# THE ENVISAT AATSR PROCESSING ALGORITHMS AND DATA PRODUCTS

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ABSTRACT

The Advanced Along-Track Scanning Radiometer (AATSR) is the successor to ATSR-2 and will fly aboard ENVISAT-1 to provide continuing accurate and precise global measurements of sea surface temperature. This paper presents an overview of the AATSR system, with particular reference to the AATSR ground processor architecture, processing algorithms and data products. The AATSR processor makes full use of the ATSR series heritage, but the data products have been redeveloped. The new products are introduced and differences from the ATSR-2 products outlined.

## 1. INTRODUCTION

The Advanced Along-Track Scanning Radiometer is the third in the series of radiometers that includes ATSR [2] and ATSR-2 [5], and has as its primary objective the collection of accurate and precise global measurements of Sea Surface Temperature (SST), and thereby the continuation of the consistent, long-term set of global SST measurements from ATSR-1 and ATSR-2.

AATSR is functionally identical to ATSR-2, although its design has been modified to match the environment of the ENVISAT platform. One important difference relating to product generation is that sufficient telemetry bandwidth will be available to eliminate the need for compressed data modes. Therefore there will be no analogues of the compressed pixel selection maps that are used with ATSR-2; all AATSR data will be equivalent to H-rate ATSR-2 data.

Although the instruments are identical, the data products will differ in some ways from those with which ATSR-2 users are familiar. This paper aims to introduce the products and to outline these differences, so that users are aware of what they will encounter when AATSR data becomes available. These differences are primarily in relation to the product format and structure, not to the scientific content, which makes full use of the ATSR series heritage. Many of the differences arise from requirements imposed to ensure uniformity of product structure across the whole set of ENVISAT instruments.

## 2. AATSR SYSTEM OVERVIEW

The ENVISAT AATSR instrument design is a development of ATSR series of instruments [2]. Radiometric measurements are made in seven co-located channels in the infra-red and visible part of the spectrum, at wavelengths of 12, 11, 3.7 and 1.6 micron (infra-red) and 0.87, 0.67 and 0.55 micron (visible). All channels are measured simultaneously with a resolution of 1 km, while the conical scanning geometry covers a 500 km wide swath.

The unique scanning geometry ensures that each point on the surface of the Earth is measured at two angles of incidence. This feature permits an improved correction for atmospheric effects to be made, in comparison with a nadir-viewing instrument, and this in conjunction with an accurate on-board calibration system permits very precise retrievals of SST from the thermal infra-red channel data.

The three visible channels are provided to permit quantitative measurements over land surfaces, and will be used to derive global vegetation indices; they will also enable the measurement of a variety of cloud parameters. An on-board diffusing plate permits a visible channel calibration to be obtained once per orbit.

AATSR data will be systematically recorded on the on-board tape recorders and dumped once per orbit.

## 3. AATSR DATA PROCESSING

All AATSR data will be processed on the AATSR Generic Processor that is to be installed in the ESA Payload Data Handling Stations (Kiruna and ESRIN-Frascati) and at the ENVISAT Processing and Archiving Centres (PACs) and national stations offering ESA AATSR services. The use of a Generic Processor will ensure product compatibility between the different processing centres, in terms of identical format and processing algorithms, thus simplifying the product validation.

The AATSR generic processor will produce all data products (Level 1b, Level 2 and Browse) systematically both in near real-time (NRT) and off-line.

To enable the validation of the delivered processor, a Reference Processor (RP) has been developed at the Rutherford Appleton Laboratory (RAL). The AATSR operational processor will be validated against test data sets (TDS) produced by the RP. In addition to its role in TDS generation, the RP may also be used to test new algorithms, and may be used as an AATSR processor in its own right, as required.

## 4. PROCESSING ALGORITHMS

The processing algorithms for AATSR are based on those developed for ATSR and ATSR-2 [3], and therefore make full use of the considerable experience gained in the generation of ATSR and ATSR-2 data products.

