National Remote Sensing Centre Limited

ERS ALONG TRACK SCANNING RADIOMETER ATS.GBT PRODUCT USER GUIDE

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NOTICE

ERS ALONG TRACK SCANNING RADIOMETER
ATS.GBT PRODUCT USER GUIDE

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Contents

1 INTRODUCTION

1.1 Introduction

This document is a user guide for the ERS-1 and ERS-2 Along Track Scanning Radiometer Gridded Brightness Temperature/Reflectance Product (ATS.GBT) produced by the United Kingdom Processing and Archiving Facility (UK-PAF).

1.2 Scope of Document

This document provides information about the parameters which are contained in the ATS.GBT product and gives information about how to interpret these parameters. It also describes the CEOS format of the product to enable users to extract these parameters.

1.3 Intended Audience

This document is intended for use by all scientists who intend to use ATSR data.

1.4 Document Structure

Following this section the document has three main sections and one Annex:

- 2 The ATSR Sensor
- 3 Calibration
- 4 The ATS.GBT Product
- Annex A ATS.GBT CEOS Format Definition

1.5 Point of Contact

For further information on the UK-PAF and UK-PAF products please contact:

ESRIN ERS Help Desk
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WWW	http://services.esrin.esa.it/

1.6 Abbreviations and Acronyms

The following is a list of the abbreviations and acronyms which are used in this document.

ATSR	Along Track Scanning Radiometer (on ERS-1)
ATSR-2	Along Track Scanning Radiometer 2 (on ERS-2)
ATS.GBT	ATSR Gridded Brightness Temperature/Reflectance Product
BT/R	Brightness Temperature/Reflectance
CEOS	Committee on Earth Observation Satellites
EECF	Earthnet ERS Central Facility
ERS-1/2	First/Second European Remote Sensing Satellite
ESA	European Space Agency
ESRIN	European Space Research Institute
EPIS	EECF to PAF Interface Specification
GBT	SADIST Gridded Brightness Temperature/Reflectance Product
LSB	Least Significant Bit
MSB	Most Significant Bit
NRSC	National Remote Sensing Centre Limited
ORRE	Restituted Orbit File
PATC	Time Correlation File
PCD	Product Confidence Data
RAL	Rutherford Appleton Laboratory
SADIST	Synthesis of ATSR data into Sea Surface Temperatures
SST	Sea Surface Temperature
UK-PAF	United Kingdom Processing and Archiving Facility
UTC	Universal Time Co-ordinated
YSM	Yaw Steering Mode

1.7 Reference Documents

The following documents are reference documents and when referred to in the text are identified as RD-n, where n is the number of the document from the list below.

RD-1 SADIST-2 v100 Products, Paul Bailey, Space Science Department, Rutherford Appleton Laboratory, 6th September 1995 release

RD-2 ERS-2 Ground Segment Products Specification, ER-IS-EPO-GS-0201

2 THE ATSR SENSOR

2.1 Design Objectives

The ATSR (see Figure 2.1) was designed to provide the following types of data and observations:

- sea surface temperature with absolute accuracy of better than 0.5°K with a spatial resolution of 50 km and in conditions of up to 80% cloud cover

- images of surface temperature with 1 km resolution and 500 km swath, relative accuracy around 0.1°K.

The 1.6 µm channel was added to the original three channel radiometer to improve sea surface temperature retrievals by detecting cloud during day-time operation of the Infra-Red Radiometer.

The Microwave Sounder in Figure 2.1, although a separate instrument, is physically attached to the ATSR.

