MEMO

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SUBJECT : Envisat's Yaw Axis Drift Investigation

This memorandum provides the results of the IDEAS+ AATSR QC team's investigation of a drift that was observed in the colocation performance of products produced by one of the instruments included in Envisat's payload, the Advanced Along-Track Scanning Radiometer (**AATSR**).

Introduction

Envisat's high pointing performance, granted by tight control of the satellite's attitude (defined by 3 parameters: pitch (x-axis, rotation about the orbit normal vector), roll (y-axis, rotation about the velocity vector) and yaw (z-axis, rotation about the nadir vector)), was achieved using the combined operation of the satellite's attitude measurement and attitude actuator subassemblies (for detailed descriptions, see [RD.1]). This allowed for AATSR products to be accurately geolocated and colocated.

An assessment on the colocation performance of AATSR Level 1B products (performed by Rutherford Appleton Laboratory (**RAL**) Space, see [RD.2]), however, quantitatively identified a positional offset which drifted from +1 to -1 image pixels, occurring distinctly in the across-track direction, throughout the operational life of the instrument (see Figure 1); it was considered a possibility that the source of this drift might originate from Envisat's yaw axis.

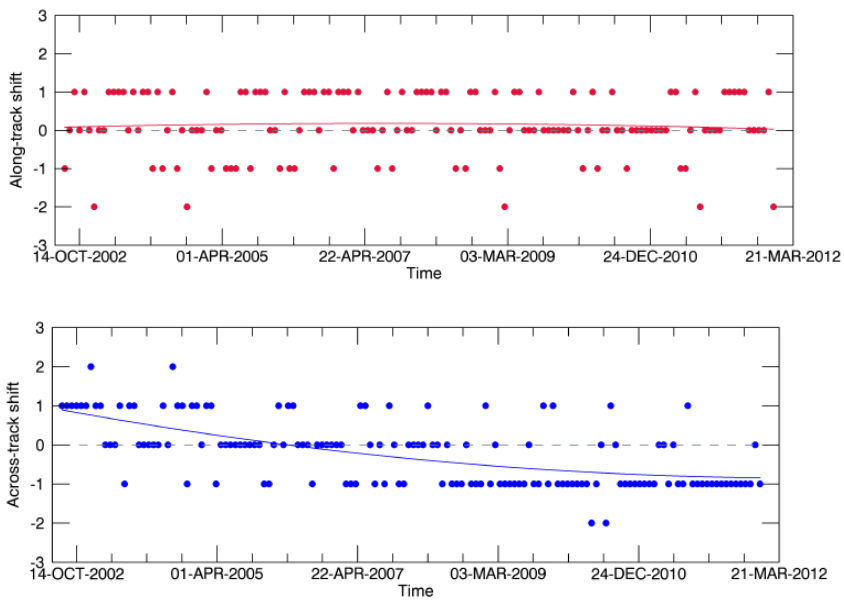

Figure 1. The positional offset, an indicator of colocation performance, of AATSR L1B products viewing the Arabian desert region – along-track (top) and across-track (bottom) direction. Taken from [RD.2].

Results

For this investigation, time-series plots were constructed from attitude estimator output data, which reports on the satellite's attitude in terms of pitch, roll and yaw mispointing with respect to the controlled frame of reference as retrieved from housekeeping telemetry, extracted from the restituted attitude auxiliary files available for Envisat (see [RD.3]).

The first time-series generated for this investigation is a daily time-series of attitude mispointing data referring to Envisat's yaw axis, see Figure 2. This figure not only demonstrates the periodic behaviour that is characterised by the relative motion of the satellite about its yaw axis (as it orbits the Earth) but also large mispointings that can result from the performance of a satellite manoeuvre (performed occasionally throughout the mission in order to maintain tight control of the satellite's orbit and attitude configuration).

