Sentinel-3 SLSTR Uncertainties in Level-1 Products Input and Output Data Definition

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CHANGE LOG

Date	Issue	Revision	Pages	Reason for change
11-Apr-2019	1	0		Creation
04-Sep-2019	2	0		RIDs from EUMETSAT included
28-Oct-2019	3	0		- Potential Evolutions included - Output file name changed to <b>_ uncertainties _<g><v>.nc as requested in RIDs
03-Dec-2021	4	0		Modified to account for external SLSTR Level-1 combined uncertainties file.

CONTENTS

Terms, Definitions and Abbreviations

Terms and Definitions

Channel- Spectral channel (S1-S9 + F1-F2)

Calibration is the process of quantitatively defining the system response to known, controlled system inputs.

Error is defined as the difference between a result obtained and the 'true' value.

Field-Of-View - is the angular extent of a given scene that is viewed by the instrument.

Infrared (IR) radiation is electromagnetic radiation of wavelengths between about 750nm and 1mm. This is broken down into 5 wavelength regions

> **Near-IR** - 0.75-1.4 µm
>
> **Short-Wave IR** - 1.4-3 µm
>
> **Medium-Wave IR** - 3-8 µm
>
> **Long-Wave IR** - 8–15 µm

Image swath - Maximum distance on ground between the positions of two spatial samples belonging to the same row.

Image sample - image element containing radiance measurements of co-registered pixels for all bands.

Precision is defined as the difference between one result and the mean of several results obtained by the same method.

Traceability is the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.

Uncertainty parameter associated with the result of a measurement, that characterises the dispersion of the value that could reasonably be attributed to the measurand.

> **Type A evaluation (of uncertainty)** method of evaluation of uncertainty by the statistical analysis of series of observations. This is usually given by the standard deviation of a number of measurements of a variable.
>
> **Type B evaluation (of uncertainty)** method of evaluation of uncertainty by means other than the statistical analysis of series of observations. This is usually based on existing knowledge, for example data provided in calibration and other certificates or an estimation of the uncertainty based on previous experience.

Visible light is electromagnetic radiation detectable by the human eye with a wavelength between approximately 400nm and 700nm.

Validation is the process of assessing by independent means the quality of the data products derived from the system outputs.

Acronyms

ADF	Auxiliary Data File
ATBD	Algorithm Theoretical Basis Document
BB	Blackbody
BT	Brightness Temperature
CPU	Central Processing Unit
HDF5	Hierarchical Data Format-5
IODD	Input Output Data Definition
IR	Infrared
LUT	Lookup Table
NetCDF	Network Common Data Format
NEΔL	Noise Equivalent Differential Radiance
NEΔT	Noise Equivalent Differential Temperature
RAL	STFC Rutherford Appleton Laboratory, UK
SLSTR	Sea and Land Surface Temperature Radiometer
STFC	Science and Technology Facilities Council
SRD	System Requirements Documents
SWIR	Short-Wave Infrared
TIR	Thermal Infrared
VIS	Visible
VISCAL	Visible Calibration Unit

Documents

Applicable Documents

The applicable documents are:

	Document title	Document reference
AD1	Sentinel-3 SLSTR Uncertainties in Level-1 Products Algorithm and Theoretical Basis Document	SLSTR-RAL-EUM-TN-003

Scope of Document / Introduction

This document provides the description of the input and output SLSTR Level-1 product files as used and generated by the Python script to estimate the Level-1 uncertainties at the pixel level. This work was performed under the European Union's Copernicus Programme, and managed by EUMETSAT through the contract EUM/CO/18/4600002122/AOC. The document has been updated to include Level-1 external uncertainty files as part of EUM/CO/21/4600002574/AOC - Order 450021556

Summary

This document provides the description of the input and the output SLSTR Level-1 product files as used and generated by the Python script to estimate the Level-1 uncertainties at the pixel level.

The input files required by the Python tool are the SLSTR Level-1 data chosen by the user, and the Level-1 and the Level-2 auxiliary data files. In addition, the algorithm, MapnoiS3 v2.0, has been implemented so radiometric uncertainties derived per orbit can be ingested in the tool.

The two sets of ADFs are already provided with the python tool. We propose to include the temperature-to-radiance LUT currently available in Level-1 ADF, into the Noise Data file contained in the Level-2 ADF, so that all the inputs required by the Python tool will be available in just one set of ADFs.

The python tool generates one output directory per SLSTR Level-1 product, which contains a NetCDF file per each channel and each scan view selected. The NetCDF file contains the NE∆L and the radiometric uncertainties at the pixel level for the VIS/SWIR channels, and the NE∆T, the radiometric uncertainties, and the slope dL/dT for the infrared and the fire channels.

The generated output products are converted into 16 bits integer to reduce the size of the products. The size of one output product generated for a full SLSTR Level-1 product (all channels and both scan views), is 22% smaller than the correspondent input SLSTR Level-1 product.