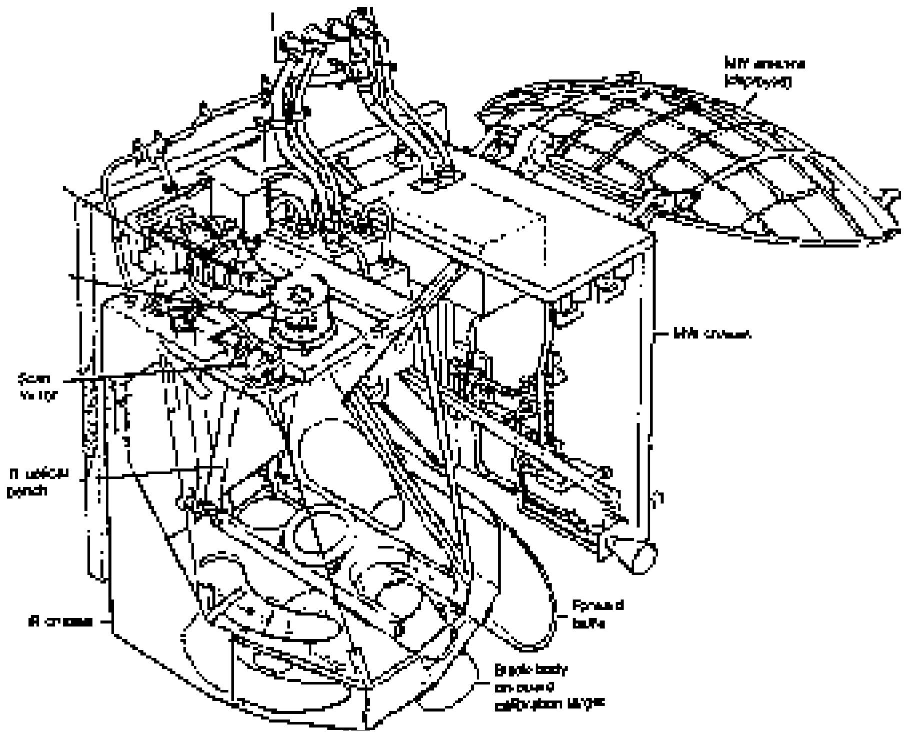

Figure 2.1 — ATSR Line Drawing

2.2 Operational Concept

The ATSR employs a rotating mirror giving a conically scanned field of view of the Earth's surface in two curved swaths, 500 km wide and separated by about 900 km (see Figure 2.2 and 2.3). Data from these two swaths is combined to retrieve accurate and precise atmospheric corrections for radiometric measurements from space. For comparison purposes Figure 2.2 includes the Microwave Sounder (MWS) coverage spots. Although the ATSR is simple in concept, it involves several technically advanced features. On-board calibration, which must be achieved with great precision, is carried out by the incorporation of two controlled reference targets (black bodies) into the instrument scan pattern. The black bodies have been carefully designed for high emissivity, uniformity, stability and precise monitoring. The other advanced technical feature is the use of a mechanical cooler mechanism which ensures that the detectors reach temperatures of as low as 77°K without the use of large and cumbersome passive radiators.