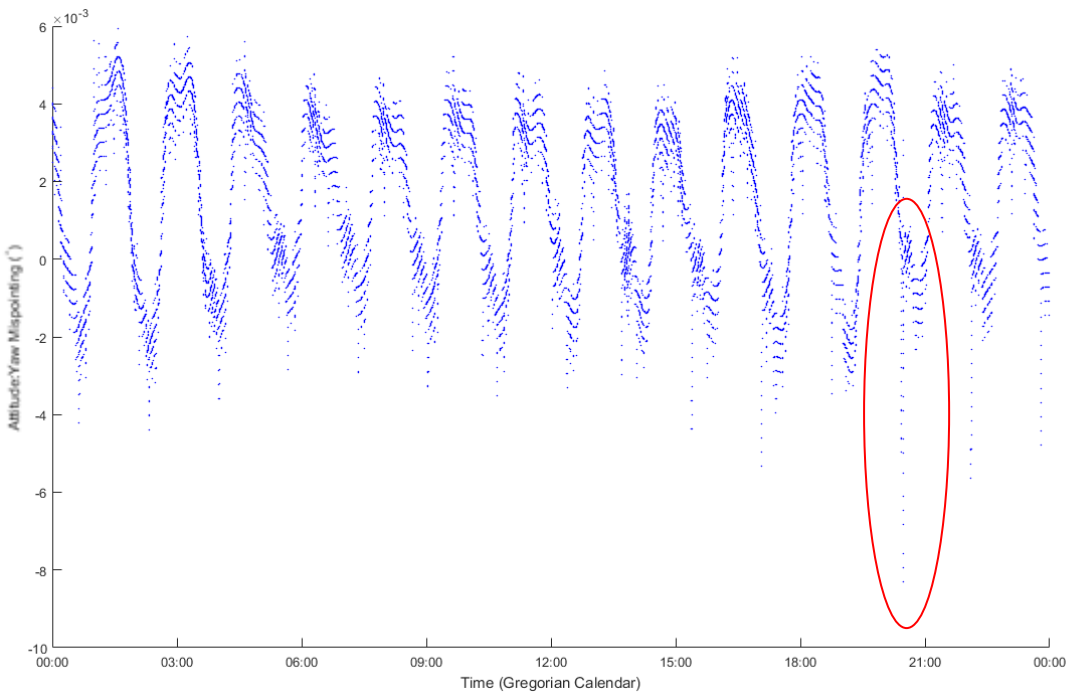

Figure 2. Envisat yaw mispointing yaw daily time-series (02/01/2008).

In Figure 2, the large yaw mispointing observed may be attributed to the Stellar Fine Control Manoeuvre (**SFCM**) (an in-plane manoeuvre used to control the semi-major axis of the satellite, performed every 30-50 days depending on the rate of orbital decay) that took place at 20:29:00.10 on the 2nd January 2008 (see [RD.4]).

The second time-series generated is a time-series of attitude mispointing data covering the entire duration of the mission (except for prior to the 27th January 2005, as attitude estimator output data was not included in the restituted attitude files during this time), see Figure 3. This particular time-series allows for useful observations on the evolution of Envisat's yaw axis to be made.

