Contract N°15993/02/I-LG	**MERIS ABSOLUTE GEOLOCATION STATUS**	
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Purpose of the document

The aim of this report is to provide geolocation accuracy results on absolute measurements. Assessed how well the MERIS instrument matches a location on the Earth is essential for land applications such as agriculture monitoring applications.
For this purpose time series of data acquired during 2002, 2003, 2004 over the northern and southern hemispheres are used.
Absolute geolocation accuracy results for these three periods provide precious information on the temporal stability of the MERIS data geolocation. They are essential for the characterization of the image deformation as well.
A special attention is paid to verify that the ENVISAT flight software update occurring Year 2003, Day of Year (DOY) 343 has improved significantly the geolocation performances.

Data set and method

Input data set

Testing data set

The MERIS Full Resolution data set used in this analysis is a level 1B product. The absolute geolocation accuracy has been evaluated on 16 images acquired over the northern hemisphere (France, Italy) and 6 images over the south hemisphere (South Africa, Austalia). Images are a combination of channels 2, 5, 8 (BGR).
The three periods 2002, 2003, 2004 are defined as follow:
(I) 2002 period includes three (3) products acquired during 2002, DOY 200, 226, 231.
(II) 2003 period includes nine (9) products acquired during Year 2003 from DOY 150 to 342.
(III) 2004 period includes nine (9) products acquired from Year 2003, DOY 343 to Year 2004 DOY 91.
Since absolute geolocation assessment process requires geocoded products, the overall testing data are map projected in Universal Transverse Mercator (UTM) geographical coordinates according the UTM zone at which the scene centre belongs. Map projection process is performed using BEAM/VISAT software.

Reference data set

European Joint Research Center (JRC) supplies reference data set over France and Italy countries through the European Landsat ETM+ mosaic *Image2000.*
Because reference data set related to the southern hemisphere was not available, Landsat ETM+ data and their corresponding 1:25 000 scale maps were used for the construction of an accurate registered image data base, specifically for the South Africa and Australia countries.

In both cases, the data are free from terrain relief effects. The panchromatic band is used and resampled to 125 metres. This pixel resolution is convenient for the matching process with the MERIS 290 meters (nadir) data.

Ellipsoid

Absolute geolocation accuracy assessment is performed on the basis of the World Geodetic Reference System of 1984 (WGS84). The Earth fixed global reference frame WGS84 includes an Earth model. This one is defined by a set of parameters related to the Earth reference ellipsoid and to the Earth gravity model.

Matching method

Selection of ground control points

By definition, a Ground Control Point (GCP) is a physical feature detectable in a scene, whose characteristics (location and elevation) are known precisely.
The control points should be well distributed and stable. Some of the features commonly used as control points are; airport, highway intersections, fields intersection, geological and field patterns, and other similarly prominent stable features.
Since MERIS products are not free from terrain relief parallax, errors could be introduced when selecting point over elevated area. These errors are more pronounced for GCP points distant from nadir. Care should be taken to pick GCP over relatively flat area and if possible close to the nadir of the satellite orbital path.
For one working image, a sample of about twenty GCPs is necessary for a consistent evaluation of the absolute geolocation accuracy.

Matching of ground control points

The next step is to match the selected control points on the two images. The matching method consists on locating and selecting manually the GCP. This is done interactively, the operator identifying visually the points both on the reference and on the working image.

Geolocation error analysis

Geolocation accuracy assessment is based on the computation of residual errors provided by the GCP location mismatch between reference and working images.
For every GCP, $GCP[i]$, the residual errors ($x\_residual[i], y\_residual[i]$) are computed from the difference between GCP geographical coordinates given by the reference image and the ones given by the working image.
Considering a N sample GCPs, the four criteria on which the analysis is based are the following ones:

(I) The arithmetic mean of residual errors in (X,Y), ($m[x\_residual]$, $m[y\_residual]$).
(II) The standard deviation of residual errors in (X,Y), ($\sigma[x\_residual]$, $\sigma[y\_residual]$).
(III) The Root Mean Square (RMS) or quadratic mean of residual errors in (X,Y), ($ERMS_x$, $ERMS_y$). For the x-axis, the following formula defined $ERMS_x$:

$$ERMS_X = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x\_residual\ [i])^2} = \sqrt{m[x\_residual]^2 + \sigma[x\_residual]^2}$$

(IV) The modulus or Euclidean norm of ERMS vector known as ERMS absolute geolocation, is defined as follow:

$$\left|ERMS\right| = \sqrt{ERMS_x^{2} + ERMS_y^{2}}$$

The latest criterion summarizes as best the geolocation accuracy. Arithmetic mean and standard deviation informs about distribution of residual errors. If the mean is different from the zero value, geolocation results are here called “non-centred results”. An additional process relies on the computation of the fourth criteria seen above where residual errors are centred on their mean. It leads to results here called “centred results”.

Results interpretation

The four previous criteria are fundamental for the characterization of the image deformations. Two kinds of deformations should be discerned, global and local.
A global deformation is mainly linear and is applied similarly over each image pixel. Local deformations are more specific and appear in particular areas.
Artihmetic mean of residual error values informs more likely on the magnitude of the global deformation. The main displacement (vector orientation) is characterized when checking the mean of residual errors within the (X,Y) plan. Linear shift can be due to platform perturbation, unreliable ephemeredes or other external effects.
Standard deviation of residual errors exhibits local deformations occurring on the working image. Geometric distortions such as scene elevations, atmospheric turbulence, and sensor non-linearity are magnified.
For two different products, ERMS results can be similar although this is not the case for both the mean and the standard deviation. So, non-centred and centred results are useful to evaluate how the mean and the standard deviation contribute to the ERMS value.

Results and discussion

Northern hemisphere area

The geolocation accuracy assessment for the Northern hemisphere is based on sixteen (16) products.
Table here below presents statistics on the quadratic means and make a distinction between non-centred and centred results. In both cases, along-track accuracy is higher than the across-track one.
These results magnify that a persistent cross-track shift has occurred for periods 2002 and 2003 correlated to an along- track shift for period 2003.
When residual errors are centred on their mean, the statistics shows that the along-track and across-track geolocation are roughly similar (about 110 m) for periods 2002 and 2004.

Period	Quadratic mean of residual errors, non centred (m)		Quadratic mean of residual errors, centred (m)	
	across-track mean	along-track mean	across-track mean	along- track mean
2002	207,41	135,94	116,56	110,00
2003 [(1)]	254,76	213,21	146,47	121,49
2004 [(2)]	146,68	122,82	110,79	103,50

