Troubleshooting of the MERIS processors during the commissioning phase

Vincent Fournier-Sicre[(1)]
Simon Belanger[(2)]

[(1)] ***Email : vfs@acri-st.fr***
ACRI-ST
260 Route du Pin Montard, BP 234
06904 Sophia Antipolis – France

[(2)] ***Email : Simon.Belanger@esa.int***
ESA/ESRIN - Data Handling Division
Via Galileo Galilei - Casella Postale 64
00044 Frascati - Italy

The MERIS Level 1b and Level 2 prototype software was developed by the ACRI company, while the operational software used in the ENVISAT Payload Data Segment was developed by the GMV company (Madrid). The prototype was developed to exercise and to validate the specifications of the MERIS processing. It was also used as a reference to verify the implementation of the processing chain in the PDS. This paper describes the methodology that was used to perform that task, and it presents the agreement that was met at the end of this activity.

Introduction:

The goal of the MERIS troubleshooting was to assure that the L1b/L2 prototypes and operational software were fully in line. The trouble shooting has been ongoing since the first TDS were sent to GMV but large discrepancies remained at the time of the launch: more than 10% of errors on given products, and agreement on no more than 30 % for certain flags. Therefore, after the launch, the work had to be pursued. The trouble shooting activities therefore continued for several months until an extremely good agreement was found; this was achieved after two ACRI/GMV collocations that took place at GMV (the company that was in charge of implementing the processing in the IPF), and more than 50 reprocessing on certain images.

As the activity was progressing, some differences, that were in the first place thought to be of numerical origin were in fact due to bugs or to different interpretation of the specification. At the end of this activity, the agreement between the two processors would be met only if a marginal fraction (of the order of 0.005% of the image) of pixels would show more than one quantification step of difference – for the chlorophyll, this would be equivalent to have around 0.5% of difference. This paper describes the methodology that was used and presents the discrepancies that were reached at the end of this activity, on 26 July 2002.

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The objectives:

The implementation of the processing was verified during the course of the development of the IPF by sending to GMV a Test Data Set (TDS). A TDS is a collection of input and output files produced by the prototype software with the auxiliary files that were used. This set of files was used as a reference by GMV which had to make sure that their software was producing the same results. This procedure was exercised a number of times during the three years of development of the MERIS IPF but discrepancies were still remaining when the MERIS commissioning activities started in March 2003.

The purpose of the trouble-shooting activities were to make sure that the results produced by the MERIS Ground Segment Instrument data Processing Facility (IPF) and the MERIS prototype software were equivalent. This activity had to start at the beginning of the commissioning phase because the prototype software is the tool used for the verification activities.

The possible sources of discrepancies:

The discrepancies may be due to sources of very different kinds. First of all, the language that was used for both developments was different: the IPF was developed using C++ language whereas the prototype software was developed using C language. The architecture of the two software is different and different types of computers platforms were used (Sun Workstation for the prototype versus IBM workstations for the IPF). Of course – since the coding languages were different – the compiling options were also different. The interpretation of the specifications could also have lead the two development teams to a different interpretation and consequently to divergences. Finally, considering that 22000 and 33000 lines of code - not counting the Input/Output functions - were respectively needed for the Level 1b and Level 2 prototype, the risk of a plain bug found anywhere was always possible.

The methodology:

The methodology that was used evolved during the activity. To start with, a complete Test Data Set (meaning a collection of input/intermediate/output files with their associated auxiliary products) were sent to GMV that had to make sure that they would reproduce the same results – within the numerical errors. This proved not too be really sufficient because, at that time, there was no tool that could give an overview (at the image scale) of the differences by giving the worst difference for each geophysical product and that could associate it to a location. Consequently, a tool was developed that would evaluate for any corresponding set of GMV/ACRI L2 or L1b produced images, and for any given product, the worst error and where it was located on that image. An example of report that is produced for the geophysical parameters is given below:

```
# Wed Jul 17 14:32:14 2002
# file1: K:\megs.5.2\folders\TDS_42\Zaire\files\l2_rr.prd
# file2: J:\GMV\Zaire\MER_RR__2PTGMV20020615_084616_00000175X000_00000_00000_0001.N1
#   Analysis is based on Numerical Counts!!!!!
```

