Compact VIIRS SDR Product Format User Guide

Doc.No.	:	EUM/TSS/DOC/13/708025
Issue	:	v1C
Date	:	21 August 2014
WBS	:	

EUMETSAT
Eumetsat-Allee 1, D-64295 Darmstadt, Germany
Tel: +49 6151 807-7
Fax: +49 6151 807 555
http://www.eumetsat.int

Page intentionally left blank

Document Change Record

Issue / Revision	*Date*	*DCN. No*	*Summary of Changes*
v1	24 October 2013		Initial version for review
v1A	12 December 2013		Added missing attributes in Table 4. Adjusted definition of expansion and alignment coefficients in Sections 10.10and 10.11. Corrected name of `VIIRS-MOD-GEO_All` group from Compact VIIRS SDR.
v1B	4 April 2014		Adjusted definition of expansion and alignment coefficients in Section 10.5. Corrected $-\sin(lat)$ to $-\sin(lon)$ in section 10.9.
V1C	21 August 2014		Added second paragraph in 10.14 and a new section 10.14.1 Determination of Offset and Scale Factors. Modified the use of Fill Values in section 7.1, step 6 and step 17. Table 19 updated to account for actual range of instrument data.

Table of Contents

1 INTRODUCTION

1.1 Purpose

During the implementation of the EUMETSAT provided VIIRS Regional Service a need was indentified to develop a Compact VIIRS SDR Product Format (Level 1) to achieve a cost efficient distribution of the VIIRS data via EUMETCast, EUMETSAT's satellite based data distribution system.

This document specifies the Compact VIIRS SDR Product Format and how it relates to the Original VIIRS SDR Product Format developed as part of the Suomi-NPP Programme. It provides guidelines on how to construct the Compact product format from the Original and on how to reconstruct the Original product format from the Compact.

1.2 Scope

The document has been prepared as a product format specification and as guide for users and developers of tools for handling, visualising and processing the data from the VIIRS Regional Service.

The main use case is expected to be that VIIRS data distributed via EUMETCast in the Compact SDR format is converted back to the Original VIIRS SDR format for further processing and visualisation by the service users. However, it is also expected that tools will be developed for visualising and utilising the data directly from the Compact VIIRS SDR format without first reconstructing the Original VIIRS SDR format.

In combination with the relevant NPP and HDF5 documentation this document provides a sufficient level of detail for the development of tools capable of reading and writing the Compact VIIRS SDR format. Additionally, EUMETSAT intends to provide prototype software for converting between the two product formats.

1.3 Applicable Documents

AD-1	Joint Polar Satellite System (JPSS) Common Data Format Control Book - External Volume I - Overview	474-00001-01-B0122, September 17, 2012
AD-2	Joint Polar Satellite System (JPSS) Common Data Format Control Book - External Volume III - SDR/TDR Formats	474-00001-03-B0123, July 2, 2013
AD-3	Joint Polar Satellite System (JPSS) Common Data Format Control Book – External Volume V - Metadata	474-00001-05-B0123 December 11, 2012

1.4 Reference Documents

RD-1 Compact VIIRS SDR - Representation of Observations EUM/TSS/REP/13/710728

1.5 Document Structure

Section 1 General information (this section).

Section 2 Summarises the EARS-VIIRS Service Specification.

Section 3 Provides an overview of the EARS System Architecture.

Section 4 Provides an overview of both the Original and the Compact VIIRS SDR Product Format.

Section 5 Describes the detailed content of the Original VIIRS SDR Product Format with cross references to the Compact VIIRS SDR Product Format.

Section 6 Describes the detailed content of the Compact VIIRS SDR Product Format.

Section 7 Lists the steps required for generating the Compact VIIRS SDR from the Original VIIRS SDR.

Section 8 Lists the steps required for reconstructing the original VIIRS SDR from the Compact VIIRS Product.

Section 9 Defines the Product file naming conventions

Section 10 Details the mathematical algorithms required for generating and applying the geolocation data of the Compact VIIRS SDR.

Section 11 Provides recommended and typical parameters for the mathematical algorithms

1.6 Open Issues

1	Complete the list of Applicable and Reference Documents
2	Consider generalising the descriptions to also cover the VIIRS I-band Channels
3	Consider including integer based height information to support terrain and reference ellipsoid based geolocation

4	Add section introducing the prototype conversion tools to be provided by EUMETSAT
5	Add explanation on how to operationally maintain the parameter values provided in section 11

2 EARS-VIIRS SERVICE SPECIFICATION SUMMARY

The Operational Service Specification for the new regional VIIRS service is summarised in the Table 1 below.

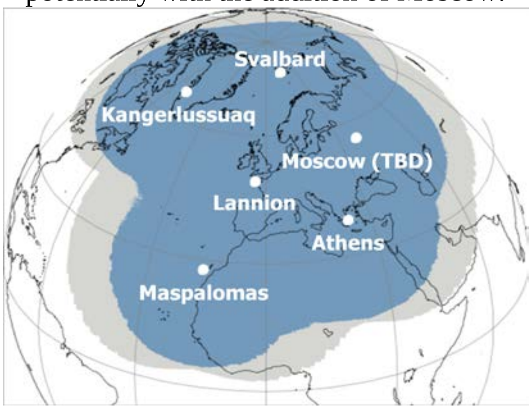
EARS-VIIRS	
Geographical Coverage	Core European EARS direct readout reception stations, potentially with the addition of Moscow. 
Product Processing	RT-STPS/CSPP as provided by the NASA/CIMSS, configured and run by EUMETSAT.
Product Segmentation	Segments each containing 86 seconds of observations consistent with the granule size of the NOAA VIIRS SDR products. Duplicate segments removed before dissemination.
EUMETCast Ku-Band Europe	SDR (Level 1) format, single product containing calibrated VIIRS M-Band observations (16 channels) plus geolocation information on tie-point grid. HDF5 product format, bzip2 compression.
Timeliness	15 minutes.
Products on GTS	None.
Archiving	None.

Table 1 EARS-VIIRS processing, formatting and dissemination

3 EARS SYSTEM OVERVIEW

It is planned to re-use as much as possible the existing EARS infrastructure:

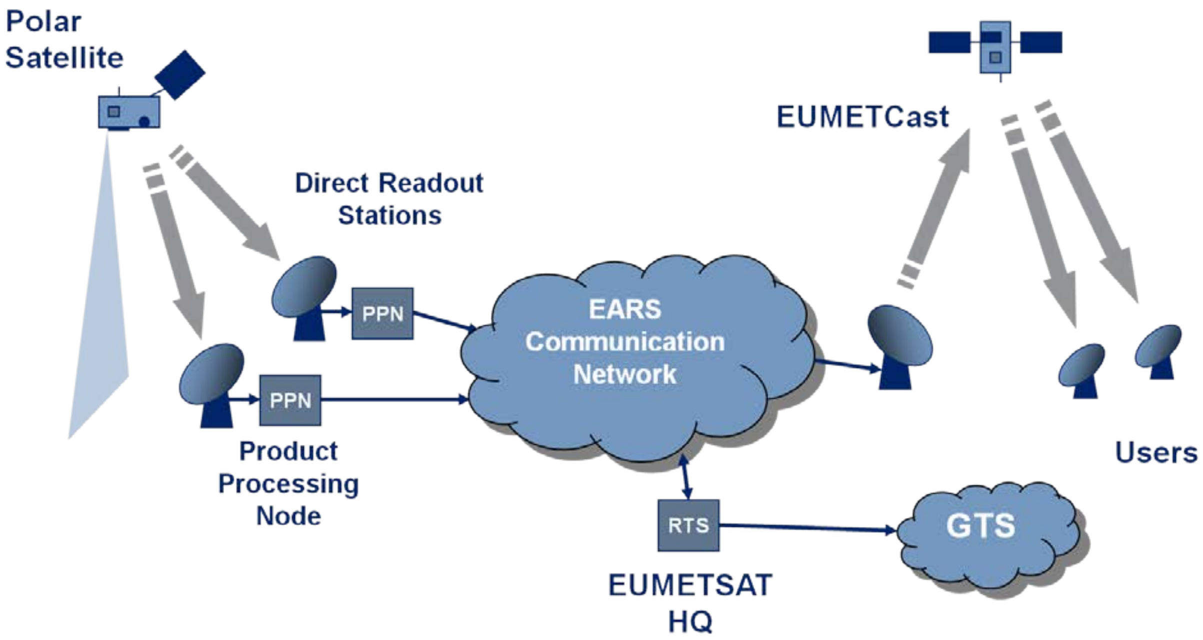


Figure 2 EARS System Overview

The VIIRS SDR processing and formatting is foreseen to take place at each remote Product Processing Node (PPN), with a direct dissemination of the segment files to EUMETCast.

The processing steps involved are the following:

NPP HRD n-minute input file (CCSDS CADU format, all instruments) → RT-STPS → n-minute RDR file → CSPP → SDR files (granule size 85.752 seconds) + non-terrain corrected geolocation (GMODO) → VFP → Bzip2 → dissemination to EUMETCast.

VFP is the VIIRS Formatting Package, developed by EUMETSAT. From the SDR and GMODO files, it creates a product according to the Compact VIIRS SDR format specification. This software is associated to coordinating software running at each remote node and communicating with a central server ensuring that all duplicates are removed before dissemination. This coordination software is already used in the context of the EARS-AVHRR service.

4 OVERVIEW OF THE ORIGINAL AND THE COMPACT VIIRS SDR PRODUCT FORMAT

This section explains the VIIRS scanning geometry and provides an overview of the Original and the new Compact VIIRS SDR Product format.

4.1 The VIIRS Scanning Geometry

The VIIRS instrument has a wide swath of 3000 km and performs a scan every 1.786 s. Each scan contains 16 M-Band scan lines and 32 I-Band Scan lines. To ensure a more uniform pixel size across the swath, the VIIRS instruments performs a pixel aggregation in the scan direction. In the central 3:1 Aggregation Zone below the spacecraft three instrument pixels are aggregated to one pixel at the product level, in the intermediate 2:1 Aggregation Zone two instrument pixels are aggregated to one pixel at the product level and in the outer 1:1 Aggregation Zone each instrument pixel results in one pixel at the product level. The result is 3200 pixels in the scan direction for the VIIRS M-band and 6400 for the VIIRS I-Band at the product level. The Figure 1 shows the VIIRS M-Band scan and aggregation zone geometry. Note that in the figure the Track direction is not to scale relative to the Scan direction.

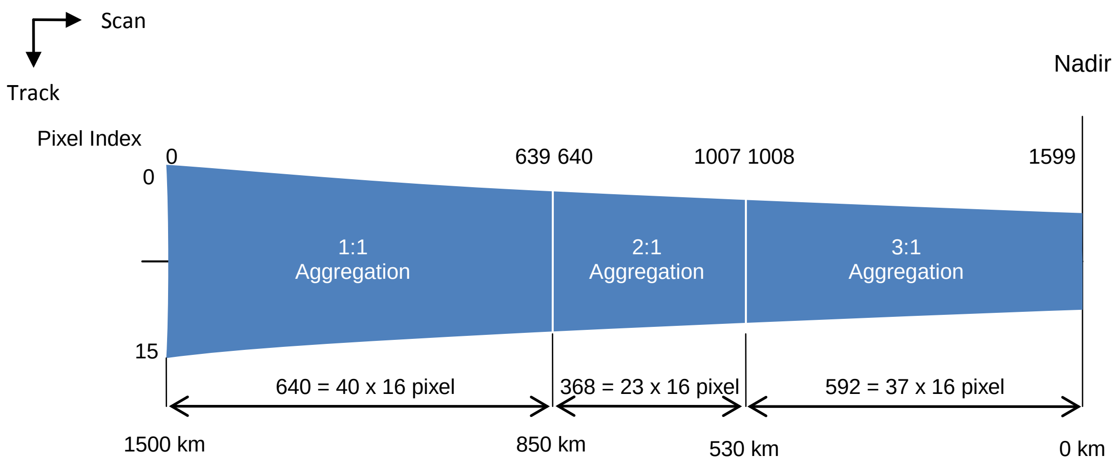


Figure 1 VIIRS M-Band scan and aggregation zone geometry shown for one half of a full scan. A full scan has 3200 pixel along scan and 16 pixel along track.

4.2 The VIIRS SDR Granules

The VIIRS SDR product is organised in granules, each consisting of 48 VIIRS instrument scans in a single file. The granule boundaries and the granule (file) naming and numbering are accurately defined i.e. granules generated by different processing centres are aligned and identically named.

For the VIIRS M-Band a granule with 48 instrument scans contains 768 lines along the track. Similarly the VIIRS I-Band a granule with 48 instrument scans contains 1536 lines along the track.

4.3 Geolocation Data in the Original VIIRS SDR Product

In the Original VIIRS SDR Product the geolocation data is provided in full for each pixel. It is organised in separate two dimensional HDF5 datasets for each geolocation parameter as shown in Figure 2.

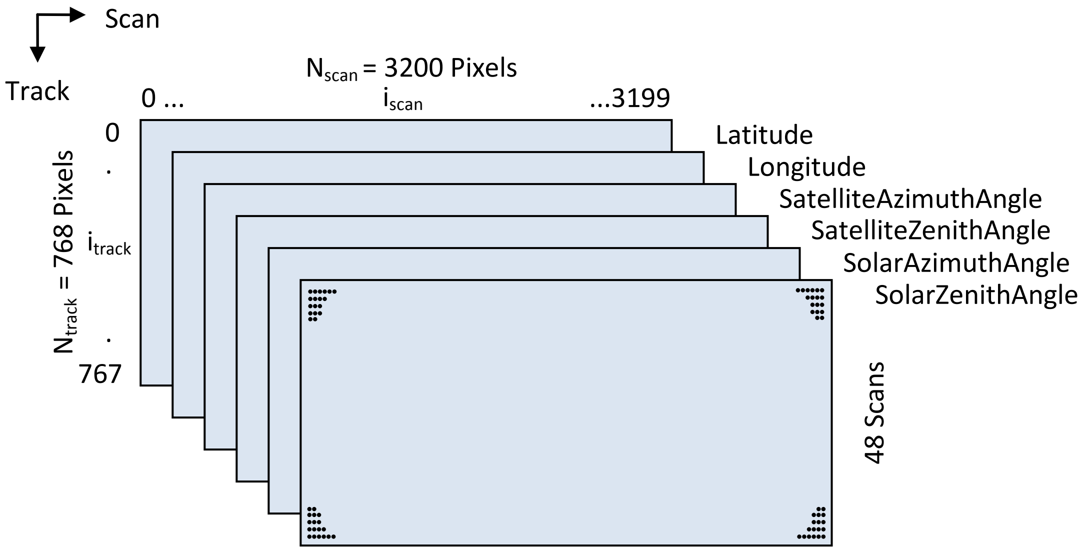


Figure 2 Layout of the Geolocation data in the original VIIRS SDR Product, based on the example of one granule of the VIIRS M-Band.

