QC Report for ASAR Medium Resolution Products processed under the DSI Bulk Processing Campaign

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
1.0	30/05/2017	First issue
1.1	21/07/2017	Updated issue after initial comments
1.2	03/10/2017	Updated after receiving feedback from Task 2 team and software maintainer, MDA, on the outstanding investigations
1.3	21/02/2018	Updated with remaining feedback from the software maintainer, MDA, on the outstanding investigations

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1. INTRODUCTION

This document provides the description and results of quality control checks performed on the Level 1 (L1) ASAR Medium Resolution products (APM, GM1, IMM and WSM). L1 Medium Resolution products have been generated as a result of a Data Services Initiative (DSI) ASAR Bulk Processing Campaign using the PF-ASAR v6.03.

All L1 products have been delivered to the IDEAS+ SAR Quality Control (QC) team through FTP. A selection of L1 products for each mode has been checked from the full dataset. This document provides a list of the products that were checked, details of the QC checks performed, QC results and conclusions.

1.1 References

RD.1 ENVISAT-1 Products Specifications, Volume 5: Product Structures, PO-RS-MDA-GS-2009, Issue 3D, 22/11/2007

RD.2 Volume 8: ASAR Product Specification, PO-RS-MDA-GS-2009, Issue 4C, 20/01/2012

RD.3 ASAR Bulk QC Tool Architecture, IDEAS+-VEG-TOO-REP-2327, Issue 2.0, 09/11/2016

RD.4 IDEAS – Envisat ASAR Performance Report, IDEAS-BAE-SOM-REP-1126, Issue 1.0, 08/11/2012

RD.5 Miranda, N., B. Rosich, P.J. Meadows, K. Haria, D. Small, A. Schubert, M. Lavalle, F. Collard, H. Johnsen, A. Monti Guarnieri & D. D'Aria, 2013, The ENVISAR ASAR mission: a look back at 10 years of operation, *Proc. 'ESA Living Planet Symposium 2013'*, Edinburgh, UK

2. QUALITY CONTROL PLAN

2.1 Introduction

2.1.1 Activity Overview

This bulk processing campaign was carried out in order to process all L0 ASAR data from the start of the mission to the end of 2005 to L1 medium resolution products: APM, GM1, IMM and WSM. The reason for this processing campaign was to provide users with a complete medium resolution dataset, instead of processing products on demand, as was performed operationally. As a result, a large proportion of the products processed during this bulk processing campaign have not been processed before.

Therefore, this activity is not a validation of a processor update, but a quality control (QC) activity to ensure that the bulk processing campaign is generating products of an expected level of quality. QC is only needed for products that will be made available to users, therefore only products after the end of the Commissioning Phase need to be checked, i.e. from 2002-2005 (note: GM products are only distributed to users from February 2004 onwards).

It was agreed that a sample of one month's worth of data would be checked for each of the four modes (approximately 4000 products in total). These products were selected at random from the full list of bulk processed products made available via FTP. For the purpose of this QC activity, the tests performed are described in the following sections. It should be noted that, as this is not a reprocessing activity (and therefore most products have not been processed before), it will not be possible to compare the majority of the bulk processed products with older product versions. Comparisons will only be possible if products processed on demand at one of the original PACs are still available and have the same validity as the bulk processed products.

2.1.2 Processor Changes

The processor used during this bulk processing campaign (PF-ASAR v6.03) is an updated version compared to that used during operational and on demand processing. The 57 'original' products used for the comparison activity were processed using a number of different processor versions, depending on when they were requested. These versions are:

- PF-ASAR v3.06 (3 GM1 products)
- PF-ASAR v3.08 (8 GM1 products)
- PF-ASAR v4.00 (2 APM products)
- PF-ASAR v4.01 (18 APM and 19 IMM products)
- PF-ASAR v5.04 (7 GM1 products)

These various processor changes will in turn introduce specific changes into the L1 ASAR medium resolution products undergoing QC. Changes that will be visible in the products themselves are investigated as part of our QC checks. The list below provides a brief description of the processor changes and the products these changes should have impacted:

Changes implemented in PF-ASAR v3.07

These updates will affect the 3 GM1 products processed using PF-ASAR v3.06:

1. Mean scene altitude introduction when calculating the geometry (affects the angles for Antenna Pattern correction calculated on high terrain areas)

Changes implemented in PF-ASAR v4.00

These will affect the 3 GM1 products processed using PF-ASAR v3.06 and the 8 GM1 products processed using PF-ASAR v3.08:

2. Fixed Delta Doppler coefficients to contain the difference between SS1 and SSN, rather than the actual coefficient for each sub-swath polynomial

3. Fixed a problem where the state vectors in MPP are consistent with start/stop time annotated in MPP, but last line time is not the same as the Zero Doppler time of the last Measurement Data Set Record in the swath

4. Fixed a problem where the WSC processor did not properly calculate timings when the first burst to process is not from SS1

Changes implemented in PF-ASAR v4.02

This update will affect the 2 APM products processed using PF-ASAR v4.00:

5. Corrected an anomaly discovered with the timing of AP mode, responsible for geolocation errors and inconsistencies in AP products generated by the PDS.

Changes implemented in PF-ASAR v4.03

This update will affect the 3 GM1 products processed using PF-ASAR v3.06, the 8 GM1 products processed using PF-ASAR v3.08, all APM and all IMM products:

6. Problem with ASAR MPH/SPH Geolocation Grid: Fixed ASAR geolocation grid values for stripline medium resolution products

This update will affect all IMM products:

7. Chirp annotation problems in IMM: Fixed chirp annotation timing problems for IMM products (SPR-100K0-0894-ESA)

Changes implemented in PF-ASAR v6.00

These updates will affect all products:

8. Calibration vector annotations added (‘Calibration Vector Reference Look Angle (per swath)’, ‘Gamma Calibration Vector’ and ‘Sigma Calibration Vector’ fields) and field values should be non-zero

9. Time since last ascending node annotation added (‘Elapsed time between the zero Doppler time of first output image line and the preceding ascending node’ field) and field values should be non-zero

These updates will affect all APM products:

10. Noise subtraction for APM and WSM products added (‘Noise Subtraction Applied (APP, APG, APM, WSM products only)’ field)

11. DRC failing for AP products: a fix to correct the problem that the receive gain correction in the DRC was not being initialised but the receive gain correction was being applied, resulting in small changes to the Doppler

This update will affect all GM1 products:

12. ASAR GM swath alignment anomaly: change to code so that the SWST for the first source packet is assumed to be correct and the first SWST of the first source packet of each swath has 10000 added to it if the first three SWSTs in a swath do not match (PR-10-05479)

This update will affect the 7 GM1 products processed with PF-ASAR v5.04:

13. Leap UTC now correctly annotated for Level 0 and Level 1 products. This issue was seen in higher level output products generated by ASAR Linux v5.02 onwards (NA-PR-09-04889, ASAR-NCR-09-04139)

Changes implemented in PF-ASAR v6.03

This update will affect all products:

14. Reference document and software version updated in MPH

This could affect all GM1 products:

15. L1 GM product Leap Sign fix: updated to consistently produce a correct leap sign value for Level 1 products (IDEAS+ Anomaly Report (AR) 160)

2.2 Bulk QC Tool Checks

Details of the tools used for these tests are provided in APPENDIX A.

2.2.1 Test 1 – MPH Check

This test ensures that all fields in the MPH match the expected formats as described in RD.1. A full description can be found in RD.3. The possible results of the QC test are:

- 1 – test passed
- 0 – test failed

2.2.2 Test 2 – SPH Check

This test ensures that all fields in the SPH match the expected formats as described in RD.2. A full description can be found in RD.3. The possible results of the QC test are:

- 1 – test passed
- 0 – test failed

2.2.3 Test 3 – ADF Validity Check

The four ADFs used in processing the ASAR product (CON, INS, XCH and XCA) are read from the relevant Data Set Descriptors (DSD) in the SPH. The ADFs are checked against a master list to ensure that they are the latest version and part of the consolidated ADF dataset. The validity period of each ADF is also checked to ensure that it completely covers the product being assessed. A full description can be found in RD.3. The possible results of these two tests are:

- 1 – test passed
- 0 – test failed

2.2.4 Test 4 – Product Information Check

The information in the product filename is checked against the corresponding header fields. This includes the filename, processing stage, originator, product start time, product duration, phase, cycle number, relative orbit, and absolute orbit. The file size is also compared to the expected size (calculated from the DSD, MPH and SPH sizes). A full description can be found in RD.3. The possible results of these QC tests are:

- 1 – test passed
- 0 – test failed

2.2.5 Test 5 – Doppler Centroid (D0) Validity Check

The D0 component of the Doppler Centroid is checked against user defined thresholds (-1500 to 1000 Hz). For products that have multiple Doppler Centroid Data Set Records (DSRs) each record is checked. A full description can be found in RD.3. The possible results of each of these QC tests are:

- 1 – test passed
- 0 – test failed for one or more DSR

2.3 Detailed Checks

Once the Bulk QC Tool checks are complete, detailed analysis is carried out on five products for each mode for each issue identified (or fewer if five products are not available). Details of the tools used for these checks are provided in APPENDIX B. These checks are outlined below:

2.3.1 Check 1 – Visual inspection

For this check products are opened and the product scene is visually inspected to identify any image anomalies. To pass this test no image anomalies should be present.

2.3.2 Check 2 – Missing lines

The product's Summary Quality Annotation Data Set (ADS) is read to identify whether the product contains any missing lines. To pass this test no missing lines should be present.

2.3.3 Check 3 – Corner coordinates

The scene corner coordinates are compared to the header coordinates taken from the SPH. To do this the SARCON Interpolated Corners geometry setting is used, unless the product is in the Polar Regions. In this case Interpolated Orbit is more appropriate. To pass this test both sets of corner coordinates should match to 3 decimal places (dp) (which corresponds to approximately 100 m accuracy at the Equator). Through this check is may also be possible to verify processor update #6 (problem with the MPH/SPH geolocation grid values).

2.3.4 Check 4 – Geolocation accuracy

Where possible, one or more features within a scene are used to check the geolocation accuracy. The feature coordinates are determined using SARCON, with the Interpolated Orbit geometry setting, and are then compared with the coordinates of the same feature in Google Maps. Features checked should have an elevation as near to sea level as possible. The recorded value will be the greatest offset seen in that image compared to Google Earth (see Figure 1 for an example).

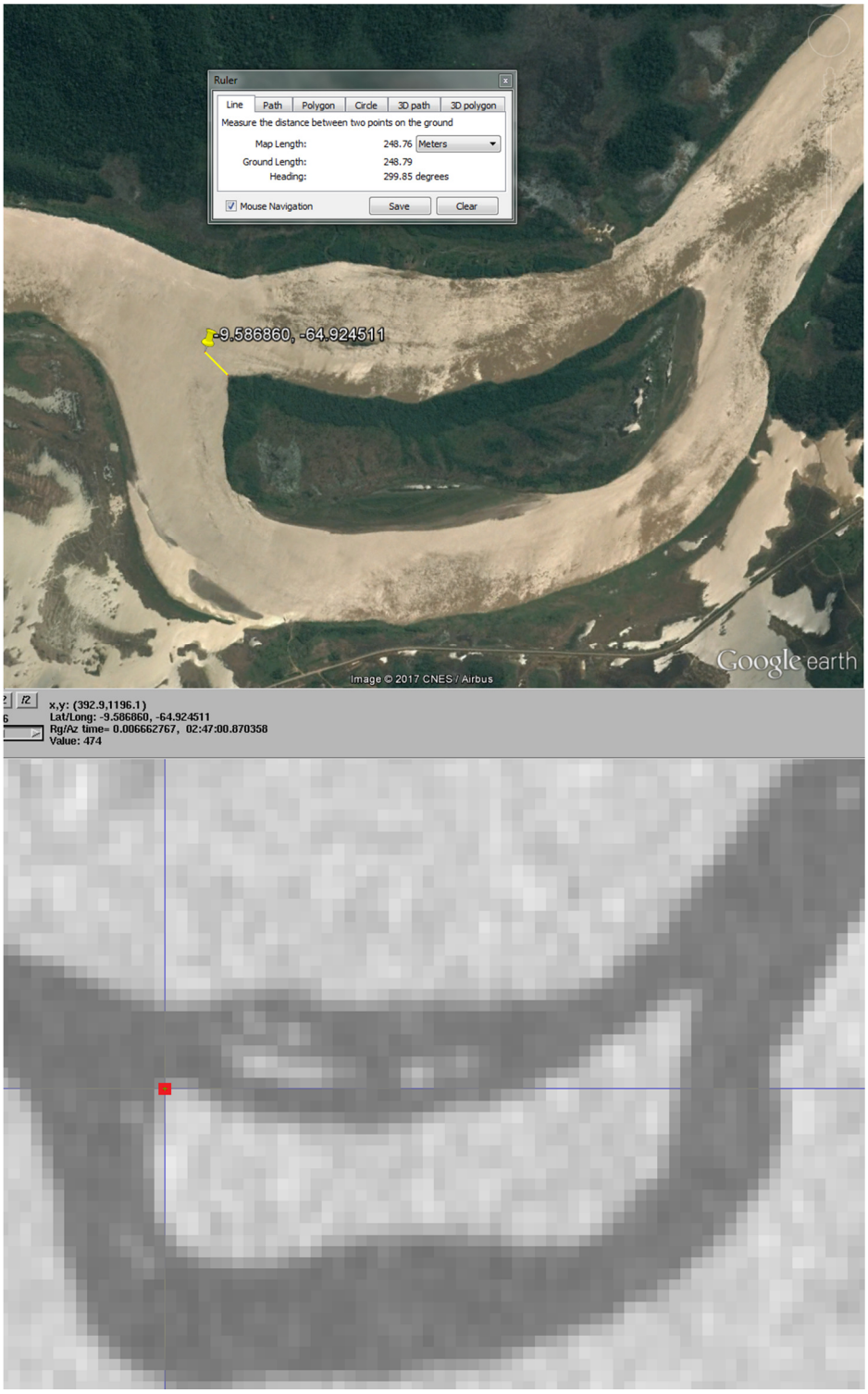


Figure 1 - Example of geolocation approach

RD.2 provides both the geometric resolution and geometric accuracy of all ASAR product types. The stated geometric accuracy of each product type is given in Table 1. To pass this test the geolocation accuracy should be less than or equal to the Pass/Fail Criteria, allowing a small tolerance to account for orbit errors (no more than few meters).

