

	LANDSAT 8 Level 1 Product Performance	
Réf: IDEAS-TN-10-CyclicReport	Cyclic Report Month/Year: November 2015	Date: 24/11/2015 Issue/Rev:1/7

1.Scope of this document

On May 30, 2013, data from the Landsat 8 satellite (launched as the Landsat Data Continuity Mission on February 11, 2013) became available. ESA distributes Landsat 8 products as a near real time service (<https://landsat8portal.eo.esa.int/portal/>).

The scope of this document is the Level 1 product accuracy performance of products processed by ESA. The radiometric calibration stability, the geolocation accuracy and the interband registration accuracy is monitored on a monthly basis. Comparison with results from the USGS cal/val is done.

Hence the document is organized as follow

\$1) Scope of this document	To introduce this document
\$2) Change record	To log version of cycle reporting and input TDS considered for the month
\$3)Executive Summary:	To provide a quick overview on the main findings of the month and to provide updated accuracy statistics.
\$4) QC Issue	This part is dedicated to the tracking of operational issue found during exercise
\$5) Radiometric accuracy stability monitoring	This part provides statistics and figures (trends) regarding the multi temporal stability of radiometric calibration of visible/NIR/SWIR data.
\$6) Geolocation accuracy stability monitoring	This part provides statistics and figures on multi temporal stability of geolocation accuracy. The panchromatic image is analyzed.
\$7) Interband registration	This part provides statistics and figures on geometric registration of OLI & TIRS images observed in a same date.
\$8)Test site description	This part provides very brief description of test sites that are considered for our analysis.

Note that:

An insight on methods is given in “IDEAS-TN-02-L8_DataValidation.docx”;

The test data set is detailed in “TDS_L8_cyclic.xlsx”, this file is regularly updated.

2.Change record

Iss.	Rev.	Date	Reason	Comments
1	0	08/04/2015	Document creation	
1	1	26/05/2015	May 2015 cyclic report	
1	2	06/07/2015	June 2015 cyclic report	
1	3	29/07/2015	July 2015 cyclic report	
1	4	28/08/2015	August 2015 cyclic report	
1	5	28/09/2015	September 2015 cyclic report	
1	6	26/10/2015	October 2015 cyclic report	
1	7	25/11/2015	November 2015 cyclic report	

3.Executive summary

Landsat 8 data validation purpose is to assess the continuity of data accuracy of Landsat Project.

Validation Item	Comment
Radiometric accuracy stability monitoring	Temporal stability is correct (TOA reflectance standard deviation under 0.6 for blue, green, red and NIR bands and under 1.5 for SWIR1 and SWIR2 bands).
Geolocation accuracy stability monitoring (Relative location)	Relative location results show a correct matching between Landsat 8 products (RMS values under 5m in both directions) No bias and no trend No site influence Temporal stability is correct (standard deviation errors under 5m in both direction)
Interband Registration	A strong influence of site is observed especially for TIRS band A seasonal effect is also observed for desert and Saragossa site Jumps over CCD are visible on correlation maps for B10/B11 twin and all visible twin bands.

4.QC Issues

L1T is not systematically processed

From ESA catalog¹, data is mostly available as Level L1T (precision and terrain corrected) products. It is important to note that sometimes instead of L1T, L1Gt might be proposed. Based on the input IDEAS dataset, used for our performance monitoring, the repartition of L1Gt and L1T products is as follow:

- ✓ “Libya4” site : 15 L1GT products / 25 L1T products;
- ✓ “La Crau” site : 13 L1GT products / 32 L1T products;
- ✓ “Granada” site : 8 L1GT products / 30 L1T products;
- ✓ “Saragossa1” site : 9 L1GT products / 30 L1T products.

The cause of this discrepancy is not explained. It is observed that:

- Whatever s/w version (at ESA, « LPGS_2.3.0 / LPGS_2.4.0”), the situation is the same;
- A same reference processed at USGS will be L1T and not L1Gt;
- L1Gt image is mostly free from cloud contamination, presence of water ... Therefore it is not a limiting factor for L1T generation.

¹ <https://landsat8portal.eo.esa.int/portal/>

5. Radiometric accuracy stability monitoring

5.1. Objective

The objective is to assess radiometric stability of Landsat 8 data.

5.2. Methods

The method consists in monitoring the Top of Atmosphere (TOA) reflectance acquired on a bright site referred by "Libya4", known as spatially uniform (as seen with L8/OLI spatial resolution) and spectrally stable in time.

For input images, a region of interest corresponding to an area of one square degree is extracted and statistics computed. The Libyan site "Libya4" is located at latitude 28.55N, longitude 23.39E, at altitude 118m.

It is expected that the temporal evolution of TOA measurements over mission lifetime is stable.

5.3. Results and Discussions

The statistics listed in table below are computed based on dataset of 33 products (from 29/01/2014 to 16/11/2015). There are 9 products removed because of cloud contamination. The S/W version is not same in all cases, since archive is not reprocessed.

The temporal uncertainty remains mostly below 2% and within 1 % in case of visible/ NIR bands. Having images of two different processing levels (L1Gt and L1T), the ROIs are not exactly the same, the geometric registration of temporal images may be degraded in some cases. This issue influences negatively this assessment.

The USGS results are slightly better than IDEAS ones. Indeed, in the article², a temporal uncertainty below 0.5 % for visible/NIR bands is given. In addition, an accuracy difference between SWIR1 & SWIR2 is observed, respectively (0.4% / 1.77%), the situation is different on our side.

Band	Blue (band 2)	Green (band 3)	Red (band 4)	NIR (band 5)	SWIR1 (band 6)	SWIR2 (band 7)
TOA Mean	0.2412	0.32792	0.44403	0.56853	0.65397	0.59754
TOA Standard deviation	0.0023532	0.0024525	0.0045503	0.006085	0.012632	0.014774
Temporal Uncertainty (%)	1	0.7	1	1	1.9	2.5
Linear interpolation Estimated Slope	-5.0342e-6	-6.2257e-6	-8.2509e-6	-7.3544e-6	-1.2516e-6	-2.3078e-5

² Nischal Mishra and Al. "Radiometric Cross Calibration of Landsat 8 Operational Land Imager (OLI) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) ". Remote Sensing 2014, 6, 12619-12638.

