Envisat AATSR Performance Report

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1. INTRODUCTION

1.1 Purpose and Scope

This document describes the performance of the AATSR (Advanced Along-Track Scanning Radiometer) instrument throughout the whole Envisat mission and the subsequent impact upon data quality. AATSR was the third in a series of instruments primarily designed to make accurate measurements of the Sea Surface Temperature (**SST**) and it operated continuously throughout the Envisat mission.

The performance details reported here encompass many different aspects, including routine operations, non-nominal events and special investigations conducted by IDEAS. Instrument events are recorded and detailed in the accompanying Envisat AATSR Events Report [RD.2]. Both documents are focused purely on AATSR and as such only contain limited details on the performance of, or events occurring on, the Envisat satellite itself.

Quality control (**QC**) activities were performed by IDEAS in conjunction with the work of the Expert Support Laboratory (**ESL**) and the Calibration and Validation (**Cal/Val**) teams. The teams share information and support, mainly through the forum of the Quality Working Group (**QWG**), ensuring that activities are complementary and comprehensive. For AATSR, the University of Leicester (**UoL**) provides Validation support and the Rutherford Appleton Laboratory (**RAL**) holds both the ESL and the Calibration roles.

A reprocessing of AATSR data is planned to be completed in 2013, this will be the third such reprocessing of AATSR data; where this will affect information provided in this report, an indication of the impact is given.

1.2 Structure of the Document

After this introduction, the document is divided into a number of major sections that are briefly described below:

2 STATUS AT ENVISAT END OF MISSION

An overview of the operational status of AATSR in April 2012.

3 AATSR PROCESSOR AND ADF UPDATES

This section presents a summary of the updates to the processor and ADFs that took place throughout the Envisat mission.

4 ROUTINE MONITORING PERFORMANCE

This section gives a summary of the performance indicators that were routinely reported on, generally in Cyclic Reports, throughout the Envisat mission.

5 KNOWN NON-NOMINAL DATA PERIODS

A list of periods during which AATSR data were generated but were not nominal is presented here.

6 SPECIAL INVESTIGATIONS

In response to routine QC and user feedback, a number of investigations were undertaken into AATSR data by IDEAS; details are given in this section.

7 CALIBRATION/VALIDATION ACTIVITIES AND RESULTS

Calibration and validation activities undertaken by other QC participants are summarised here.

8 SUMMARY AND FUTURE PLANS

This section presents the summary of instrument performance and data quality. Plans for the forthcoming reprocessing are also outlined.

9 GLOSSARY

This section presents the abbreviations commonly used in this document.

APPENDIX A MONTHLY L3 PLOTS FOR MARCH 2012

The final L3 monthly plots for SST are reproduced here for reference.

1.3 Referenced Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

RD.1 ENVISAT AATSR Instrument Performance – End of Mission Report, PO-RP-RAL-AT-0621, Version 1.

RD.2 Envisat AATSR Events Report, IDEAS-VEG-OQC-REP-1141, Version 1.0.

RD.3 Merchant, C. J. *et al*. (2006) Retrievals of sea surface temperature from infra-red imagery: origin and form of systematic errors. Q. Jl Met. Soc. 132, 1205–1223.

RD.4 AATSR Geo-location case studies with respect to the GlobSnow snow extent product, ESA Study TN ESRIN Contract 21703/08/I-EC, Version 0.1/01.

RD.5 Minutes from the 13th AATSR QWG, 11/12 July 07, AEP.MIN.021_1 QWG13 Minutes.pdf, Version 1.

RD.6 Increased Rates of CRC Errors Seen in AATSR Data From 2006, OSME-DPQC-SEDA-TN-06-0257, Version 1.

RD.7 AATSR E2010+ Mini-Commissioning Report, IDEAS-VEG-OQC-REP-0732, Version 1.

RD.8 AATSR Geolocation Report, IDEAS-VEG-OQC-REP-0674, Version 1.

RD.9 AATSR Geolocation assessment for new CH1 file, IDEAS-VEG-OQC-REP-0826, Version 1.

RD.10 MERIS Absolute Geolocation Status, S. Saunier & P. Goryl: Issue 1 Revision 0, 19th August 2004.

RD.11 MERIS Absolute Geolocation Status, S. Saunier & P. Goryl: Issue 3 Revision 0, 5th April 2006.

RD.12 Zeller, O. and Ghent, D. (2011) AATSR Absolute Geolocation Accuracy, UL-LST-P03, Issue 2A.

RD.13 Cox, C. (2012) ESL Support Presentation to the 24th AATSR QWG, February 2012.

RD.14 O'Carroll, A. G. *et al*. (2006) Validation of the AATSR meteo product sea surface temperature. J. Atmos. Oceanic Tech. 23, 711–726.

RD.15 Embury, O. and Corlett, G. K. (2010) AATSR SST retrieval: updated retrieval coefficients based on ARC project findings, UL-SST-P04, Issue 1A dated 15/11/2010.

RD.16 O'Hara, S. et al. (2012) Quality control and reprocessing of AATSR data. In Proc. Sentinel-3 OLCI/SLSTR and MERIS/(A)ATSR Workshop, ESRIN, Frascati, Italy, 15-19 Oct. 2012.

1.4 Definitions of Terms

The following terms have been used in this report with the meanings shown.

Term	Definition
ESL	Expert Support Laboratory, one of the three main entities responsible for operational QC activities, along with IDEAS and the Cal/Val teams. The ESL for AATSR is the Rutherford Appleton Laboratory (RAL).
FOS	Flight Operations Support, contract work undertaken by RAL in support of the AATSR instrument.
IDEAS	Instrument Data quality Evaluation and Analysis Service, reporting to the ESA Data Quality and Algorithms Management Office (EOP-GMQ), responsible for quality of data provided to users including the data calibration and validation, the data processing algorithms, and the routine instrument and processing chain performances.
QWG	Quality Working Group, comprising the project Principal Investigator, ESA, ESL, FOS, IDEAS, Calibration and Validation Scientists and interested parties. The QC teams share information and support, mainly through the forum of the QWG, ensuring that activities are complementary and comprehensive.

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2. STATUS AT ENVISAT END OF MISSION

At the time of the Envisat end of mission (8th April 2012), AATSR was functioning nominally. RD.1 contains a comprehensive summary of the instrument performance and events throughout its lifetime; the main issues being summarised here. Based on an assessment of the housekeeping and science data, AATSR would have continued to operate beyond 2014 with clear margins.

This document addresses the performance aspects of AATSR; a full listing of AATSR events throughout the whole of the Envisat mission is given in RD.2.

2.1 AATSR Output Products

A list of the operational products that were routinely generated at the end of the Envisat mission is given in Table 1. Note that the Product ID for the Level 2 Pre-processed (**L2P**) products will change as a result of the third AATSR reprocessing.

Table 1. AATSR product list at Envisat end of mission

Product ID	Description
ATS_NL__0P	AATSR Level 0 (not routinely distributed)
ATS_TOA_1P	AATSR Level 1: Gridded brightness temperature and radiance product. Full resolution for all channels/both views
ATS_AST_BP	AATSR Level 1: Browse product (three-colour composite)
ATS_NR__2P	AATSR Level 2: Gridded surface temperature
ATS_AR__2P	AATSR Level 2: Spatially averaged surface temperature
ATS_MET_2P	AATSR Level 2: Meteo product (spatially averaged SST); routine production in Near Real Time (**NRT**) only
yyyymmdd-ATS_NR_2P-UPA-L2P-ATS_NR__2P	AATSR Level 2: L2P netCDF product containing dual-view SST from the named NR product

Figure 1 shows the AATSR product tree. (Note that the processing heritage for the L2P products will change for the third AATSR reprocessing.)

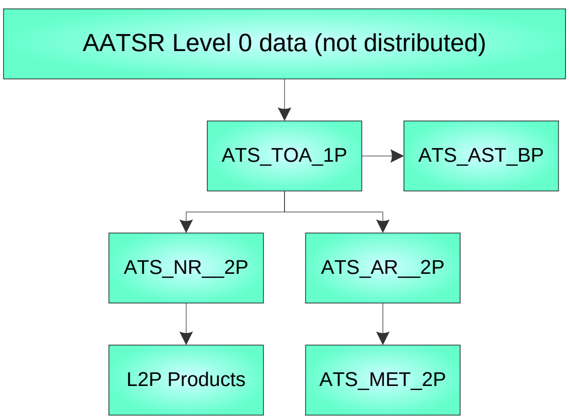

Figure 1. The AATSR product tree.

2.2 Reporting

Routine daily monitoring reports for AATSR are available at https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/quality-control-reports/daily-quality-reports. This resource gives a comprehensive summary of the daily status of the satellite, instrument and products from September 2005 up to the end of mission.

Routine Cyclic Reports (**CR**) for AATSR are available at https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/quality-control-reports/cyclic-quality-reports from Cycle 16 (April 2003) to the end of mission (Cycle 113, April 2012). These reports were distributed at the end of each Envisat cycle by the AATSR IDEAS team on behalf of the QWG to keep the AATSR community informed of any modification regarding instrument performance, the data production chain and the results of any calibration and validation campaigns.

The AATSR page on the European Space Agency (**ESA**) Sensor Performance, Products and Algorithms (**SPPA**) website (https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/sensor-description contains access to the reports mentioned above, as well as supplementary information on AATSR-related articles and studies, and the AATSR archive status.

2.3 Software and ADF Configuration

At the end of mission, the AATSR processing chain was running under the configuration given below for the Instrument Processing Facility (**IPF**) and L2P processor software versions and the auxiliary data file (**ADF**) configuration. (Note that for the third reprocessing of AATSR data, new versions of both the IPF and L2P processor will be used, and also some auxiliary files will be updated. Information on these differences will be provided to users of the reprocessed data.)

2.3.1 Software version

AATSR IPF for Level 1 and Level 2:	Version 6.03
AATSR L2P Processor:	Version 1.5.

2.3.2 Auxiliary data files

AATSR processing used the following instrument-specific ADFs:

Browse Product Lookup Data	(ATS_BRW_AX)
L1b Characterisation Data	(ATS_CH1_AX)
Cloud Lookup Table Data	(ATS_CL1_AX)
General Calibration Data	(ATS_GC1_AX)
AATSR Instrument Data	(ATS_INS_AX)
Visible Calibration Coefficients Data	(ATS_VC1_AX)
L1B Processing Configuration Data	(ATS_PC1_AX)
L2 Processing Configuration Data	(ATS_PC2_AX)
SST Retrieval Coefficients Data	(ATS_SST_AX)
Land Surface Temperature (**LST**) Coefficients Data	(ATS_LST_AX)

Generic Envisat files used in AATSR routine processing were:

Land/Sea Mask Data	(AUX_LSM_AX)
Digital Elevation Data	(AUX_DEM_AX)
Orbit State Vector Data	(AUX_FRO{FPO}_AX)

The filename for each AATSR ADF file in use in the Payload Data System (**PDS**) at end of mission is given in Table 2. Due to the fact that the PC1 file contained the orbit period, two versions had to be maintained after the mission extension orbit manoeuvres. Note that the VC1 ADFs were dynamic files, with one being produced for almost every L1 product, and therefore it is not practical to list these individually.

Table 2. AATSR auxiliary files in use at the PDS at end of mission

Product name
ATS_BRW_AXVIEC20020123_072338_20020101_000000_20200101_000000
ATS_CH1_AXVIEC20070720_093530_20020301_000000_20200101_000000
ATS_CL1_AXVIEC20101015_104659_20020301_000000_20200101_000000
ATS_GC1_AXVIEC20070720_093834_20020301_000000_20200101_000000
ATS_INS_AXVIEC20070720_094014_20020301_000000_20200101_000000
ATS_LST_AXVIEC20101018_094830_20020301_000001_20200101_000000
ATS_PC1_AXVIEC20101015_101827_20020301_000000_20101021_235959 ATS_PC1_AXVIEC20101015_100604_20101022_000000_20200101_000000
ATS_PC2_AXVIEC20020123_074151_20020101_000000_20200101_000000
ATS_SST_AXVIEC20051205_102103_20020101_000000_20200101_000000
Plus ATS_VC1_AX dynamic files

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3. AATSR PROCESSOR AND ADF UPDATES

This section lists the main updates that took place to the AATSR processors and the ADFs throughout the mission.

