ATSR-2 in the ERS-2 Post Gyro Failure Period

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This report investigates the quality of the absolute nadir geolocation and the forward−nadir view colocation of ATSR-2 products during the ERS-2 post gyro failure period of early 2001. It is recommended that products that are not of acceptable quality are segregated.

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1. INTRODUCTION

During validation of the (A)ATSR Third Reprocessing dataset, a period of high robust standard deviation (RSD) was found for ATSR-2 in the first half of 2001 [RD1]. Figure 1 reproduces fig. 4-1 from [RD1]. There is no indication from Figure 1 that the period of low quality data continues to 2002.

This period coincides with the implementation of certain Attitude and Orbit Control System (AOCS) modes for ERS-2. Due to previous problems with the ERS-2 gyroscopes, a single-gyroscope AOCS mode had been running since February 2000 [RD2]. In anticipation of the loss of a further gyro, ESA began testing Extra Backup Mode (EBM), using no gyros, on 16 January 2001. This was due to end on 19 January 2001, however since another gyro failed before this date, ERS-2 continued in EBM until the implementation of Zero Gyro Mode (ZGM) in June 2001. This was followed by the

implementation of Yaw Control Monitoring mode (YCM) at the beginning of 2002. Further details of ERS-2 navigation modes throughout the mission are given in [RD3, fig. 1].

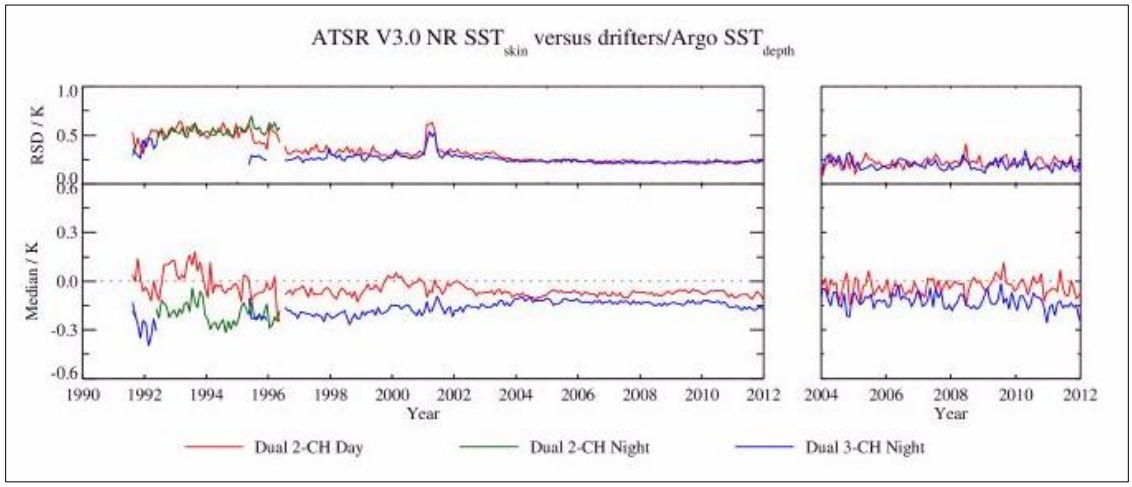

Figure 1. Figure 4-1 from [RD1]. Left: Time series of (lower) median discrepancy and (upper) robust standard deviation (RSD) for the ATSR v3.0 NR dataset compared to drifting buoys. Results are shown for daytime dual-view 2-channel (red), nighttime dual-view 2-channel (green) and dual-view 3-channel nighttime (blue) match-ups. Right: Equivalent time series for comparisons to Argo. Each point in the time series has at least 30 match-ups.

Currently, the majority of ATSR-2 products from January to June 2001 are contained within the main archive and are not segregated. This report aims to define the period of low-quality data, so that the affected products may be moved to the segregated section of the archive.

It was noted that the ERS-2 SAR team have outlined the disruption to their products due to the implementation of various AOCS modes [RD3, RD4].

2. ERS-2 AOCS MODES: JANUARY−JUNE 2001

Using information contained within RAL's ATSR-2 operations anomaly log [RD5], Table 1 shows the dates of implementation of different AOCS modes during this time. Further information on these modes is given in [RD3].

Table 1. Implementation dates for ERS-2 AOCS modes from January to June 2001

AOCS mode	Date of implementation
Single-gyro	10 February 2000
EBM	16 January 2001
EBM−YSM	30 March 2001
ZGM−YSM	06 June 2001

EBM: Extra Back-up Mode; YSM: Yaw Steering Mode; ZGM: Zero Gyro Mode

2.1 ATSR-2 operations anomaly log

Itemised below are real-time entries from the RAL ATSR-2 operations anomaly log [RD5] relating to ERS-2 AOCS mode implementations, payload shutdowns and ATSR-2 instrument operations during this period:

16th January 2001 EBM (Extra Back-up Mode) for no-gyro operation commenced at 06:30:00 UTC and is expected to be completed by 19th January 17:00:00 UTC. Instrument pointing will be degraded. The ATSR-2 IRR will remain on during those activities and it's expected that co-location of forward/nadir views in the data processing will be affected.

17th January 2001 At 19:53:00 UTC there has been a payload shutdown.

8th February 2001 ATSR-2 was successfully restarted at 11:43.

9th February 2001 The cool down to 80 K was completed at 07:49 and ATSR-2 is now back to nominal operations. The ERS-2 spacecraft attitude is operating in EBM (no gyros). This will have a significant effect on ATSR-2 images, in particular the co-location of nadir and along-track views. ESA hope to improve the performance of the attitude control as the orbit behaviour becomes more understood. The aim is to attain optimum attitude control by June in readiness for the launch of ENVISAT-1 in July. To provide data for the orbit analysis, ESA will run the AMI instrument in wind-wave mode for an extended period. This means that there will be no ATSR-2 H-Rate data until 16 February (TBC).

