AATSR Quality and Classification Flags

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The purpose of this document is to provide users with information on quality and classification (i.e. cloud and surface) flags contained within (A)ATSR Level 1B and Level 2 products generated by the 3rd (A)ATSR Reprocessing, and within (A)ATSR Level 1B products generated by the 4th (A)ATSR Reprocessing.

IDEAS+-VEG-OQC-REP-2982 *Issue 1.0* *27 September 2018*

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
1.0	27 September 2018	Initial release

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose and Scope

This document sets out to explain the quality and classification flags contained within AATSR Level 1B and Level 2 products from the 3rd (A)ATSR Reprocessing (see Section 2), and AATSR Level 1B products from the 4th (A)ATSR Reprocessing (see Section 3).

Quality and classification flags contained within ATSR-1 and ATSR-2 products are not specifically displayed in this document but they are the same as those contained within AATSR products, where they share the same product format.

Full technical details on each reprocessing, and their products, are available from a number of sources which include the AATSR Handbook [RD-1], the Envisat Product Specifications (Volume 7: AATSR Products Specifications) [RD-2] document, and the (A)ATSR FAST L1B Product Definition [RD-3] document, which concerns products in the new SLSTR-like product format (to be introduced by the 4th (A)ATSR Reprocessing).

Information on access to the (A)ATSR products at ESA can be found at https://earth.esa.int/web/guest/data-access/browse-data-products. If users have any further queries, the ESA Contact Us link can be used.

General quality information can also be found in [RD-4].

1.2 Structure of the Document

This document is divided into a number of sections which are briefly described below:

1 INTRODUCTION

This chapter provides explanations of the document's purpose and scope, structure, referenced documentation, the definition of terms, and a list of the acronyms and abbreviations.

2 3RD (A)ATSR REPROCESSING

This chapter provides detailed descriptions of the quality and classification flags contained within the AATSR products generated by the 3rd (A)ATSR Reprocessing.

3 4TH (A)ATSR REPROCESSING

This chapter provides detailed descriptions of the quality and classification flags to be contained within the AATSR products generated by the 4th (A)ATSR Reprocessing.

4 ANNEX A

The Annex contains ancillary information relevant to the preceding sections.

1.3 Referenced Documentation

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] European Space Agency: Envisat AATSR Product Handbook, Issue 2 Revision 2, 27 February 2007. Accessed at: http://envisat.esa.int/handbooks

[RD-2] Envisat-1 Products Specifications: AATSR Product Specifications (Volume 7), IDEAS-SER-IPF-SPE-0288, Issue 4 Revision C, 05 September 2013. Accessed at: https://earth.esa.int/documents/700255/2042507/Vol-07-Aats4C.pdf/71cd7964-7860-4df7-abe5-5042b76cc31f

[RD-3] (A)ATSR Expert Support Laboratory FAST L1b Product Definition, PO-TN-RAL-AT-0568, Issue 1.4, 19 March 2018. Accessed at: https://earth.esa.int/documents/700255/2482719/PO-TN-RAL-AT-0568+-+FAST+Level+1b+Product+Definition+Issue+1.4/ecb0344b-32c4-4172-b7a7-e32bddf40309

[RD-4] AATSR Product Quality Readme (PQR) Information (for all Level 1 and 2 AATSR products). Accessed at: https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/products-anomalies

[RD-5] AATSR Technical Note: The Use of the Attachment Flag in (A)ATSR Products, Issue 0 Revision D, June 2012. (On request from AATSR QC team via the ESA help desk)

[RD-6] AATSR Technical Note: Improvements to the AATSR IPF Relating to Land Surface Temperature and Cloud Clearing over Land, Issue 6 Revision 0, September 2007. Accessed at: https://earth.esa.int/pub/ESA_DOC/ENVISAT/AATSR/LSTNote_IPFv6.0.pdf