The IPF generated the nominal Envisat format products. The L2P processor was a separate processor installed in the ground segment. It repackaged the NR L2 SST data into netCDF format along with ancillary information. Note that for the third reprocessing, a new processor will be used to generate these products (see below for further information).

3.1 IPF Processor

Table 3 lists the main updates to the AATSR IPF that took place during the mission. Note that version 6.05 is the IPF version that will be used in the third AATSR reprocessing, along with the new ADFs outlined in Section 3.3, but it was never implemented operationally. Two previous reprocessings were carried out, in 2004 (v5.58) and 2007 (v6.01).

Table 3. Main AATSR IPF updates during the mission

Date	IPF version	Details
Feb 2002	5.01	Launch version
Jun 2002	5.02	Scan jitter error corrected Browse algorithm improved
Jan 2003	5.55	Modifications to Viscal algorithm
Mar 2004	5.58	New LST algorithm for NR product Further Viscal algorithm modifications
Jan 2007	5.60	AST confidence word correction Cloud flagging errors corrected
Mar 2007	6.0	Cloud-clearing over land improved Improvements to LST algorithm
Jul 2007	6.01	Correction for wrong ANX calculation
Sep 2009	6.02L02	Processor platform ported from AIX to Linux; no algorithm change
Jun 2010	6.03	Preparations for Envisat 2010+ AST 17km cell confidence word fixed
(2012)	*6.05*	*Improved viscal algorithm (version for third reprocessing)*

Table 4 shows the dates (and orbits) of the first product processed with the new IPF version for each processing centre. Due to reprocessing, IPF changes prior to version 6.01 are not included here. Please note that the dates given in the table refer to the acquisition date of the product in question and are not the dates of implementation at the processing centre (although this is generally the same for NRT processing but not for consolidated data). Processing time and software version information for a particular product can be obtained from the Main Product Header (**MPH**).

The processing centres for NRT data are Payload Data Handling System-ESRIN (**PDHS-E**) and Payload Data Handling System-Kiruna (**PDHS-K**) and for Consolidated data is the UK Multi-Mission Product Archive Facility (**UK-MM-PAF**).

Table 4. IPF version implementation details

IPF Version	NRT		Consolidated
	ESRIN (PDHS-E)	Kiruna (PDHS-K)	UK-MM-PAF
6.01	02/07/07 (orbit 27910)	02/07/07 (orbit 27902)	All previous data
6.02L02	28/09/09 (orbit 39623)	28/09/09 (orbit 39624)	28/09/09 (orbit 39632)
6.03	16/06/10 (orbit 43369)	16/06/10 (orbit 43361)	17/06/10 (orbit 43379)

A reprocessing took place for data up to 23 July 2007; users inspecting data acquired before this date should be using the reprocessed products, which were generated using processor version 6.01. Likewise after completion of the third reprocessing, users should ensure that all their data were processed with version 6.05 of the IPF.

AATSR IPF changes are detailed in the AATSR IPF Change Log, available at: https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/products-and-algorithms/processor-releases.

3.2 L2P Processor

In December 2008 ESA took over the responsibility of producing L2P products in netCDF format as part of AATSR operations. These products had been initiated by the DUE (Data User Element) Project Medspiration, as part of the European contribution to the Group for High Resolution SST (**GHRSST**) and they were essentially a repackaging of the L2 NR products with some added ancillary information.

Table 5 lists the main updates that took place to the L2P processor during the mission. Note that version 1.5. was the version used to generate the consolidated archive of L2P products for all three ATSR instruments.

Table 5. Main AATSR L2P updates during the mission

Date	L2P version	Details
Dec 2008	1.1	Initial version (NRT only)
(Feb 2009)	(1.1)	(Format of xml description files updated)
May 2009	1.5	Addition of Aerosol Optical Depth Addition of satellite minus SST analysis Lat/lon coords provided for pixel centre Header time fields include UTC keyword View difference only provided for SST pixels
Nov 2009	1.5.	Order of two metadata file parameters swapped
(2012)	*TBD*	*New processor (see below for details)*

Unlike the Envisat format data, both NRT and consolidated L2P products were generated at the UK-MM-PAF; Table 6 shows the dates (and orbits) of the first product processed with new L2P processor versions. Please note that the dates given in the table refer to the acquisition date of the product in question and are not the dates of implementation (although this is generally the same for NRT processing but not for consolidated data).

Table 6. L2P processor version implementation details

L2P Processor Version	UK-MM-PAF	
	NRT	Consolidated
L2P V1.1 (Initial version)	01/12/08 (orbit 35316)	(not used)
L2P V1.1 (xml files change)	6/02/09 (orbit 36565)	(not used)
L2P V1.5	29/05/09 (orbit 37885)	(not used)
L2P V1.5.	04/11/09 (orbit 40163)	All data

All AATSR L2P changes are detailed in the AATSR IPF Change Log, available at: https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/products-and-algorithms/processor-releases.

For the third AATSR reprocessing, a new processor, based on the ATSR Reprocessing for Climate (**ARC**) processor, is being developed to produce L2P (and Level 3 Uncollated (**L3U**)) data products. The main difference to the previous L2P products is that these will now be calculated directly from L1B data. The ARC processing scheme also provides improved cloud detection and SST retrieval [RD.3]. The L2P and L3U products will be GHRSST Data Specification v2.0 format netCDF products.

3.3 Main ADF Changes

Table 7 lists the main updates that took place to the AATSR ADFs during the mission. Note that the italicised entries refer to updated ADFs produced for use in the third AATSR reprocessing.

AATSR ADF changes are also detailed in the AATSR IPF Change Log, available at: https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/products-and-algorithms/processor-releases.

Table 7. Main AATSR ADF updates during the mission

ADF name	Date	Details
ATS_VC1_AX	Sep 2002	Corrected scaling errors; replaced by daily files
	Nov 2005	To account for Viscal drift
	Dec 2006	Viscal drift correction update
	Feb 2007	Orbital files delivery started
	2012	*Complete set of orbital files reproduced for reprocessing, including measured drift correction*
ATS_CH1_AX	Nov 2002	Colocation correction
	2012	*Colocation and geolocation correction*

ADF name	Date	Details
ATS_PC1_AX	Jan 2003 Aug 2004 *2012*	To support IPF v5.55 update Updated solar irradiance data *To support IPF v6.05 update*
ATS_GC1_AX	Dec 2004	1.6 µm non-linearity correction
ATS_SST_AX	Dec 2005 *2012*	Revised SST coefficients *Updated SST coefficients (using ARC)*
ATS_CL1_AX	Mar 2007 *2012*	Cloud test changes (for IPF v6.0) *1.6 µm & gross cloud test corrections*

4. ROUTINE MONITORING PERFORMANCE

This section outlines the mission performance of those instrument parameters and data Quality Control indicators that were routinely monitored and reported on in the AATSR Cyclic Reports.

4.1 Monitoring of Instrument Parameters

The instrument parameters were monitored by the ESL and Flight Operations Support (**FOS**) teams. The details given in Section 4.1 are taken from RD.1, which contains full details on these and other instrument parameters.

4.1.1 Jitter

The Scan Mirror Unit (**SMU**) provided both the mechanical location and rotation of the scan mirror. The scan mechanism has completed an estimated 2.1 billion revolutions since being activated on 15 March 2002, with no anomalies reported. Daily monitoring of the scan counters typically showed the counter to be incrementing linearly with time; indicating that the scan period is being maintained at 150 ms.

Within each 150 ms scan, there should be exactly 2000 75-μs pixels. Occasionally a scan mirror 'jitter' occurs due to an electronic race condition between the pixel clock and the scan synch pulse or mechanical friction, resulting in more than 2000 pixels per scan. For each orbit of data processed, the average, maximum and minimum jitters per second are computed and saved to a text file available on the AATSR operations web site: http://www.aatsrops.rl.ac.uk/EDSX/MissionTrends/JitterHistory/Jitter_History.dat. (Try an alternative browser if this link does not open.) The time series of the detected jitters is shown in Figure 2, where the blue trace represents the mean jitter rate per orbit, and the red trace represents the maximum jitter rate per orbit. The solid lines represent the fitted trend to the data.

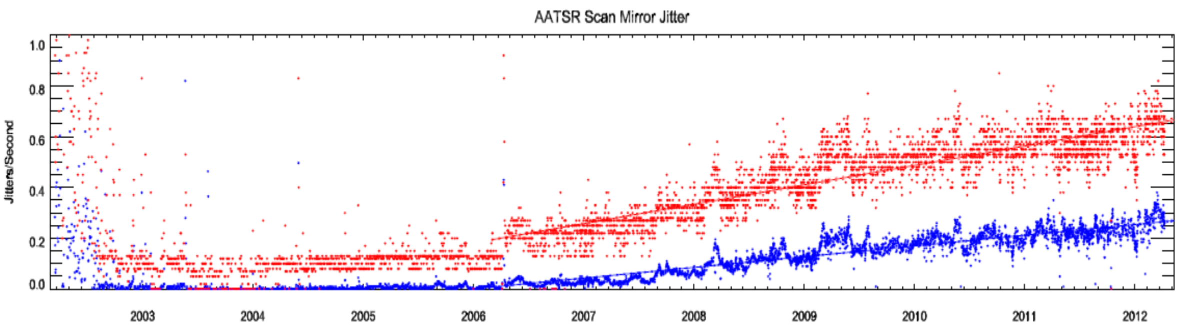

Figure 2. Scan mirror jitter rate for the Envisat mission (taken from RD.1).

At the start of the mission the average jitter rate was typically 5% per orbit but fell off to negligible rates within a few months. This was consistent with the normal running-in of the mechanism.

Occasional 'spikes' in the jitter rate can be seen that coincide with some of the instrument outages. After a period of inactivity, the mechanism bearings will have cooled down significantly. When the instrument is restarted the bearings will run on a different 'track' until the mechanism has returned to operating temperatures.

Between the end of 2002 and April 2006, the mean rate of jitters remained negligible and the maximum rate was stable at ~0.1 per second (~2%). Since an Envisat Service

Module anomaly in April 2006, the mean jitter rate gradually increased to ~0.23 per second (3.5% per orbit) at the end of mission.

4.1.2 Sensor temperature

The cooler performed well throughout the mission and maintained the InfraRed Focal Plane Assembly (**IR-FPA**) at 80 ± 0.5K during normal operations, see Figure 3. The outliers in the plot are due to biases introduced by the conversion function rather than variations in the detector temperature (see RD.1 for full details).