30th March 2001 ERS-2 attitude and orbit control system (AOCS) software updated with the new yaw steering control mode known as EBM-YSM. This took place around 10:30 UTC. Co-location of ATSR imagery should be improved.

21st May 2001 Due to platform anomaly the ERS-2 payload was turned off at 18:12:31 UTC. Recovery will involve coarse attitude mode and 3 gyro pointing in order to re-instate EBM attitude control.

29th May 2001 After difficulty re-installing the platform attitude control mode, ATSR-IRR finally was reconfigured on 29th May when the start up and cool down went uneventfully with a return to nominal operation at 15:40 UTC.

01st June 2001 ESOC begin a campaign of AOCS testing to improve the YSM steering, the impact will be continued lack of H/R data for the IRR whilst global wind/wave data products are taken to be used for YSM performance characterisation.

06th June 2001 Platform AOCS using ZGM mode (Zero Gyro Mode).

The entries in the anomaly log show that the geolocation and colocation of ATSR-2 could be problematic between 06:30 on 16 January 2001 and 06 June. However, further information retrieved from the processor scripts at RAL revealed the following:

```
#32035(tbc) ZGM-YSM starts 06-JUN-2001 but ...

#32464(tbc) ... ZGM-YSM not fully tuned until 06-JUL-2001
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This information implies that products generated between 06 June and 06 July 2001 may also be affected by the attitude control issues.

2.2 ATSR-2 archive status

Two sets of ATSR-2 data are segregated for the period January–July 2001. These are products with start times from 2001/02/08 at 11:47 to 2001/02/09 at 00:35; and from 2001/05/29 at 07:07 to 15:15. These correspond to the instrument cool down times required once the satellite payload has been put back in operation after a shutdown (see Section 2.1).

All other available products are in the main archive, therefore no segregation for navigation reasons has taken place during January–July 2001.

Segregation has taken place for navigation reasons at other times (e.g. May, October, December 2000). Note that the entries in [RD5] do not continue after April 2002, although the ATSR-2 archive is populated until June 2003.

3. ATSR-2 PRODUCT INVESTIGATION

3.1 Input data

Based on the information in Section 2, ATSR-2 L1B products were selected throughout the January–July 2001 period. A full list of the products inspected is given in Table 4 in APPENDIX A.

3.2 Method

Each product was opened in BEAM. An assessment of absolute nadir geolocation and nadir–forward view colocation was carried out for each product as outlined in the following subsections.

3.2.1 Absolute nadir geolocation

A nadir-view RGB image (1.6, 0.87, 0.55 µm) was inspected for targets that could be easily identified and were small enough to locate accurately, e.g. small islands and lakes. A pin was inserted in the selected pixel, and the corresponding location was assessed independently via http://www.satsig.net/maps/lat-long-finder.htm (this uses Google Map© geographical information). The distance between the BEAM pixel coordinates and the independent coordinates was calculated.