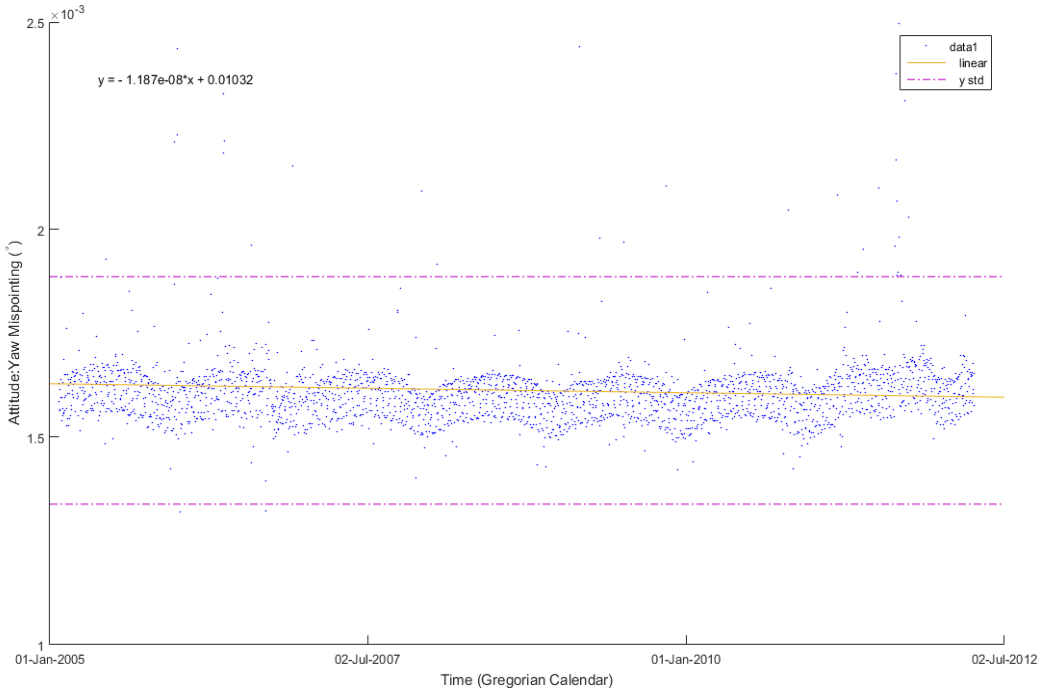

Figure 3. Envisat yaw mispointing time-series.

The statistics used to describe the time-series shown in Figure 3 in this particular time-series are listed in Table 1.

Table 1. Envisat's yaw mispointing time-series statistics

Yaw Mispointing Statistics	Value (º)	Comments
Range	Min: - 3.33 x 10^{-3}	Total range approx. 1.40 x 10^{-2} º
	Max: 1.10 x 10^{-2}	
Standard Deviation	2.74 x 10^{-4}	No comments
Mean	1.61 x 10^{-3}	Largely biased due to the misalignment of the AATSR sensor

In addition to the statistics provided in Table 1, the time-series was modelled through performing linear regression and revealed a drift of (-)1.19 x 10^{-8} º/day, or a total of approximately 3.0 x 10^{-5} º over the seven year period covered in this investigation, in Envisat's yaw axis. As the latter result is not of the same magnitude that represents the angular separation of an image pixel (which varies slightly depending on if the pixel is from a nadir or forward view, where in the scan or swath the pixel lies, etc.), this drift can be ruled out as the likely cause of the observed drift in colocation performance.

Summary

The results of this investigation suggest that the observed drift in the colocation performance of AATSR products was not caused by a drift in Envisat's yaw axis. This is because the magnitude of the drift observed is of several orders smaller than the angular separation that an AATSR image pixel represents (averaged nadir and forward views, approximately 6 x 10^{-2} º). However, after having reported these results to the AATSR QWG at the 33rd AATSR QWG meeting (September 2016), it was then suggested that this colocation drift may originate from common thermo-elastic effects on the satellite's structure and so further work would be needed in order to explore this potential source in more detail at a later date.

References

RD.1 Bargellini, P. et al. (2005) Envisat Attitude and Orbit Control In-orbit Performance: An Operational View, 6th International ESA Conference on Guidance, Navigation and Control Systems, held 17-20 October 2005 in Loutraki, Greece. ESA SP-606. European Space Agency, 2006.

RD.2 AATSR Nadir-Forward Image Views Co-registration, PO-TN-RAL-AT-0569, April 2016.

RD.3 Envisat 1 Products Specifications: Volume 16: Auxiliary Data Files, PO-RS-MDA-GS-2009, Issue 3, Revision G, 20th November 2011.

RD.4 ERS and Envisat Orbit Manoeuvres, IDEAS-BAE-SOM-REP-1249, Issue 1.1 Revision 0, 12th June 2013.