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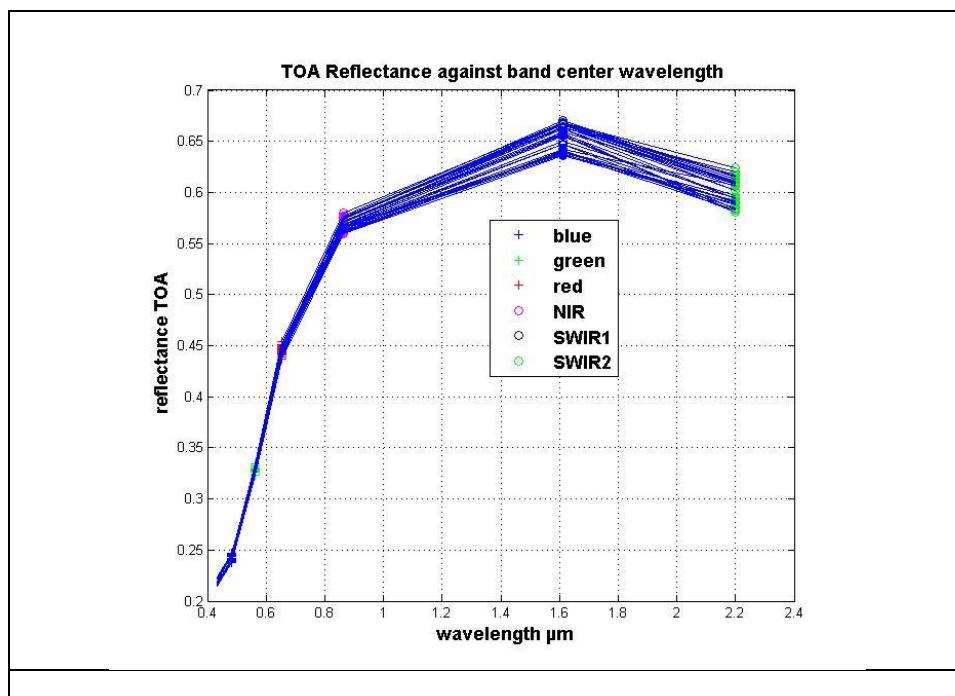
Date: 24/11/2015

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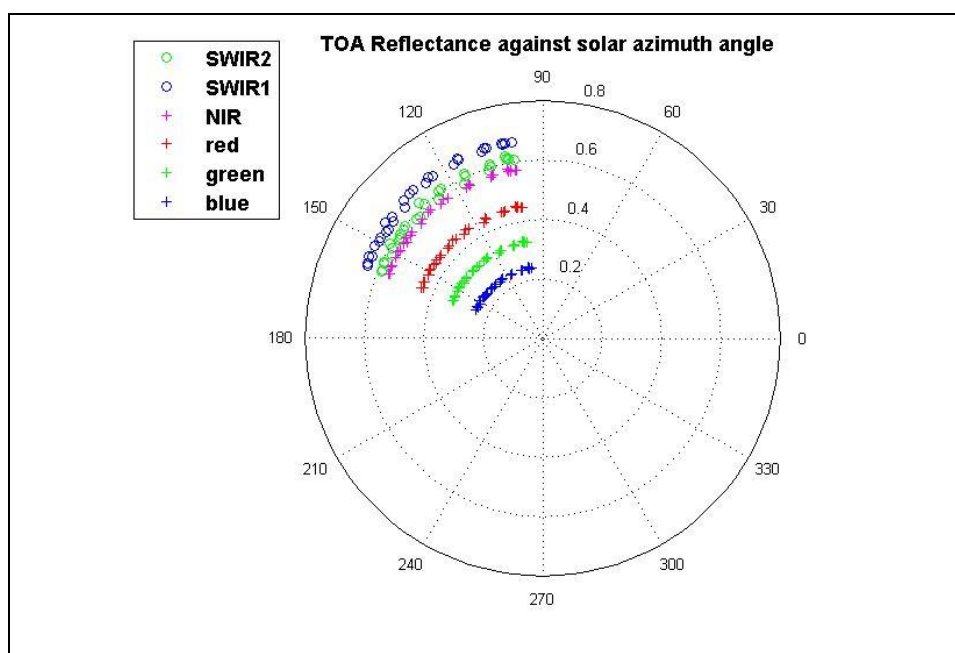
Linear interpolation Estimated Intercept	0.2447	0.33225	0.44976	0.57364	0.65484	0.61358
Norm of Residuals error	0.012139	0.012116	0.024132	0.033484	0.071443	0.079731

Table 1 - Landsat 8 / OLI - Statistics on Temporal stability of radiometric calibration.

As shown in the figure below, the dispersion of TOA measurements around each center wavelength value remains quite small, except for SWIR channels, influenced by water vapor content. The spectral behavior remains correct.



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*Figure 1-- Up) Reflectance profile as indicator of uncertainty
Bottom) Configuration of observations.*

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The six figures below show the temporal evolution of TOA reflectance measurements for B2, B3, B4, B5, B6 and B7. Sub Cycles in time series are due to BRDF and scatter. Uncertainty is due to the atmosphere (to be checked).