4.4 Geolocation Data in the Compact VIIRS SDR Product

In the Compact VIIRS SDR Product the geolocation data and viewing angles are stored only at so-called Tie-Points, shown as point A, B, C and D in Figure 3 for a single Tie-Point Zone. The Tie Point zone has been defined to have a size of 16x16 M-Band pixels. Interpolation functions are defined to interpolate the data to reconstruct the geolocation and viewing angles for each pixel. This is addressed in more detail in the subsequent sections of this document.

Note that the Tie-Points A, B, C and D shown in Figure 3 are located at the corners of the 16x16 M-Band pixel Tie-point Zone. Consequently the same Tie-Points can be used to reconstruct the full set of geolocation data for both the 16x16 M-Band pixels and the 32x32 I-Band pixels contained in the Tie-point Zone.

The process of generating the six parameters corresponding to the four Tie Point Zone corner points A, B, C and D uses exactly the same interpolation functions that a user would use to reconstruct the parameters at each pixel centre starting from the Tie Points. However, in this case the functions are set up to extrapolate the parameters from the centre of the four corner pixels to the four Tie Point Zone corner points A, B, C and D. This is also addressed in more detail in the subsequent sections of this document.

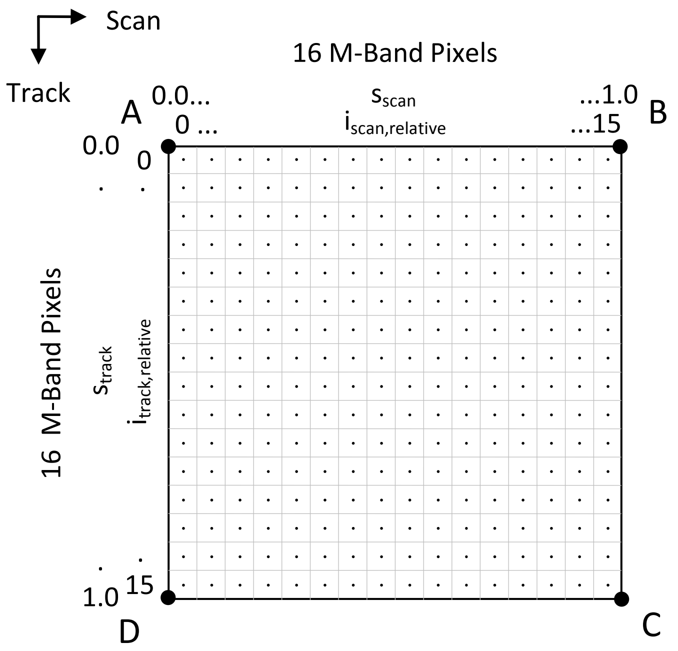


Figure 3 Tie Point Zone Layout. The Compact VIIRS SDR Product stores the six geolocation and angular parameters only in the four corner points A, B, C and D.

The resulting layout of the parameters within the Compact VIIRS SDR Product Format is shown in Figure 4. Each parameter is stored in an HDF5 array of the size 96x201. This corresponds to 200 Tie Point Zones for each of the 48 scans.

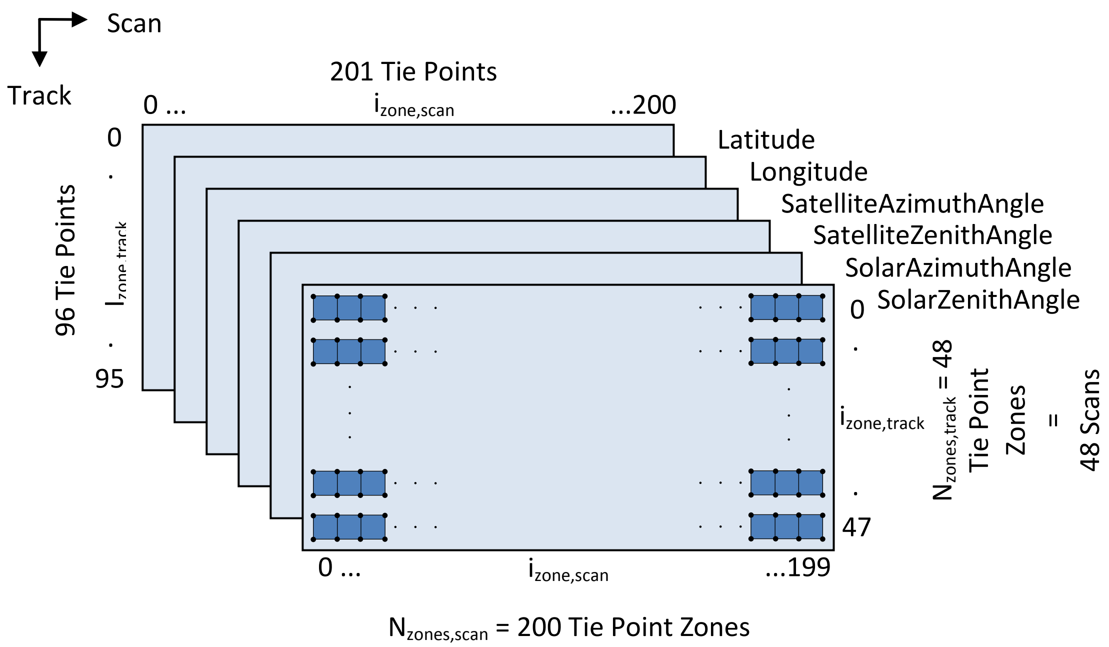


Figure 4 Geolocation and Angular parameter Layout in the Compact VIIRS SDR Product for the M- and I-Band.

Note that for neighbouring Tie Point Zones along the scan direction, the corner points are shared and the parameters are only stored once in the Compact VIIRS SDR Product. From comparing Figure 4 and Figure 5 it can be seen that the corner points B and C of the first Tie Point Zone in the Scan are identical to the corner points A and D respectively of the second Tie Point Zone. Corner points between individual scans are not shared since they are not identical due to the bow tie effect of the VIIRS scanning geometry.

From Figure 5 it can be seen that there is a discontinuity in the pixel size at the Aggregation Zone boundary. However, this does not impact the interpolation scheme as all Aggregation Zone boundaries coincide with a Tie-Point Zone boundary.

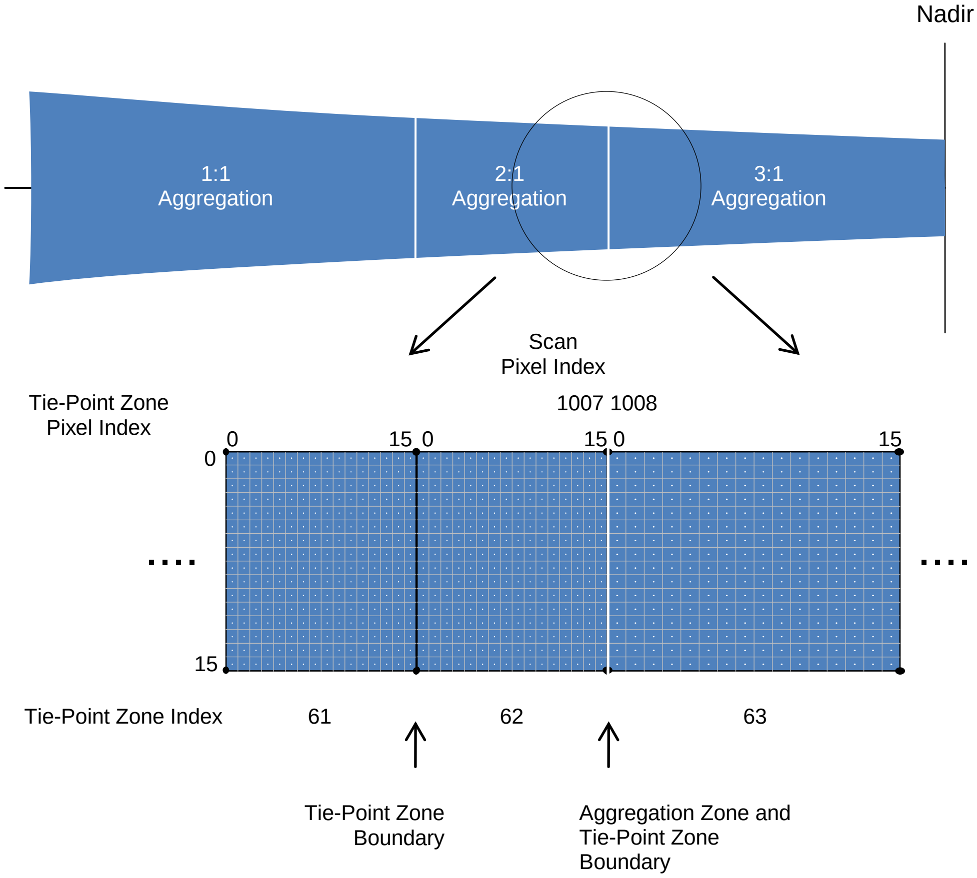


Figure 5 Aggregation Zone and Tie Point Zone Layout. The discontinuity in the pixel size at the Aggregation Zone boundary does not impact the interpolation within the Tie-Point Zones as the Aggregation Zone boundary coincides with a Tie-Point Zone boundary

4.5 Observation Data in the Original and Compact VIIRS SDR Product

Common to the Original VIIRS SDR and the Compact VIIRS SDR is that all the observation data of a granule is stored in separate two dimensional HDF2 dataset for each channel and representation. The dataset size is 768x3200 for an M-Band channel and 1536x6400 for an I-Band Channel. The layout of the Compact VIIRS SDR product observations is shown in Figure 6.

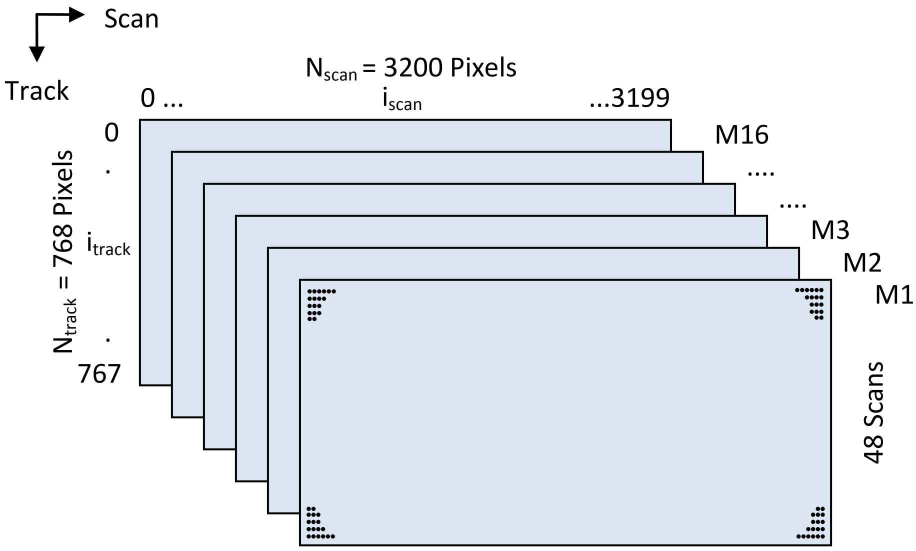


Figure 6 Layout of the Observation data in the Compact VIIRS SDR Product, based on the example of one granule of VIIRS M-Band data.

The main differences between the Observation data contained in the Original VIIRS SDR and in the Compact VIIRS SDR are that were the Original VIIRS SDR contains Radiances, Reflectances and Brightness Temperatures the Compact VIIRS SDR contains only Radiances and that were the Original VIIRS SDR makes use of both floating point and integers for storing the values the Compact VIIRS SDR only uses integers. This is shown in Figure 7.

Moreover, the Compact VIIRS SDR uses a dual-scale representation for storing Radiance values as 16 bit unsigned integers. It is based on two offset and scale factor sets, one for low radiance values and one for high radiance values. The representation thereby matches the characteristics of the VIIRS dual gain channels and ensures a higher accuracy of low radiance values.

The Compact VIIRS SDR contains supporting parameters for reconstructing both the Reflectances and Brightness Temperatures to an accuracy well within the instrument noise. A separate document is available demonstrating the performance of the reconstruction of the Reflectances and Brightness Temperatures (RD-1).

Original VIIRS SDR			
Ch	Radiance	Reflectance	Bright.Tem.
M1	16 bit uint	16 bit uint	
M2	16 bit uint	16 bit uint	
M3	32 bit float	16 bit uint	
M4	32 bit float	16 bit uint	
M5	32 bit float	16 bit uint	
M6	16 bit uint	16 bit uint	
M7	32 bit float	16 bit uint	
M8	16 bit uint	16 bit uint	
M9	16 bit uint	16 bit uint	
M10	16 bit uint	16 bit uint	
M11	16 bit uint	16 bit uint	
M12	16 bit uint		16 bit uint
M13	32 bit float		32 bit float
M14	16 bit uint		16 bit uint
M15	16 bit uint		16 bit uint
M16	16 bit uint		16 bit uint

Compact VIIRS SDR	
Ch	Radiance
M1	16 bit uint
M2	16 bit uint
M3	16 bit uint
M4	16 bit uint
M5	16 bit uint
M6	16 bit uint
M7	16 bit uint
M8	16 bit uint
M9	16 bit uint
M10	16 bit uint
M11	16 bit uint
M12	16 bit uint
M13	16 bit uint
M14	16 bit uint
M15	16 bit uint
M16	16 bit uint

Single Gain Channel
Dual Gain Channel
Single Scale Representation
Dual Scale Representation

Figure 7 Observation data in the Original and the Compact VIIRS SDR Product based on 32 bit floating point, 16 bit integer Single Scale and 16 bit integer Dual Scale.

4.6 HDF5 Files

The Original VIIRS SDR data product is separated in individual HDF5 files for each channel and for the geolocation data. The Compact VIIRS SDR combines all data in one HDF5 file while maintaining the HDF5 groups names consistent with Original VIIRS SDR, see Figure 8.