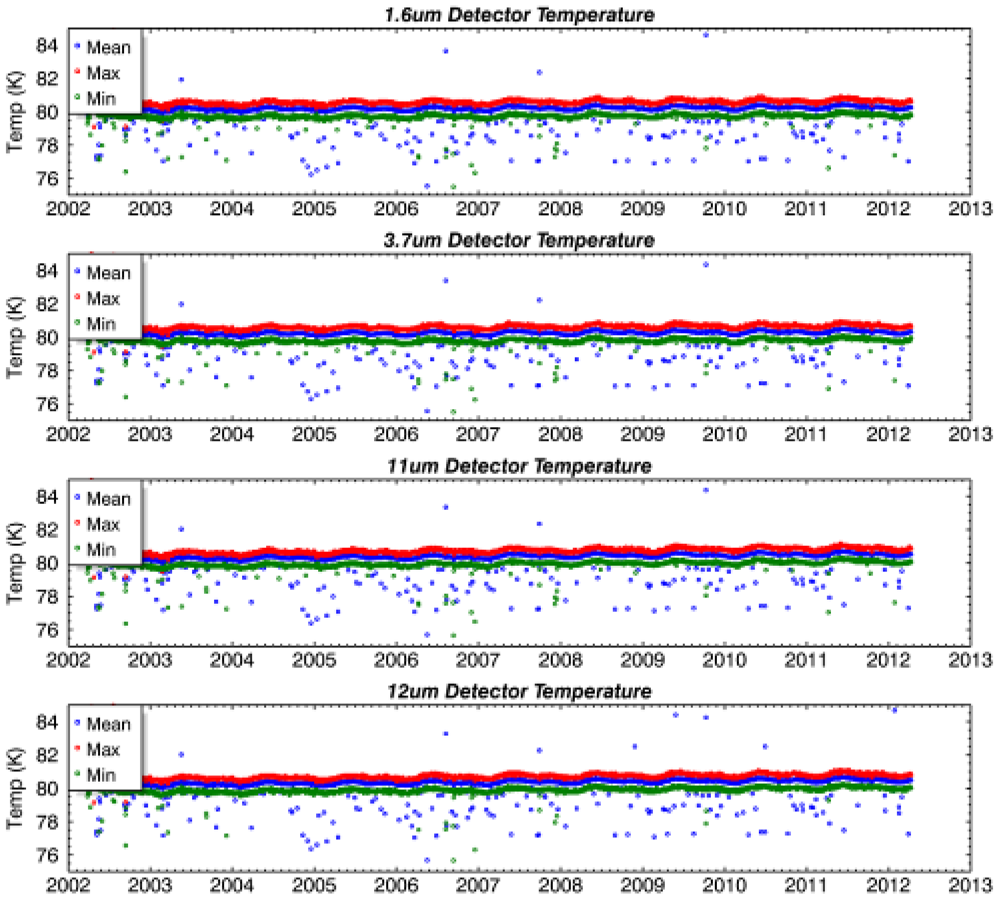

Figure 3. AATSR infrared detector temperatures during the Envisat mission (taken from RD.1).

4.1.3 Visible calibration

The optical throughput of the 1.6 µm, 0.87 µm, 0.66 µm and 0.56 µm channels is monitored using the Visible Calibration (**VISCAL**) system. Figure 4 shows the 1.6 µm, 0.87 µm, 0.66 µm and 0.56 µm visible channel calibration levels, G, relative to the level at the start of the mission, G_0 (taken from RD.1).The data in Figure 4 have been adjusted to allow for the variation of the solar intensity, and show that performance of the visible channels was strongly affected by the build-up of contamination on the IR-FPA. Prior to November 2002, the throughput of short wavelength channels fell off sharply after running the IR-FPA at 80 K for a few weeks.

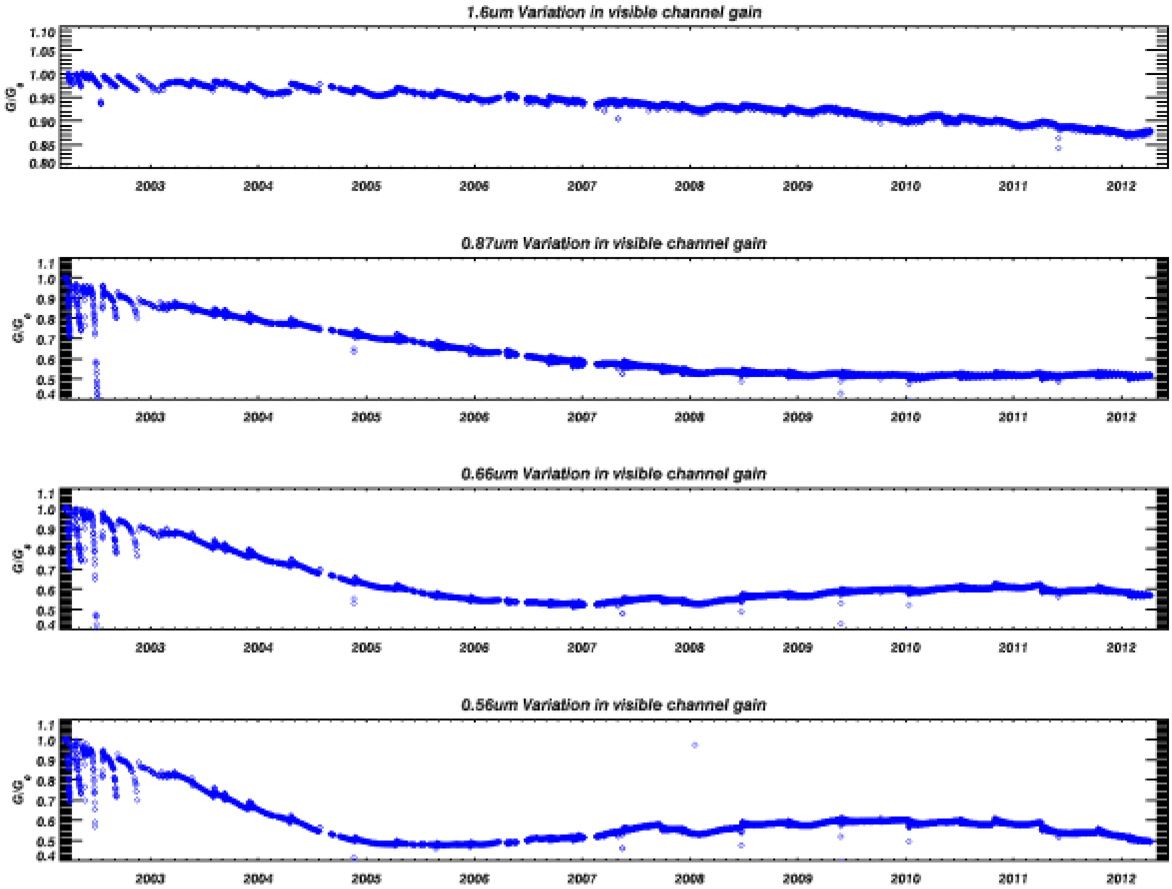

Figure 4. The 1.6 µm, 0.87 µm, 0.66 µm and 0.56 µm visible channel calibration levels, G, relative to the level at the start of the mission, G_0 (taken from RD.1).

After November 2002, the fall-off in signal was much less as the condensation rate reduced to rates approaching those seen at the start of the ATSR-2 mission. Although the contamination rate had slowed down, the condensation layer on the relay lens became more coherent resulting in interference fringes of the type seen at the start of the ERS-2 mission, as seen in Figure 5. The data in Figure 5 have been adjusted to allow for the variation of the solar intensity, and the oscillations in the signal are due to the build-up of a thin condensation layer causing a thin film interference effect.

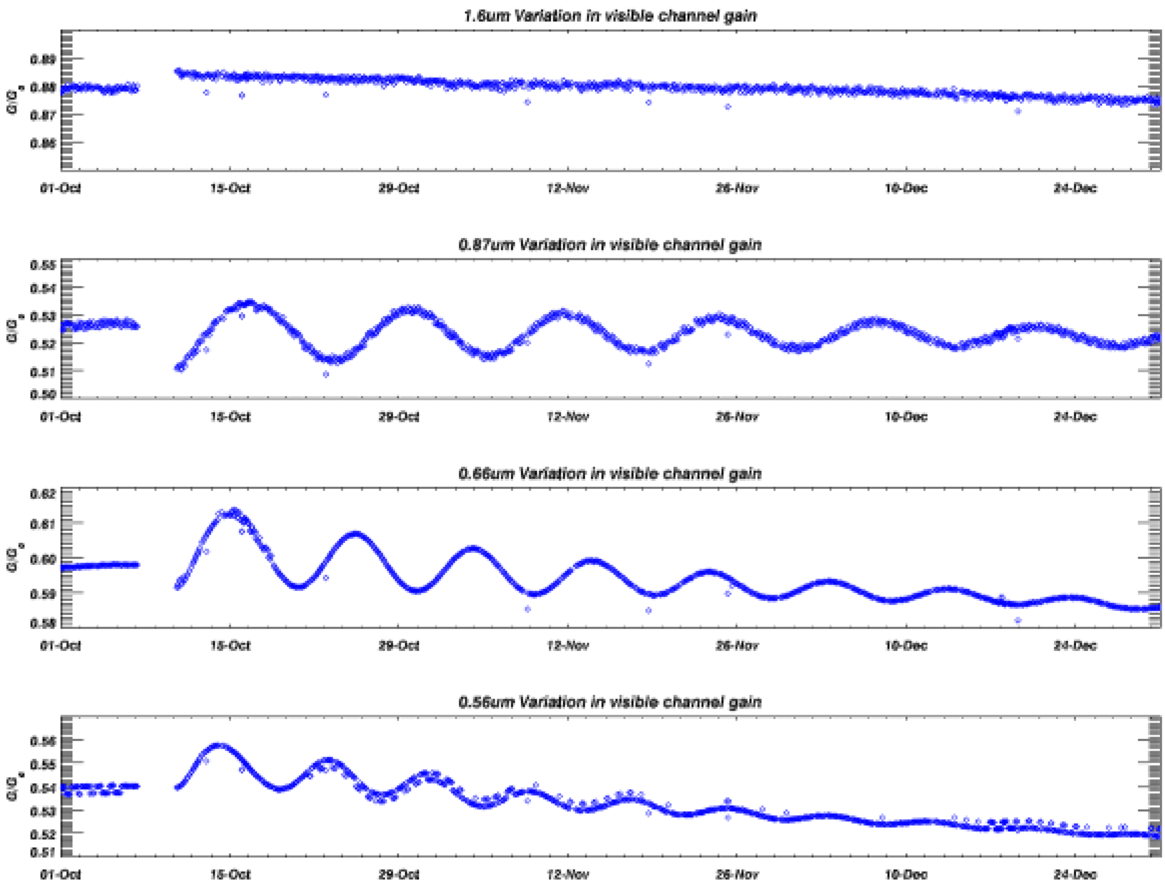

Figure 5. Detail for the period from 01 October 2011 to 31 December 2011 showing the 1.6 µm, 0.87µm, 0.66 µm and 0.56 µm visible channel calibration levels, G, relative to the level at the start of the mission, G_0 (taken from RD.1).

4.1.4 NEΔT

For AATSR, the standard deviation of the signal channel counts from the on-board calibration sources were used to obtain values of Noise Equivalent Delta Temperature (**NEΔT**) at the hot blackbody (**HBB**) and cold blackbody (**CBB**) temperatures.

In Figure 6 we see that the NEΔTs for the thermal infrared channels have remained stable for the duration of the mission. The mean values over this time are given in Table 8; they are within the requirements and are comparable with the pre-launch calibration measurements.

There have been a few occasions where the noise has increased above the baseline level, possibly due to contamination or a warmer thermal environment, however, the noise has remained within the specified limits.