3.2.2 Nadir–forward view colocation

Using pins previously selected in the nadir geolocation assessment, nadir and forward views of the 0.87 µm channel were displayed together, and a qualitative assessment of the correspondence between them was undertaken.

3.3 Results

3.3.1 Absolute nadir geolocation

3.3.1.1 Before and after the start of the EBM

Figure 2 displays the distance between the product coordinates and the independently assessed location of the chosen pixel before and after the start of the EBM on 16 January at 06:32 (shown by vertical dotted line).

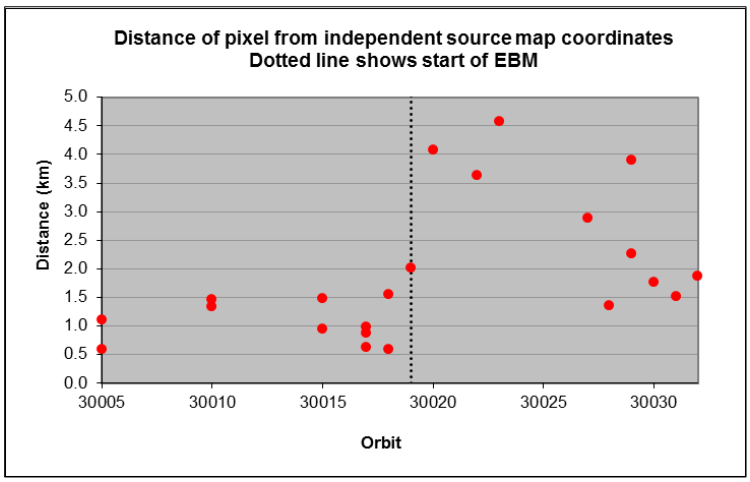

Figure 2. Distance of ATSR-2 pixels from independent coordinates before and after the start of the EBM (noted by vertical dotted line) for 15−17 January 2001.

It can be seen from Figure 2 that there is a clear decrease in geolocation accuracy immediately after the start of the EBM, but that this appears to improve after a few orbits. The mean distance of the pixels from independent coordinates before the EBM was 1.1 km (*SD* 0.4 km). The mean distance after the EBM was 2.7 km (*SD* 1.1 km), from the points shown in Figure 2.

3.3.1.2 All modes January−July 2001

Figure 3 shows the distances between the pixel product coordinates and the independently assessed location of the chosen pixel for all products inspected from January to July 2001, for the different AOCS modes. It can clearly be seen that the EBM−YSM and the beginning of the ZGM−YSM contain products with pixels that are subject to poor quality geolocation. Although there are some reasonable values (< 2 km) within the EBM period, the mean distance of inspected pixels from independent coordinates for the EBM period is 3.1 km (*SD* 2.4 km).

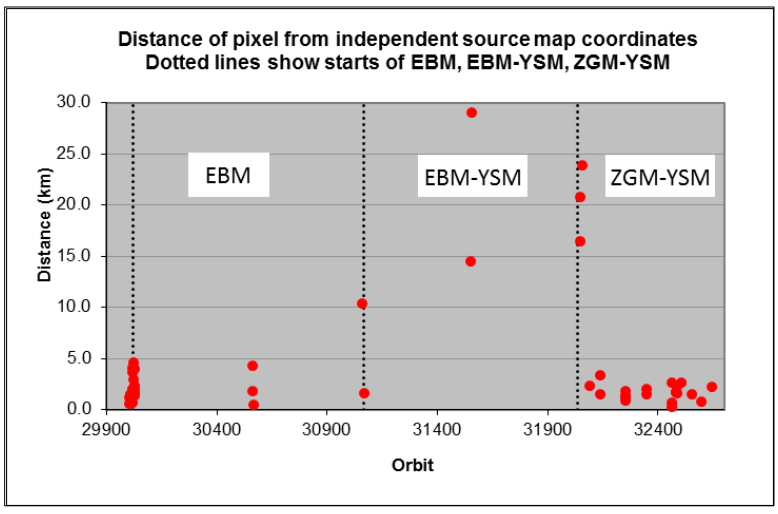

Figure 3. Distance of ATSR-2 pixels from independent coordinates for all AOCS modes: 15 January−18 July 2001.

Figure 3 reveals that the geolocation of ATSR-2 pixels begins to improve some time after the implementation of ZGM−YSM (distances less than 5 km are noted from orbit 32138 on 13 June).

3.3.1.3 After the start of the ZGM−YSM

Figure 4 shows the detail of Figure 3 after the start of the ZGM−YSM (left vertical dotted line); the scale is such that the first few points (distances of 15–25 km) are not shown. The vertical dotted line on the right indicates the end of the tuning period.

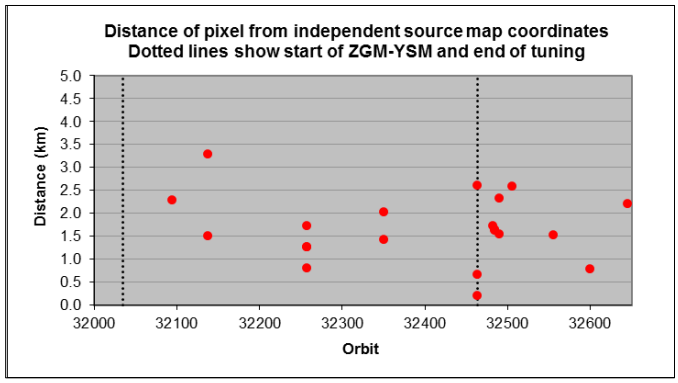

Figure 4. Distance of ATSR-2 pixels from independent coordinates after the start of the ZGM−YSM (left dotted line) and continuing after the end of the tuning period (right dotted line); very high initial values are not shown.