Table 1 - Expected geolocation accuracies as given in RD.2: ASAR Products Specifications

Product Type	Geometric Sampling	Geometric Resolution	Geometric Accuracy	Pass/Fail Criteria
APM	75 x 75 m	~150 x 150 m	25 m + orbit data error	~25 m
GM1	500 x 500 m	~1000 x 1000 m	1000 m + orbit data error	~ 1000 m
IMM	75 x 75 m	~150 x 150 m	150 m + orbit data error	~150 m
WSM	75 x 75 m	~150 x 150 m	150 m + orbit data error	~150 m

2.4 Comparison with 'Original' Products

Where possible, reprocessed products are directly compared to 'original' products processed operationally that have the same product start times and durations, based on the filenames. This allows non-regression testing to be carried out. For this QC activity the following checks are performed.

2.4.1 Bulk QC Tool

The original and reprocessed products are run through the Bulk QC Tool that performs the five tests described in Section 2.2. The results of these checks are compared to identify any changes between the two datasets.

2.4.2 Detailed Checks

Detailed comparison checks are performed on all selected products. This includes Checks 1-4 described in Section 2.3, as well as the following additional checks. Please note that for the all detailed checks on the comparison products, a product will pass the test if the reprocessed image has an equal or improved level of quality compared to the original product. The test will fail if the reprocessed product has a reduced level of quality.

2.4.2.1 Check 4 – Geolocation accuracy

As well as the Geolocation accuracy check described in Section 2.3.4, a feature location check, or relative geolocation check, will be carried out. For this the product pairs are opened and distinctive features are selected for coordinate comparison. Due to the SNAP projection method and the way it displays the image coordinates, only features at the 'near' end of the image should be used. To pass this test the features should be within 3 dp of each other. Furthermore, processor update #4 (fix of WSC processor problem calculating timings when the first burst to be processed is not from SS1) and #5 (fix of an anomaly with the timing in AP products) can be verified through this check as timing errors will be reflected in geolocation errors and inconsistencies. It may also be possible to verify processor updates #11 and #12 as both Doppler Centroid and SWST changes can have an impact on geolocation accuracy.

2.4.2.2 Check 5 – Gaps between sub-swaths

This check is only applicable to GM1 and WSM products. These products are opened and the product scene is visually inspected to identify whether gaps are present between the sub-swaths. To pass this test no gaps should be present in the original or reprocessed images.

2.4.2.3 Check 6 – Product coverage

All products are analysed to compare the coverage of the original and reprocessed products. The analysis is performed looking at the latitude and longitude coordinates of image corner points, at timing information and at product Google Earth overlays.

To pass this test the image coverage of both products should be almost identical: some differences are expected due to changes in the processor configuration (slight differences in the data cut strategy); a maximum 1% difference w.r.t. the original image coverage is considered acceptable. Coverage preservation is also considered a mandatory requirement for the generation of GM data mosaics, in order to avoid the introduction of holes.

2.4.2.4 Check 7 – Radiometric normalisation

To pass this check the original and reprocessed products should have the same calibration profiles. Minor, negligible differences in the order of 0.1/0.2 dB are acceptable and are attributed to the update of auxiliary processing files, in particular Elevation Antenna Patterns and External Calibration Constants (see APPENDIX B). Furthermore, this check can be used to verify processor update #1: introduction of a mean scene altitude when calculating the geometry.

2.4.2.5 Check 8 – Radiometric resolution

To pass this check the equivalent number of looks (ENL) should be preserved between the original and reprocessed products. Minor, negligible differences in the order of 5% are acceptable and are attributed mainly to the inability of selecting exactly the same portion of data in the two images and to the various updates of the processor.

3. BULK QC RESULTS

The number of products processed as part of this bulk processing campaign can be seen in Table 2 below. The 'Total number of products' is a count of all products made available on the FTP server. It was agreed that 1 month's worth of data would be checked for each mode; the requested number of products (5240) represents an estimate of 1 month of data. The number of products actually checked (9956) is significantly larger than this due to the FTP server setup and the way in which the Bulk QC Tool downloads products. This total also includes the 50 products of each mode used during the Bulk QC Tool test.

Table 2 - Number of products processed and QC checked

	APM	GM1	IMM	WSM	Total
Total number of products	8971	24901	49006	66260	149138
Number or products requested	240	2000	1200	1800	5240
Number of products checked	**674**	**4174**	**1509**	**3599**	**9956**
% of total products checked	7.51%	16.76%	3.08%	5.43%	6.68%

A list of all the products checked and the Bulk QC Tool test results for each product is available in APPENDIX A. These results are summarised in the table below and in the following sections:

Table 3 – Number of test failures (and as a percentage of products checked) per product type

Test	APM	GM1	IMM	WSM	Total Products Flagged	Result details
Test 1: MPH	9 (1.34%)	0	4 (0.27%)	0	13 (0.13%)	Section 3.1
Test 2: SPH	0	0	0	0	0	Section 3.2
Test 3: ADF	28 (4.15%)	0	0	69 (1.92%)	97 (0.97%)	Section 3.3
Test 4: Product Info	154 (22.85%)	382 (9.15%)	788 (52.22%)	2341 (65.05%)	3665 (36.81%)	Section 3.4
Test 5: Doppler Centroid	0	0	1 (0.07%)	0	1 (0.01%)	Section 3.5

3.1 Test 1 Results

In the test of the MPH fields, 13 products failed for the following fields:

- ***Field 5:*** 4 IMM products failed due to an invalid ACQUISITION_STATION field in the MPH. The station given was 'DLR-NZ', which is not one of the expected stations. However, previous reprocessing campaigns have also encountered data acquired from different stations, therefore this is not a concern
- ***Field 32:*** 9 APM products failed due to an invalid LEAP_SIGN field in the MPH. The field did not contain one of the expected values (+001, +000 or -001). The values were instead +018 or +184

Although the "DLR-NZ" acquisition station was unexpected, based on RD.1, this has no effect on the overall product quality.

Invalid LEAP_SIGN field values had previously been observed in GM1 products (processor update 15 listed in Section 2.1.2). This issue was tracked as IDEAS+ AR 160 and was due to a memory error that is sensitive to the platform used. A patch was implemented that solves the problem by implementing a minor change to the "ERSM_ERSControl" (ERSM_ERSMain) resulting in PF-ASAR v6.02 being updated to v6.03. No information was recorded in the AR on whether other modes were affected. However, as this issue has now been observed in APM products, further investigation was required.

With the assistance of the Task 2 team and the software maintainer, our investigations found that the issue was, in fact, due to these 9 APM products being processed with the old version of the processor: PF-ASAR v6.02. Once this was identified, the processor version of all products tested during this activity was checked. In total, 10% of all APM products checked (71 of 674) were processed using PF-ASAR v6.02. This issue does not affect the other modes, as they were all processed using PF-ASAR v6.03. Analysis of the processing times of the APM products showed that there is a gap in processing date between the 15th and 23rd of June 2015. All APM products processed on or before the 15th of June used PF-ASAR v6.02 and all those processed on or after the 23rd of June used PF-ASAR v6.03. Therefore, during this gap the processor must have been updated from v6.02 to v6.03. As a result, the AR tracking the issue of the invalid LEAP_SIGN field does not need to be reopened. Instead, it is recommended that all APM products processed using PF-ASAR v6.02 are reprocessed using the most recent version of the processor to remove all occurrences of this issue.

Test **FAILED** (failure percentage: 0.13%).

3.2 Test 2 Results

No SPH fields in the products failed this test.

Test **PASSED** (failure percentage: 0.00%).

3.3 Test 3 Results

In the test of the ADFs, 97 products failed for the following reasons:

- ***ADF coverage:*** 1 product failed as its validity crossed a XCA file boundary. As a result, 4 seconds at the end of the product do not have XCA coverage. However, the selected XCA is the most suitable as the majority of the product validity was covered
- ***ADF check:*** 96 APM and WSM products failed as the XCA file used was not on the master list. The XCA file has been replaced with newer files; however, the new files validity has changed, meaning that these products are no longer covered by any of the new ADFs. Further investigation found that this change in XCA file validity was intentional to exclude a period of poor data quality. Therefore, these 96 products are actually from a period of poor quality data and should not be available to users.

The failure due to ADF coverage has no effect on the product quality and is due to PF-ASAR being unable to select more than one XCA file to provide full coverage. Therefore this product is nominal.

The 96 products flagged due to the selection and use of an old ADF file should be removed from the EO Data Gateway as they are from a period of poor data quality. The

most up to date set of XCA files contain a gap so that coverage is not provided for the period of poor quality data (08:00:40 14/09/2005 to 19:57:33 16/09/2005), thus ensuring that products are not processed from this period. The reason that these 96 products were processed is because the DSI auxiliary file data set contained an old XCA file created in 2005. As this file is the only one that provided coverage it was selected. However, this file should not have been available for use, so these products were wrongly processed and should not be part of the available dataset. The original information on this period of poor data is provided on the SPPA website, in the table of all product anomalies. All other products which fall within this period of poor quality data, but not included in this test, should also be removed. Full details are provided in the Conclusion (Section 6).

Test **FAILED** (failure percentage: 0.96%).

3.4 Test 4 Results

In the product information test 3665 products failed for the following reason:

- ***Filename duration:*** 3665 products failed because the duration calculated by the tool, using the SPH start/stop times, differed from that recorded in the product filename. On further investigation, this was found to be due to differences in rounding (the Bulk QC tool rounds all times down). In all cases, the difference was only 1 second.

These failures were found to be due to differences in the way in which the ASAR processor and the Bulk QC tool calculate product duration, but are not an indication of poor product quality. Therefore, these products are nominal.

Test **PASSED** (failure percentage: 0.00%).

3.5 Test 5 Results

In the Doppler Centroid test, 1 IMM product failed for the following reason:

- ***D0 thresholds:*** the D0 values in 3 of the 24 DSRs of this product fell outside the thresholds of -1500 to 1000 Hz (values of: -1581.57, -1697.82 and -1817.06). This issue only affected the IMM product: ASA_IMM_1PNDSI20050306_083103_000000372035_00179_15764_0000.

This product was investigated further and was found to contain an image anomaly: curved ends (see Section 4.1). The product acquisition times were used to check whether the product was acquired during or close to a manoeuvre, but it was not. The curved ends could be a result of these high Doppler Centroid values, in particular if the values vary greatly in the range direction. Since the product has not been acquired close to a manoeuver and, given that the scene is mainly over ocean, the origin of the high Doppler Centroid values could be geophysical (ocean currents). This seems to be confirmed looking at the estimated (and annotated) Doppler Centroid polynomials (Doppler Centroid grids not available), presenting very high values over ocean. Further details on the analysis of this product are provided in Section 4.1.

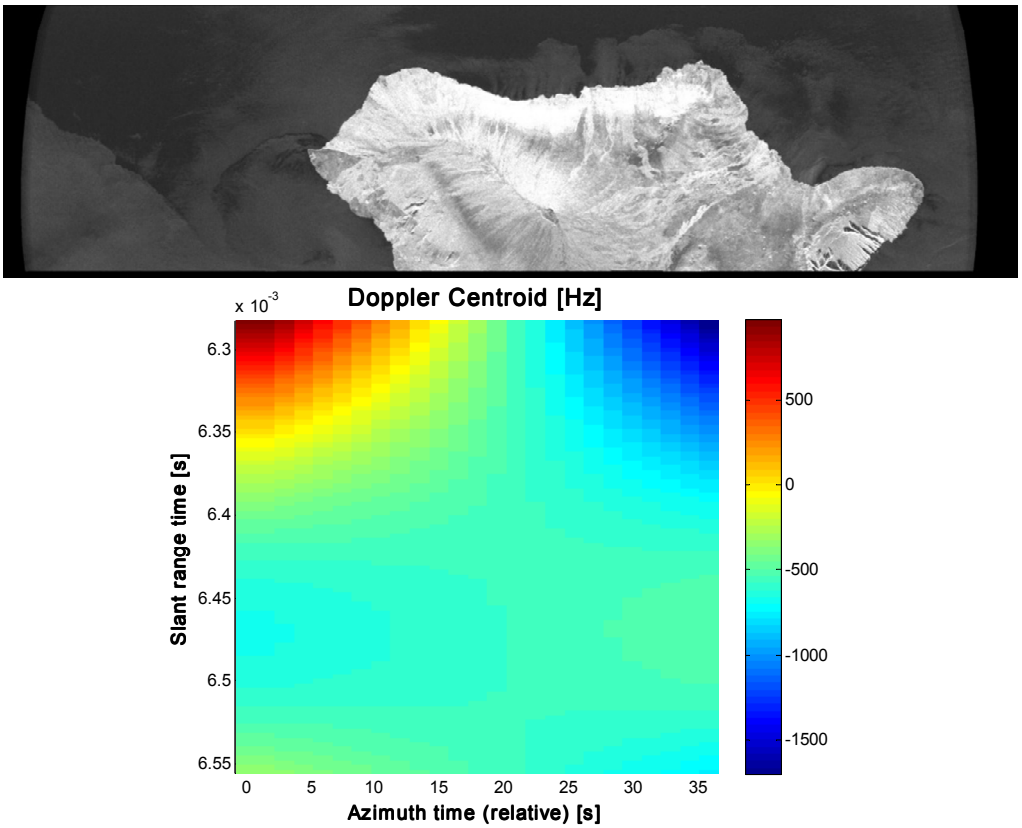


Figure 2 - Estimated Doppler Centroid polynomials for product ASA_IMM_1PNDSI20050306_083103_000000372035_00179_15764_0000. Credit: Aresys.

As only one single product has failed this test (out of the total 9956 checked), overall this test is considered to have passed.

Test **PASSED** (failure percentage: 0.01%).

3.6 Bulk QC Summary

The table below summarises the results of these tests, updated from Table 4 to account for our further analysis into flagged products. Note that the percentage failure in the Result column may be different from that in the Products Flagged column as this takes into account our analysis and findings. The full results are given as Pass or Fail (in red text for easy identification) in APPENDIX A.