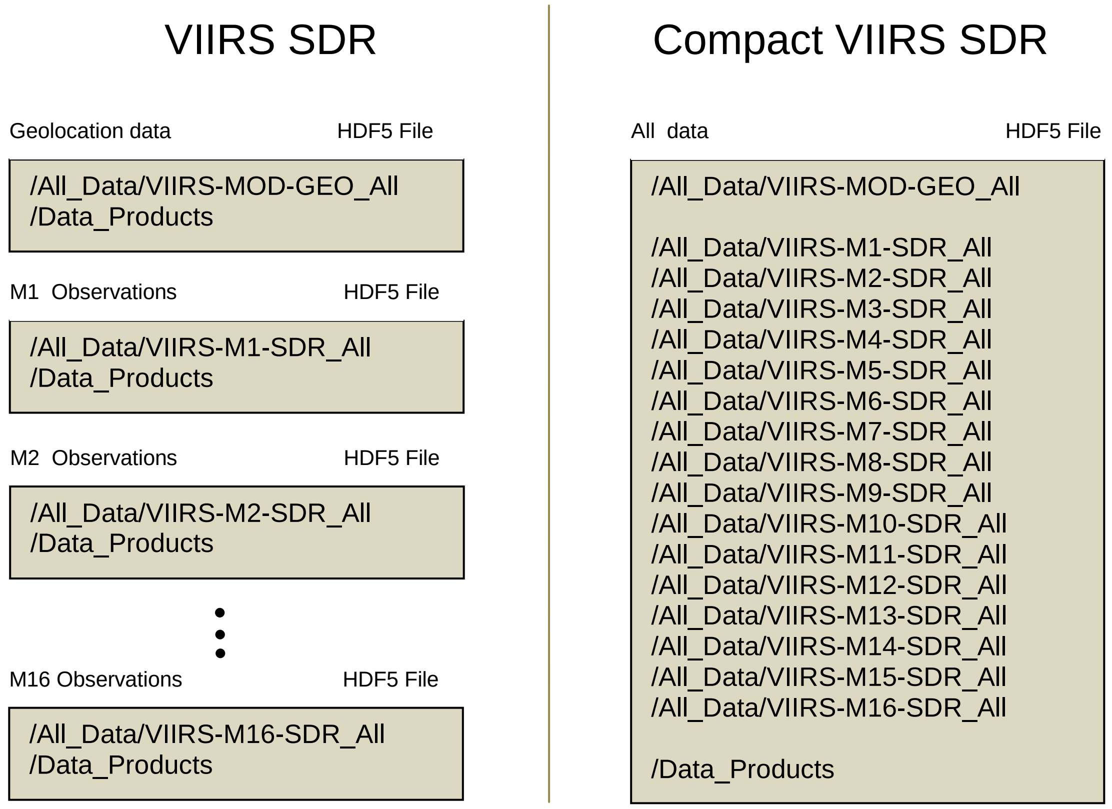


Figure 8 HDF5 file structure for the Original VIIRS SDR and the Compact VIIRS SDR.

5 CONTENT OF THE ORIGINAL VIIRS SDR

This section defines the groups and datasets of Original VIIRS SDR product and indicates which of these are included in the Compact VIIRS SDR Product.

5.1 Geolocation and Angular Data

Geolocation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
StartTime	Starting of each scan in IET (1/1/1958)	64 bit int	[48]	microsec	✓	Included as is
MidTime	Mid-Time of each scan IET (1/1/1958)	64 bit int	[48]	microsec	✓	Included as is
Latitude	Latitude of each pixel (positive North)	32 bit float	[768,3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Longitude	Longitude of each pixel (positive East)	32 bit float	[768, 3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Solar ZenithAngle	Zenith angle of sun at each pixel position	32 bit float	[768, 3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Solar AzimuthAngle	Azimuth angle of sun (measured clockwise positive from North) at each pixel position	32 bit float	[768, 3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Satellite ZenithAngle	Zenith angle to Satellite at each pixel position	32 bit float	[768, 3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Satellite AzimuthAngle	Azimuth angle (measured clockwise positive from North) to Satellite at each pixel position	32 bit float	[768, 3200]	degree	✓	Included at tie-points, interpolation scheme for all pixels
Height	Ellipsoid-Geoid separation	32 bit float	[768, 3200]	meter	-	Currently not included, but under consideration
SatelliteRange	Line of sight distance from the ellipsoid intersection to the	32 bit float	[768, 3200]	meter	-	Currently not included, but under consideration

Geolocation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
	satellite					
SCPosition	Spacecraft position in ECR Coordinates (X, Y, Z) at the mid-time of scan	32 bit float	[48, 3]	meter	✓	Included as is
SCVelocity	Spacecraft velocity in ECR Coordinates (dx/dt, dy/dt, dz/dt) at the mid-time of scan	32 bit float	[48,3]	m/s	✓	Included as is
SCAttitude	Spacecraft attitude with respect to the Geodetic Reference Frame Coordinates (roll, picth, yaw) at the midtime of scan	32 bit float	[48,3]	arc second	✓	Included as is
SCSolar ZenithAngle	The angle from the normal vector of the Solar Diffuser surface (z-axis of the solar diffuser frame) to the solar vector	32 bit float	[48]	degree	✓	Included as is
SCSolar AzimuthAngle	The angle from the Solar Diffuser reference frame x-axis to the projection of the solar vector onto the solar diffuser surface (x-y plane), measured counterclockwise (observer looking toward the SD surface)	32 bit float	[48]	degree	✓	Included as is
ModeScan	The VIIRS operational mode, reported at the scan level	8 bit uchar	[48]	unitless	✓	Included as is
ModeGran	The VIIRS operational mode, reported at the granule level	8 bit uchar	[48]	untiless	✓	Included as is
PadByte1	Pad byte	8 bit uchar	[3]	unitless	✓	Included as is
NumberOf Scans	Actual number of VIIRS scans that were used to create this	32 bit int	[1]	unitless	✓	Included as is

Geolocation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
	granule					
QF1_SCAN_ VIIRSSDR GEO	Scan-level quality flag	8 bit uchar	[48]	unitless	✓	Included as is
QF2_SCAN_ VIIRSSDR GEO	Scan-level quality flag	8 bit uchar	[48]	unitless	✓	Included as is
QF2_VIIRS SDRGEO	Pixel-level quality flag	8 bit uchar	[768, 3200]	unitless	-	Not considered relevant as geolocation data is based on interpolation scheme

5.2 Observation Data

Observation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-*Ch*-SDR_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
Radiance M1, M2, M6, M8-M12, M14-M16	Calibrated Top of Atmosphere (TOA) Radiance for each VIIRS pixel	16 bit uint	[768,3200]	W/(m2 sr µm)	✓	Included as is
Radiance Factors M1, M2, M6, M8-M12, M14-M16	Radiance scale and offset: array[scale, offset]	32 bit float	[2]	unitless	✓	Included as attributes of the Radiance dataset
Radiance M3-M5, M7, M13	Calibrated Top of Atmosphere (TOA) Radiance for each VIIRS pixel	32 bit float	[768,3200]	W/(m2 sr µm)	✓	Included as dual scale integer representation
Reflectance M1-M11	Calibrated TOA Reflectance for each VIIRS pixel	16 bit uint	[768,3200]	unitless	-	Can be derived from the corresponding radiance

Observation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-*Ch*-SDR_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
Reflectance Factors M1-M11	Reflectance scale and offset: array[scale, offset]	32 bit float	[2]	unitless	-	Only meaningful with the reflectance
Brightness Temperature M13	Calibrated TOA Brightness Temperature for each VIIRS pixel	32 bit float	[768, 3200]	K	-	Can be derived from the corresponding radiances
Brightness Temperature M12, M14-M16	Calibrated TOA Brightness Temperature for each VIIRS pixel	16 bit uint	[768, [3200]	K	-	Can be derived from the corresponding radiances
Brightness Temperature Factors M12, M14-M16	Brightness Temperature scale and offset: array[scale, offset]	32 bit float	[2]	unitless	-	Only meaningful with the brightness temperature
ModeScan	The VIIRS operational mode, reported at the granule level	8 bit uchar	[48]	unitless	-	Included as part of the geolocation data
ModeGran	The VIIRS operational mode, reported at the granule level	8 bit uchar	[1]	unitless	-	Included as part of the geolocation data
PadByte1	Pad Byte	8 bit uchar	[3]	unitless	✓	Included as is
NumberOfScans	Actual number of VIIRS scans that were used to create this granule	8 bit uchar	[1]	unitless	-	Included as part of the geolocation data
NumberOfMissingPkts	Number of missing packets in scan	32 bit int	[48]	unitless	✓	Included as is
NumberOfBadChecksums	Number of packets with bad checksum in scan	32 bit int	[48]	unitless	✓	Included as is
NumberOfDiscardedPkts	Number of discarded packets in scan	32 bit int	[48]	unitless	✓	Included as is
QF1_VIIRSMBANDSDR	Quality Flag for each pixel (per channel)	8 bit uchar	[768,3200]	unitless	✓	Included as is
QF2_SCAN_S	Quality Flag for Scan	8 bit	[48]	unitless	✓	Included as is

Observation Data in Original VIIRS SDR Product HDF5 Datasets in Group /All_Data/VIIRS-*Ch*-SDR_All					Compact VIIRS SDR Product	
Dataset Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
DR	(indicates general SDR information) (per channel)	uchar				
QF3_SCAN_SDR	Quality Flag for Scan (indicates general SDR information) (per channel)	8 bit uchar	[48]	unitless	✓	Included as is
QF4_SCAN_SDR	Quality Flag for Scan (indicates general SDR information) (per channel)	8 bit uchar	[48]	unitless	✓	Included as is
QF5_GRAN_BAD_DETECTOR	Quality Flag – Bad detector (per channel)	8 bit uchar	[16]	unitless	✓	Included as is

5.3 Attributes of Geolocation and Observation data

HDF5 Attributes of Root Group /					Compact VIIRS SDR Product	
Attribute Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
Distributor	Designates the distributor of the data.	String	[1]	unitless	✓	Included as is
Mission_Name	The character string by which the mission is known.	String	[1]	unitless	✓	Included as is
N_Dataset_Source	The producer of the HDF5 files.	String	[1]	unitless	✓	Included as is
N_GEO_Ref *Contained in Observation data only*	Filename of the HDF5 file containing the related Geolocation information.	String	[1]	unitless	✓	Included as is
N_HDF_Creation_Date	The date that the HDF5 file was created.	String	[1]	unitless	✓	Included as is

HDF5 Attributes of Root Group /					Compact VIIRS SDR Product	
Attribute Name	Description	Data Type	Dim.	Units	Incl.	Comment/ Cross Reference
	Expressed as YYYYMMDD.Paired with N_HDF_Creation_Time					
N_HDF_Creation_Time	The time that the HDF5 file was created Expressed as HHMMSS.SSSSSSZ Paired with N_HDF_Creation_Date.	String	[1]	unitless	✓	Included as is
Platform_Short_Name	An acronym, or shorter form of the platform name, used to identify the platform.	String	[1]	unitless	✓	Included as is

Table 3. HDF5 Attributes of Root Group of Geolocation and Observation data .

5.4 Meta Data

The meta data is contained in the group /All_Data/Data_Products and it is included in full in the Compact VIIRS SDR product. The Meta data is not described in further detail in this document, but is described in AD-3.

6 CONTENT OF THE COMPACT VIIRS SDR

The HDF5 file has the following structure. When possible and for consistency, the SDR HDF5 element name defined in the original VIIRS SDR product has been kept.

The top root structure of the Compact VIIRS SDR Product Structure is the following:

```
COMPACT_VIIRS_SDR
|
|_ + All_Data (type: group)
   |____VIIRS-MOD-GEO_All (type: group, Geolocation information)
   |____VIIRS-M1-SDR_All  (type: group, MBand channel 1 information)
   |____VIIRS-M2-SDR_All  (type: group, MBand channel 2 information)
   |____VIIRS-M3-SDR_All  (type: group, MBand channel 3 information)
   |____VIIRS-M4-SDR_All  (type: group, MBand channel 4 information)
   |____VIIRS-M5-SDR_All  (type: group, MBand channel 5 information)
   |____VIIRS-M6-SDR_All  (type: group, MBand channel 6 information)
   |____VIIRS-M7-SDR_All  (type: group, MBand channel 7 information)
   |____VIIRS-M8-SDR_All  (type: group, MBand channel 8 information)
   |____VIIRS-M9-SDR_All  (type: group, MBand channel 9 information)
   |____VIIRS-M10-SDR_All (type: group, MBand channel 10 information)
   |____VIIRS-M11-SDR_All (type: group, MBand channel 11 information)
   |____VIIRS-M12-SDR_All (type: group, MBand channel 12 information)
   |____VIIRS-M13-SDR_All (type: group, MBand channel 13 information)
   |____VIIRS-M14-SDR_All (type: group, MBand channel 14 information)
   |____VIIRS-M15-SDR_All (type: group, MBand channel 15 information)
   |____VIIRS-M16-SDR_All (type: group, MBand channel 16 information)
```

The HDF group VIIRS-MOD-GEO_All contains the geolocation information and the groups VIIRS-*Ch*-SDR_All contain the corresponding observations for channel *Ch*.

6.1 Geolocation and Angular Data

The group /All_Data/VIIRS-MOD-GEO_All contains datasets needed for the calculation of the geolocation and viewing angles for each VIIRS pixel and is described in detail in Table 4 below. Additional channel specific datasets needed are included as attributes of the individual channel groups /All_Data/VIIRS-*Ch*-SDR_All, see
***Table** 7*.

HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Symbol in Docu-ment
Dataset Name	Description	Data Type	Dimension	Units	
NumberOfTie PointZonesTrack	Number of Tie Point Zones in the Track direction	32 bit int	[1]	zones	$N_{zones,track}$
NumberOfTie	Number of Tie Point	32 bit	[1]	zones	$N_{zones,scan}$

HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Symbol in Document
Dataset Name	Description	Data Type	Dimension	Units	
PointZonesScan	Zones in the Scan direction	int			
Latitude	Latitude of each Tie Point (positive North)	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	lat
Longitude	Longitude of each Tie Point (positive East)	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	lon
SolarZenithAngle	Zenith angle of sun at each Tie Point position	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	zen
SolarAzimuthAngle	Azimuth angle of sun (measured clockwise positive from North) at each Tie Point position	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	azi
SatelliteZenithAngle	Zenith angle to Satellite at each Tie Point position	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	zen
SatelliteAzimuthAngle	Azimuth angle (measured clockwise positive from North) to Satellite at each Tie Point position	32 bit float	$[2 \cdot N_{zones,track}, N_{zones,scan} + 1]$	degree	azi
ExpansionCoefficient	Correction coefficient accounting for the variation in Pixel size along the Scan direction each	32 bit float	$[N_{zones,scan}]$	unitless	$c_{expansion}$
AlignmentCoefficient	Correction coefficient accounting for the Pixels not being linearly aligned along the track direction	32 bit float	$[N_{zones,scan}]$	unitless	$c_{alignment}$
QF1_SCAN_VIIRSSDRGEO	Scan level quality flag	8 bit uchar	[48]	unitless	
QF2_SCAN_VIIRSSDRGEO	Scan level quality flag	8 bit uchar	[48]	unitless	
SCVelocity	Spacecraft position in ECR Coordinates (X, Y, Z) at the mid-time of scan	32 bit float	[48,3]	meter	
SCPosition	Spacecraft velocity in ECR Coordinates (dx/dt, dy/dt, dz/dt) at the mid-time of scan	32 bit float	[48,3]	m/s	
SCAttitude	Spacecraft attitude with respect to the Geodetic	32 bit float	[48,3]	arc second	

HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All					Symbol in Document
Dataset Name	Description	Data Type	Dimension	Units	
	Reference Frame Coordinates (roll, picth, yaw) at the midtime of scan				
StartTime	Starting of each scan in IET (1/1/1958)	64 bit int	[48]	micro sec	
MidTime	Mid-Time of each scan IET (1/1/1958)	64 bit int	[48]	micro sec	
PadByte1	Pad Byte	8 bit uchar	[3]	unitless	
SCSolar ZenithAngle	The angle from the normal vector of the Solar Diffuser surface (z-axis of the solar diffuser frame) to the solar vector	32 bit float	[48]	degree	
SCSolar AzimuthAngle	The angle from the Solar Diffuser reference frame x-axis to the projection of the solar vector onto the solar diffuser surface (x-y plane), measured counterclockwise (observer looking toward the SD surface)	32 bit float	[48]	degree	

Table 4 HDF5 Datasets in Group /All_Data/VIIRS-MOD-GEO_All.

