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Title : **IDEAS – LANDSAT Products Description Document**

Abstract : This document acts as a User Guide to the Landsat MSS, TM and ETM+ archives, focussing more specifically on the Landsat TM and ETM+ products from the Kiruna, Maspalomas and Matera archives (including from the Matera, Fucino, Neustralitz, O'Higgins, Malindi, Libreville and Bishkek ground stations) that have been generated as part of the ESA archive bulk-reprocessing project.

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TABLE OF CONTENTS

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Table of Figures

Table of Tables

AMENDMENT POLICY

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

AMENDMENT RECORD SHEET

ISSUE	DATE	DCI No	REASON
0.1	29 Aug 2013	N/A	Initial Issue
1.0	06 Sept 2013	N/A	Document for v2.03 Dataset Release
2.0	28 Feb 2014	N/A	Document for v3.03 Dataset Release (containing updates and feedback from the Landsat Team for v3.03 of the IPF) regarding product specification of the Landsat TM Kiruna dataset.
3.0	06 June 2014	N/A	Document for v3.03 Dataset Release. Updated to include additional information on Landsat TM products from the Maspalomas Ground Station.
4.0	5 Aug 2014	N/A	Document for v3.03 Dataset Release. Updated to include information on Landsat ETM+ products from the Kiruna and Maspalomas Ground Stations.
5.0	7 Nov 2014	N/A	Document for v3.03 Dataset Release. Updated to include information on Landsat ETM+ products from the Matera archive (including the Matera, Fucino and Nesutralitz ground stations).
6.0	24 Feb 2015	N/A	This document for v3.03 Dataset Release. Updated to include information on Landsat TM products from the Matera archive (including data acquired from the Matera, Fucino, Neustralitz, O’Higgins, Malindi, Libreville and Bishkek ground stations).

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1. INTRODUCTION

1.1 Purpose and Scope

This document is intended as a User Guide describing the Landsat products generated by the European Space Agency (**ESA**) in the framework of the ESA Landsat archive bulk-reprocessing project.

This document provides an introduction to the Landsat missions as a whole and then focuses more specifically on the Landsat 5 Thematic Mapper (**TM**) and the Landsat 7 Enhanced Thematic Mapper + (**ETM+**) product format specifications, data processor description and User Notes for version 3.03 of the ESA dataset for the Kiruna (**KSE**), Maspalomas (**MPS**) and Matera (**MTI**) archives. Please note that the Matera archive also includes products from the Neustralitz (**NSG**) (Germany), Fucino (**FUI**) (Italy), O'Higgins (**OHG**) (Germany), Malindi (**MLD**) (Kenya), Libreville (**LBG**) (Gabon) and Bishkek (**BSK**) (Kyrgyzstan) Ground Stations (**GS**).

Note: V3.03 of the ESA processor has been developed to be used with MSS, TM and ETM+ data, but at the time of compiling this document, only Landsat TM and ETM+ data has been released.

1.2 Structure of the Document

After this introduction, the document is divided into a number of major sections that are briefly described below:

2 THE LANDSAT MISSIONS AND THE ESA ARCHIVE

An introduction to the Landsat missions and ESA activities related to Landsat.

3 ESA LANDSAT PROCESSING AND PRODUCTS

A basic introduction to the ESA Landsat processor and its products.

4 COMPARISON OF ESA AND USGS PRODUCTS

Notes for the User on the differences between the USGS and ESA processors and products and their impact on product format.

5 KNOWN LANDSAT ANOMALIES

Known Landsat anomalies and how they may be represented in the dataset.

6 DATASET INFORMATION AND LIMITATIONS

Limitations of the v3.03 ESA dataset.

7 FAQS

Frequently Asked Questions related to common User questions specifically for these datasets.

8 GLOSSARY

The Glossary contains definitions of acronyms, abbreviations and terms used throughout the document.

APPENDIX A v3.03 TM Metadata (MTL) Parameters and Values

MTL parameters for TM products

APPENDIX B v3.03 ETM+ Metadata (MTL) Parameters and Values

MTL parameters for ETM+ products

1.3 Referenced Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

RD.1 G. Chander, B. L. Markham, D. L. Helder, Summary of Current radiometric calibration coefficients for Landsat MSS, TM, ETM+ and EO-1 ALI Sensors, Remote Sensing of Environment, Volume 113, Issue 5, 15 May 2009

RD.2 J. Storey, P. Scaramuzza, G. Schmidt, Landsat 7 Scan Line Corrector Off-Gap Filled Product Development, October 2005

RD.3 USGS Landsat Thematic Mapper (TM) Level 1 (L1) Data Format Control Book (DFCB), LS-DFCB-20, Version 5

RD.4 ESA Products Naming Standard Convention, PGSI-GSEG-EOPG-TN-06-0001, Version 2

RD.5 Landsat Naming Convention Memo, EOP-GSI/CL/2013/0002

RD.6 ODISSEO Station Code Reference, IODI-GSEV-EOAD-TN-02-0001, Version 1.5.9

RD.7 Landsat 4/5 thematic Mapper (TM) Image Assessment System (IAS) Radiometric Algorithm Theoretical Basis Document (ATBD)

RD.8 ngEO Tailoring for Landsat, GMES-GSEG-EOPG-TN-12-0068, Issue 1

RD.9 ngEO Browse Report File Generic Interface (BRGICD), ngEO-13-ICD-MFR-059, Version 1.5

RD.10 Landsat 7 Image Assessment System (IAS) Radiometric Algorithm Theoretical Basis Document (ATBD)

RD.11 Landsat Monthly Update - USGS, April 2002, available at: http://catalogos.conae.gov.ar/landsat/bumpermode.pdf

RD.12 USGS Landsat Enhanced Thematic Mapper Plus (ETM+) Level 1 (L1) Data Format Control Book (DFCB), LSDS-272, Version 17.0

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2. THE LANDSAT MISSIONS AND THE ESA ARCHIVE

The European Space Agency (**ESA**) is part of the Landsat International Ground Station (**IGS**) Network and in effect operates the ground stations within Europe as well as repatriating Landsat data from stations in the US, Brazil and Canada; In parallel with the United States Geological Survey (**USGS**) activities, ESA have developed and operate their own processing system / archiving system / receiving station for Landsat which allows users to access an important collection of historical products.

At this stage (and documented in detail herein) only the Landsat TM and ETM+ archives from Kiruna, Maspalomas and Matera have been bulk processed and are being released to the user community. Section 2.2.1 details the available spatial and temporal coverage of these datasets.

2.1 Landsat History

The Landsat program is a joint USGS and National Aeronautics and Space Administration (**NASA**) led enterprise for Earth Observation (**EO**) that represents the world's longest running system of satellites for moderate-resolution optical remote sensing for land, coastal areas and shallow waters.

Since 1972, Landsat satellites have provided EO data to support work in agriculture, geology, forestry, education, mapping, emergency response and disaster relief, as well as providing a long-term record of natural and human-induced changes to the Earth.

As technological capabilities improved, instruments on board consecutive missions changed (as shown in Table 2-1) and subsequently, four 'families' of Landsat satellites have been distinguished based on sensor and platform characteristics: also discussed in RD.1.

- **Landsat 1, Landsat 2 and Landsat 3** with the Multi Spectral Scanner (**MSS**) and the Return-Beam Vidicon (**RBV**) instruments as the payload on a 'Nimbus like' platform. The spatial resolution of MSS was approximately 79 m with four bands ranging from the visible blue to the NIR. The MSS sensor on Landsat 3 includes a fifth spectral band operating in the Thermal InfraRed (**TIR**) wavelength of the electromagnetic spectrum.

- **Landsat 4 and Landsat 5** with the MSS instrument and the TM instrument on the Multi-mission Modular Spacecraft (**MMS**) platform. The MSS sensor was included to provide continuity with the earlier Landsat missions, but TM data quickly became the primary source of information used from these satellites because the data offered enhanced spatial, spectral, radiometric, and geometric performance. The TM sensor has a spatial resolution of 30 m for the six reflective bands and 120 m for the thermal band (resampled to 30m). As there were no on-board recorders on these sensors, acquisitions were limited to real-time downlink only.

- **Landsat 6 and Landsat 7** with the Enhanced Thematic Mapper (**ETM**) and the ETM+ instruments (respectively). No MSS instrument was on board. The Landsat 6 mission failed at Launch. The ETM+ instrument has a spatial resolution of 30 m for the six reflective bands and 60 m for the thermal band and includes a panchromatic band with a 15 m resolution. A major event of the Landsat 7 mission was the failure of the Scan Line Corrector (**SLC**) in 2003. This failure, without interrupting the mission itself, has dramatically reduced the spatial coverage of a nominal World Reference System (**WRS**) scene (see RD.2 and Section 5.5).

- **Landsat 8** carries an Operational Land Imager (**OLI**) and a Thermal Infrared Sensor (**TIRS**) instrument on board. Landsat OLI image data consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and Band 9. The resolution of Band 8 (panchromatic) is 15 meters. Landsat TIRS image data consists of two thermal bands with a spatial resolution of 100 meters (resampled to 30) for Bands 10 and 11 (https://lta.cr.usgs.gov/L8). By comparing with data from earlier Landsat missions, images from new spectral bands are now proposed; coastal blue band for water penetration/aerosol detection and Cirrus band for cloud masking.

For more information on the bands, wavelengths and applications of each Landsat instrument please see the USGS web pages at: http://landsat.usgs.gov/best_spectral_bands_to_use.php.

Table 2-1: Characteristics of Landsat -1 to -8 Missions

Landsat	Launched	Decommissioned	Instruments	Orbit
-1	July 23, 1972	January 6, 1978	RBV, MSS	18 days/ 900km
-2	January 22, 1975	July 27, 1983	RBV, MSS	18 days/ 900km
-3	March 5, 1978	September 7, 1983	RBV, MSS	18 days/ 900km
-4	July 16, 1982	June 15 2001	MSS, TM	16 days/ 705km
-5	March 1, 1984	June 5 2013	MSS, TM	16 days/ 705km
-6	October 5, 1993	Failed to launch	ETM	16 days/ 705km
-7	April 15, 1999	Operational	ETM+	16 days/ 705km
-8	February 11, 2013	Operational	OLI, TIRS	16 days/ 705km

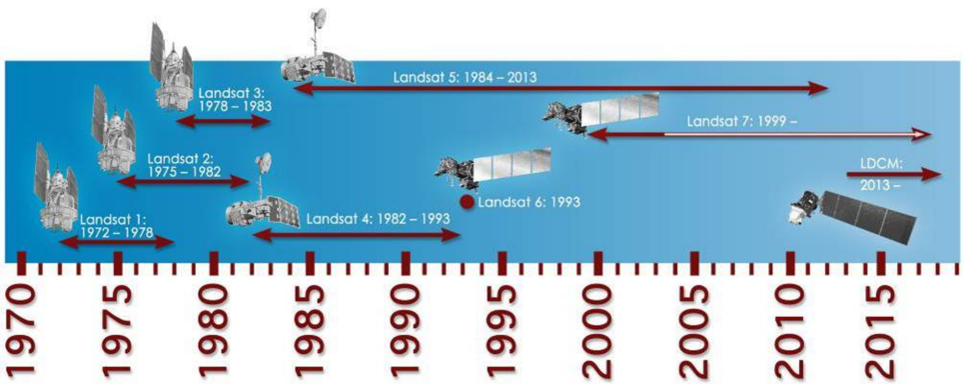


Figure 2-1: Landsat Timeline. ***Image: NASA***

2.2 ESA Landsat Archive

This section is intended to give an overview of the Landsat product coverage for v3.03 of the ESA dataset. As described in Section 1.1, this includes data from the Kiruna, Masplaomas, Matera, Neustralitz, Fucino, O'Higgins, Malindi, Libreville and Bishkek Ground Stations. Specific details of the ESA processor and the products can be found in Sections 3, 4, 5 and 6 of this document.

2.2.1 Spatial and Temporal Coverage

The temporal coverage of the ESA Level 1 dataset is not uniform as there are periods where the data was not collected. For example, Figure 2-2 highlights these periods at the Maspalomas ground station for the TM and ETM+ datasets.

The spatial coverage of the products processed by ESA for the Landsat 5 TM datasets is shown in Table 2-2. This table highlights the Level 1T (**L1T**), Level 1G (**L1G**) and the Total Spatial Coverage, for the Kiruna, Maspalomas and Matera archives. Table 2-3 highlights the L1T, Level 1Gt (**L1Gt**) and Total Spatial Coverage of the ETM+ datasets.

New L1G and L1Gt products have been generated over areas of sea and ocean where not previously available. The middle figures in both tables highlight this.

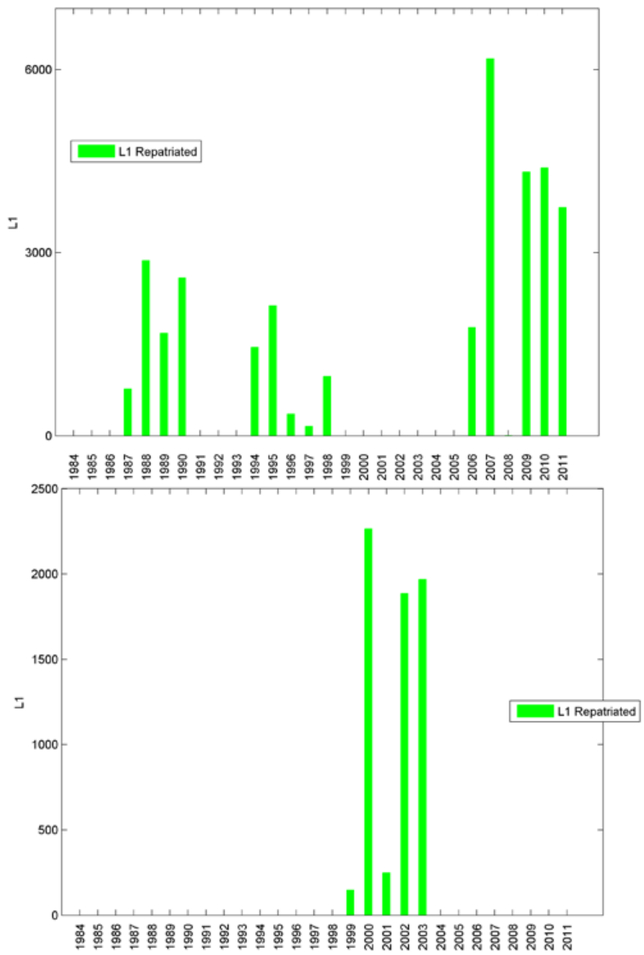
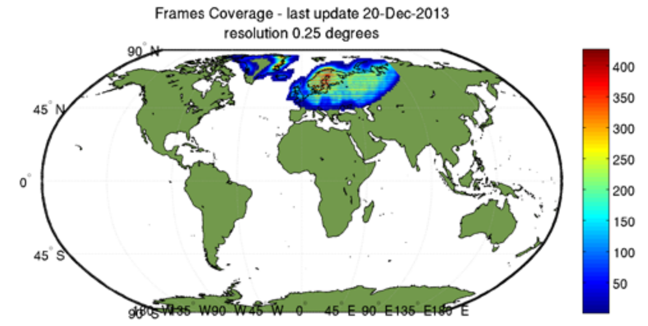
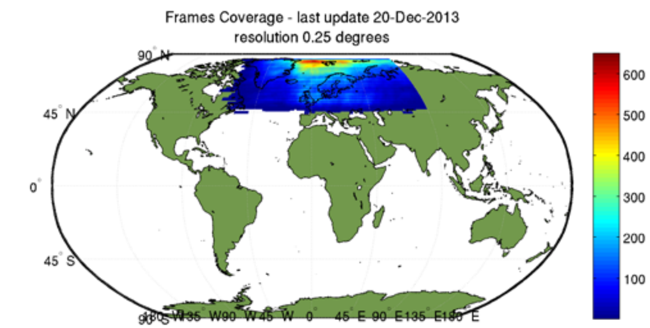
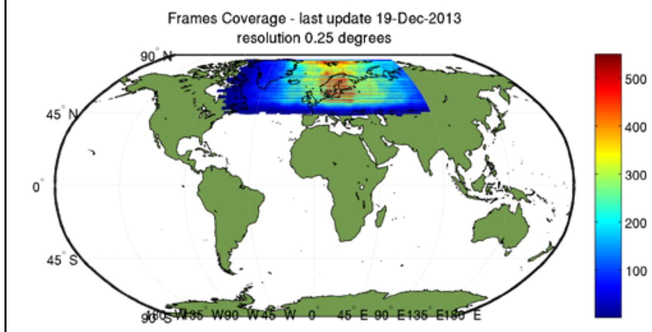


