

REVIEW OF ASAR PERFORMANCE AND PRODUCT QUALITY EVOLUTION AFTER 5 YEARS OF OPERATIONS

B. Rosich⁽¹⁾, P.J. Meadows⁽²⁾, A.Monti-Guarnieri⁽³⁾, D.D'Aria⁽⁴⁾, M. Tranfaglia⁽⁵⁾, M. Santuari⁽⁵⁾, I. Navas⁽⁶⁾

⁽¹⁾European Space Agency, ESA-ESRIN, Italy; E-mail: brosic@esa.int

⁽²⁾BAE SYSTEMS Advanced Technology Centre, United Kingdom, E-mail: peter.meadows@baesystems.com

⁽³⁾Politecnico di Milano, Italy, E-mail: monti@elet.polimi.it

⁽⁴⁾ARESIS s.r.l., Italy, E-mail: davide.daria@aresys.it

⁽⁵⁾Serco S.p.A, Italy, Email: mtranfaglia@serco.it, santuari@serco.it

⁽⁶⁾I. Navas, ESA-ESTEC, The Netherlands, E-mail: inavas@esa.int

ABSTRACT

ENVISAT ASAR is successfully operating since March 2002 and resulting ASAR products are operationally distributed to the user community since December 2002.

This paper provides an update of the ASAR performance, from the instrument status to the product quality assessment.

1. ASAR INSTRUMENT STATUS

Routine monitoring of the 320 antenna T/R modules is daily performed using Module Stepping Mode (MSM). In MSM, the instrument samples all 320 T/R modules in less than one second for gain and phase.

Several failures in the antenna sub-assembly, due to different reasons but resulting in any case in a certain number of T/R modules not operating, have been experienced since launch. The first failure in April 2002, was the loss of the power averaging module of PSU-1 in Tile C1. As a result, the four modules sharing the affected PSU are failed in transmit (both H & V) but still fully operational in receive. The second one in February 2003, with the complete loss of PSU-1 in Tile D2, resulting in the 4 T/R modules of this PSU being failed both in Tx and Rx, and in H & V polarisation. Later on, six individual T/R modules failures have been experienced (April 2004, May 2004, November 2004, January 2005, November 2005 and January 2007), three of them in H polarisation and three of them in V polarisation. Finally, the four modules sharing PSU-1 in Tile B3 have also been lost in February 2007. Fig. 1 shows the current status of the antenna, in H and V polarisation.

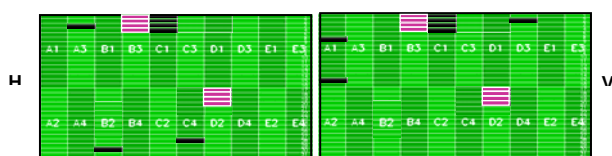


Fig. 1. ASAR antenna modules failures in H (left) and V (right) polarisations. Modules highlighted in black have been lost in Tx only while modules in pink have been lost both in Tx and in Rx.

In total, there are 15 TRMs failed for Tx-H, 15 for Tx-V and 8 for Rx H and V. Up to 6% of failures (i.e. 19 modules) in a given mode (e.g. Tx H) are allowed by design before there is an impact on the instrument performance. Although the failures experienced up to now have not significantly degraded the instrument performance, changes in the antenna radiation have been experienced and corrected on ground, resulting in new auxiliary calibration files.

The antenna TRMs may not only fail but their gain and phase settings may also drift in time. A major gain & [hase correction activity was performed in September 2005, as described in more detail in [1].

2. ASAR OPERATIONS

ASAR is providing nominally data quality in all modes after 5 years of operations.

Nevertheless, an increase of the number of particular ASAR instrument anomalies while operating in Alternating Polarisation (AP) Mode has been observed [1] and the reasons for this “AP related anomalies” are being deeply investigated. It is known however that the risk of having these anomalies is ANX dependent and also varies from beam to beam.

Two temporary measures to limit these anomalies have been implemented until the investigation is completed:

- 1) Reduce the overall AP mode usage, by reducing the AP background mission planning in AP mode and by changing some AP into IM after user consultation. This reduction has been progressively implemented since early 2007.