The CPU processing run time is ~65 with average CPU usage of 45.5 % for a full SLSTR Level-1 product. But, these values are estimate on one particular product, and they might differ from product to product, particularly, when S4 and S7 channels are included in the processing. The processing time of these two channels is subject to cloudiness and saturation, for S4 and S7, respectively.

TIR Input Data

Figure 1 shows a diagram of the input files necessary for estimate the Level-1 uncertainties at the pixel level and for the TIR channels

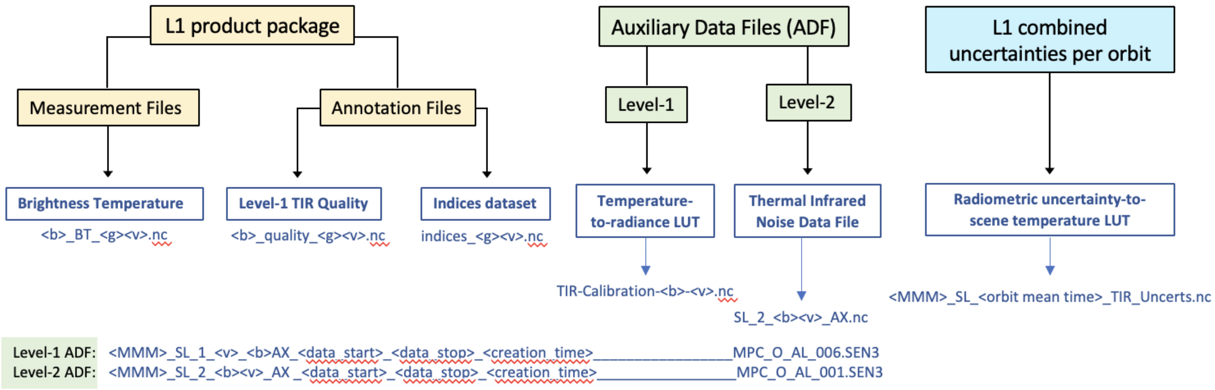

Figure 1 TIR Input files for the Python script

The naming convention of the input data is described in Table 1 using the place holders for the band, view, and grid names, which are to be substituted for each valid combination.

Table 1 Abbreviation meaning of the place holders for the band, view, and grid names.

Variable	Place holder	Possible Values
Mission ID	<MMM>	S3A or S3B
band	<b>	S7 to S9, F1, F2
view	<v>	– 'n' for nadir view – 'o' for oblique view
grid	<g>	'i' for 1km Thermal Infrared grid

Measurement Files

The Level-1 SLSTR product contains five measurement files (<b>_BT_<g><v>.nc) for each of the nadir and oblique views, given in NetCDF format:

- One brightness temperature dataset for each thermal infrared channels S7 to S9
- One brightness temperature dataset for each fire channels F1 and F2

From all the data and attributes contained in the measurement files, the Python code only requires the brightness temperature data. The BT data includes a set of BT values and attributes explained in Table 2.

Table 2 Description, range or values, type and dimensions of the elements on the BT data

Element name	Description	Range or value	Type of data	Dimension
<b>_BT_<g><v>	Gridded pixel brightness temperatures		f64	[row,column] (along track,across track grid size)
_FillValue	Value indicating missing data	2^{15}	i16	1
Add_Offset	Offset used to in decoding packed data	283.73	f64	1
Long_Name	CF long name	Gridded pixel brightness temperature for channel <b> (1km TIR grid, nadir view)	string	1
Scale_Factor	Scaling factor used in decoding	0.01	f64	1
Standard_Name	CF standard name	toa_brightness_temperature	string	1
Units	Unit name	K	string	1

The BT values are sampled at 1 km resolution and are calibrated in units of temperature K.

Annotation files

The annotation files contain the Level-1 Thermal Infrared Quality Annotation data file and the Indices dataset.

Level-1 Thermal Infrared Quality Annotation Data

The Level-1 Thermal Infrared quality dataset named as

<b>_quality_<g><v>.nc

contains estimates of detector noise measured from the blackbody signals, and the LUT of radiometric calibration uncertainty estimates.

The SLSTR Annotation files comprise one Level-1 Thermal Infrared Quality data files for each of the nadir and oblique views, for each thermal infrared channels S7 to S9, and for each fire channels F1 and F2. The next tables (

Table 3, Table 4, and Table 5) describe the values, type, and dimensions of the variables inside the TIR quality files that are required in the Python script.