Figure 2-2: The temporal coverage of the ESA Maspalomas Landsat TM Level 1 dataset (top) and the Maspalomas Landsat ETM+ Level 1 dataset (bottom). *Images: X-PReSS*

Table 2-2: Spatial Coverage of ESA Landsat 5 Kiruna, Maspalomas and Matera TM frames 1984-2011. ***Images: X-PReSS***

<table>
<tr><th></th><th>L1T (GTC)</th><th>L1G (GEO)</th><th>Total Spatial Coverage</th></tr>
<tr><td>Kiruna</td><td>
</td><td>
</td><td>
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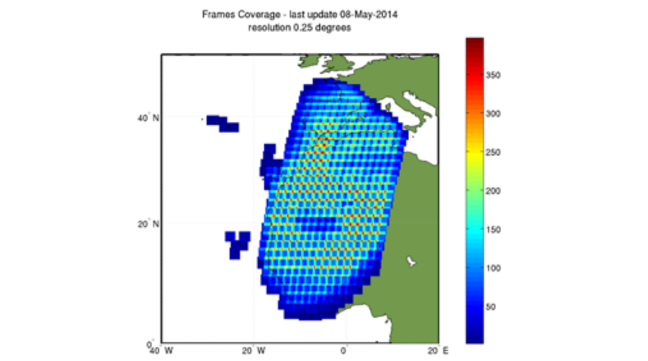
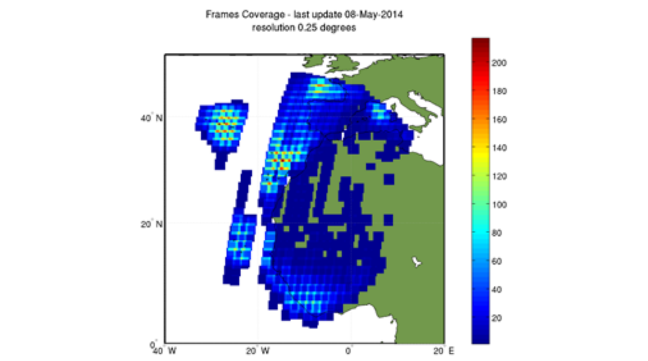
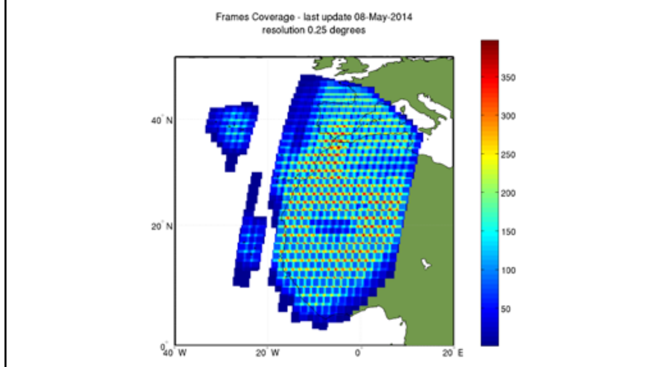
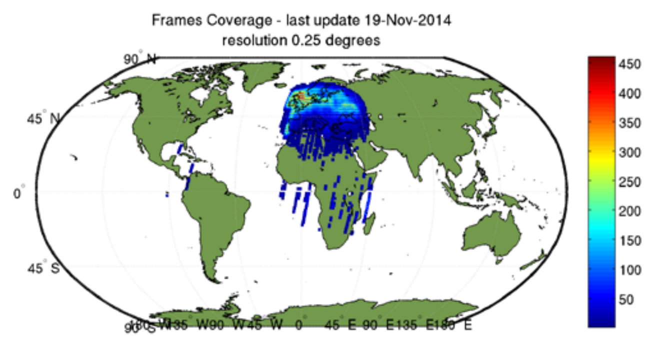
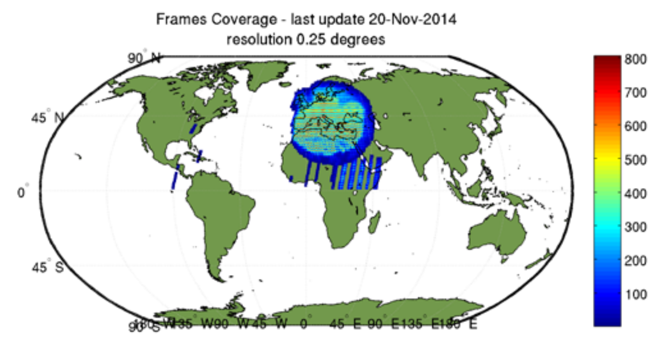
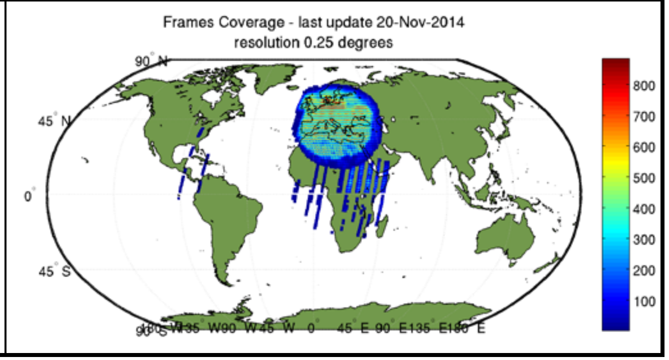
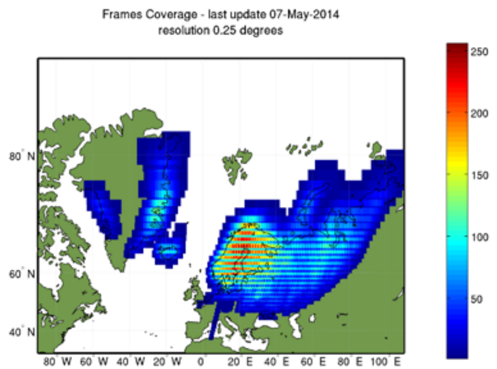
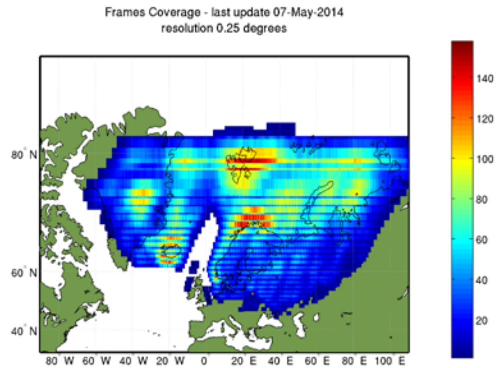
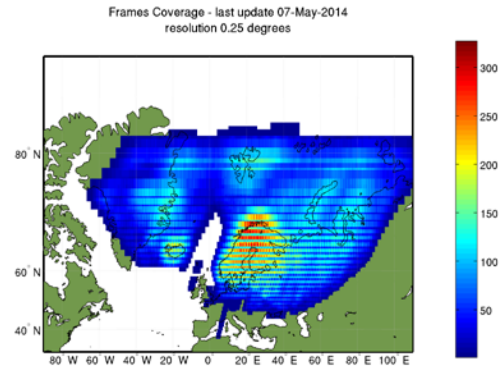
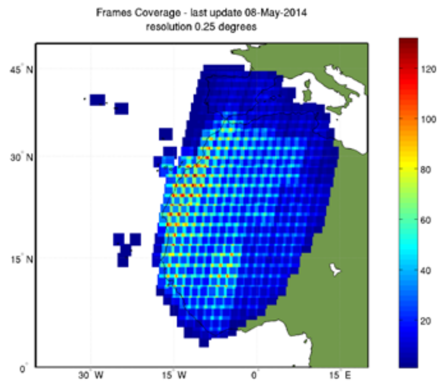
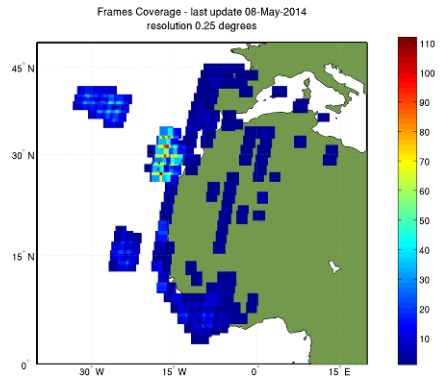
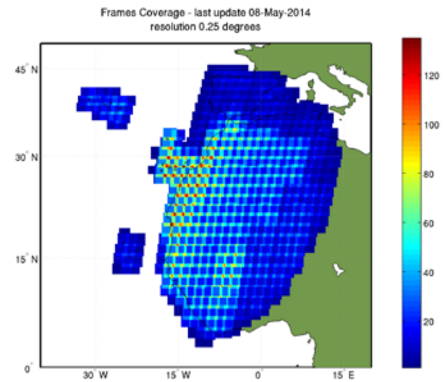
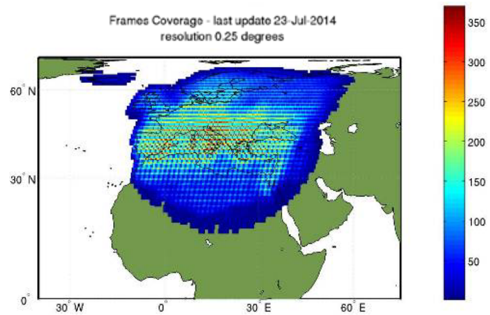
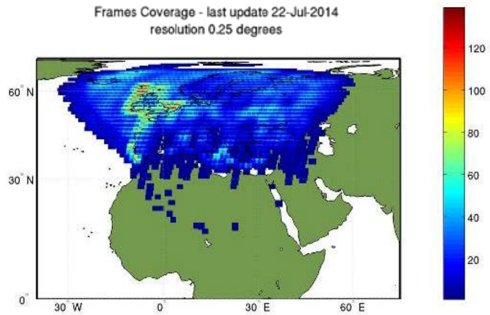
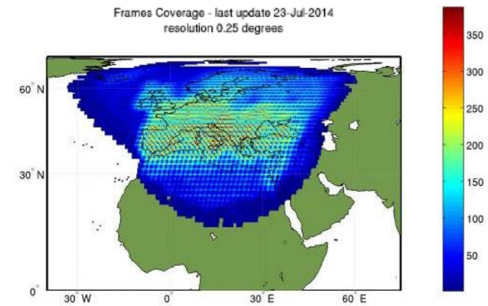
<tr><td>Maspalomas</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Matera</td><td>
</td><td>
</td><td>
</td></tr>
</table>

Table 2-3: Spatial Coverage of ESA Landsat Kiruna, Maspalomas and Matera ETM+ frames 1999-2003. ***Images: X-PReSS***

	L1T (GTC)	L1Gt	Total Spatial Coverage
Kiruna			
Maspalomas			
Matera			

3. ESA LANDSAT PROCESSING AND PRODUCTS

This section outlines the main characteristics of the ESA Instrument Processing Facility (**IPF**), products and details of specific databases used within the processing.

3.1 Scenes Concept

The IPF is designed to compute all the valid frames (standard WRS scenes) belonging to any input Landsat TM Wide Long Term Multi-Satellite Archive (**WILMA**) data Level 0 (**L0**) segment. Landsat 1, 2 & 3 utilised WRS-1, whereas Landsat 4, 5, 7 & 8 utilised WRS-2.

The processing is done according to a set of parameters defined in a Job Order file. In this version of the processor, it is not possible for Floating Scenes (scenes with a full swath width that are not restricted in the Along Track (**AL**) direction by the WRS path/row extents) to be created.

The first and last WRS scenes, when requested, are processed only if they contain at least 50% of image data in the AL direction (an improvement compared to the current USGS processing). For more information see Section 4.4.1.

3.2 Inputs

The list of the input files required by the Systematic Landsat Archive Processing (**SLAP**) IPF is as follows:

Table 3-1: Input files

Landsat MSS/TM/ETM+
Job Order
Auxiliary Data (Ephemerides (**EPH**), Calibration Parameter Files (**CPF**), Digital Elevation Model (**DEM**) and Ground Control Points (**GCP**))
L0 data (WILMA format)

3.2.1 Auxiliary data

The CPF and EPH are mandatory auxiliary files whilst the DEM and GCP data are involved in processing of Terrain Corrected (L1T) products (see Section 3.3.1).

3.2.1.1 Calibration Parameter Files (CPF)

The CPF files are released by the Image Assessment System (**IAS**) / USGS team for Landsat processing. These processing parameters are mostly results of on-ground calibration and characterization activities in fields of geometric, radiometric and image quality aspects.

CPFs are maintained and periodically updated by the USGS. In order to achieve the highest levels of product accuracy, the most recent version of the CPF file is used by the ESA processor where possible.

3.2.1.2 Ephemeris (EPH) Data

For geometrically correcting Landsat processing, ephemeris data is used. Predictive Ephemeris data is generated by the Ground Segment for initial data acquisition. Definitive

Ephemeris data is generated from telemetry received from the satellite. Thus, Definitive Ephemeris is more accurate than Predictive, and is used where possible for optimal product geolocation accuracy. The EPHEMERIS_TYPE field can be found in the GROUP = PRODUCT_METADATA information of the accompanying Metadata (**MTL**) file.

Restituted ephemerides are sometimes used by ESA when no definitive ephemerides are available. See Section 4.2.1 for more information on identifying Ephemeris data in ESA products.

3.2.1.3 Digital Elevation Model (DEM) database

In the case of Standard Terrain Corrected (L1T) products the DEM database is file-system based and utilises the GLS2000 dataset (for more information on this dataset, see http://glcf.umd.edu/data/glsdem/). This information can be found in the GROUP = PRODUCT_METADATA (ELEVATION_SOURCE) field of the accompanying MTL.