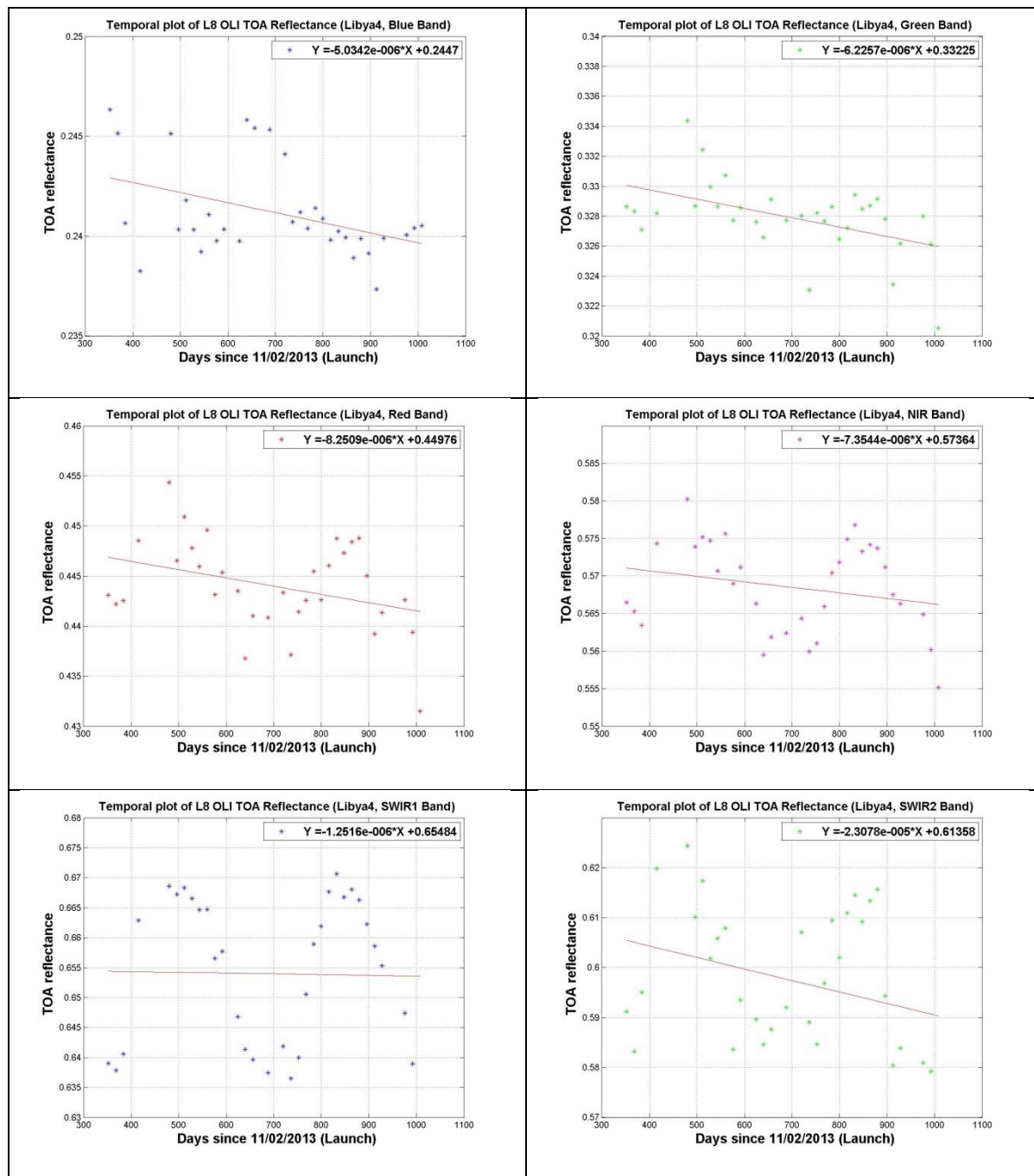


Figure 2-- Temporal Trends of L8 OLI TOA Reflectances.

6.Geolocation accuracy stability monitoring

6.1.Objective

The objective is to assess geometric stability of Landsat 8 data. According to USGS certification document³, the standard deviation of the difference in the line and sample components between L1T reference product band and each L1T corresponding product band should be less than 12m.

6.2.Methods

Basically, method is based on the following processing stages:

- ✓ Dense matching processing between reference product and each product;
- ✓ Correlation grid filtering;
- ✓ Accuracy analysis.

The panchromatic image (band 8), included in L1T product, image resampled to pixel size of 15 m, is validated against a geometric reference.

Three ROI distributed over three sites are used:

- ✓ La Crau (reference product : LC81960302013243NSG00)
- ✓ Granada (reference product : LC82000342014146MTI00)
- ✓ Saragossa (reference data : LC82000312014066MTI00)

6.3.Results and Discussions

The overall statistics over 45 L1T products (from 30/07/2013 to 18/09/2015) are the following ones, all data merged together, without taking into account the test site.

Parameter/Measure	Value	Comments
Mean Error Easting Direction	0.15m	No bias – No trend No site influence
Mean Error Northing Direction	0.31m	
Standard Deviation Error Easting Direction	3.83m	Correct temporal stability

³ “Landsat Data Continuity Mission (LDCM) International Ground Station (IGS) Data Validation and Exchange (DV&E) and

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Standard Deviation Error Northing Direction	3.84m	Correct correlation points repartition No site influence
Root Mean Square Easting Direction	3.83m	Correct RMS in both directions
Root Mean Square Nothing Direction	3.85m	
Root Mean square 2D	5.42m	
CE 90	1.79m	Correct CE 90

Table 2 – Landsat 8 / OLI panchromatic band – Statistics on temporal stability of geolocation accuracy.