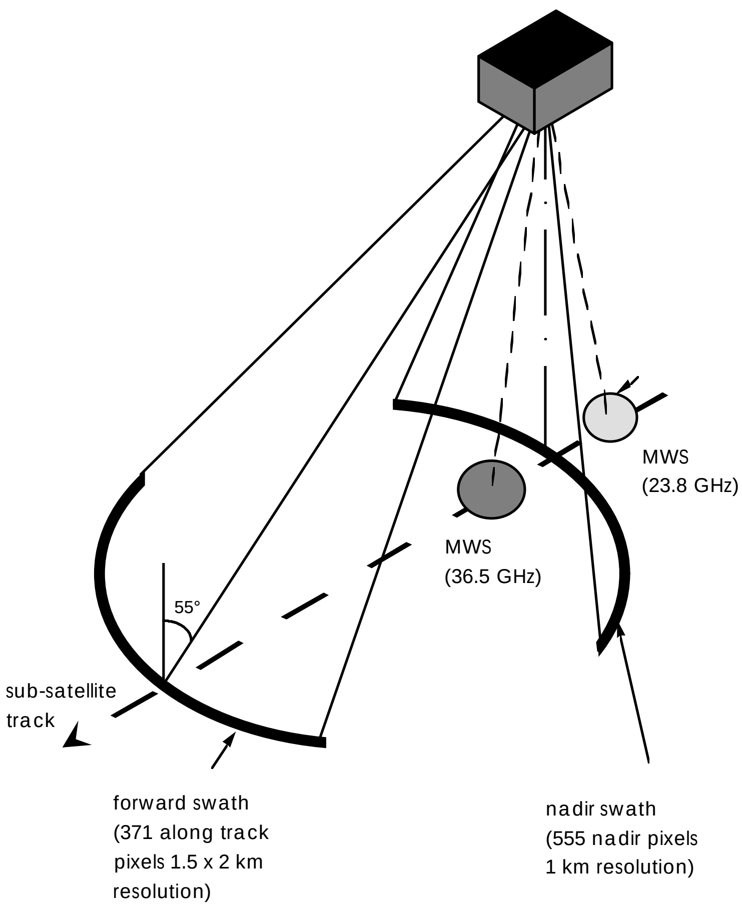

Figure 2.2 — ATSR Viewing Geometry

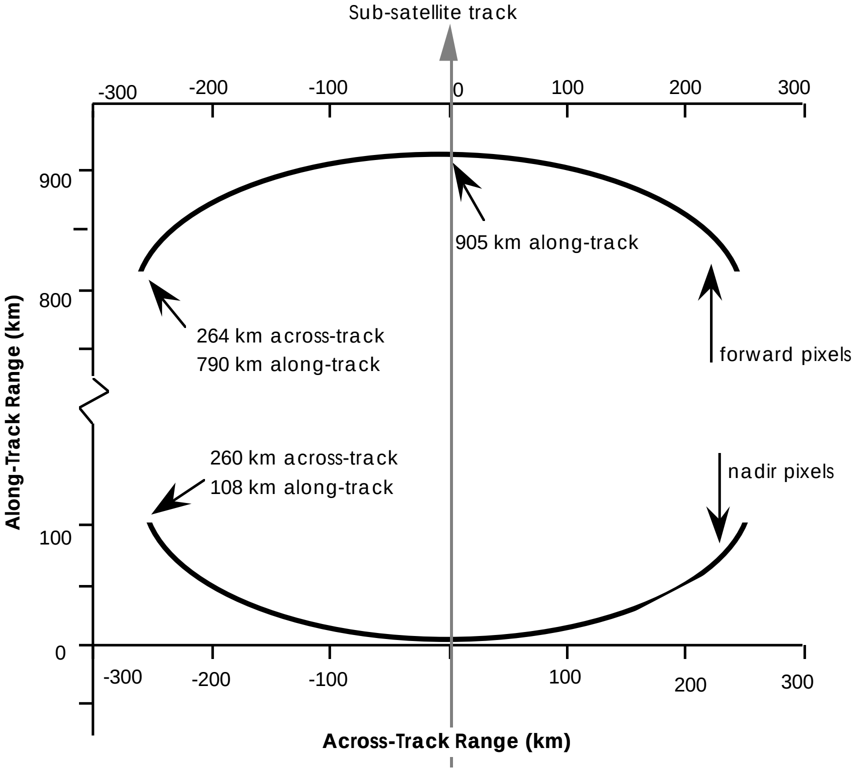

Figure 2.3 — ATSR Scans Projected onto the Earth's Surface

2.2.1 Predicted Accuracy

The predicted accuracy of the average Sea Surface Temperature (SST) Product is better than 0.5°K under most conditions over an area of over 50 x 50 km areas, each containing 2500 pixels within the 500 km wide swath. To obtain the necessary signal resolution performance single-element HgCdTe and InSb detectors are used, cooled by a Stirling-cycle mechanical cooler.

2.2.2 Scanning Optics

To achieve the along track viewing and the swath coverage, a plane inclined mirror is continuously rotated to scan a cone of viewing vectors into the primary paraboloid.

The overall scan parameters are determined by the spacecraft's orbit. The orbital velocity (6.7 kms^{-1}) causes a movement of 1 km per scan during a 150 msec scan period. A scan cone angle of 46.9° gives a zenith angle in the along track view of about 55°. This cone provides adequate atmospheric path length discrimination at the edges of a 500 km swath. A ground resolution of 1 km in the nadir view requires 2000 pixels per scan, corresponding to a full angle of view of 1/777 radian or 0.0737°. The signal channels interogate each pixel for 75 msec, the time taken for ATSR's instantaneous field of view to clear itself.

Therefore, along the scan, the pixel sensitivity profile to incoming radiation is essentially an equilateral triangle of half width 1 km and full width 2 km. Similarly, this profile across the scan is 1 km at nadir, but increased by geometry to 2 km at the along track point. The sampling of nadir view pixels, moved along the scan by the mirror and across the scan by spacecraft motion, is roughly on a 1 x 1 km matrix.

Objective	Sea surface temperature, cloud observations, land and ice surface emissivity
Spectral channels	4 co-registered thermal channels 1.6, 3.7, 10.8 and 12 µm. Note: 3.7 µm channel stopped working end May 1992.
IFOV	1 km x 1 km (nadir), 1.5 km x 2 km (forward view)
Swath width	500 km
Scanning method	Mechanical-rotating plane mirror. Provides two Earth views (nadir and approx. 55° to nadir - approx. 900 km apart). Field of view conically scanned
Detector	Single element HgCdTe and InSb
Cooler	Stirling cycle - mechanical cooler ensures temperatures as low as 77°K
Radiometric precision	< 0.1°K
Predicted SST Accuracy	0.5°K over a 50 x 50 km area with 80% cloud cover
Calibration	Two on-board black bodies which are referenced in the scan pattern
Instrument housing	Carbon fibre composite structure featuring an independent optical bench ensuring optical alignment

Table 2.1 :— ATSR Technical Characteristics

3 CALIBRATION

3.1 Internal Calibration

Internal calibration is achieved through the monitoring of instrument functions and parameters and the derivation of corrections using data provided by the on-board spacecraft systems. The data is processed on the ground.

3.2 External calibration

External calibration is the derivation of corrections through comparison with independent references. Instrument operations over calibration sites with natural or man-made targets of known parameters (e.g. location, backscatter coefficient) provide the necessary references within the instrument data.

3.3 Geophysical calibration

Geophysical calibration is the tuning of the ground processing systems to provide accurate values of geophysical parameters (e.g. sea-surface temperature). The processing uses models to produce the geophysical parameters from instrument engineering data. Results from the models are compared with independent in-situ data. Systematic errors are corrected by updating parameters in the model.

3.4 ATSR calibration

As with other sensitive radiometers, the ATSR detectors and their electronics suffer from unavoidable drifts in gain and offset. In addition, the transmission of the ATSR's optical components may vary during the mission, for example, due to vapour condensation. In order to achieve the sea surface temperature measurement accuracy needed for climatic research, the ATSR needs to be calibrated continuously in-flight and this is achieved by means of an on-board calibration sub-system, which consists of two temperature reference targets, together with their associated electronics.

These targets, which are viewed for the equivalent of 16 pixels, as part of the ATSR's conical scan, are simulated black body sources of very accurately known temperature and radiation output. The required absolute accuracy of this calibration is 0.1°K an emissivity of > 0.998, temperature non-uniformity of < 0.03°K and temperature measurement error of < 0.03°K. Tests have shown that these requirements are and will be met during the lifetime of the satellite and the on-board calibration system ensures that the ATSR will be the most accurate radiometer to have been flown in space.

The two on-board black bodies are measured by platinum resistance thermometers, but the 1.6 µm channel will be calibrated by observing ground features, of which the albedo values are known.

In 1989 the ATSR instrument was subjected to a series of tests covering field of view determination, radiometric calibration, thermal vacuum temperature cycling and thermal balance tests, in addition to standard instrument check-outs.