[RD-7] Sentinel 3 – Land-Water Mask Technical Note, Issue 1 Revision 2, 14 August 2015. Accessed at: https://earth.esa.int/documents/700255/702296/S3_LandWaterMask_v1_2.pdf/d8b05464-3960-4694-80ac-062f572302de

[RD-8] ARC_L2P Product Guide, Version 1 Revision 3, 01 September 2013. Accessed at: https://earth.esa.int/documents/10174/56700/L2P_Product_Description

[RD-9] The Recommended GHRSST Data Specification (GDS), Issue 2 Revision 5, 09 October 2012. Accessed at: https://www.ghrsst.org/wp-content/uploads/2016/10/GDS20r5.pdf

[RD-10] (A)ATSR Land Surface Temperature (LST) Product (UOL_LST_L2) Level 2 User Guide, Issue1 Revision 0, 17 December 2013. Accessed at: https://earth.esa.int/documents/10174/1415229/ATSR_UOL_LST_L2_User_Guide_v1-0

[RD-11] (A)ATSR 4th Reprocessing Product Format User Summary, IDEAS+-VEG-OQC-MEM-2317, Issue 1 Revision 0, 20 April 2017. Accessed at: https://earth.esa.int/documents/700255/2946879/%28A%29ATSR+4th+Reprocessing+Product+Format+-+User+Summary/373f80f2-6fe4-4214-bf92-1b6c4e07e70d?version=1.0

1.4 Definition of Terms

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

Term	Definition
ATSR	The Along-Track Scanning Radiometer instrument series (ATSR-1, ATSR-2)

Term	Definition
(A)ATSR	The Along-Track Scanning Radiometer instrument series (ATSR-1, ATSR-2 and AATSR)

1.5 Acronyms and Abbreviations

The following acronyms and abbreviations have been used in this report with the meanings shown.

Acronym	Description
AATSR	Advanced Along-Track Scanning Radiometer
ARC	ATSR Reprocessing for Climate
ATSR	Along-Track Scanning Radiometer
CCI	Climate Change Initiative
ESA	European Space Agency
GHRSST	Group for High Resolution Sea Surface Temperature
LST	Land Surface Temperature
QWG	Quality Working Group
SST	Sea Surface Temperature

2. 3RD (A)ATSR REPROCESSING

AATSR Level 1B, Level 2 and Level 3 products from the 3rd (A)ATSR Reprocessing are available to users via ESA Earth Online. For additional information regarding the 3rd (A)ATSR Reprocessing (including information on dataset improvements and product updates), please see the ESA news item from September 2013.

The AATSR products generated by the 3rd (A)ATSR Reprocessing, and whether they are covered within the scope of this document, are summarised in Table 2-1. Official product specifications for these products are given in [RD-2].

Table 2-1. 3rd Reprocessing AATSR Products

Processing Level	Product Type	Comment (if not covered in this document)
Level 0 (Raw data)	ATS_NL__0P	AATSR Level 0 products are not available to users.
Level 1B (Gridded, Radiometric Data)	ATS_AST_BP	AATSR browse products are for image viewing.
	ATS_TOA_1P (L1B)	
Level 2 (Gridded, Geophysical Data)	ATS_NR__2P (L2 NR)	
	ATS_AR__2P (L2 AR)	These products are not commonly used.
	ATS_MET_2P (L2 MET)	These products are a subset of ATS_TOA_1P L1B products.
	ATS_UPA_L2P (L2P ARC-like SST)	
	ATS_LST_2P (L2 UoL LST)*	
Level 3 (Gridded, Geophysical Data)	ATS_UPA_L3U (L3U ARC-like SST)	The contents of the AATSR L3U product are essentially the same as the AATSR L2P product from which it was derived, the only variation is that the geophysical data is given on a 0.1º grid.

* These products are not available via the ESA archives (i.e. Earth Online) for ATSR-1/-2. Instead, users are directed to the CEDA archives.

An example filename for each AATSR product type listed in Table 2-1 is provided in Table 4-1 (Annex A).