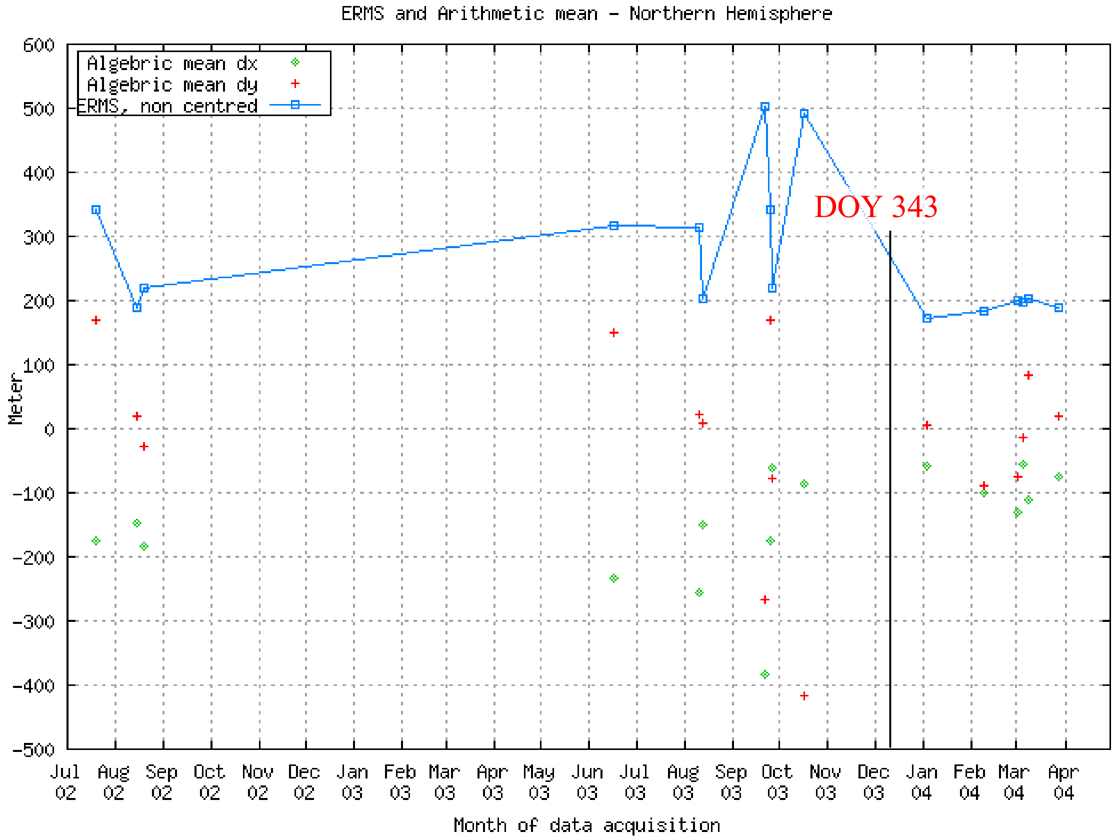
[(1)] 2003 period spans products acquired from Year 2003 DOY 150 to Year 2003 DOY 342.
[(2)] 2004 period spans products acquired from Year 2003 DOY 343 to Year 2004 DOY 90.

The next table here below lists statistics on ERMS absolute geolocation results for the three periods of interest. Mean and standard deviation of non-centred and centred ERMS results are illustrated. It shows that the ERMS mean for the period 2003 (342,26 m) is greater than the ones of period 2002 and 2003. Centred results are more homogenous but remain higher for period 2003 (192 m).