6.2 Observation Data

The group VIIRS-*Ch*-SDR_All contains the M Band channel information. Each group contains the information related to one channel and all the VIIRS-*Ch*-SDR_All groups have the same structure in the Compact VIIRS SDR Product Format.

Below is the list of datasets contained in this group. The attributes of the dataset Radiances contained in the group are described in section 6.2.1. The attributes of the group itself are described in section 6.2.2.

HDF5 Datasets in Group /All_Data/VIIRS-*Ch*-SDR_All					Symbol in Docu-ment
Dataset Name	Description	Data Type	Dim.	Units	
Radiance	Integer representation of Calibrated Top of Atmosphere (TOA) Radiance for each VIIRS pixel	16 bit uint	[96, 201]	unitless	C
QF1_VIIRSMBANDSDR	Quality Flag for each pixel (per channel)	8 bit uchar	[48]	unitless	-
QF2_SCAN_SDR	Quality Flag for Scan (indicates general SDR information) (per channel)	8 bit uchar	[48]	unitless	-
QF3_SCAN_RDR	Quality Flag for Scan (indicates general SDR information) (per channel)	8 bit uchar	[48]	unitless	-
QF4_SCAN_SDR	Quality Flag for Scan (indicates general SDR information) (per channel)	8 bit uchar	[768]	unitless	-
QF5_GRAN_BADDETECTOR	Quality Flag – Bad detector (per channel)	8 bit uchar	[16]	unitless	-
PadByte1	Pad Byte	8 bit uchar	[3]	unitless	-
NumberOfMissingPkts	Number of missing packets in scan	32 bit int	[48]	unitless	-
NumberOfBadChecksums	Number of packets with bad checksum in scan	32 bit int	[48]	unitless	-
NumberOfDiscardedPkts	Number of discarded packets in scan	32 bit int	[48]	unitless	-

Table 5. HDF5 Datasets in Group /All_Data/VIIRS-Ch-SDR_All.

6.2.1 Attributes of the Radiance Dataset

Each Radiance dataset has the following attributes.

HDF5 Attributes of Dataset /All_Data/VIIRS-*Ch*-SDR_All/Radiance					Symbol in Docu-ment
Attribute Name	Description	Data Type	Dim.	Units	
RadianceOffsetHigh	Offset for calculating Radiance L from its integer representation C for $C>C_{treshold}$	32 bit float	[1]	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$	a_{high}
RadianceScaleHigh	Scale factor for calculating Radiance L from its integer representation C for $C>C_{treshold}$	32 bit float	[1]	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$	b_{high}

HDF5 Attributes of Dataset /All_Data/VIIRS-*Ch*-SDR_All/Radiance					Symbol in Document
Attribute Name	Description	Data Type	Dim.	Units	
RadianceOffset Low	Offset for calculating Radiance L from its integer representation C for $C \le C_{treshold}$	32 bit float	[1]	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$	a_{low}
RadianceScale Low	Scale factor for calculating Radiance L from its integer representation C for $C \le C_{treshold}$	32 bit float	[1]	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$	b_{low}
Threshold	Integer threshold for selection of the High or Low Offset and Scale pair	16 bit uint	[1]	Unitless	$C_{treshold}$
EquivalentWidth *M1-M11*	Equivalent width. Needed for the calculation of the Reflectance	32 bit float	[1]	μm	A_{vis}
IntegratedSolar Irradiance *M1-M11*	Band-integrated solar irradiance. Needed for the calculation of the Reflectance	32 bit float	[1]	$W\ m^{-2}$	B_{vis}
EarthSun Distance Normalised *M1-M11*	Relation between the mean and the actual Earth-Sun distance. Needed for the calculation of the Reflectance	32 bit float	[1]	Unitless	d_{se}
CentralWave Length *M12-M16*	Central wavelength. Needed for the calculation of the Brightness Temperature	32 bit float	[1]	m	λ_C
BandCorrection CoefficientA *M12-M16*	Band Correction Coefficient A. Needed for the calculation of the Brightness Temperature	32 bit float	[1]	Unitless	A_{ir}
BandCorrection CoefficientB *M12-M16*	Band Correction Coefficient B. Needed for the calculation of the Brightness Temperature	32 bit float	[1]	K	B_{ir}

Table 6. HDF5 Attributes of Dataset /All_Data/VIIRS-Ch-SDR_All/Radiance.

6.2.2 Attributes of the Observation Data Group

Each VIIRS-*Ch*-SDR_All group has the following attributes.

HDF5 Attributes of Group /All_Data/VIIRS-*Ch*-SDR_All					Symbol in Document
Attribute Name	Description	Data Type	Dim.	Units	
TiePointZone SizeTrack	Size of the Tie Point Zone in the Track direction	32 bit int	[1]	pixels	Z_{track}

HDF5 Attributes of Group /All_Data/VIIRS-*Ch*-SDR_All					Symbol in Document
Attribute Name	Description	Data Type	Dim.	Units	
TiePointZone SizeScan	Size of the Tie Point Zone in the Scan direction	32 bit int	[1]	pixels	Z_{scan}
PixelOffsetTrack	Offset in Track direction of Pixel [0,0] centre relative to Tie Point A	32 bit float	[1]	pixels	$p_{offset, track}$
PixelOffsetScan	Offset in Scan direction of Pixel [0,0] centre relative to Tie Point A	32 bit float	[1]	pixels	$p_{offset, scan}$
Original Reflectance Offset M1-M11	Offset used in the Original VIIRS SDR Product for representing the Radiance as an integer	32 bit float	[1]	Unitless	$a_{reflectance}$
Original ReflectanceScale M1-M11	Scale factor used in the Original VIIRS SDR Product for representing the radiance as an integer	32 bit float	[1]	Unitless	$b_{reflectance}$
Original Brightness Temperature Offset M12, M14-M16	Offset used in the Original VIIRS SDR Product for representing the Radiance as an integer	32 bit float	[1]	K	a_{bt}
Original Brightness Temperature Scale M12, M14-M16	Scale factor used in the Original VIIRS SDR Product for representing the radiance as an integer	32 bit float	[1]	K	b_{bt}

Table 7. HDF5 Attributes of Group /All_Data/VIIRS-Ch-SDR_All.

6.3 All_Data

The group /All_Data contatins datasets related to the VIIRS instrument. These datasets are applicable to both geolocation and observation data and are described in detail in *Table 8* bellow.

HDF5 Datasets in Group /All_Data					Symbol in Document
Dataset Name	Description	Data Type	Dim.	Units	
NumberOfScans	Actual number of VIIRS scans that were used to create this granule	8 bit uchar	[1]	unitless	-
ModeScan	The VIIRS operational mode, reported at the granule level	8 bit uchar	[48]	unitless	-

HDF5 Datasets in Group /All_Data					Symbol in Document
Dataset Name	Description	Data Type	Dim.	Units	
ModeGran	The VIIRS operational mode, reported at the granule level	8 bit uchar	[1]	unitless	-

Table 8. HDF5 Datasets in Group /All_Data

6.4 Attributes of Geolocation and Observation data

The root group / has the flowing attributes

HDF5 Attributes of Root Group /					Symbol in Document
Attribute Name	Description	Data Type	Dim.	Units	
Distributor	Designates the distributor of the data.	String	[1]	unitless	-
Mission_Name	The character string by which the mission is known.	String	[1]	unitless	-
N_Dataset_Source	The producer of the HDF5 files.	String	[1]	unitless	-
N_GEO_Ref	Filename of the HDF5 file containing the related Geolocation information.	String	[1]	unitless	-
N_HDF_Creation_Date	The date that the HDF5 file was created. Expressed as YYYYMMDD.Paired with N_HDF_Creation_Time	String	[1]	unitless	-
N_HDF_Creation_Time	The time that the HDF5 file was created Expressed as HHMMSS.SSSSSSZ Paired with N_HDF_Creation_Date.	String	[1]	unitless	-
Platform_Short_Name	An acronym, or shorter form of the platform name, used to identify the platform.	String	[1]	unitless	-

Table 9. HDF5 Attributes of Root Group /

6.5 Meta Data

The meta data is contained in the group /All_Data/Data_Products of the Original VIIRS SDR product and it is included in full in the Compact VIIRS SDR product. The Meta data is not described in further detail in this document, but is described in AD-3.

7 STEPS FOR GENERATING THE COMPACT VIIRS SDR FROM THE ORIGINAL VIIRS SDR

7.1 Generating the Geolocation and Angular Data

The table below lists the steps required for generating the geolocation data of the Compact VIIRS SDR Product from the Original VIIRS SDR Product. Each step contains a short description as well as references to sections of this document giving more detailed instructions.

Step	Description	References
1	Create the target group /All_Data/VIIRS-MOD-GEO_All in the Compact VIIRS SDR HDF5 file.	HDF5 definitions www.hdf5.org
2	Access the source group /All_Data/VIIRS-MOD-GEO_All in the Original VIIRS SDR HDF5 geolocation file.	
3	From the source group read the Latitude, Longitude, SatelliteAzimuthAngle, SatelliteZenithAngle, SolarAzimuthAngle, and SolarZenithAngle data sets in full.	Section 5.1
4	Iterate over all Tie Point Zones and perform the Steps 5-15 for each Tie Point Zone.	Tie Point Zones Section 4.4
5	Extract from the data read from file in Step 3, the data for the Pixels with relative indices (0,0), (0, Z_{scan} -1), (Z_{track} -1, 0) and (Z_{track} -1, Z_{scan} -1) and use it as the temporary Tie Points A', B', C' and D' respectively of the Tie Point Zone.	Indices Section 10.1
6	If any of the dataset values associated with the temporary Tie Points A', B', C' and D' are a floating point Fill Value as defined in Table 16, then set all values of the final Tie Points A, B, C and D of the Tie Point Zone to the floating point Fill Value. If different Fill Values are present, use the one with the smallest absolute value. Else perform Steps 7-15	Fill Values Section 10.17
7	For each of the temporary Tie Points A', B', C' and D' Calculate from the Longitude and Latitude the Position Unit Vector.	Calculation Section 10.7.1
8	For each of the temporary Tie Points A', B', C' and D' calculate from the SatelliteAzimuthAngle and SatelliteZenithAngle the Satellite Unit Vector and transform the vector from the Pixel Centred to the Earth Centred Frame.	Calculation Section 10.8.1 Transformation, section 10.9.1

Step	Description	References
9	For each of the temporary Tie Points A’, B’, C’ and D’ calculate from the SolarAzimuthAngle and SolarZenithAngle the Solar Unit Vector and transform the vector from the Pixel Centred to the Earth Centred Frame.	Calculation Section 10.8.1 Transformation, section 10.9.1
10	Calculate the Pixel Expansion Correction coefficient $c_{expansion}$ based on temporary Tie Points A’, B’, C’ and D’.	Section 10.10
11	Calculate the Pixel Alignment Correction coefficient $c_{alignment}$ based on temporary Tie Points A’, B’, C’ and D’.	Section 10.11
12	Iterate over the four final Tie Points A, B, C and D of the Tie Point Zone and perform Steps 13-15 for each Tie Point.	
13	Based on the temporary Tie Points, calculate the interpolation parameters s_{track} and s_{scan} for the Tie Point.	Section 10.13
14	Based on the temporary Tie Points, calculate the corrected interpolation parameters α_{track} and α_{scan} for the Tie Point.	Section 10.5
15	Based on the temporary Tie Points, use the Vector Interpolation to calculate the Position Unit Vector, Satellite Unit Vector and Solar Unit Vector for the Tie Point.	Interpolation, section 10.12.1
16	Iterate over all Tie Point Zones. If the Tie Point Zone has a neighbour Tie Point Zone in the scan direction, perform Steps 17. This step forces the Tie Points that are shared between Tie Point Zones to be identical by using the midpoints of the calculated values.	Tie Point Zones Section 4.4
17	For each of the vectors Position Vector, Satellite Vector and Solar Vector, calculate the midpoint between the Vector for the Tie Point B of this Tie Point Zone and Tie Point A of the neighbour Tie Point Zone, and replace the Vector of both Tie Points with the result. If one of the two input vectors contains Fill Values as defined in Table 16, then use the vector without Fill Values as the result. If both vectors contains Fill Values, the set the result to the one with the smallest absolute value. Repeat this above for the Tie Point C of this Tie Point Zone and Tie Point D of the neighbour Tie Point Zone.	Midpoint Section 10.12.2 Fill Values Section 10.17
18	Iterate over all Tie Point Zones and perform the Step 19-24 for each Tie Point Zone.	Tie Point Zones Section 4.4

Step	Description	References
19	Iterate over the four final Tie Points A, B, C and D of the Tie Point Zone and perform Steps 20-22 for each Tie Point.	
20	If the Position Vector contains Fill Values as defined in Table 16, then set the Latitude and Longitude for the Tie Point to the Fill Value. Else covert the Position Vector for the Tie Point to the longitude and latitude representation. The result of this step is the Latitude and Longitude for the Tie Point.	Fill Values Section 10.17 Conversion, section 10.7.2
21	If the Satellite Vector contains Fill Values as defined in Table 16, then set the SatelliteAzimuthAngle and SatelliteZenithAngle for the Tie Point to the Fill Value. Else transform Satellite Vector for the Tie Point from the Earth Centred to Pixel Centred Frame and covert the result back to azimuth and zenith angle representation. The result of this step is the SatelliteAzimuthAngle and SatelliteZenithAngle for the Tie Point.	Fill Values Section 10.17 Transformation, section 10.9.2 Conversion, section 10.8.2
22	If the Satellite Vector contains Fill Values as defined in Table 16, then set the SolarAzimuthAngle and SolarZenithAngle for the Tie Point to the Fill Value. Transform the Solar Vector for the Tie Point from the Earth Centred to Pixel Centred Frame and covert the result back to azimuth and zenith angle representation. The result of this step is the SolarAzimuthAngle and SolarZenithAngle for the Tie Point.	Fill Values Section 10.17 Transformation, section 10.9.2 Conversion, section 10.8.2
23	If any of the values associated with the final Tie Points A, B, C and D contains Fill Values as defined in Table 16, the set cexpansion to zero. Else, recalculate the Pixel Expansion Correction coefficient $c_{expansion}$ now based on the final Tie Points A, B, C and D.	Section 10.10
24	If any of the values associated with the final Tie Points A, B, C and D contains Fill Values as defined in Table 16, the set cexpansion to zero. Recalculate the Pixel Alignment Correction coefficient $c_{alignment}$ now based on the final Tie Points A, B, C and D.	Section 10.11
25	Add to the target HDF5 file the size of the Tie Point Zone, Z_{track} and Z_{scan}, and the Pixel Offset $p_{offset,track}$ and $p_{offset,scan}$ as HDF5	Section 6.2.2