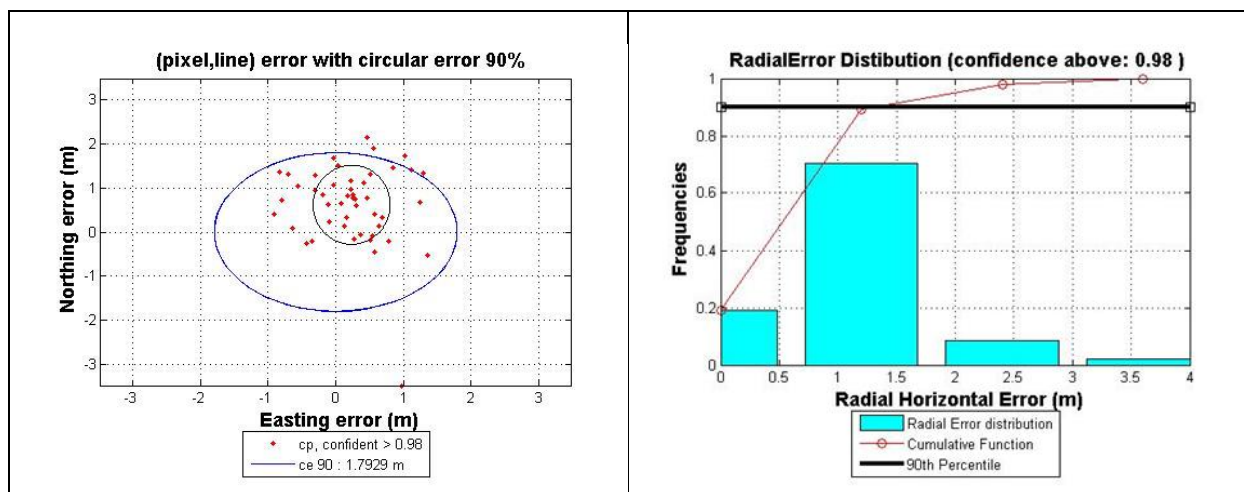
The four figures below show a very high matching between Landsat 8 products.

In the upper left figure, each point corresponds to one validated product. The black ellipse is 1D sigma error ellipse in normal distribution hypothesis. Global CE 90 is equal to 1.79m, which is very low compared to 15m resolution. No bias and no trend can be noticed. There is no site influence.

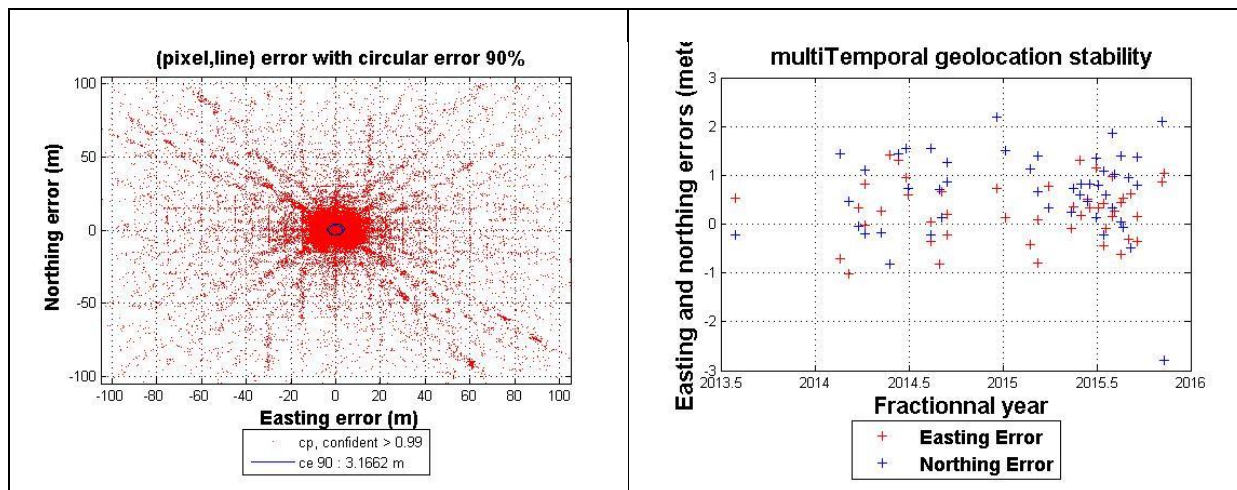
The radial error distribution shows that 90% of validated products have a radial error less than 2m. It confirms bias and trend absence.

In the lower left figure, each point corresponds to a correlation point. The black ellipse is still 1D sigma error ellipse in normal distribution hypothesis. Points outside the ellipse correspond to correlation noise. Global CE 90 is equal to 3.16m, which is very low.

The last figure shows a correct stability of geolocation accuracy. However, the stability figure shows that the mean northing error is stronger as usual for the two last products processed by 2.5.1 processor.



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**Figure 3 — Up Right) Product Circular Error @90
Up Left) Product Radial Error Distribution
Bottom Right) Point Circular Error @ 90
Bottom Left) Temporal Trends of easting and northing errors.**

The correlation method is applied only on cloud free products (less than 15% of cloud coverage).