Table 3 Description of the black body random noise parameters used by the Python script

Element name	Description	Range or value	Type of data	Dimension
<b>_T_BB1_<g><v>	Hot Black body temperature		f64	[rows] (alongtrack grid size)
_FillValue	Value indicating missing data	-1.0	f64	1
Long_Name	CF long name	Black body temperature 1	string	1
units	Unit name	K	string	1
<b>_T_BB2_<g><v>	Cold Black body temperature		f64	[rows]
_FillValue	Value indicating missing data	-1.0	f64	1
Long_Name	CF long name	Black body temperature 2	string	1
units	Unit name	K	string	1
<b>_dT_BB1_<g><v>	Hot Black body noise equivalent brightness temperature		f64	[detec,integr,row]
_FillValue	Value indicating missing data	-1.0	f64	1
Long_Name	CF long name	Black body 1 noise equivalent brightness temperature	string	1
units	Unit name	K	string	1
<b>_dT_BB2_<g><v>	Cold Black body noise equivalent brightness temperature		f64	[detec,integr,row]
_FillValue	Value indicating missing data	-1.0	f64	1
Long_Name	CF long name	Black body 2 noise equivalent brightness temperature	string	1
units	Unit name	K	string	1

Table 4 Description of the band centre parameters included in the Level-1 Quality files

Element name	Description	Range or value	Type of data	Dimension
<b>_band_centre_<g><v>	Detector filter band centre		f64	[detectors]
_FillValue	Value indicating missing data	NaN		1

Long_Name	CF long name	Detector filter band centre for channels S8 (1km TIR grid, nadir view)	string	1
units	Unit name	m	string	1
Standard_Name	CF standard name	Radiation_wavelength	string	1

Table 5 Description of the uncertainty lookup table parameters used by the Python script. Nelem is the number of elements on the uncertainty lookup table

Element name	Description	Range or value	Type of data	Dimension
<b>_radiometric_uncertainty_<g><v>	IR channels radiometric uncertainty estimates at BTs in scene temperature array		f64	[detector, Nelem]
_FillValue	Value indicating missing data	NaN		1
Long_Name	CF long name	IR channel radiometric uncertainty estimates at BTs in scene temperature array	string	1
units	Unit name	K	string	1
<b>_scene_temperature_<g><v>	Scene temperature for IR channel uncertainty estimates	[180,340] for S7 [150,450] for S8, S9 [250,500] for F1 [200,500] for F2	f64	[Nelem]
_FillValue	Value indicating missing data	NaN		1
Long_Name	CF long name	Scene temperature for IR channel uncertainty estimates	string	1
units	Unit name	K	string	1

Level-1 combined Uncertainties per orbit LUT

The netCDF file containing the Level-1 TIR combined uncertainties reported at coverage factor k=3 per orbit as a function of scene temperature LUT is named as:

<MMM>_SL_1_UNCOAX_<START_ORBIT>_<STOP_ORBIT >_<CREATION DATE>_EUM_O_AL_001

where <date> is the date and mean time of the orbit.

The file contains estimates of uncertainties from Level-0 monitoring data for each thermal infrared channels S7 to S9, and for each fire channels F1 and F2.

Table 6 describe the values, type, and dimensions of the variables inside the Level-1 TIR combined uncertainties file that are required in the Python script.

Table 6 Description of the Level-1 TIR combined uncertainties

Element name	Description	Range or value	Type of data	Dimension
<b>_radiometric_uncertainty	IR channels radiometric uncertainty (k=3) estimates per orbit		f64	[Nelem]
_FillValue	Value indicating missing data	NaN		1
Coverage factor	k	3	int	1
units	Unit name	K	string	1
scene_temperature	Scene temperature for IR channel uncertainty estimates	[180,500]	f64	[Nelem]
_FillValue	Value indicating missing data	NaN		1
units	Unit name	K	string	1

Indices

The Indices dataset named as:

indices_<g><v>.nc

contains the pixel, detector and scan number of the image in the original instrument coordinates.

The Python script uses the gridded pixel detector number (Table 7) to assign each detector noise or uncertainty to the corresponding pixel on the gridded image. The SLSTR Annotation files contain two Level-1 Thermal Infrared Indices data files, one for each of the nadir and oblique view.

Table 7 Description of the detector number parameters

Element name	Description	Range or value	Type of data	Dimension
detector_<g><v>	Gridded pixel detector number	0 or 1	u8	[row,column] (along track,across track grid size)
_FillValue	Value indicating missing data	$2^8 - 1$	u8	1
Long_Name	CF long name	Gridded pixel detector number	string	1

Auxiliary Data Files

Temperature-to-Radiance lookup table

The SLSTR Level-1 TIR Auxiliary Data File (ADF) required are:

<MMM>_SL_1_<v>_<b>AX_<data_start>_<data_stop>_<creation_time>_MPC_0_AL_001.SEN3

There are two ADFs for each channel (S7 to S9, F1 and F2), one for each scan view <v>. They comprise NetCDF files with the name

updated_v3_<MMM>_SL_CCDB_CHAR_TIR-Calibration-<b>-<v>.nc

that contains a two-dimension temperature-to-radiance lookup tables, one table for each detector. However, the temperature-to-radiance LUT is identical for both views and for both detectors.

The temperature and the radiance parameters are defined in Table 8.

