# 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 | |

# 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)<br>No bias and no trend<br>No site influence<br>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<br>A seasonal effect is also observed for desert and Saragossa site<br>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 catalog[1], 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 / 23 L1T products;
- ✓ "La Crau" site : 13 L1GT products / 31 L1T products;
- ✓ "Granada" site : 8 L1GT products / 27 L1T products;
- ✓ "Saragossa1" site : 9 L1GT products / 28 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 29/09/2015). There are 5 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 article[2], a temporal uncertainty below 0.5 % for visible/NIR bands is given. In addition, a accuracy difference between SWIR1 & SWIR2 is observed, respectively (0.4% / 1.77%), the situation is different on our side.

It might be explained the ESA TDS & USGS TDS are different; the number of products and periods are different, The ESA TDS is bigger compared to USGS ones (29 / 17). The site remains the same.

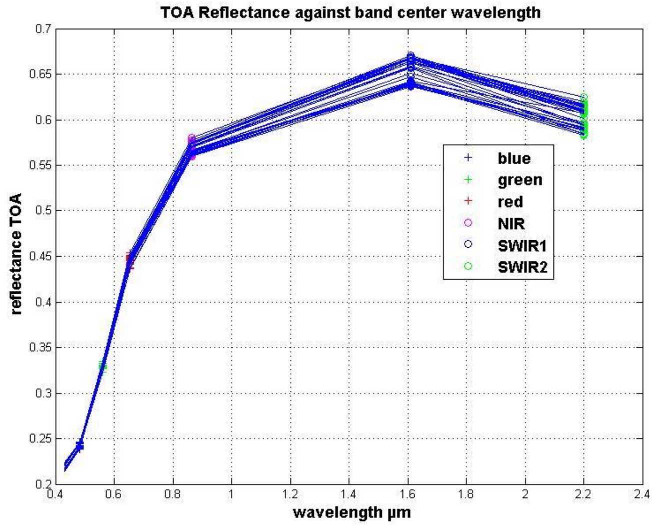
| Band | Blue (band 2) | Green (band 3) | Red (band 4) | NIR (band 5) | SWIR1 (band 6) | SWIR2 (band 7) |
|---|---|---|---|---|---|---|
| TOA Mean | 0.24142 | 0.32833 | 0.44449 | 0.56917 | 0.65479 | 0.59808 |
| TOA Standard deviation | 0.002609 | 0.0021722 | 0.0039595 | 0.0053824 | 0.011805 | 0.015419 |

[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.

| | | | | | | |
|---|---|---|---|---|---|---|
| Temporal Uncertainty (%) | 1 | 0.7 | 0.9 | 0.9 | 1.8 | 2.5 |
| Linear interpolation Estimated Slope | -3.0857e-6 | -3.2924e-6 | -4.711e-6 | -1.9133e-6 | 5.0684e-6 | -2.4964e-6 |
| Linear interpolation Estimated Intercept | 0.2435 | 0.33055 | 0.44767 | 0.57046 | 0.65137 | 0.61491 |
| Norm of Residuals error | 0.014401 | 0.011795 | 0.021849 | 0.030381 | 0.066569 | 0.08322 |

*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.