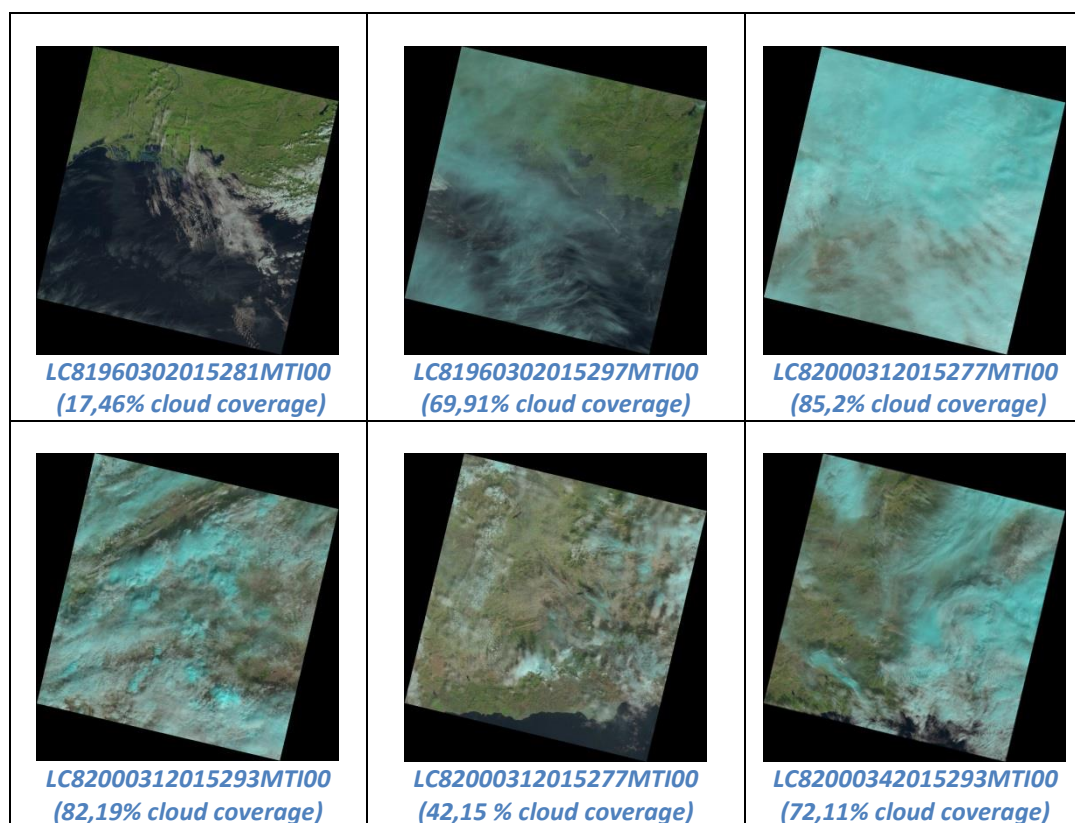


Figure 4—Examples of cloud contaminated images (quicklooks).

7. Interband registration accuracy

7.1. Objective

The objective is to validate band registration accuracy by performing a Band-to-Band (B2B) alignment analysis upon validated products. According to USGS certification document⁴, the RMSE-line and RMSE-sample error threshold for B2B, averaged for all within-band comparisons is:

- 0,15 pixels (4,5m) for OLI
- 0.18 pixels (18m) for TIRS
- 0.3 pixels (30m) for OLI/TIRS comparisons.

7.2. Methods

The interband registration is assessed by mean of correlation processing between two consecutive bands. A sub-sampling of 20% is done to compute correlation maps. Panchromatic band is resampled to 30m for comparing it to B2, B3 and B4 (near from spectral view).

7.3. Results and Discussions

The four figures below show a correct matching between Landsat 8 OLI bands. RMS values are upper than the threshold for B2B including TIRS bands.

Influence of site is strong for OLI/TIRS comparisons. Rms values are stronger on desert sites (Egypt1 and Libya4).

⁴ “Landsat Data Continuity Mission (LDCM) International Ground Station (IGS) Data Validation and Exchange (DV&E) and Certification Plan LS-IC-12 Version 2.0”.

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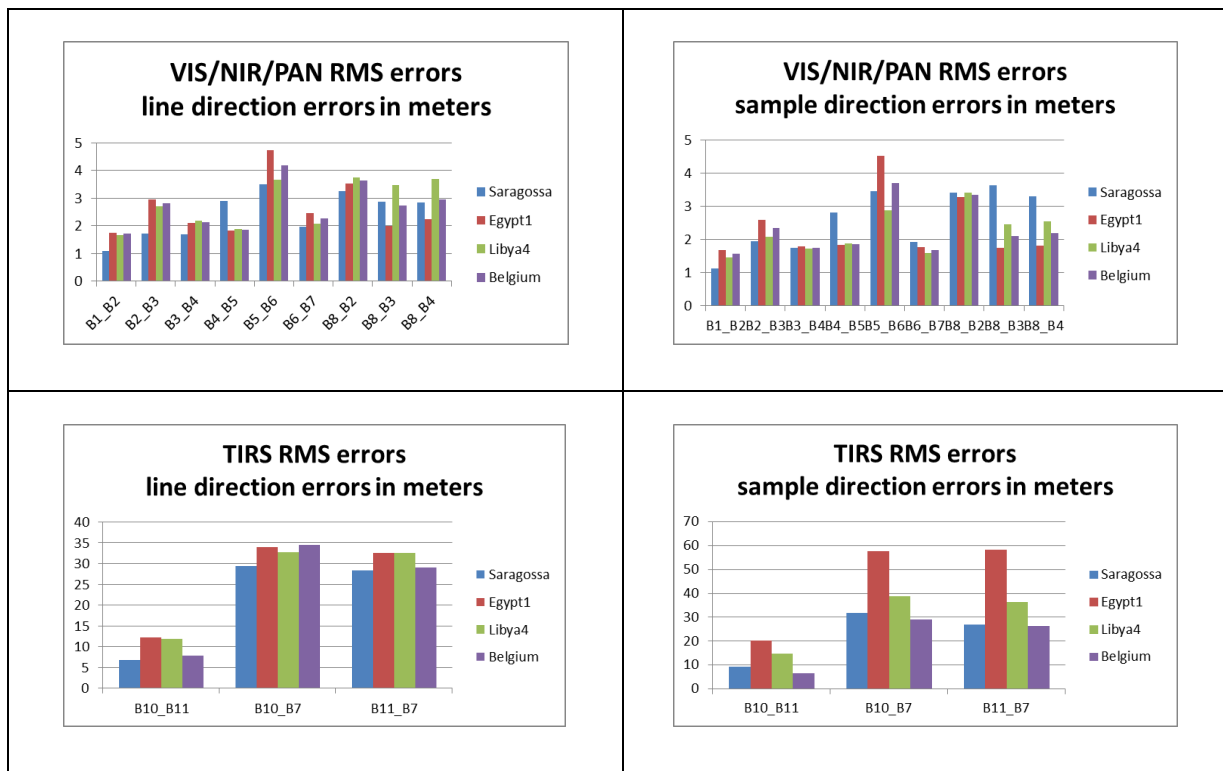


Figure 5 – Landsat 8 OLI/TIRS band to band registration RMS errors

Influence of test site on results can also be highlighted by comparing number of confident pixels per site for each consecutive band twin. The last figure shows the percentage of correlation points is poor for B4/B5 and B5/B6 twins only for Saragossa and Belgium sites. Desert sites (Egypt1 and Libya4) are not impacted. It proves a strong influence of site on correlation for these two band twins due to spectral content.