Table 8 Description of the temperature-to-radiance LUT parameters

Element name	Description	Range or value	Type of data	Dimension
temperature	Temperature for temperature-to-radiance LUT	[77,330] for S7 to S9 [200,500] for F1 and F2	f64	Nelem
Long_Name	CF long name	Temperature abscissa for temperature-to-radiance LUT	string	1
Units	Unit name	K	string	1
radiance	Radiance for temperature-to-radiance LUT		f64	[detector, Nelem]
Long_Name	CF long name	Radiance ordinate for temperature-to-radiance LUT	string	1
Units	Unit name	$\mathrm{Wm^{-2}sr^{-1}\mu m^{-1}}$	string	1

Thermal Infrared Noise Data File

The algorithm requires the Thermal Infrared Noise Data File. The SLSTR Level-2 ADF

<MMM>_SL_2_<b><v>_AX_<data_start>_<data_stop>_<creation_time>_MPC_0_AL_001.SEN3

This file contains a NetCDF file with the name

SL_2_<b><v>_AX.nc

which contains a LUT of detector noise as a function of scene temperature and detector temperature.

There are two ADFs for each TIR channel (S7 to S9), one for each view. There is only one ADF file for fire channels, specifically for F1 nadir view.

Table 9 describes the scene temperature and the noise parameters.

Table 9 Description of the radiometric noise to temperature LUT parameters. (*) check the proposed modifications given on Section 0

Element name	Description	Range or value	Type of data	Dimension
B_temperature	Brightness temperature of NEΔT estimates	[150,350] for TIR channels [150,500] for F1	f64	[Nelem]
Long_Name	CF long name	Brightness temperatures of NEΔT_LUT	string	1
Units	Unit name	K	string	1
NEDT_LUT	Radiometric Noise from black body		f64	[view,detec,Nelem,integr] for S8 and S9 [detec,Nelem,integr] for S7 and F1
Long_Name	CF long name	(*) S7 nadir single pixel NEΔT estimate LUT	string	1
Units	Unit name	K	string	1

TIR Output Data

For a SL_1_RBT PDU input product, the Python script creates an output product file in NetCDF format for each selected channel and scan view, which is identified as

<b>_uncertainty_<g><v>.nc (see Table 1 for the meaning of the place holders)

Table 10 shows the CPU processing time for a single channel and for all five TIR/Fire channels processed together for both scan views. In addition, the table contains the output products size in MB.

In order to reduce the output product size, the data are converted to 16-bit signed integer by using the scaling factors and the offsets provided in the attributes of each variable.

The size of one output product containing all the TIR/Fire channels and both views is 86.5 MB. It is only ~15 % of the total size of the original SLSTR Level-1 product.

Table 10 CPU Processing time and the output product size in MB for the TIR/Fire channels in nadir and oblique views

Channel	Number of Channels	View	Processing Time (CPU)	Product Size (MB)
TIR/Fire	1	Nadir	1.6	10.8
		oblique	1.2	6.5
		nadir & oblique	2.8	17.3
	5	Nadir	7.7	54.0
		oblique	5.0	32.5
		nadir & oblique	13.0	86.5

In order to reduce the output product size, the data are converted to 16-bit signed integer by using the scaling factors and the offsets provided in the attributes of each variable.

Every output NetCDF file contains a set of dimensions, variables and attributes.

The global attributes are:

a) '_ncproperties': Version of the NetCDF and the HDF5 libraries used at creation time
b) 'Description': Indicates the channel, the detector array and the scan view
c) 'Source': gives information of the software version used
d) 'References': string containing the ATBD and the IODD documents number
e) 'Product_name': corresponds to the identifier of the input SLSTR Level-1 product package
f) 'L1_ADF_Product_name': indicates the identifier to the input SLSTR Level-1 ADF
g) 'L2_ADF_Product_name': indicates the identifier to the input SLSTR Level-2 ADF
h) 'contact': it should contain a EUMETSAT email address
i) 'creation_time': indicates the date and time of when the <b>_uncertainty_<g><v>.nc file was created

The output file contains the brightness temperature uncertainty and the noise equivalent brightness temperature mapped onto the Level-1 image two-dimensional grid of 1 km resolution. In addition, the output file also includes a gridded pixel image of the partial derivative of the radiance as a function of temperature $\frac{\partial L}{\partial T}$, sampled at 1 km.

Table 11 and Table 12 describe the values, type and dimensions of the variables inside the output uncertainty file created by the Python script.

Table 11 Description of the output uncertainty file

Element name	Description	Range or value	Type of data	Dimension
<b>_radiometric_uncertainties_<g><v>	Gridded pixel radiometric uncertainties		i16	[row,column] (along track,across track grid size)
_FillValue	Fill Values	-32768	i16	1
Units	Unit name	K	string	1
Standard_name	Standard name	Toa brightness temperature uncertainty	string	1
Long_Name	CF long name	Radiometric uncertainties at the scene BT on the Level-1 image per pixel. 1km TIR grid	string	1
scaling_factor	Scaling factor used in decoding packed data		f64	1
add_offset	Offset used in decoding packed data		f64	1
<b>_NEDT_<g><v>	Gridded pixel radiometric noise		f64	[row,column] (along track,across track grid size)
_FillValue	Fill Values	-32768	i16	1
Units	Unit name	K	string	1
Standard_name	Standard name	Noise Equivalent brightness temperature	string	1
Long_Name	CF long name	Noise Equivalent brightness temperature at the scene BT on the Level-1 image per pixel. 1km TIR grid	string	1
scaling_factor	Scaling factor used in decoding packed data		f64	1
add_offset	Offset used in decoding packed data		f64	1
<b>_dLdT_<g><v>	Gridded pixel of $\frac{\partial L}{\partial T}$		f64	[row,column] (along track,across track grid size)