Step	Description	References
	attributes of each radiance data set contained in the product.	
26	Add to the target HDF5 file the number of Tie Point Zones $N_{zones,track}$ and $N_{zones,scan}$ within the HDF5 data object /All_Data/VIIRS-MOD-GEO_All.	Section 6.1
27	Add to the target HDF5 file correction coefficients $c_{expansion}$ and $c_{alignment,}$ for the full scan $I_{zone,track}$ = 24, within the HDF5 data object /All_Data/VIIRS-MOD-GEO_All.	Section 6.1
28	Add, for all Tie Point, the calculated Latitude, Longitude, SatelliteAzimuthAngle, SatelliteZenithAngle, SolarAzimuthAngle, and SolarZenithAngle values to the target HDF5 file in the data object /All_Data/VIIRS-MOD-GEO_All.	Section 6.1 Index relations Section 10.3
29	From the source group copy the datasets StartTime, MidTime, SCPosition, SCVelocity, SCAttitude, QF1_SCAN_VIIRSSDRGEO and QF2_SCAN_VIIRSSDRGEO to the target group.	Section 5.1 Section 6.1
30	From the source group copy the datasets ModeScan, ModeGran and NumberOfScans to the target group /All_Data	Section 5.1 Section 6.3

Table 10 Steps for generating the geolocation data of the Compact VIIRS SDR Product

7.2 Generating the Observation Data

The table below lists the steps required for generating the observation data of the Compact VIIRS SDR Product from the Original VIIRS SDR Product. Each step contains a short description as well as references to sections of this document giving more detailed instructions.

Step	Description	References
1	Iterate over the VIIRS channels *Ch* = M1-M16 and perform the Steps 2-21 for each channel.	
2	Create the target group /All_Data/VIIRS-*Ch*-SDR_All in the Compact VIIRS SDR HDF5 file.	
3	Access the source group /All_Data/VIIRS-*Ch*-SDR_All in the Original VIIRS SDR HDF5 file for *Ch*.	
4	From the source group copy the datasets QF1_VIIRSMBANDSDR, QF2_SCAN_SDR,	Section 5.2

Step	Description	References
	QF3_SCAN_SDR, QF4_SCAN_SDR, QF5_GRAN_BAD_DETECTOR, PadByte1, NumberOfMissingPkts, NumberOfBadChecksums and NumberOfDiscardedPkts to the target group.	Section 6.2
5	If *Ch* is one of the channels M1, M2, M6, M8-M12, M14-M16 then perform Steps 6-8.	
6	Copy the 16 bit uint source group dataset Radiance to the target group.	Section 5.2 Section 6.2
7	Add the scale contained in the source group dataset RadianceFactors twice to the dataset Radiance in the target group as the attributes b_{low} and b_{high}.	Section 5.2 Section 6.2.1
8	Add the offset contained in the source group dataset RadianceFactors twice to the dataset Radiance in the target group as the attributes a_{low} and a_{high}.	Section 5.2 Section 6.2.1
10	If *Ch* is one of the channels M3-M5, M7, M13 then perform Steps 11-14.	
11	Read the 32 bit floating point source group dataset Radiance	Section 5.2
12	Convert each 32 bit floating point value in the Radiance dataset to a 16 bit uint using the dual-scale representation. Use the values of a_{low}, b_{low}, a_{high}, b_{high} and the threshold as provided in Table 19.	Section 10.14.2 Section 11
13	Write the 16 bit uint dataset Radiance to the target group.	Section 6.2
14	Add a_{low}, b_{low}, a_{high}, b_{high} and $C_{threshold}$ as attributes to the dataset Radiance in the target group.	Section 6.2.1
15	If *Ch* is one of the channels M1-M11 then perform Steps 16-18.	
16	Lookup A_{vis} and B_{vis} for the channel *Ch* in Table 18 and add them as the attributes EquivalentWidth and IntegratedSolarIrradiance of the dataset Radiance in the target group.	Section 6.2.1 Section 11
17	Calculate the normalised Earth-Sun distance d_{se} and add it as the attribute EarthSunDistanceNormalised	Section 6.2.1

Step	Description	References
	of the dataset Radiance in the target group	Section 10.14.3
18	Add the offset and scale contained in the source group dataset ReflectanceFactors as the attributes OriginalReflectanceOffset and OriginalReflectanceScale of the target group.	Section 5.2 Section 6.2.2
19	If *Ch* is one of the channels M12-M16 then perform Steps 20-21.	
20	Lookup λ_C , A_{ir} and B_{ir} for the channel *Ch* in Table 20 and add them as the attributes CentralWaveLength, BandCorrectionCoefficientA, and and CorrectionCoefficientB of the dataset Radiance in the target group.	Section 6.2.1 Section 11
21	Add the offset and scale contained in the source group dataset BrightnessTemperatureFactors as the attributes OriginalBrightnessTemperatureOffset and OriginalBrightnessTemperatureScale of the target group.	Section 5.2 Section 6.2.2

Table 11 Steps for generating the observation data of the Compact VIIRS SDR Product

7.3 Generating the Meta Data

The table below lists the steps required for generating the meta data of the Compact VIIRS SDR Product from the Original VIIRS SDR Product.

Step	Description	References
1	Read the group /All_Data/Data_Products from the Original VIIRS SDR HDF5 geolocation file and add it as the group /All_Data/Data_Products to the Compact VIIRS SDR HDF5 file.	

Table 12 Steps for generating the meta data of the Compact VIIRS SDR Product

8 STEPS FOR RECONSTRUCTING THE ORIGINAL VIIRS SDR FROM THE COMPACT VIIRS SDR

8.1 Reconstructing the Geolocation and Angular Data

The table below lists the steps required for reconstructing the geolocation data for each Pixel starting from the Tie Point based information contained in the Compact VIIRS SDR Product. Each step contains a short description as well as references to sections of this document giving more detailed instructions.

Step	Description	References
1	From the Compact VIIRS SDR HDF5 file read the following attributes of group /All_Data/VIIRS-M01-SDR_ALL TiePointZoneSizeTrack, TiePointZoneSizeScan, PixelOffsetTrack and PixelOffsetScan.	HDF5 definitions www.hdf5.org Section 6.2.2
2	Create the target group /All_Data/VIIRS-MOD-GEO_All in the Original VIIRS SDR HDF5 geolocation file.	
3	Access the source group /All_Data/VIIRS-MOD-GEO_All in the Compact VIIRS SDR HDF5 file.	
4	From the source group read the datasets NumberOfTiePointZonesTrack, NumberOfTiePointZonesScan, ExpansionCoefficient, AlignmentCoefficient, Latitude, Longitude, SatelliteAzimuthAngle, SatelliteZenithAngle, SolarAzimuthAngle, and SolarZenithAngle in full.	Section 6.1
5	If any of the dataset values associated with the temporary Tie Points A’, B’, C’ and D’ are a floating point Fill Value as defined in Table 16, then set all values of the final Tie Points A, B, C and D of the Tie Point Zone to the floating point Fill Value. If different Fill Values are present, use the one with the largest absolute value. Else perform Steps 6-17	Fill Values Section 10.17
6	Iterate over all Tie Point Zones and perform the Steps 7-17 for each Tie Point Zone.	Tie Point Zones Section 4.4
7	Associate the data read from file in Step 1-4 with the corresponding Tie Points A, B, C and D of the Tie Point Zone using the index relations.	Index relations Section 10.3

Step	Description	References
8	If any of the dataset values associated with the Tie Points A, B, C and D are a floating point Fill Value as defined in Table 16, then set the value of Latitude, Longitude, SatelliteAzimuthAngle, SatelliteZenithAngle, SolarAzimuthAngle, and SolarZenithAngle to the floating point Fill Value for all Pixels within the Tie-Point Zone. If different Fill Values are present, use the one with the largest absolute value. Else perform Steps 8-16	Fill Values Section 10.17
9	If the Tie Point Zone, defined by the positions of its four Tie Points A, B, C and D, crosses the Datum Line or lies within the polar regions, then calculate from the Longitude and Latitude the Position Unit Vector for each of the Tie Points A, B, C and D.	Condition, section 10.6.1 Calculation Section 10.7.1
10	If, for Tie Points A, B, C and D, the range of the SatelliteAzimuthAngle values is large or the points are close to one of the Poles or the SatelliteZenithAngle is small, then, for each of the Tie Points A, B, C and D, calculate from the SatelliteAzimuthAngle and SatelliteZenithAngle the Satellite Unit Vector and transform the vector from the Pixel Centred to the Earth Centred Frame.	Condition, section 10.6.2 Calculation Section 10.8.1 Transformation, section 10.9.1
11	If, for Tie Points A, B, C and D, the range of the SolarAzimuthAngle values is large or the points are close to one of the Poles or the SolarZenithAngle is small, then, for each of the Tie Points A, B, C and D, calculate from the SolarAzimuthAngle and SolarZenithAngle the Solar Unit Vector and transform the vector from the Pixel Centred to the Earth Centred Frame.	Condition, section 10.6.3 Calculation Section 10.8.1 Transformation, section 10.9.1
12	Iterate over all Pixels within the Tie Point Zone and perform Steps 13-17 for each Pixel.	
13	Calculate the interpolation parameters s_{track} and s_{scan} for the pixel.	Section 10.4
14	Calculate the corrected interpolation parameters α_{track} and α_{scan} for the pixel.	Section 10.5
15	If the Position Unit Vectors were calculated in Step 7, use the Vector Interpolation to calculate the	Interpolation, section 10.12.1

Step	Description	References
	Position Unit Vector for the Pixel and covert the result back to the longitude and latitude representation. Otherwise, interpolate directly in longitude and latitude. The result of this step is the Latitude and Longitude for the Pixel.	Conversion, section 10.7.2 Interpolation, section 10.12.3
16	If the Satellite Unit Vectors were calculated in Step 8, use the Vector Interpolation to calculate the Satellite Unit Vector for the Pixel, transform the vector from the Earth Centred to Pixel Centred Frame and covert the result back to azimuth and zenith angle representation. Otherwise, interpolate directly in azimuth and zenith angle. The result of this step is the SatelliteAzimuthAngle and SatelliteZenithAngle for the Pixel.	Interpolation, section 10.12.1 Transformation, section 10.9.2 Conversion, section 10.8.2 Interpolation, section 10.12.4
17	If the Solar Unit Vectors were calculated in Step 9, use the Vector Interpolation to calculate the Solar Unit Vector for the Pixel, transform the vector from the Earth Centred to Pixel Centred Frame and covert the result back to azimuth and zenith angle representation. Otherwise, interpolate directly in azimuth and zenith angle. The result of this step is the SolarAzimuthAngle and SolarZenithAngle for the Pixel.	Interpolation, section 10.12.1 Transformation, section 10.9.2 Conversion, section 10.8.2 Interpolation, section 10.12.4
18	Write, for all Pixels, the calculated Latitude, Longitude, SatelliteAzimuthAngle, SatelliteZenithAngle, SolarAzimuthAngle, and SolarZenithAngle values to the target group.	Section 5.1
19	From the source group copy the datasets StartTime, MidTime, SCPosition, SCVelocity, SCAttitude, PadByte1	Section 6.1 Section 5.1

Step	Description	References
	and QF1_SCAN_VIIRSSDRGEO to the target group.	
20	From the source group /All_Data copy the datasets NumberOfScans , ModeScan and ModeGran to the target group.	Section 6.3 Section 5.1

Table 13 Steps for reconstructing geolocation data of the Original VIIRS SDR Product

8.2 Reconstructing the Observation Data

The table below lists the steps required for generating the observation data of the Original VIIRS SDR Product from the Compact VIIRS SDR Product. Each step contains a short description as well as references to sections of this document giving more detailed instructions.

Step	Description	References
1	Iterate over the VIIRS channels *Ch* = M1-M16 and perform the Steps 2-23 for each channel.	
2	Access the source group /All_Data/VIIRS-*Ch*-SDR_All in the Compact VIIRS SDR HDF5 file.	
3	Read the target group attribute OriginalFilename and create a new Original VIIRS SDR HDF5 file for channel *Ch*.	Section 6.2.2
4	Create the target group /All_Data/VIIRS-*Ch*-SDR_All in the Original VIIRS SDR HDF5 file.	
5	From the source group copy the datasets QF1_VIIRSMBANDSDR, QF2_SCAN_SDR, QF3_SCAN_SDR, QF4_SCAN_SDR, QF5_GRAN_BAD_DETECTOR, PadByte1, NumberOfMissingPkts, NumberOfBadChecksums and NumberOfDiscardedPkts to the target group.	Section 6.2 Section 5.2
6	From the source group /All_Data copy the datasets NumberOfScans , ModeScan and ModeGran to the target group.	Section 6.3 Section 5.2
7	Read the source group Radiance dataset attributes RadianceOffsetHigh, RadianceScaleHigh, RadianceOffsetLow and RadianceScaleLow	Section 6.2.1

Step	Description	References
	corresponding to a_{high}, b_{high}, a_{low} and b_{low}.	
8	If *Ch* is one of the channels M1, M2, M6, M8-M12, M14-M16 then perform Steps 8-9.	
9	Copy the 16 bit uint source group dataset Radiance to the target group.	Section 6.2 Section 5.2
10	Add b_{low} and a_{low} as scale and offset respectively to the source group dataset RadianceFactors.	Section 6.2.1 Section 5.2
11	Read the 16 bit uint source group dataset Radiance.	Section 6.2
12	Convert each 16 bit uint value in the Radiance dataset to a 32 bit floating point using the dual-scale representation conversion.	Section 10.14.1
13	If *Ch* is one of the channels M3-M5, M7, M13 then write the 32 bit floating point dataset Radiance to the target group.	Section 5.2
14	If *Ch* is one of the channels M1-M11 then perform Steps 14-17.	
15	Read the source group Radiance dataset attributes EquivalentWidth, IntegratedSolarIrradiance and EarthSunDistanceNormalised corresponding to A_{vis}, B_{visand} and d_{se}.	Section 6.2.1
16	For each value in the 32 bit floating point dataset Radiance find the corresponding /All_Data/VIIRS-MOD-GEO_All/SolarZenithAngle for the pixel and calculate the Reflectance.	Section 10.14.3
17	Read the source group attributes OriginalReflectanceOffset and OriginalReflectanceScale corresponding to $a_{reflectance}$ and $b_{reflectance}$ and write them to the target group dataset ReflectanceFactors.	Section 6.2.2 Section 5.2
18	For each Reflectance value, calculate the integer representation based on $a_{reflectance}$ and $b_{reflectance}$ and write it to the target group Reflectance dataset	Section 10.15 Section 5.2
19	If *Ch* is one of the channels M12-M16 then perform Steps 19-21.	
20	Read the source group Radiance dataset attributes CentralWaveLength, BandCorrectionCoefficientA,	Section 6.2.1

Step	Description	References
	and BandCorrectionCoefficientB corresponding to λ_C , A_{ir} and B_{ir}	
21	Read the source group attributes OriginalBrightnessTemperatureOffset and OriginalBrightnessTemperatureScale corresponding to a_{bt} and b_{bt} and write them to the target group dataset BrightnessTemperatureFactors.	Section 6.2.2 Section 5.2
22	For each value in the 32 bit floating point dataset Radiance calculate the Brightness Temperature.	Section 10.14.4
23	If *Ch* is one of the channels M12, M14-M16 then convert the Brightness Temperatures to the integer representation based on a_{bt} and b_{bt} and write it to the target group BrightnessTemperature dataset	Section 10.16 Section 5.2
24	If *Ch* is the channel M13 then write the Brightness Temperatures to the target group BrightnessTemperature dataset	Section 5.2

Table 14 Steps for reconstructing the observation data of the Original VIIRS SDR Product

8.3 Reconstructing the Meta Data

The table below lists the steps required for reconstructing the meta data of the Original VIIRS SDR Product from the Compact VIIRS SDR Product

Step	Description	References
1	Read the group /All_Data/Data_Products from the Compact VIIRS SDR HDF5 file and add it as the group /All_Data/Data_Products to each Original VIIRS SDR HDF5 file.	