2.1 Level 1B AATSR Products

The AATSR L1B product (full-resolution gridded brightness temperature and reflectance) in Envisat format consists of measurement datasets (MDS), annotated datasets (ADS) and product header information. See [RD-2] for product specification. Table 2-2 displays the L1B MDS contents: MDS 1 – 14 are the brightness temperatures and reflectances measured by each channel (at different wavelengths) of the AATSR instrument in the nadir and forward views, MDS 15 and 16 are the nadir and forward view confidence flags which provide information on the quality of the measurement pixels, and MDS 17 and 18 are the nadir and forward view cloud flags which provide information on the cloudiness and surface classification of the measurement pixels.

Table 2-2. AATSR L1B MDS contents

MDS	Contents
1 – 7	Nadir view measurements in channels 12, 11, 3.7, 1.6, 0.87, 0.67, 0.55 μm
8 – 14	Forward view measurements in channels 12, 11, 3.7, 1.6, 0.87, 0.67, 0.55 μm
15	Nadir view confidence words: all channels
16	Forward view confidence words: all channels
17	Nadir view cloud words: all channels
18	Forward view cloud words: all channels

The AATSR L1B product confidence and cloud words are usually the first quality, cloud and surface classification information flags that users notice and these are explained in the following subsections.

2.1.1 Quality Flags

2.1.1.1 Confidence Words MDS

The confidence words contain a series of quality information flags for each measurement pixel (field name “conf_wd_flags”). The confidence words, provided for the nadir and forward views separately (see Table 2-2), are listed in Table 2-3 along with the circumstances of when they usually occur. Note that a confidence flag is set for all channels, even if only one channel has the issue, and more than one flag may be set for any one pixel.

Table 2-3. AATSR L1B confidence words (MDS 15 and 16)

Bit	Meaning if set	Usual occurrence
0	Blanking pulse	Often throughout
1	Cosmetic fill pixel	Often throughout the forward channels, seldom in the nadir
2	Entire scan absent from telemetry	Often at night
3	Pixel absent from telemetry	Often at night
4	Pixel not decompressed owing to error in packet validation	Often at night
5	No signal in some channel (zero count)	Over cold cloud; sporadically at night
6	Saturation in some channel (maximum count)	Common over cold cloud and bright targets (e.g. desert); sporadically at night
7	Derived radiance of some channel outside range of calibration	Often at night
8	Calibration parameters unavailable for pixel	Seldom
9	Pixel unfilled (cosmetic fill algorithm unable to find nearest neighbour pixel)	Seldom
10–15	Unused	
Note: Bits are numbered from (most significant bit) 15 to (least significant bit) 0		

More information on the confidence words is given below:

- Bit 0: The blanking pulse flag indicates that one of the radar instruments on the satellite was transmitting at the time of the pixel measurement. It is provided so that if there were any interference between the radar and AATSR instruments, it would be possible to identify affected pixels.
- Bit 1: Set to indicate a cosmetically filled pixel; this may have become necessary after the transfer of curved swath instrument data to the regular quasi-Cartesian grid of the gridded product, which can result in empty gridded pixels. These are then filled by nearest-neighbour values.
- Bits 2 – 9: Taken from the pixel exception values for each channel (see Section 2.1.1.2 for further information). However, the bit within the confidence word is set if the corresponding pixel exception value is set for any of the channels. Therefore, even if only one channel is affected by the exception value, the bit will be set within the confidence word. If a user needs to know which particular channel set this confidence word, then reference must be made to the equivalent pixel in the physical measurement datasets to identify the channel(s).

It must be noted that, at night, the noise in the visible channels can mimic the exception values (see Section 2.1.1.2), so that the interpretation of negative visible channel reflectances is ambiguous. This has the consequence of causing the confidence words to be wrongly set. The latter might affect any user who is using the confidence words to filter the data, regardless of whether the user is interested in the visible channels or not. Users are advised to take note of this effect if using the confidence words or visible channel reflectances in night-time data. This is not strictly an error in the AATSR processing scheme, but rather an unexpected result of adopting the ATSR-2 processing scheme for AATSR (ATSR-2 visible channel data were not available at night).