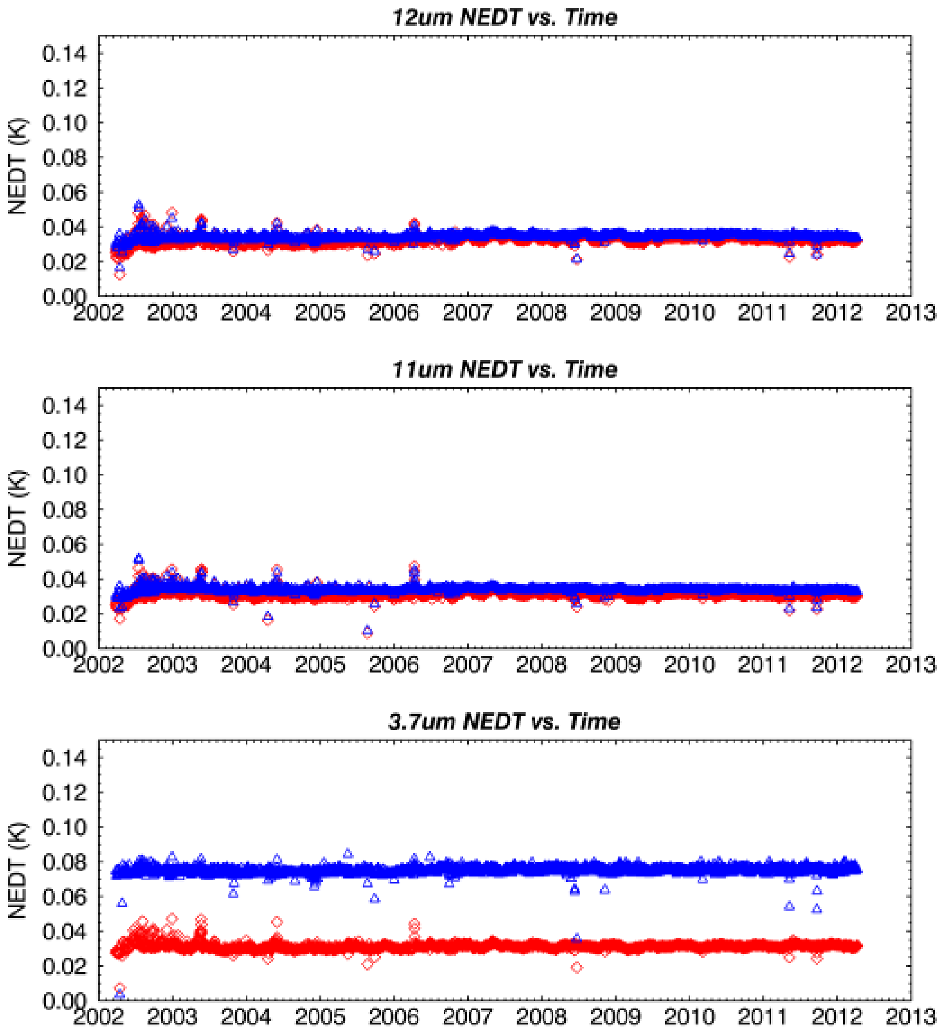

Figure 6. NEΔT for 12 µm, 11 µm and 3.7 µm channels for the Envisat mission (taken from RD.1).

Table 8. In-flight NEΔT values compared with requirement and pre-launch measurements (taken from RD.1)

		3.7 µm	11 µm	12 µm
Requirement	T=270K	0.080 K	0.050 K	0.050 K
On-Orbit Average	T=CBB (251K)	0.075 K	0.034 K	0.035 K
	T=HBB (301 K)	0.031 K	0.031 K	0.033 K
Pre-Launch	T=270 K	0.037 K	0.025 K	0.025 K
	T=CBB (253 K)	0.065 K	0.030 K	0.030 K
	T=HBB (295 K)	0.020 K	0.020 K	0.020 K

4.1.5 Instrument performance summary

RD.1 gives a full and complete description of the performance of AATSR throughout the Envisat mission, as well as the main events that occurred. The performance of the key subsystems mentioned in this document is summarised below:

- The scan mirror completed approximately 2.1 billion revolutions since being activated on 15 March 2002, with no anomalies reported. Between the end of 2002 and April 2006, the mean rate of jitters remained negligible and the maximum rate was stable at ~0.1 per second (~2%). Since an Envisat Service Module anomaly in April 2006, the mean jitter rate gradually increased to ~0.23 per second (3.5% per orbit) at the end of mission, but this had negligible impact on the data.
- The IR channels performed well within specifications with very limited degradation over the mission lifetime.
- The visible - shortwave infrared (**VIS**-**SWIR**) channels performed well over the mission. Although there was a loss of optical throughput due to degradation of the optical components, the signal-to-noise ratio remained within specification throughout.
- The blackbodies used for the calibration of the thermal IR channels remained stable throughout the mission. Trend analysis of the thermometers, and periodic cross-over tests indicated that the calibration drifts were negligible.
- The VISCAL system provided a stable calibration source for the VIS–SWIR channels. Using vicarious calibration results to correct for expected long-term degradation of the diffuser and optics, the signal channels could be calibrated to an uncertainty less than 3%.
- The instrument thermal design has ensured that the temperatures of the optical enclosure have remained stable throughout the mission.

Excluding the main commissioning phase up to 23 July 2002, AATSR measurement data were available for more than 95% of the mission.

4.2 Level 3 Products

Monthly Level 3 products were routinely generated by the IDEAS team from the Meteo products for QC monitoring purposes. Plots generated from the monthly L3 data were published in the AATSR CR, but the data were not otherwise distributed. As an example, and to illustrate the continued quality of AATSR data up to the end of the mission, the final whole-month L3 maps for March 2012 are provided in APPENDIX A.

The global maps included in the CR displayed the average SST from dual-view and nadir-only data, the standard deviation and the number of contributory orbits. The displayed statistics exhibited SSTs of high quality, and showed the seasonal SST trends. Later CRs also contained maps of the anomalies of the monthly averages using, as a reference, the Global Ocean Surface Temperature Atlas (**GOSTA**) SST climatology.

Occasionally, the SST maps highlighted localised regions where some SST values showed up as very cold compared to surrounding SSTs, and investigations revealed the underlying cause was due to poor cloud detection. These areas were not always obvious in monthly averaged maps and so in order to monitor the issue better, the production of daily L3 maps was undertaken to try to identify the specific problem products. These then fed into research on improving the cloud identification tests for the AATSR L1B products. Although the problem was not sustained or widespread, it was of concern to operational users of SST; see Section 6.5 for information on these investigations.

4.3 Product Quality Readme Files

Throughout the mission there have been a number of Product Quality Readme (**PQR**) files (previously termed "disclaimers") released to users to inform them of possible quality issues with the data. The QWG deemed it acceptable for some of these issues to remain understood but unresolved; otherwise the underlying problem was resolved and the PQR left in place for reference in case the affected data products were still in use.

The PQRs for AATSR are available online at the ESA website, on the Status of Envisat Products webpage: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/content?p_r_p_564233524_assetIdentifier=status-of-envisat-products-4072.

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5. KNOWN NON-NOMINAL DATA PERIODS

AATSR supplied high-quality scientific data for over 95% of the operational mission. However, there are some known periods of non-nominal data that are contained within the archive. These are listed in this section, along with the time periods of the affected data.

Note that, after the third AATSR reprocessing, we expect all the data mentioned in this section to be available in the AATSR archive. However, the affected products will likely be segregated. This is to ensure that as much data as possible is still available to users, but the segregation of non-nominal products will ensure that users do not unintentionally access these products without being aware of the issues involved.

Note on AATSR Product Orbit Numbering

The orbit start and end numbers of these periods are also given where known, but it must be noted that, since nominal AATSR archived products start before the ascending node crossing (**ANX**) of a particular orbit, they are generally *named* with the orbit number previous to the one for the whole orbit that they represent.

Figure 7 illustrates this issue, referring to both nominal length products and short length products.

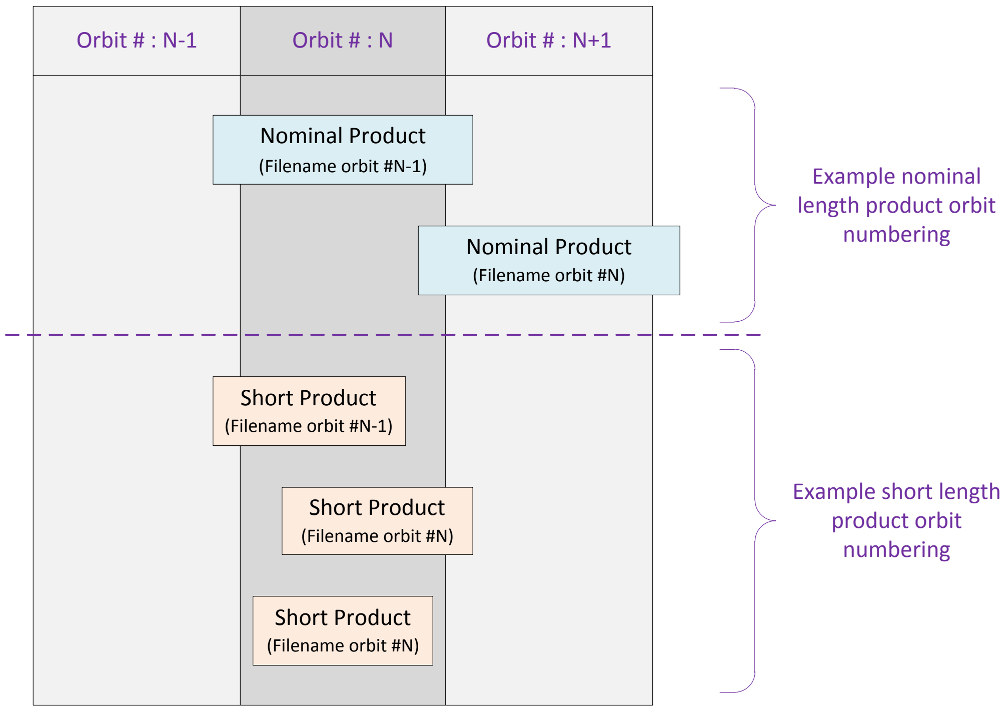

Figure 7. Illustration of AATSR product orbit numbering.

The name of an Envisat product contains the orbit number from the first line of data. In nominal circumstances, AATSR products (due to the dual-view formulation) start in Envisat orbit N-1 and therefore the product name contains orbit N-1, even though most data contained within the product is from Envisat orbit N. A later start time for a nominal product would find it named correctly with Envisat orbit N. Short AATSR products may have the same formulation as a nominal product and start in Envisat N-1, start later or even be contained wholly within one orbit.

For these reasons, it is recommended that reference be made to the start time information in the AATSR product name rather than relying on the orbit number.

The tables in this section refer to the Envisat orbit number, unless stated otherwise.

5.1 AATSR Outgassings and Blackbody Crossover Tests

There were two housekeeping activities routinely carried out that affected AATSR data:

- Periodic planned outgassing activities where the cooler drive amplitudes were commanded to zero to allow the IR-FPA to warm up to ambient for decontamination. AATSR remained in MEASUREMENT mode, but the data it recorded were compromised.
- Blackbody (**BB**) cross-over tests that were performed to determine any gross calibration errors of the on-board blackbodies. AATSR remained in MEASUREMENT mode during this test to allow generation of L0 data for analysis, but resulting L1B/L2 were not suitable for scientific use.

The above procedures occurred periodically throughout the Envisat routine operational phase. Full details are given in RD.1 and RD.2; Table 9 lists the periods in time order for reference.

Table 9. Periods of AATSR outgassings and blackbody crossover tests

Start time	End time	Orbit start	Orbit end	Details
30/04/2002	02/05/2002	(not known)	(not known)	Blackbody cross-over test (commissioning phase)
22/07/2002 09:06	24/07/2002 11:21	02051	02081	Commanded outgassing
31/01/2003 09:39	03/02/2003 17:15	04814	04861	Commanded outgassing
01/08/2003 09:17	05/08/2003 10:34	07419	07477	Commanded outgassing
25/11/2003 10:10	28/11/2003 18:30	09080	09128	Commanded outgassing
16/04/2004 08:40	19/04/2004 17:04	11126	11183	Commanded outgassing
21/04/2004 07:42	23/04/2004 08:17	11197	11226	Blackbody cross-over test
23/07/2004 09:00	27/07/2004 15:39	12529	12576	Commanded outgassing
19/11/2004 10:00	22/11/2004 18:10	14233	14281	Commanded outgassing
08/04/2005 08:19	11/04/2005 13:16	16236	16283	Commanded outgassing
17/05/2005 07:47	19/05/2005 08:24	16794	16823	Blackbody cross-over test
22/08/2005 08:46	25/08/2005 15:07	18183	18230	Commanded outgassing
16/12/2005 09:40	19/12/2005 15:07	19844	19891	Commanded outgassing
26/06/2006 07:20	28/06/2006 08:10	22591	22620	Blackbody cross-over test
18/05/2007 08:19	21/05/2007 11:50	27258	27303	Commanded outgassing
24/09/2007 12:27	28/09/2007 13:39	29107	29165	Envisat service module (SM) anomaly + outgassing
13/11/2007 07:53	15/11/2007 08:30	29820	29849	Blackbody cross-over test
23/06/2008 07:46	26/06/2008 14:18	33012	33059	Commanded outgassing
25/11/2008 08:10	28/11/2008 21:33	35231	35282	Commanded outgassing

Start time	End time	Orbit start	Orbit end	Details
21/04/2009 07:53	23/04/2009 08:31	37335	37364	Blackbody cross-over test
26/05/2009 09:32	29/05/2009 21:09	37837	37887	Commanded outgassing
11/01/2010 09:01	14/01/2010 14:07	41129	41175	Commanded outgassing
26/05/2010 08:18	28/05/2010 08:55	43061	43090	Blackbody cross-over test
29/06/2010 08:49	02/07/2010 20:31	43548	43598	Commanded outgassing
20/10/2010 16:12	27/10/2010 18:55	45170	45272	Commanded outgassing (Note 1)
04/04/2011 13:50	06/04/2011 15:41	47553	47583	Envisat SM anomaly + outgassing
25/05/2011 10:46	27/05/2011 11:12	48284	48313	Blackbody cross-over test
07/10/2011 08:19	10/10/2011 14:49	50222	50269	Commanded outgassing
23/01/2012 07:28	26/01/2012 13:52	51773	51820	Envisat SM memory fault + outgassing

Note (1): Data were generated and are available in the archive from the beginning of this outgassing period. However, from 23/10/2010 22:47 to 27/10/2010 18:55 (orbits 45217 to 45272), AATSR was taken out of MEASUREMENT mode for manoeuvres connected with the Envisat Mission Extension (see Sections 5.4 and 6.2).