_FillValue	Fill Values	-32768	i16	1
Units	Unit name	$mW.m^{-2}.sr^{-1}.nm^{-1}.K^{-1}$	string	1
Standard_name	Standard name	Partial derivative of the radiance as a function of temperature	string	1
Long_Name	CF long name	Partial derivative of the radiance as a function of temperature on the Level-1 image per pixel. 1km TIR grid	string	1
scaling_factor	Scaling factor used in decoding packed data		f64	1
add_offset	Offset used in decoding packed data		f64	1

Table 12 Description of the output NetCDF file for TIR channels in nadir view

```
# dimensions: 2
# Variables: 3
# Global attributes: 9
  There are no unlimited dimensions.

  Dimensions 0 Name: along-track Size: 1200 1 Name: across-track Size: 1500

  Global Atributtes 0 _ncproperties: version=1|netcdflibversion=4.6.1|hdf5libversion=1.10.2 1 description: S3 SLSTR L1
        radiometric uncertainty and NEDL. Channel=s8, Array=i, View=nadir 2 source: mapnoiS3.py 3 references: SLSTR-
        RAL-EUM-TN-003 and SLSTR-RAL-EUM-TN-005 4 Product_name:
        S3A_SL_1_RBT____20180531T073043_20180531T073343_20180531T093806_0179_031_377_2520 … 5 L1_ADF_Product_name:
        S3A_SL_1_N_S8AX_20160216T000000_20991231T235959_20170324T120000… 6 L2_ADF_Product_name:
        S3A_SL_2_S8N_AX_20000101T000000_20991231T235959_20151214T120000… 7 contact ops@eumetsat.int8 creation_time Wed Aug
        14 10:09:41 2019

  Variables and attributes
        0 s8_radiometric_uncertainty_in: int16(1500,1200)= int16(across-track,along-track)
         0 _FillValue: -32768
         1 Units: K
         2 standard_name: toa brightness temperature uncertainty
         3 long_name: Radiometric uncertainties at the scene BT on the Level-1 image
                                       per pixel. 1km TIR grid
         4 scaling_factor: 1.83082627E-05
         5 add_offset: 0.0

        1 s8_NEDT_in: double(1500,1200)= double(across-track,along-track)
         0 _FillValue: -32768
         1 Units: K
         2 standard_name: noise equivalent brightness temperature
         3 long_name: Noise Equivalent brightness temperature at the scene radiance on the
         Level-1 image per pixel. 1km TIR grid
         4 scaling_factor: 1.22021700E-06
         5 add_offset: 0.0

        2 s8_dLdT_in: double(1500,1200)= double(across-track,along-track)
         0 _FillValue: -32768
         1Units:mW m^-2 sr^-1 nm^-1 nm^-1 K^-1
         2 standard_name: Partial derivative of the radiance as a function of temperature
         3 long_name: Partial derivative of the radiance as a function of temperature on the
         Level-1 image per pixel. 1km TIR grid
         4 scaling_factor: 1.52590218E-05
         5 add_offset: 0.0
```

VIS/SWIR Input Data

Figure 2 shows a diagram of the input files necessary for estimate the Level-1 uncertainties at the pixel level and for the visible and SWIR channels. As in the case of the TIR and Fire channels, the SLSTR Level-1 product package is required as an input in the algorithm. However, the algorithm doesn't need any auxiliary data files or characterization data files.

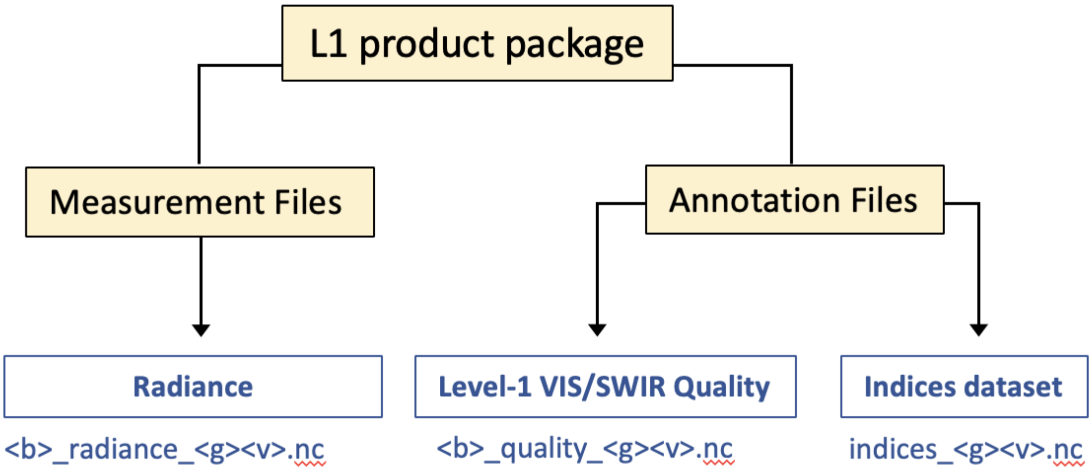

Figure 2 VIS/SWIR Input files for the Python script.

