ABSTRACT

This paper presents results regarding the geometry control of MERIS Full Resolution product geometry assessment.

The first part will be dedicated to the results of the specific tool AMARGOS aiming to improve the geolocation of the MERIS Full Resolution (FR) products while the second part will report on the geolocation accuracy of the standard MERIS FR products.

Validation of the geometric accuracy is performed on a MERIS camera basis. A processing chain that encompasses preprocessing and geometric recalibration, automatic correlation procedure and statistic analysis has been set up. Validation criteria are based on Circular Error (90) and Root Mean Square (RMS) results. Camera orientations are also checked through analysis of along and across track residual errors. Since ENVISAT launch, geodetic location accuracy of FR 1B products is monitored.

This paper aims at providing geolocation results and qualitatively analyzing time series of some key results.

1. INTRODUCTION

Geometric accuracy is a key issue in remote sensing. Assessing how MERIS instrument matches a location on the Earth is essential for a major part of applications and becomes crucial in a multi temporal framework.

Reliability of Earth phenomena monitoring is strongly dependant of multi date products registration. Earth Observation projects are highly demanding for a perfect image to image registration and continuously express their needs for an improved pixel geolocation.

As example, based on MERIS Full Resolution images, the ESA project GLOBECOVER [I] performs a land classification on pixel basis approach. The project required a geolocation accuracy systematically below 150 meters.

Initially, the standard MERIS FR level 1B products did not meet these requirements. A specific tool, AMORGOS, has been developed to overcome this issue. AMORGOS takes in input the MERIS Full Resolution Full Swath, the restituted satellite attitude and orbit, and a digital elevation model to correct the relief effect. The output is a product called FR-FS-O (Full Resolution Full Swath Ortho-georeferenced) in the original instrument geometry, with no resampling. The latitude, longitude and altitude are given for every single pixel.

Since ENVISAT launch, absolute location accuracy of FR 1B products is monitored through a standard semi automatic method that forms a good basis for appreciating product geodetic location performance. Requirements for sub pixel accuracy and constraints inherit from the instrument geometry specificities, make this method not efficient anymore when validating geometry of FR-FS-O products.

Within a common FR-FS-O grid, comparison through an automatic image matching technique has been considered. Disparity analysis algorithms involved in validation procedure have demonstrated their efficiency and reliability [II].

2. GEOMETRIC ACCURACY OF FR-FS-O

Purpose of geometric accuracy is to qualitatively and quantitatively evaluate residual internal geometric distortions [III].

A sub pixel approach has been adopted for validating geometry of FR FS-O product.

2.1. Dataset Characteristics

Reference dataset

Especially for this validation, a dedicated Landsat mosaic has been prepared. This synthesis is based on single scenes and their references are recalled in [table 1]. Landsat scenes have been provided by ESA through a CAT-1 ordering mode. All scenes have been acquired and processed at Maspalomas station (INTA). Geometric corrections have been performed using consolidated ephemeris data.
Cartographic maps ordered at the Geographical Institute of Senegal enabled improving geodetic accuracy of scenes belonging to WRS path 205, western coast.

The mosaic was generated after the single scene ortho rectification. The absolute location accuracy is estimated to be less than 50 metres RMS.

Finally, Landsat ETM+ data has been rescaled to the MERIS mean spatial on-ground pixel size (260 m, FOV 0 degree) by using a “mean” algorithm.

FR-FS-O products are processed into TIFF format and include nineteen (19) data files with 16-bit values: fifteen (15) for image bands, three (3) for geolocation information (latitude, longitude & altitude) and one (1) for flag indexes.

Latitude and longitude values are expressed in degree unit, and altitude values in metre. The pixel geolocation is associated to the image pixel upper left corner.

Image pixel of FR-FS-O product band is “ortho geo-referenced”. Namely, its associated geolocation (latitude, longitude, altitude values) is the intersection of the detector viewing direction with terrestrial surface (Digital Elevation Model) and the ellipsoid of reference.