Landsat TM/ETM+: The DEM is in Universal Transverse Mercator (**UTM**) at 90m pixel-spacing organized by WRS-2 Landsat standard WRS row-path. The WRS-2 DEM database is also used for the ESA Landsat 4 and 5 MSS processing chain. The DEM database includes a sub-directory for each WRS “path”. Each “path” directory contains a sub-directory for each “row”.

3.2.1.4 Ground Control Point (GCP) Database

In the case of Ground Terrain Corrected (**GTC**) products, prior to the ortho-rectification process, the scene is registered to a common reference map thanks to a pre-defined GCP database.

The GCP database is file-system based and also extracted from the GeoCover dataset, organized according to Landsat WRS scene (WRS-1 for Landsat’s 1-3, and WRS-2 for Landsat’s 4-7). Information on the GCPs used in the v3.03 products is contained in the Ground Control Points file (LT*_GCP.txt) that accompanies the product delivery for L1T products (those that do not use Multi-Scene Refinement).

Note that, there is one database for the ESA MSS processing chain and one for the ESA TM/ETM+ processing chain.

3.3 Outputs (Product Levels)

The ESA Landsat IPF generates Landsat products according to three processing levels; Level 1T (**L1T**), Level 1Gt (**L1Gt**) and Level 1G (**L1G**) (L1Gt currently Landsat 7 ETM+ only). The processing level of the output product depends on:

- The mission / instrument;
- The availability and quality of auxiliary information;
- The availability of GCPs identified in the input image.

Generally speaking, a Level 1 product is delivered as a geocoded product, with radiometric and geometric corrections applied by using the standard processing parameters defined in Section 3.4 (resampling algorithm, image orientation, map projection).

Depending on the geometric corrections applied, there are three categories of Level 1 product. These are defined as follows:

- L1G: Level 1 **G**eo coded – the basic product;

- L1G**t**: Level 1 Geo coded and **t**errain corrected – the basic ortho corrected product;

- L1T**:** Level 1 **T**errain corrected – the precision ortho corrected product.

All three Level 1 processing levels differ depending on the geometric corrections applied, which can be summarized as follows:

- The L1G is processed by using 'a priori' geolocation information and effects of the terrain relief *are not* accounted for.

- The L1Gt is processed by using 'a priori' geolocation information and effects of the terrain relief *are* accounted for.

- The L1T is processed by using 'a posteriori' geolocation information and effects of the terrain relief *are* accounted for.

The 'a posteriori' geolocation information is defined as 'a priori' geolocation information that has been refined by using reference data (the ground control point database). Consequently, it is for the L1T products that the best geometric accuracy is achieved.

The main objective of the reprocessing is to generate the most accurate products; Level 1T products are generated by default. However, there are some cases for which this is not possible, and whereby the L1G or L1Gt products are generated. It is therefore the scope of the next sections to address these cases level by level.

3.3.1 Basic Level 1 Product (Level 1G)

Normally, L1G products are generated where there is a lack of GCPs, and are derived purely from data collected by the sensor and spacecraft e.g. the ephemeris data.

Cases where L1T products cannot be produced by the processor, and therefore L1G products are generated, are when at least one of the following is true:

- There is no image chip database available for the WRS scene;

- The a priori geolocation error (mean error in both x and y directions) between the input images and the raster reference is *above* a given threshold (a configurable value of 15 pixels);

- The geographical extent / distribution of the GCP set or the number of the GCPs is not correct with respect to mapping accuracy requirements.

The position of each GCP in the input image is estimated by means of image matching techniques applied between a reference and working image patch centred on the GCP.

There are some cases for which the number of GCPs, is too small. Conversely the number of GCPs can be important, but the relative geolocation error deduced from image matching is above a given threshold. This is mainly related to atmospheric (cloud cover), environmental (snow and ice cover) and terrain conditions.

3.3.2 Basic Ortho-Corrected Product (Level 1Gt)

Due to it being a “recent” mission, the 'a priori' geolocation accuracy of Landsat 7 ETM+ spacecraft has always been within specification (250m, RMSE). As a consequence, and for this satellite / instrument only, it has been decided to process Landsat 7 ETM+ Terrain Corrected products, without refining the geometric model by means of a GCP Database.

The 'a priori' geolocation accuracy of Landsat TM / MSS missions is not correct, thereby it does not allow Terrain Corrected (L1Gt) products to be created for these instruments as the geometric model has not been refined. In reality, the systematic geolocation shift is too significant resulting in a wrong geometric registration between elevation data and the input scene.

3.3.3 Precision Ortho-Corrected Product (Level 1T)

The processing of MSS / TM / ETM+ L1T products are the most accurate level of processing as they incorporate GCPs and a DEM to provide systematic geometric and topographic accuracy; with geodetic accuracy dependent on the number, spatial distribution and accuracy of the GCPs over the scene extent, and the resolution of the DEM used.

For more information on the DEM and GCP databases, see Section 3.2.1.

3.3.4 Summary of Processing Levels

The rules for the processing of ESA Landsat products are:

3.3.4.1 Landsat MSS/TM products

- Generate L1T (terrain corrected) products where estimated geolocation error is below a given threshold (see Section 3.3.1); the ideal scenario.

- Generate L1G (radiometrically and geometrically corrected) products where estimated geolocation error is above a given threshold.

3.3.4.2 Landsat ETM+ products

- Generate L1T products where estimated geolocation error is below a given threshold (ideal scenario).

- Generate L1Gt (systematically terrain corrected) products where estimated geolocation error is above a given threshold.

Table 3-2: Auxiliary information used for each type of Landsat processing level

	Processing Level		
Auxiliary Information	L1T	L1Gt	L1G
CPF / Ephemeris	x	x	x
Digital Elevation Model	x	x	
GCP Database	x		

N.B. There are cases where products are processed to L1T but fail Quality Control (**QC**) inspections. This can occur when the geolocation accuracy of the product is within specification, but the number of GCPs is below the QC threshold of 15. More information about these products is given in Section 6.1.

3.4 Product Format

All Landsat standard data products are processed to a set of standardised parameters in order to provide homogeneity between datasets, even those that are processed with different processors (i.e. USGS and ESA).

Table 3-3 lists the standard parameters for products processed used by the USGS, which is replicated by the ESA IPF.

Table 3-3: Parameters for Landsat standard data products

Parameter	Specification
Output format	GeoTIFF
Resampling method	Cubic Convolution (**CC**)
Pixel size	60 metres (MSS), 30 metres (TM, ETM+), 15 metres (ETM+ Panchromatic Band). **Note:** The Thermal TM Band (Band 6) was acquired at 120 metre resolution. Products processed before February 25 2010 are resampled to 60 metre pixels. Products processed after this date are resampled to 30 metre pixels. The Thermal ETM+ Band (Band 6) is acquired at 60 metre resolution. Products processed after February 25 2010 are resampled to 30 metre pixels.
Map Projection	UTM
Datum	World Geodetic System (**WGS**) 84
Image Orientation	MAP (North-up)
DEM (Ortho product)	GLS2000 Dataset* DEM cartographic grid is UTM with a map spacing of 90m. Data are organised by WRS-2 Landsat row-path.
GCP (Ortho product)	GeoCover Dataset (GLS Epoch 2000 is used for TM & ETM+)

* The GLSDEM is a collection of different DEMs based on the Shuttle Radar Topography Mission (**SRTM**) and complemented for higher latitudes with national DEMs, including the National Elevation Dataset (**NED**) of the USA and the Canadian Digital Elevation Dataset (**CDED**). Together these cover most of the globe: from 84°N to 56°S. GLSDEM v4.0 is used in the ESA TM and ETM+ processing.

3.4.1 Product Structure

All ESA Landsat products are delivered in Tagged Image File Format (**TIFF**). The product structure is similar for all processing levels and instruments (MSS / TM / ETM+); the descriptions below indicate the specific product structure and contents for each product type.

3.4.1.1 L1T

ESA L1T products (see Section 3.3.3) are delivered in GTC format.

Table 3-4: Landsat scene directory. Landsat 5 TM Kiruna scene used as an example

File	Description
LS05_RKSE_TM__GTC_1P_*.ZIP	Product ZIP
LS05_RKSE_TM__GTC_1P_*.BP.PNG	Quicklook Image in Portable Native Graphic (**PNG**) Format Note this is a small file (1-2 MB in size) that provides an overview of the Landsat scene in true colour. A 1.8% radiometric stretch has been applied to the Quicklook (**QL**) to offer a more realistic representation of the scene, and the image dimension has been set to 1448 x 1448 pixels.
LS05_RKSE_TM__GTC_1P_*.BP.XML	Quicklook Image metadata in Extensible Markup Language (**XML**) format
LS05_RKSE_TM__GTC_1P_*.MTR.XML	Metadata Report (**MTR**) in XML format
LS05_RKSE_TM__GTC_1P_*.QR.PDF	AMALFI Quality Control Report (**QR**) in Portable Document Format (**PDF**). This report details the results of the systematic QC for each product.
LS05_RKSE_TM__GTC_1P_*.QR.XML	AMALFI QR in XML format
LS05_RKSE_TM__GTC_1P_*.TIFF	Product Folder
LT5*_Bn.TIF	Full resolution image processed to GeoTIFF format. <Bn> B1 = Band 1, B2 = Band 2, B3 = Band 3, B4 = Band 4, B5 = Band 5, B6 = Band 6, B7 = Band 7
LT5*_MTL.txt	Metadata file - an **ASCII** (American Standard Code for Information Interchange) file that includes all metadata associated to the product. Its content is mainly described in RD.3, RD.12, APPENDIX A and APPENDIX B.
LT5*_GCP.txt (This file is L1T processing level specific, it is not present for L1G or L1Gt)	Ground Control Points file - statistics file which aims to report on accuracy of the geometric model adjustment to GCP Database. **Note:** 1. GCP-based residual errors listed in the GCP file are computed by using the GCP set involved as reference for geometric refinement. No independent checks are used. 2. The geometric quality information written into the MTL file is a summary of statistics reported in this GCP file. 3. Where Multi-scene Refinement is used, the product delivery does NOT contain this file.

3.4.1.2 L1Gt

Each L1Gt ZIP file is constructed as above for the L1T products; however the GCP.txt file is not present for these products (because GCPs are not used). As they are only generated for ETM+ products, the filename is as follows (for a Kiruna scene as an example):

LS07_RKSE_ETM_GTC_1P_*.ZIP

See Section 3.3.2 for more information on these products.

3.4.1.3 L1G

Each L1G ZIP file is constructed as above for the L1T products; however the GCP.txt file is not present for these products and the filename is as follows (for a Landsat 5 Kiruna TM scene as an example):

LS05_RKSE_TM__GEO_1P_*.ZIP

See Section 3.3.1 for more information on these products.

For more details on the Metadata Parameters and values for v3.03 of the Landsat 5 TM dataset, see APPENDIX A. For more details on the Metadata Parameters and values for v3.03 of the Landsat 7 ETM+ dataset, see APPENDIX B.

3.4.2 ESA Landsat Product Naming Convention

The ESA Landsat file naming standard convention (detailed in RD.4) has been modified to include new path and row information in the product name. This new naming convention is detailed in RD.5 whereby the following has been used:

MMNN_CCCC_TTTTTTTTTT_yyyymmddThhmmss_YYYYMMDDTHHMMSS_oooooo_pppp_rrrr_vvvv.EEEE

Table 3-5: ESA's new naming convention

Name Element Description	Pattern	Comment
Satellite Name and Mission Number	MMNN	2 uppercase letters and 2 numbers
File Class/Originator	CCCC	4 uppercase characters (For reprocessing: 1 char R – Repro, 3 char station as per RD.6; KSE for Kiruna; MPS for Maspalomas; MTI for Matera; FUI for Fucino; NSG for Neustralitz; MLD for Malindi; LBG for Libreville; BSK for Bishkek; OHG for O'Higgins)
Ten character Product/File Type	TTTTTTTTTT	10 uppercase letters, digits and underscores "_" (Instrument code and Product level)
Validity Start Date and Time:	yyyymmddThhmmss	15 characters (separated by "T")
Validity End Date and Time:	YYYYMMDDTHHMMSS	15 characters (separated by "T")

Name Element Description	Pattern	Comment
Absolute orbit at sensing start time	oooooo	Up to 6 characters, no leading zeros
Path and Row (i.e. Track and Frame)	pppp, rrrr	4 digits indicating path number, 4 digits indication row number (separated by "_")
File Version or counter	vvvv	4 digits indicating a unique product identifier
File extension	EEEE	Up to 4 characters identifying file extension

Note: This convention is applied to all files in the product except for the GeoTIFF product contents (Bn.TIF, GCP.txt, MTL.txt) which continues to conform to the USGS convention (detailed in RD.3 and RD.12) as follows:

<LANDSAT_SCENE_ID>_BN.XXX, where LANDSAT_SCENE_ID is LMSPPPRRRYYYYDOYGSIVV, where

Table 3-6: USGS naming convention for Landsat GeoTIFF products

Pattern	Comment
L	Landsat
M	Mission: M = Landsat MSS T = Landsat TM E = Landsat ETM+
S	Satellite 1 = Landsat 1 2 = Landsat 2 3 = Landsat 3 4 = Landsat 4 5 = Landsat 5 7 = Landsat 7
PPP	Three-digit starting path
RRR	Three-digit starting row
YYYY	Four-digit acquisition year
DOY	Three-digit acquisition day of the year
GSI	Ground Station Identifier
VV	Two-digit version

Pattern	Comment
BN	Band Number (**BN**): B1 = Band 1 B2 = Band 2 B3 = Band 3 B4 = Band 4 B5 = Band 5 B6 = Band 6 (MSS and TM products only) B6_VCID_1 = Band 6 VCID_1 (ETM+ products only) B6_VCID_2 = Band 6 VCID_2 (ETM+ products only) B7 = Band 7 B8 = Band 8 (ETM+ products only) Note: BN is replaced with “GCP” for a Ground Control Points file; and “MTL” for a Metadata file
XXX	File type: = TIF file extension for all image data = JPG file extension for the verification browse (USGS products only) = .txt file extension for GCP, VER, and L1 Metadata (MTL) Files

Figure 3-1 highlights the naming convention used in an ESA-reprocessed Landsat 5 TM L1T (GTC) product, obtained from the Kiruna ground station (Station Code Reference KSE – see RD.6), where multi-scene refinement has not been used.

Filename

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.ZIP

As extracted:

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.BP.PNG

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.BP.XML

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.MTR.XML

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.QR.PDF

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.QR.XML

LS05_RKSE_TM__GTC_1P_19900630T165127_19900630T165155_033672_0034_0002_0001.TIFF:

LT50340021990181ESA00_B1.TIF

LT50340021990181ESA00_B2.TIF

LT50340021990181ESA00_B3.TIF

LT50340021990181ESA00_B4.TIF

LT50340021990181ESA00_B5.TIF

LT50340021990181ESA00_B6.TIF

LT50340021990181ESA00_B7.TIF

Figure 3-1: Contents of a Landsat 5 TM zip file whereby the new naming convention is used (example product)

4. COMPARISON OF ESA AND USGS PRODUCTS

Note: V3.03 of the ESA processor has been developed to be used with MSS, TM and ETM+ data, however this section currently only deals with TM and ETM+ products.