The naming convention of the input data is described in Table 13 using the place holders for the band, view, and grid names, which are to be substituted for each valid combination.

Table 13 Abbreviation meaning of the place holders for the band, view, and grid names for VIS/SWIR channels

Variable	Place holder	Possible Values
Band	<b>	S1 to S6
View	<v>	– 'n' for nadir view – 'o' for oblique view
Grid	<g>	– 'a' for 0.5km visible and SWIR "A stripe" grid – 'b' for 0.5km SWIR "B stripe" grid

Measurement Files

The Level-1 SLSTR product contains in total 9 measurement files for each view, named as

<b>_radiance_<g><v>.nc

- One radiance dataset for each visible channel S1 to S3
- Two radiance datasets for each SWIR channels S4 to S6; one data set for each array ‘a’ or ‘b’.

From all the data and attributes contained in the measurement files, the Python code only requires the radiance data. The radiance data includes a set of TOA radiance values and attributes explained in Table 14.

Table 14 Description, range or values, type and dimensions of the elements on the radiance data

Element name	Description	Range or value	Type of data	Dimension
<b>_radiance _<g><v>	Gridded pixel TOA radiances		i16	[row,column] (along track,across track grid size)
_FillValue	Value indicating missing data	2^{15}	i16	1
Add_Offset	Offset used to in decoding packed data	0.0	f64	1
Long_Name	CF long name	TOA radiance for channel <b> (<g> stripe grid, <v> view)	String	1
Scale_Factor	Scaling factor used in decoding	0.0145	f64	1
Standard_Name	CF standard name	toa_radiance	String	1
Units	Unit name	mW m-2 sr-1 nm-1	String	1

The TOA radiance values are sampled at 500 m resolution.

Annotation files

The annotation files contain the Level-1 Visible and Shortwave Infrared Quality Annotation data file and the Indices dataset.

Level-1 Visible and SWIR Quality Annotation data

The algorithm requires a combination of the radiometric uncertainties as a function of scene radiance derived from the pre-launch calibration, and the estimates of noise and radiance from the VISCAL and the cold blackbody provided in the Level-1 Visible and SWIR Quality data sets

<b>_quality_<g><v>.nc

The SLSTR VIS/SWIR Annotation files contain 18 Level-1 VIS/SWIR Quality data files:

- 2 files, one for each scan view, for each visible channel S1 to S3.
- 4 files for each SWIR channel, one file for each scan view and for each stripe.

The next tables (Table 15, Table 16 and Table 17) describe the values, type and dimensions of the elements inside the VIS/SWIR quality files that are required in the Python script.

Table 15 Description of the VISCAL and the blackbody noise and radiance parameters used by the Python script

Element name	Description	Range or value	Type of data	Dimension
<b>_solar_irradiance_<g><v>	Solar irradiance at top of atmosphere		f64	Detectors
_FillValue	Value indicating missing data	NaN		1
Long_Name	CF long name	Solar irradiance at top of atmosphere	string	1
units	Unit name	mW m-2 nm-1	string	1
<b>_L_viscal_<g><v>	Radiance measured at the VISCAL unit		f64	Detectors
_FillValue	Value indicating missing data	-1	f64	1
Long_Name	CF long name	VISCAL radiance	string	1
units	Unit name	mW m-2 sr-1 nm-1	string	1
<b>_dL_viscal_<g><v>	VISCAL radiance noise		f64	[integrator,detector]
_FillValue	Value indicating missing data	-1	f64	1
Long_Name	CF long name	VISCAL radiance noise	string	1
units	Unit name	mW m-2 sr-1 nm-1	string	1
<b>_L_BB_<g><v>	Radiance from cold blackbody		f64	[Detectors,Nelem]
_FillValue	Value indicating missing data	-1	f64	1
Long_Name	CF long name	Radiance from cold BB	string	1
units	Unit name	mW m-2 sr-1 nm-1	string	1
<b>_dL_BB_<g><v>	Radiance noise from cold blackbody		f64	[detec,integr,Nelem]
_FillValue	Value indicating missing data	-1	f64	1
Long_Name	CF long name	Radiance noise from cold BB	string	1
units	Unit name	mW m-2 sr-1 nm-1	string	1
<b>_cal_gain_<g><v>	Calibration Gain		f64	[integrator,detector]
_FillValue	Value indicating missing data	-1	f64	1
Long_Name	CF long name	Scale factor multiplying detector count	string	1
units	Unit name	mW m-2 sr-1	string	1