Table 4 - Bulk QC test result summary (with percentage failure rate)

Test	Products Flagged	Result
Test 1: MPH	13 (0.13%)	**FAIL** (0.13%)
Test 2: SPH	0 (0.00%)	**PASS** (0.00%)
Test 3: ADF	97 (0.97%)	**FAIL** (0.96%)
Test 4: Product Info	3665 (36.81%)	**PASS** (0.00%)
Test 5: Doppler Centroid	1 (0.01%)	**PASS** (0.01%)

To summarise, 9 APM products were found with an incorrect LEAP_SIGN field value. An AR tracked this issue in GM1 products (IDEAS+ AR 160) and was closed in PF-ASAR v6.03. The importance of the original PR was 'normal'. The reason that this issue has arisen is due to some (~10%) of the APM dataset checked being processed using an old version of the processor (PF-ASAR v6.02). To remove all cases of this issue we recommend that all products processed using v6.02 are reprocessed using PF-ASAR v6.03. The affected products are listed as 'Fail' for Test 1 in APPENDIX A in red text for easy identification. This problem may also affect other products in the bulk processed dataset not highlighted in this report; however, this issue is considered **Not Critical** and should not delay the release of the data.

As described above, 96 APM and WSM products were flagged for using an old XCA ADF file. Normally it would be recommended that these products be reprocessed with the most recent XCA ADF file available, however as these products were from a period of poor data quality the more recent auxiliary file excluded this time period to prevent these products being processed. Therefore our recommendation is that these products are not made accessible to users. The affected products are listed as 'Fail' for Test 3 in APPENDIX A in red text for easy identification. Any other products in the bulk processed dataset that may be affected by this issue should be identified and removed. This issue is considered **Critical**.

Finally, 1 IMM product failed the Doppler test, having some D0 values below the lower threshold. This product also contains an image anomaly (reported in a later section). The reason for the high D0 values is discussed in more detail in Section 4.1. As only one product failed this test out of the 9956 checked, this issue is not expected to occur regularly, and therefore, this issue is considered **Not Critical** and should not delay the release of the dataset.

With the exception of these 106 products, based on these tests, all remaining products checked are of good quality and can be made available to users.

4. DETAILED CHECK RESULTS

Detailed analysis was performed on 5 products for each mode for each issue identified, where possible. The number of products checked in detail was as follows:

Table 5 - Number of products checked in detail (and as a percentage of all products checked)

Check Failed	Mode	No. of products Flagged in Bulk QC Tests	No. of these products Checked	
Test 1: MPH ACQUISITION_STATION	IMM	4	4	(100.00%)
Test 1: MPH LEAP_SIGN	APM	9	5	(55.56%)
Test 3: ADF Coverage	WSM	1	1	(100.00%)
Test 3: ADF Master List	APM, WSM	96	10	(10.42%)
Test 4: Product Info file duration	All	3665	20	(0.55%)
Test 5: Doppler Centroid	IMM	1	1	(100.00%)
Total		3776	41	(1.09%)

A list of the products checked and the detailed check results for each product is available in APPENDIX B. The results are summarised in the following table and sections.

Table 6 – Number of check failures per product type (and as a percentage of products checked)

Check	APM	GM1	IMM	WSM	Total Products Flagged	Result details
Check 1: Visual inspection	3	2	1	11	17 (41.46%)	Section 4.1
Check 2: Missing lines	4	0	1	0	5 (12.20%)	Section 4.2
Check 3: Corner coordinates	2	4	2	6	14 (34.15%)	Section 4.3
Check 4: Geolocation accuracy	14	0	8	8	30 (76.92%)	Section 4.4

4.1 Check 1 Results

The visual inspection check identified a range of image anomalies in 17 products, as detailed below:

- ***Bright interference:*** 2 images (1 APM, 1 GM1) were affected by this anomaly
- ***Bright natural point targets:*** 1 APM image was affected by this anomaly
- ***Visible azimuth/swath lines:*** 12 images (2 GM1, 10 WSM) were affected by this anomaly (see Figure 3)
- ***Curved ends:*** 2 images (1 APM, 1 IMM) were affected by this anomaly (see Figure 4). The APM image is over Germany and has a slightly curved far end. The IMM product is over Hawai'i and has significantly curved near and far ends.

- ***Unfocussed image:*** 1 APM image was affected by this anomaly (see Figure 5) and is the same APM image that contains the bright interference. This image is over the Netherlands.

Both the bright interference and bright natural point targets are due to features in the image and cannot be changed. Therefore they are considered nominal and were not included in the failure percentage.

The remaining 15 anomalies are related to the processor. The image with curved ends over Hawai'i also failed the Doppler Centroid test in the previous section. This issue has been observed in ASAR data in the past (see RD.4 for example). However, these issues were raised with the software maintainer, via the Task 2 team, for further investigation and to identify whether these are issues for which a fix could be implemented in future. Feedback from the software maintainer is as follows:

- ***Visible azimuth/swath lines:*** In the WSM example, there is a significant Doppler Centroid estimate change over a relatively short period. This is known to give rise to visible swath lines and is caused by poor quality Doppler estimates. As the problem is inherent in the Doppler Centroid estimate algorithm, which would require significant changes to improve results, it will not be addressed at present.

- ***Curved ends:*** The artifacts in the IMM example are also suspected to be caused by poor quality Doppler Centroid estimates. As with the anomaly above, an update to the Doppler Centroid estimate algorithm is not planned at present.

- ***Unfocussed image:*** The affected product comes from early in the mission when there were problems with the echo window timing and other issues specific to AP mode. Therefore, this issue is not a feature created by the processor.

Test **FAILED** (failure percentage: 36.59%).

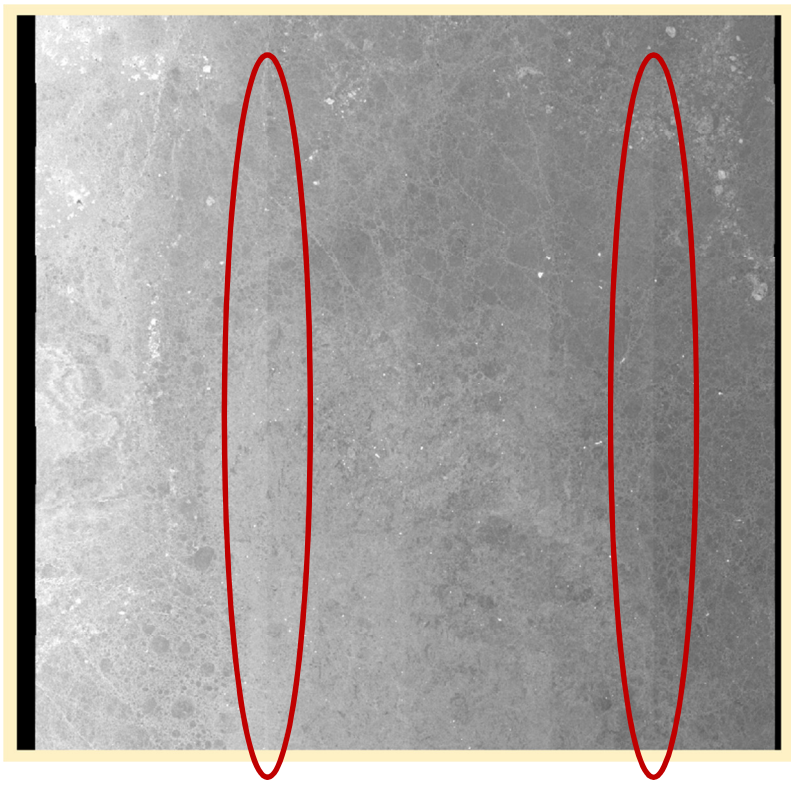


Figure 3 - Example of visible azimuth/swath lines (two lines circled) from product ASA_WSM_1PNDSI20031202_035817_000001902022_00104_09176_0000

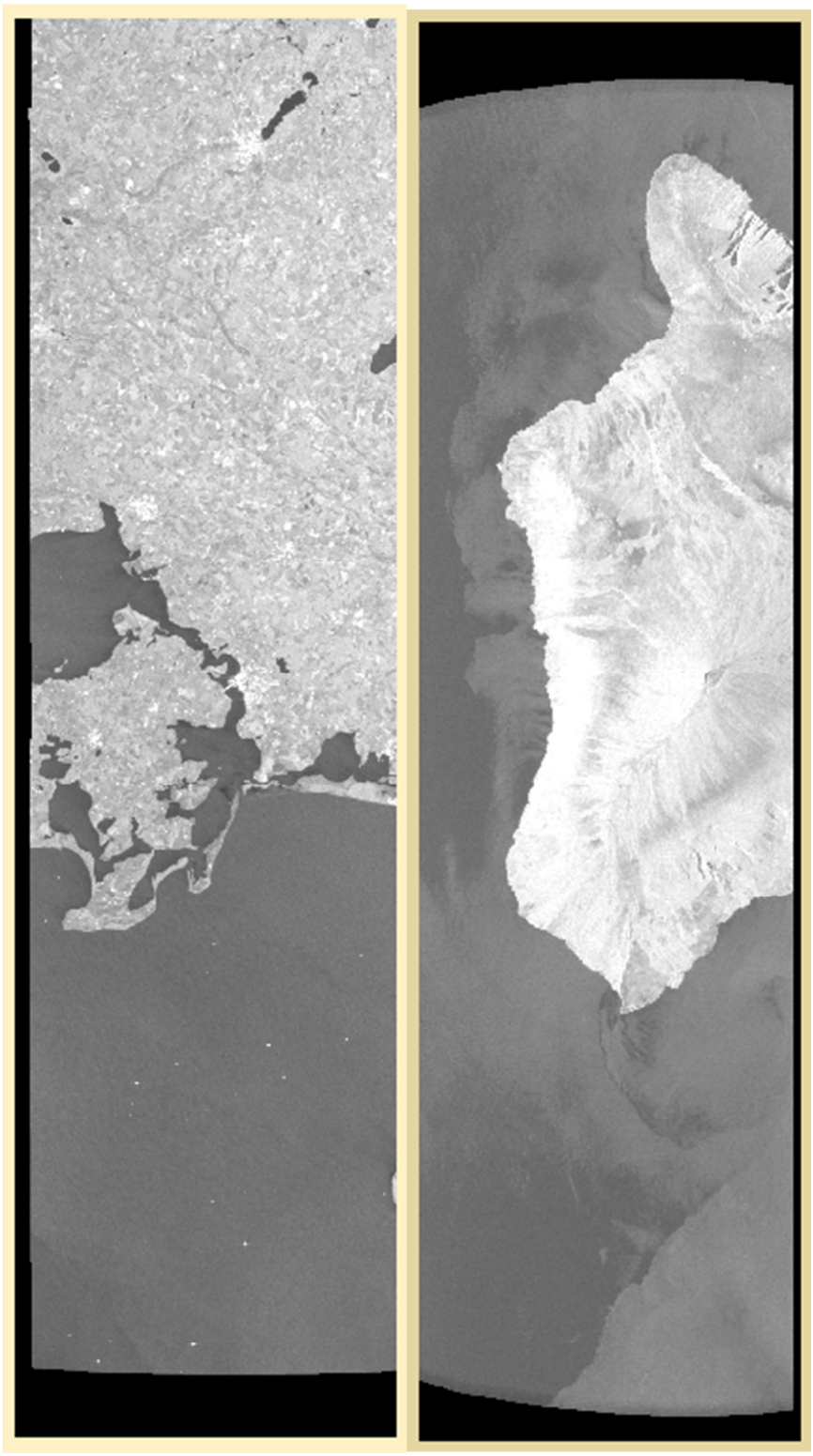


Figure 4 – Left: slightly curved far end affecting the APM product (ASA_APM_1PNDSI20050915_205906_000000672040_00444_18534_0000). Right: distinctive curved near and far ends of the IMM product (ASA_IMM_1PNDSI20050306_083103_000000372035_00179_15764_0000)

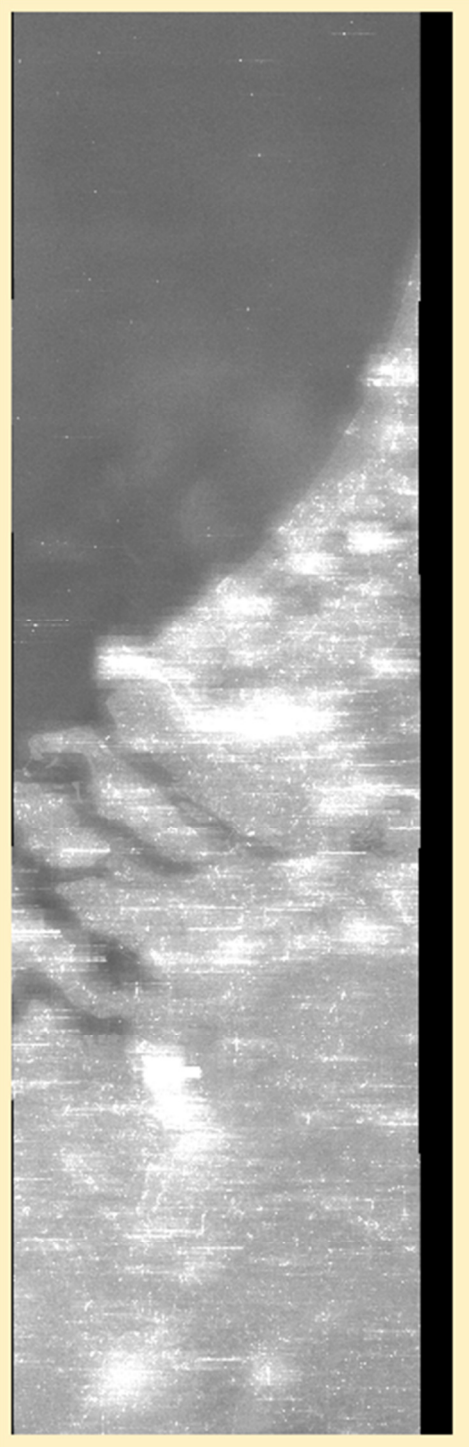


Figure 5 - Example of an unfocussed image from product (ASA_APM_1PNDSI20030512_213252_000000932016_00201_06267_0000)

4.2 Check 2 Results

In this check, 5 products (4 APM and 1 IMM) were found to have missing lines. However, as the number of missing lines (range 4 to 32) was small and did not affect the overall product quality this test has been recorded as passed.

Test **PASSED** (failure percentage: 12.20%).