The following sections outline the similarities and differences between the ESA and the USGS processors.

4.1 Processing Similarities

There are many similarities between the ESA and USGS processors; however, one of the most important things to note is the Radiometric Processing.

Both processors (ESA and USGS) use the same input Auxiliary files (CPF and Ephemeris) for TM and ETM+ processing as well as implementing a Memory Effect (**ME**) correction and Scan Correlated Shift (**SCS**) conforming to RD.7 and RD.10 (see Sections 4.4.4 and 4.4.6 for more information).

For these reasons, the radiometric processing is almost identical.

4.2 Processing Differences

The ESA IPF deviates from the USGS processor in certain areas that mainly affect the product format and geometry. ESA product standards are very similar to Level 1 Product Generation System (**LPGS**) products (and different to National Land Archive Production System (**NLAPS**) products). Hence the comparison in Table 4-1 below is done referring to LPGS products, assuming that the format of the GeoTIFF LPGS products follow the specification defined in RD.3 and RD.12. This table summarises the processing differences which are discussed in more detail below.

Table 4-1: ESA and USGS Processing differences

Components		ESA / USGS Processing Differences
Input		ESA Input data is in L0 WILMA format not Level 0 Reformatted (**L0R**) format (USGS). Restituted Ephemeris (4.2.1) is used (Landsat TM).
Output	TM	L1G (GEO) systematically corrected products are generated wherever L1T products are unable to be produced (Landsat TM).
	ETM+	L1Gt radiometrically and geometrically corrected products are generated wherever L1T products are unable to be produced (Landsat ETM+).
Geometric Processing		Multi-scene Refinement (4.4.4) is used for ESA L1T processing. GeoCover data is used as the reference for the sensor model refinement (for refining the accuracy of the geometric model). It is not used for verification purposes, and thus *_VER.txt and *VER.jpg files are not produced in the ESA product.
Cloud cover		The ESA cloud cover assessment is applied at L1T (post processing). The USGS cloud cover assessment is applied at L0R (before geometric correction).

Components	ESA / USGS Processing Differences
Product Packaging	Landsat scene directory is included into a packaged directory into which ngEO files are included, RD.8 and RD.9 (4.2.2).
Quick Look Image	The ESA QL image is not included in the Landsat scene directory but at the upper level, in the product package. The ESA QL image is not a Verification Browse Image. The ESA QL image does not include a GCP-set vector layer. The band combination involved in QL creation is 7-5-3 instead of the 1-2-3 used by the USGS. A 1.8 % radiometric stretch is applied in ESA QLs. The dimension of the ESA QL image is 1448 pixels x1448 pixels instead of 1024 pixels x 901 pixels in the USGS QL.

4.2.1 Ephemeris

During mission operations, Ephemeris data is downlinked from the Payload Correction Data (**PCD**) stream from the satellite to the ground station. These are then interpolated and refined by using external data and methods to create Definitive Ephemeris. Definitive Ephemerides are used as default where available as they are the most accurate.

When Definitive Ephemeris is not available, the unrefined 'raw' ephemeris are cleaned / filtered to create Restituted Ephemeris data. Where Restituted Ephemerides are not available, Predicted Ephemeris data is used (as delivered by the USGS). These requirements arise as a consequence of the incomplete nature of the consolidated ephemeris dataset used for the IPF processing due to the unavailability of some Definitive Ephemeris. These requirements are most applicable prior to the year 1990. The use of Ephemeris data is therefore defined by one of two conditions:

1. In instances where Definitive Ephemeris is ***not*** available, the Restituted Ephemeris is used.

2. In instances where Definitive or Restituted Ephemeris is ***not*** available, Predicted Ephemeris is used.

Note: The use of Restituted or Predictive Ephemeris data reduces geometric accuracy of the products.

The use of Predictive, Restituted, or Definitive Ephemeris is noted in the relevant field in the MTL file of the product. For more details of the MTL contents, see APPENDIX A and APPENDIX B.

4.2.2 Metadata linked to ngEO

The Next Generation User Services for Earth Observation (**ngEO**) project's objective is to provide online user services; primarily access to operational data for both GMES and non-GMES missions. As ngEO will "harvest" product metadata, v3.03 generates an XML format Metadata Report for each Frame together with the following:

- A browse/Quicklook image in PNG format and 1448 x 1448 pixels in size. Two text fields are included in the PNG with keys "TrackNo" and "FrameNo", highlighting the respective WRS Path and Row number of the processed Level 1 image.

- An XML report file.

For more information on the ngEO concepts, how the service is tailored to satisfy Landsat products, product metadata and browse format information, see RD.8 and RD.9.

4.3 Impact on Product Format

The differences between the ESA and the USGS processors discussed above lead to differences in the content of the accompanying MTL file included within the Landsat scene directory. Table 4-2 aims to show the deviations with respect to the format specification (RD.3).

Table 4-2: Parameters contained within USGS metadata, but not present in ESA metadata

MTL GROUP	TM PARAMETER	ETM+ PARAMETER
PRODUCT_METADATA	DATA_TYPE_L0RP = "TMR_L0RP"	DATA_ACQUIRED_GAP_FILL
	REPORT_VERIFY_FILE_NAME = "LT5*_VER.txt"	GAP_FILL
	BROWSE_VERIFY_FILE_NAME = "LT5*_VER.jpg"	
IMAGE_ATTRIBUTES	GROUND_CONTROL_POINTS_VERIFY	GROUND_CONTROL_POINTS_VERSION
	GEOMETRIC_RMSE_VERIFY	
PROJECTION_PARAMETERS	MAP_PROJECTION_L0RA = "NA"	SCAN_GAP_INTERPOLATION
	VERTICAL_LON_FROM_POLE	VERTICAL_LON_FROM_POLE
	TRUE_SCALE_LAT	TRUE_SCALE_LAT
	FALSE_EASTING	FALSE_EASTING
	FALSE_NORTHING	FALSE_NORTHING

4.4 Data Quality Enhancements

4.4.1 Level 1T Processing: Additional Partial Frames Processed

In v3.03, whole orbital passes are presented for processing and the optimum number of Frames generated as a result. In this processing setup, *only* L1T Standard WRS Scenes are processed i.e. the Floating Scene processing option of previous ESA processing chains has been removed. This is an improvement compared to the current USGS processing for Landsat TM and ETM+ products.

As mentioned in Section 3.1, the first and last WRS scenes in a pass are processed when at least 50% of the image lines exist. More specifically:

- The first WRS scene is processed only if the centre of the scene is below the first image line of the pass;
- The last WRS scene is processed only if the centre of the scene is above the last image line of the pass.

The Latitude limit for ESA Landsat processing has also been extended to 84° North (previously 60° North).

4.4.2 Bias Correction

In October 2012, the USGS updated the way detector bias was computed in Landsat 5 TM processing to use lifetime model bias values written into the CPF. Prior to this the detector biases were estimated by using dark current data as part of the Internal Calibration (**IC**) recorded at the end of each scan, but studies showed that the pre-detector biases estimated from the lifetime night data trends were much more stable. Therefore, in v3.03 for Landsat TM scenes, both the calibration Gain and Bias are calculated from the CPF (apart from Band 6, the Thermal Band, which is nominally calculated by IC (shutter bias). In cases of poor telemetry data, and where the processor is unable to perform the internal calibration for Band 6, it is calculated from the CPF). This is recorded in the GROUP = PRODUCT_PARAMETERS within the MTL file.

4.4.3 Memory Effect Correction

ME is a noise pattern that can be observed as alternating lighter and darker horizontal stripes and can be found in data that has had geometric correction applied. ME can be present across the full swath, or in a part of a swath, and is most noticeable near a significant change in brightness levels within a product e.g. a cloud/water boundary. In v3.03 of the processor, ME is automatically corrected and radiometric data quality is improved as a result.

4.4.4 Multi-Scene Refinement

In routine processing of L1T (GTC) products, GCPs are used to refine the geo referencing model involved in the ortho-rectification process of an individual Level 1 scene (frame). In v3.03, where routine GCP processing is not normally possible – such as in areas containing a significant percentage of cloud cover, or water, or where the NIR band is homogeneous or saturated – multi-scene refinement is used. Multi-scene refinement is based on the geo referencing model refined by using GCPs extracted from the full path, involved in the production of the GTC product.

Multi-scene Refinement products are **not** accompanied by a GCP.txt file, and its use is identified in the accompanying MTL metadata file:

GROUND_CONTROL_POINT_FILE_NAME = "Not Applicable - geometric refinement using neighbouring scenes"

The introduction of Multi-scene Refinement is an improvement compared to the current USGS processing for Landsat 5 TM products, and has resulted in a greater number of L1T products than are currently available from the USGS Catalogue. Of the L1T products in the v3.03 dataset, approximately 10% are produced as a result of Multi-scene refinement.

Note: Those input products that do not result in L1T (either via GCP or Multi-scene Refinement processing) are subjected to L1G (TM) or L1Gt (ETM+) processing.

4.4.5 Residual Striping Correction

Residual Striping occurs as a result of each of the detectors, in the AL direction for each of the Visible and Mid-Infrared Bands, having slightly different response characteristics to its neighbour. This difference in response will affect the output radiance value (in Digital Number (**DN**)) for each of the 16 detectors, and potentially be visible as a marked difference in neighbouring AL pixels across the full width of the image. This difference may be amplified in relatively uniform (homogeneous) areas such as large expanses of desert, water, ice and snow.

During calibration, the data is linearly adjusted to match the mean and standard deviation of each detector compared to a reference detector or average of the detectors, with the residual striping being the differences that remain after the absolute and relative calibration has occurred.

4.4.6 Scan Correlated Shift Correction

The SCS Correction is a sudden, random, change in bias level. It occurs across all detectors during the short time interval between active scans. In the time interval between active scans, no data are acquired, and the sudden change introduces a 'pseudo-constant' bias level for each scan of image and calibration data. In v3.03 of the processor, SCS is automatically corrected for and improves radiometric data quality.

5. KNOWN LANDSAT ANOMALIES

The section below outlines known Landsat anomalies that are present in the ESA TM and ETM+ datasets. For more detailed information regarding each issue, please visit the ESA anomalies page: https://earth.esa.int/web/guest/-/landsat-product-anomalies-3798. Please note that these pages have not been updated to account for the reprocessing activity and so are to be used as information only i.e. the 'scrap' method is no longer valid nor necessary.

5.1 Data Loss

Data loss, sometimes referred to as the "Christmas Tree effect", occurs when there is a data loss in all bands and is present for some of the Landsat 5 products processed with this processor. The values for the missing scanlines are zero and it is an issue originating from the Level 0 data, confirmed by its presence in the EOLi Catalogue and the Level 0 QC undertaken by Magellium within the Data Services Initiative (**DSI**) project.

The missing data can be treated in three ways:

- Substituted with telemetry data;
- Replaced by null values; or
- Filled with a designated fill pattern.

When data loss occurs in all bands, it can be identified in the RGB Quicklook by the presence of Red, Green and Blue pixels or dark areas in the Across Track direction.

5.2 Gain Change (Landsat 7 ETM+ products)

A Gain Change only occurs for the ETM+ instrument on board Landsat 7 and generally occurs at the beginning or end of a scene. It splits the image into two areas of varying brightness; the upper section is brighter than the lower section in the case of switching band gain from high to low mode (descending scenes). Users are advised to use these scenes with caution by applying appropriate rescaling gain and offset in order to compute the correct radiance values for the scene.

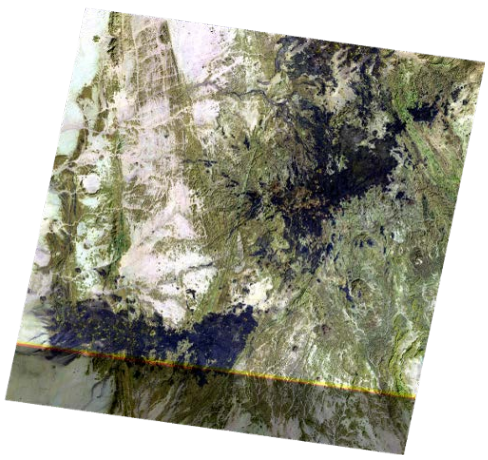


Figure 5-1: An example of a Landsat 7 ETM+ product with Gain Change

LS07_RMPS_ETM_GTC_1P_20000213T095713_20000213T095742_004424_0192_0044_F343.BP

5.3 Missing Pixels

Missing pixels / speckle noise (subsets of Impulse Noise) are a known issue with Landsat data. This is due to data lost either during data downlink (from the satellite to the receiver (GS)), or during transcription from tape to the digital media, in the case of the old archive.

Unfortunately, this speckle is in the data and so the data is lost and cannot be recovered. However, in some cases its visual and numerical influence can be reduced, but this will also influence the non-speckle data to some degree. The simplest image processing technique to use in order to reduce (but not completely remove) such noise would be to apply a median filter to the product.

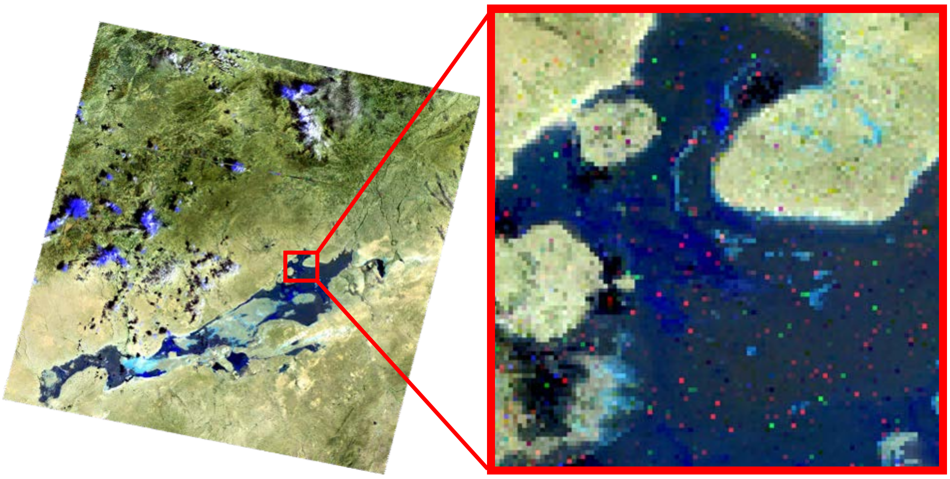


Figure 5-2: An example of a scene containing missing pixels

5.4 Swath and Line Misalignment

This anomaly relates to a large or small swath shift and line / detector displacement. Its occurrence is due to the wrong scan length information registered in the telemetry data and is most visible near areas of high contrast i.e. roads, rivers and coasts. This is a known issue with Landsat data that affects a relatively low number of products.

The worst affected scenes fail QC inspections and so are not released to the users; however, there may be cases where products containing a low number of misaligned rows are in the accessible dataset.