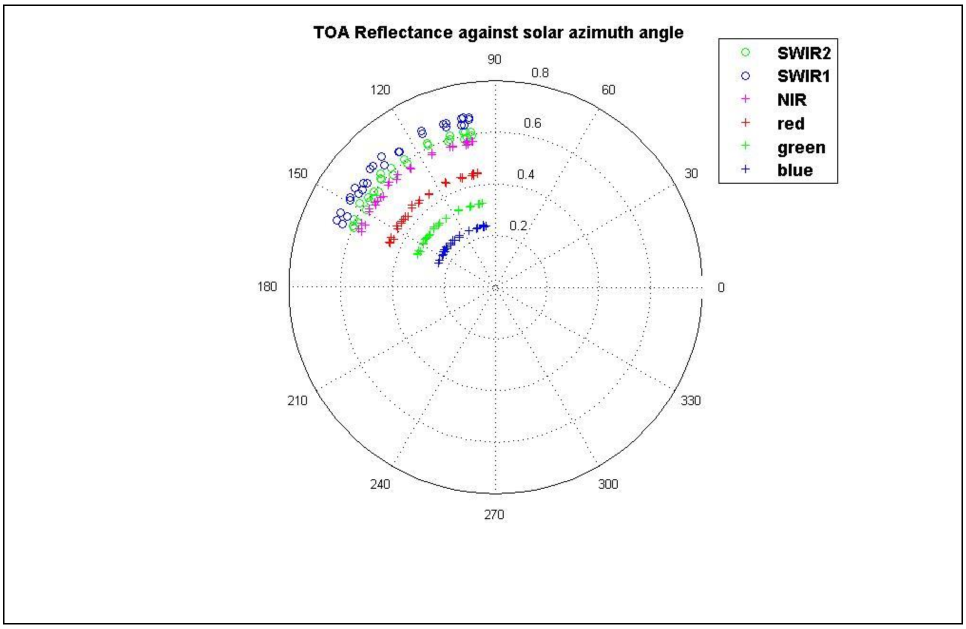



*Figure 1 -- Up) Reflectance profile as indicator of uncertainty. Bottom) Configuration of observations.*

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).