4.3 Check 3 Results

The corner coordinates check revealed the following results:

Table 7 - Corner Coordinates results

Degree of accuracy	APM	GM1	IMM	WSM	Total
All corners precise to 3 dp or better	13 (87%)	1 (20%)	8 (80%)	5 (45%)	27 (66%)
One or more corners precise to only 2 dp	2 (13%)	2 (40%)	2 (20%)	4 (36%)	10 (24%)
One or more corners precise to only 1 dp	0	2 (40%)	0	2 (18%)	4 (10%)

All 27 products that were within 3 dp, or better, are considered to be of good quality. Those with a worse accuracy (14 products) have failed this test. Further investigation found that all products with poor corner precision, with the exception of two GM1 products, were over the Arctic or Antarctica, which causes problems with how SARCON interpolates the coordinates.

Test **FAILED** (failure percentage: 34.15%).

4.4 Check 4 Results

This check compared selected features in the image to Google Earth to check the geolocation accuracy. Two products could not be geolocated due to high elevations or a lack of suitable features. The results were as follows (full results in APPENDIX B):

Table 8 - Geolocation results (thresholds as stated in Section 2.3.4)

Geolocation Result	APM	GM1	IMM	WSM	Total
Within threshold	0	5 (100%)	2 (20%)	2 (20%)	9 (23.08%)
Exceeded threshold	14 (100%)	0	8 (80%)	8 (80%)	30 (76.92%)

In summary, only 9 of the products checked met the expected geolocation accuracy and the remaining 30 failed this test. The orbit file usage was investigated and all products checked correctly used the DORIS Precise Orbit State Vector (DOR_VOR_AX) files. However, it was concluded that, due to issues identifying features both in the ASAR images and in some cases in Google Earth (no images were available for this activity that over stable targets, such as transponders), this test was inconclusive. A more suitable test of geolocation accuracy is presented in Section 5.3.4 where newly processed products are compared to original products processed operationally.

Test **FAILED** (failure percentage: 76.92%).

4.5 Detailed Checks Summary

The table below summarises the results of these tests. The full results are given as Pass or Fail (in red text for easy identification) in APPENDIX B.

Table 9 – Detailed check result summary

Test	Result
Check 1: Visual inspection	**FAIL** (36.59%)
Check 2: Missing lines	**PASS** (12.20%)
Check 3: Corner coordinates	**FAIL** (34.15%)
Check 4: Geolocation accuracy	**FAIL** (76.92%)

To summarise, visual anomalies were identified in 15 products, which are related to the processor or instrument, rather than natural features. Following investigation of these issues, it was agreed that the low number of occurrences does not justify an update to the processor. These specific anomalies have no other adverse impact on the quality of the rest of the imagery. However, in its current state the unfocussed image will be of little use to users. While it is expected that a few products across the bulk processed dataset may contain image anomalies, this issue is considered **Not Critical** and should not delay the release of the data to users.

As described in Section 4.2, the five products that failed the missing lines test had so few missing lines that there was no other adverse effect on the image quality. It is expected that a few products across the bulk processed dataset may contain missing lines, but as all products were successfully processed the images will still be of use to users. Therefore this issue is considered **Not Critical.**

Analysis of the corner coordinate and geolocation accuracy tests found that the results were **Inconclusive** as the approach taken was too imprecise and no images were available for analysis over stable targets, such as transponders. However, further tests will be carried out in the following section to compare reprocessed products to original products to check whether the newly processed products are of an equal or improved level of quality.

5. COMPARISON RESULTS

In order to carry out comparison checks, operational or 'original' products and reprocessed products with the same filename start times and durations were identified. The number of matching pairs found for each mode is listed in Table 10.

Table 10 - Product pairs identified

Product type	Number of pairs
APM	20
IMM	19
GM1	18
WSM	0
Total	**57**

The results of the detailed analysis of these 57 pairs (114 products) are summarised in the following sections. It should be noted that only 7 product pairs had exactly the same times when checking the product headers and they were all GM1 products. All other products had times that were different by a few milliseconds.

5.1 Processor Changes

The expected changes to the products as a result of processor version updates were explained in Section 2.1.2. Evidence of these changes will be highlighted were relevant in the following sections. Changes that were not observed as part of the defined checks (as described in Section 2.3), but have been checked separately, are described below. To maintain consistency with the processor change descriptions in Section 2.1.2, the same numbers have been used below and in the following sections.

2. The update to change the Delta Doppler coefficients to be the difference between the sub swaths instead of the actual coefficient is visible between the GM1 products processed using PF-ASAR v3.06 and v3.08. This change is shown in Figure 6.

3. The fix implemented in PF-ASAR v4.00 to the last state vector in the Main Processing Parameters (MPP) so that it matches the Zero Doppler time in the last MDSR can also be observed by comparing these two values in the original and reprocessed products. This change is shown in Figure 7.

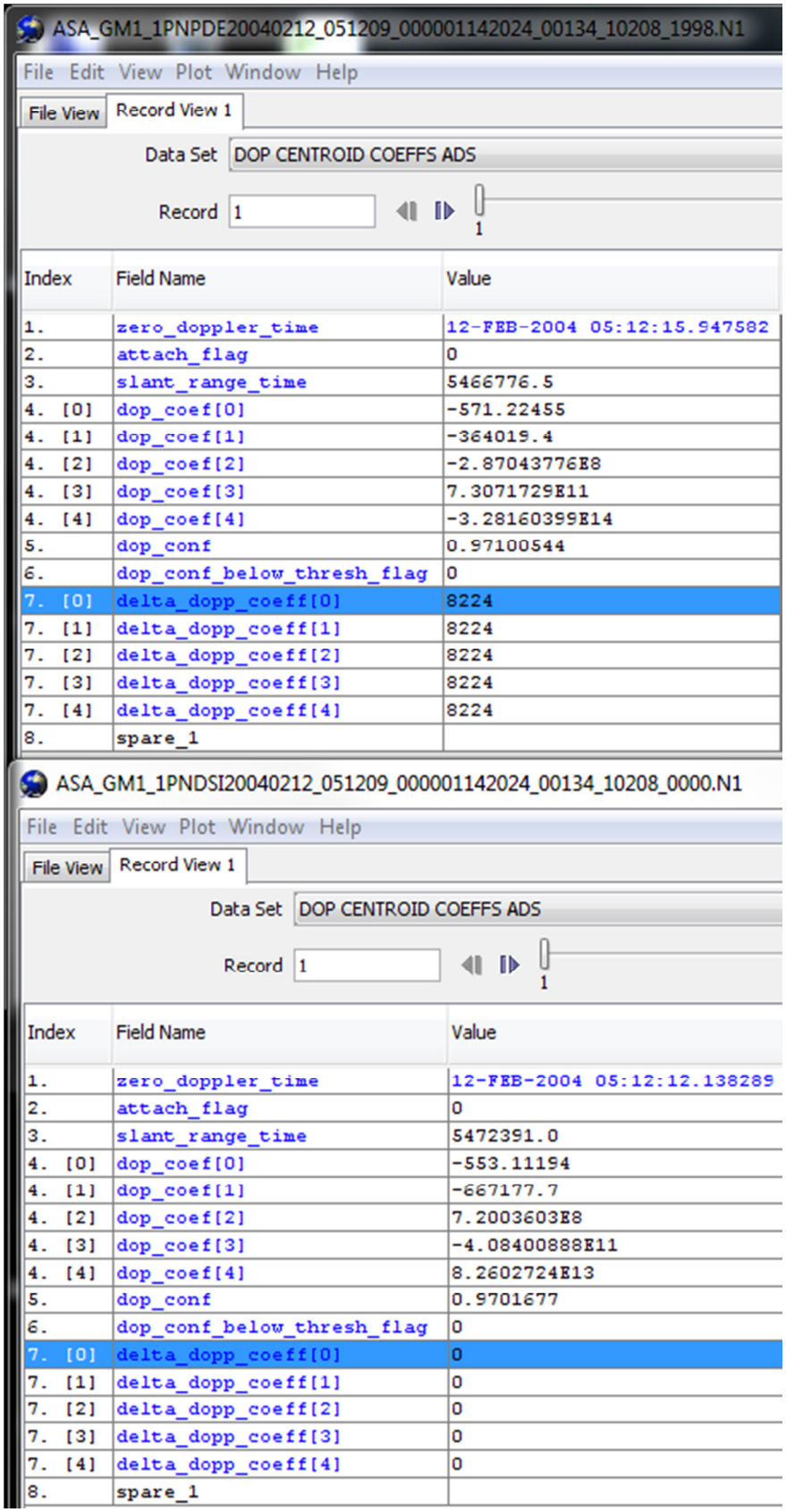


Figure 6 - Update to the Delta Doppler coefficients in GM1 products (field 7) between the original product (top) and the reprocessed product (bottom)

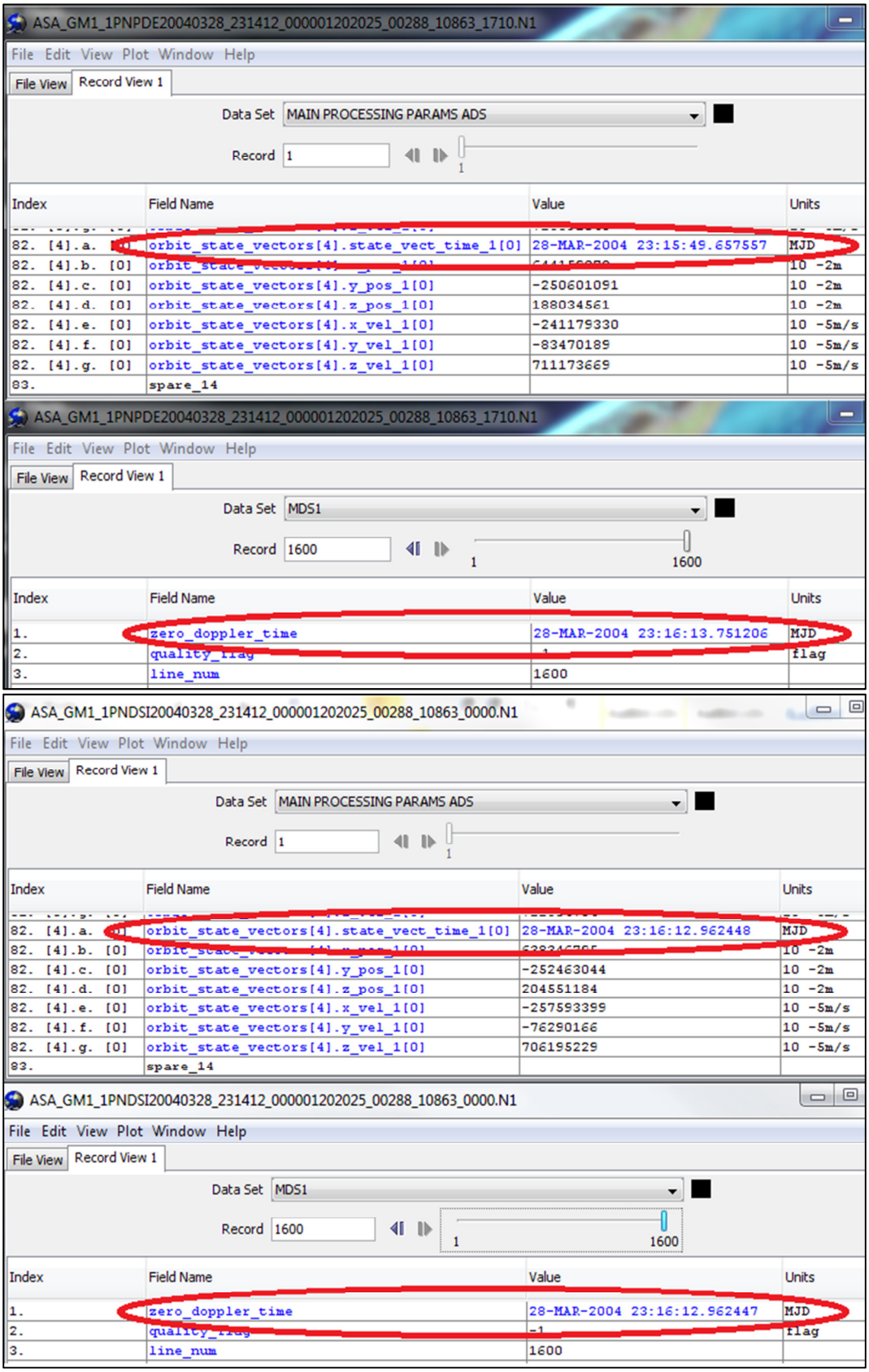


Figure 7 - The original product (top) shows that the State vector time does not match the last zero Doppler time, however, in the reprocessed product (bottom) the two times match confirming the fix to final orbit state vector time.

7. For the update to the chirp annotation timing problems in IMM, it has not been possible verify this update as no differences in the chirp annotations can be found. Furthermore, no more details on this SPR can be found currently. It is assumed therefore that this issue affected only some IMM products and the issue didn't occur in the subset of products checked in this activity.

8. The addition of the three new Calibration vector annotation header fields (Cal Vector Ref Look Angle, the Gamma Calibration Vector and the Sigma Calibration Vector as named by SARCON) can be confirmed by comparing the headers of the original and reprocessed products. It can be confirmed that all reprocessed products contain the new fields as expected (see Figure 8, lower image), whereas the original products do not (see Figure 8, top image).

9. The addition of the new Elapsed time header field (ANX as named by SARCON) can be confirmed by comparing the headers of the original and reprocessed products. It can be confirmed that all reprocessed products contain the new fields as expected (see Figure 8, lower image), whereas the original products do not (see Figure 8, top image).