The mean distance of product pixels from independent coordinates of the points shown in Figure 4 is 1.6 km (*SD* 0.7 km). This is a definite improvement over the EBM−YSM period, and better than the EBM, although the mean value is not as low as those products that were assessed in this study for single-gyro mode (1.1 km). There is also clear evidence of high variability within a product, e.g. orbit 32464 contains pixel distance values of 2.6 and 0.2 km.

3.3.2 Nadir–forward view colocation

Figure 5 to Figure 20 display the forward and nadir views of the ATSR-2 0.87 µm channel using BEAM. Both views have been colocated by the BEAM software and would display the same earth view if the attitude control were nominal. If the same earth view cannot be seen, there is still the possibility of acceptable colocation if a pin in the nadir view falls in the same feature in the forward view, however, the instrument's dual-view capability would be compromised.

Qualitative colocation assessments for the products inspected are given in Table 2.

Table 2. Colocation assessment for the different modes

Time	Colocation assessment
Before EBM start	Figure 5. (16 January) Forward–nadir view colocation appears nominal. The location of the pin is appropriate in each view.
Orbits after EBM start	Figure 6. (16 January) Forward–nadir view colocation has already drifted at 13:14 on 16 January. The location of the pin in the forward view does not correspond to that in the nadir view. Figure 7 is Figure 6 reproduced with the land flag overlaid in green. This clearly shows the incorrect navigation of the forward view (left). Figure 8 (16 January) shows a product that had a pixel with acceptable nadir geolocation after the EBM start. It can be seen that the colocation also appears to be acceptable.

Time	Colocation assessment
Mid-point of EBM	Figure 9. (23 February) The forward and nadir views are not colocated, and the forward view can be seen to curve within the BEAM display. The pin falls outside the forward image.
Before EBM−YSM start	Figure 10. (30 March) An amount of edge distortion can be seen in the forward view and the pin is not colocated correctly.
After EBM−YSM start	Figure 11. (30 March) Although the pin is not well located, there is not the forward-view distortion that could be seen for Figure 9 and Figure 10.
Mid-point of EBM−YSM	Figure 12. (03 May) Similar to Figure 11, the forward view is not distorted but the pin is not accurately located. Figure 13. (03 May) Unlike Figure 12, the forward view is subject to an amount of disruption (which occurs to varying degrees throughout the product) and the edges of the view are curved. The pin is not accurately located.
Day after ZGM−YSM start	Figure 14. (07 June) Distortion is apparent in both views, the forward view is not colocated with the nadir view, and the pin in the forward view is very far from its expected location.
One week after ZGM−YSM start	Figure 15. (13 June) The same scene is not seen in the different views. The forward view is distorted and it is not clear if the pin is correctly placed since it is outside the scene