2) Suspend temporarily AP IS5 acquisitions (beam with highest probability of instrument anomalies). This has been implemented since end 2006

In addition, the preliminary results of the investigation point to an insufficient synchronisation frequency in AP mode, which could be increased by modifying the mode timeline. A test campaign to acquire AP mode data with a reduced number of pulses per burst has been performed:

- from 2007-02-28 to 2007-03-07: for IS2, IS3, IS5, IS6, IS7
- from 2007-02-21 to 2007-03-08: for IS5 (over a specific ANX interval)

AP mode data has been acquired during this test using a timeline different from the nominal one by setting the number of pulses per burst to the same value as IS1 (which is the beam with smallest number of pulses per burst), as shown in Table 1.

Swath	number pulses per burst	
	current timeline	new timeline
IS1	194	194
IS2	196	194
IS3	257	194
IS4	218	194
IS5	277	194
IS6	238	194
IS7	297	194

Table 1. Comparison between the original AP timeline and the test timeline,

The main impact of reducing the number of pulses per burst on the product quality is a slight degradation of the azimuth resolution for any AP Level-1 product, particularly for IS3, IS5, IS6 and IS7.

Worst case values for the new azimuth resolution, compared with nominal values are provided in Table 2.

Swath	Azimuth resolution [m]			
	APP/APG (min PRF)		APM (min PRF)	
	current timeline	new timeline	current timeline	new timeline
IS1	27	27	155	155
IS2	27	27	155	156
IS3	27	36	156	207
IS4	27	31	155	175
IS5	28	39	157	224
IS6	27	33	155	191
IS7	28	42	157	240

Table 2. Worst case azimuth resolution for AP mode data acquired during the test as compared with the nominal values.

Additional tests with AP mode are envisaged in the future to confirm the hypothesis derived from the anomaly investigation. Any change in the nominal AP mode characteristics to support the investigation will be announced by EOHELP to AP mode users and it will also be published on line at the ESA EO news.

Operations in all other modes are fully nominal.

GM data is systematically acquired over land, sea-ice and ice through the background regional mission (BRM) and made available on line in near real time (NRT).

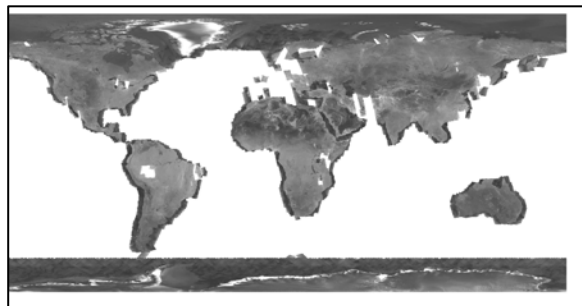


Fig. 2 Global Mosaic of GM data acquired during March and April 2005.

2. EXTERNAL CALIBRATION

Calibration of ASAR products and monitoring of ASAR product quality is performed based on data acquired over various calibration sites, namely:

- the four ASAR precision transponders
- the 4 RADARSAT transponders, deployed in Canada and used for ASAR performance monitoring under agreement with the Canadian Space Agency (CSA) and with the support from CCRS until 2006
- ASAR receiving ground stations
- the Amazon Rain Forest area
- corner reflectors deployed for specific calibration campaigns

Data acquired over the transponders is used for product quality monitoring and radiometric calibration. Data acquired over the ground stations is used primarily for monitoring the radiometric stability. Data acquired over the Amazon rain forest is used mostly for elevation antenna pattern monitoring and data acquired over the corner reflectors has been used till now for geometric product calibration. [3]

The 4 ASAR transponders were initially deployed in The Netherlands. Calibration acquisitions over the transponders shall be performed routinely and they shall cover all modes, beams and polarisations. Since the end of the Commissioning Phase (Dec. 2002), the number of conflicts with user requests over the area was increasing and it was therefore decided to redeploy the ASAR transponders. In selecting the new sites, the following criteria were considered:

- more than one new location should be chosen and they should be at different latitudes to verify the instrument around orbit calibration;
- at least one location should be at very high (or low) latitude to ensure a very high revisit time;
- at least one transponder should be close to one of the RADARSAT transponders used for ASAR calibration;

As a result, 1 ASAR transponder has been left at the initial location in The Netherlands (Edam), 2 ASAR transponders have been redeployed in Canada (1 close to the RADARSAT transponder in Resolute Bay (very high latitude and very large number of potential passes per cycle) and one close to the RADARSAT transponder in Ottawa) and 1 ASAR transponder has been moved to Indonesia (Kalimantan), close to the Equator. Complete details about the redeployment activities and new locations are provided in [4].