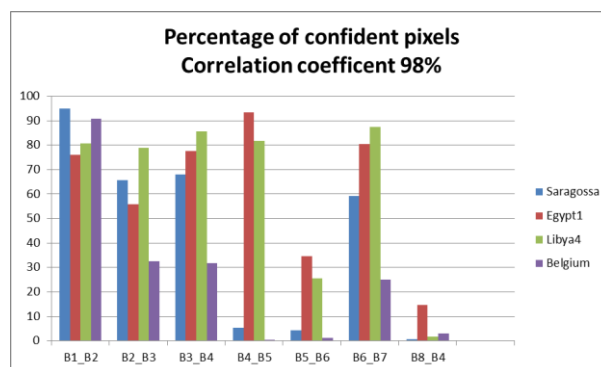
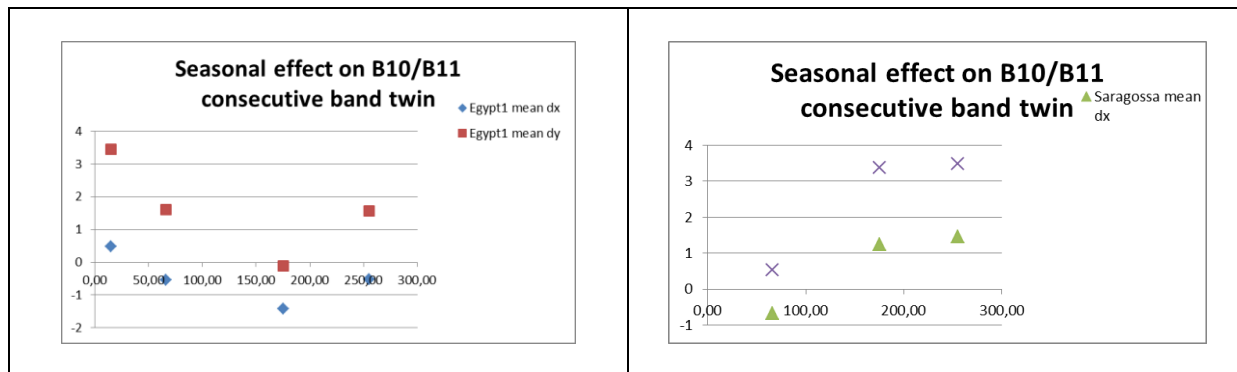


Figure 6 – Landsat 8 OLI band to band registration percentage of confident pixels

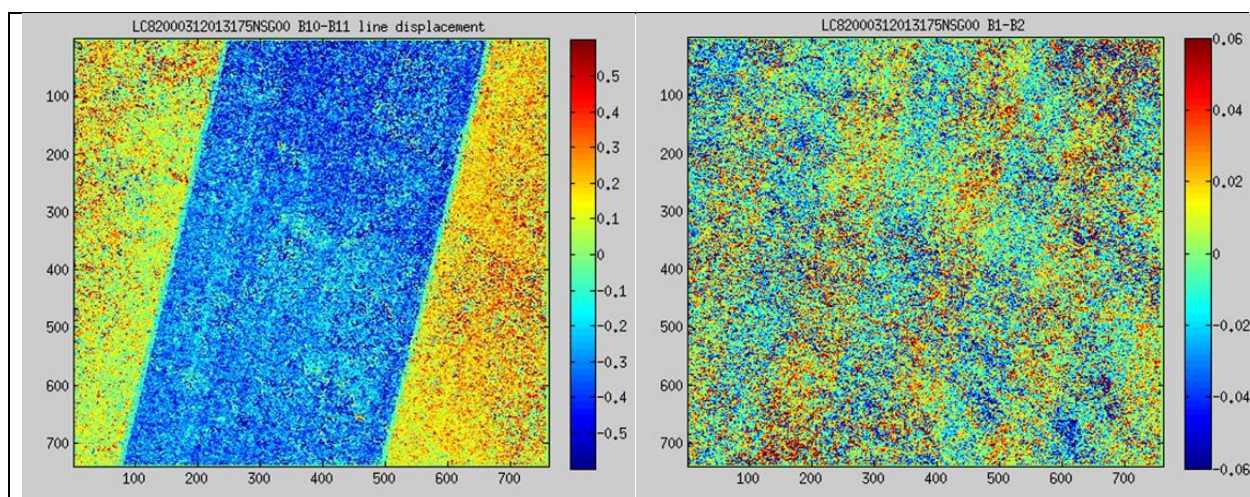
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The figures below show a seasonal effect on mean displacements on both directions on “Egypt1” and “Saragossa1” sites.



**Figure 7 – Left) Temporal Trend of mean line and sample errors “Egypt1” site
Right) Temporal Trend of mean line and sample errors “Saragossa1” site**

Jumps over CCD are visible on correlation maps for B10/B11 twin and all visible twin bands.



**Figure 8 – Left) correlation map for B10/B11 LC82000312013175NSG00 –
Right) correlation map for B1/B2 LC82000312013175NSG00**

8. Test site description

A short description of test site used in the context of this work is given herein.