5.2 Envisat Fine Pointing Mode Period

In order to maintain the orbit of Envisat in accordance with the agreed operations scenario, routine Orbital Control Manoeuvres (**OCMs**) were executed. (The provision of details of all Envisat OCMs is outside the scope of this document.) Since it was routine practice to remove AATSR from MEASUREMENT mode during Envisat OCMs, there are usually no products available for these periods. There was one exception, however, where data was made available when Envisat was still in Fine Pointing Mode (**FPM**) and had not yet returned to the nominal (Stellar) Yaw Steering Mode (**(S)YSM**). Table 10 lists the Envisat FPM period for which AATSR products were generated.

Table 10. The Envisat FPM period during which AATSR products were generated

Start time	End time	Orbit start	Orbit end
28/10/2003 06:26	28/10/2003 13:10	08677	08681

RD.4, conducted under the auspices of the GlobSnow project, was a case study investigation into AATSR geolocation. Data from the FPM event period in October 2003 was inadvertently selected as one of their case studies, and the results showed that the AATSR data was offset from some Alpine lakes (using three water masks as reference) by more than 10 pixels. Internal investigation showed that the displacement at the centre of the swath was zero, that it varied across the track and was indicative of a platform yaw error. This displacement is not representative of nominal AATSR data and reinforces the rationale behind segregating data that are of known non-nominal quality.

5.3 Commissioning Phase Data

The Envisat operational phase started on 23 July 2002, and AATSR products are available in the main archive from 22 July 2002, 23:37 UTC. The period after launch and before 23 July 2002 was the Commissioning Phase, during which AATSR was often in a non-standard configuration. Although products obtained during this period have not to-date been available for users to access, the third AATSR reprocessing will generate some products from this period. Because the quality of these products cannot be guaranteed, they will be segregated from the main archive, but users will be able to access them should they wish.

Table 11 lists the start and end times of the Commissioning Phase data that will be available in the segregated archive after the third AATSR reprocessing. Note that products are not continuously available between these times. The orbit numbers stated in this table are those that feature in the AATSR product names.

Table 11. Commissioning Phase data that will be available to users after the third AATSR reprocessing (orbit numbers from product name)

Start time	End time	Orbit start	Orbit end
20/05/2002 09:52	22/07/2002 23:42	01149	02058

5.4 Envisat Mission Extension Manoeuvres

In October 2010 the Envisat satellite underwent a series of manoeuvres to place it in a new orbit, 17.4 km lower than the original one. This was to save fuel in order to be able to operate all payloads up to end of 2013 and to maintain orbit manoeuvre capabilities afterwards. ESA announced that the Envisat data flow was being suspended between 22 October and 02 November 2010. It was cautioned that: “some data are acquired during this period…However users are invited to discard such data as they are destinated [*sic*] only for the ESA internal verification.”

Part of this period is already included in Table 9, since the opportunity was taken to perform an AATSR outgassing prior to the main manoeuvres. AATSR returned to measurement on 27 October 2010; however Envisat was not in nominal attitude control (SYSM) until 02 November and was not completely in the new configuration until 04 November 2010. Table 12 lists the period during which the quality of AATSR data cannot be guaranteed due to the Envisat manoeuvres; as the platform had returned to SYSM, data quality was considered acceptable between the End time in Table 12 and 04 November 2010.

Table 12. Envisat mission extension period affecting AATSR products

Start time	End time	Orbit start	Orbit end
27/10/2010 18:55	02/11/2010 10:25	45272	45353

IDEAS was involved in a Mini-Commissioning for Envisat once Phase 3 began; results of this for AATSR are given in Section 6.2.

6. SPECIAL INVESTIGATIONS

6.1 High CRC Errors

During processing by the AATSR processing software, a Cyclic Redundancy Check (**CRC**) was performed for each AATSR source packet received. This calculated the check sum for the packet and compared this with the CRC check sum contained within the packet itself. If a packet failed this test then it was not processed any further; these packets can be observed visually within the L1B/L2 data products as missing scan lines.

Ideally, there would be zero CRC errors for almost all orbits with only sporadic anomalous orbits showing some errors (normally fewer than 5). However, there were a few occasions during the mission where a continued high number of CRC errors were flagged.

Table 13 lists the known periods of high CRC errors, the average number of CRC errors per orbit during the period and the maximum number of CRC errors seen in any one orbit during the period. The reason for the CRC errors is also given. The average is low for the period in August–September 2008 since there were few orbits affected by CRC errors, however the ones that were affected were obviously anomalous.

Table 13. Periods of high CRC errors affecting AATSR data

Period	Average no.	Maximum no.	Station affected	Reason
12/06/06 – 21/07/06	18	64	Kiruna (PDHS-K)	Vegetation affecting data reception [informal communication]
26/04/07 – 04/05/07	30	940	Kiruna (PDHS-K)	Faulty cabling connection [RD.5]
30/08/08 – 18/09/08	2	22	Kiruna (PDHS-K)	Antenna thermostat problem [informal communication]

An investigation was conducted into the increased number of CRC errors seen in June/July 2006 [RD.6]. This concluded that the problem was restricted to data received only by one particular ground station, and therefore was not an instrument anomaly. In fact for each period all the occurrences were observed only in products received by a particular ground station and were not indicative of an AATSR performance issue but were a ground segment issue (and therefore also affected other Envisat instruments).

These periods are included here, despite being a ground station issue rather than a problem with instrument performance, since the AATSR archive contains products that are affected by these CRC errors and therefore may contain a large number of missing scan lines. Whilst these missing scan lines are visually unappealing, the quality of the remaining data in the products is unaffected.

6.2 Envisat 2010+ Mini-Commissioning Phase

Section 5.4 contains some details of the manoeuvres necessary to place Envisat into Phase 3; the change project was named "Envisat 2010+". The IDEAS AATSR QC team, the ESL, the QWG and the Cal/Val team carried out extensive monitoring, calibration and validation activities for the Envisat 2010+ Mini-Commissioning Phase for Phase 3, the results of which are contained in RD.7. The summary of results from RD.7 is given here for reference.

AATSR successfully executed the planned operations during the Envisat mission extension orbit lowering manoeuvres and continued with routine operations.

The following instrument subsystems were monitored:

- Scan mechanism
- Cooler performance
- Blackbody temperature stability
- IR channel performance
- Visible channel performance

Assessment of the trends revealed that the subsystems were not affected by the manoeuvres and the performance was nominal.

The quality of AATSR data products was also rigorously assessed: the AATSR Level 1 and Level 2 products continued to be of good quality, with no anomalies or differences observed during examination of data from after the orbit lowering manoeuvres.

Examination of the colocation of the nadir and forward views showed no evidence of any change from the previous phase. The geolocation of AATSR data after the orbit lowering was checked and found to be comparable to the performance seen prior to the manoeuvres.

Initial validation findings indicated that there was no change in SST data quality as a result of the lowering of the orbit.

It was concluded that the Envisat orbit lowering did not result in a degradation of AATSR instrument performance and operations, nor did it impact upon the data quality of the AATSR products.

6.3 Geolocation

There were two specific assessments made of the absolute AATSR geolocation accuracy by IDEAS: RD.8 and RD.9. There was also a time-series geolocation assessment carried out for the Envisat 2010+ Mini-Commissioning Phase [RD.7].

6.3.1 Assessment vs. MERIS

RD.8 used a select set of comparatively cloud-free AATSR orbits and compared these to colocated, regridded Medium Resolution Imaging Spectrometer (**MERIS**) Full Resolution (**FR**) scenes. This had the advantage of ensuring that the comparisons were performed on data which were acquired over the test site at the same time of day and year. MERIS FR data had a 290 m (nadir) pixel size, and had already had its geolocation assessed, to an accuracy of 170 ± 10 m, through comparison to Landsat ETM+ data [RD.10, RD.11].

In total, 14 AATSR products were compared with 20 MERIS scenes (1 AATSR orbital product can correspond to more than 1 MERIS scene). Within each of the 20 scene comparisons, a number of test sites were identified by eye; these were commonly quarries, lakes, coastal or terrain features and industrial sites that could be easily identified by single pixels. The results of the 124 individual pixel-scale comparisons indicated that there was a systematic offset of approximately one pixel along-track and one pixel across-track for AATSR vs MERIS; this resulted in an approximate data shift of 1.4 km. There was no evidence of any latitudinal dependency in this shift, and these conclusions were supported by other geolocation analyses, including one led by the Validation Scientist at the University of Leicester [RD.12].

Following from the results given in RD.8 and other reports, an improved CH1 ADF file was generated by the ESL in order to try to improve the geolocation of AATSR. RD.9 repeated the investigation of RD.8 but used products generated using the improved CH1 file. In this study 21 AATSR products were compared with 41 MERIS scenes. During this assessment almost 600 matching sites were found, and all the individual sites identified were equally geolocated in both AATSR and MERIS data. AATSR products generated using the new CH1 ADF now have no systematic displacement when compared with the regridded MERIS data. The new CH1 ADF had not been integrated operationally before the Envisat end-of-mission but will be used in the third AATSR reprocessing

An illustration of the geolocation improvement when using the new CH1 ADF is given here. Figure 8 shows data from orbit 04666. The left-hand image is from the current operational product and the right-hand image is from a test product generated using the new CH1 file.

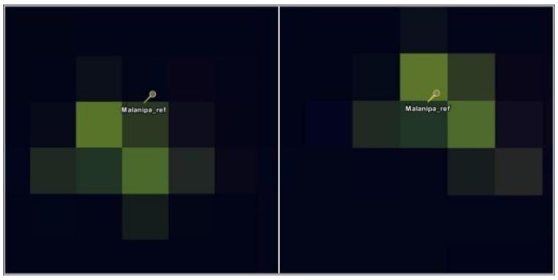

Figure 8. Geolocation improvement for orbit 04666: operational product (left) and test product using new CH1 (right).

The pin in Figure 8 marks the coordinates of the reference site: Malanipa Island in the Philippines (coordinates 6.8861° N, 122.2826° E), and shown in Figure 9 (Imagery ©2012 DigitalGlobe, GeoEye; Map data ©2012 Google). The green arrow in Figure 9 shows the reference pin location.

Figure 9. Malanipa Island, the Philippines.

Initial visual inspection shows that the right-hand image of Figure 8 has the centre of the main four pixels closest to the reference pin. The centre coordinates of the main four pixel “block” in both the operational and the test product were compared with the reference coordinates; the results are shown in Table 14.