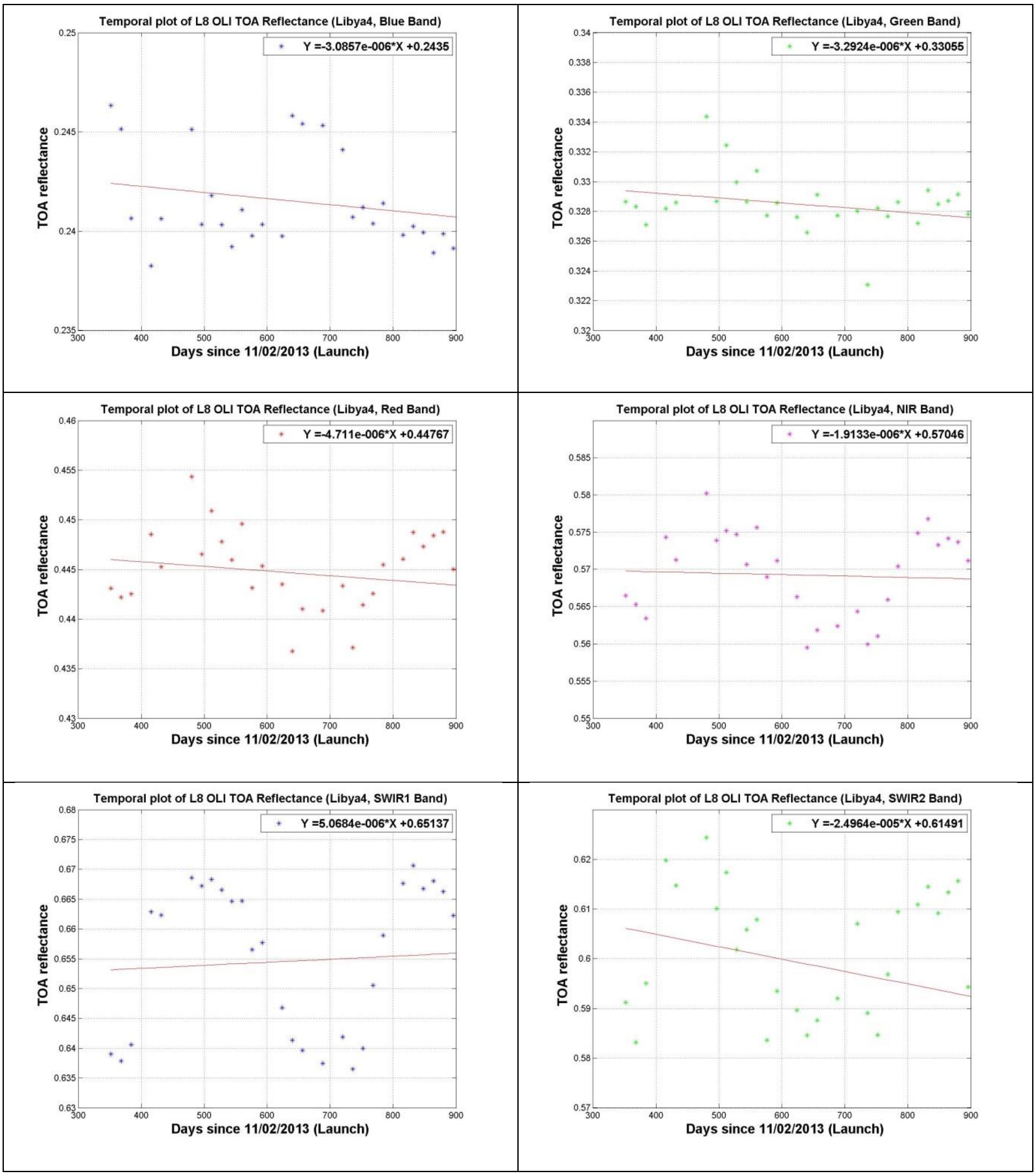



*Figure 2-- Temporal Trends of L8 OLI TOA Reflectances.*

# 6. Geolocation accuracy stability monitoring

## 6.1. Objective

The objective is to assess geometric stability of Landsat 8 data. According to USGS certification document[3], 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<br>No site influence |
| Mean Error Northing Direction | 0.31m | |
| Standard Deviation Error Easting Direction | 3.74m | Correct temporal stability<br>Correct correlation points repartition<br>No site influence |
| Standard Deviation | 3.74m | |

[3] "Landsat Data Continuity Mission (LDCM) International Ground Station (IGS) Data Validation and Exchange (DV&E) and Certification Plan LS-IC-12 Version 2.0".

| | | |
|---|---|---|
| Error Northing Direction | | |
| Root Mean Square Easting Direction | 3.74m | Correct RMS in both directions |
| Root Mean Square Nothing Direction | 3.75m | |
| Root Mean square 2D | 5.29m | |
| CE 90 | 1.67m | Correct CE 90 |

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

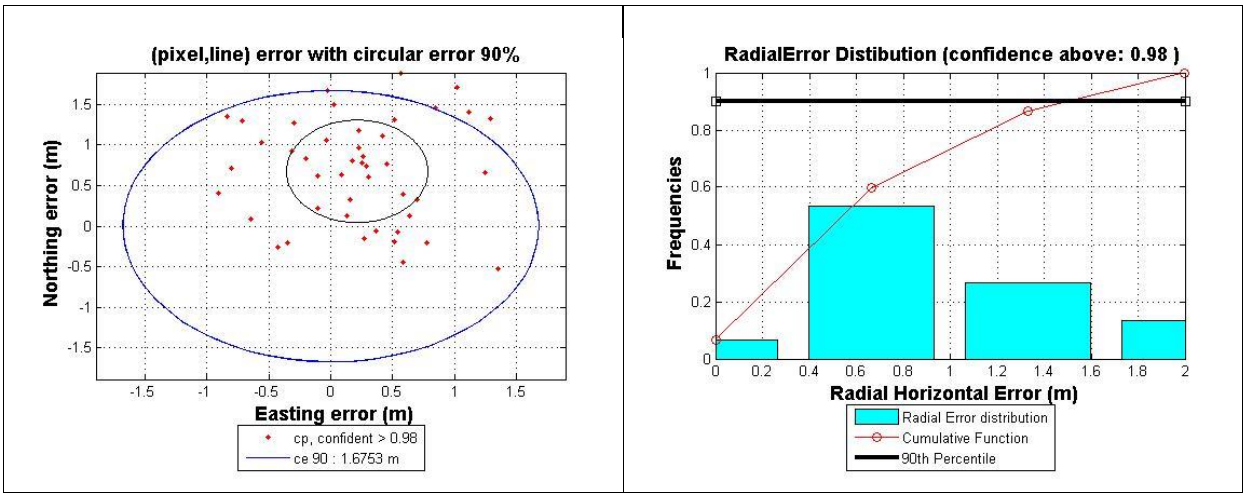
The four figures below show a very high matching between Landsat 8 products.