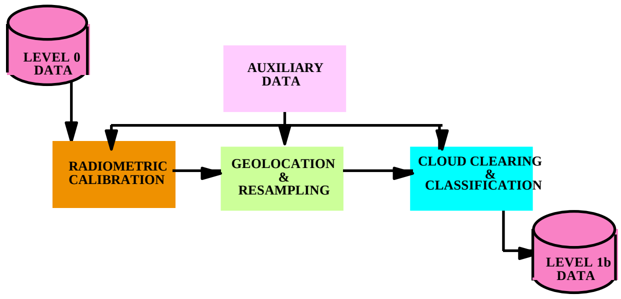


Figure 1. Level 1b Processing Architecture.

Figure 1 shows the main features of the Level 1b processing architecture. The main steps in the Level 1b processing are as follows:

**Radiometric calibration.** Initial processing unpacks the level 0 data, converts auxiliary data to engineering units, and applies a number of quality checks to the unpacked data. Calibration parameters are then derived for the seven channels.

The infra-red channels are calibrated with respect to a pair of on-board black bodies of known temperature. Calibration parameters (offset and slope) that describe the linear relationship between the detected pixel count and radiance for the three thermal infra-red channels are determined from the black body pixel counts and the black body temperatures. These calibration coefficients are subsequently used to convert the pixel data to brightness temperature via look-up tables for the conversion of radiance to brightness temperature.

An on-board diffusing plate (the VISCAL unit), which is illuminated by the sun once per orbit, is provided to enable calibration of the 1.6 micron and visible channels. Calibration parameters are derived from the VISCAL data, once per orbit (if present) when the VISCAL unit is in sunlight. These calibration parameters are written to an external database of Visible Calibration Coefficients. Calibration parameters to be used for the visible channels in the current orbit are derived from a previous orbit, and are read from an input file.

**Geolocation and resampling:** The purpose of these modules is to determine the geographic co-ordinates of the instrument pixels, and to map them onto a rectangular grid centred on the satellite ground track.

Geolocation is initially performed on selected tie point pixels. The geodetic latitude and longitude, and the x-y (across-track and along-track) co-ordinates are determined for each tie point pixel, and positions of other instrument pixels are then determined by linear interpolation between them. Solar and viewing angles required for cloud clearing are also determined at this stage. The calculation of the x and y co-ordinates differs from that in ATSR and ATSR-2 processing by the introduction of revised geodetic length formulae.

The scanning geometry of AATSR is such that pixels are measured on a sequence of curved instrument scans. The purpose of the resampling step is to relocate calibrated AATSR pixels into co-located forward and nadir images on a rectangular grid of approximately 1 km resolution (modified to allow for equal time sampling along-track), using the pixel positions derived above. Cosmetic filling of the images is then performed, to fill any remaining image pixels.

The regridding process as described above differs from that used in ATSR and ATSR-2 processing in two ways; the introduction of equal time interval sampling, and the introduction of minor changes to the mapping between instrument pixels and their final positions in the image array. The reasons for the latter change are somewhat technical, and will not be discussed here.

The move to equal time interval sampling is motivated in part by the change to orbit based products (ATSR and ATSR-2 products are based on 512 km square images). Equal time interval sampling permits (though it does not guarantee) continuity of sampling in the overlap region. The adoption of this approach also permits the updated regridding to operate with minimal impact on the cosmetic fill algorithm.

Of the differences noted above, the use of geodetic length formulae is the change having the most obvious physical rationale, but the equal time interval sampling may well be the most obvious change to the user.

**Cloud Clearing and Surface Classification.** Given the image pixel latitude and longitude, the surface type for each image pixel is determined with reference to an external land-sea mask. Cloud-clearing algorithms are used to identify all image pixels as cloudy or cloud-free. Up to nine distinct tests, using different channel combinations are applied to each pixel.