Table 14. Coordinate data taken from the operational product and the test product (new CH1 file) in Figure 8

	Latitude	Longitude	Offset
Reference	6.88611° N	122.2826° E	
Operational	6.87850° N	122.2752° E	1.18 km
New CH1	6.88553° N	122.2860° E	0.38 km

6.3.2 Envisat 2010+ geolocation assessment

As part of the Envisat 2010+ Mini-Commissioning (see Section 6.2 and RD.7) a time-series assessment of AATSR geolocation was undertaken. The aim was to assess any possible change in AATSR geolocation when going from Envisat Phase 2 to Phase 3, i.e. that the post-extension geolocation was still in-line with results achieved for pre-extension products.

Seven locations (in Australia, Korea, India, Morocco, South Africa, Florida and Mexico) were selected as test sites and their geolocation was assessed in products from before and after the mission extension. For the seven specific sites, a total of 124 geolocation assessments were made, using AATSR products from January 2010 to January 2011 (see RD.7 for full details).

The investigations showed no major differences in the geolocation precision between data before and after the orbit change and the pixel centre coordinates were still within 1 kilometre distance of the pre-extension average coordinates. It was noted that the geolocation was displaced by about 1 km south and west (daytime views) from the approximated test site location, which matched the 1 pixel along track and 1 pixel across track displacement reported from previous analysis of AATSR geolocation.

Following on from Envisat 2010+, the IDEAS QC team continued to compile a time-series of geolocation data from these seven sites until the Envisat end-of-mission was declared.

6.4 Colocation

The new CH1 ADF generated to improve the geolocation accuracy (Section 6.3) also contained corrections to remove the offset between the nadir and forward views of AATSR. Previous colocation assessments had showed that the AATSR forward view was shifted in relation to the nadir view by around 2 pixels in the along-track direction and by around 1 pixel in the across-track direction.

RD.9 also contained an assessment of the colocation of the two views between archived AATSR products and those generated using the new CH1. Difference images between the nadir and forward 870 nm bands were generated, and inspection of coastlines allowed an assessment of the old vs the new colocation. Figure 10 illustrates the expected improvement in colocation for the reprocessed data, based on data from orbit 33584, where the left-hand image is the operational product difference, and the right-hand image is the difference from the product processed using the new CH1 file.

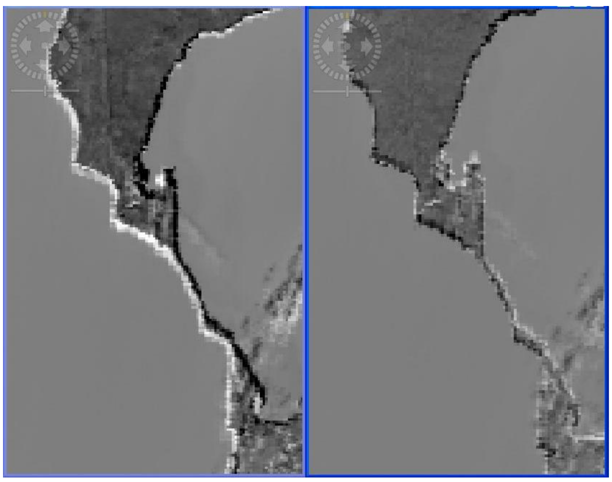

Figure 10. Nadir minus forward views for the 870 nm band for orbit 33584 for the operational product (left) and the product processed with new CH1 file (right).

The improvement can also be seen in the image statistics; Table 15 shows the mean and standard deviation of the difference images for the example shown above and also the average of all data tested with the new file (11 scenes). A significant reduction can be seen in both the mean and the standard deviation of the difference between nadir and forward views with the new CH1 file.

Table 15. View difference image statistics

	Operational Products		Test Products	
	Mean	**STD**	**Mean**	**STD**
Orbit 33584	3.15	8.70	1.74	5.15
All average	3.28	8.70	1.91	5.15

The new CH1 ADF had not been integrated operationally before the Envisat end-of-mission but will be used in the third AATSR reprocessing.

6.5 Cloud Clearing

Following the routine production of daily SST L3 anomaly maps at the end of 2011 (see Section 4.2), it became easier to pinpoint orbits and locations where the cloud-clearing algorithm had failed to detect cloud in the field of view. The ESL had already engaged in updating the CL1 ADF to use new gross cloud test thresholds. It was posited that this new file might actually reduce some of the problems seen with the cloud detection. The details of some known problem orbits were passed on to the ESL and reprocessing of these few products with the new CL1 ADF confirmed that, in 9 of 12 test cases, the processing successfully detected cloud where previously it had not [RD.13].

Figure 11 shows the potential improvement that could result from use of the updated CL1 ADF. It shows nadir-view data from orbit 51362. The RGB image on the left (from the 870, 670 and 550 nm channels) clearly shows the scene is covered in cloud. In the middle (operational) and right (test output) images the cloud flag is shown in yellow; clearly in the middle image not all cloudy pixels have been identified as such, whereas the identification is much better in the right-hand image, which has used the new CL1 ADF.

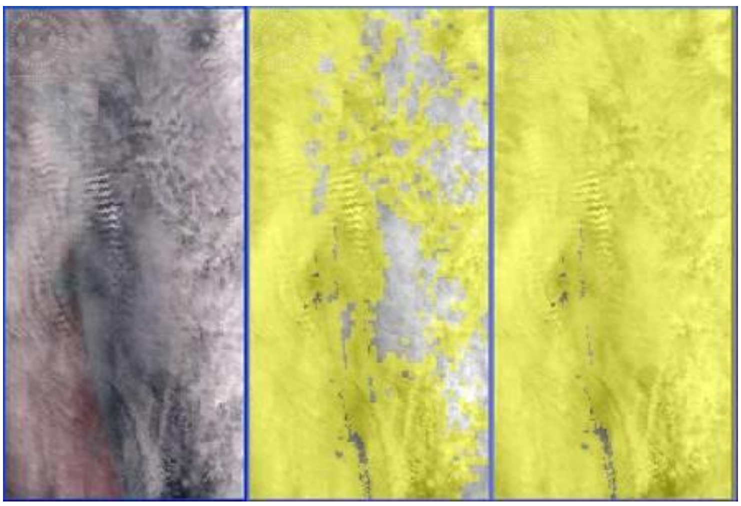

Figure 11. Data from orbit 51362: RGB (left), operational product (middle), test product (right).

The new CL1 ADF had not been integrated operationally before the Envisat end-of-mission but will be used in the third AATSR reprocessing.

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7. CALIBRATION/VALIDATION ACTIVITIES AND RESULTS

7.1 Calibration

Routine monitoring of the VISCAL system, carried out by the FOS team, was detailed in Section 4.1.3; this information was routinely published in the AATSR CRs. Detailed calibration investigations were also carried out by FOS, and are outlined in RD.1. A summary from RD.1 is provided here.

The long-term stability of the VISCAL system is established by measurements over desert and ice targets and inter-comparisons with other missions. These techniques have been used extensively for calibration and monitoring of satellite data from many instruments.

The principal assumptions made of the targets are:

- Uniform reflectance over large areas
- Long term-radiometric stability of the calibration sites
- Long-term stability of the Top-Of-Atmosphere (**TOA**) albedo (and of seasonal variations, if any) or reflectance over large spatially uniform areas
- High surface reflectance to maximise the signal-to-noise and minimise atmospheric effects on the radiation measured by the satellite

The long-term drift, D(t), is established by comparing AATSR measurements, R(t), against reference measurements, Rref, i.e. D(t) = R(t)/Rref. The reference could either be a stable reference sensor such as MERIS, the reference BRDF (Bidirectional Reflectance Distribution Function) derived from early ground measurements and/or models.

For the early phase of the mission, the calibration trend followed an exponential decay function as predicted from the experience of, e.g. ATSR-2, such that D(t) = exp(-kt).

Figure 12 displays the AATSR visible channel drift using BRDF for desert targets, Greenland and Dome-C targets (taken from RD.1). The combined AATSR visible channel long-term drift measurements versus date in years for all desert sites (red), Dome-C (blue) and Greenland (green) are given. The solid line shows the rolling average of the drift values. The 5σ uncertainties in the drift are included in the plot as a dashed line. The dotted line shows R/Rref = 1.0.

The results in Figure 12 show that the exponential decay model was incorrect in the case of the AATSR visible channels. The observed long-term trends suggested that the drift was caused by a thin-film interference effect (Etalon) of the form D(t) = 1+Asin2(2πnxt/λ) (where n is the refractive index and x is the thickness).

Documentation of the three main improvements to the VISCAL system throughout the mission lifetime can be accessed below, these were:

- 14 Dec 2004: A correction for the 1.6 µm non-linearity was introduced (https://earth.esa.int/documents/700255/708753/technote_nonlinear_corr_AATSR_GBT.pdf/e065da62-c383-4fd6-b723-28e84c871afc?version=1.0)
- 29 Nov 2005: Exponential correction for visible calibration drift was applied https://earth.esa.int/documents/700255/709003/VisChannelLTTrends_TN-0542_is1.pdf/fb570cc6-5034-4cd3-9c2c-22396aeb3bd0?version=1.0
- 18 Dec 2006: The drift correction was changed to one based on a thin-film model (https://earth.esa.int/documents/700255/708791/Visible_Channel_Update_TN-0552.pdf/ddef33cc-491e-43e8-9ca0-e3711c20a406?version=1.0)

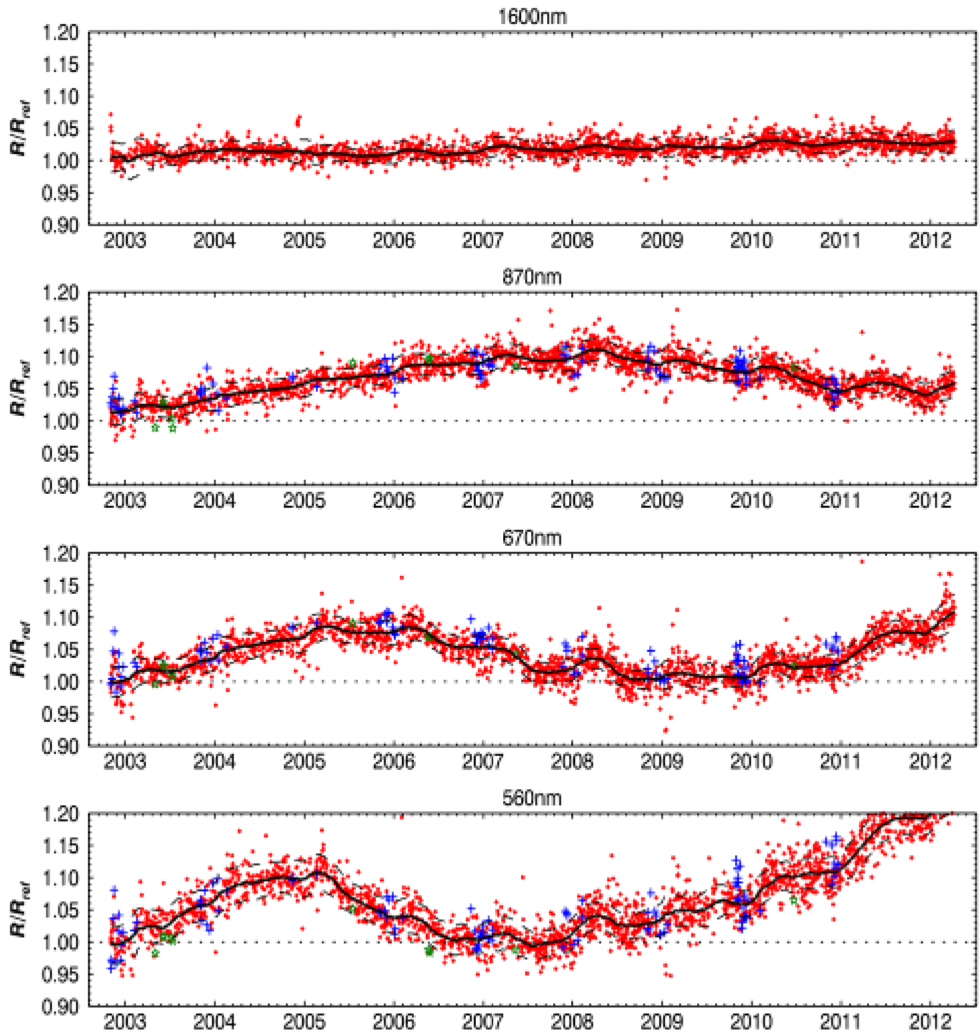

Figure 12. AATSR visible channel drift using BRDF for desert targets, Greenland and Dome-C targets (taken from RD.1).