10. The addition of the new Noise Subtraction applied flag header field can be confirmed by comparing the headers of the original and reprocessed products. It can be confirmed that all reprocessed products contain the new fields as expected (see Figure 8, lower image), whereas the original products do not (see Figure 8, top image).

```
ref_look_angle_IS1:           16.628000 deg
ref_look_angle_IS2:           20.138000 deg
ref_look_angle_IS3:           25.243000 deg
ref_look_angle_IS4:           29.533000 deg
ref_look_angle_IS5:           32.818000 deg
ref_look_angle_IS6:           35.633000 deg
ref_look_angle_IS7:           38.058000 deg
ref_look_angle_SS1:           19.163000 deg
Pointing error:               0.0000 deg


INS filename:        /home/Ideas/SARCON/qc_data/AUX_files/ASA_INS_AXVIEC20031209_113421_20030211_
```

```
ref_look_angle_IS1:           16.628000 deg
ref_look_angle_IS2:           20.138000 deg
ref_look_angle_IS3:           25.243000 deg
ref_look_angle_IS4:           29.533000 deg
ref_look_angle_IS5:           32.818000 deg
ref_look_angle_IS6:           35.633000 deg
ref_look_angle_IS7:           38.058000 deg
ref_look_angle_SS1:           19.163000 deg
Pointing error:               0.0000 deg

ANX: 41.308014
Noise Subtraction applied flag: 0
Calibration Vector Parameters
Cal Vector Ref Look Angle: 19.163000 25.243000 29.533001 32.818001 35.632999
Gamma Calibration Vector:

 1.095521e-08 1.099309e-08 1.103096e-08 1.106881e-08 1.110676e-08 1.114450e-08 1.118233e-08

 ...

Sigma Calibration Vector

 1.139446e-08 1.143709e-08 1.147975e-08 1.152244e-08 1.156526e-08 1.160789e-08 1.165066e-08
```

Figure 8 – Top: extracts from SARCON of the original product header (ASA_GM1_1PNPDE20040212_051209_000001142024_00134_10208_1998). Bottom: the reprocessed product header showing the new fields: ANX, Noise Subtraction applied flag, and Calibration Vector Parameters – Cal Vector Ref Look Angle, the Gamma Calibration Vector and the Sigma Calibration Vector (ASA_GM1_1PNDSI20040212_051209_000001142024_00134_10208_0000).

14. All Reference Document (REF_DOC) and Software Version (SOFTWARE_VER) fields were extracted from the original and reprocessed products. In the original products, the contents of these fields varied according to the document version that was correct at the time of processing. All reprocessed products correctly show the reference document "PO-RS-MDA-GS-2009_4/C" and software version "ASAR/6.03" as expected.

15. This update was implemented to fix an issue with the Leap Sign field in GM1 products. However, this issue did not affect all products and was not seen in any of the original products. Therefore, it is not possible to confirm that this issue has been fixed using the comparison dataset.

5.2 Bulk QC Tool Results

The first step of the comparison study involved running the original and reprocessed products through the Bulk QC Tool, to perform the five tests described in Section 2.2. A list of the products checked and the Bulk QC test results for each product is available in APPENDIX C, where the tests are given the status:

- **'Pass'** if the product pairs have the same quality level
- **'Updated'** if the original product was flagged due to something that is "out of date" now, but was considered correct at the time of processing
- **'Improved'** if the reprocessed product is better quality than the original product
- **'Degraded'** if the reprocessed product is worse quality than the original product.

Table 11 shows the number of flags for each check for the original and the reprocessed products.

Table 11 - Summary of Bulk QC test failures (and as a percentage of products checked)

Test	No. of Products Flagged		Result details
	Originals	Reprocessed	
Test 1: MPH	57 (100%)	0	See Section 5.2.1
Test 2: SPH	0	0	See Section 5.2.2
Test 3: ADF	57 (100%)	0	See Section 5.2.3
Test 4: Product Info	57 (100%)	4 (7.02%)	See Section 5.2.4
Test 5: Doppler Centroid	0	0	See Section 5.2.5

5.2.1 Test 1 Results

In the MPH fields check, no errors were flagged for the reprocessed products; however flags were raised for the original products for the following fields:

- ***Field 3:*** 50 original products failed due to an invalid REF_DOC field in the MPH. The reference document listed was an older version than that expected by the tool, but was correct at the time of processing
- ***Field 31:*** 7 original GM1 products failed due to an invalid LEAP_UTC field in the MPH. The field should contain the UTC time related to the leap second or should

be set to zero if not used. In these products this field was left blank, therefore this field was correctly flagged

The tool is set to expect the document name in the format of the most recent reference document; therefore, the old reference documents, which had a different format, were correctly flagged. All reprocessed products contain the most recent reference document "PO-RS-MDA-GS-2009_4/C" in the correct format as described in Section 5.1.

13. The LEAP_UTC MPH failures were seen in all 7 original GM1 products processed with PF-ASAR v5.04. This issue was tracked under NA-PR-09-04889 and ASAR-NCR-09-04139 and was fixed in processor version v6.03. For this reason the issue is not seen in the reprocessed products.

Therefore, both changes are expected due to processor updates and the reprocessed products are considered nominal.

Test **PASSED** (reprocessed failure percentage: 0%).

5.2.2 Test 2 Results

No SPH fields in the products checked failed this test; therefore the reprocessed products have the same level of quality as the original products.

Test **PASSED** (reprocessed failure percentage: 0%).

5.2.3 Test 3 Results

In the test of the ADFs, no errors were flagged for the reprocessed products; however flags were raised for the original products for the following fields:

- ***ADF check:*** all 57 products failed as one or more of the four ADFs used in processing were not on the master list. This is because more recent ADFs have been created since the original files were processed, replacing those available at the date of processing. The number of products with an older ADF version are as follows: AUX_CON_AX: 57, AUX_INS_AX: 50, AUX_XCA_AX: 50, AUX_XCH_AX: 51

All of the original ADFs were correct at the time of operational processing. However, the reprocessed products are using newer ADFs as expected. As part of investigations into the impact of using new auxiliary files, changes between file versions have been recorded in APPENDIX B.

Furthermore, the SWST bias values used in the original and reprocessed products, taken from 4 different INS files, were compared and checked against the expected value recorded in RD.5. All four INS products were found to contain the same SWST bias and they all matched the expected value of 5.0995E-7s.

Test **PASSED,** with the reprocessed products using updated auxiliary files.

5.2.4 Test 4 Results

In the product information test 57 original products and 4 reprocessed products were flagged for the following reasons:

- ***Filename originator:*** all 57 original products failed because the expected originator specified in the tool is 'DSI' whereas these products have different originators (PDE or PDK). Since the originators were correct at the time of processing, this is not a problem

- ***Filename duration:*** 4 product pairs (both original and reprocessed products) failed this test because the duration calculated using the SPH start/stop times differed from that recorded in the product filename. On further investigation, this was found to be due to differences in rounding (the Bulk QC tool rounds all times down). In all cases, the difference was only 1 second

As the difference in originator doesn't impact the product quality, the reprocessed products have the same quality as the original products.

Test **PASSED,** with the reprocessed products showing expected updates.

5.2.5 Test 5 Results

No Doppler Centroid values were flagged in the products (i.e. both the original and reprocessed products' Doppler Centroid values fall within the expected thresholds). Therefore the reprocessed products are considered to have the same level of quality as the original products.

A further check was performed to compare the Doppler Centroid values of the reprocessed products to those of the original product.

The 7 GM1 products that had exactly the same start and stop times were found to have the same Doppler Centroid values; therefore no change has occurred between these original and reprocessed products. These GM1 products were the 7 processed with PF-ASAR v5.04.

All other product pairs showed different Doppler Centroid values, ranging from differences <10 Hz to ~93 Hz. In particular:

- 45 pairs show mean Doppler Centroid differences below 10 Hz
- 12 pairs (4 APM, 5 GM1 and 3 IMM) show mean Doppler Centroid differences between 10 Hz and 42 Hz

All products with a mean Doppler Centroid difference of more than 10 Hz are considered to have failed this test. Investigation into the cause of these Doppler Centroid differences was tracked in RT under ticket #6332. The findings of the software maintainer are below:

"Some of these products were processed by versions of the processor released more than 10 years ago. Back then we were still processing on AIX using the old PF-HS interfaces. The big switch to Linux, with the new interfaces, was when the processor went from PF-ASAR 4.XX to 5.XX. One of the key differences when the interfaces changed was that, before 5.XX, the slicing of data for stripline products (WS, GM, APM, and IMM) was handled by PF-HS outside of the PF-ASAR processor. Now, the slicing and concatenation of slice products is handled inside the PF-ASAR processor. So, even if the times match between the old products and the new, what that means in terms of the actual imagery included in the products can be different – the lengths of slices and the amount of overlap may have changed, the location of the granules may have changed, etc. In other words, the blocks of data used in order to calculate the Doppler Centroid estimates likely changed between the old and new versions of the processor.

On top of that, there were other changes made to the multi-swath Doppler estimator (used for WS and GM) in the various 4.XX releases when WSS products were added and the calculation of "delta Doppler coefficients" was included. There were many other small changes that happened over time. We believe all of these reasons combined would explain these relatively small Doppler differences, and the main change is probably due to the change in stripline handling between AIX and Linux."

Based on this feedback, it can be concluded that the differences are due to processor algorithm changes and are not a change in product quality. The RT ticket has now been resolved.

Test **FAILED**, but with the differences in Doppler Centroid being due to processor updates.

5.3 Detailed Checks

Detailed comparison checks were performed on all matching product pairs, covering Checks 1-4 of Section 2.3 and Checks 5-10 of Section 2.4.2. A list of the products checked and the detailed check results for each product is available in APPENDIX C. The results are marked as:

- **'Pass'** if the product pairs have the same quality level
- **'Improved'** if the reprocessed product is better quality than the original product
- **'Degraded'** if the reprocessed product is worse quality than the original product.

The results for each check applied to the product pairs are summarised in Table 12.

Table 12 - Summary of Detailed check failures

Check	No. of Products Flagged		Result details
	Originals	Reprocessed	
Check 1: Visual inspection	7	6	See Section 5.3.1
Check 2: Missing lines	0	0	See Section 5.3.2
Check 3: Corner coordinates	8	8	See Section 5.3.3
Check 4: Geolocation accuracy	11	9	See Section 5.3.4
Check 5: Gaps between sub-swaths	0	0	See Section 5.3.5
Check 6: Product coverage	N.A.	N.A.	See Section 5.3.6
Check 7: Radiometric normalisation	N.A.	N.A.	See Section 5.3.7
Check 8: Radiometric resolution	N.A.	N.A.	See Section 5.3.8

5.3.1 Check 1 Results

The visual inspection check identified a range of image anomalies in 7 product pairs. However, only those where the reprocessed image showed a difference to the original product are described below:

- ***Curved ends:*** in 1 APM pair this anomaly affected the original product only (see Figure 9). This pair of products was situated over Burkina Faso, Africa. The different behaviour finds its origin in the different Doppler Centroid polynomials (see Figure 10): the higher range variation in the original image introduces the observed curved end.

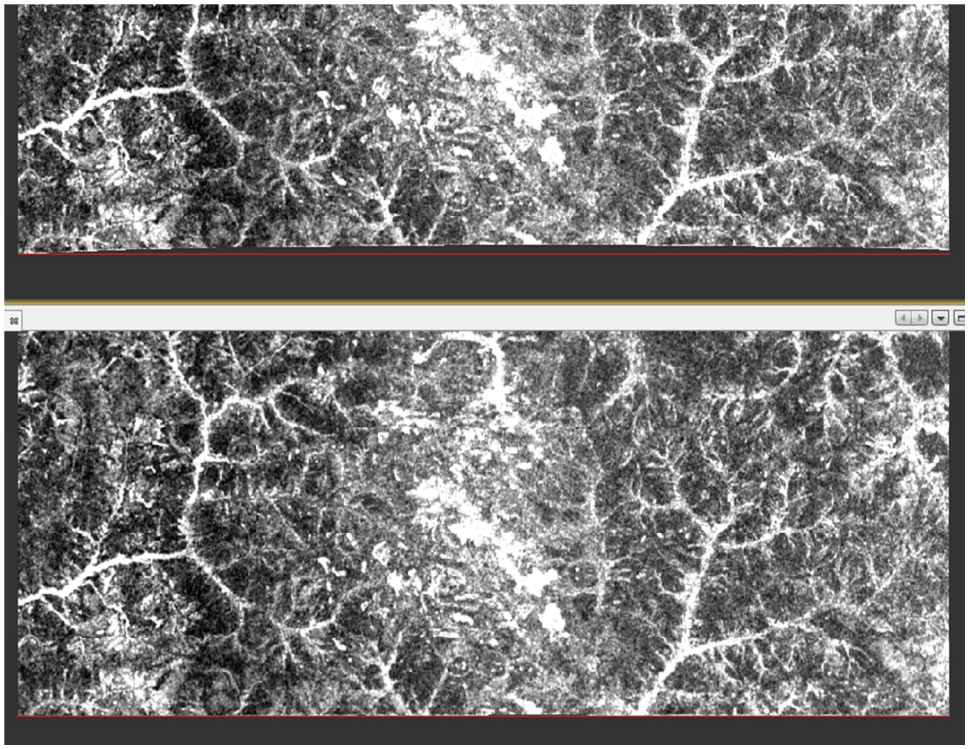


Figure 9 – Top: curved end (visible below the straight red line in the top image) is present in the original (ASA_APM_1PNPDE20050602_094634_000000582037_00437_17024_9257). Bottom: the issue has been corrected in the reprocessed image (ASA_APM_1PNDSI20050602_094634_000000582037_00437_17024_0000).

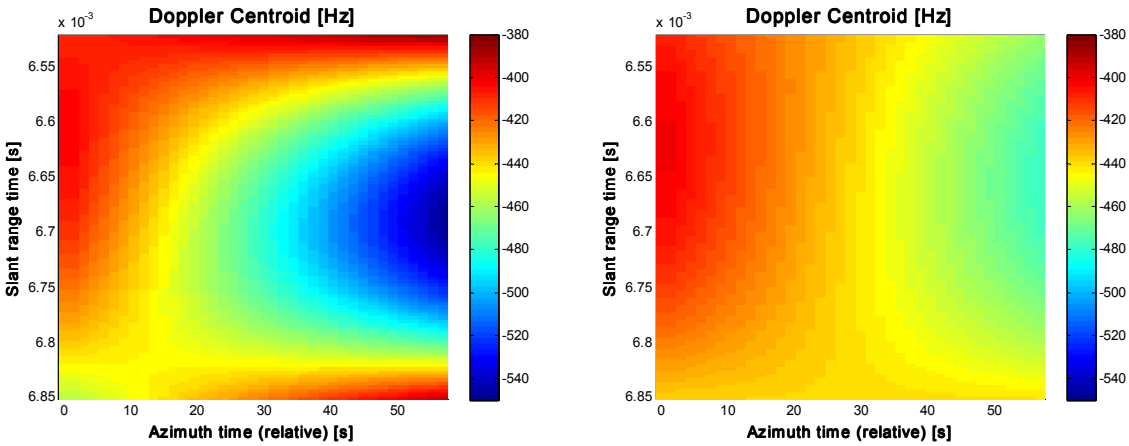


Figure 10 – Doppler Centroid polynomials for the images in previous figure (original on the left, reprocessed on the right). Credit: Aresys.