Wavelength µm	Gain mW/count	NEDT K	Digitisation K per count
Black-body Temperature=261.44 K, N=500 samples			
10.8	0.03451	0.026	0.030
11.8	0.03814	0.036	0.031 (2x for 11 bit digitisation)
3.7	0.00022	0.065	0.107
Black-body Temperature=298.03 K, N=500 samples			
10.8	0.03451	0.019	0.021
11.8	0.03814	0.028	0.022 (2x for 11 bit digitisation)
3.7	0.00022	0.025	0.020

Table 3.1 — Black-body calibration

Verification of ATSR data depends on the collection of ground truth data during the satellite overflights, principally by radiometers on aircraft, ships, towers and by surface and upper air meteorological observations. Sea surface temperature is required in two forms: 'skin' temperature as measured by radiometers and 'bulk' temperature from immersed instruments. A comparison can then be made between ground measurements and ATSR temperatures, aided by knowledge of local conditions, to resolve uncertainties caused by imperfect atmospheric modelling and meteorological effects.

4 THE ATS.GBT PRODUCT

4.1 Description

The ATSR product ATS.GBT is generated at the UK-PAF on DEC-Alpha computer under VMS operating systems using the latest version of the software provided by Rutherford Appleton Laboratory, which is called SADIST-2. This software will be able to process data from both the ATSR-1 sensor on ERS-1 and the ATSR-2 sensor on ERS-2.

The ATS.GBT product is a gridded Brightness Temperature/Reflectance (BT/R) product consisting of 512km by 512km BT/R images at a resolution of 1Km, for both nadir and forward views for all available ATSR channels together with associated positional and confidence information.

The ATS.GBT product contains data from a single frame of ATSR-1 or ATSR-2 data.

4.2 Interpretation

The following section gives details about how the data content of the CEOS format product should be interpreted. Some information has been reproduced from RD-1 where appropriate.

4.2.1 Product Overview

Each ATSR-2/SADIST-2 product will consist of two parts. These are the ‘SADIST-2 header’ and the ‘product contents’. The header shown in Table 4.1 is common to all SADIST-2 products. The actual product contents are individual to each of the gridded, ungridded and spatially-averaged products. The parameters in the SADIST-2 product header are described in more detail in the next section (3.2.2).

SADIST-2, to allow for flexibility and simplicity, splits ATSR-2/SADIST-2 product contents into several significant categories. Each catergory is represented by a single letter code in product requests, and in product file-names. With a combination of codes it is possible to, in a precise way define the actual product contents. The product content catergories as detailed in Table 4.1 below are:

Nadir-view only (N): only those records containing nadir-view data. (The presence of this option indicates the absence of product records, ie those containing forward-view data)

Thermal infra-red detectors (T): records containing the thermal infra-red/near infra-red(12.0µm, 11.0µm, 3.7µm, 1.6µm) channels, which are available from both the ATSR-1 and ATSR-2 instruments.

Visible detectors (V): records containing the visible/near-infra-red (1.6µm, 0.87µm, 0.65µm, 0.55µm) channels, which are available from only the ATSR-2 instrument.

Pixel latitude/longitude positions (L): records containing precise Earth-locations for ATSR instrument pixels.

Pixel X/Y coordinate positions (X): records containing precise pixel-locations (for ungridded products), or sub-pixel offsets (gridded products) in the across-track/along-track coordinate system defined by the ERS platform trajectory.

Cloud-clearing/land-flagging results (C): records containing the detailed results of cloud-clearing tests and pixel land-flagging.

Not every category is available for each product type, so not all product options are always available. There are default product types for each product and instrument (ATSR-1, ATSR-2), and most product types have been chosen to both satisfy most product users and minimise the possible product size.

<u>The SADIST-2 product header</u>

The header shown in Table 4.1 is present at the beginning of all SADIST-2 products. The header contents are wholly ASCII text, though there are ASCII representations of integers, floating-point numbers and character strings.

The size of this header is 4096 bytes, and always occupies a whole number of records at the beginning of the product. Since the SADIST-2 products have differing record-lengths, the number of records occupied by the header varies from product to product; however it is always the smallest number of records capable of holding 4096 bytes.

If the product record length is not an integer factor of the 4096-byte header-length, the last product record used to hold the header will contain some unused bytes.

Byte Range	# Bytes	Parameter Description	Type	Unit
0-1	2	Byte-order word	Char	None
2-61	60	Product file-name	Char	None
62-67	6	Instrument name (ATSR1 or ATSR2)	Char	None
		Orbit parameters		
68-72	5	Type of ERS state vector used by orbit propogation	Char	None
73-88	16	Ascending node time (days since January 1st, 1950)	Real	Days
89-113	25	Universal time at ascending node	Char	None
114-152	3x13	Ascending node state vector position (x, y, z)	Real	Km
153-179	3x9	Ascending node state vector velocity (x, y, z)	Real	Km/s
180-190	11	Longitude of the ascending node	Real	Degrees
		Clock Calibration Parameters		
191-206	16	Reference Universal time (days since January 1st 1950)	Real	Days
207-219	13	Reference ERS satellite clock time	Integer	see below
220-232	13	Period of ERS satellite clock	Integer	ns
		Product optional contents parameters		
233-234	2	(N) Nadir-only records present	Integer	None
235-236	2	(T) Thermal infra-red detector recordspresent	Integer	None
237-238	2	(V) Visible/near-infra-red detector records present	Integer	None
239-240	2	(L) Latitude/longitude records present	Integer	None
241-242	2	(X) X/Y coordinate records present	Integer	None
243-244	2	(C) Cloud-clearing land-flagging records present	Integer	None
		Product position and time parameters		
245-256	2x6	Along-track distance of product start and end	Integer	Km
257-306	2x25	Universal time of data acquisition at product start and end	Char	None
307-338	4x8	Latitudes of product corner-points: LHS at start; RHS at start; LHS at end; RHS at end	Real	Degrees
339-374	4x9	Longitudes of product corner points: LHS at start; RHS at start; LHS at end; RHS at end	Real	Degrees