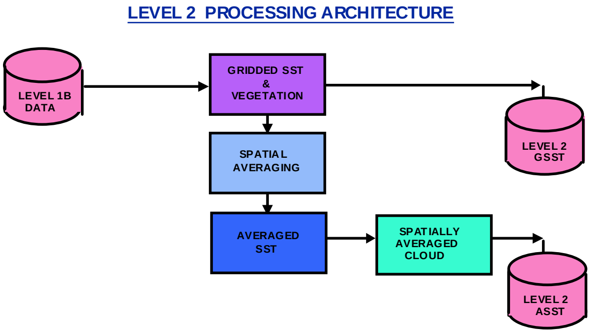


Figure 2. Level 2 Processing Architecture.

Figure 2 shows the main features of the Level 2 processing architecture. The main steps in the production of the Level 2 products are as follows:

**Derivation of Sea Surface Temperature** (SST) and other parameters, at 1 km resolution, from the Level 1b regridded brightness temperatures. SST is derived from the infra-red brightness temperatures using a linear regression algorithm [4]. Over land, a normalised difference vegetation index (NDVI) is derived at 1 km resolution, using cloud free data.

**Generation of averaged brightness temperatures** and reflectances from the Level 1b regridded brightness temperatures and visible channel reflectances.

**Derivation of averaged SST** from the averaged brightness temperatures, and of NDVI from the averaged reflectances.

For the averaged products in half-degree cells, the globe is imagined as divided into cells 0.5° in latitude by 0.5° in longitude, and these cells are further subdivided into 9 sub-cells extending 10 arcmin in latitude by 10 arcmin in longitude. Averaged brightness temperatures and reflectances are derived, for cloud-free and cloudy pixels separately, over these cells.

Averaged SST is derived from the averaged brightness temperatures, for cells and sub-cells containing sea, as described in reference [4]. Similarly, averaged NDVI is calculated for each sub-cell for which average reflectances over land have been calculated. Finally, an estimate of cloud-top temperature is derived based on the half-degree cells.

Similar spatially averaged quantities are derived averaged over cells and sub-cells of nominal dimensions 50 km x 50 km, and 17 x 17 km, respectively, to give an averaged product based on equal area cells.

## 5. AATSR PRODUCTS

Table 1 summarises the AATSR products to be generated. All AATSR products will be orbit-based.

**Table 1. ENVISAT AATSR Products**

| Level | Description | Availability |
|---|---|---|
| 0 | Instrument Source Packet Data | NRT: 1 day<br>Off-line: 2 weeks |
| 1b | Gridded Brightness Temperature/Reflectance (GBTR) | NRT: 3 hours<br>Off-line: 2 weeks |
| 1b | Browse (nadir view only, 4 km resolution) | NRT: 3 hours<br>Off-line: 3 days |
| 2 | Average Surface Temperature (AST) | NRT: 3 hours<br>Off-line: 2 weeks |
| 2 | Gridded Sea Surface Temperature (GSST) | NRT: 3 hours<br>Off-line: 2 weeks |
| 2 | Spatially Averaged Surface Temperature Product for Meteo Users (sub-set of AST Product above) | NRT only: 3 hours |

### AATSR Level 1b (GBTR) Product [1]

The GBTR product contains top of atmosphere brightness temperatures for the three infra-red channels and reflectance values for the 1.6 micron and visible channels. Values are provided in separate measurement data sets (MDS) for the nadir and forward views, and in addition the product contains cloud flag and confidence words and annotation data; the annotation data includes geolocation data (pixel latitude and longitude), topographic data, solar and viewing angles, and data to show the mapping between the image and instrument pixels.