As illustrated with [fig. 2] and [fig. 3] image geometry is the instrument one. Overlapping between cameras is managed as image background area. Green lines superimposed over [fig. 3] highlight detectors of camera four (4) set to zero value.
Requirements for disparity analysis

Automatic approach of image matching technique depends on several parameters which impact more or less seriously expected accuracy. For successful comparison, the level of information should be sufficient. Because of parallax effects, terrain elevation and slope variability should be as low as possible.

In addition, the difference between acquisition dates of both images should not exceed two months and the overlapping of spectral bandwidths ensures better results.

Prior to the disparity processing, the pixel scale of both images shall be similar and the pixel registration shall be below one pixel.

Processing chain

Landsat data is geometrically recalibrated, image data is transformed into the common FR-FS-O location grid. MERIS / ETM+ image pair is now comparable; all computations are done in the MERIS instrument geometry.

Radiometric rescaling of 16-bit resolution MERIS data to 8-bit are performed prior to disparity analysis.

Disparity measurements are output from Telimago® DISPAR process, [V], which performs correlation and post-processing steps (Anomaly filtering, Missing tie-point).

As part of a “Micro registration” tool, DISPAR process has been implemented in the frame of the MERIS WORLD SYNTHESIS (Mars-April 2003), [VI].

Displacement and confidence maps associated to statistics relative to the relevance and distribution of $\delta X$ and $\delta Y$ components are then used for computing validation items such as RMS, CE90 and camera orientation profile.

Validation criteria are set as parameters, RMS and CE90 results are successful if below 0.5.

Product grid gives the opportunity to associate to a specific detector number a residual error.

Camera profile is a plot of residual error estimated on each detector of the camera. Residual error plot purpose is to verify across track pointing stability and discern if geometric distortions occur within the working camera.

Results

For every single MERIS camera, RMS and CE90 results are respectively listed in [table 3] and [table 4] and can be summarized as follow:

(I) Validation of MERIS camera 1 is successful; RMS Validation Item (VI) (0,5) and CE90 VI (0,41) are both below 0,5.

(II) Validation of MERIS camera 2 is successful for RMS VI (0,36) and unsuccessful for CE90 VI (0,53). This is due to the important variability of measurements according to the across-track direction (0,26).

(III) Validation of MERIS camera 3 is successful; RMS VI (0,46) and CE90 VI (0,41) are both below 0,5.

(IV) Validation of MERIS camera 4 is unsuccessful; RMS VI (0,62) and CE90 VI (0,58) are both above 0,5.
Validation of MERIS camera 5 is successful; RMS VI (0.28) and CE90 VI (0.4) are both below 0.5.

MERIS camera geolocation accuracy average is:

\[
\text{0.445 pixel} \pm 0.2
\]

<table>
<thead>
<tr>
<th>Camera</th>
<th>Confidence Threshold</th>
<th>Candidate pixels</th>
<th>CE90 Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.98</td>
<td>5491</td>
<td>0.41225</td>
</tr>
<tr>
<td>2</td>
<td>0.98</td>
<td>8159</td>
<td>0.53851</td>
</tr>
<tr>
<td>3</td>
<td>0.98</td>
<td>11124</td>
<td>0.41222</td>
</tr>
<tr>
<td>4</td>
<td>0.95</td>
<td>11078</td>
<td>0.58297</td>
</tr>
<tr>
<td>5</td>
<td>0.97</td>
<td>10565</td>
<td>0.40</td>
</tr>
</tbody>
</table>

The validation magnifies some deviations regarding the inner orientation of camera number 4. For this camera, along track bias (-0.4 pixel) is unusual in comparing with results from other ones (below 0.25). In addition, a more important across track variability (0.33) can be noticed [fig. 8].

A long term monitoring should be considered for making results more consistent.