During tuning period	Figure 16. (21 June) The same scene is not seen in the different views, but the pin in the forward view appears to be in the expected location. Figure 17. (28 June) The same earth scene is seen in the different views, and the pin in the forward view appears to be in the expected location.
Orbit at end of ZGM−YSM tuning period	Figure 18. (06 July) The same earth scene is seen in the different views, and the pin in the forward view appears to be in the expected location.
Day after ZGM−YSM tuning period	Figure 19. (07 July) The same earth scene is seen in the different views, and the pin in the forward view appears to be in the expected location.
12 Days after ZGM−YSM tuning period	Figure 20. (18 July) The same earth scene is seen in the different views, and the pin in the forward view appears to be in the expected location.

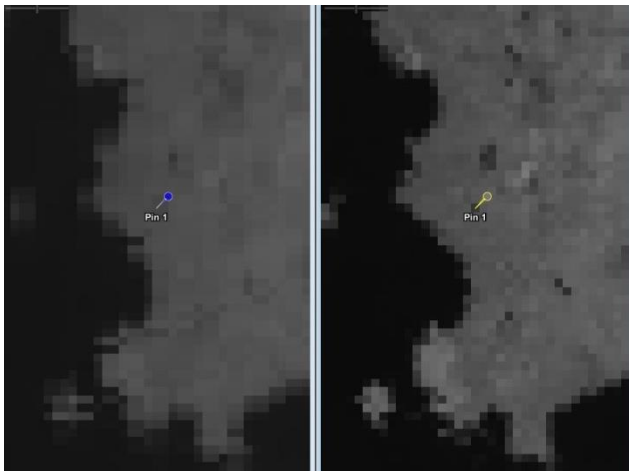

Figure 5. Before EBM start.
ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 30017, 16 Jan. 2001 at 03:11.

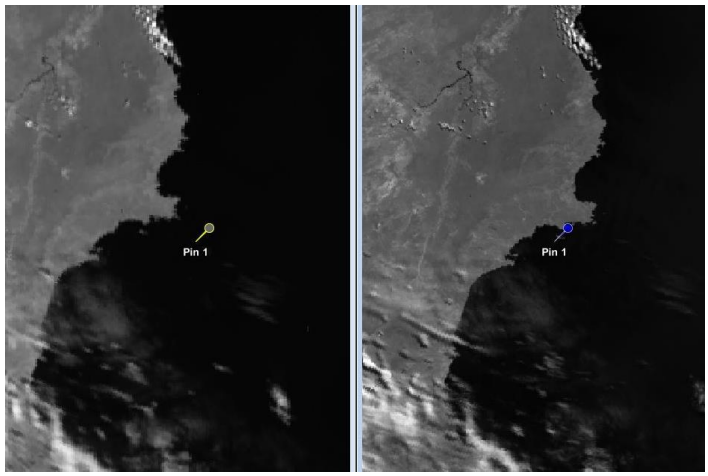

Figure 6. After EBM start.
ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 30023, 16 Jan. 2001 at 13:14.

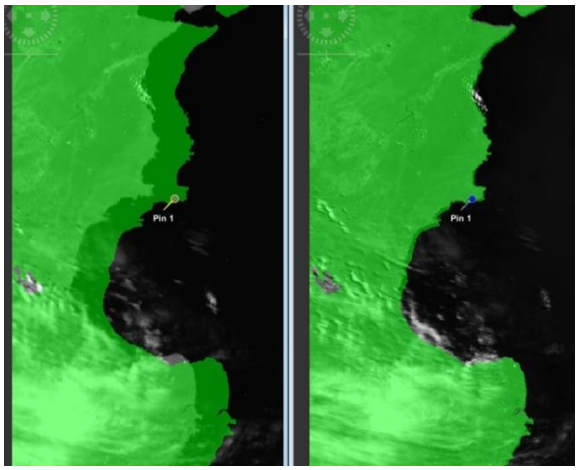

Figure 7. Expanded view of Figure 6, with the forward and nadir land flags shown in green on the appropriate view.

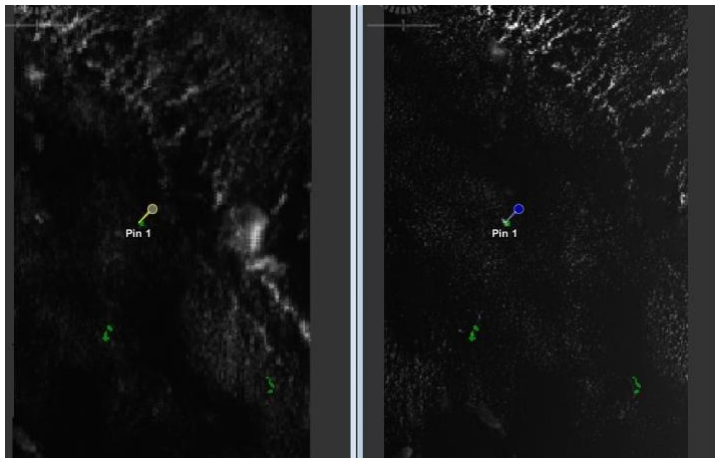

Figure 8. After EBM start.
ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 30028, 16 Jan. 2001 at 21:37.

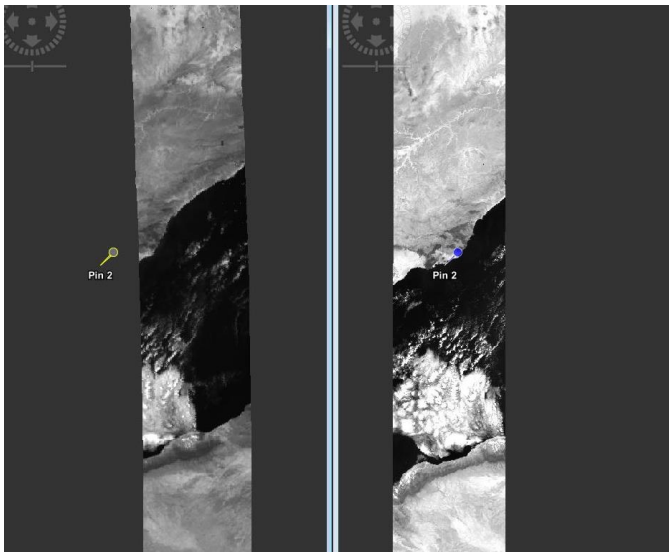

Figure 9. Mid-point of the EBM period. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 30563, 23 Feb. 2001 at 06:38.

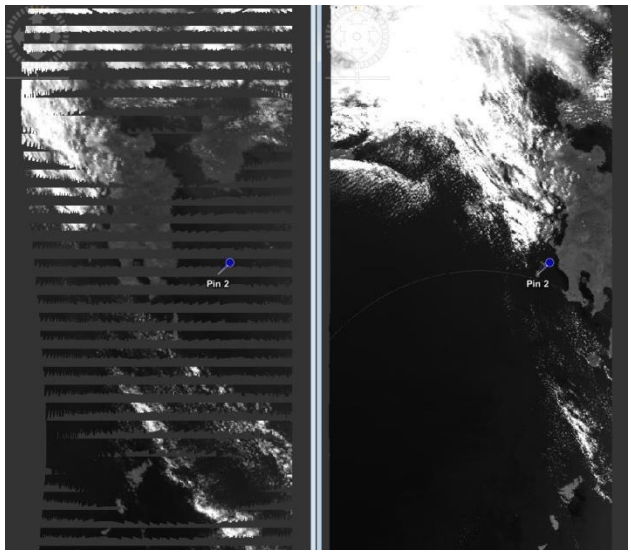

Figure 10. Before the start of the EBM-YSM period. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 31061, 30 March 2001 at 01:36.

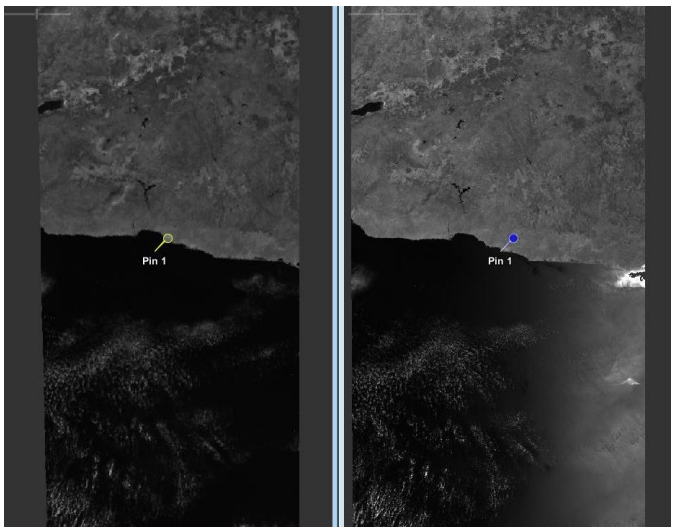

Figure 11. After the start of the EBM-YSM period. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 31070, 30 March 2001 at 16:41.

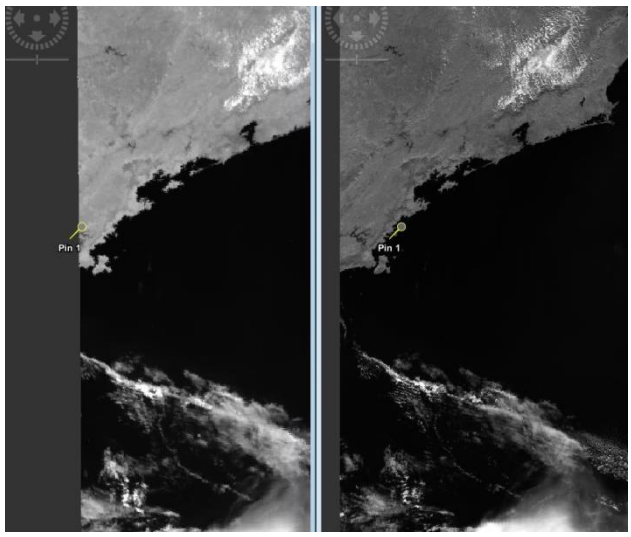

Figure 12. Mid-point of the EBM-YSM period. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 31554, 03 May 2001 at 12:11.

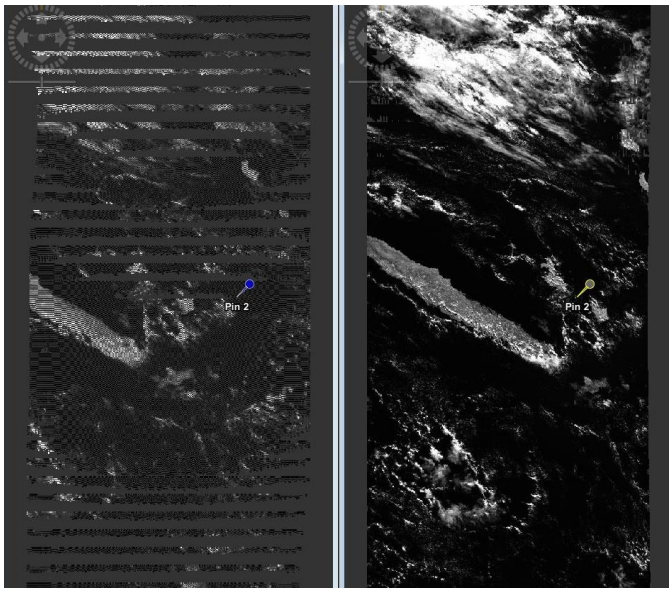

Figure 13. Mid-point of the EBM-YSM period. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 31560, 03 May 2001 at 22:15.

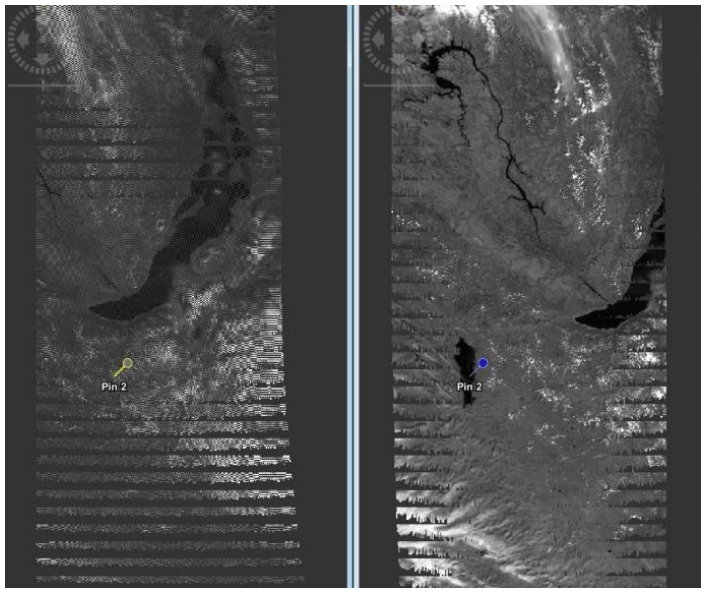

Figure 14. The day after the start of ZGM-YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32050, 07 June 2001 at 03:48.

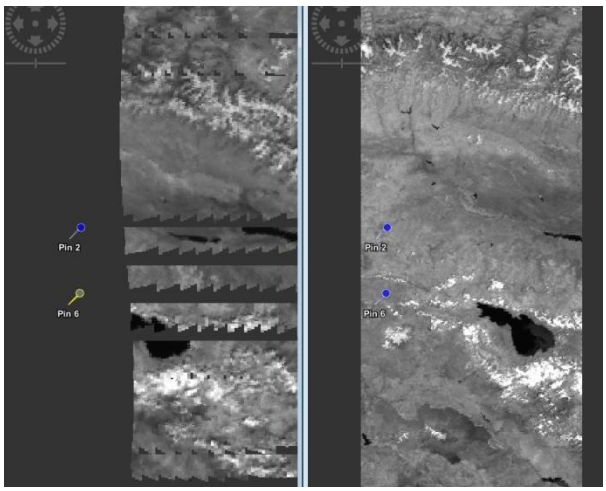

Figure 15. One week after the start of ZGM-YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32138, 13 June 2001 at 07:20.

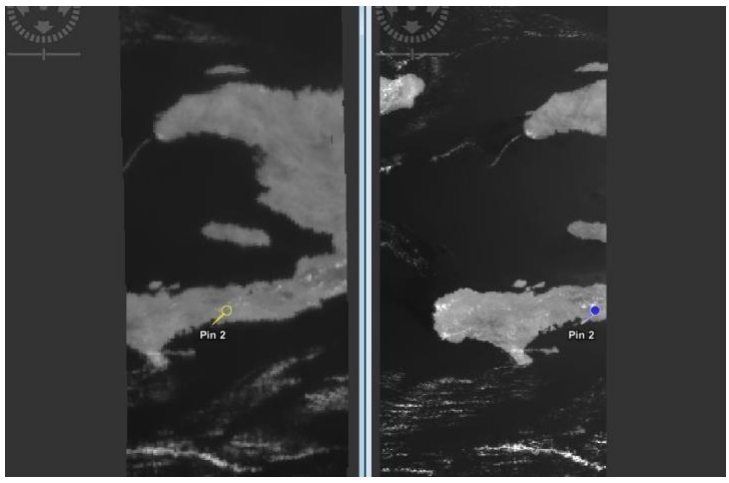

Figure 16. Mid-point of suspected tuning for ZGM-YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32257, 21 June 2001 at 14:52.

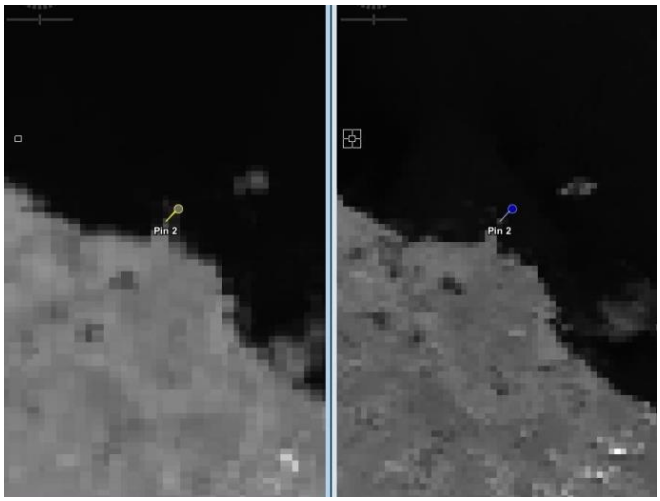

Figure 17. During tuning period for ZGM−YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32350, 28 June 2001 at 02:47.

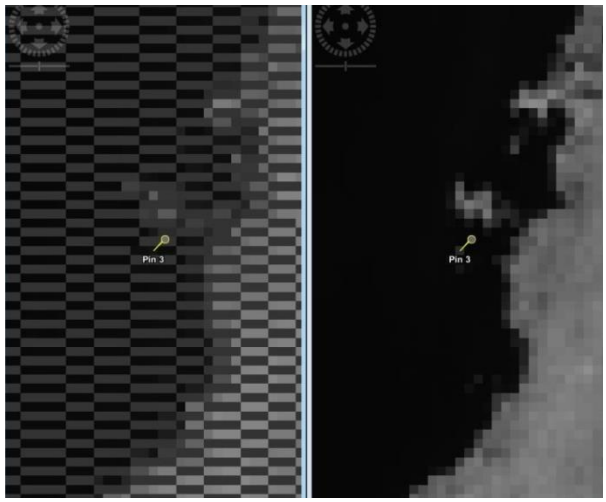