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 1.67m, 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 55% of validated products have a radial error less than 1m. 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 3.15m, which is very low.

The last figure shows a correct stability of geolocation accuracy.



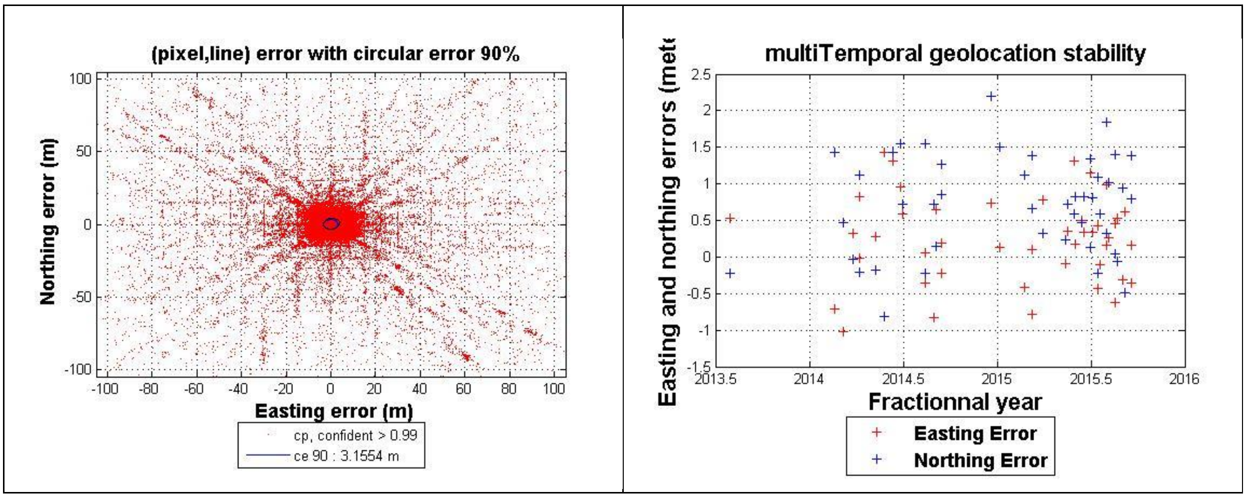



*Figure 3 — Up Right) Product Circular Error @90 - Up Left) Product Radial Error Distribution – Bottom Right) Point Circular Error @ 90 – Bottom Left) Temporal Trends of easting and northing errors.*

# 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 document[4], 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 (5,4m) for TIRS
- 0.3 pixels (9m) 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".