# Field	# pixels 1	# pixels 2	# Common	#NotCommon	Quant. Step	= 1step	%	> 1step	%	MaxDiff	iCol	iLin
RN1_413	1060738	1061480	1060738	742	1.52593e-005	1510	0.14	0	0.00	1.00000	1051	0
RN1_442	1060738	1061480	1060738	742	1.52593e-005	1487	0.14	0	0.00	1.00000	342	2
RN1_490	1060738	1061480	1060738	742	1.52593e-005	1172	0.11	0	0.00	1.00000	662	1
RN1_510	1060738	1061480	1060738	742	1.52593e-005	1141	0.10	0	0.00	1.00000	630	0
RN1_560	1060738	1061480	1060738	742	1.52593e-005	1079	0.10	0	0.00	1.00000	993	1
RN1_620	1060738	1061480	1060738	742	1.52593e-005	1073	0.10	0	0.00	1.00000	856	0
RN1_665	1060738	1061480	1060738	742	1.52593e-005	1056	0.09	0	0.00	1.00000	532	1
RN1_681	1060738	1061480	1060738	742	1.52593e-005	1079	0.10	0	0.00	1.00000	617	4
RN1_708	1060738	1061480	1060738	742	1.52593e-005	1206	0.11	0	0.00	1.00000	533	0
RN1_753	1060738	1061480	1060738	742	1.52593e-005	1683	0.15	0	0.00	1.00000	805	0
RN1_778	1060738	1061480	1060738	742	1.52593e-005	1739	0.16	0	0.00	1.00000	1075	1
RN1_865	1060738	1061480	1060738	742	1.52593e-005	1944	0.18	0	0.00	1.00000	607	0
RN1_885	1060738	1061480	1060738	742	1.52593e-005	1817	0.17	0	0.00	1.00000	537	0
WVAP	859903	859903	859903	0	0.100000	5	0.00	0	0.00	1.00000	320	248
CHL_1	0	0	0	0	No common pixel available							
TOAVI	631837	631837	631837	0	0.00393701	13	0.00	0	0.00	1.00000	665	348
CTP	387609	387609	387609	0	4.02756	6	0.00	0	0.00	1.00000	1052	84
YS	0	0	0	0	No common pixel available							
SPM	0	0	0	0	No common pixel available							
RECT_RHO_IR	631837	631837	631837	0	0.00393701	0	0.00	0	0.00	0.000000	NA	NA
RECT_RHO_NIR	631837	631837	631837	0	0.00393701	5	0.00	0	0.00	1.00000	325	22
CHL_2	0	0	0	0	No common pixel available							
BOAVI	675192	675192	675192	0	0.00393701	8	0.00	0	0.00	1.00000	375	236
PRES	669805	669805	669805	0	2.36220	28	0.00	0	0.00	1.00000	189	25
PAR	9	9	9	0	2.75591	0	0.00	0	0.00	0.000000	NA	NA
C_ALB	387538	387538	387538	0	0.00393701	2	0.00	0	0.00	1.00000	865	900
EPSILON	133042	133042	133042	0	0.00393701	4	0.00	0	0.00	1.00000	492	403
AERO_THICK	133042	133042	133042	0	0.00629921	1	0.00	0	0.00	1.00000	159	512
CLOUD_THICK	387180	387180	387180	0	1.00000	3	0.00	0	0.00	1.00000	495	16
CLOUD_TYPE	387180	387180	387180	0	1.00000	0	0.00	1	0.00	3.00000	879	381

With this knowledge, the search for explanation of discrepancies could then proceed in parallel between GMV and ACRI by working through a debugger on a questionable pixel and step by step reach the source of error.

The tool may be exercised on any set of L1b (or L2) images produced from the prototype and the operational software provided that the same Level 0 (or L1b) image is used in both cases. It is very fast (typically less than 1 minute for an image with 1500 frames) and may be exercised on a collection of images in a batch mode. It may therefore be exercised very easily if any doubt subsists and important discrepancies still remain between the IPF and the prototype software.