Figure 18. Orbit at the end of the tuning period for ZGM−YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32464, 06 July 2001 at 01:55.

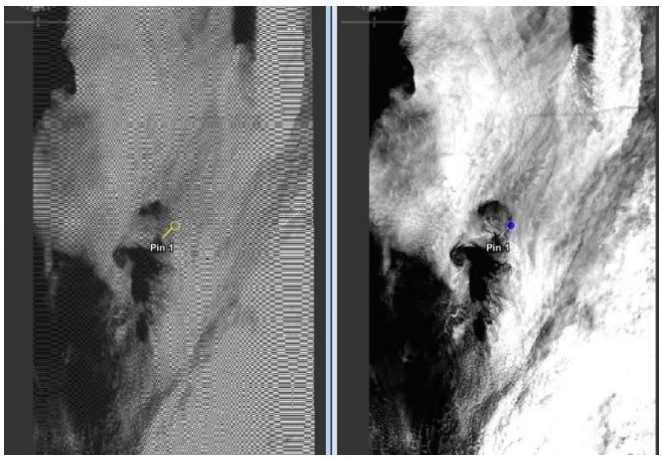

Figure 19. One day after the end of the tuning period for ZGM-YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32484, 07 July 2001 at 11:27.

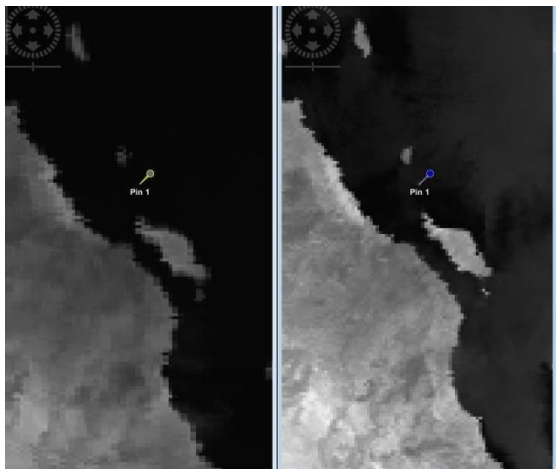

Figure 20. Twelve days after the end of the tuning period for ZGM-YSM. ATSR-2 0.87 µm channel: forward view (left) and nadir view (right). Product orbit number 32645, 18 July 2001 at 17:24.

3.3.3 Non-nominal images

From the figures above, it can be seen that there are cases in which the imagery is not nominal. There are a number of reasons for this that may apply singly or may combine:

1. During the AOCS mode changes, ATSR-2 operations in High-rate mode were sometimes suspended in order to use AMI wind/wave mode data for navigational tuning (see Section 2.1). This affected the ATSR-2 visible channels which were then available only in Low-rate mode, resulting in reduced swath width with 12-bit digitisation or in reduced 8-bit digitisation. Figure 14 has many empty pixels and many cosmetically filled pixels (where empty pixels are filled with values from their nearest neighbours). This is the case in the nadir view, as well as in the forward view. It is suspected this is due to the use of Low-rate mode.

2. In situations where there are many cosmetically filled pixels, this causes the visual effect of blocked groupings of pixels, since the neighbouring pixels are displaying the same values; Figure 18 displays this effect clearly in the forward view.
3. Where pixel exception values are contained within the measurement data set (MDS), BEAM software displays them as measurements. For example, an exception value of -8 (an unfilled pixel, no nearest neighbour found) is considered to be a reflectance value of -0.08% by BEAM, and the pixel in the image is therefore seemingly displaying data when it is empty. This situation applies to both Figure 14 and Figure 18.

3.3.4 Summary

Inspection of ATSR-2 products show problems with geolocation and colocation during the AOCS manoeuvres in the first half of 2001. For the products to be retained in the main archive, it is necessary that both the nadir geolocation and the forward−nadir view colocation are of an acceptable quality.

Table 3 summarises the quality of the geolocation and colocation of the inspected ATSR-2 products during the AOCS changes. We have assumed that the end of the ZGM−YSM tuning period is that given in Section 2.1 (06 July 2001).

Table 3. Summary of geolocation and colocation inspection

Time	Nadir geolocation	Colocation
Before EBM start	Nominal	Nominal
During EBM	Some products acceptable, some not	Some products acceptable, some not
During EBM−YSM	Unacceptable	Unacceptable
Day after ZGM−YSM start	Unacceptable	Unacceptable
One week after ZGM−YSM start	Unacceptable	Unacceptable
Two--three weeks after ZGM−YSM start	Improving	Improving
End of ZGM−YSM tuning period	Acceptable	Acceptable