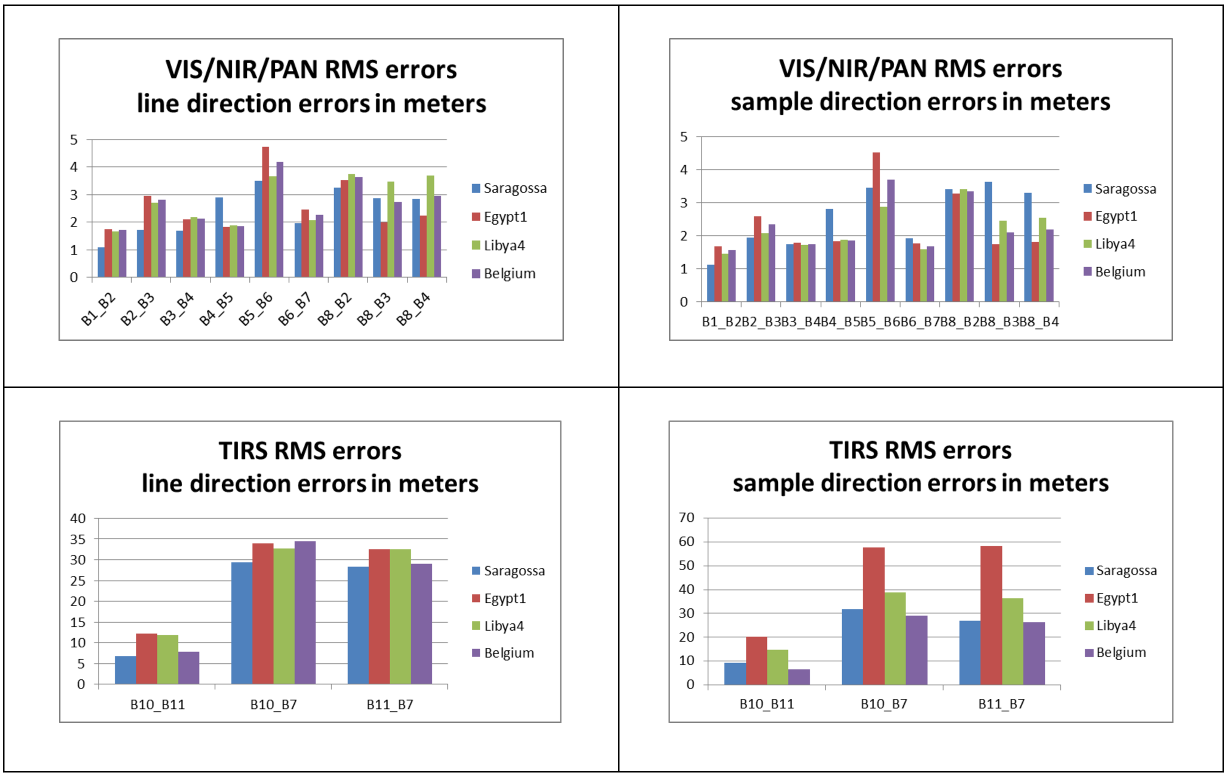



*Figure 4 – Landsat 8 OLI/TIRS band to band registration RMS errors*

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.

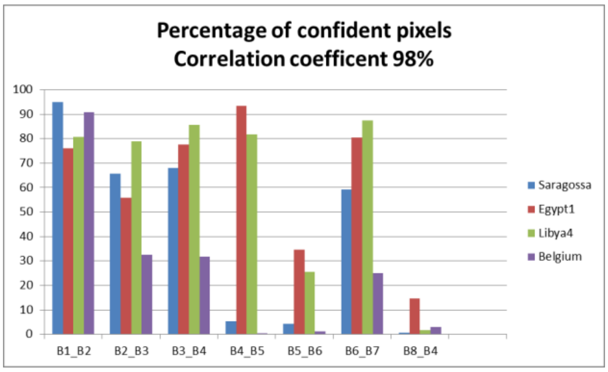



*Figure 5 – Landsat 8 OLI band to band registration percentage of confident pixels*

