SSMISBASE file is then used as input to the satellite intercalibration process.

D.3 SATELLITE INTERCALIBRATION

No intercalibration has been performed. This means that the Level 1C calibration is identical to the source data, which are the FNMOC SSMI/S SDR brightness temperature data.

D.4 QUALITY CONTROL

The following quality control procedures were implemented for SSMI/S.

1. Scan check for missing scan: Missing scans are flagged and all pixel values are set to missing.
2. Pixel check for nonphysical values: Checks that individual brightness temperature values are within physical limits (currently 50K to 325K), and lat/lon values are within range (-90 to 90 and -180 to 180). Pixels outside range are flagged accordingly and set to missing.
3. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

D.5 STATIC DATA FILES

TBD

D.6 REFERENCES

1. Interface Design Document for the Special Sensor Microwave Imager/Sounder (SSMI/S) Ground Processing Software.
2. PPS GPM SSMISBASE File Specification.
3. PPS GPM 1CSSMIS File Specification.

APPENDIX E. L1C AMSR-E

E.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C AMSR-E algorithm.

E.1.1 L1C AMSR-E Input Data Description

The source for the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) L1C product is the AMSR-E Level 1B data produced by the Japan Aerospace Exploration Agency (JAXA). The data contain brightness temperatures and are in HDF format. Details about the data content and format can be obtained from the AMSR-E Level 1 Product Format Description Document.

E.1.2 L1C AMSR-E Product Description

L1CAMSRE contains common calibrated brightness temperature from the AMSR-E passive microwave instrument flown on the AQUA satellite. L1CAMSRE has three swaths and 50 overlapping scans before and after the granule.

Swath S1 has 10 low-frequency channels (6V 6H 10.65V 10.65H 18.7V 18.7H 23.8V 23.8H 36.5V 36.5H). Swath S2 has two high-frequency A channels (89V 89H). Swath S3 has two high-frequency B channels (89V 89H). Data for all three swaths are observed in the same revolution of the instrument. High-frequency A and high-frequency B data are observed in separate feed-horns.

Earth observations for all three swaths are taken during a 122° segment of the instrument rotation when AMSR-E is looking in the forward direction. We define the spacecraft vector (v) at the center of this segment. “v” is used in the definition of the variable SCorientation.

Relation between the swaths: Each S1 scan contains low-frequency channels sampled 196 times along the scan. Each S2 scan contains high-frequency A channels sampled 392 times along the scan. Each S3 scan contains high-frequency B channels sampled 392 times along the scan. Both swath S2 and swath S3 have exactly twice as many pixels as swath S1. S1 pixels 1, 2, 3, ... coincide with S2 pixels 1, 3, 5, ... S1, S2, and S3 scans are repeated every 1.5s and the scans of one swath are about 10 km apart along the direction of the satellite track. Along an S1 scan, every other center of an S2 pixel coincides with the center of an S1 pixel, but the S3 pixels are offset from S1 and S2 pixels by 15 km in the direction normal to the scan direction on the aft side; in other words, S3 pixels are 15 km “behind” the S1 and S2 pixels for the same scan.

Figure E-1 shows the locations of the centers of pixels of scans 1 and 2 for all three swaths in mid-scan. The shaded circles represent the centers of low-frequency samples of swath S1. The black dots represent the centers of high-frequency A samples of swath S2. The striped dots represent the centers of high-frequency B samples of swath S3. The annotation labels each swath and scan. For example, S1:1, S2:1 means the row of pixels to the left is both swath S1 scan 1 and swath S2 scan 1.

Details about the product content and data format can be obtained from the GPM PPS 1CAMSRE File Specification Document.