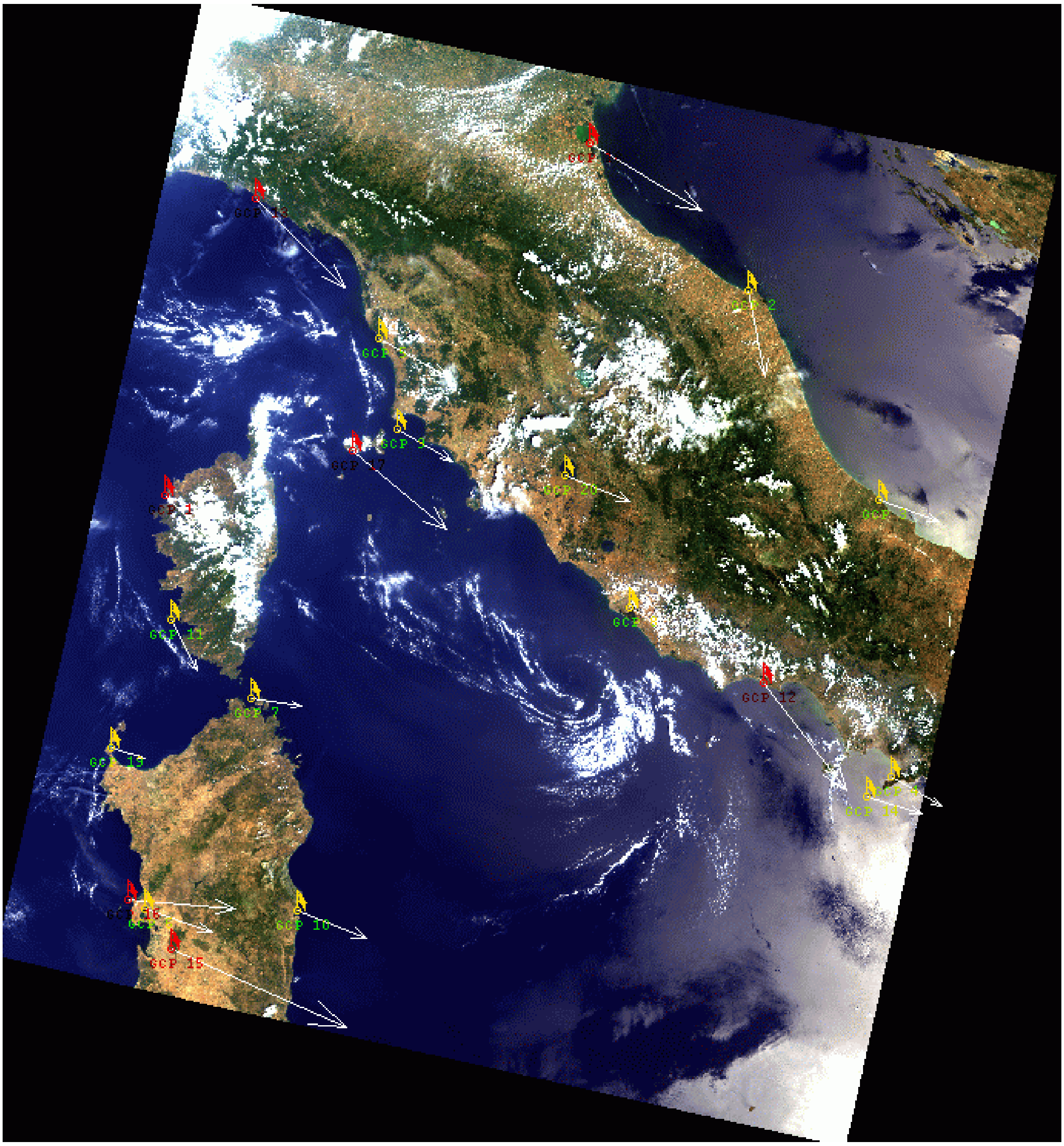
Period	ERMS absolute geolocation, non centred (m)		ERMS absolute geolocation, centred (m)	
	Mean	Std	Mean	Std
2002	251,24	81,33	160,36	69,88
2003 [(1)]	342,26	118,57	192,08	41,11
2004 [(2)]	191,68	12,71	151,83	24,73