3.4 Conclusions

The results confirm that there is a large degree of disruption for both the absolute nadir geolocation and the nadir−forward view colocation in the period following the start of the no-gyro AOCS modes on 16 January 2001 at 06:30. This date and time is considered to be the start point for products of unacceptable quality. Products inspected during the EBM and EBM−YSM attitude modes did not always have acceptable geolocation, and the colocation was also problematic in most of the products that were inspected. While the EBM period was found to contain products that seemed to be of acceptable quality (e.g. orbit 30028), it is not possible to identify all such products individually and so segregation must be recommended for the whole period.

Implementation of the ZGM−YSM attitude controls on 06 June 2001 appeared to improve the navigation issues, but not immediately. Results showed that after 2 weeks the issues were greatly alleviated, and improving. At the end of the specified tuning period (4 weeks after the onset of ZGM−YSM) the navigation appeared stable. We cannot state that the quality of the geolocation fully returned to that of the single-gyro mode period, since the mean distance of product pixels from independent sources from 13 June (1 week after

implementation) to 18 July was assessed in this study as 1.6 km (against 1.1 km for single-gyro mode).

Due to the nature of the tuning required for ZGM−YSM, identification of the first acceptable product is not clear-cut, therefore we are being guided by RAL's processing script, and will recommend segregation for products up to and including those generated for 05 July.

In conclusion, we find that the quality and stability of the geolocation of the inspected products is unacceptable from 16 January to 05 July 2001. This corresponds to the data in Figure 1, where, after the initial increase in RSD, the values return to those seen before the AOCS mode adjustments in the second half of 2001.

4. RECOMMENDATION

The results presented in this report confirm a large degree of navigation disruption after the ERS-2 gyro failure in January 2001. ATSR-2 products are subject to poor quality geolocation and colocation from the start of the EBM on 16 January 2001 to the end of the ZGM−YSM tuning period on 05 July 2001.

Therefore, the recommendation from this investigation is that:

- All ATSR-2 products from and including start time 16 January 2001 at 06:32:30 (product orbit 30019) to 05 July 2001 at 22:34:40 (product orbit 32462) should be moved to the segregated section of the archive.

This recommendation is referred to the AATSR QWG for consideration.

5. REFERENCES

RD1. G. Corlett (2015) ATSR V3.0 Sea Surface Temperature Validation Report. University of Leicester, ATSR_V3_SST_Validation_Report_Issue1A.pdf (6th March 2015).

RD2. L. de La Taille *et al*. (1999) Design of one gyro AOCS for the ERS-2 extended mission. In: *Proc. 4th ESA Int. Conf. Spacecraft Guidance, Navigation and Control Systems*, ESTEC, Noordwijk, 18−21 October 1999, ESA SP-425.