Section 2.1.3 gives some visual examples of common circumstances arising in flag settings.

2.1.1.2 Pixel exception values

It is possible that a valid physical measurement (i.e. in MDS 1 – 14) is not available for a pixel; in this case the pixel will contain an exception value instead of a physical measurement. The exception value is a small negative number, the value of which gives information about the particular fault encountered. Table 2-4 displays the possible values and their meanings, which have been transferred to Bits 2 – 9 of the confidence words MDS.

Some exception conditions only affect a particular channel; for example one channel may saturate, or one channel may have no signal, while other channels contain a valid measurement. Other exception conditions may affect all channels, as when an instrument scan is missing or could not be decompressed because of a Cyclic Redundancy Check (CRC) error. A CRC error occurs when a source packet of data bits contains one or more bits in error (identified through a count, based on the content of the packet so far, that is inserted at the end of the given source packet; if this count does not match the content when checked at the receiver's end then an error is given) and, as a result, the faulty packet may be dropped.

Table 2-4. Pixel exception values contained within the physical measurement dataset (MDS 1 – 14) for each channel and view

Exception value	Meaning
-1	Scan absent (null packet)
-2	Pixel absent
-3	Not decompressed

Exception value	Meaning
-4	No signal in channel
-5	Saturation in channel
-6	Derived radiance outside calibration
-7	Calibration parameters unavailable
-8	Unfilled pixel (set by cosmetic fill algorithm)

Note that the allocation of cosmetic fill pixels is determined entirely on geometrical considerations, so that a cosmetic fill pixel will show an exception value if the neighbouring pixel from which it is copied does.

2.1.1.3 Record quality indicator in the MDS header field

Each MDS has a similar structure: four header fields precede 512 fields of image row data. One of the header fields is the record quality indicator (field name “quality_flag”), a flag that is set to **-1** if the record contains no valid data, and to **0** otherwise. This definition is generic, and applies to all ENVISAT instruments. In the particular case of AATSR, the curved scan geometry is such that each record may contain pixels from 100 or more (curved) instrument scans and so it is unlikely that the record quality indicator will be set to **-1**, unless there is a substantial data gap.

It was noted above that pixel exception values convey information for when there is no physical measurement possible. Therefore, these are also considered to be valid data and again, this means that the record quality indicator is unlikely to be set.

2.1.1.4 Attachment flag in the ADS records

The attachment flag, only set correctly within the Geolocation and Summary Quality ADS records, is set to **1** if a granule, consisting of 32 consecutive records or image rows, of data is missing from all MDS [RD-5]. The attachment flag is set to **0** otherwise.

2.1.2 Classification Flags

Classification flags include both pixel surface flags and flags set by the cloud-clearing algorithm.

2.1.2.1 Cloud Words MDS

The cloud words MDS contain cloud and surface classification information flags (field name “cl_land_flags”) for each pixel. The cloud words, provided for the nadir and forward views separately (see Table 2-2), are listed in Table 2-5. Note that several of the cloud tests are applied to the forward and nadir view images separately and thus may give different results for colocated pixels in the different views.

Table 2-5. AATSR L1B cloud words (MDS 17 - 18)

Bit	Meaning if set
0	Pixel is over land
1	Pixel is cloudy (result of all cloud tests)
2	Sun-glint detected in pixel

Bit	Meaning if set
3	1.6 μm reflectance histogram test shows pixel cloudy (daytime only)
4	1.6 μm spatial coherence test shows pixel cloudy (daytime only)
5	11 μm spatial coherence test shows pixel cloudy
6	12 μm gross cloud test shows pixel cloudy
7	11/12 μm thin cirrus test shows pixel cloudy
8	3.7/12 μm medium/high level test shows pixel cloudy (night-time only)
9	11/3.7 μm fog/low stratus test shows pixel cloudy (night-time only)
10	11/12 μm view-difference test shows pixel cloudy
11	3.7/11 μm view-difference test shows pixel cloudy(night-time only)
12	11/12 μm thermal histogram test shows pixel cloudy
13	Visible channel test shows pixel cloudy
14	NDSI snow flag
15	Unused
Note: Bits are numbered from (most significant bit) 15 to (least significant bit) 0	