Correction of pointing file associated to one camera has been performed in fitting to across / along track residual errors a one-order polynomial model. Looking at linear tendencies, camera profiles plot [fig.10], [fig.11], magnifies that the correction method is efficient. We may wondered if for at least camera 4, a higher degree model would not be more suitable.
3. GEODETIC ACCURACY OF STANDARD FR 1B

Method
Monitoring of FR-1P geodetic accuracy is performed through the use of a semi-automatic technique [VII].

Dataset
Assessment is done on MERIS product acquired over France / Italy target zones and over South Africa / Australia ones.

For areas belonging to northern hemisphere, reference dataset is the JRC ETM+ European mosaic. Reference dataset for southern hemisphere area has been produced at GAEL Consultant.

Results

Overall results: RMS is decreasing

Table just here after synthesizes geolocation results (mean, sigma) for all periods and according to scene location; northern or southern hemisphere.

When computing statistics for all periods RMS non-centered results remain below 300m. When looking statistics per each separate period [table 5], we notice a degradation of the accuracy for Y2003 period and a significant improvement starting during Y2004 and confirmed during Y2005.

<table>
<thead>
<tr>
<th>Periods</th>
<th>Statistics</th>
<th>Northern hemisphere</th>
<th>Southern hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nbr of products</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>280.6491935</td>
<td>284.097625</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>93.31329245</td>
<td>109.0207081</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>267.829</td>
<td>257.0775</td>
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</table>

<table>
<thead>
<tr>
<th>Periods</th>
<th>Statistics</th>
<th>Northern hemisphere</th>
<th>Southern hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y2002</td>
<td>nbr of products</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>342.255</td>
<td>394.527</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>116.5748217</td>
<td>16.5279139</td>
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<tr>
<td></td>
<td>median</td>
<td>318.009</td>
<td>394.527</td>
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<table>
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<tr>
<th>Periods</th>
<th>Statistics</th>
<th>Northern hemisphere</th>
<th>Southern hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y2003</td>
<td>nbr of products</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>273.7716316</td>
<td>295.9256364</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>78.44708911</td>
<td>104.864154</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>267.829</td>
<td>263.145</td>
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</table>

<table>
<thead>
<tr>
<th>Periods</th>
<th>Statistics</th>
<th>Northern hemisphere</th>
<th>Southern hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y2005 (partially)</td>
<td>nbr of products</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>174.4775</td>
<td>167.1086667</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>15.985563</td>
<td>22.02961074</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>174.4775</td>
<td>178.876</td>
</tr>
</tbody>
</table>

Table 5 - Statistics on RMS results for all periods

Traditionally RMS results were higher for data from southern hemisphere than from northern one. Last assessment performed on product acquired over Australia and South Africa during Y2005 magnified a dramatic improvement. Northing and Easting RMS results magnified this assertion as well [table 6], [table 7].

<table>
<thead>
<tr>
<th>Period</th>
<th>Quadratic mean of residual errors, non centred (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting mean</td>
</tr>
<tr>
<td>2002</td>
<td>207.41</td>
</tr>
<tr>
<td>2003</td>
<td>254.76</td>
</tr>
<tr>
<td>2004</td>
<td>178.53</td>
</tr>
<tr>
<td>2005</td>
<td>133.35</td>
</tr>
</tbody>
</table>

Table 6 - Northing & Easting RMS, northern hemisphere area

The ENVISAT flight software update occurring Year 2003, Day of Year (DOY) 343 has improved significantly the geolocation accuracy according to the Easting axis. By extent, we may formulate that this
event has contribute to improve platform across track positioning estimate.

Last period results let us think that the new model of satellite attitude (Year 2004, Day of Year 365), applied to product of Year 2005 is correlated with a significant improvement of the Northing RMS (around 100 m). In this case, from these results, we may formulate this event has enabled a better control of the localization in time. For the both hemispheres, Easting RMS has decreased (around 50 m) as well.

**Non centred and centred results are closed together**

RMS centered results are free from linear errors (bias) and temporal results reflect the stability of the internal geometry consistency.

If the deviation between centred and non-centred results is important, it means that the scene bias is significant.