RD3. N. Miranda *et al*. (2004) Review of the impact of ERS-2 piloting modes on the SAR Doppler stability. In: *Proc. FRINGE 2003 Workshop,* ESRIN, Italy, 1−5 December 2003. ESA SP-550, June 2004; http://earth.esa.int/fringe03/proceedings/papers/26_miranda.pdf

RD4. B. Rosich *et al*., The ERS-2 mono-gyro and extra backup piloting modes: impact on SAR performance. CEOS- SAR01-043.

RD5. ATSR-2 Anomaly log archive, RAL (1998−2002); http://www.atsr.rl.ac.uk/satellite/logs/anomaly/archive/atsr-2/index.shtml

APPENDIX A ATSR-2 PRODUCTS INSPECTED

Table 4 lists the ATSR-2 products that were inspected in this investigation.

Table 4. List of ATSR-2 products that were inspected

Product
AT2_TOA_1PURAL20010115_070407_0000.00001060_00091_30005_0000.E2
AT2_TOA_1PURAL20010115_152706_0000.00001060_00096_30010_0000.E2

Product
AT2_TOA_1PURAL20010115_235006_0000.00001060_00101_30015_0000.E2
AT2_TOA_1PURAL20010116_031118_0000.00001060_00103_30017_0000.E2
AT2_TOA_1PURAL20010116_045154_0000.00001060_00104_30018_0000.E2
AT2_TOA_1PURAL20010116_063230_0000.00001060_00105_30019_0000.E2
AT2_TOA_1PURAL20010116_081305_0000.00001060_00106_30020_0000.E2
AT2_TOA_1PURAL20010116_121018_0000.00001060_00108_30022_0000.E2
AT2_TOA_1PURAL20010116_131453_0000.00001060_00109_30023_0000.E2
AT2_TOA_1PURAL20010116_195717_0000.00001060_00113_30027_0000.E2
AT2_TOA_1PURAL20010116_213753_0000.00001060_00114_30028_0000.E2
AT2_TOA_1PURAL20010116_231829_0000.00001060_00115_30029_0000.E2
AT2_TOA_1PURAL20010117_005904_0000.00001060_00116_30030_0000.E2
AT2_TOA_1PURAL20010117_023940_0000.00001060_00117_30031_0000.E2
AT2_TOA_1PURAL20010117_042016_0000.00001060_00118_30032_0000.E2
AT2_TOA_1PURAL20010223_063820_0000.00001061_00148_30563_0000.E2
AT2_TOA_1PURAL20010223_164157_0000.00001061_00154_30569_0000.E2
AT2_TOA_1PURAL20010330_013623_0000.00001062_00145_31061_0000.E2
AT2_TOA_1PURAL20010330_164145_0000.00001062_00154_31070_0000.E2
AT2_TOA_1PURAL20010503_121130_0000.00001063_00137_31554_0000.E2
AT2_TOA_1PURAL20010503_221504_0000.00001063_00143_31560_0000.E2
AT2_TOA_1PURAL20010607_034809_0000.00001064_00132_32050_0000.E2
AT2_TOA_1PURAL20010607_185330_0000.00001064_00141_32059_0000.E2
AT2_TOA_1PURAL20010610_053426_000000001064_00176_32094_0000.E2
AT2_TOA_1PURAL20010613_072046_0000.00001064_00220_32138_0000.E2
AT2_TOA_1PURAL20010621_145201_0000.00001064_00339_32257_0000.E2
AT2_TOA_1PURAL20010628_024738_0000.00001064_00432_32350_0000.E2
AT2_TOA_1PURAL20010706_015552_0000.00001065_00045_32464_0000.E2
AT2_TOA_1PURAL20010707_080639_0000.00001065_00063_32482_0000.E2
AT2_TOA_1PURAL20010707_112750_0000.00001065_00065_32484_0000.E2
AT2_TOA_1PURAL20010707_213126_0000.00001065_00071_32490_0000.E2
AT2_TOA_1PURAL20010709_002100_000000001065_00087_32506_0000.E2
AT2_TOA_1PURAL20010712_103020_000000001065_00136_32555_0000.E2
AT2_TOA_1PURAL20010715_135716_000000001065_00181_32600_0000.E2
AT2_TOA_1PURAL20010718_172411_000000001065_00226_32645_0000.E2