Table 4.1: SADIST-2 product header, part 1

Byte Range	# Bytes	Parameter Description	Type	Unit
		Instrument modes and temperature parameters		
375-380	2x3	1st and 2nd ATSR-2 Pixel Selection Maps in nadir-view	Integer	None
381-386	6	Along-track distance of 1st PSM change in nadir-view	Integer	Km
387-392	2x3	1st and 2nd ATSR-2 Pixel Selection Maps in forward-view	Integer	None
393-398	6	Along-track distance of 1st PSM change in forward-view	Integer	Km
399-400	2	ATSR-2 data-rate at start of nadir-view	Char	None
401-406	6	Along-track distance of 1st ATSR-2 data-rate change in nadir-view	Integer	Km
407-408	2	ATSR-2 data-rate at start of forward-view	Char	None
409-414	6	Along-track distance of 1st ATSR-2 data-rate change in forward-view	Integer	Km
415-422	8	Minimum Stirling Cycle Cooler (SCC) cold-tip temperature	Real	Kelvin
423-462	5x8	Minimum instrument detector temperatures: 12.0µm, 11.0µm, 3.7µm, 1.6µm, 0.87µm	Real	Kelvin
463-510	6x8	Maximum temperatures, as bytes 415-462	Real	Kelvin
		Solar angle and viewing angle parameters		
511-609	11x9	Nadir-view solar elevations at start of product	Real	Degrees
610-708	11x9	Nadir-view solar elevations at end of product	Real	Degrees
709-807	11x9	Nadir-view satellite elevations at start of product	Real	Degrees
808-906	11x9	Nadir-view satellite elevations at end of product	Real	Degrees
907-1005	11x9	Nadir-view solar azimuths at start of product	Real	Degrees
1006-1104	11x9	Nadir-view solar azimuths at end of product	Real	Degrees
1105-1203	11x9	Nadir-view satellite azimuths at start of product	Real	Degrees
1204-1302	11x9	Nadir-view satellite azimuths at end of product	Real	Degrees
1303-2094	88x99	Forward-view solar/viewing angles, as bytes 511-1302	Real	Degrees
		Product confidence information		
2095-2130	6x6	ERS platform modes during nadir-view, as # of scans in YSM, FCM, OCM, FPM, RTMM, RTMC	Integer	None
2131-2166	6x6	ERS platform modes during forward-view, as # of scans in YSM, FCM,OCM,FPM,RTMM,RTMC	Integer	None
2167-2214	8x6	Acquisition PCD information during nadir-view, as # of scans for each condition	Integer	None
2215-2262	8x6	Acquisition PCD information during forward-view, as # of scans for each condition	Integer	None
2263-2322	10x6	SADIST-2 packet validation during nadir-view, as # of scans for each condition	Integer	None
2323-2382	10x6	SADIST-2 packet validation during forward-view, as # of scans for each condition	Integer	None
2383-2386	4	Maximum single-pixel error code	Integer	None
		Reserved for future use		
2387-4095	n/a	n/a	n/a	n/a

Table 4.1: SADIST-2 header, part 2

Product Contents

The product contents for the ATS.GBT product sequence of records is displayed in Table 4.2. The contents of this table are explained in more detail in section 4.2.3 below. The ATS.GBT product has a fixed-length 1024 byte record format.

Record #	Code	Contents	Units
0-511	T	Nadir-view 12.0µm brightness temperature image, 512 records of 512 two-byte integers (12.0µm negated to show blanking-pulse)	K/100
512-1023	T	Nadir-view 11.0µm brightness temperature image, (11.0µm negated to show cosmetic-fill)	K/100
1024-1535	T	Nadir-view 3.7µm brightness temperature image	K/100
1536-2047	T/V	Nadir-view 1.6µm reflectance image	%/100
2048-2559	V	Nadir-view 0.87 µm reflectance image (ATSR-2 only) (0.87µm negated to show blanking-pulse)	%/100
2560-3071	V	Nadir-view 0.65µm reflectance image (ATSR-2 only) (0.65µm negated to show cosmetic-fill)	%/100
3072-3583	V	Nadir-view 0.55µm reflectance image (ATSR-2 only)	%/100
3584-4095	T (not N)	Forward-view 12.0µm brightness temperature image 512 records of 512 two-byte integers (12.0µm negated to show blanking-pulse)	K/100
4096-4607	T (not N)	Forward-view 11.0µm brightness temperature image (11.0µm negated to show cosmetic-fill)	K/100
4608-5119	T (not N)	Forward-view 3.7µm brightness temperature image	K/100
5120-5631	T/V (not N)	Forward-view 1.6µm reflectance image	%/100
5632-6143	V(not N)	Forward-view 0.87µm reflectance image (ATSR-2 only) (0.87 µm negated to show blanking-pulse)	%/100
6144-6655	V(not N)	Forward-view 0.65µm reflectance image (ATSR-2 only) (0.65µm negated to show cosmetic-fill)	%/100
6656-7167	V(not N)	Forward-view 0.55µm reflectance image (ATSR-2 only)	%/100
7168-8191	L	Latitudes of image pixels, 1024 records of 256 four-byte integers	degrees/10^3
8192-9215	L	Longitudes of image pixels, 1024 records of 256 four-byte integers	degrees/10^3
9216-9471	X	X coordinate offsets (across-track) of nadir-view pixels, 256 records of 1024 unsigned one-byte integers	Km/256
9472-9727	X	Y coordinates offsets (along-track) of nadir-view pixels, 256 records of 1024 unsigned one-byte integers	Km/256
9728-9983	X (not N)	X coordinates offsets (across-track) of forward-view pixels, 256 records of 1024 unsigned one-byte integers	Km/256
9984-10239	X (not N)	Y coordinates offsets (along-track) of forward-view pixels, 256 records of 1024 unsigned one-byte integers	Km/256
10240-10751	C	Nadir-view cloud-clearing/land-flagging results, 512 records of 512 two-byte composite words, see Table 4.7	n/a
10752-11263	C(not N)	Forward-view cloud-clearing/land-flagging results, 512 records of 512 two-byte composite words, see Table 4.7	n/a