Further information on the cloud and surface classification flags is given below:

- Bit 0: The land flag is set using the pixel latitude and longitude, and referencing to external information (i.e. from the Envisat Land/Sea Mask).
- Bit 1: The pixel is flagged as cloudy if any one of the cloud tests (Bit 3 – 13) indicates the presence of cloud.
- Bit 2: The sun-glint flag is set if the pixel lies within a region that is affected by the specular reflection of sunlight. The extent and location of this region is determined from the solar and viewing angles computed during the geolocation process.
- Bits 3 – 12: The details of these cloud identification tests are given in Section 2.6.1.1.10 of the AATSR Handbook [RD-1], and the appropriate flag is set according to the results of the test(s) performed.
- Bit 13: The details of this cloud identification test, using visible channel data only, is given in section 2.3 of [RD-6]. Note although this test is defined for both land and sea pixels, it has not been implemented over sea so as not to compromise the existing ocean cloud flag.
- Bit 14: The details of the snow flag, containing NDSI (Normalised-Difference Snow Index) values, and how it is set, is given in section 2.4 of [RD-6].

2.1.3 Quality Flag Examples

Information on the flags contained within the product relies on appropriate readers to be used. However, the ESA SNAP visualisation software loads the products and has appropriate masks set for all the flags. Given here are some examples of circumstances that can arise.

2.1.3.1 Night-time flags

Figure 2-1 shows four quality flags: entire scan absent (orange), pixel absent (green), pixel not decompressed (blue) and derived radiance outside range of calibration (red) set on the 12 μm nadir BT channel (left), with the 0.87 reflectance channel (right) displaying

the transition from local night to day. Even though there is data within the 12 µm band at night, it can be seen that the flags are set because the reflectance channels have no valid measurements at night.

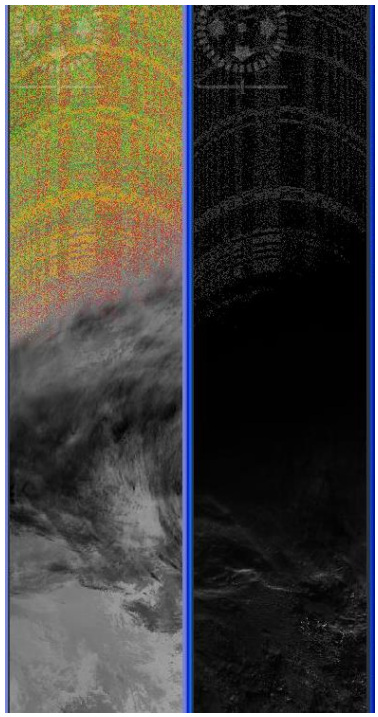

Figure 2-1. The 12 µm nadir brightness temperature (left) and the 0.87 µm reflectance (right). Flags marked on the 12 µm channel are: entire scan absent (orange), pixel absent (green), pixel not decompressed (blue) and derived radiance outside range of calibration (red). Note the flags are no longer set as the satellite moves into local day and the reflectance channels become active.

2.1.3.2 Cosmetic fill flag

Due to the instrument scanner characteristics, there are many cosmetically filled pixels, particularly in the forward view, within the high-resolution gridded products. Figure 2-2 shows this flag (yellow) set in both the nadir (left) and forward (right) views of the same scene.