Table 15 Steps for reconstructing the meta data of the Original VIIRS SDR Product

9 FILE NAMING CONVENTION

The file naming convention for the Compact VIIRS SDR follows the convention for the Original VIIRS SDR as defined in AD-1 section 3.4.1. The structure is shown in **Figure 9** below.

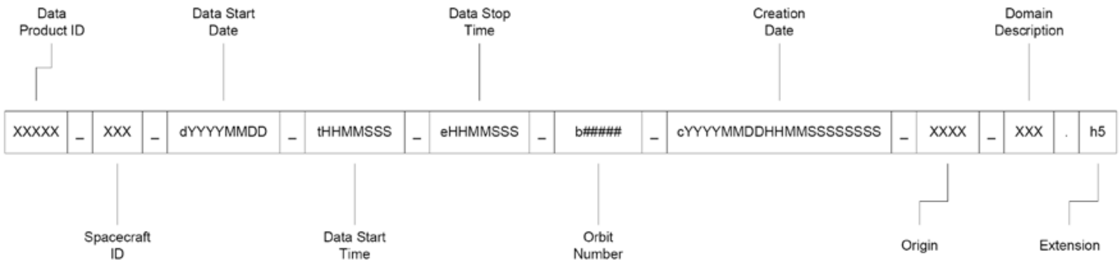


Figure 9 File Name Structure

9.1 Original VIIRS SDR File Naming Convention

Examples of file names for the M-Band VIIRS SDR observation files are:

SVM01_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_noaa_ops.h5
SVM02_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_noaa_ops.h5
.
.
SVM16_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_noaa_ops.h5

and the corresponding geolocation file:

GMODO_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_noaa_ops.h5

9.2 Compact VIIRS SDR File Naming Convention

In the file name convention for the Compact VIIRS SDR the Data Product ID defined as SVMC, where S stands for SDR, V for VIIRS, M for M-Band and C for Compact.

An example file name for an uncompressed Compact VIIRS SDR file would be:

SVMC_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_eum_ops.h5

and for a compressed Compact VIIRS SDR file:

SVMC_npp_d20030125_t0847056_e0848301_b00015_c20090513182937523620_eum_ops.bz2

10 MATHEMATICAL ALGORITHMS

The section details the mathematical algorithms required for generating and applying the geolocation data of the Compact VIIRS SDR Product. The individual sections are referenced in the steps defined in sections 7and 8.

10.1 Relative and Absolute Pixel Indices

Within the Tie Point Zone a pixel is given relative indices ($i_{track,relative,}$, $i_{scan,relative}$) starting at (0,0) at the Tie Point A and counting up to (Z_{track} -1, Z_{scan} -1) at Tie Point C, where Z_{track} and Z_{scan} are the size of the Tie Point Zone along the track and scan directions respectively. In the case of the VIIRS M-band, ($i_{track,relative,}$, $i_{scan,relative}$) runs from (0,0) through (15,15) as shown in Figure 4.

Similarly, within the granule a pixel is given an absolute indices ($i_{track,}$, i_{scan}) starting at (0,0) and counting up to (N_{track} -1, N_{scan} -1), where N_{track} and N_{scan} are the size of the Granule along the track and scan directions respectively. In the case of the VIIRS M-band, (i_{track}, i_{scan}) runs from (0,0) through (95, 3199).

As the Tie Point Zones are all the same size across the full VIIRS swath, the conversions from relative to absolute pixel indices

$$i_{relative,track} = remainder\left(\frac{i_{track}}{Z_{track}}\right)$$
$$i_{relative,scan} = remainder\left(\frac{i_{scan}}{Z_{scan}}\right)$$

as well as the conversion from absolute to relative pixel indices

$$i_{track} = i_{zone,track} \cdot Z_{track} + i_{relative,track}$$

$$i_{scan} = i_{zone,scan} \cdot Z_{scan} + i_{relative,scan}$$

are simple. Here ($i_{zone,track,}$ $i_{zone,scan}$) are the indices of the Tie Point Zone within the Granule as shown in Figure 4.

In the Compact VIIRS SDR Product the size of the Tie Point Zone Z_{track} and Z_{scan} are stored as attributes of each contained observation group, see section 6.2.2.

10.2 Tie Point Zone Indices

The Tie Point Zone indices ($i_{zone,track,}$ $i_{zone,scan}$) can be calculated from the absolute pixel indices ($i_{track,}$, i_{scan}) as n

$$i_{zone,track} = integer\left(\frac{i_{track}}{Z_{track}}\right)$$
$$i_{zone,scan} = integer\left(\frac{i_{scan}}{Z_{scan}}\right)$$

In the case of the VIIRS M-band, ($i_{zone,track,}$, $i_{zone,scan}$) runs from (0,0) through (5,199) corresponding to a full Granule.

10.3 HDF5 Data Array Indices

The Tie Point Zone indices ($i_{zone,track,}$ $i_{zone,scan}$) are used for calculating the location of geolocation and angular parameters within the HDF5 data array. For each of the Ties Points A, B, C and D the array indices are

$$(i_A, j_A)_{HDF5} = (2 \cdot i_{zone,track}, i_{zone,scan})$$

$$(i_B, j_B)_{HDF5} = \left(2 \cdot i_{zone,track}, i_{zone,scan} + 1\right)$$

$$(i_C, j_C)_{HDF5} = (2 \cdot i_{zone,track} + 1, i_{zone,scan} + 1)$$

$$(i_D, j_D)_{HDF5} = (2 \cdot i_{zone,track} + 1, i_{zone,scan})$$

10.4 Interpolation Parameters and Pixel Offset

Where the pixel indices are an integer number, the interpolation parameters s_{track} and s_{scan} are real numbers varying as function of relative pixel indices

$$s_{track}(i_{relative,track}) = \frac{p_{offset,track} + i_{relative,track}}{Z_{track}}$$

$$s_{scan}(i_{relative,scan}) = \frac{p_{offset,scan} + i_{relative,scan}}{Z_{scan}}$$

Here the Pixel Offsets ($p_{offset,track}$, $p_{offset,scan}$) indicates the offset of the corner pixel centre with respect to its nearest Tie Point A as shown in Figure 10, where the corner pixel is the one with local indices (0,0) within its Tie Point Zone. The Pixel Offset is measured in units of pixels and in the case of the VIIRS instrument, the Pixel Offset is (0.5, 0.5) for all bands and channels.

In the Compact VIIRS SDR Product the Pixel Offset ($p_{offset,track}$, $p_{offset,scan}$) is stored as attributes of each contained observation group, see section 6.2.2.

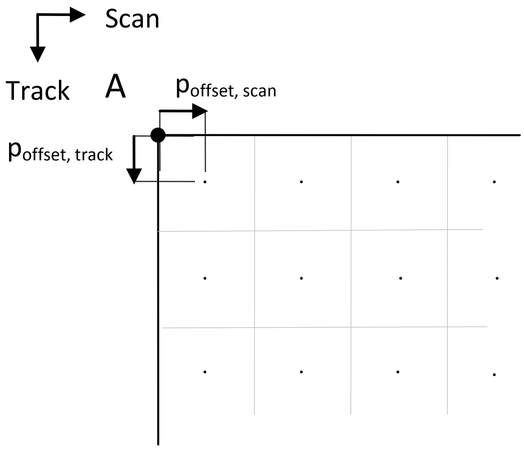


Figure 10 Definition of the Pixel Offset

10.5 Scanning Geometry Corrections

Two geometrical corrections are applied to the Interpolation Parameters s_{track} and s_{scan} introduced in section 10.4, resulting in the Corrected Interpolation Parameters α_{track} and α_{scan}

$$\alpha_{scan} = s_{scan} + s_{scan}(1 - s_{scan})c_{\text{expansion}} + s_{track}(1 - s_{track})c_{\text{alignment}}$$

$$\alpha_{track} = s_{track}$$

Both corrections are approximated as second order polynomials in s_{track} and s_{scan}. The corrections depend on the coefficients $c_{\text{expansion}}$ and $c_{\text{alignment}}$ that can be considered constant for each Tie Point Zone.

The first correction, expressed by the coefficient $c_{\text{expansion}}$, accounts for the variation in Pixel size across each Tie Point Zone and is described in further detail in section 10.10.

The second correction, expressed by the coefficient $c_{\text{alignment}}$, accounts for the Pixels not being linearly aligned along the track direction and is described in further detail in section 10.11.

In the Compact VIIRS SDR Product the geometrical correction coefficients $c_{\text{expansion}}$ and $c_{\text{alignment}}$ are included once for each Tie Point Zone scan index $i_{\text{zone,scan}}$, corresponding to a total of $N_{\text{zones,scan}}$ of each coefficient, see section 6.1. These coefficient values can be applied for all scans contained in the granule.

10.6 Interpolation Conditions

Within a given Tie Point Zone, the conditions defined in this section determine if the Vector Interpolation method must be applied for the Pixel Position, Satellite Direction and Solar Direction respectively, to ensure numerical accuracy.

The Vector Interpolation method is generally applicable and always provides the best possible accuracy. However, for reasons of computational speed, it is recommended to use the simpler direct interpolation methods whenever possible.

The indices A, B, C and D used in the expressions refer to the four Tie Points of the Tie Point Zone.

10.6.1 Pixel Position Interpolation Condition

For the Pixel Position, Vector Interpolation must be applied if the Tie Point Zone crosses the Datum Line

$$\max(lon_A, lon_B, lon_C, lon_D) - min(lon_A, lon_B, lon_C, lon_D) > 90°$$

or if the Tie Point Zone lies within the Polar regions

$$\max(|lat_A|, |lat_B|, |lat_C|, |lat|_D) > \ lat_{position\ limit}$$

where a typical value of the limit is $lat_{position\ limit} = 60°$.

Otherwise, the longitude and latitude can interpolated directly.

10.6.2 Satellite Direction Interpolation Condition

For the Satellite Direction, Vector Interpolation must be applied if the range of the Satellite Azimuth Angle is large

$$\max(azi_A, azi_B, azi_C, azi_D) - min(azi_A, azi_B, azi_C, azi_D) > azi_{satellite\ limit}$$

where a typical value of the limit is $azi_{satellite\ limit} = 5°$, or if the Satellite Zenith Angle is small

$$\min(zen_A, zen_B, zen_C, zen_D) < \ zen_{satellite\ limit}$$

where a typical value of the limit is $zen_{satellite\ limit} = 10°$, or if the Tie Point Zone is close to one of the Poles

$$\max(|lat_A|, |lat_B|, |lat_C|, |lat|_D) > \ lat_{satellite\ limit}$$

where a typical value of the limit is $lat_{satellite\ limit} = 80°$.

Otherwise, the azimuth and zenith angles can interpolated directly.

10.6.3 Solar Direction Interpolation Condition

For the Solar Direction, Vector Interpolation must be applied if the range of the Solar Azimuth Angle is large

$$\max(azi_A, azi_B, azi_C, azi_D) - min(azi_A, azi_B, azi_C, azi_D) > azi_{solar\ limit}$$

where a typical value of the limit is $azi_{solar\ limit} = 5°$, or if the Solar Zenith Angle is small

$$\min(zen_A, zen_B, zen_C, zen_D) < zen_{solar\ limit}$$

where a typical value of the limit is $zen_{solar\ limit} = 10°$, or if the Tie Point Zone is close to one of the Poles

$$\max(|lat_A|, |lat_B|, |lat_C|, |lat|_D) > lat_{solar\ limit}$$

where a typical value of the limit is $lat_{solar\ limit} = 80°$.

Otherwise, the azimuth and zenith angles can interpolated directly.

10.7 Position Conversions

In the interpolation scheme a position can either be represented as longitude and latitude or as a vector pointing from the centre of the Earth towards the position. The advantage of using the vector for interpolation is that it provides the same good accuracy for all longitudes and latitudes. However, it is computationally more demanding.

Note that, for the purpose of interpolation within a Tie Point Zone, it is sufficiently accurate to assume a spherical Earth.

10.7.1 Longitude, Latitude to Unit Vector

The conversion from longitude and latitude to a Position Unit Vector is

$$x = \cos(lat)\cos(lon)$$
$$y = \cos(lat)\sin(lon)$$
$$z = \sin(lat)$$

10.7.2 Vector to Longitude, Latitude

The conversion from Position Vector to longitude and latitude is

$$lon = \tan^{-1}\left(\frac{y}{x}\right)$$

$$lat = \tan^{-1}\left(\frac{z}{\sqrt{x^2 + y^2}}\right)$$

For correct computation of $\tan^{-1}(y/x)$ use the dual argument function atan2(y,x) provided in most programming languages.

10.8 Direction Conversions

In the interpolation scheme a direction can either be represented as azimuth and zenith angle or as a vector.