Table 4.2: Gridded brightness temperature/reflectance product (GBT): product contents

4.2.2 The ATS.GBT Leader File

The Image Header record of the Leader file contains the information copied from the SADIST-2 headers of the GBT product.

Orbit parameters (fields 11 to 20)

These parameters provide information about the ERS orbital elements used by SADIST-2 to perform propogation of the satellite orbit. They are the basis for all geolocation of ATSR data.

The parameter ‘Type of ERS state vector used by orbit propogation’ indicates the source and type of the ERS orbit state vector used by SADIST-2 to perform orbit propagation, via ESA’s ERSORB software. If this parameter is MPH, the state vector represents an orbit prediction, and was extracted by SADIST-2 from the main product headers (MPH) associated with the raw ATSR data. If this parameter is ORPD, the state vector also represents an orbit prediction, but this was retrieved by SADIST-2 from its archive of ESRIN-distributed state vectors. If however the parameter is ORRE, the state vector represents a post-orbit restitution, and was retrieved by SADIST-2 from its archive of ESRIN-distributed state vectors.

Whilst restituted state vectors should provide better geolocation accuracy, the differences in geolocation which result from using predicted and restituted state vectors are measured in hundreths if not thousands of Kilometres, and that therefore these differences are generally smaller than other errors in geolocation accuracy.

The parameter ‘Ascending node time’ and ‘Universal time at ascending node’ show the same time, but in different formats, of the ascending node crossing whose state vector is represented by the parameters ‘Ascending node state vector position’ and ‘Ascending node state vector velocity’. This state vector is the one which has been used to propogate the ERS orbit, and to provide the basis for geolocation of ATSR data. The longitude of the ascending node crossing, in degrees East, is given as the parameter ‘Longitude of the ascending node’.

Clock Calibration Parameters (Fields 21,22,23)

To derive a Universal Time from the ERS satellite clock time, the following formula should be applied

$$Required\_UT = field\_21 + (ERS\_clock\_time - field\_22) \times \frac{field\_23}{8.64 \times 10^{13}}$$

where the Required_UT and field 21 are in days in the same epoch.

Product Optional Contents (fields 24 to 29)

The ATS.GBT product will always contain the following optional contents:

ATSR-1 Thermal IR Detector records present (field 25 = 1), Latitude/Longitude records present (field 27 = 1), X/Y coordinate records present (field 28 = 1) and Cloud Clearing/Land Flagging records present (field 29 = 1)

ATSR-2 Thermal IR Detector records present (field 25 = 1), Visible/Near IR Detector records present (field 26 = 1), Latitude/Longitude records present (field 27 = 1), X/Y coordinate records present (field 28 = 1) and Cloud Clearing/Land Flagging records present (field 29 = 1).

Product Position and Time Parameters (fields 30 to 41)

Along Track Distances (fields 30 and 31) are true along track distance from ascending node to start/end of product.

The universal times (fields 32 and 33) correspond to the time that the nadir view of the ground track crossed the start/end of the product.

The image geolocation information (fields 34 to 41) corresponds to:

- latitude and longitude of the left-most nadir/forward view pixel in the first image scan in the product (fields 34 and 38).
- latitude and longitude of the right-most nadir/forward view pixel in the first image scan in the product (fields 35 and 39).
- latitude and longitude of the left-most nadir/forward view pixel in the last image scan in the product (fields 36 and 40).
- latitude and longitude of the right-most nadir/forward view pixel in the last image scan in the product (fields 37 and 41).

Instrument Modes and Temperature Parameters (fields 42 to 63)

Fields 42, 43, 45 and 46 give the first two pixel selection maps (PSM) which have been used for the nadir and forward views respectively. The first ATSR-2 pixel selection map (PSM) is a code which indentifies the strategy employed by the ATSR-2 instrument for selecting and packing the science data into the available down-link telemetry. This holds more importantance for ATSR-2 than ATSR-1, since the introduction of visible channels increases the competition for down-link space. The PSM is an indicator of the general availability of science data from each of the ATSR-2 detectors.