Although the thin-film model provided a reasonable representation of the observed drift, analysis showed that it could not adequately account for all variations in the measured drift. Instead, the smoothed average of the actual drift measurements from Figure 12, along with uncertainties, was used to create a drift correction look-up table. These were routinely produced and saved throughout the mission (available to the AATSR user community via the AATSR engineering data system (EDS) at http://www.aatsrops.rl.ac.uk/EDSX/OtherInfo/). The data and IDL code needed to apply the corrections are freely available to users, provided that the source of the data is acknowledged, and some evidence is provided in return that shows the improvements to retrievals as a result of the calibration corrections being applied to the data.

The third reprocessing of AATSR data will incorporate the final drift correction for the full AATSR mission (see Section 8.3).

Comparisons with other satellite sensors have shown that AATSR agrees within 3% of MERIS and the Moderate Resolution Imaging Spectrometer (**MODIS**). These results are supported by similar comparisons performed using different methodologies from ESA, CNES and VITO [fully outlined in RD.1].

7.2 Validation

The University of Leicester was the main contact for AATSR validation studies and the Validation Scientist provided routine support and feedback to the QWG. However, there were many parties involved in the ongoing validation of AATSR data, and feedback from users was commonly reported to the QWG, thus enabling the continuous improvement of the processed data throughout the mission.

UoL provided the monthly validation summaries for the L2 SST product that were published in the AATSR CRs (see Section 2.2). The UK Met Office matched AATSR SSTs to drifting buoy observations [RD.14]. These matches were then compiled into a match-up database, and UoL carried out subsequent statistical analysis.

The most recent validation details were provided by UoL for the Envisat Closure meeting in October 2012, and are given here in Table 16 and Table 17.

Table 16 displays a comparison of AATSR L1B products with those of MERIS, also on-board Envisat. Note that the AATSR geolocation and colocation values are for the products that will be generated following the third AATSR reprocessing. (See Sections 3 and 8.3 for details of the updates involved.)

Table 16. Comparison of MERIS and AATSR L1B data

Products	Specification	Accuracy	Comments
MERIS Radiometry	< 2 %	< 2 %	Within the accuracy of the methods. Verification methods for calibration: Rayleigh, stable sites (desert, snow), glitter. Sites and best practise follow the CEOS recommendations
AATSR Radiometry	Thermal < 0.2 K	< 0.1 K	From SST validation and algorithm sensitivity study
	Visible < 5 %	< 3 %	Vicarious calibration using stable sites (Desert, Greenland) and cross-sensor with MERIS
MERIS Geolocation	< 2000 m	< 150 m	Ground Control Point / reference map methods, Globcover reference
AATSR Geolocation	Absolute nadir	< 1 pixel	Absolute geolocation was assessed using comparisons to Globcover and other ground targets
	Colocation of nadir and forward views	<< 1 pixel	Colocation between nadir and forward views was evaluated using brightness temperature comparisons and SST match-ups to drifting buoys

Table 17 shows validation information for AATSR SST and LST derived from AATSR L1B products. These values are calculated for the current best possible SST and LST derivations from AATSR data, which are considered to be those produced by the ARC project [RD.3, RD.15], which uses AATSR L1B data as inputs.

Table 17. Validation of SST and LST L2 measurements derived from AATSR L1B data

Products	Specification	Accuracy	Precision	Comments
SST day (1 km)	< 0.3 K (1 σ)	< 0.04 K	< 0.20 K	Based on ARC comparisons to SISTeR, M-AERI, ISAR and drifting buoys
SST night (1 km)	< 0.3 K (1 σ)	< 0.02 K	< 0.15 K	
LST day (1 km)	< 2.5 K	0.2 → 3.8# K	0.9 → 1.4 K	Based on results from many site including Valencia, Niger, Oklahoma and Cardington
LST night (1 km)	< 1.0 K	0.0 → 2.0# K	0.5 → 1.5 K	

A large bias has been observed for some biomes (and also for MODIS and SEVIRI (Spinning Enhanced Visible and InfraRed Imager) data). Work is ongoing to identify the source (possibly satellite, in situ or validation methodology).

Ship-borne instruments: SISTeR: Scanning Infrared Sea Surface Temperature Radiometer; M-AERI: Marine Atmospheric Emitted Radiance Interferometer; ISAR: Infrared Sea Surface Autonomous Radiometer.

The specifications required for AATSR radiometric and SST data are outlined in Table 16 and Table 17, and it can be clearly seen that the instrument has met and greatly improved upon them. Although not tailored to measure LST, gains have been made in the accuracy of retrieved LST from AATSR in recent years.

8. SUMMARY AND FUTURE PLANS

8.1 Summary of Instrument Performance

Section 4 has outlined the performance of the instrument parameters that were routinely monitored throughout the mission. RD.1 concluded that AATSR performed exceptionally well over the mission lifetime and successfully generated the high-quality data needed for accurate SST retrievals. Based on its assessment of the housekeeping and science data, AATSR would have continued to operate beyond 2014 with clear margins.

Excluding the main commissioning phase up to 23 July 2002, AATSR measurement data were available for more than 95% of the mission.

8.2 Summary of Data Quality

Ongoing monitoring of AATSR products, i.e. availability and data quality, along with routine calibration and validation activities (see earlier sections) showed that the data produced by the AATSR instrument achieved a very high level of both quality and consistency. Their production chain has also been carefully monitored and is very well characterised and understood. The specification required for AATSR was outlined in Table 16 and Table 17 and the values achieved clearly show that AATSR SSTs exceed these original performance requirements. Although AATSR was not intended as an instrument to measure LST, gains in this area have also been made, especially in recent years, and it is expected that there is still scope for improvement in both SST and LST should any longer-term reprocessing take place.

There are almost 10 years of high-quality AATSR SST data available to the user community; combined with the SST data from both ATSR-1 and ATSR-2, there is a 20-year almost continuous high-quality SST resource available for users. The quality of this 20-year consistent dataset will be further improved following the third reprocessing (see Section 8.3).

8.3 Future Plans

As mentioned throughout this document, plans are already well in hand for a full reprocessing of AATSR data; this should be largely completed by summer 2013.

The scientific improvements that are expected to AATSR products after the third reprocessing are as follows:

- SST retrievals will be improved via the use of updated SST coefficients. These coefficients have been supplied by the ARC project, and incorporate updates and improvements from the knowledge acquired by this project, including a temperature-dependent emissivity and updated spectroscopy.
- An improved and consistent visible calibration will be implemented: accurate correction for the long-term drift will be applied via the use of a new VC1 dataset; better extraction of calibration data will come from the updated processor and the updated PC1 ADFs.
- Cloud identification will be improved due to the changes in the cloud test auxiliary file.
- The colocation displacement between the nadir and forward views will be improved via the use of the new L1B characterisation file (CH1 ADF).
- The absolute nadir geolocation accuracy will be increased also via the use of the new CH1 ADF.

The reprocessed data will undergo thorough QC, as outlined in RD.16, overseen by the QWG. Once all parties are satisfied that the AATSR reprocessed dataset is as complete as possible and the quality assessment has been completed, a recommendation will be made by the QWG that it is ready for release.

ESA will inform the users of the official release of the reprocessed data; this will also include the final report on the QC of the data. All things having proceeded as expected, this shall also cover ATSR-1, ATSR-2 and AATSR data in all formats, meaning that users will have access to an improved, near-continuous dataset of accurate SSTs spanning 20 years.

9. GLOSSARY

The following acronyms and abbreviations have been used in this report.

(S)YSM	(Stellar) Yaw Steering Mode
ADF	Auxiliary Data File
ANX	Ascending Node Crossing
ARC	ATSR Reprocessing for Climate
BB	BlackBody
Cal/Val	Calibration and Validation
CBB	Cold BlackBody
CR	Cyclic Report
CRC	Cyclic Redundancy Check
ESA	European Space Agency
ESL	Expert Support Laboratory
FOS	Flight Operations Support
FPM	Fine Pointing Mode
FR	Full Resolution
GHRSST	Group for High Resolution SST
GOSTA	Global Ocean Surface Temperature Atlas
HBB	Hot BlackBody
IPF	Instrument Processing Facility
IR-FPA	Infrared Focal Plane Assembly
L2P	Level 2 Pre-processed
L3U	Level 3 Uncollated
LST	Land Surface Temperature
MERIS	MEdium Resolution Imaging Spectrometer
MODIS	MODerate resolution Imaging Spectrometer
MPH	Main Product Header
NEΔT	Noise Equivalent Delta Temperature
NRT	Near Real Time
OCM	Orbital Control Manoeuvre
PDHS-E	Payload Data Handling System-ESRIN
PDHS-K	Payload Data Handling System-Kiruna
PDS	Payload Data System
PQR	Product Quality Readme
QC	Quality Control
QWG	Quality Working Group
RAL	Rutherford Appleton Laboratory
RD	Reference Document

SM	Service Module
SMU	Scan Mirror Unit
SPPA	Sensor Performance, Products and Algorithms
SST	Sea Surface Temperature
TOA	Top-Of-Atmosphere
UK-MM-PAF	UK Multi-Mission Product Archive Facility
UoL	University of Leicester
VISCAL	Visible Calibration
VIS-SWIR	Visible-ShortWave InfraRed

APPENDIX A MONTHLY L3 PLOTS FOR MARCH 2012

The March 2012 L3 monthly maps were produced from 439 products from orbits 52318 to 52759 (orbit numbers taken from AATSR product names). Figure 14, Figure 15, Figure 16 and Figure 17 show the SST average in dual and nadir views, the standard deviation and the number of contributory orbits for March 2012. Please note that individual colour scales for each plot are not available, however the scheme used for these figures is given in Figure 13, and the data ranges of each plot are specified in the accompanying caption.

Figure 18 and Figure 19 show anomalies of the monthly averages from an SST climatology (the GOSTA dataset), and were published in the CRs (from CR #106). Figure 18 and Figure 19 display the SST anomalies for dual- and nadir-view SSTs for March 2012, respectively. The anomaly scale runs from -10 K (blue) to +10 K (red). Orbits affected by cloud-clearing failures, which would show up as strong blue in the anomaly maps, were listed in the CRs and any orbit which was found to have exhibited a cloud-clearing failure was also mentioned in the AATSR Daily Report (see Section 2.2).

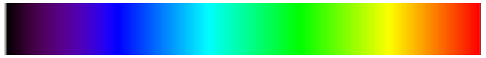

Figure 13. The colour spectrum used for Figure 14 to Figure 17.

Violet (left) is the lowest value and red the highest. The data range is specified within each figure caption.