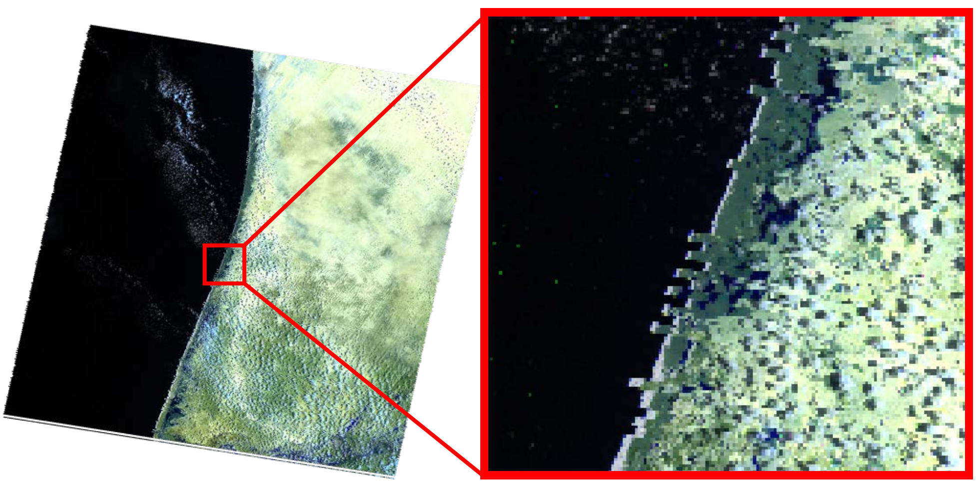


Figure 5-3: An example of a product that contains small swath shift

Please note: the above example is considered as badly affected and is therefore not available for user download.

5.5 Scan Line Corrector Anomaly

On May 31st 2003, the SLC on board Landsat 7 suffered a total failure, impacting the quality of the acquired images, with areas on the centre of the image being acquired twice and some areas at the edge of the image not being acquired at all (see Figure 5-4). As a result of this failure, and its impact on the products, routine acquisition of Landsat ETM+ data by ESA was halted in June 2003. There are however, a small number of products in the ESA dataset that contain this anomaly, these products should be used with caution (it is advised that the centre of the scene be used only).

More information on the behaviour of the SLC can be found on the USGS website: http://landsat.usgs.gov/products_slcoffbackground.php

http://landsat.usgs.gov/using_Landsat_7_data.php

Additional information on methods to overcome the gaps within products from the failure in the SLC can be found here: http://landsat.usgs.gov/products_slcoffgapmask.php

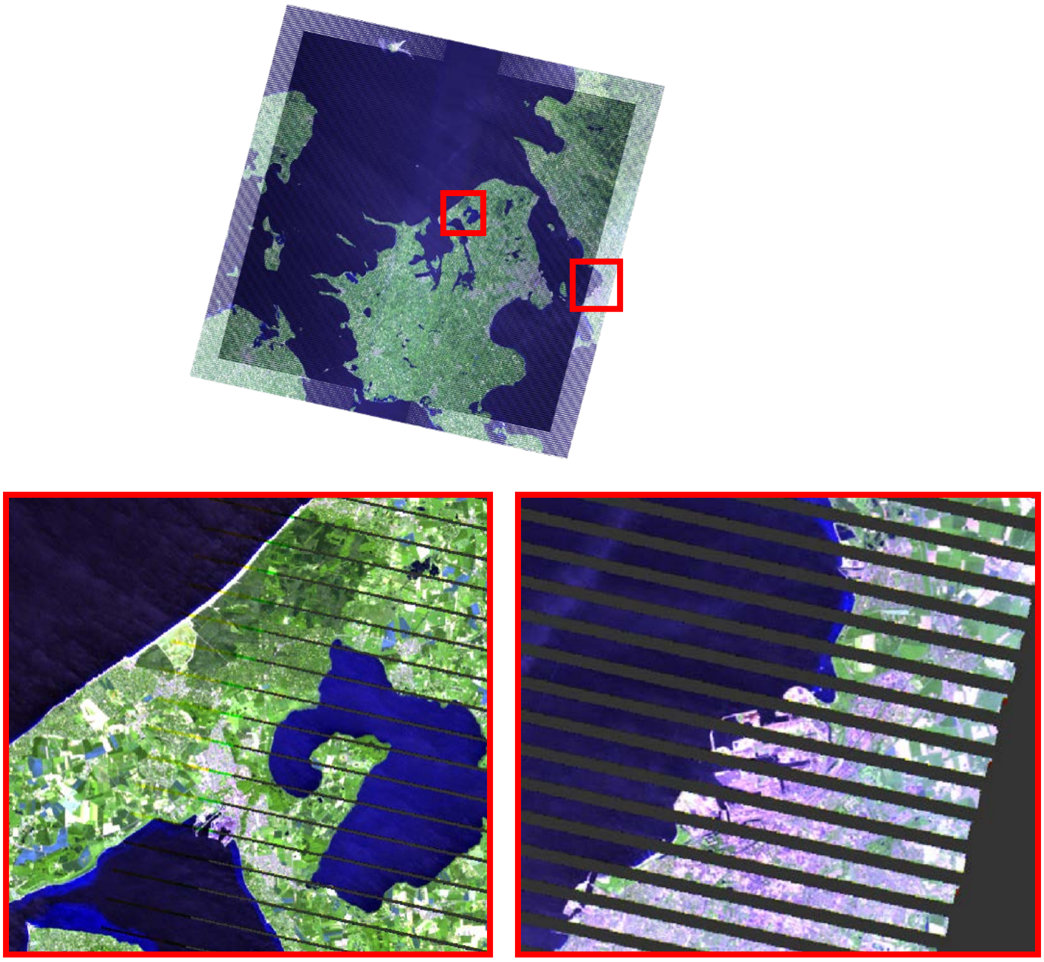


Figure 5-4: A Landsat 7 ETM+ Quicklook acquired after the SLC failure

LS07_RKSE_ETM_GTC_1P_20030602T100234_20030602T100303_021972_0195_0021_5DFE.TIFF

5.6 Shutter Synchronisation Anomalies

Shutter Synchronisation Anomaly (**SSA**) is the term given to any anomaly that causes the Landsat Internal Calibrator (IC) shutters to be visible in the product as seen in Figure 5-5. This is due to a failure in the synchronisation between the shutter and the primary scan mirror and includes Scan Mirror Anomalies (**SMAs**), Late Start Anomalies (**LSAs**) and Caterpillar Tracks.

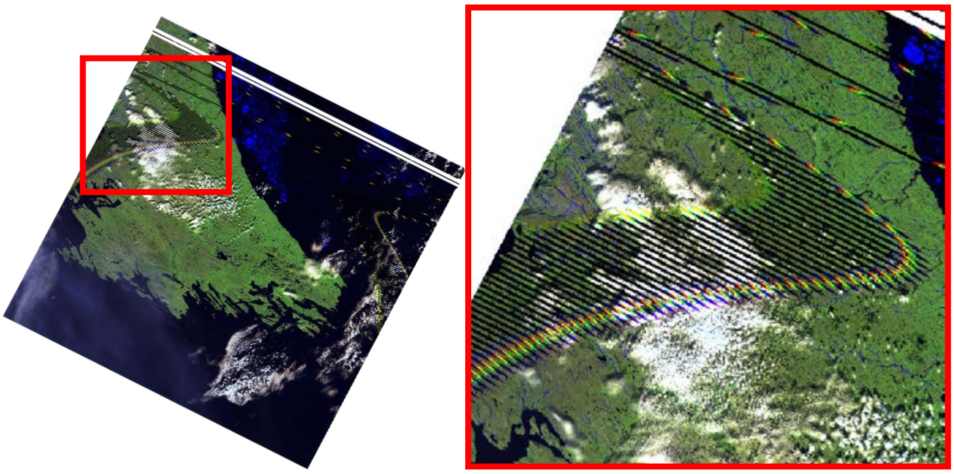


Figure 5-5: ETM+ Kiruna scene with shutter synchronisation anomaly

LS07_RKSE_ETM_GTC_1P_20000715T075721_20000715T075750_006651_0175_0010_987E.BP

5.6.1 Caterpillar Tracks – TM Matera

Caterpillar tracks occur when the Scan Mirror Turn-Around-Time has increased beyond the point at which synchronisation with the calibration shutter can be maintained, often occurring towards the end of an instruments lifetime. The resulting features are visible as shutter ‘tracks’ in the TM Matera archive predominantly during 2001 and 2002. To help correct issues such as these, as well as increase the longevity of the satellite, the TM instrument was switched to the ‘backup’ BUMPER mode on March 1 2002, see RD.11.

Despite the data contained within these products being of adequate quality for scientific use, it is advised to use them with caution.

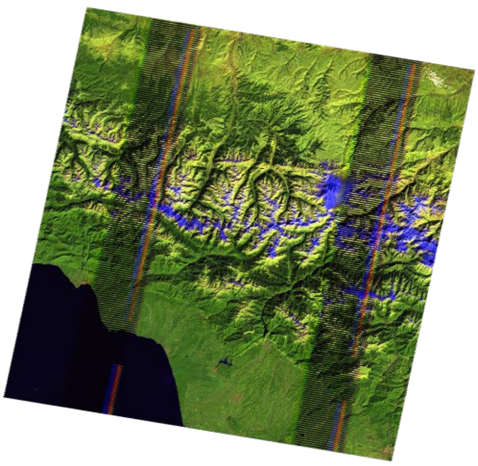


Figure 5-6: TM Matera scene with caterpillar tracks

LS05_RMTI_TM__GTC_1P_20011009T073512_20011009T073541_093649_0172_0030_5340.BP

6. DATASET INFORMATION AND LIMITATIONS

This section is intended to offer information regarding the limitations of the TM and ETM+ Datasets.

Please note that the blue effect of the QLs seen at high latitudes and often during the winter months is a known consequence of the RGB band combination (7-5-3) used by ESA, and is not an anomaly.

6.1 Duplicate Products (TM & ETM+ Matera)

As a consequence of the TM and ETM+ Matera archives consisting of products processed from raw data which have been recorded at the Matera, Fucino, Neustralitz, Malindi, O'Higgins, Libreville and Bishkek ground stations, there are occurrences of duplicate products within the dataset.

For example, the following two scenes are the same length and quality however one has been received at Fucino, and the other at Neustralitz. Both products in each pair of duplicates remain in the dataset archive for the User to download their preferred scene.

LS07_RFUI_ETM_GTC_1P_19990729T080620_19990729T080648_001525_0175_0029_4398.TIFF

LS07_RNSG_ETM_GTC_1P_19990729T080620_19990729T080648_001525_0175_0029_E27E.TIFF

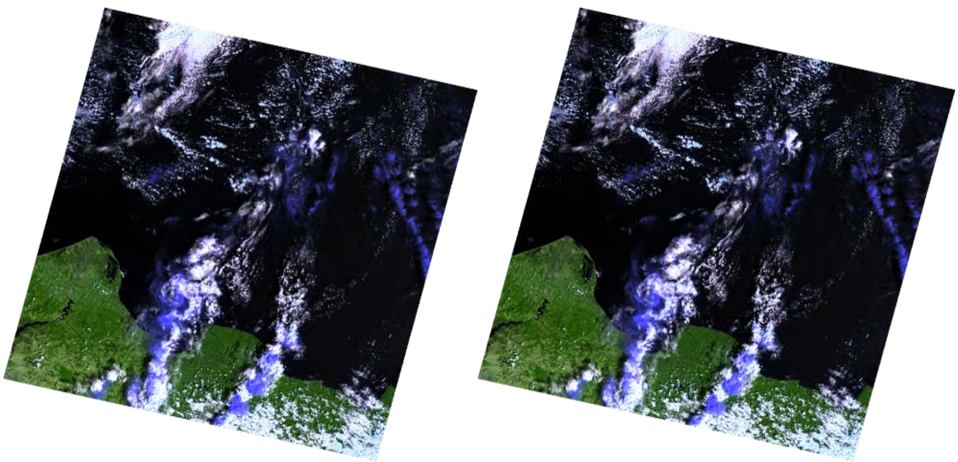


Figure 6-1: Two duplicated products. Left: a Fucino product, Right: a Neustralitz product

6.2 GeoTIFF Metadata Tag

In the ESA processor, the following GeoTIFF metadata tag has been used: AREA_OR_POINT=Area. In the USGS processing an alternative tag has been used: AREA_OR_POINT=Point. Therefore, the coordinates of the pixel are the upper left corner of the pixel for 'Area' and centre of the pixel for 'Point', which can cause a half a pixel shift in the georeferencing if not accounted for correctly.

Most GIS software should be able to handle either version of the metadata tag and so this is normally transparent to the user. However, it is important for those writing their own code.

6.3 Noisy Products over Seas or Oceans

Due to the upgrades of the v3.03 processor and the generation of the new L1G (GEO) products that use the satellites orbital information, numerous new products are produced over areas of sea / ocean. As Landsat is not strictly designed for these types of acquisitions, they are generally quite noisy products.

The noise arises as the reflectance value of a body of water depends on the amount of matter suspended within it, with areas (such as coastal or inland waters) that contain high levels of suspended particles (such as plankton and inorganic sediments) having a greater contributing effect – and consequently a higher return signal – as a result of scattering of light, than the comparatively clearer ocean waters (that result in a lower return signal). Thus, the presence of noise in the product acquired over coastal or inland waters is reduced in comparison with products acquired over sea or Open Ocean.

6.4 Image Distortions

There may be cases where the product is offset, i.e. not square, see the examples below. This is due to a large shift in the attitude data or the estimated ortho-rectified affine transformation and normally the products fail QC so are not released to the users.

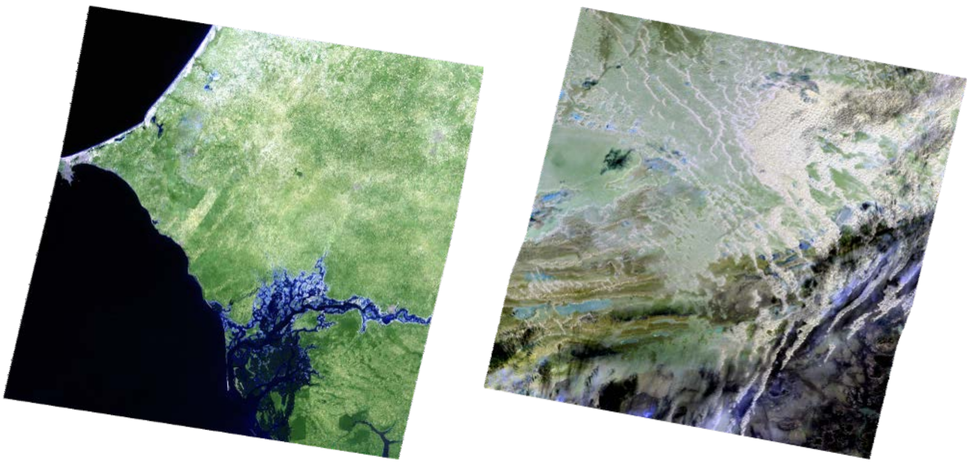


Figure 6-2: Offset products of the Maspalomas dataset

6.5 Offset Quicklook Edges

There are occasions where the imaging of one band in a scene finishes before another. Under normal circumstances, the ESA processor cuts the edges of a scene so that each band is of the same length. However, for scenes where the scan length is shorter than normal, the cutting is not effective and the image edge contains some bands but not all, giving a coloured appearance as in Figure 6-3.