10.8.1 Azimuth Angle, Zenith Angle to Unit Vector

The conversion from azimuth and zenith angles to a Direction Unit Vector is

$$x = \sin(zen)\sin(azi)$$
$$y = \sin(zen)\cos(azi)$$
$$z = \cos(zen)$$

10.8.2 Vector to Azimuth Angle, Zenith Angle

The conversion from a Direction Vector to azimuth and zenith angles is

$$azi = \tan^{-1}\left(\frac{x}{y}\right)$$
$$zen = \frac{\pi}{2} - \tan^{-1}\left(\frac{z}{\sqrt{x^2 + y^2}}\right)$$

For correct computation of $\tan^{-1}(y/x)$ use the dual argument function atan2(y,x) provided in most programming languages.

10.9 Reference Frame Transformations

Two reference frames are being used in the interpolation scheme.

In the Pixel Centred reference frame the x-axis points to the East, the y-axis to the North and the z-axis to the Zenith. Generally the azimuth and zenith angles are expressed in the Pixel Centred reference frame.

In the Earth Centred reference frame the z-axis points to the North, the x-axis to the 0° longitude and the y-axis completes the system.

Vector interpolation are performed in the Earth Centred reference frame to ensure that that the interpolated coordinate values all refer to the same reference frame.

The rotation from the Earth Centred reference frame to the Pixel Centred reference frame can be expressed using the orthogonal transformation matrix

$$M = \begin{pmatrix} m_{0,0} & m_{0,1} & m_{0,2} \\ m_{1,0} & m_{1,1} & m_{1,2} \\ m_{2,0} & m_{2,1} & m_{2,2} \end{pmatrix} = \begin{pmatrix} -\sin(lon) & \cos(lon) & 0 \\ -\sin(lat)\cos(lon) & -\sin(lat)\sin(lon) & \cos(lat) \\ \cos(lat)\cos(lon) & \cos(lat)\sin(lon) & \sin(lat) \end{pmatrix}$$

10.9.1 Pixel Centred to Earth Centred

A vector expressed in the Pixel Centred reference frame (PC) can be transformed to the Earth Centred (EC) reference frame using

$$x_{EC} = m_{0,0}x_{PC} + m_{0,1}y_{PC} + m_{0,2}z_{PC}$$
$$y_{EC} = m_{1,0}x_{PC} + m_{1,1}y_{PC} + m_{1,2}z_{PC}$$
$$z_{EC} = m_{2,0}x_{PC} + m_{2,1}y_{PC} + m_{2,2}z_{PC}$$

10.9.2 Earth Centred to Pixel Centred

A vector expressed in the Earth Centred (EC) reference frame can be transformed to the Pixel Centred reference frame (PC) using

$$x_{PC} = m_{0,0}x_{EC} + m_{1,0}y_{EC} + m_{2,0}z_{EC}$$
$$y_{PC} = m_{0,1}x_{EC} + m_{1,1}y_{EC} + m_{2,1}z_{EC}$$
$$z_{PC} = m_{0,2}x_{EC} + m_{1,2}y_{EC} + m_{2,2}z_{EC}$$

10.10 Pixel Expansion Correction

For the VIIRS M-Band and I-Band, pixels are sampled at constant increments in the instrument scanning angle φ, see Figure 6. Consequently the on-ground pixel size increases towards the edge of the swath. This means that the pixel centres are not linearly distributed along the scan direction within a Tie Point Zone.

To characterise this effect the coefficient $c_{expansion}$ is introduced. It expresses the pixel centre shift, normalised against the scan direction size of the Tie Point Zone, for a Pixel at the midpoint of the Tie Point Zone. The actual correction is a function of s_{scan} and can be approximated as a second order polynomial

$$s_{scan}(1 - s_{scan})c_{\text{expansion}}$$

where s_{scan} varies from 0.0 to 1.0 across the Tie Point Zone.

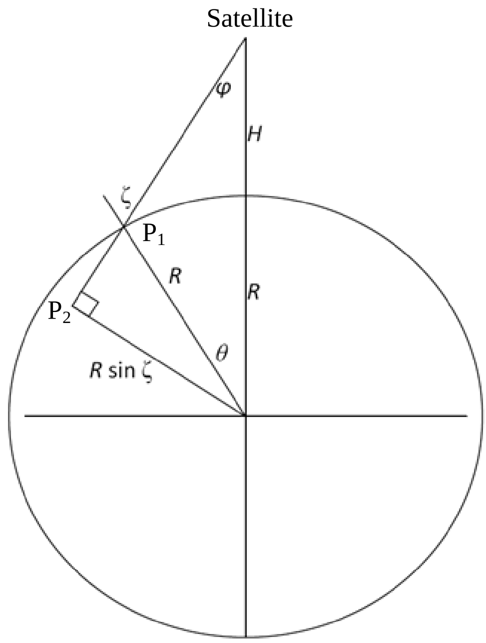


Figure 11 View along the track direction of the VIIRS scanning geometry

The Satellite Zenith Angles at Tie Point A and B are written ζ_A and ζ_B respectively.

The corresponding scan angles can be computed from

$$\varphi_A = sin^{-1}\left(\frac{\mathrm{R} \cdot \sin{(\zeta_A)}}{R + H}\right)$$

$$\varphi_B = sin^{-1}\left(\frac{\mathrm{R} \cdot \sin{(\zeta_B)}}{R + H}\right)$$

where the mean Earth radius R = 6371 km and the mean orbital height H = 824 km are sufficiently accurate as a basis for the calculation of the geometrical correction considered in this section.

The corresponding values of θ are

$$\theta_A = \zeta_A - \varphi_A$$

$$\theta_B = \zeta_B - \varphi_B$$

At the scan midpoint

$$\varphi = \frac{\varphi_A + \varphi_B}{2}$$

$$\zeta = sin^{-1}\left(\frac{(\mathrm{R} + \mathrm{H}) \cdot \sin{(\varphi)}}{R}\right)$$

$$\theta = \zeta - \varphi$$

For use in the quadratic approximation of the pixel size variation across the Tie Point Zone, the following correction factor is defined

$$c_{\text{expansion}} = 4 \cdot \frac{\frac{\theta_A + \theta_B}{2} - \theta}{\theta_A - \theta_B}$$

10.11 Pixel Alignment Correction

The VIIRS instrument scans 16 M-Band lines and 32 I-Band lines during one instrument scan. At the sub-satellite point the 16 or 32 pixels are linearly aligned along the track direction. However, away from the sub-satellite point, the pixels are located along a curved arc formed by the intersection of the along track scan plane and the Earth surface.

To characterise this effect the coefficient $c_{\text{alignment}}$ is introduced. It expresses the pixel centre shift in the scan direction, normalised against the size of the Tie Point Zone, for a Pixel at the midpoint of the Tie Point Zone. The actual correction is a function of s_{track} and can be approximated as a second order polynomial

$$s_{track}(1 - s_{track})c_{\text{alignment}}$$

where s_{track} varies from 0.0 to 1.0 across the Tie Point Zone.

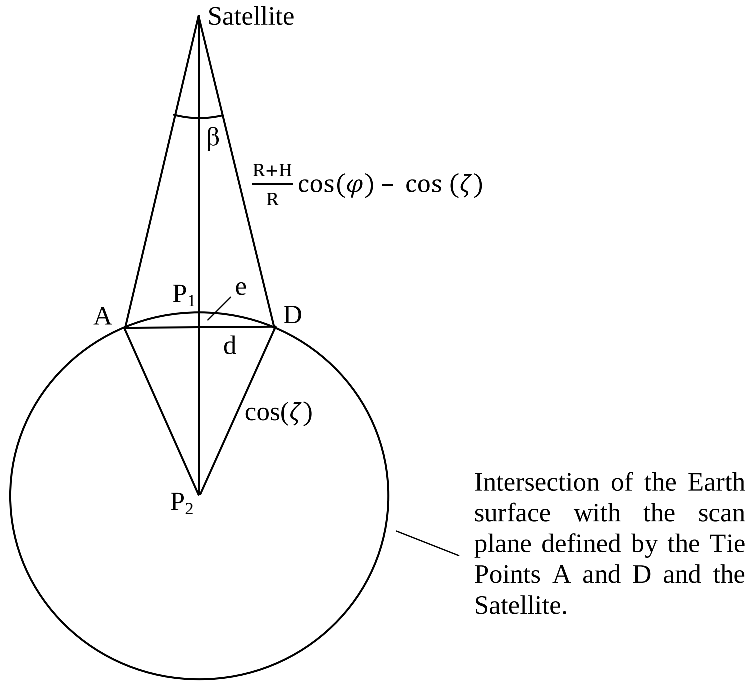


Figure 12 View of the VIIRS scanning geometry in a plane perpendicular to the track direction and containing the line through P_1, P_2 and the satellite introduced in Figure 11.

An overview of the geometry is given in Figure 12. A and D are two Tie Points, the distance d is half the scan width and can be fund from

$$d = \left(\frac{R+H}{R}\cos(\varphi) - cos(\zeta)\right)\sin\left(\frac{\beta}{2}\right)$$

where an approximate value of $\sin\left(\frac{\beta}{2}\right) \approx \frac{11.9\text{ km}}{2\cdot 824\text{ km}}$ found from the VIIRS scan width at the sub-satellite point and the mean orbit height is sufficiently accurate for the purpose of this correction.

In the plane considered in Figure 12, the correction e can be expressed as

$$e = cos(\zeta) - \sqrt{cos^2(\zeta) - d^2}$$

which must be projected to the horizontal plane and normalised against the scan direction size of the Tie Point Zone to give

$$c_{\text{alignment}} = 4 \cdot \frac{e \cdot \sin(\zeta)}{\theta_A - \theta_B}$$

10.12 Interpolation

The indices A, B, C and D used in the expressions refer to the four Tie Points of the Tie Point Zone.

10.12.1 Vector Interpolation

Within a Tie Point Zone, a vector can be interpolated based on the Tie Points A, B, C and D as well as the corrected interpolation parameters α_{track} and α_{scan} for the pixel

$$\begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} = (1 - \alpha_{scan})\begin{pmatrix} x_A \\ y_A \\ z_A \end{pmatrix} + \alpha_{scan}\begin{pmatrix} x_B \\ y_B \\ z_B \end{pmatrix}$$

$$\begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix} = (1 - \alpha_{scan})\begin{pmatrix} x_D \\ y_D \\ z_D \end{pmatrix} + \alpha_{scan}\begin{pmatrix} x_C \\ y_C \\ z_C \end{pmatrix}$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = (1 - \alpha_{track})\begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} + \alpha_{track}\begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix}$$

10.12.2 Direction Vector and Position Vector Midpoint

The midpoint between two direction vectors can be calculated using

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = 0.5 \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} + 0.5 \begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix}$$

10.12.3 Longitude, Latitude Interpolation

Within a Tie Point Zone, a latitude and longitude can be interpolated based on the Tie Points A, B, C and D as well as the corrected interpolation parameters α_{track} and α_{scan} for the pixel

$$\begin{pmatrix} lat_1 \\ lon_1 \end{pmatrix} = (1 - \alpha_{scan}) \begin{pmatrix} lat_A \\ lon_A \end{pmatrix} + \alpha_{scan} \begin{pmatrix} lat_B \\ lon_B \end{pmatrix}$$

$$\begin{pmatrix} lat_2 \\ lon_2 \end{pmatrix} = (1 - \alpha_{scan}) \begin{pmatrix} lat_D \\ lon_D \end{pmatrix} + \alpha_{scan} \begin{pmatrix} lat_C \\ lon_C \end{pmatrix}$$

$$\begin{pmatrix} lat \\ lon \end{pmatrix} = (1 - \alpha_{track}) \begin{pmatrix} lat_1 \\ lon_1 \end{pmatrix} + \alpha_{track} \begin{pmatrix} lat_2 \\ lon_2 \end{pmatrix}$$

10.12.4 Azimuth, Zenith Angle Interpolation

Within a Tie Point Zone, azimuth and zenith angles can be interpolated based on the Tie Points A, B, C and D as well as the corrected interpolation parameters α_{track} and α_{scan} for the pixel

$$\begin{pmatrix} azi_1 \\ zen_1 \end{pmatrix} = (1 - \alpha_{scan}) \begin{pmatrix} azi_A \\ zen_A \end{pmatrix} + \alpha_{scan} \begin{pmatrix} azi_B \\ zen_B \end{pmatrix}$$

$$\begin{pmatrix} azi_2 \\ zen_2 \end{pmatrix} = (1 - \alpha_{scan}) \begin{pmatrix} azi_D \\ zen_D \end{pmatrix} + \alpha_{scan} \begin{pmatrix} azi_C \\ zen_C \end{pmatrix}$$

$$\begin{pmatrix} azi \\ zen \end{pmatrix} = (1 - \alpha_{track}) \begin{pmatrix} azi_1 \\ zen_1 \end{pmatrix} + \alpha_{track} \begin{pmatrix} azi_2 \\ zen_2 \end{pmatrix}$$

10.13 Extrapolation of Parameters for Tie Points

When the Tie Points are derived from the geolocation data of the original VIIRS SDR Product the following parameters s_{track} and s_{scan} support the extrapolation of the geolocation data from the centres of the four Tie Point Zone corner Pixels to the Tie Points A, B, C and D.

$$s_{A,track} = \frac{-p_{offset,track}}{z_{track}-1} \qquad s_{A,scan} = \frac{-p_{offset,scan}}{z_{scan}-1}$$

$$s_{B,track} = \frac{-p_{offset,track}}{z_{track}-1} \qquad s_{B,scan} = \frac{z_{scan} - p_{offset,scan}}{z_{scan}-1}$$

$$s_{C,track} = \frac{z_{track} - p_{offset,track}}{z_{track} - 1} \qquad s_{C,scan} = \frac{z_{scan} - p_{offset,scan}}{z_{scan} - 1}$$

$$s_{D,track} = \frac{z_{track} - p_{offset,track}}{z_{track} - 1} \qquad s_{D,scan} = \frac{-p_{offset,scan}}{z_{scan} - 1}$$

10.14 Radiance Representation Conversions

A dual-scale representation is used for storing radiance values as 16 bit unsigned integers.
It is based on two offset and scale factor sets, one for low radiance values and one for high radiance values. The representation thereby matches the characteristics of the VIIRS dual gain channels and ensures a higher accuracy of low radiance values. The two offset and scale factor sets a_{low}/b_{low} and a_{high}/b_{high} as well as the integer threshold $C_{threshold}$ determining the set to be used when converting from the integer to the float representation are included in the Compact VIIRS SDR, see section 6.2.1.

Values stored in the original product as 16 bit unsigned integers are converted into a dual-scale representation for storage in the compact format with identical coefficients a_{low}=a_{high} and b_{low}=b_{high} and arbitrary thresholds. Original values stored as 32 bit floating point numbers are converted into a dual-scale representation with 16 bit unsigned integers.

Typical values for the offsets a_{low} and a_{high}, the scale factors b_{low} and b_{high} are provided in Table 19 in section 11.2 and may change throughout the mission.