2.1 Radiometric calibration

A significant recalibration activity has been possible after the redeployment of the ASAR transponders using the increasing number of calibration measured in all modes, beams and polarisations. Most recent results for the radiometric accuracy and the radiometric stability are provided in Table 3.

Product Type	Relative Radar Cross Section (RelRCS) [db]							
	All swaths (bias±stddev)	IS1	IS2	IS3	IS4	IS5	IS6	IS7
IMP	-0.05±0.42	-0.01	-0.08	-0.02	-0.04	-0.01	-0.05	-0.1
IMG	-0.01±0.43	-0.04	-0.11	-0.04	-0.05	0.24	0.04	0.1
IMS	0.00±0.42	-0.02	-0.02	-0.09	0	0.02	0.03	0.1
IMM	0.04±0.95							
APP	-0.06±0.39	-0.28	-0.22	-0.07	0.03	-0.01	0.01	-0.03
APG	-0.04±0.47	-0.3	-0.31	-0.03	-0.06	-0.02	0.22	-0.09
APS	-0.06±0.53	-0.1	-0.4	-0.01	-0.25	-0.06	0.17	0.16
APM	-0.06±0.98							
WSM	0.45±1.26							

Table 3. Radiometric calibration accuracy & stability for ASAR products based on measured over the ASAR transponders (all polarisations included).

Results for IMP and APP products for different polarisations (all swaths included) are provided in Table 4.

Product Type	Mean Relative RCS [dB]			
	VV	HH	VH	HV
IMP	-0.03	-0.1		
APP	0.08	-0.04	-0.1	-0.07

Table 4. Radiometric calibration accuracy for ASAR IMP and APP products (all swaths together).

2.2 Elevation antenna pattern monitoring

Evolution of the antenna radiation pattern shall be regularly monitored, particularly in the case of an active phase array antenna.

Accuracy of synthesized ASAR elevation antenna patterns (up to 0.5 dB) is lower than required (about 0.2 dB) due to the limited accuracy of instrument characterisation data. Azimuth pattern can be more accurately estimated using synthesis (also more stable in time).

Therefore, monitoring of the ASAR elevation antenna pattern is based on data routinely acquired over the Amazon Rain forest [1], using mostly Wide Swath, Image precision (IMP) and Alternating Polarisation precision (APP) products.

The use of Wide Swath mode products is particularly important since it offers the possibility to monitor 5 beams simultaneously (SS1, IS3-SS2, IS4-SS3, IS5-SS4, IS6-SS5). However, since no measurement is performed on the overlapping areas between neighbouring beams, WSM products are combined together with Image and AP products in order to measure the pattern over the maximum possible range extend. The table below indicates the updates performed for each beam and polarisation. Please note that the table provides the date for each update (i.e. the creation dates for the auxiliary calibration files) but does not show the applicable time period for each update.

BEAM	POL	RECENT ELEVATION ANTENNA PATTERN UPDATES					
SS1	HH	27/06/2003	06/04/2004	12/06/2004	13/10/2005	19/12/2005	15/02/2007
SS1	VV	27/06/2003	06/04/2004		13/10/2005	19/12/2005	22/02/2007
IS1	HH		09/12/2003				
IS1	VV		09/12/2003	06/04/2004			
IS1	HV					23/02/2006	17/07/2006
IS1	VH		09/12/2003	06/04/2004		23/02/2006	17/07/2006
IS2	HH			06/04/2004		03/11/2005	
IS2	VV		09/12/2003	06/04/2004		03/11/2005	
IS2	HV			06/04/2004			23/02/2006
IS2	VH			06/04/2004			17/07/2006
IS3	SS2	HH	27/06/2003	09/12/2003	12/06/2004	27/10/2004	13/10/2005
IS3	SS2	VV	27/06/2003		12/06/2004	27/10/2004	13/10/2005
IS3	SS2	HV					23/02/2006
IS3	SS2	VH					17/07/2006
IS3	SS2	VH					23/02/2006
IS4	SS3	HH			12/06/2004		13/10/2005
IS4	SS3	VV				27/10/2004	13/10/2005
IS4	SS3	HV		06/04/2004			23/02/2006
IS4	SS3	VH		06/04/2004			23/02/2006
IS4	SS3	VH					17/07/2006
IS5	SS4	HH	27/06/2003		06/04/2004	27/10/2004	13/10/2005
IS5	SS4	VV	27/06/2003				13/10/2005
IS5	SS4	HV			06/04/2004		23/02/2006
IS5	SS4	VH			06/04/2004		23/02/2006
IS6	SS5	HH				27/10/2004	13/10/2005
IS6	SS5	VV					13/10/2005
IS6	SS5	HV		06/04/2004			23/02/2006
IS6	SS5	VH		06/04/2004			23/02/2006
IS7	HH						
IS7	VV						23/02/2006
IS7	HV						17/07/2006
IS7	VH						23/02/2006