Table 16 Description of the radiometric uncertainty lookup table parameters used by the Python script. Nelem is the number of elements on the uncertainty lookup table

Element name	Description	Range or value	Type of data	Dimension
<b>_radiometric_uncertainty_<g><v>	Radiometric calibration uncertainty estimates for VSI/SWIR channels		f64	[detector, Nelem]
_FillValue	Value indicating missing data	NaN		1
Long_Name	CF long name	Radiometric uncertainty at Lref	string	1
units	Unit name	mW.m-2.sr-1.nm-1	string	1
<b>_scene_radiance_<g><v>	Scene radiance for VIS/SWIR channel uncertainty estimates	The maximum scene radiance is limited by the dynamic range of each channel (see Table 17)	f64	[Nelem]
_FillValue	Value indicating missing data	NaN		1
Long_Name	CF long name	Scene radiance for VIS/SWIR channel calibration uncertainty estimates	string	1
units	Unit name	mW.m-2.sr-1.nm-1	string	1

Table 17 Dynamic range and maximum scene radiance value in the LUT

Channel	SRD Req. Lmax ($mWm^{-2}sr^{-1}nm^{-1}$)	LUT Lmax ($mWm^{-2}sr^{-1}nm^{-1}$)
S1	585.0	600.0
S2	475.0	500.0
S3	295.0	300.0
S4	113.1	125.0
S5	74.0	75.0
S6	24.3	25.0

Indices

The Indices dataset

indices_<g><v>.nc

contains information on the gridded pixel, detector and scan number. The Python script uses the gridded pixel detector number (Table 18) to assign each detector noise or uncertainty to the corresponding pixel on the gridded image.

The SLSTR Annotation files contain 2 Level-1 VIS/SWIR Indices data files, one for each of the nadir and oblique view and for each ‘a’ and ‘b’ stripe.

Table 18 Description of the detector number parameters for the VIS and the SWIR channels

Element name	Description	Range or value	Type of data	Dimension
detector_<g><v>	Gridded pixel detector number	0, 1, 2, or 3	u8	[row,column] (long track,across track grid size)
_FillValue	Value indicating missing data	2^8-1	u8	1
Long_Name	CF long name	Gridded pixel detector number	string	1

VIS/SWIR Channels Output Files

For a SL_1_RBT PDU input product, the Python script creates an output product file in NetCDF format for each selected channel and scan view, which is identified as

<b>_ uncertainty_<g><v>.nc (see Table 1 for the meaning of the place holders).

Table 19 shows the CPU processing time for a single channel and for all five VIS/SWIR channels processed together for both scan views. In addition, the table contains the output products size in MB.

The size of the SWIR output products is twice larger than the size of the VIS outputs because, the code provides two NetCDF files, one for each detector array for each SWIR channel.

To reduce the output product size, the data are converted to 16-bit signed integer by using the scaling factors and the offsets provided in the attributes of each variable.

The size of one output product containing all the VIS/SWIR channels and both views is 415 MB. It is ~72.9 % of the total size of the original SLSTR Level-1 product

Table 19 CPU Processing time and the output product size in MB for the VIS and the SWIR channels in nadir and oblique views

Channel	Number of Channels	View	Processing Time (CPU)	Product Size (MB)
VIS	1	Nadir	3.6	28.8
		oblique	2.1	17.3
		nadir & oblique	5.9	92.2
	3	Nadir	11.4	86.4
		oblique	6.9	51.9
		nadir & oblique	18.3	138.3
SWIR	1	Nadir	7.6	57.6
		oblique	4.7	34.5
		nadir & oblique	12.6	92.2
	3	Nadir	20.8	172.8
		oblique	12.7	103.7
		nadir & oblique	33.9	276.6
VIS & SWIR	6	Nadir	32.2	259.3
		oblique	19.8	155.7
		nadir & oblique	52.3	415.0

Every output file contains a set of dimensions, attributes and variables.

The global attributes are:

a) '_ncproperties': Version of the NetCDF and the HDF5 libraries used at creation time
b) 'Description': Indicates the channel, the detector array and the scan view
c) 'Source': gives information of the software version used
d) 'References': string containing the ATBD and the IODD documents number
e) 'Product_name': corresponds to the identifier of the input SLSTR Level-1 product package
f) 'contact': it should contain a EUMETSAT email address
g) 'creation_time': indicates the date and time of when the <b>_uncertainty_<g><v>.nc file was created

The output file contains the radiance uncertainty and the noise equivalent radiance mapped onto the Level-1 image grid of 500 m resolution.

Table 20 and Table 21 describe the values, type and dimensions of the elements inside the output uncertainty file provided by the Python script for the VIS/SWIR channels.

To reduce the output product size, the data are converted to 16-bit signed integer by using the scaling factors and the offsets provided in the attributes of each variable.