10.14.1 Determination of Offset and Scale Factors

The two offset and scale factor sets a_{low}/b_{low} and a_{high}/b_{high} are determined as follows, cf. as well Figure 13,

$$b_{low} = \frac{F_T - F_{min}}{I_T - I_{min}}, a_{low} = F_{min} - b_{low} * I_{min}$$
$$b_{high} = \frac{F_{max} - F_T}{I_{max} - I_T}, a_{high} = F_T - b_{high} * I_T$$

where I is in the domain of definition, e.g. [1; 65527][1], and F is the range of observations, e.g. [-0.25; 702][2].

I_T and F_T are set according to the requirements, e.g. I_T=32767 and F_T=107[3], and with the following condition

$$I_{min} < I_T < I_{max} \quad \text{and} \quad F_{min} < F_T < F_{max}.$$

[1] For a 16 bit integer we choose [1; 65527] instead of the possible range [0; 65535] as 0 is an error identificator and values between [65528; 65535] are used as fill values.
[2] For radiances of SVM03.
[3] High-Low gain switch of SVM03.

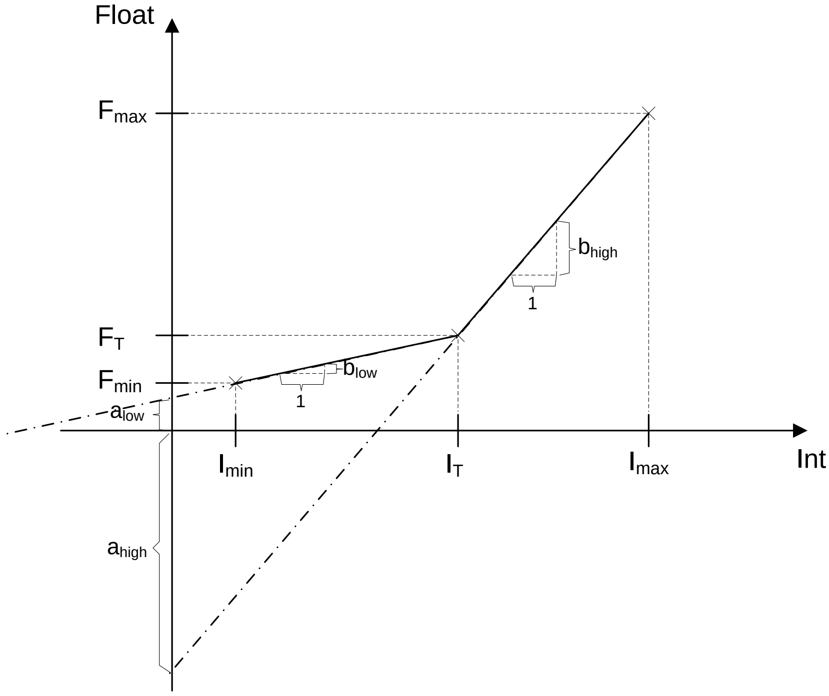


Figure 13 Determination of Offset and Scale Factors

10.14.2 Integer to Floating Point

If the integer radiance value *C* matches one of the integer Fill Values defined in Table 16, then set L to the corresponding floating point Fill Value.

Else, depending on the value of the integer representation *C*, calculate the floating point radiance value as follows

$$L = a_{low} + b_{low} \cdot C \qquad 0 \le C \le C_{threshold}$$
$$L = a_{high} + b_{high} \cdot C \qquad C_{threshold} < C \le 65527$$

10.14.3 Floating Point to Integer

The threshold to be used when converting from floating point radiance to the integer representation can be calculate as

$$L_{threshold} = a_{low} + b_{low} \cdot C_{threshold}$$

If floating point radiance L matches one of the floating point Fill Values defined in Table 16, then set *C* to the corresponding integer Fill Value.

Else, depending on the value of the floating point radiance *L,* then calculate the integer radiance value as follows:

$$C = nint\left\{\frac{L - a_{low}}{b_{low}}\right\} \qquad L \le L_{thres}$$
$$C = nint\left\{\frac{L - a_{high}}{b_{high}}\right\} \qquad L > L_{thres}$$

If the computed integer C is outside the range $0 \le C \le 65527$, then set C to the Fill Value SOUB_UINT16_FILL defined in **Table 16**, indicating that the scaling is out of bounds.

10.14.4 Visible channels Radiance to Reflection conversion

In the original VIIRS SDR, both, radiances and the associated reflectances are stored. The reflectances for all 11 visible channels are represented by 16-bit integer counts. The reflectance conversion is performed with a slope value that can in principle be channel dependent, but is the same for all channels.

If the radiance value L matches one of the floating point Fill Values defined in Table 16, then set r to this floating point Fill Value.

If the solar zenith angle Θ_{sol} is greater or equal than π/2, then set the value of r to the Fill Value NA_FLOAT32_FILL defined in Table 16.

Else, convert the radiance value *L* to a reflectance value *r* the using the following formula

$$r = \frac{\pi L}{cos(\Theta_{sol})} \frac{\int \Phi(\lambda) d\lambda}{\int \Phi(\lambda) E_{sun}(\lambda) d\lambda} \; d_{se}^2 = \frac{\pi L}{cos(\Theta_{sol})} \frac{A_{vis}}{B_{vis}} \; d_{se}^2$$

where λ is the channel wavelength, $\Phi(\lambda)$ the response function and $E_{sun}(\lambda)$ *the* Spectral solar irradiance (W m^{-2} μm^{-1}).
If the resulting r is greater than the Fill Value NA_FLOAT32_FILL defined in Table 16, or if the calculation of *r* otherwise fails, then set the value of *r* to the Fill Value ERR_FLOAT32_.
.

The parameters required for the actual calculation of the reflectance are:

	Description	Reference
Θ_{sol}	Actual solar zenith angle (rad)	Included in Compact VIIRS SDR at tie-points, see section 6.1. Interpolation required for reconstructing value for each pixel, see section 7.1.
A_{vis}	Equivalent width (µm)	Included in the Compact VIIRS SDR, see section 6.2.1. May change throughout the mission.
B_{vis}	Band-integrated solar irradiance (W m^{-2})	Included in the Compact VIIRS SDR, see section 6.2.1.Typical values are provided in table Table 18, in section 11.2.

d_{se}	Relation between the mean and the actual Earth-Sun distance (Unitless)	Included in the Compact VIIRS SDR, see section 6.2.1. Given the Julian Day D_{Jul} of the Year (0-366), the actual value of d_{se} is $d_{se} = 1 - 0.01673 \cdot \cos\left[0.9856\,(D_{Jul} - 4)\,\pi/_{180}\right]$

10.14.5 Infrared channels Radiance to Brightness Temperature conversion

Once calibrated Earth view radiances *L* have been computed, the calculation of the equivalent blackbody temperature, henceforth referred to as brightness temperature *T*, will be performed by a single equation:

$$T = \left[\frac{hc}{k\,\lambda_c \ln\left(1 + \frac{2hc^2}{\lambda_c^5\,L_{ir}}\right)}\right] \cdot A_{ir} + B_{ir}$$

where L must be given in W/(m2 sr m) and not in W/(m2 sr µm). If the calculation of *T* fails, then set the value of *T* to the Fill Value ERR_FLOAT32_FILL defined in Table 16.

The parameters required for the actual calculation of the brightness temperature are:

	Description	Reference
A_{ir}	Band Correction Coefficient (Unitless)	Included in the Compact VIIRS SDR, see section 6.2.1. May change throughout the mission. Typical values are provided in Table 20, in section 11.2.
B_{ir}	Band Correction Coefficient (K)	
c	Speed of Light (m s^{-1})	299792458 m s^{-1}
h	Planck constant (m^2 kg s^{-1})	6.6260755 10^{-34} m^2 kg s^{-1}
k	Boltzmann constant (m^2 kg s^{-2} K^{-1})	1.380658 10^{-23} m^2 kg s^{-2} K^{-1}
λ_c	Central wavelength (m)	Included in the Compact VIIRS SDR, see section 6.2.1. May change throughout the mission. Typical values are provided in table Table 20, in section 11.2.

10.15 Reflectance Conversion from Floating Point to Integer

When reconstructing the Original VIIRS SDR product from the Compact VIIRS SDR product, the floating point reflectance L must be converted to the integer reflectance value C.

If L matches one of the floating point Fill Values defined in Table 16, then set C to the corresponding integer Fill Value.

Else, the integer value is calculated as follows:

$$C = nint\left\{\frac{L - a_{reflectance}}{b_{reflectance}}\right\}$$

where the offset $a_{refelctance}$ and the scale factor $b_{reflectance}$ used in the Original SDR are included in the Compact SDR, section 6.2.1.

If the calculation of *C* fails, then set the value of *C* to the Fill Value ERR_UINT16_FILL defined in **Table 16**.

If the computed integer *C* is outside the range $0 \leq C \leq 65527$, then set *C* to the Fill Value SOUB_UINT16_FILL defined in **Table 16**, indicating that the scaling is out of bounds.

10.16 Brightness Temperature Conversion from Floating Point to Integer

When reconstructing the Original VIIRS SDR product from the Compact VIIRS SDR product, the floating point brightness temperature L must be converted to the integer brightness temperature value C.

If L matches one of the floating point Fill Values defined in Table 16, then set C to the corresponding integer Fill Value.

Else, the integer value is calculated as follows:

$$C = nint\left\{\frac{L - a_{bt}}{b_{bt}}\right\}$$

where the offset a_{bt} and the scale factor b_{bt} used in the Original SDR are included in the Compact SDR, section 6.2.1.

If the calculation of *C* fails, then set the value of *C* to the Fill Value ERR_UINT16_FILL defined in Table 16, If the computed integer *C* is outside the range $0 \leq C \leq 65527$, then set *C* to the Fill Value SOUB_UINT16_FILL defined in Table 16, indicating that the scaling is out of bounds.

10.17 VIIRS Pixel Level Fill Values

A summary of the Pixel Level Fill Values relevant to the Compact VIIRS SDR product format is provided in Table 16, below. For a full definition of Fill Values see section 3.5.6 of AD-1 in combination with section 2.16 of AD-2.

Pixel Level	Definition	Values	
Algorithm Exclusions	The pixel/cell was not computed because it is not applicable to this situation (i.e., NA is the correct answer)	NA_FLOAT32_FILL	-999.9
		NA_UINT16_FILL	65535
Missing at Time of Processing	C3S provided a fill value, the S/C did not provide the value, or AP missing	MISS_FLOAT32_FILL	-999.8
		MISS_UINT16_FILL	65534
Onboard Pixel Trim	The VIIRS pixel was trimmed on the S/C (e.g., overlap omitted)	ONBOARD_PT_FLOAT32_FILL	-999.7
		ONBOARD_PT_UINT16_FILL	65533
On-ground Pixel Trim	The VIIRS pixel was trimmed during processing (i.e., we intentionally chose not to process the pixel)	ONGROUND_PT_FLOAT32_FILL	-999.6
		ONGROUND_PT_UINT16_FILL	65532
Cannot Calculate	The algorithm could not compute the pixel/cell because of a software or hardware problem (e.g., could not converge to a solution)	ERR_FLOAT32_FILL	-999.5
		ERR_UINT16_FILL	65531
Ellipsoid Intersection Failed	The observation does not intersect the earth's surface This is an indication of a calibration manoeuvre.	ELINT_FLOAT32_FILL	-999.4
		ELINT_UINT16_FILL	65530
Value Does Not Exist	The data was not available - it is not missing, nor is any attempt made to calculate the data	VDNE_FLOAT32_FILL	-999.3
		VDNE_UINT16_FILL	65529
Scaling Out Of Bounds	The scaled data was out of bounds of the data type	SOUB_FLOAT32_FILL	-999.2
		SOUB_UINT16_FILL	65528

Table 16 Summary of the Pixel Level Fill Values relevant to the Compact VIIRS SDR product format.

11 RECOMMENDED AND TYPICAL PARAMETER VALUES

11.1 Recommended Parameter Values

Description	Symbol	Value	
		M-Band	I-Band
Number of Tie Point Zones in the Track direction	Nzones,track	48	48
Number of Tie Point Zones in the Scan direction	Nzones,scan	200	200
Size of the Tie Point Zone in the Track direction	Ztrack	16	32
Size of the Tie Point Zone in the Scan direction	Zscan	16	32
Offset in Track direction of Pixel [0,0] centre relative to Tie Point A	poffset, track	0.5	0.5
Offset in Scan direction of Pixel [0,0] centre relative to Tie Point A	poffset, scan	0.5	0.5

Table 17 Geolocation parameters

11.2 Typical Parameter Values

VIIRS |Channel	A_{vis} Equivalent Width (µm)	B_{vis} Band-integrated solar irradiance (W m^{-2})
M1	0.1979783550E-01	33.83940249
M2	0.1430752221E-01	26.66728877
M3	0.1900157705E-01	37.98883065
M4	0.2093922533E-01	39.14834573
M5	0.1996985823E-01	30.56515889
M6	0.1459505595E-01	18.69858623
M7	0.3869968280E-01	37.24469424
M8	0.2712116949E-01	12.38904874
M9	0.1500406861E-01	5.398250081
M10	0.5875030532E-01	14.41161119
M11	0.4669837281E-01	3.506045974

Table 18: Equivalent width and band-integrated solar irradiance for the 11 VIIRS visible M-Band channels

VIIRS Channel	a_{low} Radiance Offset Low (W m^{-2} sr^{-1} µm^{-1})	b_{low} Radiance Scale Low (W m^{-2} sr^{-1} µm^{-1})	a_{high} Radiance Offset High (W m^{-2} sr^{-1} µm^{-1})	b_{high} Radiance Scale High (W m^{-2} sr^{-1} µm^{-1})	L_{thres} (W m^{-2} sr^{-1} µm^{-1})
M3	-0.25327321	0.00327321	-686.16944444	0.02420635	107
M4	-0.20238662	0.00238662	-694.16495726	0.02356532	78
M5	-0.20180675	0.00180675	-712.16474359	0.02353480	59
M7	-0.10088812	0.00088812	-402.09209402	0.01315629	29
M13	-0.02010856	0.00010856	-653.06626987	0.02003855	3.537

Table 19. Coefficients used to convert 32-bit floating point radiances to 16-bit counts

VIIRS Channel	λ_c Central Wave Length (m)	A_{ir} Band Correction Coefficient (Unitless)	B_{ir} Band Correction Coefficient (K)
M12	3.692118094E-6	1.000869385	-0.637890868
M13	4.063950468E-6	1.000524131	-0.338046119
M14	8.574690139E-6	1.000666830	-0.201236951
M15	10.68610341E-6	1.004393762	-1.049491534
M16	11.81466532E-6	1.003041012	-0.649809876

Table 20. Coefficients used for the central wavelengths and the band corrections to convert Earth view Radiances to Brightness Temperatures