Table 5. Update of elevation antenna pattern performed for each ASAR beam and polarisation.

Updated information is maintained on line at: http://earth.esa.int/pcs/envisat/asar/public_reports/. The elevation antenna patterns are provided in the ASAR External Calibration auxiliary file (ASA_XCA_AX), which is updated every time a new update is performed. These auxiliary files are provided on line at: http://earth.esa.int/services/auxiliary_data/asar/

3. ASAR PRODUCTS QUALITY

Product quality analysis is mainly based on data acquired over the ASAR and RADARSAT transponders and it shows a nominal quality in all modes.

The measured Impulse Response Function (IRF) parameters are provided in Table 6.

Product type	Az. Resolution [m]	Range resolution [m]	ISLR [dB]	PSLR [dB]
IMP	22.13±0.49	rg-variant	-13.43±0.57	-16.67±0.98
IMG	22.35±0.45	21.8-35.4	-13.52±0.56	-16.83±1.00
IMS	4.76±0.04	9.44±0.05	-14.47±0.28	-19.19±0.52
IMM	146.87±3.34	rg-variant	-7.01±4.5	-15.52±3.42
APP	27.62±0.82	rg-variant	-12.85±0.47	-19.13±1.02
APG	27.72±0.86	23-35.4	-12.87±0.49	-19.20±1.00
APS	4.38±1.88	8.40±0.07	4.04±2.53	-1.87±1.41
APM	145.03±2.86	rg-variant	-8.29±5.13	-15.39±3.43
WSM	107.24±2.26	rg-variant	-9.06±3.92	-18.83±1.27

Table 6. Measured IRF parameters (mean & standard deviation) for the different product types.

It should be noted that results for AP single look complex (APS) products are very different from the IM single look complex products (IMS), which is a consequence of the processing strategy adopted for APS products.

The range resolution for ground range product varies with the incidence angle. The measured ground range resolution for IM and AP high resolution multi-look detected products (IMP and APP), as compared with the theoretical resolution is provided in Fig 3. An excellent agreement is observed, with results well below the requirement of 30 m at mid range.

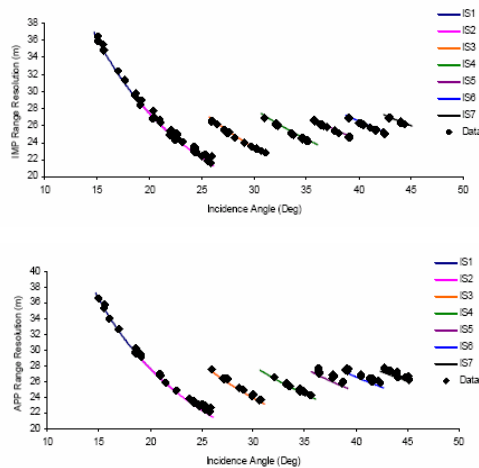


Fig. 3. Measured (dots) ground range resolution for IMP (top) and APP (bottom) products and comparison with theoretical values (lines).

The spatial resolution for WSM products is shown in Fig. 4.