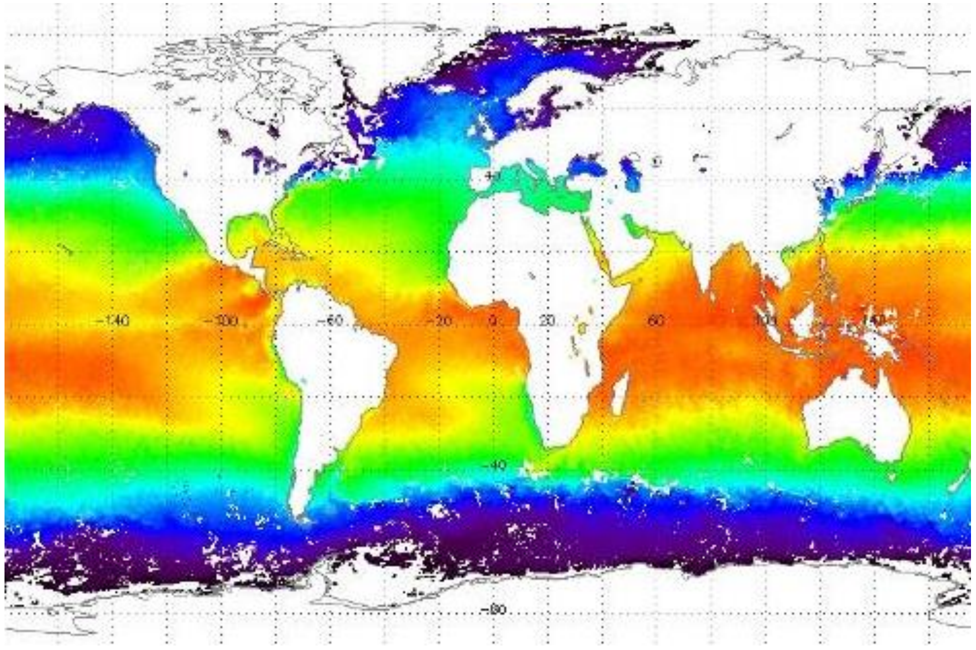

Figure 14. Monthly average dual-view SST, with a data range of 270 – 305 K for March 2012.

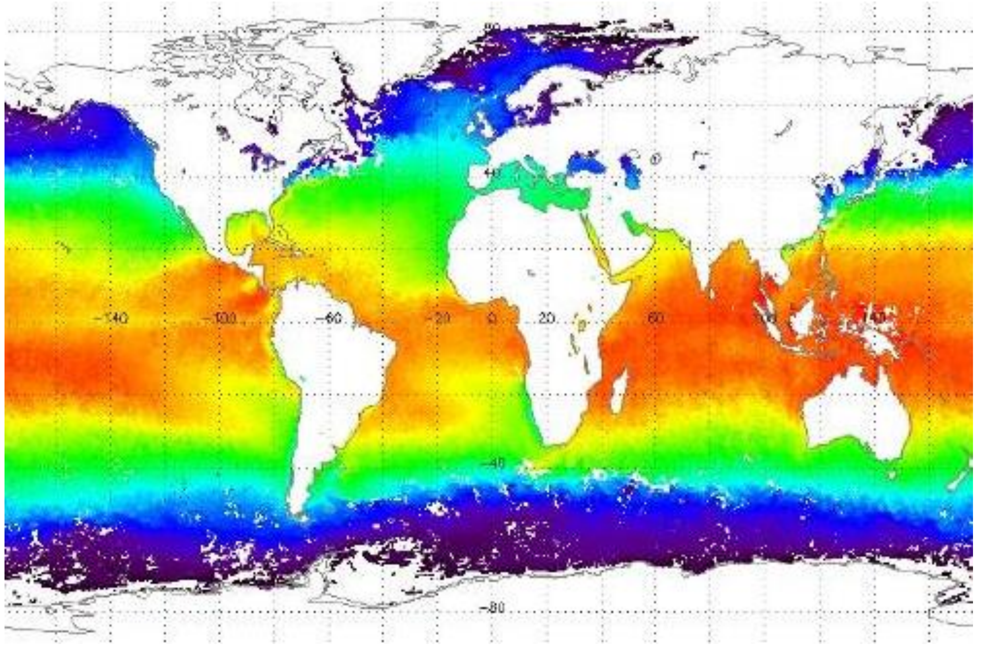

Figure 15. Monthly average nadir-view SST, with a data range of 270 – 305 K for March 2012.

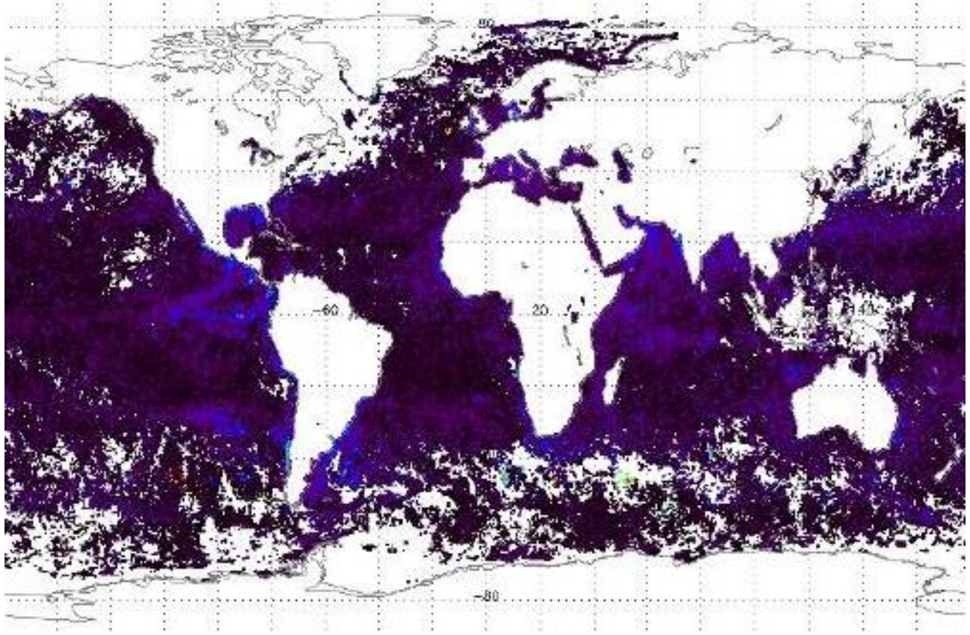

Figure 16. Standard deviation of the monthly average SST with a colour key range of 0 to 5 K, and a maximum value of 9 K for March 2012.

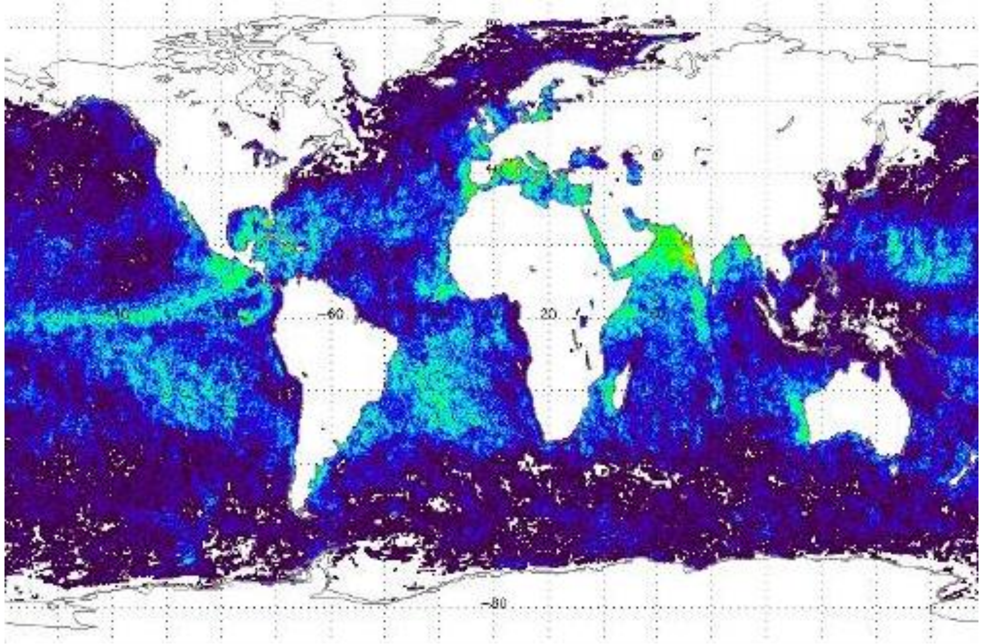

Figure 17. Number of contributory orbits to the calculation of the SST, with a colour key range of 0 to 16 (maximum value) for March 2012.

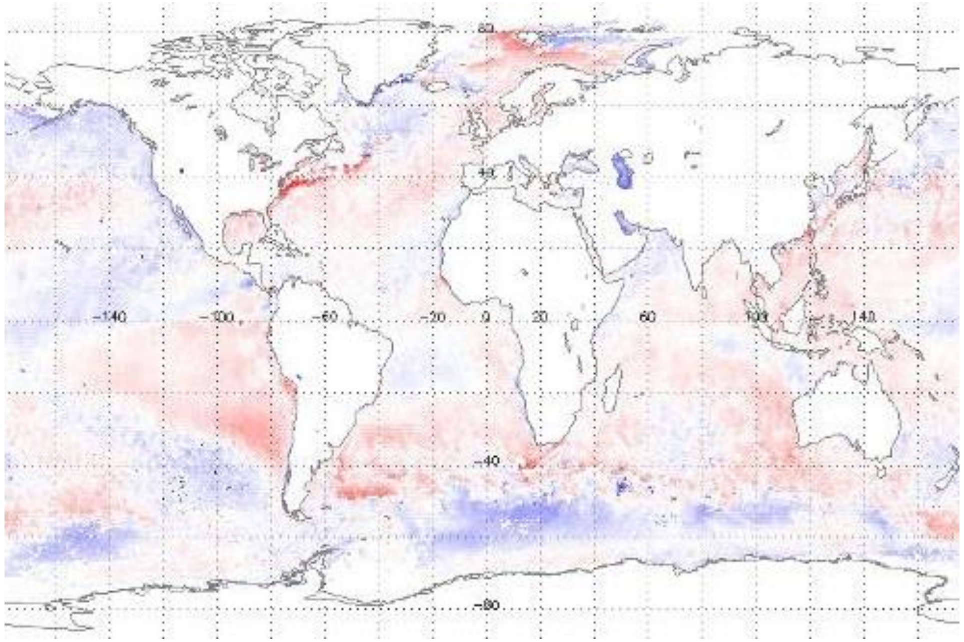

Figure 18. Anomaly map of dual-view SST for March 2012.

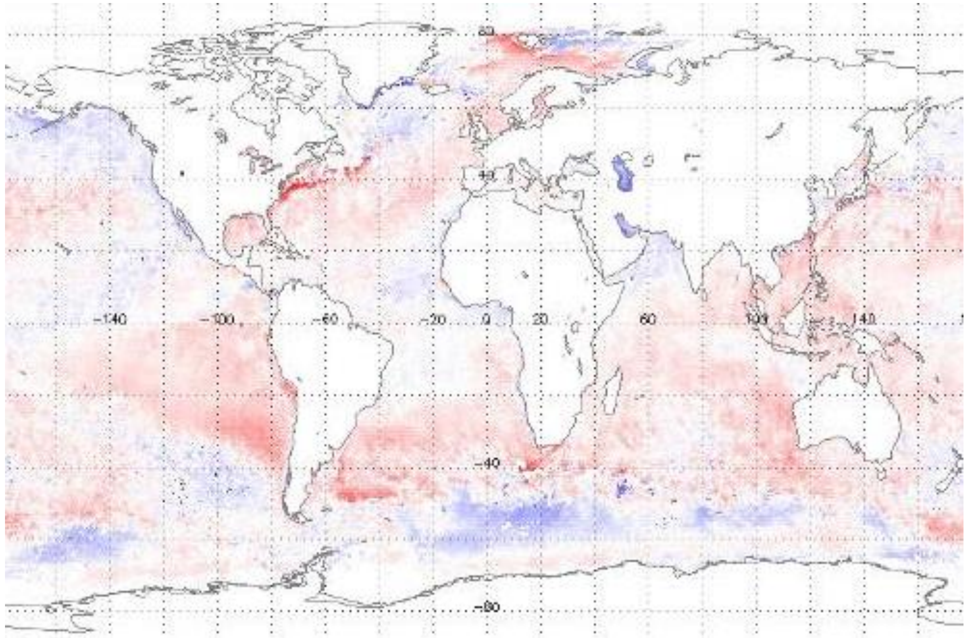

Figure 19. Anomaly map of nadir-view SST for March 2012

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