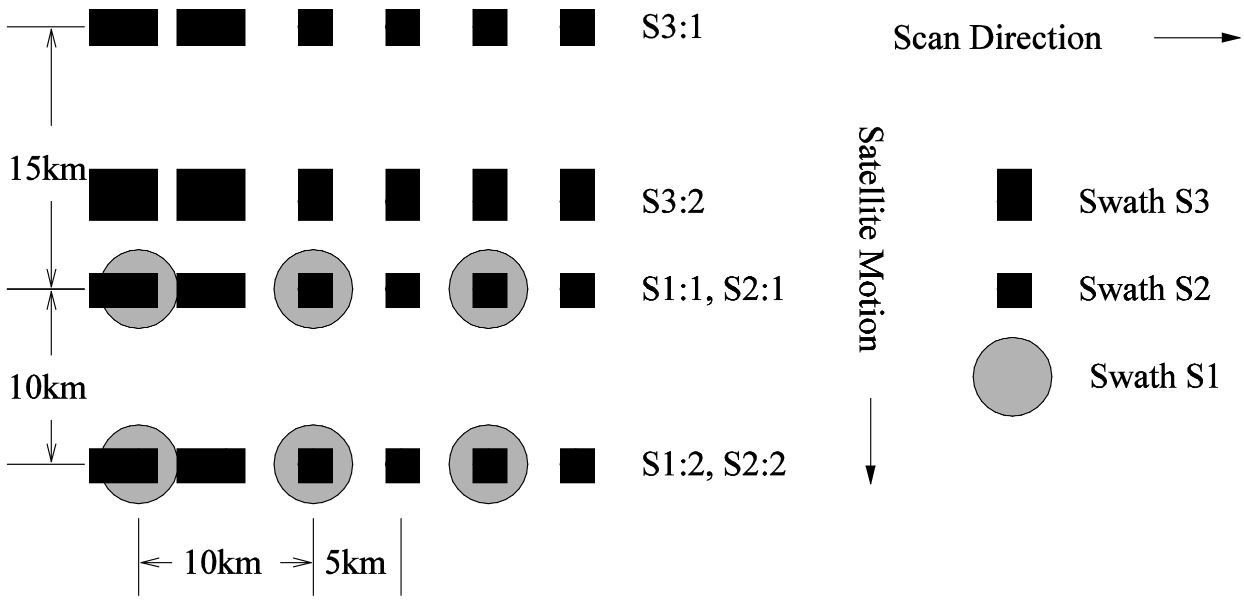

Figure E-1. Relation Between Swaths for L1C AMSR-E

E.2 ORBITIZATION

Orbitization processing was first done to the input AMSR-E L1B files to reorbitize and reformat them into the GPM standard orbital base file (AMSREBASE). The resulting AMSREBASE file is then used as input to the satellite intercalibration process.

E.3 SATELLITE INTERCALIBRATION

No intercalibration has been performed. This means that the Level 1C calibration is identical to the source data, which are the JAXA AMSR-E Level 1B brightness temperature data (Tb).

E.4 QUALITY CONTROL

The following quality control procedures were implemented for AMSR-E.

1. Scan check for missing scan: Missing scans are flagged and all pixel values are set to missing.
2. Pixel check for nonphysical values: Checks that individual brightness temperature values are within physical limits (currently 50K to 325K), and lat/lon values are within range (-90 to 90 and -180 to 180). Pixels outside range are flagged accordingly and set to missing.
3. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

E.5 STATIC DATA FILES

TBD

E.6 REFERENCES

1. AMSR-E Level 1 Product Format Description Document.
2. PPS GPM AMSREBASE File Specification.
3. PPS GPM 1CAMSRE File Specification.

APPENDIX F. L1C WINDSAT

F.1 INTRODUCTION

This document describes sensor-specific information for the GPM Level 1C WindSat algorithm.

F.1.1 L1C WindSat Input Data Description

The source for the WindSat L1C product is the SDR data produced by the Navy's FNMOC. The data contain brightness temperatures and are in binary format. Details about the data content and format can be obtained from the WindSat SDR Format rev. 02 Feb 2005 Document.

F.1.2 L1C WindSat Product Description

L1CWIND contains common calibrated brightness temperature from the WindSat passive microwave instrument flown on the Coriolis satellite. L1CWIND has only one swath and 20 overlapping scans before and after the granule.