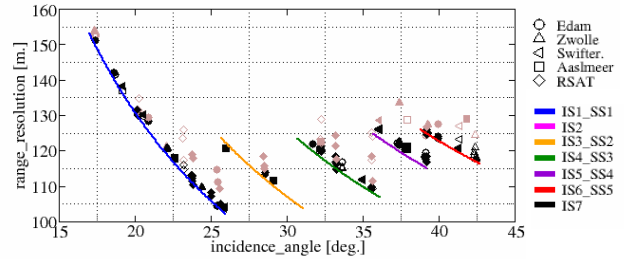


Fig.4. Range Resolution for WSM products versus incidence angle. Black samples are for 40 m pixel spacing products and brown for 75 m pixel spacing.

As it can be observed two types of measures are provided, for 40 m and 75 m pixel spacing, and they are compared with the theoretical values. Wide Swath Mode products are under-sampled, since pixel spacing is 75 m but azimuth resolution is about 110 m and range resolution at mid swath is about 120 m. For this reason, results with standard products (75 m pixel spacing) appear to be larger than expected. To verify the spatial resolution, IRF analysis of WSM products is performed on products specially processed at 40 m pixel spacing to avoid aliasing. It can be observed in figure 4 that results from products processed without under-sampling are in excellent agreement with the theoretical values.

As part of the routine analysis of ASAR products, additional quality parameters are monitored, such as the radiometric resolution and noise equivalent sigma nought.

Table 7 shows the measured radiometric resolution and effective number of looks (ENL) for IMP, IMG, IMS and APS products, for which the radiometric resolution is basically constant for all beams. Table 8 shows the measured radiometric resolution and ENL for APP and APG products, for which the radiometric quality varies slightly from beam to beam.

	ENL	Rad. Res [dB]
IMP/IMG Products	3.95	1.77
IMS Products	0.96	3.05
APS Products	0.93	3.09

Table 7. Measured radiometric resolution and ENL for IMP, IMG, IMS and APS products.

	APP/APG Products						
	IS1	IS2	IS3	IS4	IS5	IS6	IS7
ENL	1.76	1.73	2.25	2.66	3.3	3.78	3.73
Rad. Res [dB]	2.44	2.45	2.22	2.08	1.91	1.8	1.81

Table 8. Measured radiometric resolution and ENL for IMP, IMG, IMS and APS products.

The measures noise equivalent sigma nought (NES0) for APP products as a function of the incidence angle for HV and VH polarisations is provided in Fig. 5 as compared with the expected values.

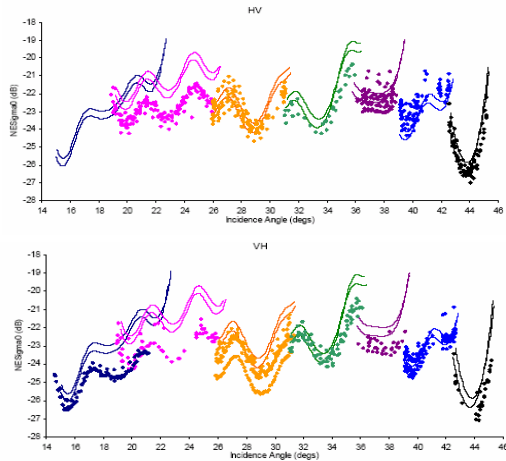


Fig. 5 Measured NES0 for APP HV and VH products (dots) and expected values (solid lines).

4. RECENT PRODUCT QUALITY IMPROVEMENTS

4.1 Doppler Grid availability

The Doppler Grid ADS provides a grid of fine Doppler Centroid estimates within the product, tagged with the zero Doppler azimuth time and slant range time of the set of data used to perform each Doppler estimate.

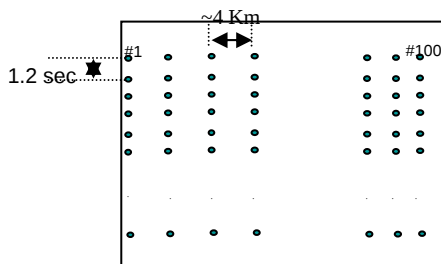


Fig. 6. Doppler Grid ADS Structure.

The Doppler Grid ADS was originally introduced in the new ASAR WS Single Look Complex Products

(ASA_WSS) to support de estimate of ocean surface currents.