If the second ATSR-2 pixel selection map (PSM) used in the product is the same as the initial PSM throughout the product, fields 43 and 46 will be set to -1. Fields 44 and 47 give the along track distance of the first image scan which used the second PSM for the two views. If a second PSM was used, Along-track distance of change from 1st to 2nd PSM gives the along-track distance at which the change occurred. If this is an ungridded product this would be the relative scan number of the first instrument scan containing the second PSM. If it is a gridded and spatially-averged product, this is the along-track distance of the first image scan to which the second PSM contributed.

Solar Angle and Viewing Parameters (fields 64 to 79)

Solar and viewing angles are given for both views at eleven equally spaced points at the start and end of the product. These points are equally spaced about the ground track and correspond to across track distances from -250km (to the left of the ground track) to +250km (to the right of the ground track) in steps of 50km. The sixth set of angles thus relate to the ground track itself.

Solar elevations (fields 64, 65, 72 and 73) show the elevation of the sun from the pixel in the range ±90°.

Satellite elevations (fields 66, 67, 74 and 75) show the elevation of the ERS satellite from the pixel in the range 0° to +90°.

Solar azimuths (fields 68, 69, 76 and 77) show the azimuth of the sun from the pixel, relative to North in the range ±180°.

Satellite azimuths (fields 70, 71, 78 and 79) show the azimuth of the ERS satellite from the pixel, relative to North in the range ±180°.

Product Confidence Information (fields 80 to 96)

The ERS Platform Modes fields (80 to 91) provide information about which platform modes were in use during the duration of the product and how many image scans were used for each mode. As an image scan contains contributions from many instrument scans the sum of all platform mode counters may exceed the total number of image scans in the product. Table 4.3 displays the ERS platform modes, giving comments on the operations within each.

Code	Meaning	Operation Comments
YSM	Yaw Steering Mode	Nominal satellite operation mode
FCM	Fine Control Mode	Small along-track ÆV to maintain orbit longitude (return to TSM converged within 120 seconds maximum)
OCM	Orbit Control Mode	Main orbit manoeuvres. Payload in standby (repeat cycle changes, etc.)
FPM	Fine Pointing Mode	Used in between RTM manoeuvres
RTMM	Roll-Tilt Mode Manoeuvre	Manoeuvre from FPM to RTMC or from RTMC to FPM (less than 5 minutes manoeuvre duration)
RTMC	Roll-Tilt Mode Converged	Stable RTM (Maximum Duration 10 minutes)

Table 4.3: ERS platform modes

It should be noted that the geolocation and collocation of the product may be compromised if the satellite is not in Yaw Steering Mode, although despite this there is no attempt within SADIST-2 to remove from product generation any scans aquired during non-yaw-steered platform modes. These fields can be used to provide a measure of the product quality if the satellite is in Yaw Steering Mode, and therefore the geolocation and collocation of the product can not be compromised.

The Acquisition Product Confidence Data (PCD) (fields 92 and 93) provide information about the downlink, acquisition and transcription of the low-rate data. This information is provided as a series of counters which indicate the number of image scans which have data which have an unknown or erroneous acquisition status. It should be noted that this information is provided in the SADIST-2 product headers for information only. Within SADIST-2 there is no attempt to use this information to influence data-processing, and nor is there any clear method of doing so. Table 4.4 gives a list of the eight counters which are provided and their meaning. RD-2 provides further information on PCD information.

No.	Meaning
1	PCD summary flag
2	Performance of downlink and X-band acquisition chain
3	HDDT
4	Frame synchroniser
5	Frame synchroniser to processor interface
6	Checksum analysis on low-rate frames
7	Quality of downlinked formats and source packets
8	Quality of auxiliary data

Table 4.4 – Acquisition PCD counters

The counters are derived from the PCD words contained within low-rate main product headers (MPH) provided within the ATSR source packets. The flags present within the MPH PCD words are summarised to present a general statement on the quality of the low-rate data aquisition.

The SADIST-2 packet validation fields (94 and 95) give information on the number of source packets which were not completely validated by SADIST-2. This information is provided as a series of counters which indicate the total number of invalid source packets in the product. Table 4.5 shows the counters and their meanings. There is a one-to-one correspondence between source packets and scans for low-rate data. However, for high-rate data a single scan may occupy two consecutive source packets, thus the packet validation applies to the combination of these two source packets.

No.	Test	Meaning
1	Null Packet	Packet was completely empty and was added by the SADIST-2 preprocessor to restore data continuity following a data break
2	Basic Validation	Packet failed a basic validation check of the auxiliary data contents
3	CRC	Packet failed a Cyclic Redundancy Test
4	Buffers full	An error occurred during the construction of the packet within the ATSR Instrument Data Formatter
5	Scan jitter	Premature termination of the source packet implies corruption due to scan jitter
6	Nibble-shift	Range testing on the ATSR black-body signals implies formatting to science pixels is corrupt due to a nibble shift
7 – 9	Reserved	Reserved
10	All other errors	Packet failed a validation test other than 1-6

Table 4.5 – SADIST-2 Packet Validation counters

These counters provide information on how many packets in the contributing images failed validation. However, these pixels are not included in the derivation of this product. The counters correspond to the number of image scans from which pixels are missing as their scans failed packet validation . As an image scan contains contributions from many instrument scans the sum of the counters may exceed the total number of scans in the product.