The difference between the original and reprocessed products shown in the two figures above can be linked to the investigations carried out for Test 5 above, where differences in Doppler Centroid values between product pairs were identified.

The original product, with the curved end, was processed with PF-ASAR v4.01 and the reprocessed image was processed using PF-ASAR v6.03. A major change to the processor occurred when the processor went from PF-ASAR v4 to v5: it was switched from AIX to Linux. With this switch came a change in stripline handling, which is likely to be the primary cause of the differences seen in Figure 10 and the reason that the

reprocessed image doesn't have a curved end. Therefore, the various processor updates has resulted in the reprocessed product being of better quality that the original.

In all other product pairs, the reprocessed products were found to be the same as the originals.

Test **PASSED**, with one reprocessed product showing an improvement.

5.3.2 Check 2 Results

No products were found to have missing lines in either the original or the reprocessed products.

Test **PASSED** (reprocessed failure percentage: 0%).

5.3.3 Check 3 Results

As the original and reprocessed images all show the same level of precision with their corner coordinates, the product quality hasn't changed during reprocessing and therefore the products are considered to have passed this test.

Unfortunately, due to the lack of detailed description to accompany processor update #6, insufficient information was available for us to further investigate this change. Therefore, this update could not be verified as part of this check.

Test **PASSED** (reprocessed failure percentage: 0%).

5.3.4 Check 4 Results

Absolute geolocation accuracy test (through SARCON and SNAP)

For this check a total of 36 pairs (72 products) were checked. 21 product pairs could not be geolocated due to high elevations or no suitable features. The process undertaken to perform this check is illustrated in Figure 11.

All APM and IMM products had consistent geolocation accuracy between the original and reprocessed products. Of the 12 GM1 pairs checked, 9 of the GM1 products also showed consistent geolocation accuracy between the two products.

For the remaining 3 GM1 pairs, the reprocessed products were found to have an improved geolocation accuracy compared to the original products (see Figure 11 as an example). A summary of these improvements are provided in Table 13.

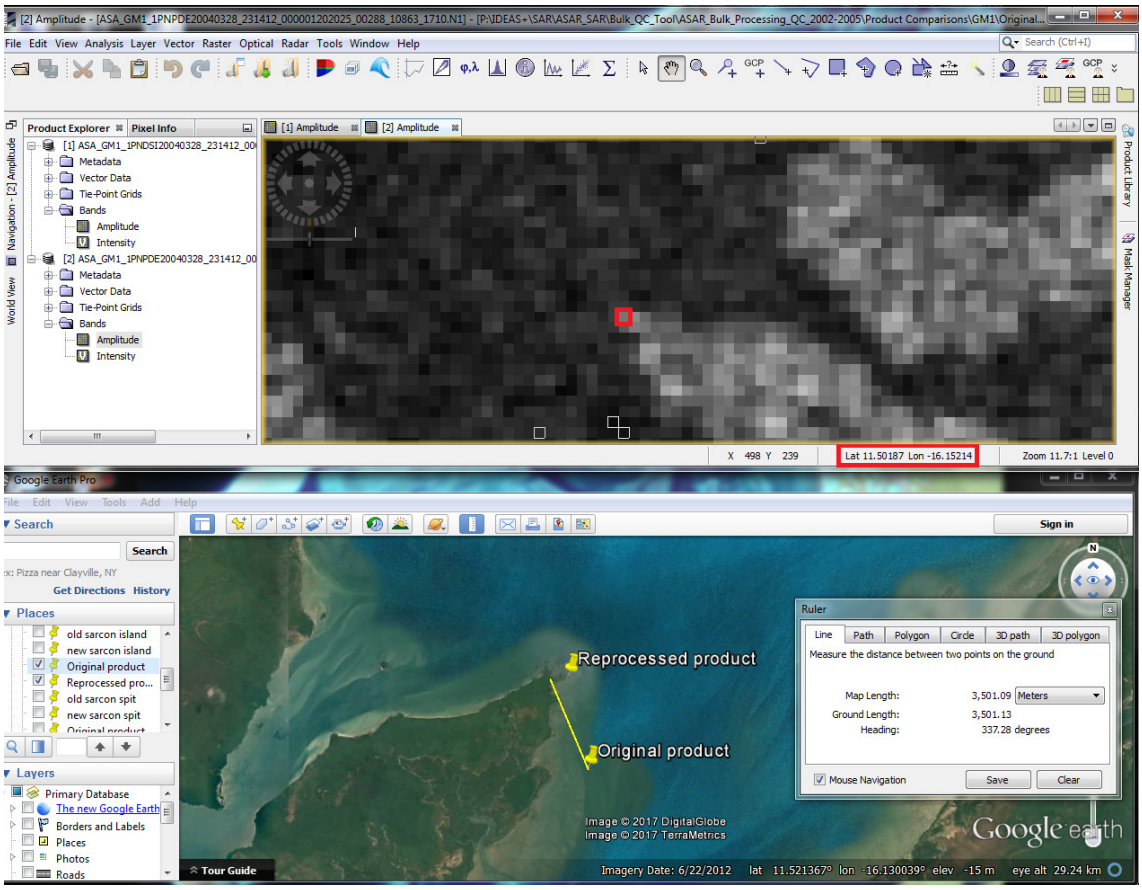


Figure 11 – An example of the geolocation differences observed, showing the reprocessed product ASA_GM1_1PNDSI20040328_231412_000001202025_00288_10863_0000 in SNAP at the top. A feature has been selected (end of an island) and the coordinates extracted. These are then plotted in Google Earth for the original and reprocessed product. The bottom image shows the distance difference between the original and reprocessed products and the feature in Google Earth.

Table 13 - Geolocation offsets compared to Google Earth (GE)

Product start time	Original Product	Reprocessed Product	Reprocessed product improvement
20040328_231412	3.5-12.8 km offset	0.7-1.5 km offset	Improved: reprocessed product closer to GE location
20040329_224055	1.5-1.9 km offset	500-900 m offset	Improved: reprocessed product closer to GE location
20040407_232805	4.2 km offset	1.5 km offset	Improved: reprocessed product closer to GE location

From the above table, it was found that three products had improved geolocation accuracy in the reprocessed products. These products were:

- ASA_GM1_1PNDSI20040328_231412_000001202025_00288_10863_0000 (original product processor version PF-ASAR v3.06)
- ASA_GM1_1PNDSI20040329_224055_000004222025_00302_10877_0000 (original product processor version PF-ASAR v5.04)
- ASA_GM1_1PNDSI20040407_232805_000001142025_00431_11006_0000 (original product processor version PF-ASAR v3.06)

As is visible from the results, the accuracy of the absolute geolocation test cannot satisfy the designated pass/fail criteria. This is due to the fact that no images were available over stable and known targets (e.g. transponders) and therefore no precise measurements can be performed. For this reason this test has been integrated with relative geolocation checks, i.e. with the verification of the position of visible features in the original and in the reprocessed images.

Relative geolocation accuracy test (through SNAP)

The feature location check (or relative geolocation check) of all image pairs found that the original and reprocessed images all show the same level of precision (to 3 dp (2 dp for 8 GM1 pairs)) when checking the locations of different features, the product quality hasn't changed during reprocessing and therefore the products are considered to have passed this test.

Relative geolocation accuracy test (through ARESYS SQT)

The relative geolocation accuracy between the original and reprocessed products has also been verified by identifying areas with evident features (e.g. buildings, strong and isolated scatterers, etc.) and estimating coregistration shifts in the latitude/longitude domain (followed by a proper data geo-projection).

In Figure 12 below is an example of an IMM image acquired on 17th June 2005 over the area of Ottawa (note: in this area at the end of 2006, in the framework of a global re-deployment activity, a transponder was installed for the ASAR mission, close to another transponder used for Radarsat, but unfortunately too late for this analysis). The same region of interest, in terms of samples and lines, has been selected in the original and reprocessed images, geo-projected on a latitude/longitude grid and then the two have been coregistered. The measured coregistration shift was in the order of ~1m in both directions, well below the expected IMM geolocation accuracy (25 m + orbit data error) and the geometric sampling (75 x 75 m). The check can, therefore, be considered to have passed.

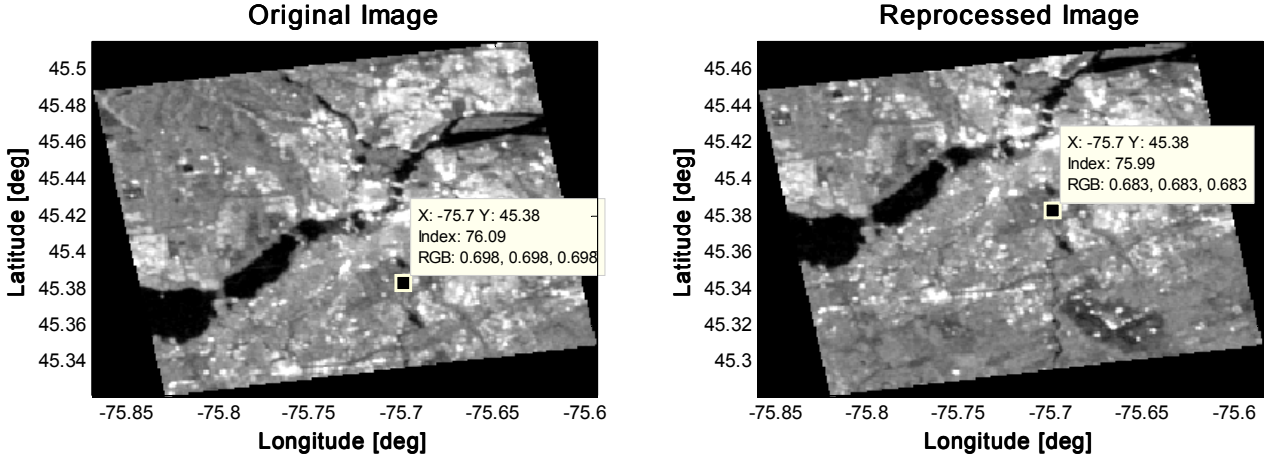


Figure 12 - Portion of ASA_IMM_1PNPDE20050617_025905_000000612038_00147_17235_0801.N1 (left: original, right: reprocessed) geo-projected on latitude/longitude grid. Credit: Aresys.

The same test has been repeated for a selection of products (at least 5 per acquisition mode, discarding the ones with high Doppler Centroid differences). Results are included in the following table: as visible, all the obtained results are good and prove the consistency between original and reprocessed products. Observed discrepancies can be explained with slight changes in the processor (Doppler Centroid estimates, etc.) and with the accuracy of the measurement method.

Table 14 - Relative geolocation accuracy results obtained using ARESYS SQT tool

Acquisition Mode	Coregistration Shifts Mean	Coregistration Shifts Std. Dev.
IMM	-0.3 m	9.5 m
APM	-1.5 m	14.5 m
GM1	4.5 m	14.5 m

While processor updates #4, #5, #11 and #12 all may have contributed to the differences seen in the relative geolocation checks, without improved results from the absolute geolocation check, it is not possible to identify which has had the greatest impact. Therefore, it was not possible to fully verify these processor updates.

Test **PASSED** (reprocessed failure percentage: 0%, considering the 36 (of 57) pairs analysed and the relative geolocation check results).

5.3.5 Check 5 Results

This check only applies to the GM1 product pairs and no gaps were observed between sub swaths in the original or reprocessed products.

Test **PASSED** (reprocessed failure percentage: 0%).

5.3.6 Check 6 Results

All product pairs were found to have very similar geographical coverage in terms of the geographical region visible in the image (based on the corner points). Figure 13 illustrates the product coverage on a global map. Looking at the coverage differences, in percentage w.r.t. the original image coverage, the majority of the images appear to be well below the defined threshold (46 out of 57 images under 1%). For images exceeding the threshold (worst case >9%) more detailed analyses have been performed, as described below.

When considering the timing information, the observations described here are confirmed. It was identified that, although the dates, times and durations in the filenames of all product pairs were the same, the start and stop times in the majority of product headers were slightly different. Only 7 GM1 product pairs had exactly the same times and therefore near-identical image coverage.