**Table 2. Level 1b (GBTR) Product**

| MDS | $\lambda$[$\mu$m ] | View | Application |
|---|---|---|---|
| 1 | 12.0 | nadir | Surface temperature, cloud clearing |
| 2 | 11.0 | nadir | Surface temperature, cloud clearing |
| 3 | 3.7 | nadir | Surface temperature, cloud clearing |
| 4 | 1.6 | nadir | Cloud clearing |
| 5 | 0.87 | nadir | Vegetation index |
| 6 | 0.67 | nadir | Vegetation index |
| 7 | 0.55 | nadir | Chlorophyll |
| 8 | 12.0 | forward | Surface temperature, cloud clearing |
| 9 | 11.0 | forward | Surface temperature, cloud clearing |
| 10 | 3.7 | forward | Surface temperature, cloud clearing |
| 11 | 1.6 | forward | Cloud clearing |
| 12 | 0.87 | forward | Vegetation index |
| 13 | 0.67 | forward | Vegetation index |
| 14 | 0.55 | forward | Chlorophyll |
| 15 | all | nadir | Confidence words |
| 16 | all | forward | Confidence words |
| 17 | all | nadir | Cloud and land/sea flags |
| 18 | all | forward | Cloud and land/sea flags |

### AATSR Level 2 (GSST) Product [1]

The GSST product contains a single MDS the contents of which are switchable, that is to say, they depend on the surface type. Specifically, the contents of the data fields depend on the setting of the forward and nadir cloud flags and the land flag according to the following table.

**Table 3. GSST Nadir and Combined Field Contents**

| nadir cloud | forward cloud | land | Nadir field | Combined field |
|---|---|---|---|---|
| 0 | 0 | 0 | SST nadir | SST combined |
| 0 | 1 | 0 | SST nadir | (reserved) |
| 1 | 0/1 | 0/1 | cloud top temp | cloud top height |
| 0 | 0/1 | 1 | Land surface temperature | NDVI |

The NDVI parameter does not appear in the current ATSR products product. Similarly the land surface temperature and cloud top height products do not have any counterpart in the corresponding ATSR-2 products, and algorithms for these parameters are currently under development.

**AATSR Level 2 (AST) Product [1]**

Averaged quantities in the AST product are provided at two different resolutions, and with respect to two different geographical grids. Measurement data sets are provided at 0.5° by 0.5° and 10 by 10 arcmin with respect to a latitude/longitude grid; these data sets provide continuity with existing ATSR-2 products. Additional data sets contain data averaged over equal area cells of 50 by 50 km and 17 by 17 km aligned with the satellite ground track. Both top-of-atmosphere and surface data sets are provided. The surface temperature data sets provide, for sea cells, nadir and dual view sea surface temperatures, and for land cells, land surface temperature and NDVI. Cloud data is also included. The data sets of the AST product are structured by surface type and resolution as shown in Table 4.

**Table 4. AST Product**

| MDS | Content / Purpose |
|---|---|
| 1 | MDS Sea Surface Temperature (SST) record, 50 kilometre cell |
| 2 | MDS SST record, 17 kilometre cell |
| 3 | MDS SST record, 10 arc minute cell |
| 4 | MDS SST record, 30 arc minute cell |
| 5 | MDS Land Surface Temperature (LST) record, 50 kilometre cell |
| 6 | MDS LST record, 17 kilometre cell |
| 7 | MDS LST record, 10 arc minute cell |
| 8 | MDS LST record, 30 arc minute cell |
| 9 | MDS BT/TOA Land Record, 50 km cell |
| 10 | MDS BT/TOA Land Record, 17 km cell |
| 11 | MDS BT/TOA Land Record, 10 arc minute cell |
| 12 | MDS BT/TOA Land Record, 30 arc minute cell |
| 13 | MDS BT/TOA Sea Record, 50 km cell |
| 14 | MDS BT/TOA Sea Record, 17 km cell |
| 15 | MDS BT/TOA Sea Record, 10 arc minute cell |
| 16 | MDS BT/TOA Sea Record, 30 arc minute cell |

## 6. CONCLUSIONS

The development of the processing algorithms for the AATSR ground segment is well advanced, making full use of the heritage of algorithms developed for the ATSR and ATSR-2 instruments.

SST is an important parameter in the understanding of the ocean-atmosphere system and of climate change, and the AATSR programme will provide continuation of the consistent, long-term set of global SST measurements from ATSR-1 and ATSR-2, as well as providing, through its visible channels, the means for development of new remote sensing applications, including studies of deforestation and land use and the determination of cloud parameters such as optical depth and ice crystal habit.

## 7. REFERENCES

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