Swath S1 is the only swath and has 10 channels (6.8V 6.8H 10.7V 10.7H 18.7V 18.7H 23.8V 23.8H 37V 37H). All of the above frequencies are in GHz. These data are a subset of the WindSat SDR 187TB data files. Only the vertical (V) and horizontal (H) polarizations in the direction of forward motion are included in the Level 1C files, resulting in a total of 10 channels with 80 pixels per scan.

The source files have been remapped to a common resolution corresponding to the 187 GHz channels (thus referred to as the 187TB files). In addition, the source data have been remapped to the spacing of every fourth 37 GHz VH observation along scan and every scan along track, resulting in approximately a 12.5 km × 12.5 km grid locally. The swath of the source data is defined as the common swath of all channels at 10.7, 18.7, 23.8, and 37.0 GHz in the forward direction. This swath is a 68° segment of the observations in the forward direction. We define the spacecraft vector (v) at the center of this forward observation segment. "v" is used in the definition of the variable SCorientation.

Relation between the swaths: S1 is the only swath, containing observations sampled 80 times along the scan.

Details about the product content and data format can be obtained from the GPM PPS 1CWIND File Specification Document.

F.2 ORBITIZATION

Orbitization processing was first done to the input WindSat SDR files to reorbitize and reformat them into the GPM standard orbital base file (WINDBASE). The resulting WINDBASE file is then used as input to the satellite intercalibration process.

F.3 SATELLITE INTERCALIBRATION

No intercalibration has been performed. This means that the Level 1C calibration is identical to the source data, which are the FNMOC WindSat SDR brightness temperature data.

F.4 QUALITY CONTROL

The following quality control procedures were implemented for WindSat.

1. Scan check for missing scan: Missing scans are flagged and all pixel values are set to missing.
2. Pixel check for nonphysical values: Checks that individual brightness temperature values are within physical limits (currently 50K to 325K), and lat/lon values are within range (-90 to 90 and -180 to 180). Pixels outside range are flagged accordingly and set to missing.
3. Pixel check for possible sun glint: Checks that individual sun glint angle values are greater than 20.0 degrees. Pixels with sun glint angle less than 20.0 degrees are flagged as possible sun glint.

F.5 STATIC DATA FILES

TBD

F.6 REFERENCES

1. WindSat SDR Format Document, Rev. 02, Feb 2005.
2. PPS GPM WINDBASE File Specification.
3. PPS GPM 1CWIND File Specification.

ACRONYMS USED IN THIS DOCUMENT AND ITS APPENDICES

AMSR-E	Advanced Microwave Scanning Radiometer – Earth Observing System
AMSU-B	Advanced Microwave Sounding Unit – B
APC	Antenna Pattern Correction
ATBD	Algorithm Theoretical Basis Document
CLASS	NOAA's Comprehensive Large Array-Data Stewardship System
DMSP	Defense Meteorological Satellite Program
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FOV	Field of View
GHz	Gigahertz
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
GSS-B	Glare Suppression System – B
GV	Ground Validation
H	Horizontal
HDF	Hierarchical Data Format
I/O	Input/Output
JAXA	Japan Aerospace Exploration Agency
L1C	Level 1C
lat/lon	Latitude/Longitude
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
OST	Orbit Start/Stop Times
PPS	Precipitation Processing System
PR	Precipitation Radar
QC	Quality Control
SDP4	Simplified Drag Perturbations Satellite Orbit Model 4
SDR	Sensor Data Record
SGP4	Simplified General Perturbations Satellite Orbit Model 4
SSMI	Special Sensor Microwave Imager
SSMI/S	Special Sensor Microwave Imager/Sounder
Ta	Antenna Temperature
Tb	Brightness Temperature
Tc	Common Intercalibrated Brightness Temperature
TDR	Temperature Data Record
TKIO	PPS Science Algorithm Input/Output Toolkit
TLE	Two-Line Element
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
V	Vertical (lower-case v stands for vector)
X-CAL	Intercalibration Working Group (GPM)
XML	Extensible Markup Language