Table 20 Description of the output uncertainty file

Element name	Description	Range or value	Type of data	Dimension
<b>_radiometric_uncertainties_<g><v>	Gridded pixel radiometric uncertainties		i16	[row,column] (along track,across track grid size)
_FillValue	Fill Values	-32768	i16	1
Units	Unit name	mW.m-2.sr-1.nm-1	string	1
Standard_name	Standard name	Toa radiance uncertainty	string	1
Long_Name	CF long name	Radiometric uncertainties at the scene radiance on the Level-1 image per pixel. 0.5 km TIR grid	string	1
scaling_factor	Scaling factor used in decoding packed data		f64	1
add_offset	Offset used in decoding packed data		f64	1
<b>_NEDL_<g><v>	Gridded pixel radiometric noise		i16	[row,column] (along track,across track grid size)
_FillValue	Fill Values	-32768	i16	1
Units	Unit name	mW.m-2.sr-1.nm-1	string	1
Standard_name	Standard name	Noise Equivalent radiance	string	1
Long_Name	CF long name	Noise Equivalent radiance at the scene radiance on the Level-1 image per pixel. 0.5 km TIR grid	string	1
scaling_factor	Scaling used in decoding packed data		f64	1
add_offset	Offset used in decoding packed data		f64	1

Table 21 Description of the output NetCDF file for VIS/SWIR channels

```
# dimensions: 2
# Variables: 2
# Global attributes: 7
  There are no unlimited dimensions.

  Dimensions 0 Name: along-track Size: 2400 1 Name: across-track Size: 3000

  Global Atributtes 0 _ncproperties: version=1|netcdflibversion=4.6.1|hdf5libversion=1.10.2 1 description:
        S3 SLSTR L1 radiometric uncertainty and NEDL. Channel=S5, Array=a, View=nadir 2 source: mapnoiS3.
        py 3 references: SLSTR-RAL-EUM-TN-003 and SLSTR-RAL-EUM-TN-005 4 Product_name:
        S3A_SL_1_RBT____20180531T073043_20180531T073343_20180531T093806_0179_031_377_2520 … 5 contact
        ops@eumetsat.int6 creation_time Wed Aug 14 10:09:41 2019

  Variables and attributes
           0 s5_radiometric_uncertainty_an: int16(3000,2400)= int16(across-track,along-track)
         0 _fillvalue: 32768
         1 units: mW m^-2 sr^-1 nm^-1
         2 standard_name: toa radiance uncertainty.
         3 long_name: Radiometric uncertainties at the scene radiance on the Level-1 image
         per pixel. 0.5km VIS-SWIR grid
         4 scaling_factor: 6.10360876E-05
         5 add_offset: 0.0

        1 s5_NEDL_an: int16(3000,2400)= int16(across-track,along-track)
         0 _fillvalue: 32768
         1 units: mW m^-2 sr^-1 nm^-1
         2 standard_name: noise equivalent radiance.
         3 long_name: Noise Equivalent radiance at the scene radiance on the Level-1 image
         per pixel. 0.5km VIS-SWIR grid
         4 scaling_factor: 5.79842832E-05
         5 add_offset: 0.0
```

Appendix-A Proposed modifications

The SLSTR ADFs required by the python tool, were defined long before SLSTR was actually built, and they have not been changed since then. In the development of this tool, we found several 'features' of the ADF that are either superfluous or missing. We propose a series of modifications on the auxiliary data files:

Changes on the Level-1 ADFs

We proposed to include the temperature and the radiance elements of the temperature-to-radiance lookup table inside the Thermal Infrared Noise Data file. So, the algorithm would require only one ADF as an input.

Changes on the Level-2 ADFs

1. The Noise Data file now contained in the SLSTR Level-2 ADF is a theoretical model which was defined back to pre-launch calibration. These files will be updated by a new model predicted based on the instrument performance. Currently, the python tool reads the theoretical noise model defined during the pre-launch calibration.
2. The dimension of the element NEΔT_LUT is not the same for all the channels. The dimension is [detectors, integrators, Nelem, detector temperature] for channels S8 and S9, and [detectors, Nelem, view] for channels S7 and F1. In addition, there are two independent ADFs for each channel, one for nadir view and one for oblique view, so the dimension related to the scan view is not necessary and should be removed from the NEΔT_LUT element. The values of NEΔT_LUT are also independent of detectors and integrators. For all these reasons, we propose to reduce the dimension of NEΔT_LUT to [Nelem] where Nelem is the number of brightness temperature values in the B_temperature element.
   Since the noise data are the same for all detectors, integrators and detector temperatures, the python tool avoids the extra dimensions by considering the same noise data as in first detector, first integrator and first detector temperature [0,Nelem,0,0] for all the detectors, integrators and detector temperatures.
3. The Long_Name value in the element NEΔT_LUT is “S7 nadir single pixel NEΔT estimate LUT” in all ADFs, independently of the channel or the view. The Long_Name value should indicate the channel and the view correctly.