The maximum single-pixel error code (field 96) is used to identify those pixels which contain error codes. Small negative error codes are used to indicate which pixels contain no scientific information. However, negation is also used to convey additional information to the valid scientific information in the pixel, e.g. blanking-pulse or cosmetic-fill flags.

Thus in order that the user can distinguish between the pixels which contain errors and those whose negation contains additional information SADIST-2 ensures that no valid pixel which is less than or equal to the absolute value of the largest (most negative) error code is negated to carry extra information. This field thus contains the absolute value of this largest error code.

Thus any negative pixel containing an absolute value less than or equal to this field contains an error code and any negative pixel containing an absolute value greater than this field has been negated to contain additional information.

4.2.3 The ATS.GBT Forward/Nadir Imagery Files

The Image Records of the Imagery files contain the actual image data derived from the SADIST-2 GBT product.

Where a channel is not available or a field is not applicable for a particular channel the fields are blank filled.

Brightness Temperatures/Reflectances (fields 8 to 14)

Fields 8 and 12 are negated to show the presence of a blanking pulse.

Fields 9 and 13 are negated to show the presence of a cosmetically filled pixel.

Table 4.6 gives the exceptional values (error codes) which may be present in these fields.

Value.	Meaning
-1	Entire scan absent from telemetry
-2	Pixel absent from telemetry
-3	Pixel not decompressed due to error during packet validation
-4	No signal in channel (zero count)
-5	Saturation in channel (maximum count)
-6	Derived radiance out of range of calibration
-7	Calibration parameters unavailable for pixel
-8	Pixel unfilled (cosmetic filling algorithm unable to find nearest neighbour pixel)

Table 4.6 – BT/R Exceptional Values

Latitude (field 15)

Latitudes are geodetic and are in the range ±90000.

Longitude (field 16)

Longitudes have the range ±180000.

X Coordinate Offsets (field 17)

This field defines for each image pixel the X coordinate offset of the centre of the instrument pixel which was allocated to that pixel by regridding. Thus the X coordinates of the original contributing instrument pixel can be determined. However, its precision is greater than its likely accuracy. This value is given relative to the left-hand side of the image pixel (as viewed in the direction of travel).

The X coordinate offsets are unsigned one byte integers in the range 0 to 255 which represent offsets from 0 to 1km in steps of 4m.

The X coordinates of image pixels are implicit since each image has a 1km by 1km grid. The ground track may be assumed to lie at the boundary between the 256th and 257th pixels.

X coordinate offsets of cosmetically filled pixels are set to zero.

Y Coordinate Offsets (field 18)

This field defines for each image pixel the Y coordinate offset of the centre of the instrument pixel which was allocated to that pixel by regridding. Thus the Y coordinates of the original contributing instrument pixel can be determined. However, its precision is greater than its likely accuracy. This value is given relative to the image pixel nearest the start of the image.

The Y coordinate offsets are unsigned one byte integers in the range 0 to 255 which represent offsets from 0 to 1km in steps of 4m.

The Y coordinates of image pixels are implicit since each image has a 1km by 1km grid. The Y coordinate (along-track distance) of the start of the product is available in field 30 of the GBT Leader File Image Header Record.

Y coordinate offsets of cosmetically filled pixels are set to zero.

Cloud Clearing/Land Flagging Results (field 19)

Table 4.7 gives the definition of the Cloud Clearing/Land Flagging Results.

Bit No.	Meaning
0	1 pixel is over land
1	1 pixel is cloudy (result of all cloudy tests)
2	1 sun-glint detected in pixel
3 – 12	**Individual Cloud Tests, if set indicate pixel is cloudy**
3	1 1.6µm reflectance histogram test (day-time only)
4	1 1.6µm spatial coherence test (day-time only)
5	1 11µm spatial coherence test
6	1 12µm gross cloud test
7	1 11µm/12µm thin cirrus test
8	1 3.7µm/12µm medium/high level test (night-time only)
9	1 11µm/3.7µm fog/low stratus test (night-time only)
10	1 11µm/12µm view-difference test
11	1 3.7µm/11µm view-difference test (night-time only)
12	1 11µm/12µm thermal histogram test
13 – 15	Unused

Table 4.7 – Cloud Clearing/Land Flagging Results Definition

4.3 CEOS Format Definitions

Present CEOS format software version number is: UK-PAF V1.0

Present ATSR product processing software version is: SADIST-2 100.

The CEOS output format for the UK-PAF product ATS.GBT is provided in Annex A.

The specification defines the files to be written, the records within each file, the fields within each record, and the format and content for each field.

The data shall be written to the output media using the IBM byte ordering convention ie words are addressed by the highest order byte when writing to the output media. In addition the following IBM bit level conventions shall be used:

- the most significant bit (MSB) of a word shall be that bit that is transferred first.
- the least significant bit (LSB) of a word shall be that bit that is transferred last.
- the MSB of a word shall be numbered 0.
- the LSB of a word shall be numbered n (eg 7, 15)
- when representing words and bytes diagrammatically the LSB shall be drawn on the right.

This specification describes the ATS.GBT logical volume data set (volume directory file, leader file, imagery file and null volume directory file) for the case where only a single physical volume is required. Where more than one physical volume is required a single logical volume will not be split across two physical volumes.

ANNEX A ATS.GBT CEOS FORMAT