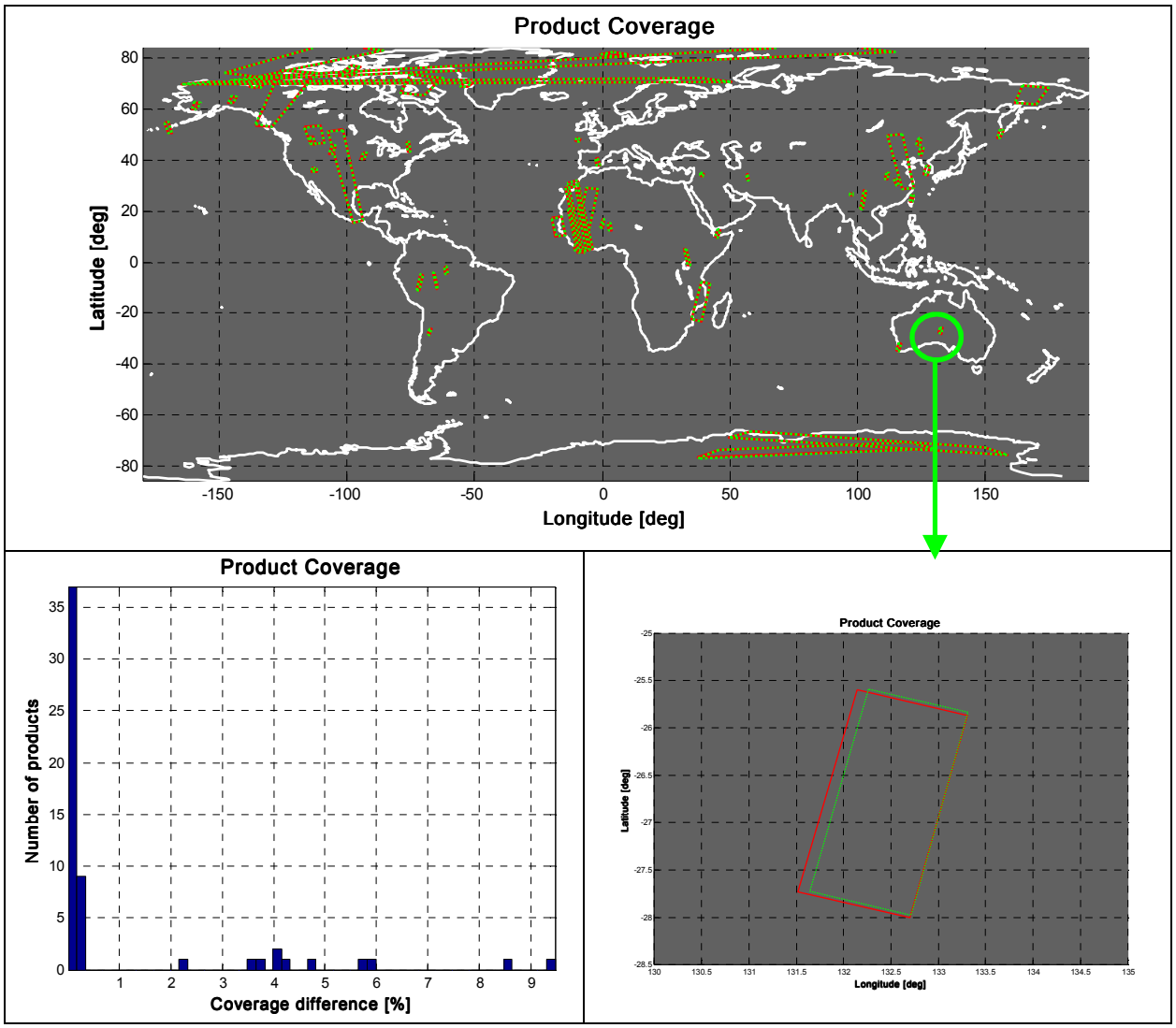


Figure 13 - Product coverage. Top: original products (solid red line) vs reprocessed products (dotted green line). Bottom left: coverage difference between original and reprocessed products in percentage. Bottom right: Product with the highest coverage difference, as a percentage (i.e. ASA_IMM_1PNPDE20051218_004041_000000362043_00274_19867_4207.N1). Credit: Aresys.

Looking at the product quick-looks, differences in the “black borders” around the images have been observed. An example is shown in Figure 14, where the original and reprocessed images do not show particular shifts or stretch effects, but the valid area is slightly different, with the original product coverage being larger. This effect originates from the different processor configuration, and small differences in the data cut strategy.

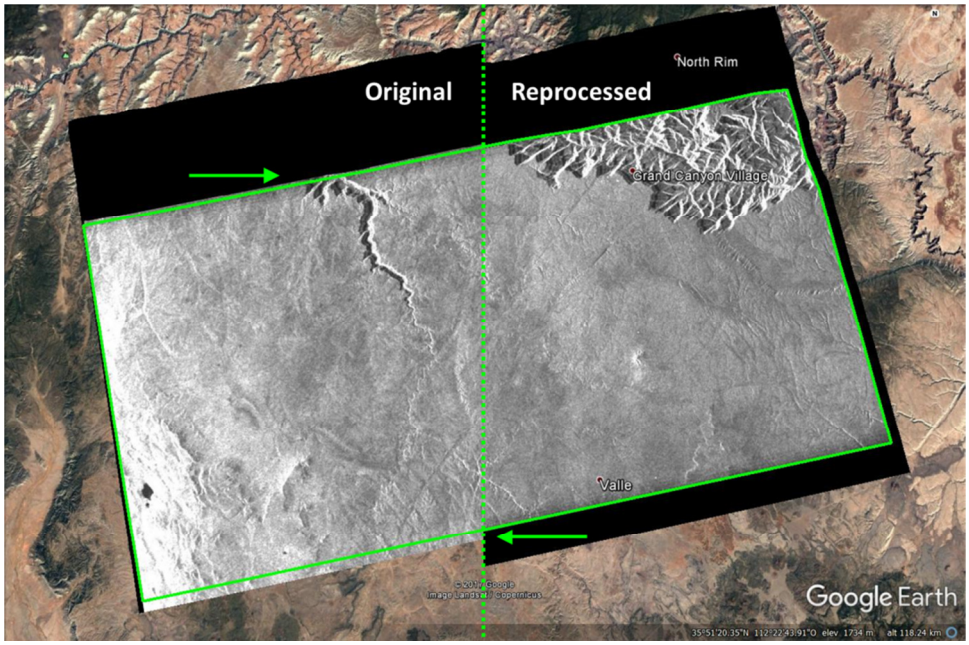


Figure 14 - Example showing how the Regions Of Interest (ROIs) can vary between product pairs (ASA_IMM_1PNPDE20051021_051749_000000102041_00449_19040_8939.N1). Credit: Aresys.

Furthermore, image stretching in the azimuth direction affected some of the GM1 products. In one case, this stretching caused the coverage to be consistently different (ASA_GM1_1PNDSI20040407_232805_000001142025_00431_11006_0000). Looking at different targets in the images (in particular along the coastline), they appear in different positions in the original and reprocessed images (shift) and this difference changes along the azimuth direction (stretch). The geolocation accuracy of the reprocessed product was better than the original; therefore, we can also conclude that the stretching seen in the reprocessed product is an improvement in image quality.

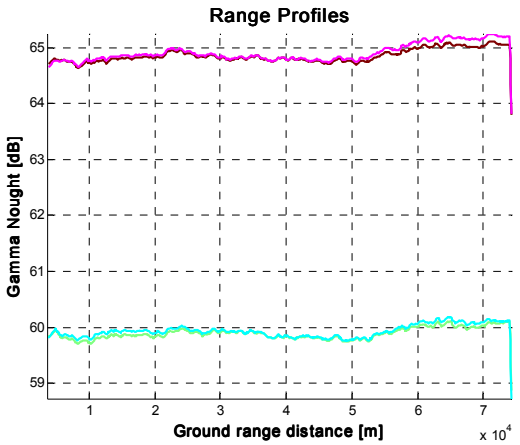
Test **PASSED** (reprocessed failure percentage: 0%).

5.3.7 Check 7 Results

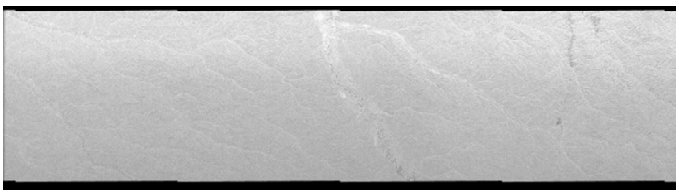
As a result of the different ROIs and the image stretching, 7 product pairs were excluded from this check. Of the remaining 50 product pairs, all images were found to be properly calibrated relative to the original products, with just some minor differences that are considered negligible (below 0.1/0.2 dB). These minor trends and biases are due to the update of auxiliary files in terms of Elevation Antenna Patterns and External Calibration Constants.

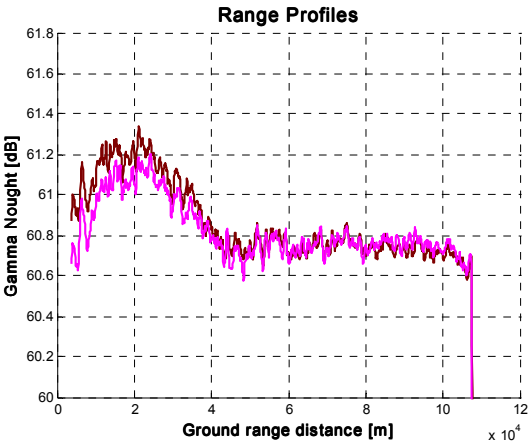
Figure 15 provides an example per product type (APM, IMM and GM1) of the radiometric gamma profiles in the original and reprocessed products. This was performed over areas as homogeneous as possible (unfortunately only IMM and APM products are available over the Amazon Rainforest, while for GM1 an area over North America has been used).

ASA_APM_1PNPDE20050601_024647_000001082037_00418_17005_9239.N1

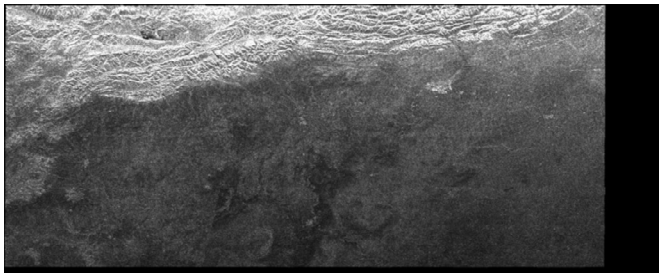


ASA_IMM_1PNPDE20050625_143122_000001012038_00268_17356_1459.N1





ASA_GM1_1PNPDE20040212_051209_000001142024_00134_10208_1998.N1



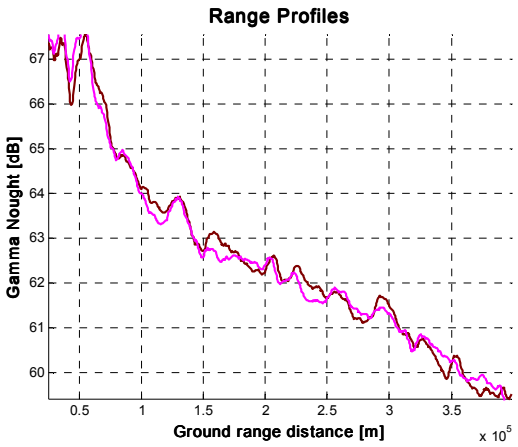


Figure 15 - Example of radiometric analysis results (1 product per type): gamma profiles for original (brown/green) and reprocessed (magenta/cyan) products. Note: only APM and IMM products are expected to have flat gamma profiles as acquired over homogeneous target. Credit: Aresys.

The good correspondence between old and new profiles is clearly visible, therefore indicating that this test has passed.

Processor update #1 was to be verified by this check; however, without more information on this update and on the expected degree of change, it is not possible to verify this update. Furthermore, the radiometry between the original and reprocessed products is consistent, suggesting that the change did not affect the reprocessed products.

Test **PASSED** (reprocessed failure percentage: 0%).

5.3.8 Check 8 Results

As a result of the different ROIs and the image stretching, 7 product pairs were excluded from this check. Of the remaining 50 product pairs, all the images were found to properly preserve the ENL, with just some minor differences that are considered negligible (below 5%) due mainly to the inability to select exactly the same portion of data in the two images.

Figure 16 below provides an example per product type (IMM, APM and GM1) of the ENL in the original and reprocessed products, using areas as homogeneous as possible (unfortunately only IMM and APM products are available over the Amazon Rainforest, while for GM1 an area over North America has been used).

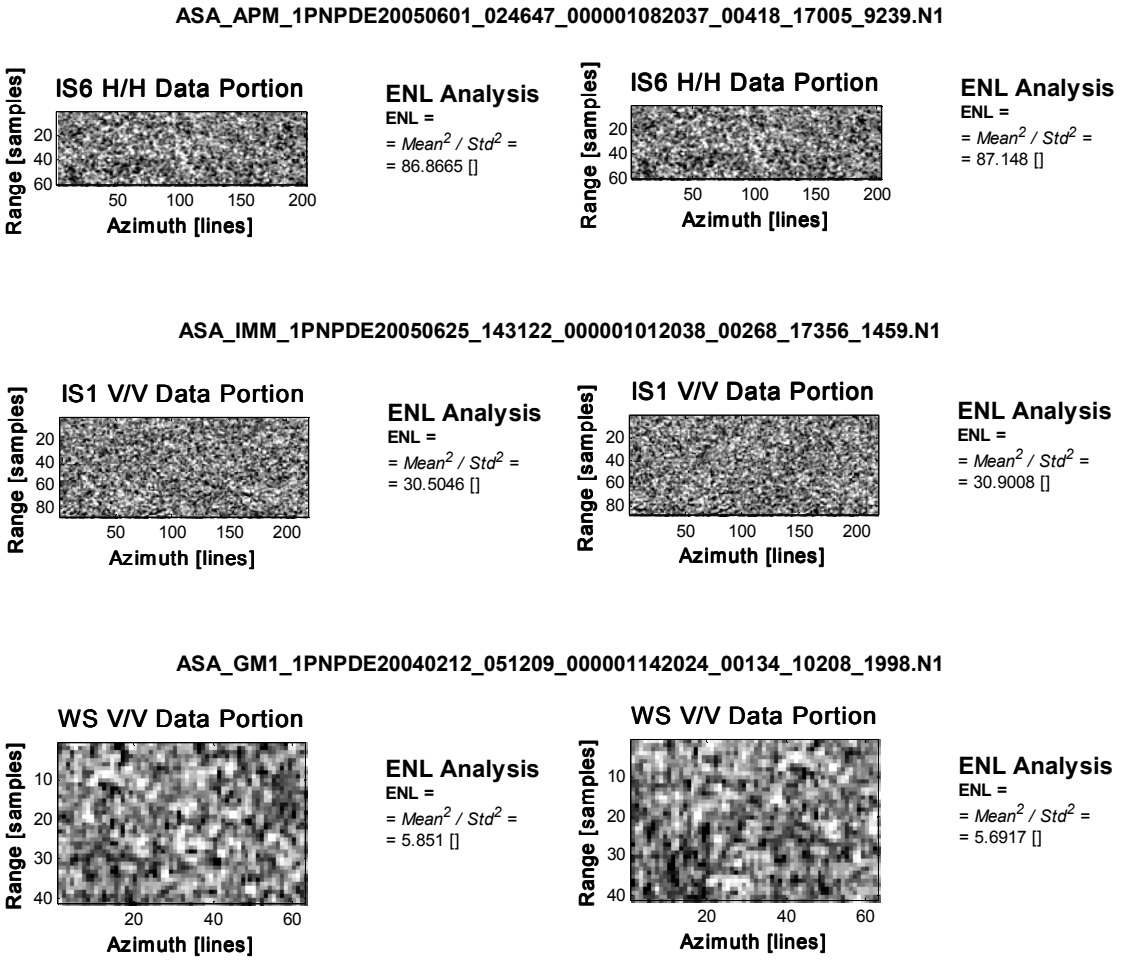


Figure 16 - Example of radiometric analysis results (1 product per type): ENL measurements for original (left) and reprocessed (right) products. Note that only APM and IMM products are expected to have reliable ENL values as acquired over homogeneous target, i.e. Amazon Rainforest. Credit: Aresys.