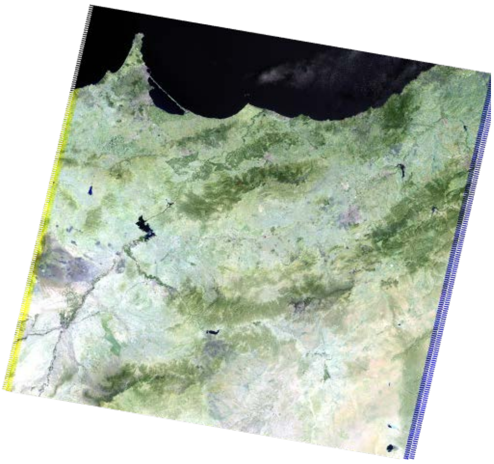


Figure 6-3: An example of a scene with an offset edge in the Quicklook

6.6 Failed AMALFI QC Reports

In some instances, products that fail systematic QC inspections have been released as part of the downloadable dataset. Users are made aware of the specific reasons for failure via the AMALFI QC report (QR.XML and QR.PDF) provided within the Level 1 data product. The following sections detail the specifications of these products and where they should be used with caution.

6.6.1 GCP Inspections

There are cases where products are processed to L1T, but fail QC inspections. This can occur when the geolocation accuracy of the product is within specification, but the number of GCPs is below the QC threshold of 15; see Section 3.3 for further details.

In such cases, a L1G product is not produced but instead, to maximise data availability, ESA have chosen to release the QC failed L1T products for User download. Only products that fail with *too few GCPs and/or residuals outside of the threshold* are released i.e. those that fail GCP inspections plus an additional or multiple inspections not detailed within this section of the document, remain segregated and unavailable to download.

6.6.2 MTL Inspections –Sensor Mode Inspection

As mentioned in Section 5.6.1, the TM instrument was switched from SAM to BUMPER mode on March 1 2002. Version 3.03 of the ESA processor is configured to generate products in BUMPER mode after *April 1 2002*, therefore products between 1 and 31 March 2002 are processed as SAM mode (SENSOR_MODE field in the MTL file) and fail QC inspections.

This is a configuration issue between the processor and the QC tool and does not affect the quality of the products which are available for User download and can be used with confidence.

6.6.3 Saturation Inspections – Band 5 (TM Maspalomas and Matera)

It is known that Landsat TM products are often saturated in Band 5 over areas of desert.

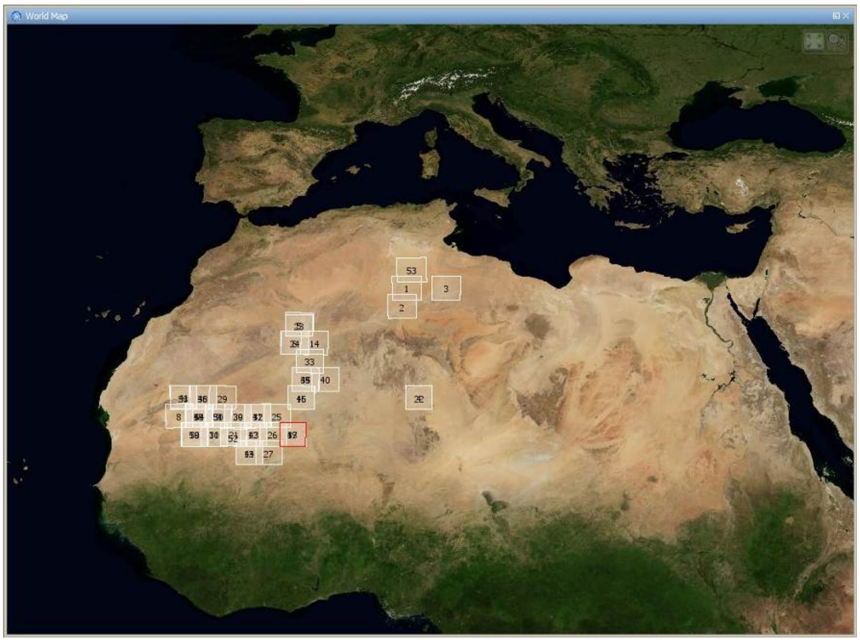


Figure 6-4: Map to show the trend in location of Maspalomas saturated products over the Saharan Desert

This is a feature of the surface reflectance and is not caused by the processor or the Level 0 data, and only occurs in the Maspalomas and Matera TM datasets. As a consequence, the data in Band 5 has very high DN values and is not a true representation of the underlying surface when used alone. The AMALFI reports accompanying these products are failed, since saturation exceeds 80% in Band 5. However, the remainder of the product is of good quality and remains suitable for scientific use. Therefore, these products have been included in the dataset and can be downloaded as normal.

The Band 5 saturated products are often easily identifiable by their bright green / yellow QL as the band combination is 7-5-3 (RGB); Figure 6-5 is an example.

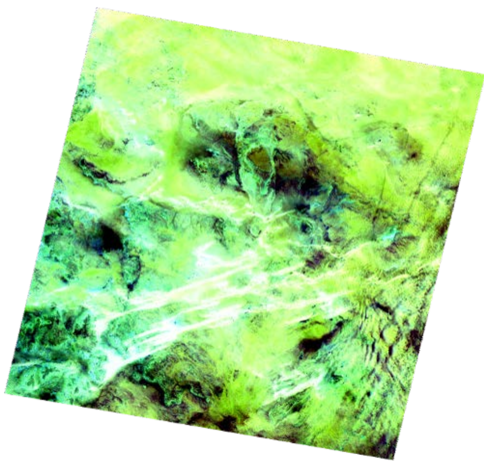


Figure 6-5: A Landsat TM Maspalomas scene over desert with saturation in Band 5

6.6.4 Saturation Inspections – Band 6 (TM Kiruna)

A very small percentage of products in the TM Kiruna v3.03 dataset contain anomalies in the Thermal Band. These are either saturation in Band 6 or where there is no data present in Band 6 (Not a Number (**NaN**)). Despite these irregularities, the products have been released with the dataset for the following reasons; the data in all other bands passes QC, is of variable DN and is considered optimal for scientific use.

6.6.5 Striping Inspections – Band 1 (TM Matera)

In the current version of the processing software, the detector to detector mis-calibration issues are corrected by using a lifetime modelling of the relative gains. The well-known image artefacts such as 'Memory Effect' (see Section 4.4.3), 'Scan Correlated Shift' (see Section 4.4.6) and 'banding' are also corrected by using post-processing algorithms applied to Bands 1, 2, 3 and 4.

The magnitude of residual errors related to these corrections is approximately <0.5 DN and therefore is, in most cases, not visible to the user.

However, it has been observed that the Band 1 image sometimes fails the AMALFI QC striping inspection. This occurs when the scene is highly contaminated with water vapor. It results in a very poor image dynamic that is confirmed with a narrow range image histogram where the information related to the scene is almost missing but the residual errors still exist.

When rendering such image in the display, it is common that the software applies an automatic stretching. Consequently, the residual errors become visible: a narrow range of digital numbers is linearly rescaled (to 8 bit interval) appearing as alternating brighter and darker swath lines in the Band GeoTIFF.

Although these very small differences may look to be significant in the image shown in the standard display (see Figure 6-6), the TM detector-to-detector DN differences in the L1 data remains very small and agree with specifications defined during the commissioning of the processing software.

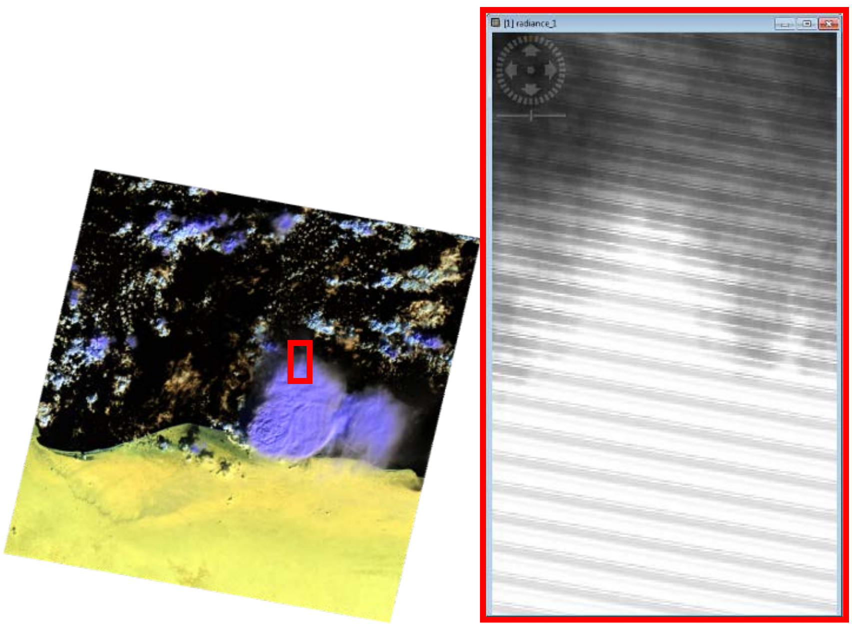


Figure 6-6: A Landsat 5 TM Matera scene containing striping in Band 1

LS05_RFUI_TM__GTC_1P_19841103T081754_19841103T081822_003595_0180_0038_9360.TIFF

7. FAQS

This Frequently Asked Questions section is designed to answer Users' common questions related specifically to the ESA v3.03 Landsat Kiruna, Maspalomas and Matera TM and ETM+ archives, whose answers cannot currently be found at the ESA or USGS FAQ websites available at:

- http://earth.esa.int/pub/ESA_DOC/landsat_FAQ/#_Toc235345934 [users should be aware this is historical and so information about the processing and products may not be correct for the v3.03 dataset]
- http://landsat.usgs.gov/tools_access_all_faqs.php

What software can I use to read Landsat data?

BEAM Visat Version 5 (developed by Brockmann Consult) is a free toolbox and development platform for viewing, analysing and processing remote sensing raster data developed for ESA/ESRIN that can be used for Landsat GeoTIFF format products.

Note: It is advised to use the latest Ceres JAI Library module (v0.14.1) within BEAM v5 if the use of Median Filters is required as there is a known anomaly with the previous version.

Erdas Imagine 2011 and ESRI ArcGIS also support Landsat TM and ETM+ GeoTIFF files. (**Note:** In ArcGIS ArcMap 10.0 the TIFF folder must be renamed as otherwise ArcMap only allows the user to open the folder as a raster dataset and then produces an error message).

What do the MTL fields mean?

See APPENDIX A for full details of the MTL parameters for the ESA TM Landsat products and APPENDIX B for full details of the MTL parameters for the ESA ETM+ parameters.

Where can I find the processing level of the product?

The "DATA_TYPE" field in the MTL file contains the processing level of the product as well as in the product filename for TM products.

What is the geolocation accuracy of Landsat 5 L1G/Gt products?

The geometric accuracy of L1G (GEO) products is within approximately 250 m (1 sigma, USGS) for low relief areas at sea level.

Why are there periods of no acquisition in the datasets?

ESA did not collect data via Kiruna, Maspalomas and Matera during these periods.

How do I access the Landsat datasets?

The Landsat TM and ETM+ bulk-processed products are made freely available for direct download at: https://landsat-ds.eo.esa.int/app/

Users must hold a My Earthnet SSO account or, if not, register for one at: https://earth.esa.int/web/guest/home

8. GLOSSARY

The following acronyms and abbreviations have been used in this report.

AL	Along Track
ASCII	American Standard Code for Information Interchange
BN	Band Number
BSK	Bishkek
CC	Cubic Convolution
CDED	Canadian Digital Elevation Dataset
CPF	Calibration Parameter Files
DEM	Digital Elevation Model
DN	Digital Number
DSI	Data Services Initiative
EO	Earth Observation
EPH	Ephemerides
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
ETM+	Enhanced Thematic Mapper +
FUI	Fucino
GCP	Ground Control Points
GS	Ground Station
GTC	Ground Terrain Corrected
IAS	Image Assessment System
IC	Internal Calibration
IGS	International Ground Station
IPF	Instrument Processing Facility
KSE	Kiruna
L0	Level 0
L0R	Level 0 Reformatted
L1G	Level 1G
L1Gt	Level 1Gt
L1T	Level 1T
LBG	Libreville
LPGS	Level 1 Product Generation System
LSAs	Late Start Anomalies
ME	Memory Effect
MLD	Malindi
MMS	Multi-mission Modular Spacecraft
MPS	Maspalomas
MSS	Multi Spectral Scanner
MTI	Matera
MTL	Metadata
MTR	Metadata Report
NaN	Not a Number
NASA	National Aeronautics and Space Administration
NED	National Elevation Dataset

ngEO	Next Generation User Services for Earth Observation
NLAPS	National Land Archive Production System
NSG	Neustralitz
OHG	O'Higgins
OLI	Operational Land Imager
PCD	Payload Correction Data
PDF	Portable Document Format
PNG	Portable Native Graphic
QC	Quality Control
QL	Quicklook
QR	Quality Control Report
RBV	Return-Beam Vidicon
RD	Reference Document
SAM	Scan Angle Monitor
SCS	Scan Correlated Shift
SLAP	Systematic Landsat Archive Processing
SLC	Scan Line Corrector
SMAs	Scan Mirror Anomalies
SRTM	Shuttle Radar Topography Mission
SSA	Shutter Synchronisation Anomaly
TIFF	Tagged Image File Format
TIR	Thermal InfraRed
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WILMA	Wide Long Term Multi-Satellite Archive
WRS	World Reference System
XML	Extensible Markup Language

APPENDIX A V3.03 TM METADATA (MTL) PARAMETERS AND VALUES

This appendix outlines the MTL parameters for TM products of the ESA dataset, and where applicable, the expected value and/or naming convention.