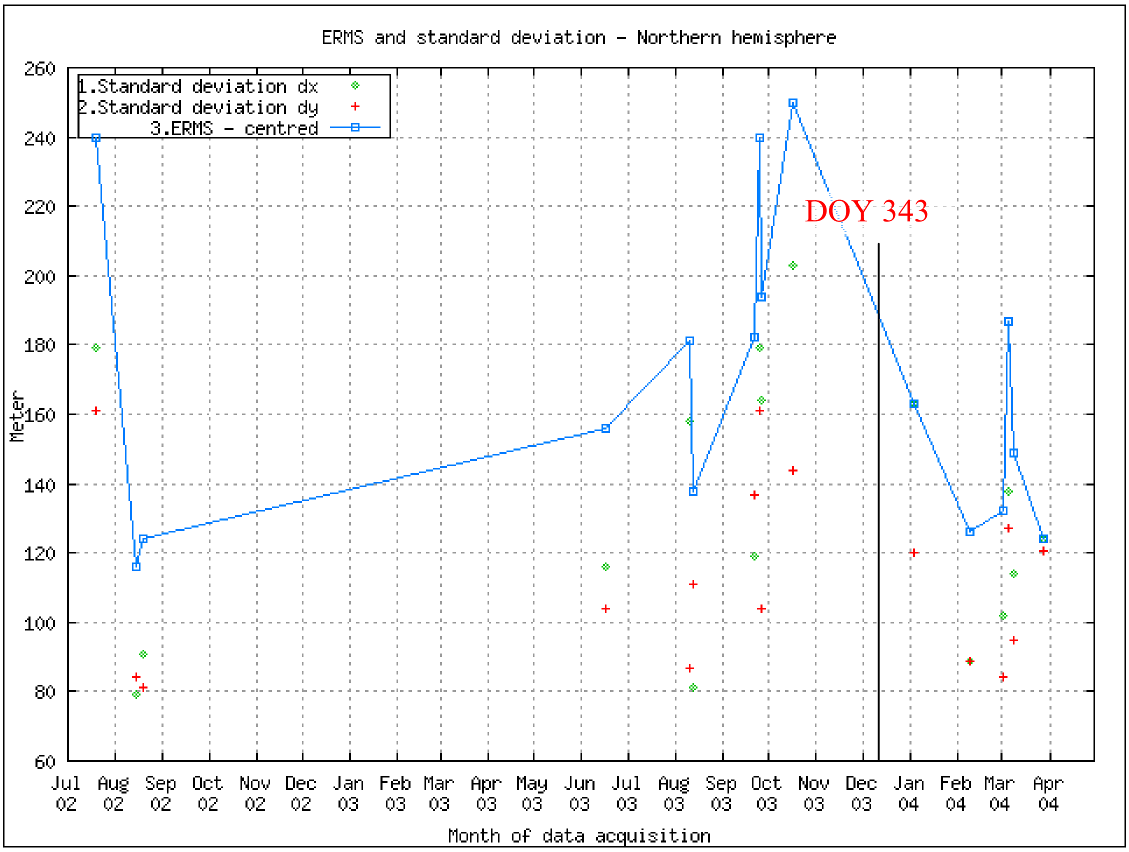
[(1)] 2003 period spans products acquired from Year 2003 DOY 150 to Year 2003 DOY 342.
[(2)] 2004 period spans products acquired from Year 2003 DOY 343 to Year 2004 DOY 90.

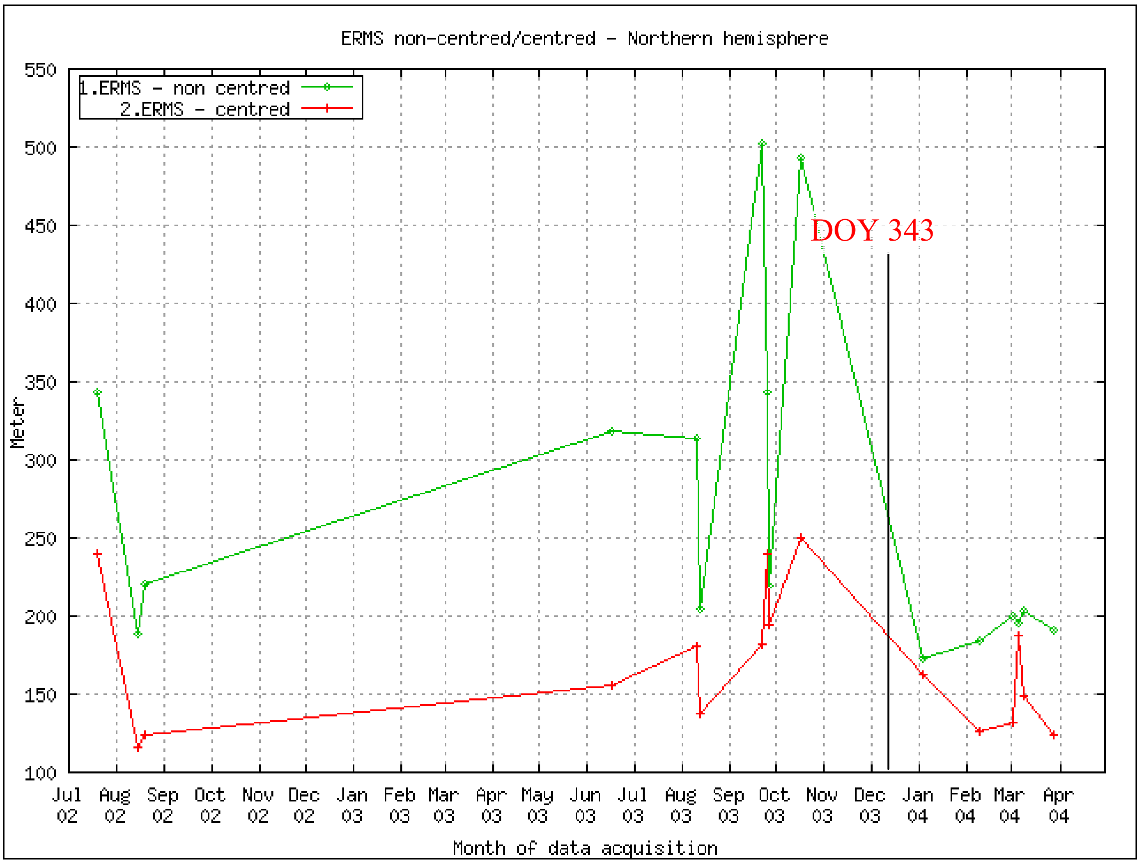
The graphic plot “ERMS and arithmetic mean” illustrated the evolution of the ERMS (non centred results) for the whole of northern hemisphere data set. In comparison with 2002 and 2004 periods, we observe an important variability of the geolocation accuracy during period 2003. For this period the linear shift is more pronounced as confirmed by algebric mean dx and dy plots where values are very scattered and the maximum value is around 400 metres (absolute value). The shift along the x-axis is more important than along the y-axis. For the 2004 period, dx and dy values are encompassed within the interval [-130, 83].