Graphic here after [fig. 12] magnifies that in tendency, flight software update event (first event) has more likely contribute to the reduction of bias magnitude.

And the second graphic [fig. 13], confirms the bias reduction and inform us that first event has mainly impacted on Easting bias magnitude.

After the second event (Y2004, DOY365), this bias has switched from negative value to positive value and remains within tolerance (below 100 meters).

In absolute values, the northing bias has decreased since launch and remains below 100 meters during Y2005. We can think that second event has partially induced the reduction of northing bias; the shift in time.

**Internal geometry is improved**

The last figures [fig. 14] deals with internal geometry consistency and results are de correlated from bias results.

We note that after the first event, standard deviation has remained quite similar to results obtained before. In addition, easting and northing results keep very closed together all along the analysis period.

Improvements of internal geometry consistency comes just after the second event; for five products acquired between January 2005 beginning and July 2005, location accuracy measurements are stable and consistent together. Centered RMS results are very low and are bringing below 150 metres.

**4. CONCLUSIONS**

This document is proposing an absolute method for measuring inner orientation of MERIS cameras. The latter has demonstrated that the method is suitable.
The method offers accuracy around 0.11 pixel; its main limitation is the number of working datasets, three are not sufficient for obtaining robust statistical results.

For improving geolocation accuracy, this study let think that the pointing file correction should be at least based on a second or above order polynomial model for certain cameras, especially for camera 4.

The geolocation accuracy less than 1/2 pixels is reached by using the post-processing tool AMORGOS. AMORGOS will be available on the web in the short future (http://envisat.esa.int).

The feasibility of integrating AMORGOS type of correction in the ENVISAT operational ground segment is now under evaluation.

The monitoring of the geolocation accuracy of the standard MERIS FR products highlighted four periods. The results can be summarized as follow:

(I) Initially, after the launch, according to results related to the 2002 period, the geolocation accuracy is on the order of ± 135 metres along-track and ± 207 metres across-track. The RMS absolute geolocation error stays within the range of 251.24 ± 81 meters.

(II) The 2003 period is characterized by a degradation of the absolute geolocation accuracy where error is around ± 209 metres along-track and ± 295 metres across-track. For this period, the RMS absolute geolocation error stays within the range of 368.39 ± 67 meters.

(III) After the flight software update event, 2004 period, MERIS geolocation is achieving the goal of 300 metres and RMS absolute geolocation error remains is about 270 ± 75 meters.

(IV) After the new attitude model event, 2005 period, MERIS geolocation is achieving the goal of 170 ± 10 metres.

This temporal analysis based on 47 products is useful for notifying how flight and/or ground segment improvements impact on the geolocation accuracy. To summarize, we note two major levels of improvements and products processed with MERIS processor version v4.1 and upper inherit to these changes.

(I) Reduction of the easting and northing bias; flight software update has mainly contributed to reduce easting bias, where as new attitude model has impact on northing bias.

(II) Improvement of internal geometry accuracy with the new attitude model.

Standard deviation results remains within the range of 87 ± 10 meters for easting direction and within the range of 93 ± 10 meters for nothing direction.

Visually, image quality has improved; artefacts due to duplicated pixels and nearest neighbour resampling seem to be less significant, GCP identification process is managed better.

Everything let think, that such improvements are highly correlated with the new model of satellite attitude on board v4.1 processor.

For further improving the geolocation accuracy, this study demonstrated that the pointing file correction should be at least based on a second or above order polynomial model for certain cameras, especially for camera 4.

Even if, a pointing correction applied at detector level is very constrained, it would be the most suitable correction method for reaching a pointing accuracy below the 0.5 pixel operational goal.

5. REFERENCES

I I. Marc Leroy and al., Globecover processing chain, MERIS-AATSR Workshop, ESRIN, September 2005.


IV C. Carmona-Moreno, Preliminary study on MERIS geometric performances, JRC, 2004.

V Telimag web page http://www.gael.fr/telimago/site/index.html