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

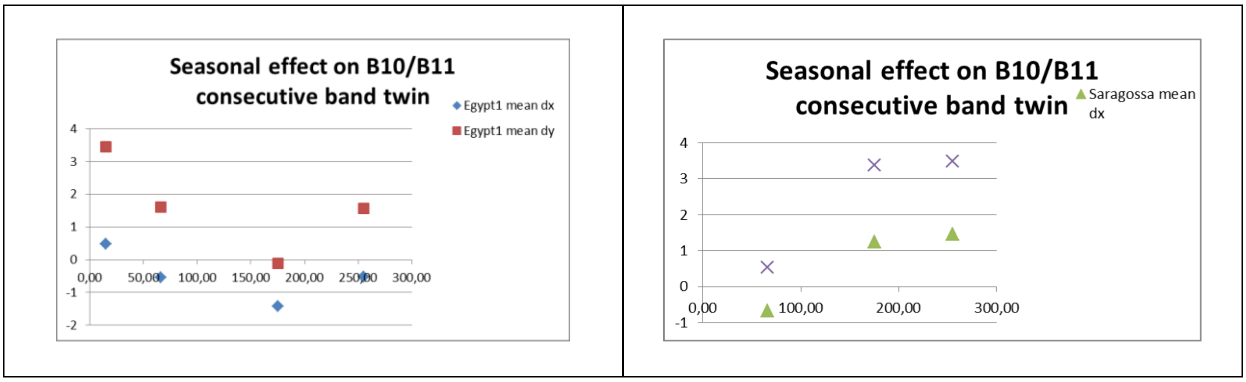



*Figure 6 – Left) Temporal Trend of mean line and sample errors "Egypt1" site Right) Temporal Trend of mean line and sample errors "Saragossa1" site*

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

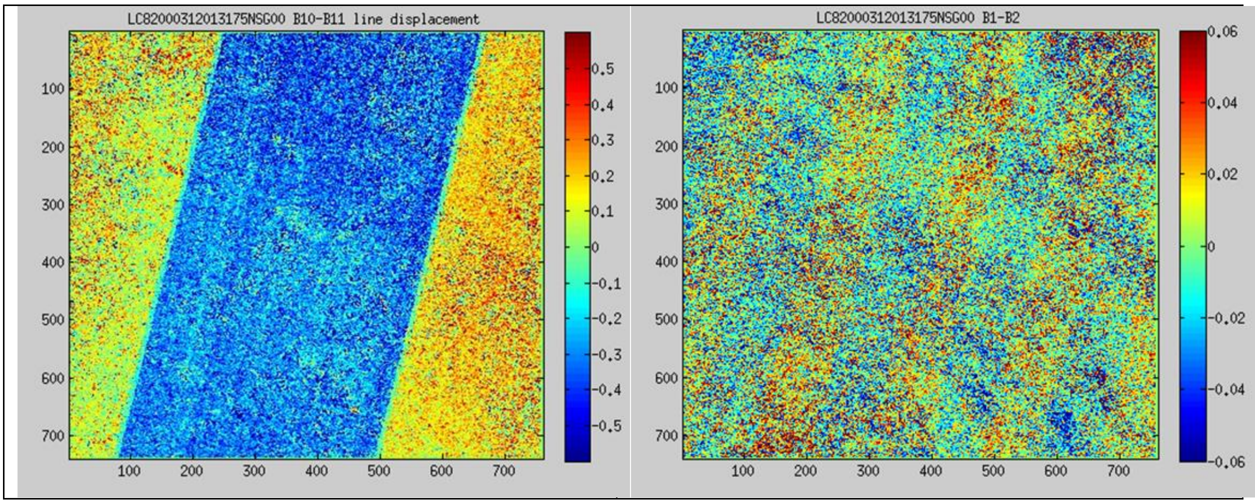



*Figure 7 – Left) correlation map for B10/B11 LC82000312013175NSG00 – Right) correlation map for B1/B2 LC82000312013175NSG00*