ERMS and Arithmetic mean - Northern Hemisphere
Algebric mean dx
Algebric mean dy
ERMS, non centred
DOY 343
Meter
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jul 02
Aug 02
Sep 02
Oct 02
Nov 02
Dec 02
Jan 03
Feb 03
Mar 03
Apr 03
May 03
Jun 03
Jul 03
Aug 03
Sep 03
Oct 03
Nov 03
Dec 03
Jan 04
Feb 04
Mar 04
Apr 04
Month of data acquisition

This MERIS FR image here below acquired in June 17th, 2003, is shifted mainly westwards. (Arrow scale: x200). A linear shift more significant along the pitch axis, satellite reference frame, is magnified (non centred ERMS is about 300 metres).




ERMS and standard deviation - Northern hemisphere
1.Standard deviation dx
2.Standard deviation dy
3.ERMS - centred
DOY 343
Meter
260
240
220
200
180
160
140
120
100
80
60
Jul 02
Aug 02
Sep 02
Oct 02
Nov 02
Dec 02
Jan 03
Feb 03
Mar 03
Apr 03
May 03
Jun 03
Jul 03
Aug 03
Sep 03
Oct 03
Nov 03
Dec 03
Jan 04
Feb 04
Mar 04
Apr 04
Month of data acquisition