Site Name ROI geo center	Validation item	Landsat WRS 2 Path/row
“Libya4” 23°23'E/28°33'N	Radiometric accuracy stability monitoring Interband registration accuracy monitoring	181/040
“La Crau” 4°51'E/43°12'N	Geolocation accuracy stability monitoring	196/030
“Granada” 3°7'W/37°28'N	Geolocation accuracy stability monitoring	200/034
“Saragossa” 1°49'W/41°45'N	Geolocation accuracy stability monitoring Interband registration accuracy monitoring	200/031
“Egypt1” 26°35'E/27°47'N	Interband registration accuracy monitoring	179/041
“Belgium” 4°20'E/50°30'N	Interband registration accuracy monitoring	198/025

Table 3 – Validation sites

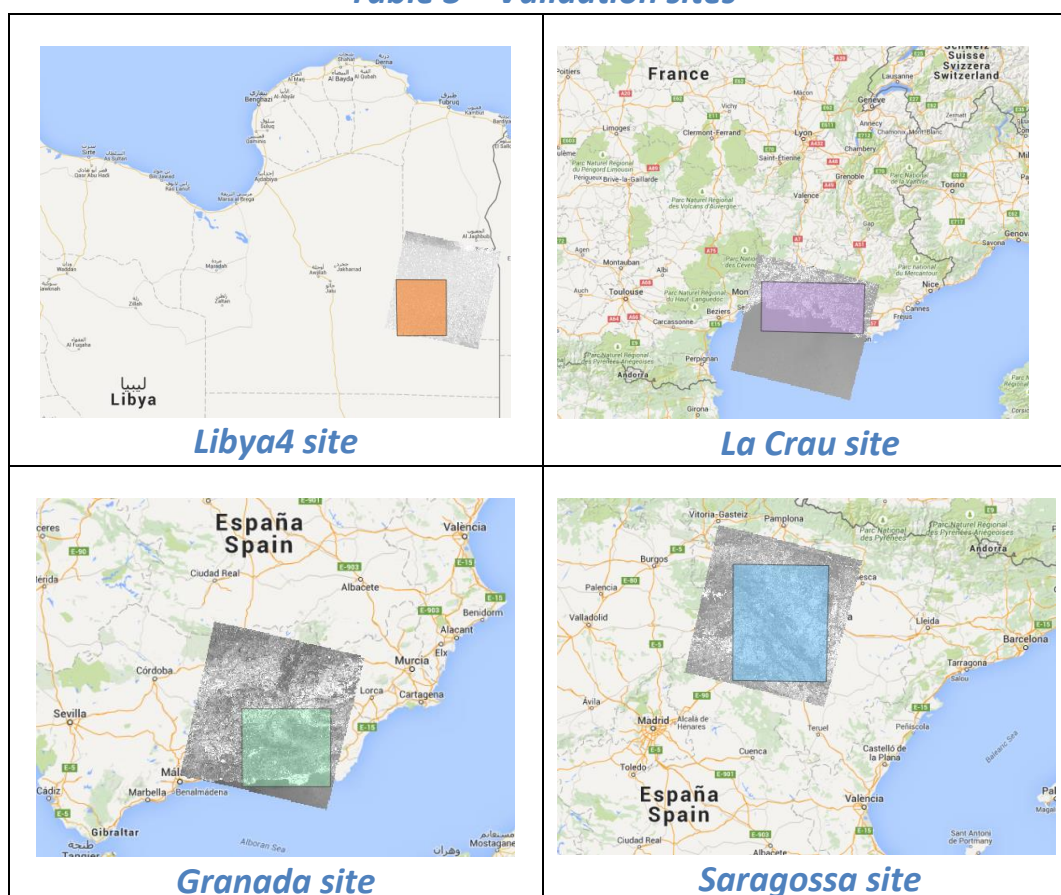


Figure 9 – ROI used for radiometric accuracy stability monitoring and geolocation accuracy stability monitoring

9. Validation data

9.1. Radiometric accuracy stability monitoring (33 products)

Product ID	Site	Observation date	Processor
LC81810402014029MTI00	Libya4	29/01/2014	LPGS_2.2.1
LC81810402014045MTI00	Libya4	14/02/2014	LPGS_2.2.1
LC81810402014061MTI00	Libya4	02/03/2014	LPGS_2.2.1
LC81810402014093MTI00	Libya4	03/04/2014	LPGS_2.2.1
LC81810402014157MTI00	Libya4	06/06/2014	LPGS_2.2.1
LC81810402014173MTI00	Libya4	22/06/2014	LPGS_2.2.1
LC81810402014189MTI00	Libya4	08/07/2014	LPGS_2.3.0
LC81810402014205MTI00	Libya4	24/07/2014	LPGS_2.3.0
LC81810402014221MTI00	Libya4	09/08/2014	LPGS_2.3.0
LC81810402014237MTI00	Libya4	25/08/2014	LPGS_2.3.0
LC81810402014253MTI00	Libya4	10/09/2014	LPGS_2.3.0
LC81810402014269MTI00	Libya4	26/09/2014	LPGS_2.3.0
LC81810402014301MTI00	Libya4	28/10/2014	LPGS_2.3.0
LC81810402014317MTI00	Libya4	13/11/2014	LPGS_2.3.0
LC81810402014333MTI00	Libya4	29/11/2014	LPGS_2.3.0
LC81810402014365MTI00	Libya4	31/12/2014	LPGS_2.3.0
LC81810402015032MTI00	Libya4	01/02/2015	LPGS_2.3.0
LC81810402015048MTI00	Libya4	17/02/2015	LPGS_2.3.0
LC81810402015064MTI00	Libya4	05/03/2015	LPGS_2.4.0
LC81810402015080MTI00	Libya4	21/03/2015	LPGS_2.4.0
LC81810402015096MTI00	Libya4	06/04/2015	LPGS_2.4.0
LC81810402015112MTI00	Libya4	22/04/2015	LPGS_2.4.0
LC81810402015128MTI00	Libya4	08/05/2015	LPGS_2.4.0
LC81810402015144MTI00	Libya4	24/05/2015	LPGS_2.4.0
LC81810402015160MTI00	Libya4	09/06/2015	LPGS_2.4.0
LC81810402015176MTI00	Libya4	25/06/2015	LPGS_2.4.0
LC81810402015192MTI00	Libya4	11/07/2015	LPGS_2.4.0
LC81810402015208MTI00	Libya4	27/07/2015	LPGS_2.4.0
LC81810402015224MTI00	Libya4	12/08/2015	LPGS_2.4.0
LC81810402015240MTI00	Libya4	28/08/2015	LPGS_2.4.0
LC81810402015288MTI00	Libya4	15/10/2015	LPGS_2.4.0
LC81810402015304MTI00	Libya4	31/10/2015	LPGS_2.5.1
LC81810402015320MTI00	Libya4	16/11/2015	LPGS_2.5.1