The good correspondence between old and new values is clearly visible, therefore indicating that this test has passed.

Test **PASSED** (reprocessed failure percentage: 0%).

5.4 Comparison Summary

The table below summarises the results of these tests. The full results are given as Pass, Updated or Improved (no cases of degraded data occurred) in APPENDIX C.

Table 15 - Comparison result summary

Test	Result	Reprocessed product improvement
Test 1: MPH	PASS	All improved
Test 2: SPH	PASS	As originals
Test 3: ADF	PASS	All improved
Test 4: Product Info	PASS	All improved
Test 5: Doppler Centroid	FAIL	Changes due to processor updates
Check 1: Visual inspection	PASS	1 improved
Check 2: Missing lines	PASS	As originals
Check 3: Corner coordinates	PASS	As originals
Check 4: Geolocation accuracy	PASS	3 improved
Check 5: Gaps between sub-swaths	PASS	As originals
Check 6: Product coverage	PASS	1 improved
Check 7: Radiometric normalisation	PASS	As originals
Check 8: Radiometric resolution	PASS	As originals

To summarise, only one test is reported as having failed in this comparison section. The reason for this failure is that 12 reprocessed products were found to have Doppler Centroid values that were different from the original products by >10 Hz. This issue was raised with the software maintainer, via the Task 2 team, to identify the cause of this change in Doppler and whether it is an improvement or a regression. The feedback received from the software maintainer has confirmed that the update to stripline handling between the AIX and Linux versions of the processor, combined with the many small changes that have happened over time explain these relatively small Doppler differences. Therefore this issue is expected and considered **Not Critical**.

With the exception of the differing Doppler Centroid values, all reprocessed products displayed the same level of quality as the original products, with some products (as summarised in the table above) showing improvements.

All expected changes between the original and reprocessed products due to processor updates, which it was possible to check with the test dataset, were confirmed. In some cases these changes also resulted in an improvement to the reprocessed products, such as the fix to the Leap UTC field.

6. CONCLUSION

6.1 Bulk QC Tool

The table below summarises the results from the Bulk QC tool test (Section 3).

Table 16 - Bulk QC test result summary (with percentage failure rate)

Test	Result (percentage failure rate)
Test 1: MPH	**FAIL** (0.13%)
Test 2: SPH	**PASS** (0.00%)
Test 3: ADF	**FAIL** (0.96%)
Test 4: Product Info	**PASS** (0.00%)
Test 5: Doppler Centroid	**PASS** (0.01%)

Two tests failed in this section. The failure in Test 1 was due to the presence of invalid LEAP_SIGN field values. This had previously been observed in GM1 products but is now present in some APM products. As the issue was fixed for GM1 previously the software maintainer was informed. Investigations identified that these products were processed with an old processor version (PF-ASAR v6.02). Furthermore, this processor version was found to have been used for ~10% of all APM products checked, although the other modes were not affected. It is recommended that all products processed with this version of the processor are reprocessed using PF-ASAR v6.03 to remove products with an invalid LEAP_SIGN field value.

The failure in Test 3 was due to the Bulk QC Tool flagging some products that were processed using an old XCA ADF file that was not one of the current and up-to-date files on the master list. The affected products are listed as 'Fail' for Test 3 in APPENDIX A. Further investigation found that these products were from a period of poor data quality. Therefore, it is recommended that these products are removed from the EO Data Gateway. If the products are not removed, a data disclaimer should be published to warn users of their poor quality. The original data disclaimer is available on the SPPA webpage (https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/asar/quality-control-reports/products-anomalies) and is provided below:

14-Sep-2005 08:00:40 to 16-Sep-2005 19:57:33

"Quality of ASAR Level-1 and Level-2 products is slightly degraded due to a temporal modification of the antenna radiation patterns. Due to an on board anomaly, data acquired during this period is affected by a change of the antenna radiation pattern. The overall quality of these data is degraded. Radiometric normalisation of Level-1 products is clearly corrupted, with significant residual antenna pattern modulation and differences from sub-swath to sub-swath in the ScanSAR cases (WS and GM). Affected products: all ASAR products, including Level-0 products".

It should also be noted that the affected products identified in this activity may not be the complete list of all affected products from the period of poor data quality (08:00:40 14/09/2005 to 19:57:33 16/09/2005). Therefore, all products between the affected times should be treated with the same action, whatever is agreed.

With the exception of the two issues highlighted above, all products selected for this QC activity passed the quality checks.

6.2 Detailed Checks

The table below summarises the results from the manual detailed checks (Section 4).

Table 17 – Detailed check result summary (with percentage failure rate)

Check	Result (percentage failure rate)
Check 1: Visual inspection	**FAIL** (36.59%)
Check 2: Missing lines	**PASS** (12.20%)
Check 3: Corner coordinates	**FAIL** (34.15%)
Check 4: Geolocation accuracy	**FAIL** (76.92%)

Three checks failed in this section. In the visual inspection test, anomalies related to the processor were identified in 15 products. Discussion between the Task 2 team and the software maintainers has identified the suspected cause of these anomalies. The unfocussed image is a result of early mission problems related to AP mode and is not due to a problem with the processor. The visible swath lines and curved ends were due to poor quality Doppler estimates, however, no updates to the processor are planned at present to fix this issue, due to the significant changes that would be required to improve the small number of affected products.

The remaining two tests that failed were checks of the corner coordinates and the geolocation accuracy. The primary tool for implementing this check was SARCON. However, the results of these checks were not as good as expected. Further investigation suggests that, for the corner coordinate check, the issue lies with SARCON itself. For the geolocation accuracy check it was concluded that the results were hampered due to issues identifying features both in the ASAR images and in some cases in Google Earth and because no images were available over stable targets, such as transponders. Therefore, the results from these two checks were found to be **Inconclusive** as the approach taken was too imprecise. More useful checks were performed in the Comparison Checks below.

6.3 Comparison Checks

The table below summarises the results from the Bulk QC and manual comparison checks (Section 5) performed on selected pairs of operational or 'original' products and reprocessed products (with the same filename start times and durations).

Table 18 - Comparison checks result summary

Test/Check	Result	Reprocessed product improvement
Test 1: MPH	**PASS**	All improved
Test 2: SPH	**PASS**	As originals
Test 3: ADF	**PASS**	All improved
Test 4: Product Info	**PASS**	All improved
Test 5: Doppler Centroid	**FAIL**	Changes due to processor updates

Test/Check	Result	Reprocessed product improvement
Check 1: Visual inspection	PASS	1 improved
Check 2: Missing lines	PASS	As originals
Check 3: Corner coordinates	PASS	As originals
Check 4: Geolocation accuracy	PASS	3 improved
Check 5: Gaps between sub-swaths	PASS	As originals
Check 6: Product coverage	PASS	1 improved
Check 7: Radiometric normalisation	PASS	As originals
Check 8: Radiometric resolution	PASS	As originals

Test 5 failed due to 13 reprocessed products having Doppler Centroid values that were different from the original products by >10 Hz. With the aid of the processor software maintainer, these differences have been traced to the various changes to the processor over the years, the most significant being the change from AIX to Linux. As a result these differences are not considered as a regression and are expected.

With the exception of Test 5, all other non-regression tests and checks passed. Overall, small improvements were observed in some reprocessed products, compared to the corresponding original products, including improved geolocation accuracy in three products and the resolution of an image anomaly in another. All remaining reprocessed products displayed the same level of quality as the original products. Furthermore, the expected changes due to processor updates, which it was possible to verify, were also observed in the reprocessed products.

6.4 Summary

As a result of these tests and checks the following recommendations were identified:

- It is recommended that the poor quality data processed with an old auxiliary file be removed from the dataset or, if the data remains available, highlight to users the list of all ASAR data disclaimers on the SPPA webpage.

- It is recommended that all products processed with PF-ASAR v6.02 are reprocessed using PF-ASAR v6.03. Some APM products processed with this processor version have invalid LEAP_SIGN field values. The affected products were APM products processed prior to the 23rd of June 2015.

There were also two outstanding issues identified during the visual check that remain present in the images. These issues will not be addressed, as they have been identified in the past and the decision was made not to change the algorithm:

- ***Visible azimuth/swath lines:*** these visual features are due to a significant Doppler Centroid estimate change over a relatively short period. This is known to give rise to visible swath lines and is caused by poor quality Doppler estimates. As the problem is inherent in the Doppler Centroid estimate algorithm, which would require significant changes to improve results.

- ***Curved ends:*** these artifacts also suspected to be caused by poor quality Doppler Centroid estimates. As with the anomaly above, an update to the Doppler Centroid estimate algorithm is not planned.

With the exception of these outstanding issues, it is concluded that all L1 APM, GM1, IMM and WSM products processed in the current bulk processing campaign can be disseminated to users.

APPENDIX A BULK QC TOOL RESULTS

The tools used to carry out each test are described in the table below:

Table 19 – Tools used for Bulk QC Checks

Test	Tool
Test 1: MPH	Bulk QC Tool
Test 2: SPH	Bulk QC Tool
Test 3: ADF	Bulk QC Tool
Test 4: Product Info	Bulk QC Tool
Test 5: Doppler Centroid	Bulk QC Tool

The Bulk QC Tool is an automated tool created by TVUK for ASAR, based on the routine tools that were used for ASAR QC when Envisat was operational. For the purpose of this QC check the tool is used to perform the following functions:

- Download of 3 MB headers
- Automated QC of Main Product Header (MPH)
- Automated QC of Specific Product Header (SPH)
- Automated QC of Auxiliary Data Files (ADF)
- Automated QC of file name and data consistency
- Automated QC of Doppler Centroid (D0)

See IDEAS+-VEG-OQC-REP-2742_QC_Report_APPENDIX_A.xlsx for full Pass/Fail results.

APPENDIX B DETAILED CHECKS RESULTS

The tools used to carry out each test are described in the table below:

Table 20 – Tools used for Detailed Checks

Test	Tool
Check 1: Visual inspection	SARCON/SNAP
Check 2: Missing lines	EnviView
Check 3: Corner coordinates	SARCON
Check 4: Geolocation accuracy	SARCON/Google Earth

SARCON is a tool developed by BAE for reading and visualising SAR products, as well as more detailed analysis. This tool was developed while ENVISAT was operational. EnviView is a tool that can be used to read the headers of ASAR products. This tool was developed while ENVISAT was operational. SNAP is a more recent tool, developed by ESA, to read and visualise many product types, including SAR data using the Sentinel 1 Toolbox.

See IDEAS+-VEG-OQC-REP-2742_QC_Report_APPENDIX_B.xlsx for full Pass/Fail results.

Changes to auxiliary files from the original to reprocessed products are provided below.

ASA_CON_AX

The updates to this auxiliary file type between the files used in the original and reprocessed products include:

- Updated Eq. Energy values for AP (different per each polarisation), WS HH SS1 (from 1.08 dB to 1.15 dB), SS3 (from 9.13 dB to 9.20 dB) and SS5 and GM HH SS1 (from 16.43 dB to 16.73 dB)
- Changed AP normalisation method from reference energy to equivalent energy
- Increased GM SS3 HH gain (by decreasing 0.5 dB the Eq. Energy for GM SS3 HH), processing gain values set and updated for WSS products
- Reference energy values updated for before/after the DSS change after May 2003 for IM, WSM products Normalisation changed to Reference Energy and Reference Energy values updated for WSM products: HH (from SS1 to SS5: 1.08, 6.96, 7.5, 7.95, 9.13) and VV (from SS1 to SS5: 1.11, 6.9, 7.5, 7.95, 9.1)
- Enable DAR for GM
- Update of the reference chirp energy value for IM IS2 VV
- Enabled “Doppler Centroid Grid ADS for ASAR WSM products.”
- File format updated to be consistent with PF-ASAR v4.0 (additional parameters in spare fields included and parameters for the new WSS product included)
- Update of the end validity date

ASA_INS_AX

The updates to this auxiliary file type between the files used in the original and reprocessed products include:

- GM ISG increased by 1 for all sub-swaths (in 2004) & End validity date extended

ASA_XCA_AX

The updates to this auxiliary file type between the files used in the original and reprocessed products include:

- New calibration constants for GMM, IMM, APM, APP, APS, APG, IMP, IMG, IMS and WSS HH & VV products
- Updated elevation patterns for SS1 HH-VV, IS1 VV-VH, IS2 HH-VV-HV-VH, IS4 HV-VH, IS5 HH-HV-VH, IS6 HV-VH, SS2-VV and SS3 VV, IS3_SS2 VV, IS4_SS3 HH &VV, IS5_SS4 VV, IS6_SS5 HH & VV, and beams IS1 to IS7 HV and VH
- Update of the reference document in the MPH
- End validity date also extended

ASA_XCH_AX

No changes have been made to this file type between the original and reprocessed products, other than the end validity date was extended.

APPENDIX C COMPARISON RESULTS

The tools used to carry out each test are described in the table below:

Table 21 – Tools used for Product Comparison Checks

Test	Tool
Test 1: MPH	Bulk QC Tool
Test 2: SPH	Bulk QC Tool
Test 3: ADF	Bulk QC Tool
Test 4: Product Info	Bulk QC Tool
Test 5: Doppler Centroid	Bulk QC Tool
Check 1: Visual inspection	SARCON/SNAP
Check 2: Missing lines	EnviView
Check 3: Corner coordinates	SARCON
Check 4: Geolocation accuracy	SARCON/Google Earth SNAP ARESYS SAR Quality Tool (SQT)
Check 5: Gaps between sub-swaths	SARCON/SNAP
Check 6: Product coverage	SNAP/Google Earth ARESYS SAR Quality Tool (SQT)
Check 7: Radiometric normalization	ARESYS SAR Quality Tool (SQT)
Check 8: Radiometric resolution	ARESYS SAR Quality Tool (SQT)

Brief descriptions of SARCON, EnviView and SNAP can be found in APPENDIX B.

See IDEAS+-VEG-OQC-REP-2742_QC_Report_APPENDIX_C.xlsx for full results.