Parameter	Value	Note
GROUP	**L1_METADATA_FILE**	
GROUP	**METADATA_FILE_INFO**	
ORIGIN	Image courtesy of ESA	Identifies the origin of the image as being from ESA
REQUEST_ID	*nnnyymmdd0000_0000* where: nnn= node number yy= year mm=month dd = day	
LANDSAT_SCENE_ID	LMSPPPRRRYYYYDDDESA00 Where: L = Landsat M = Mission (T = TM) S = Satellite (e.g. 4 or 5) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	

Parameter	Value	Note
FILE_DATE	YYYY-MM-DDTHH:MI:SSZ where: YYYY = Year MM = Month DD = Day T = Signifies the start of time information HH = Hours MI = Minutes SS = Seconds Z = Zulu (GMT) time	
STATION_ID	ESA	Ground Station/Organisation that received the data
PROCESSING_SOFTWARE_VERSION	SLAP_03.03	Software name (SLAP) followed by version number, and separated by underscores
DATA_CATEGORY	NOMINAL	Nominal data that exists within expected, acceptable limits
END_GROUP	**METADATA_FILE_INFO**	
GROUP	**PRODUCT_METADATA**	
DATA_TYPE	L1T (for Standard Terrain Corrected products) L1G (for Systematically Corrected products)	Data type Identifier
ELEVATION_SOURCE	GLS2000	Digital elevation data to perform product terrain correction.
OUTPUT_FORMAT	GEOTIFF	Product output format
EPHEMERIS_TYPE	PREDICTIVE or DEFINITIVE or RESTITUTED	Orbital ephemeris type used in processing product
SPACECRAFT_ID	LANDSAT_5	
SENSOR_ID	TM	

Parameter	Value	Note
SENSOR_MODE	SAM or BUMPER	Operational Mode: Scan Angle Monitor (**SAM**) and BUMPER Mode **Note:** Landsat 5 TM was switched to BUMPER mode on March 1 2002
WRS_PATH	194	The Orbital Path number (001 - 251)
WRS_ROW	27	(01-248) Landsat satellite Row (WRS Convention)
DATE_ACQUIRED	YYYY-MM-DD	Image Acquisition Date
SCENE_CENTER_TIME	HH:MI:SS.SSSSSSSZ where HH = Hour (00-23) MI = Minutes SS.SSSSSSS = Fractional seconds Z = "Zulu" time (same as GMT)	Scene centre time of acquired image
CORNER_UL_LAT_PRODUCT	Decimal degrees	upper-left corner Latitude value
CORNER_UL_LON_PRODUCT		upper-left corner Longitude value
CORNER_UR_LAT_PRODUCT		upper-right corner Latitude value
CORNER_UR_LON_PRODUCT		upper-right corner Longitude value
CORNER_LL_LAT_PRODUCT		lower-left corner Latitude value
CORNER_LL_LON_PRODUCT		lower-left corner Longitude value
CORNER_LR_LAT_PRODUCT		lower-right corner Latitude value
CORNER_LR_LON_PRODUCT		lower-right corner Longitude value
CORNER_UL_PROJECTION_X_PRODUCT	Feet or metres	Latitude grid
CORNER_UL_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_UR_PROJECTION_X_PRODUCT		Latitude grid

Parameter	Value	Note
CORNER_UR_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_LL_PROJECTION_X_PRODUCT		Latitude grid
CORNER_LL_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_LR_PROJECTION_X_PRODUCT		Latitude grid
CORNER_LR_PROJECTION_Y_PRODUCT		Longitude grid
REFLECTIVE_LINES	NNNN	Number of product lines for the reflective bands
REFLECTIVE_SAMPLES	NNNN	Number of product samples for the reflective bands
THERMAL_LINES	NNNN	Number of product lines for the thermal band
THERMAL_SAMPLES	NNNN	Number of product samples for the thermal band
FILE_NAME_BAND_1	LMSPPPRRRYYYYDDDESA00_Bn.TIF "Where: L = Landsat M = Mission (T = TM) S = Satellite (5) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used" Bn = Band 1 - 7	L1-file name for Band
FILE_NAME_BAND_2		L1-file name for Band
FILE_NAME_BAND_3		L1-file name for Band
FILE_NAME_BAND_4		L1-file name for Band
FILE_NAME_BAND_5		L1-file name for Band
FILE_NAME_BAND_6		L1-file name for Band
FILE_NAME_BAND_7		L1-file name for Band

Parameter	Value	Note
GROUND_CONTROL_POINT_FILE_NAME	LMSPPPRRRYYYYDDDESA00_GCP.txt Where: L = Landsat M = Mission (T = TM) S = Satellite (5) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	Ground Control Points File Identifier **Note:** this field is not present for L1G products
	Note: where Multi-scene Refinement is used, the LMSPPPRRRYYYYDDDESA00_GCP.txt file is not included, and the Parameter includes the following message: *"Not Applicable - geometric refinement using neighbouring scenes"*	Multi-Scene Refinement
METADATA_FILE_NAME	LMSPPPRRRYYYYDDDESA00_MTL.txt Where: L = Landsat M = Mission (T = TM) S = Satellite (5) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	Product Metadata File Identifier

Parameter	Value	Note
CPF_NAME	LMCPFYYYYMMDD_YYYYMMDD.nn where: L = Landsat M = Mission 5 = Landsat 5 YYYYMMDD_YYYYMMDD = Start date and End date nn = version (00-99)	
END_GROUP	**PRODUCT_METADATA**	
GROUP	**IMAGE_ATTRIBUTES**	
CLOUD_COVER	Cloud coverage (range 0 to 100 percent)	
IMAGE_QUALITY	Image Quality ranging from 0 to 9 0 = worst, 9 = best	The precise definition of this field is not given by USGS so it is nominally set to 9, subtracting 1 if lines are missing and 2 if in TM SLC_off mode
SUN_AZIMUTH	Angle from North -180.00 to 180.00 A negative value indicates angles to the west (CCW). A positive value indicates angles to the east (CW)	Sun azimuth angle in degrees for the image centre location at the image centre acquisition time
SUN_ELEVATION	-90.00000000 - 90.00000000 deg A negative value (-) indicates a night time scene A positive value indicates a daytime scene	Sun elevation angle in degrees for the image centre location at the image centre acquisition time
GROUND_CONTROL_POINTS_MODEL	1 – 999 (0 is used for L1T products that have used Multi-scene Refinement)	Number of GCPs used **Note:** this field is not present in L1G products
GEOMETRIC_RMSE_MODEL	0.000 – 9999.999	Combined Root Mean Square Error (RMSE) of the geometric residuals (metres) in both across-track and along-track directions measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1G products

Parameter	Value	Note
GEOMETRIC_RMSE_MODEL_Y	0.000 – 9999.999	RMSE of the Y direction geometric residuals (in metres) measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1G products
GEOMETRIC_RMSE_MODEL_X	0.000 – 9999.999	RMSE of the X direction geometric residuals (in metres) measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1G products
END_GROUP	**IMAGE_ATTRIBUTES**	
GROUP	**MIN_MAX_RADIANCE**	
RADIANCE_MAXIMUM_BAND_1	0.000 – 999.999	Maximum achievable spectral radiance value for Band 1 (w/(m^2 sr micron)).
RADIANCE_MINIMUM_BAND_1	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 1 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_2	0.000 – 999.999	Maximum achievable spectral radiance value for Band 2 (w/(m^2 sr micron)).
RADIANCE_MINIMUM_BAND_2	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 2 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_3	0.000 – 999.999	Maximum achievable spectral radiance value for Band 3 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_3	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 3 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_4	0.000 – 999.999	Maximum achievable spectral radiance value for Band 4 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_4	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 4 (w/(m^2 sr micron))

Parameter	Value	Note
RADIANCE_MAXIMUM_BAND_5	0.000 – 999.999	Maximum achievable spectral radiance value for Band 5 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_5	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 5 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_6	0.000 – 999.999	Maximum achievable spectral radiance value for Band 6 (w/(m^2 sr micron)).
RADIANCE_MINIMUM_BAND_6	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 6 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_7	0.000 – 999.999	Maximum achievable spectral radiance value for Band 7 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_7	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 7 (w/(m^2 sr micron))
END_GROUP	**MIN_MAX_RADIANCE**	
GROUP	**MIN_MAX_PIXEL_VALUE**	
QUANTIZE_CAL_MAX_BAND_1	255	Maximum possible pixel value (DN) for Band 1
QUANTIZE_CAL_MIN_BAND_1	1	Minimum possible pixel value (DN) for Band 1
QUANTIZE_CAL_MAX_BAND_2	255	Maximum possible pixel value (DN) for Band 2
QUANTIZE_CAL_MIN_BAND_2	1	Minimum possible pixel value (DN) for Band 2
QUANTIZE_CAL_MAX_BAND_3	255	Maximum possible pixel value (DN) for Band 3
QUANTIZE_CAL_MIN_BAND_3	1	Minimum possible pixel value (DN) for Band 3
QUANTIZE_CAL_MAX_BAND_4	255	Maximum possible pixel value (DN) for Band 4
QUANTIZE_CAL_MIN_BAND_4	1	Minimum possible pixel value (DN) for Band 4
QUANTIZE_CAL_MAX_BAND_5	255	Maximum possible pixel value (DN) for Band 5

Parameter	**Value**	**Note**
QUANTIZE_CAL_MIN_BAND_5	1	Minimum possible pixel value (DN) for Band 5
QUANTIZE_CAL_MAX_BAND_6	255	Maximum possible pixel value (DN) for Band 6
QUANTIZE_CAL_MIN_BAND_6	1	Minimum possible pixel value (DN) for Band 6
QUANTIZE_CAL_MAX_BAND_7	255	Maximum possible pixel value (DN) for Band 7
QUANTIZE_CAL_MIN_BAND_7	1	Minimum possible pixel value (DN) for Band 7
END_GROUP	**MIN_MAX_PIXEL_VALUE**	
GROUP	**PRODUCT_PARAMETERS**	
CORRECTION_GAIN_BAND_1	CPF (for CPF gains) INTERNAL_CALIBRATION (for IC gains)	Gain correction method for Band 1
CORRECTION_GAIN_BAND_2		Gain correction method for Band 2
CORRECTION_GAIN_BAND_3		Gain correction method for Band 3
CORRECTION_GAIN_BAND_4		Gain correction method for Band 4
CORRECTION_GAIN_BAND_5		Gain correction method for Band 5
CORRECTION_GAIN_BAND_6		Gain correction method for Band 6
CORRECTION_GAIN_BAND_7		Gain correction method for Band 7
CORRECTION_BIAS_BAND_1		Bias correction method for Band 1
CORRECTION_BIAS_BAND_2		Bias correction method for Band 2
CORRECTION_BIAS_BAND_3		Bias correction method for Band 3
CORRECTION_BIAS_BAND_4		Bias correction method for Band 4
CORRECTION_BIAS_BAND_5		Bias correction method for Band 5
CORRECTION_BIAS_BAND_6		Bias correction method for Band 6
CORRECTION_BIAS_BAND_7		Bias correction method for Band 7
END_GROUP	**PRODUCT_PARAMETERS**	

Parameter	Value	Note
GROUP	RADIOMETRIC_RESCALING	
RADIANCE_MULT_BAND_1	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 1 DN to reflectance
RADIANCE_MULT_BAND_2	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 2 DN to reflectance
RADIANCE_MULT_BAND_3	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 3 DN to reflectance
RADIANCE_MULT_BAND_4	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 4 DN to reflectance
RADIANCE_MULT_BAND_5	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 5 DN to reflectance

Parameter	Value	Note
RADIANCE_MULT_BAND_6	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 6 DN to reflectance
RADIANCE_MULT_BAND_7	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 7 DN to reflectance
RADIANCE_ADD_BAND_1	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 1
RADIANCE_ADD_BAND_2	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 2
RADIANCE_ADD_BAND_3	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 3
RADIANCE_ADD_BAND_4	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 4
RADIANCE_ADD_BAND_5	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 5
RADIANCE_ADD_BAND_6	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 6

Parameter	Value	Note
RADIANCE_ADD_BAND_7	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 7
END_GROUP	**RADIOMETRIC_RESCALING**	
GROUP	**PROJECTION_PARAMETERS**	
MAP_PROJECTION	UTM	Map projection used in image creation
DATUM	WGS84	Datum used in image creation
ELLIPSOID	WGS84	Ellipsoid used in image creation
UTM_ZONE	1 - 60	UTM zone number in a map projection
GRID_CELL_SIZE_REFLECTIVE	30	Grid cell size used in creating the image for the reflective band
GRID_CELL_SIZE_THERMAL	30	Grid cell size used in creating the image for the reflective band
ORIENTATION	NORTH_UP	Orientation used in image creation
RESAMPLING_OPTION	Cubic Convolution	Resampling option in image creation
END_GROUP	**PROJECTION_PARAMETERS**	
END_GROUP	**L1_METADATA_FILE**	

APPENDIX B V3.03 ETM+ METADATA (MTL) PARAMETERS AND VALUES

This appendix outlines the MTL parameters for ETM+ products of the ESA dataset, and where applicable, the expected value and/or naming convention.

Parameter	Value	Note
GROUP	**L1_METADATA_FILE**	
GROUP	**METADATA_FILE_INFO**	
ORIGIN	Image courtesy of ESA	Identifies the origin of the image as being from ESA
REQUEST_ID	*nnnyymmdd0000_0000* where: nnn= node number yy= year mm=month dd = day	
LANDSAT_SCENE_ID	LMSPPPRRRYYYYDDDESA00 Where: L = Landsat M = Mission (E = ETM) S = Satellite (e.g. 7) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	

Parameter	Value	Note
FILE_DATE	YYYY-MM-DDTHH:MI:SSZ where: YYYY = Year MM = Month DD = Day T = Signifies the start of time information HH = Hours MI = Minutes SS = Seconds Z = Zulu (GMT) time	
STATION_ID	ESA	Ground Station/Organisation that received the data
PROCESSING_SOFTWARE_VERSION	SLAP_03.03	Software name (SLAP) followed by version number, and separated by an underscore
DATA_CATEGORY	NOMINAL	Nominal data that exists within expected, acceptable limits
END_GROUP	**METADATA_FILE_INFO**	
GROUP	**PRODUCT_METADATA**	
DATA_TYPE	L1T (for Standard Terrain Corrected products) L1Gt (for Radiometrically and Geometrically Corrected products)	Data type Identifier
ELEVATION_SOURCE	GLS2000	Digital elevation data to perform product terrain correction.
OUTPUT_FORMAT	GEOTIFF	Product output format
EPHEMERIS_TYPE	PREDICTIVE or DEFINITIVE	Orbital ephemeris type used in processing product
SPACECRAFT_ID	LANDSAT_7	
SENSOR_ID	ETM	

Parameter	Value	Note
SENSOR_MODE	SAM or BUMPER	Operational Mode: SAM and BUMPER Mode **Note:** Landsat 7 was switched to BUMPER mode on April 1 2007
WRS_PATH	194	The Orbital Path number (001 - 251)
WRS_ROW	27	(01-248) Landsat satellite Row (WRS Convention)
DATE_ACQUIRED	YYYY-MM-DD	Image Acquisition Date
SCENE_CENTER_TIME	HH:MI:SS.SSSSSSSZ where HH = Hour (00-23) MI = Minutes SS.SSSSSSS = Fractional seconds Z = "Zulu" time (same as GMT)	Scene centre time of acquired image
CORNER_UL_LAT_PRODUCT	Decimal degrees	upper-left corner Latitude value
CORNER_UL_LON_PRODUCT		upper-left corner Longitude value
CORNER_UR_LAT_PRODUCT		upper-right corner Latitude value
CORNER_UR_LON_PRODUCT		upper-right corner Longitude value
CORNER_LL_LAT_PRODUCT		lower-left corner Latitude value
CORNER_LL_LON_PRODUCT		lower-left corner Longitude value
CORNER_LR_LAT_PRODUCT		lower-right corner Latitude value
CORNER_LR_LON_PRODUCT		lower-right corner Longitude value
CORNER_UL_PROJECTION_X_PRODUCT	Feet or metres	Latitude grid
CORNER_UL_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_UR_PROJECTION_X_PRODUCT		Latitude grid