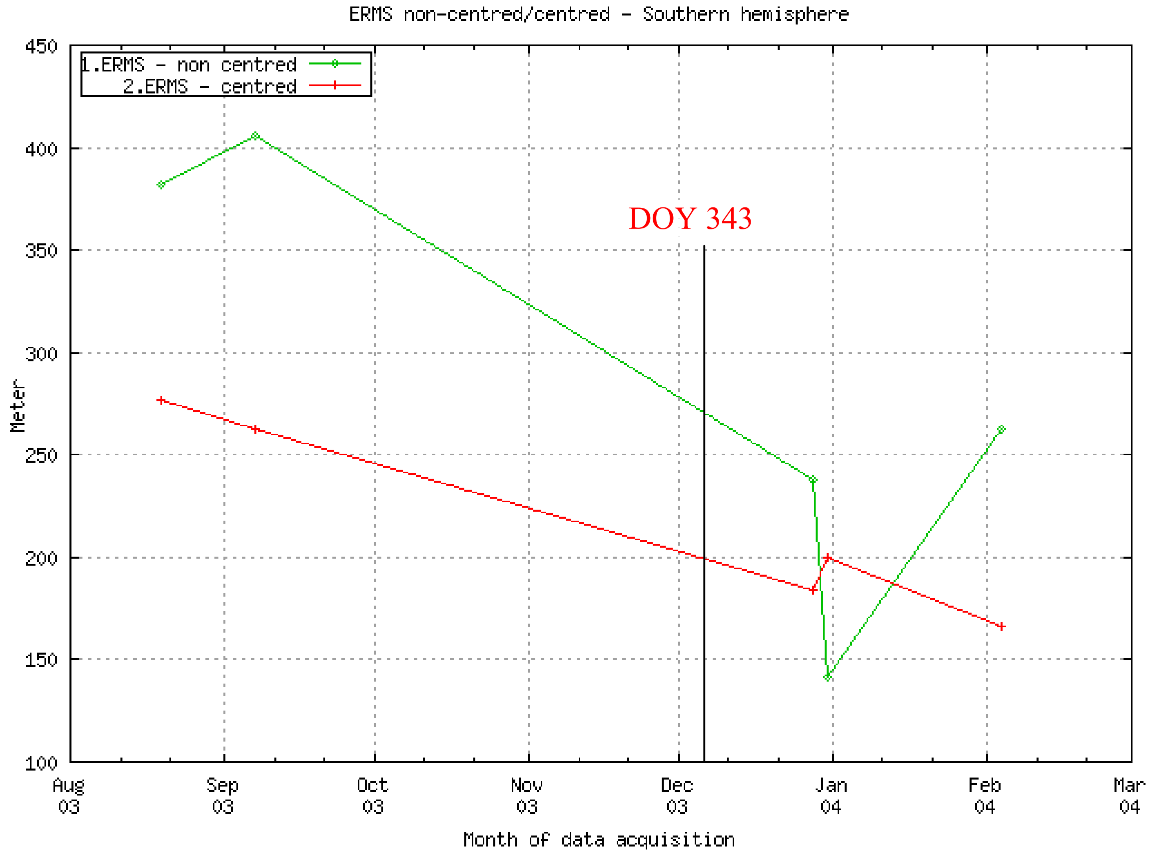


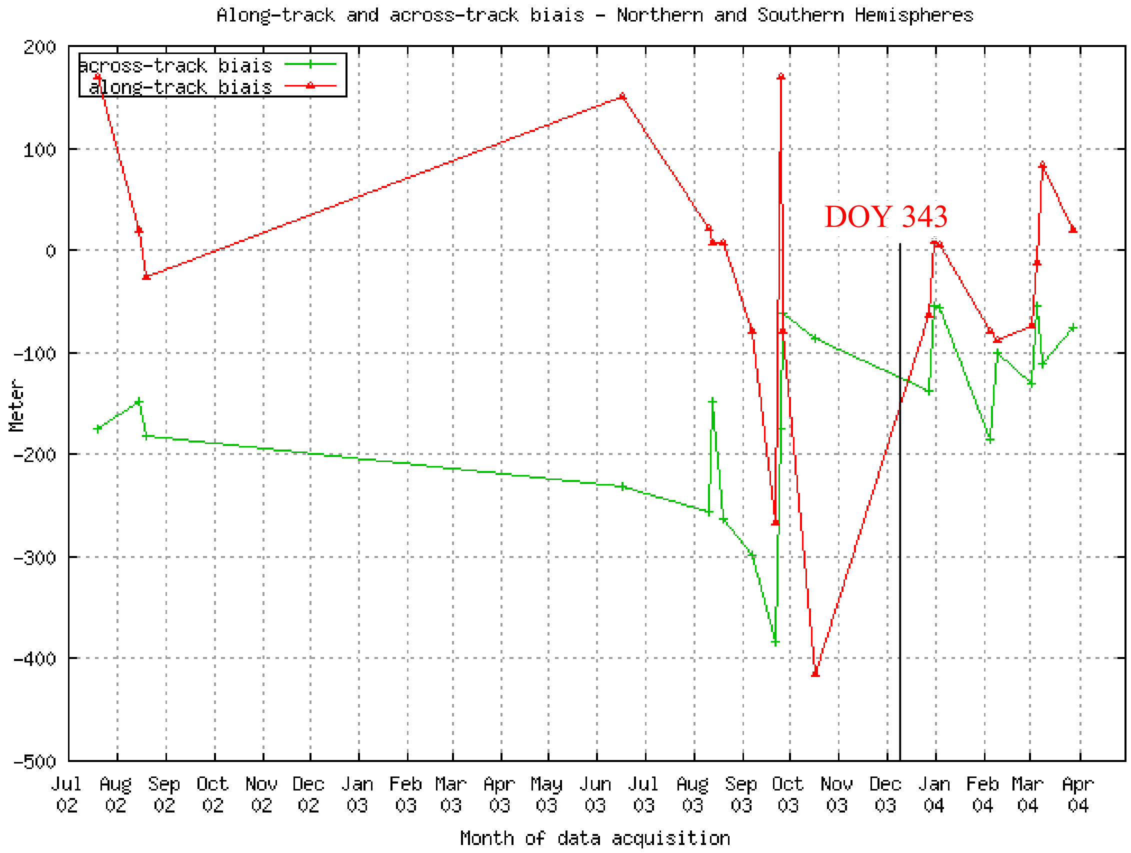
Southern hemisphere area

Period	Quadratic mean of residual errors, non centred (m)		Quadratic mean of residual errors, centred (m)	
	across-track mean	along-track mean	across-track mean	along-track mean
2003 (1)	336,13	205,89	182,47	198,41
2004 (2)	184,38	142,07	127,47	128,29

Period	ERMS absolute geolocation, non centred (m)		ERMS absolute geolocation, centred (m)	
	Mean	Std	Mean	Std
2003 (1)	394,53	16,53	270,86	9,71
2004 (2)	234,01	31,79	181,16	12,94

(1) 2003 period spans products acquired from Year 2003 DOY 210 to Year 2003 DOY 342.
(2) 2004 period spans products acquired from Year 2003 DOY 343 to Year 2004 DOY 34.


ERMS non-centred/centred - Southern hemisphere
1.ERMS - non centred
2.ERMS - centred
DOY 343
Meter
450
400
350
300
250
200
150
100
Aug 03
Sep 03
Oct 03
Nov 03
Dec 03
Jan 04
Feb 04
Mar 04
Month of data acquisition


Along-track and across-track biais - Northern and Southern Hemispheres
across-track biais
along-track biais
DOY 343
Meter
200
100
0
-100
-200
-300
-400
-500
Jul 02
Aug 02
Sep 02
Oct 02
Nov 02
Dec 02
Jan 03
Feb 03
Mar 03
Apr 03
May 03
Jun 03
Jul 03
Aug 03
Sep 03
Oct 03
Nov 03
Dec 03
Jan 04
Feb 04
Mar 04
Apr 04
Month of data acquisition

Conclusions

The accuracy specification for MERIS geolocation is 2000 m, with an operational goal of 150 metres at nadir.

The 290 metres (nadir) bands 2,5,8 are used to estimate the absolute geolocation accuracy. This analysis shows significant improvements since launch, with one major upgrade, which occurred in 2003 DOY 343. The update of the star tracker has been performed to reduce the systematic offset and improve orientation parameters. Global absolute geolocation error (north and south hemispheres) for the three consecutives periods 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 update, 2004 period, MERIS geolocation is achieving the goal of 300 metres with accuracy of ± 132 metres along-track and ± 165 metres across-track. The RMS absolute geolocation error remains within the range of **212** ± **22** meters.

When correcting products from the systematic offset (centred results), for 2004 period the RMS absolute geolocation error stays within the range of **166** ± **18** meters.

Products collection located on northern hemisphere is much larger than the one from the southern hemisphere. Comparison between the two sets of results is not trivial.

For the 2004 period, this study demonstrated the temporal stability of the absolute geolocation. More results are now needed to confirm this trend.