# 8. Test site description

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

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

*Table 3 – Validation sites*

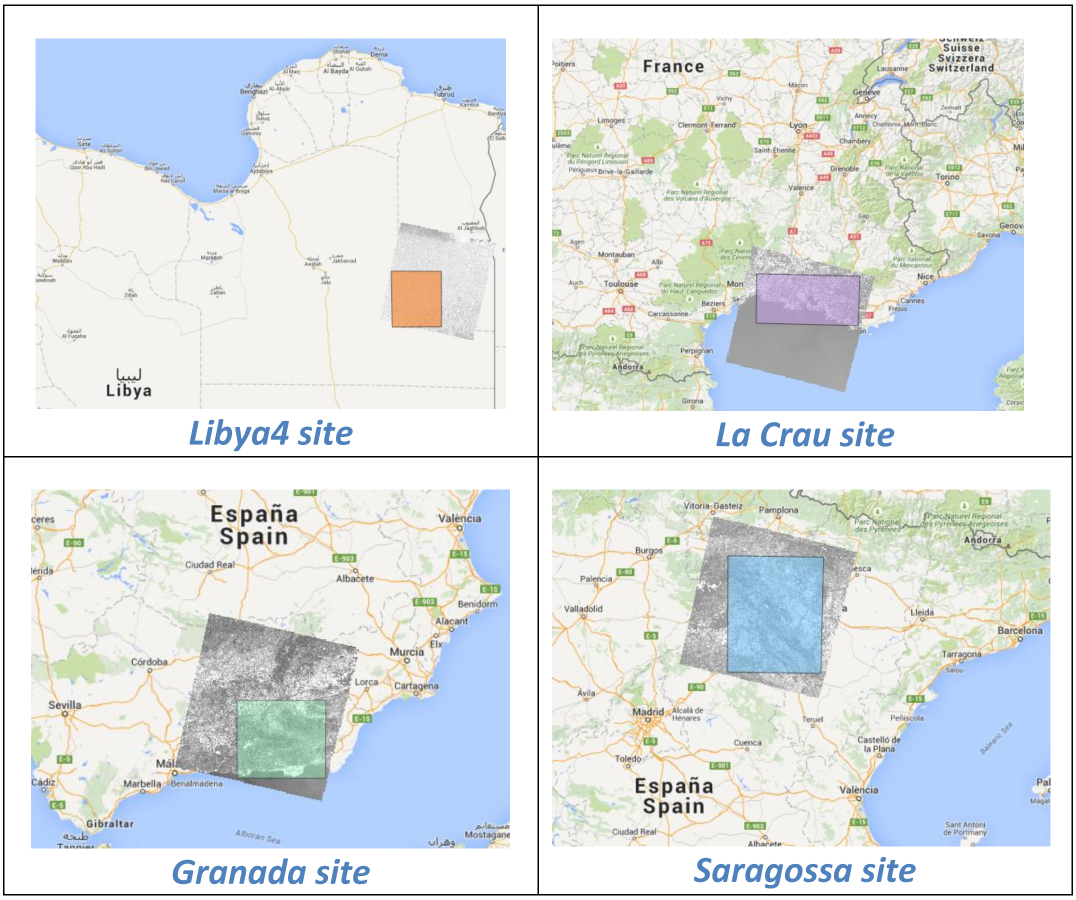



*Figure 8 – ROI used for radiometric accuracy stability monitoring and geolocation accuracy stability monitoring*

# 9. Validation data

## 9.1. Radiometric accuracy stability monitoring

| 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 |
| LC81810402014109MTI00 | Libya4 | 19/04/2014 | LPGS_2.2.1 |
| LC81810402014141MTI00 | Libya4 | 21/05/2015 | 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 |
| LC81810402015256MTI00 | Libya4 | 13/09/2015 | LPGS_2.4.0 |
| LC81810402015272MTI00 | Libya4 | 29/09/2015 | LPGS_2.4.0 |

## 9.2. Geolocation accuracy stability monitoring

| 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 |
| 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 |
| 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 |
| LO82000342014242MTI00 | 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 |
| LC82000342015133MT00 | 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 |

## 9.3.Interband registration accuracy

| 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 |
| 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 |