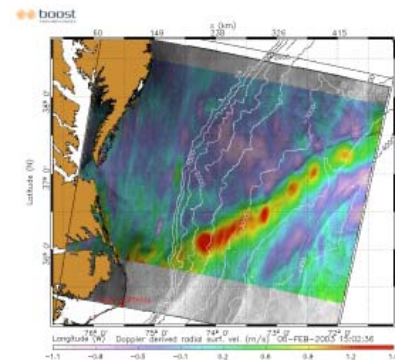


Fig. 7 Example of ocean surface currents derived from ASAR WS Doppler Grid information, Courtesy of Boost Technologies.

However, WSS products are only available on request while support to ocean applications requires data is systematically generated and made systematically available.

Therefore, WSM products have been updated (no format changes) to include as well the Doppler Grid ADS. ASAR WSM products are systematically processed and made available on line in NRT. This allows the access to the Doppler Grid information systematically in NRT since 11 April 2007.

5. ASAR WAVE MODE

5.1 ASAR Wave Mode Test Campaigns

At the latest SEASAR workshop (2006) the need for a sample WV mode data set acquired in a beam different than IS2 and using different polarisations, was raised by the users in order to improve the models for angles other than IS2.

As a result, a test campaign to acquire ASAR Wave mode data in IS4 has recently been performed as follows:

- 1) All ASAR Wave mode data acquired in **IS4 HH**:
From orbit 25621 (23-Jan-2007) to 25720 (30-Jan-2007)
From orbit 26122 (27-Feb-2007) to 26221 (06-Mar-2007)
- 2) All ASAR Wave mode data acquired in **IS4 VV**:
From orbit 25721 (30-Jan-2007) to 25820 (06-Feb-2007)

From orbit 26222 (06-Mar-2007) to 26321 (13-Mar-2007)

It should be noticed that this data set is not yet calibrated since data for deriving the absolute calibration constant was only available in IS2 up to now. Acquisitions over the Rain Forest were performed during the test campaign to calibrate the data set. Calibration constant/s will be provided through XCA updates.

The test data set will be made available on request.

5.2 ASAR Wave Mode reprocessing

The systematic quality monitoring of ASAR WV mode WVS and WVV products has been used to identify improvements to the original algorithms.

ASAR Wave mode L1 WVS and L2 WVV processing algorithms have been optimised and the prototype processor updated accordingly (Norut & Boost).

In order to have an homogeneous and quality optimised archive of ASAR WV mode L1/L2 products, it was decided to re-process the archived ASAR wave mode WVS and WVV from WVI using the prototype processor. Details on the quality improvements of the reprocessed data can be found in [5].

All WV mode data acquired since December 2002 (end C.P.) until now has been now reprocessed and it is available to the users (eohelp@esa.int for access details).

Operational ASAR processor has been upgraded accordingly and it is expected to be in operations before summer 2007. From that point, NRT WV mode products will be of the same quality as the reprocessed data.

5. SCANSAR BURST SYNCHRONISATION

Although ASAR Wide Swath mode was not designed to keep burst synchronisation between different acquisitions, the percentage of co-operative pairs was found to be higher than expected [6] (up to 80% compared with the expected 20%-30% in case of random synchronisation), which is a result of the planning strategy, the accurate ASAR timing and the precise orbit maintenance.

The analysis of the different factors contributing to the higher than expected burst synchronisation has indicated that this could be optimised with small changes in the planning strategy. Those changes are operational since 17 September 2007. Excellent results have been achieved

with those changes. The probability of having 50% burst synchronisation between two interferometric images has increased from 50% to 90% and the probability of having 70% of burst synchronisation has increased from 40% to 75 %. More details can be found in [7].

The percentage of burst synchronisation between WSM interferometric pairs can be queried on line at: http://earth.esa.int/pes/envisat/asar/wss_sync/

The information will also be available in the EOLI SA data catalogue version 5.2.
<http://eoli.esa.int/geteolisa/index.html>

6. CONCLUSIONS

ASAR instrument stability continues after five years of operation. Few antenna TRMs experienced but performance remains still within the requirements.

Product quality and performance have been optimised and improved beyond the original requirements, with new information included to support new applications (e.g. Doppler grid) and optimised burst-synchronisation probability for ScanSAR interferometry.

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