Parameter	Value	Note
CORNER_UR_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_LL_PROJECTION_X_PRODUCT		Latitude grid
CORNER_LL_PROJECTION_Y_PRODUCT		Longitude grid
CORNER_LR_PROJECTION_X_PRODUCT		Latitude grid
CORNER_LR_PROJECTION_Y_PRODUCT		Longitude grid
PANCHROMATIC_LINES	NNNNN	Number of product lines for the panchromatic band.
PANCHROMATIC_SAMPLES	NNNNN	Number of product samples for the panchromatic band.
REFLECTIVE_LINES	NNNN	Number of product lines for the reflective bands
REFLECTIVE_SAMPLES	NNNN	Number of product samples for the reflective bands
THERMAL_LINES	NNNN	Number of product lines for the thermal band
THERMAL_SAMPLES	NNNN	Number of product samples for the thermal band
FILE_NAME_BAND_1	LMSPPPRRRYYYYDDDESA00_Bn.TIF "Where: L = Landsat M = Mission (T = TM) S = Satellite (5) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used" Bn = Band 1 – 8	L1-file name for Band
FILE_NAME_BAND_2		L1-file name for Band
FILE_NAME_BAND_3		L1-file name for Band
FILE_NAME_BAND_4		L1-file name for Band
FILE_NAME_BAND_5		L1-file name for Band
FILE_NAME_BAND_6_VCID_1		L1-file name for Band
FILE_NAME_BAND_6_VCID_2		L1-file name for Band

Parameter	**Value**	**Note**
FILE_NAME_BAND_7		L1-file name for Band
FILE_NAME_BAND_8		L1-file name for Band
GROUND_CONTROL_POINT_FILE_NAME	LMSPPPRRRYYYYDDDESA00_GCP.txt Where: L = Landsat M = Mission (E = ETM) S = Satellite (e.g. 7) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	Ground Control Points File Identifier **Note:** this field is not present for L1Gt products
	Note: where Multi-scene Refinement is used, the LMSPPPRRRYYYYDDDESA00_GCP.txt file is not included, and the Parameter includes the following message: *"Not Applicable - geometric refinement using neighbouring scenes"*	Multi-scene Refinement
METADATA_FILE_NAME	LMSPPPRRRYYYYDDDESA00_MTL.txt Where: L = Landsat M = Mission (E = ETM) S = Satellite (e.g. 7) PPP = WRS Path RRR = WRS Row YYYY = Year of Acquisition DDD = Day of Acquisition Year ESA = Ground Station Identifier 00 = not used	Product Metadata File Identifier

Parameter	Value	Note
CPF_NAME	LMCPFYYYYMMDD_YYYYMMDD.nn where: L = Landsat M = Satellite (e.g. 7) YYYYMMDD_YYYYMMDD = Start date and End date nn = version (00-99)	
END_GROUP	**PRODUCT_METADATA**	
GROUP	**IMAGE_ATTRIBUTES**	
CLOUD_COVER	Cloud coverage (range 0 to 100 percent)	
IMAGE_QUALITY	Image Quality ranging from 0 to 9 0 = worst, 9 = best	The precise definition of this field is not given by USGS so it is nominally set to 9, subtracting 1 if lines are missing and 2 if in TM SLC_off mode
SUN_AZIMUTH	Angle from North -180.00 to 180.00 A negative value indicates angles to the west (CCW). A positive value indicates angles to the east (CW)	Sun azimuth angle in degrees for the image centre location at the image centre acquisition time
SUN_ELEVATION	-90.00000000 - 90.00000000 deg A negative value (-) indicates a night time scene A positive value indicates a daytime scene	Sun elevation angle in degrees for the image centre location at the image centre acquisition time
GROUND_CONTROL_POINTS_MODEL	1 – 999 (0 is used for L1T products that have used Multi-scene Refinement)	Number of GCPs used **Note:** this field is not present in L1Gt products
GEOMETRIC_RMSE_MODEL	0.000 – 9999.999	Combined Root Mean Square Error (RMSE) of the geometric residuals (metres) in both across-track and along-track directions measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1Gt products

Parameter	Value	Note
GEOMETRIC_RMSE_MODEL_Y	0.000 – 9999.999	RMSE of the Y direction geometric residuals (in metres) measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1Gt products
GEOMETRIC_RMSE_MODEL_X	0.000 – 9999.999	RMSE of the X direction geometric residuals (in metres) measured on the GCPs used in geometric precision correction **Note:** this field is not present in L1Gt products
END_GROUP	**IMAGE_ATTRIBUTES**	
GROUP	**MIN_MAX_RADIANCE**	
RADIANCE_MAXIMUM_BAND_1	0.000 – 999.999	Maximum achievable spectral radiance value for Band 1 (w/(m^2 sr micron)).
RADIANCE_MINIMUM_BAND_1	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 1 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_2	0.000 – 999.999	Maximum achievable spectral radiance value for Band 2 (w/(m^2 sr micron)).
RADIANCE_MINIMUM_BAND_2	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 2 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_3	0.000 – 999.999	Maximum achievable spectral radiance value for Band 3 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_3	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 3 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_4	0.000 – 999.999	Maximum achievable spectral radiance value for Band 4 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_4	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 4 (w/(m^2 sr micron))

Parameter	Value	Note
RADIANCE_MAXIMUM_BAND_5	0.000 – 999.999	Maximum achievable spectral radiance value for Band 5 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_5	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 5 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_6_VCID_1	0.000 – 999.999	Maximum achievable spectral radiance value for Band 6 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_6_VCID_1	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 6 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_6_VCID_2	0.000 – 999.999	Maximum achievable spectral radiance value for Band 6 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_6_VCID_2	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 6 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_7	0.000 – 999.999	Maximum achievable spectral radiance value for Band 7 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_7	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 7 (w/(m^2 sr micron))
RADIANCE_MAXIMUM_BAND_8	0.000 – 999.999	Maximum achievable spectral radiance value for Band 8 (w/ (m^2 sr micron)).
RADIANCE_MINIMUM_BAND_8	-999.999 to +999.999 inclusive	Minimum achievable spectral radiance value for Band 8 (w/(m^2 sr micron))
END_GROUP	**MIN_MAX_RADIANCE**	
GROUP	**MIN_MAX_PIXEL_VALUE**	
QUANTIZE_CAL_MAX_BAND_1	255	Maximum possible pixel value (DN) for Band 1
QUANTIZE_CAL_MIN_BAND_1	1	Minimum possible pixel value (DN) for Band 1

Parameter	Value	Note
QUANTIZE_CAL_MAX_BAND_2	255	Maximum possible pixel value (DN) for Band 2
QUANTIZE_CAL_MIN_BAND_2	1	Minimum possible pixel value (DN) for Band 2
QUANTIZE_CAL_MAX_BAND_3	255	Maximum possible pixel value (DN) for Band 3
QUANTIZE_CAL_MIN_BAND_3	1	Minimum possible pixel value (DN) for Band 3
QUANTIZE_CAL_MAX_BAND_4	255	Maximum possible pixel value (DN) for Band 4
QUANTIZE_CAL_MIN_BAND_4	1	Minimum possible pixel value (DN) for Band 4
QUANTIZE_CAL_MAX_BAND_5	255	Maximum possible pixel value (DN) for Band 5
QUANTIZE_CAL_MIN_BAND_5	1	Minimum possible pixel value (DN) for Band 5
QUANTIZE_CAL_MAX_BAND_6_VCID_1	255	Maximum possible pixel value (DN) for Band 6_VCID_1
QUANTIZE_CAL_MIN_BAND_6_VCID_1	1	Minimum possible pixel value (DN) for Band 6_VCID_1
QUANTIZE_CAL_MAX_BAND_6_VCID_2	255	Maximum possible pixel value (DN) for Band 6_VCID_2
QUANTIZE_CAL_MIN_BAND_6_VCID_2	1	Minimum possible pixel value (DN) for Band 6_VCID_2
QUANTIZE_CAL_MAX_BAND_7	255	Maximum possible pixel value (DN) for Band 7
QUANTIZE_CAL_MIN_BAND_7	1	Minimum possible pixel value (DN) for Band 7
QUANTIZE_CAL_MAX_BAND_8	255	Maximum possible pixel value (DN) for Band 8
QUANTIZE_CAL_MIN_BAND_8	1	Minimum possible pixel value (DN) for Band 8
END_GROUP	**MIN_MAX_PIXEL_VALUE**	
GROUP	**PRODUCT_PARAMETERS**	
CORRECTION_GAIN_BAND_1	CPF	Gain correction method for Band 1

Parameter	Value	Note
CORRECTION_GAIN_BAND_2	(for CPF gains) INTERNAL_CALIBRATION (for IC gains)	Gain correction method for Band 2
CORRECTION_GAIN_BAND_3		Gain correction method for Band 3
CORRECTION_GAIN_BAND_4		Gain correction method for Band 4
CORRECTION_GAIN_BAND_5		Gain correction method for Band 5
CORRECTION_GAIN_BAND_6_VCID_1		Gain correction method for Band 6_VCID_1
CORRECTION_GAIN_BAND_6_VCID_2		Gain correction method for Band 6_VCID_2
CORRECTION_GAIN_BAND_7		Gain correction method for Band 7
CORRECTION_GAIN_BAND_8		Gain correction method for Band 8
CORRECTION_BIAS_BAND_1		Bias correction method for Band 1
CORRECTION_BIAS_BAND_2		Bias correction method for Band 2
CORRECTION_BIAS_BAND_3		Bias correction method for Band 3
CORRECTION_BIAS_BAND_4		Bias correction method for Band 4
CORRECTION_BIAS_BAND_5		Bias correction method for Band 5
CORRECTION_BIAS_BAND_6_VCID_1		Bias correction method for Band 6_VCID_1
CORRECTION_BIAS_BAND_6_VCID_2		Bias correction method for Band 6_VCID_2
CORRECTION_BIAS_BAND_7		Bias correction method for Band 7
CORRECTION_BIAS_BAND_8		Bias correction method for Band 8 **Note:** this field is only present in ETM products
GAIN_BAND_1	L (for low gain) H (for high gain)	Gain state for Band 1
GAIN_BAND_2		Gain state for Band 2
GAIN_BAND_3		Gain state for Band 3
GAIN_BAND_4		Gain state for Band 4

Parameter	Value	Note
GAIN_BAND_5		Gain state for Band 5
GAIN_BAND_6_VCID_1		Gain state for Band 6_VCID_1
GAIN_BAND_6_VCID_2		Gain state for Band 6_VCID_2
GAIN_BAND_7		Gain state for Band 7
GAIN_BAND_8		Gain state for Band 8
GAIN_CHANGE_BAND_1	LL (for no gain change) HH (for no gain change) LH (for low to high) HL (for high to low) U (for unknown)	Presence and direction of gain change for Band 1
GAIN_CHANGE_BAND_2		Presence and direction of gain change for Band 2
GAIN_CHANGE_BAND_3		Presence and direction of gain change for Band 3
GAIN_CHANGE_BAND_4		Presence and direction of gain change for Band 4
GAIN_CHANGE_BAND_5		Presence and direction of gain change for Band 5
GAIN_CHANGE_BAND_6_VCID_1		Presence and direction of gain change for Band 6_VCID_1
GAIN_CHANGE_BAND_6_VCID_2		Presence and direction of gain change for Band 6_VCID_2
GAIN_CHANGE_BAND_7		Presence and direction of gain change for Band 7
GAIN_CHANGE_BAND_8		Presence and direction of gain change for Band 8
GAIN_CHANGE_SCAN_BAND_1	0 (for no gain change)	Scan line number where the first change in Band 1 gain was detected

Parameter	Value	Note
GAIN_CHANGE_SCAN_BAND_2	or 1-13,875 (for the scan line number)	Scan line number where the first change in Band 2 gain was detected
GAIN_CHANGE_SCAN_BAND_3		Scan line number where the first change in Band 3 gain was detected
GAIN_CHANGE_SCAN_BAND_4		Scan line number where the first change in Band 4 gain was detected
GAIN_CHANGE_SCAN_BAND_5		Scan line number where the first change in Band 5 gain was detected
GAIN_CHANGE_SCAN_BAND_6_VCID_1		Scan line number where the first change in Band 6_VCID_1 gain was detected
GAIN_CHANGE_SCAN_BAND_6_VCID_2		Scan line number where the first change in Band 6_VCID_2 gain was detected
GAIN_CHANGE_SCAN_BAND_7		Scan line number where the first change in Band 7 gain was detected
GAIN_CHANGE_SCAN_BAND_8		Scan line number where the first change in Band 8 gain was detected
END_GROUP	**PRODUCT_PARAMETERS**	
GROUP	**RADIOMETRIC_RESCALING**	
RADIANCE_MULT_BAND_1	-9999999999999999999.999 to +9999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 1 DN to reflectance
RADIANCE_MULT_BAND_2	-9999999999999999999.999 to +9999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 2 DN to reflectance

Parameter	Value	Note
RADIANCE_MULT_BAND_3	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 3 DN to reflectance
RADIANCE_MULT_BAND_4	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 4 DN to reflectance
RADIANCE_MULT_BAND_5	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 5 DN to reflectance
RADIANCE_MULT_BAND_6_VCID_1	-99999999999999999999.999 to +99999999999999999999.999 Inclusive	Multiplicative rescaling factor used to convert calibrated Band 6_VCID_1 DN to reflectance
RADIANCE_MULT_BAND_6_VCID_2	-99999999999999999999.999 to +99999999999999999999.999 Inclusive	Multiplicative rescaling factor used to convert calibrated Band 6_VCID_2 DN to reflectance

Parameter	Value	Note
RADIANCE_MULT_BAND_7	-99999999999999999999.999 to +99999999999999999999.999 inclusive	Multiplicative rescaling factor used to convert calibrated Band 7 DN to reflectance
RADIANCE_MULT_BAND_8	-99999999999999999999.999 to +99999999999999999999.999 Inclusive	Multiplicative rescaling factor used to convert calibrated Band 8 DN to reflectance
RADIANCE_ADD_BAND_1	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 1
RADIANCE_ADD_BAND_2	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 2
RADIANCE_ADD_BAND_3	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 3
RADIANCE_ADD_BAND_4	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 4
RADIANCE_ADD_BAND_5	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 5
RADIANCE_ADD_BAND_6_VCID_1	-9999.99999 to +9999.99999 Inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 6_VCID_1

Parameter	**Value**	**Note**
RADIANCE_ADD_BAND_6_VCID_2	-9999.99999 to +9999.99999 Inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 6_VCID_2
RADIANCE_ADD_BAND_7	-9999.99999 to +9999.99999 inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 7
RADIANCE_ADD_BAND_8	-9999.99999 to +9999.99999 Inclusive	Additive rescaling factor used to convert calibrated DN to radiance units (w/(m^2 sr um)) for Band 8
END_GROUP	**RADIOMETRIC_RESCALING**	
GROUP	**PROJECTION_PARAMETERS**	
MAP_PROJECTION	UTM	Map projection used in image creation
DATUM	WGS84	Datum used in image creation
ELLIPSOID	WGS84	Ellipsoid used in image creation
UTM_ZONE	1 - 60	UTM zone number in a map projection
GRID_CELL_SIZE_REFLECTIVE	30	Grid cell size used in creating the image for the reflective band
GRID_CELL_SIZE_THERMAL	30	Grid cell size used in creating the image for the reflective band
ORIENTATION	NORTH_UP	Orientation used in image creation
RESAMPLING_OPTION	Cubic Convolution	Resampling option in image creation
END_GROUP	**PROJECTION_PARAMETERS**	
END_GROUP	**L1_METADATA_FILE**	

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