Flags are also compared – an example of such an analysis is given below:

```
Bit # 0 : B_LOW_PRESSURE - 1131088 pixels agree (99.9999 %)
  Flag raised 910540 times in file1.
  Flag raised 910541 times in file2.
Bit # 1 : B_P_CONFIDENCE - 1131088 pixels agree (99.9999 %)
  Flag raised 107060 times in file1.
  Flag raised 107059 times in file2.
Bit # 2 : B_HIGH_GLINT - 1131089 pixels agree (100.000 %)
  Flag raised 10 times in file1.
  Flag raised 10 times in file2.
Bit # 3 : B_DDV - 1131089 pixels agree (100.000 %)
  Flag raised 133152 times in file1.
  Flag raised 133152 times in file2.
Bit # 4 : B_MEDIUM_GLINT - 1131089 pixels agree (100.000 %)
  Flag raised 2640 times in file1.
  Flag raised 2640 times in file2.
Bit # 5 : B_ICE_HAZE - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 6 : B_CASE2_Y - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 7 : B_CASE2_A - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 8 : B_CASE2_S - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 9 : B_ABSOA_DUST - 1131089 pixels agree (100.000 %)
  Flag raised 2731 times in file1.
  Flag raised 2731 times in file2.
Bit # 10 : B_ABSOA_CONT - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 11 : B_SUSPECT - 1131089 pixels agree (100.000 %)
  Flag raised 1065936 times in file1.
  Flag raised 1065936 times in file2.
Bit # 12 : B_COSMETIC - 1131089 pixels agree (100.000 %)
  Flag raised 0 times in file1.
  Flag raised 0 times in file2.
Bit # 13 : B_COASTLINE - 1131089 pixels agree (100.000 %)
  Flag raised 2403 times in file1.
  Flag raised 2403 times in file2.
Bit # 14 : B_PCD_19 - 1131089 pixels agree (100.000 %)
  Flag raised 610867 times in file1.
  Flag raised 610867 times in file2.
Bit # 15 : B_PCD_18 - 1131089 pixels agree (100.000 %)
  Flag raised 73737 times in file1.
  Flag raised 73737 times in file2.
Bit # 16 : B_PCD_17 - 1131089 pixels agree (100.000 %)
```

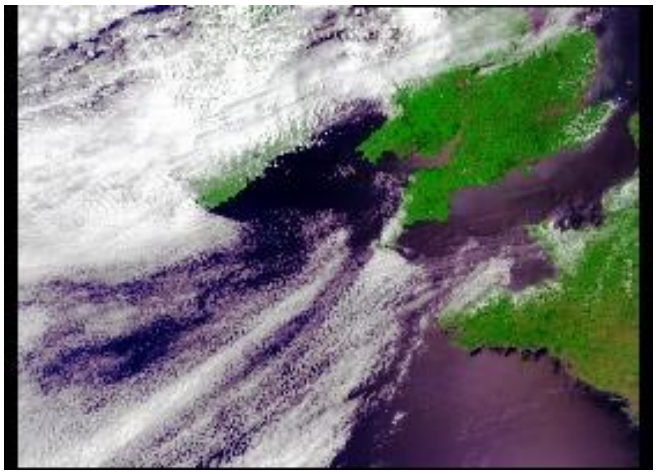
```
  Flag raised 68264 times in file2.
Bit # 17 : B_PCD_16 - 1131089 pixels agree (100.000 %)
  Flag raised 68264 times in file1.
  Flag raised 111619 times in file2.
Bit # 18 : B_PCD_15 - 1131089 pixels agree (100.000 %)
  Flag raised 111643 times in file1.
  Flag raised 111643 times in file2.
Bit # 19 : B_PCD_14 - 1131089 pixels agree (100.000 %)
  Flag raised 271186 times in file1.
  Flag raised 271186 times in file2.
Bit # 20 : B_PCD_1_13 - 1130347 pixels agree (99.9344 %)
  Flag raised 70351 times in file1.
  Flag raised 69609 times in file2.
Bit # 21 : B_WATER - 1131089 pixels agree (100.000 %)
  Flag raised 3055 times in file1.
  Flag raised 3055 times in file2.
Bit # 22 : B_CLOUD - 1131089 pixels agree (100.000 %)
  Flag raised 387633 times in file1.
  Flag raised 387633 times in file2.
Bit # 23 : B_LAND - 1131089 pixels agree (100.000 %)
  Flag raised 675248 times in file1.
  Flag raised 675248 times in file2.
```

The data used:

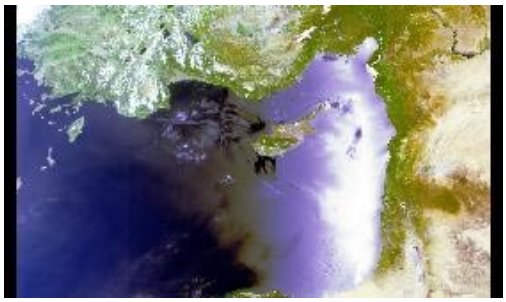
All together, for trouble-shooting the L1b and L2 processors, 39 images were used. Of these 39 images, 10 images were real (and thus 29 simulated using forward models), and 4 were of full resolution (the others being of reduced resolution). These images were chosen so as to exercise at most all the different branches and corrections of the processing. That is why the images that were chosen covered case 2 waters, case 1 waters, clouds of different kinds, highly glinted areas, deserts, areas with dark vegetation, areas with mountains etc. A subset of the images that were used are shown below in RGB mode:

Simulated Image:

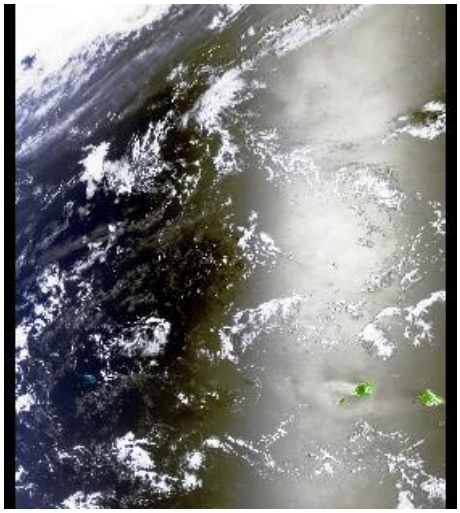
Brittany:



Cyprus:



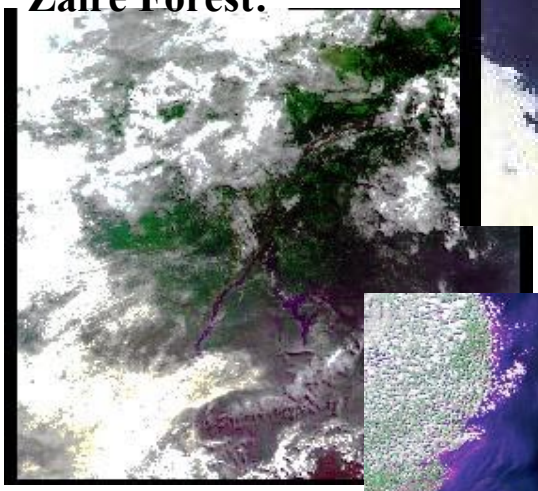
Canarian Islands:



Adriatic:

Straight of Ormuz:

Zaïre Forest:



Zeeland:

The results:

The following table presents the number of values produced on each simulated image that showed more than 1 quantification step of difference.

	# of pixels	water	land	cloud	# of values w/ more than 1 quantif. step
OceanColour	234289	202415	457	23475	0
Pressure	19057	16979	0	1432	0
RectRef	36993	202	32790	1920	0
SurfAlb	19057	6774	10770	969	0
case1_30	234289	201710	462	24175	0
case2_50	288097	274969	6960	0	0
cloud_35	288097	0	0	280901	1
land_45	36993	202	32790	1920	0
SatRad	19057	6774	10770	969	1
SatRad_b01	19057	6774	10770	969	1
SatRad_b02	19057	6774	10770	969	1
SatRad_b03	19057	6774	10770	969	1
SatRad_b04	19057	6774	10770	969	1
SatRad_b05	19057	6774	10770	969	1
SatRad_b06	19057	6774	10770	969	1
SatRad_b07	19057	6774	10770	969	1
SatRad_b08	19057	6774	10770	969	1
SatRad_b09	19057	6774	10770	969	1
SatRad_b10	19057	6774	10770	969	1
SatRad_b11	19057	6774	10770	969	1
SatRad_b12	19057	6774	10770	969	1
SatRad_b13	19057	6774	10770	969	1
SatRad_b14	19057	6774	10770	969	1
SatRad_b15	19057	6774	10770	969	1

Table 1: discrepancies identified on Level 2 simulated images

Note that the number of values here does not mean number of pixels as for any given pixel at least fifteen different values are produced. A single pixel of water may show 16 different values between the two processors (e.g. the 13 water leaving reflectances, the Chlorophyll concentration, the aerosol optical thickness and the epsilon value).

The following table presents a summary of the results that were obtained using the real image; here again the agreement was thought to be excellent.