9.2. Geolocation accuracy stability monitoring (45 products)

Product ID	Site	Observation date	Processor
LC81960302013211NSG00	La Crau	30/07/2013	LPGS_2.2.1
LC81960302014086MTI00	La Crau	27/03/2014	LPGS_2.2.1
LC81960302014182MTI00	La Crau	01/07/2014	LPGS_2.3.0
LO81960302014246MTI00	La Crau	03/09/2014	LPGS_2.3.0

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LC81960302015089MTI00	La Crau	30/03/2015	LPGS_2.4.0
LC81960302015137MTI00	La Crau	17/05/2015	LPGS_2.4.0
LC81960302015153MTI00	La Crau	02/06/2015	LPGS_2.4.0
LC81960302015169MTI00	La Crau	18/06/2015	LPGS_2.4.0
LC81960302015185MTI00	La Crau	04/07/2015	LPGS_2.4.0
LC81960302015201MTI00	La Crau	20/07/2015	LPGS_2.4.0
LC81960302015217MTI00	La Crau	05/08/2015	LPGS_2.4.0
LC81960302015233MTI00	La Crau	21/08/2015	LPGS_2.4.0
LC81960302015249MTI00	La Crau	06/09/2015	LPGS_2.4.0
LC81960302015313MTI00	La Crau	09/11/2015	LPGS_2.5.1
LC82000312014098MTI00	Saragossa1	08/04/2014	LPGS_2.2.1
LC82000312014146MTI00	Saragossa1	26/05/2014	LPGS_2.2.1
LC82000312014162MTI00	Saragossa1	11/06/2014	LPGS_2.4.0
LC82000312014178MTI00	Saragossa1	27/06/2014	LPGS_2.4.0
LC82000312014226MTI00	Saragossa1	14/08/2014	LPGS_2.3.0
LC82000312014258MTI00	Saragossa1	15/09/2014	LPGS_2.3.0
LC82000312015069MTI00	Saragossa1	10/03/2015	LPGS_2.4.0
LC82000312015149MTI00	Saragossa1	29/05/2015	LPGS_2.4.0
LC82000312015165MTI00	Saragossa1	14/06/2015	LPGS_2.4.0
LC82000312015181MTI00	Saragossa1	30/06/2015	LPGS_2.4.0
LC82000312015197MTI00	Saragossa1	16/07/2015	LPGS_2.4.0
LC82000312015213MTI00	Saragossa1	01/08/2015	LPGS_2.4.0
LC82000312015229MTI00	Saragossa1	17/08/2015	LPGS_2.4.0
LC82000312015261MTI00	Saragossa1	18/09/2015	LPGS_2.4.0
LC82000342014050MTI00	Granada	19/02/2014	LPGS_2.4.0
LC82000342014066MTI00	Granada	07/03/2014	LPGS_2.4.0
LC82000342014098MTI00	Granada	08/04/2014	LPGS_2.4.0
LC82000342014130MTI00	Granada	10/05/2014	LPGS_2.4.0
LC82000342014226MTI00	Granada	15/08/2014	LPGS_2.4.0
LC82000342014242MTI00	Granada	30/08/2014	LPGS_2.4.0
LC82000342014258MTI00	Granada	15/09/2014	LPGS_2.4.0
LC82000342014354MTI00	Granada	20/12/2014	LPGS_2.4.0
LC82000342015005MTI00	Granada	05/01/2015	LPGS_2.4.0
LC82000342015053MTI00	Granada	22/02/2015	LPGS_2.4.0
LC82000342015069MTI00	Granada	10/03/2015	LPGS_2.4.0
LC82000342015133MTI00	Granada	13/05/2015	LPGS_2.4.0
LC82000342015181MTI00	Granada	30/06/2015	LPGS_2.4.0
LC82000342015197MTI00	Granada	16/07/2015	LPGS_2.4.0
LC82000342015213MTI00	Granada	01/08/2015	LPGS_2.4.0
LC82000342015229MTI00	Granada	17/08/2015	LPGS_2.4.0
LC82000342015245MTI00	Granada	02/09/2015	LPGS_2.4.0
LC82000342015261MTI00	Granada	18/09/2015	LPGS_2.4.0
LC82000342015309MTI00	Granada	05/11/2015	LPGS_2.5.1

9.3. Interband registration accuracy (17 products)

Product ID	Site	Observation date	Processor
LC82000312013175NSG00	Saragossa1	24/06/2013	LPGS_2.2.1
LC82000312013207NSG00	Saragossa1	26/07/2013	LPGS_2.2.1
LC82000312013255NSG00	Saragossa1	12/09/2013	LPGS_2.2.1

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LC82000312014066MTI00	Saragossa1	07/03/2014	LPGS_2.2.1
LC81790412014015MTI00	Egypt1	15/01/2014	LPGS_2.2.1
LC81790412014047MTI00	Egypt1	16/02/2014	LPGS_2.2.1
LC81790412014079MTI00	Egypt1	20/03/2014	LPGS_2.2.1
LC81790412014095MTI00	Egypt1	05/04/2014	LPGS_2.2.1
LC81790412014111MTI00	Egypt1	21/04/2014	LPGS_2.2.1
LC81790412014063MTI00	Egypt1	04/03/2014	LPGS_2.2.1
LC81980252013273LGN00	Belgium	30/09/2013	LPGS_2.2.1
LC81980252014020MTI00	Belgium	09/03/2014	LPGS_2.2.1
LC81810402013154LGN00	Libya4	03/06/2013	LPGS_2.2.1
LC81810402013186LGN00	Libya4	05/07/2013	LPGS_2.2.1
LC81810402013250LGN00	Libya4	07/09/2013	LPGS_2.2.1
LC81810402014045MTI00	Libya4	14/02/2014	LPGS_2.2.1
LC81810402014061MTI00	Libya4	02/03/2014	LPGS_2.2.1