	# of pixels	water	land	cloud	# of values w/ more than 1 quantif. step
Adriatic	969665	499542	403935	7895	4
Bretagne	897921	341484	155988	361442	18
Canaria	1400129	1107408	2571	224210	730
Cyprus	736497	324807	311240	67272	109
Ormuz	575073	210621	314103	23673	23
Zaire	1131089	3055	675248	387633	1
Slovenia	790305	3847	683656	63532	26

Table 2: discrepancies identified on Level 2 real images

Likewise for the previous table the number of values does not correspond to a number of pixels.

The following table shows were the differences were found in terms of products.

	Number of pixels with differences greater than one quantification step	Worst difference
Rho_412	151	167
Rho_442	123	133
Rho_490	105	54
Rho_510	99	22
Rho_559	88	11
Rho_619	80	6
Rho_664	69	4
Rho_681	62	4
Rho_708	59	25
Rho_753	14	2
Rho_778	1	3
Rho_865	0	NA
Rho_885	0	NA
WVAP	44	8
CHL_1	12	19
TOAVI	0	NA
CTP	3	3
YS	0	NA
SPM	0	NA
RECT_RHO_IR		
RECT_RHO_NIR	0	NA
CHL_2	0	NA
BOAVI	0	NA
PRES	0	NA
PAR	6	3
C_ALB	0	NA
EPSILON	1	2
AERO_THICK	9	6
CLOUD_THICK	0	NA
CLOUD_TYPE	1	3

Table 3: discrepancies identified on Level 2 real images organised by product

As it may be seen, the worst differences occur for the reflectances (water leaving for water, cloud top for clouds, and aerosol top for land); this is due to the fact that reflectance is the product that is coded on the most amount of quantification steps (two bytes when the chlorophyll is coded on one byte). Moreover, as it may be seen, agreement degrades towards the blue; this is due to the fact that the atmospheric correction are based on red and NIR channels and as the spectrum is being extended towards the blue a very small difference in the red may result in a much larger error in the blue. Also, it must be kept in mind that over 7 millions of Level 2 pixels were considered altogether in this analysis; 151 pixels are therefore considered to be completely negligible. Moreover, it is the worst difference that is

being shown here – it does not mean that all identified pixels have this error (histogram distribution of errors is also provided in the analysis).

The following table presents a summary of the agreement that were found concerning the flags. The figure that is given here for each flag is the worst result taken over the collection of results of all images used in the analysis.

	Worst agreement (target is 100%)
B_LOW_PRESSURE	99.9996 %
B_P_CONFIDENCE	99.9999 %
B_HIGH_GLINT	99.9790 %
B_DDV	99.9999 %
B_MEDIUM_GLINT	99.9790 %
B_ICE_HAZE	100.000 %
B_CASE2_Y	100.000 %
B_CASE2_A	99.9787 %
B_CASE2_S	99.9996 %
B_ABSOA_DUST	99.9944 %
B_ABSOA_CONT	99.9970 %
B_SUSPECT	100.000 %
B_COSMETIC	100.000 %
B_COASTLINE	100.000 %
B_PCD_19	99.8873 %
B_PCD_18	99.9949 %
B_PCD_17	99.9990 %
B_PCD_16	99.9990 %
B_PCD_15	99.9961 %
B_PCD_14	100.000 %
B_PCD_1_13	99.8553 %
B_WATER	100.000 %
B_CLOUD	100.000 %
B_LAND	100.000 %

Table 4: discrepancies identified on Level 2 flags

The differences have become so small that it was thought that they were of numerical origin and in any case would not be scientifically meaningful. It was found that some differences were related to the ECMWF pressure values in the sense that when applying its scaling factor (when decoding the values), some pixels would end having their path reflectance pressure corrected in one case and not in the other (the criteria is there based on a pressure threshold, see Equation 2.6.9.1-8 of L2 DPM v5.0 page 8-41).

The equivalent analyses were performed for trouble shooting the Level 1b processor and it was also concluded that the differences were scientifically not meaningful and that they could be explained by numerical errors.

Conclusion and perspectives:

The agreement between the IPF and the prototype software for the L1b and L2 MERIS processing were scientifically not meaningful at the end of the trouble shooting exercise on 26 July 2002; they were thought to be due to numerical errors. This assumption was investigated and clear source of a numerical error was identified in the Level 2 processing.
Since the Level 1b and Level 2 specifications were updated in Fall 2002 to include a smile correction, an improved transmittance correction, and other minor updates there is a risk that the prototype and the operational software will diverge again in 2003. A trouble-shooting activity will therefore most likely be done again once the updates have been transferred into the operational software.