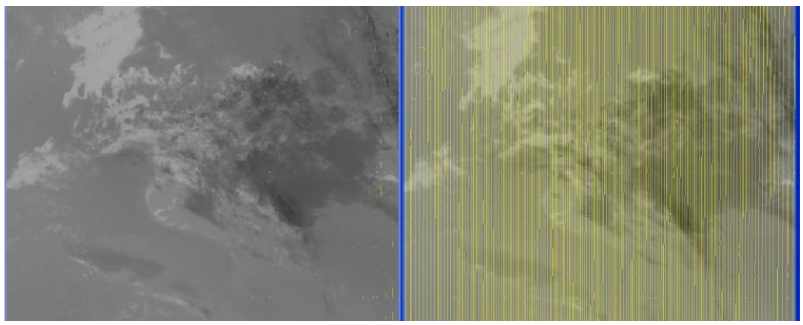

Figure 2-2. The same scene shown in the nadir view (left) and forward view (right) of the 12 µm BT channel. Cosmetic fill flags are marked in yellow.

2.1.3.3 Saturation flag

Figure 2-3 shows the saturation flag (green) set in the 12 µm band (centre). There is data in the 12 µm band (clearly shown on the right), and so inspection of all the bands must

take place if one wishes to know which channel was saturated. In this case, the 3.7 µm band is seen to have no data. This information is contained within the pixel flag of the 3.7 µm MDS; SNAP is configured to show a NaN value in such cases.

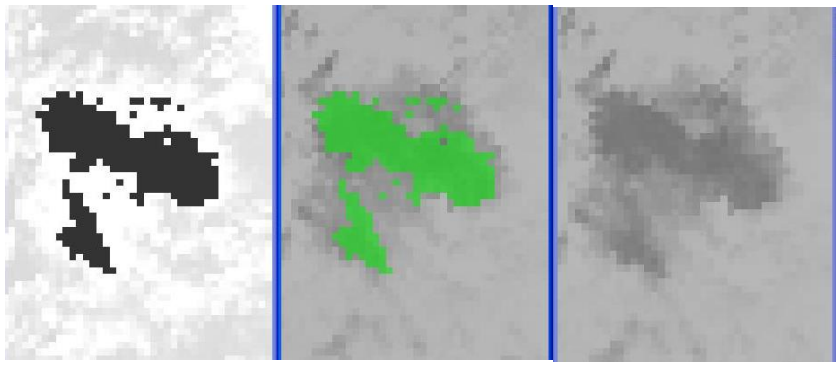

Figure 2-3. The same scene shown in the nadir views of the 3.7 µm (left) and 12 µm (centre and right) BT bands. The saturation flag is shown in green on the 12 µm band (centre).

2.1.4 Classification Flag Examples

SNAP was used to display the images given in this section.

2.1.4.1 Land flag

Figure 2-4 shows the usage of the land flag. Note there are a number of discrepancies that exist between the land/sea classification determined by the Envisat Land/Sea Mask and the pixel information contained within the gridded L1B product (most notably inland lakes and along coastlines). The Envisat Land/Sea Mask will be replaced by the Sentinel-3 Land/Water Masks in the 4th Reprocessing (for more details, see [RD-7]).

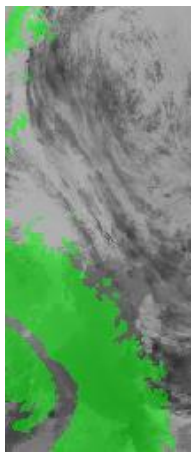

Figure 2-4. An example of the land flag (green) set in the 12 µm nadir BT channel.

2.1.4.2 Cloud and cloud test flags

Cloud clearing, or the identification of cloud-affected pixels, is accomplished by applying a series of cloud tests to the brightness temperature data provided by the 3.7, 11 and 12 µm channels as well as to the reflectance data provided by the 1.6 µm channel. A pixel is flagged as cloudy if any one of these tests indicates the presence of cloud.

Figure 2-5 provides an example, using the same scene of a product's 12 µm channel, of each cloud flag (i.e. Bit 1 and 3 – 13) being set, or in some cases not set, as a result of

the corresponding cloud tests being performed. The top left figure (Bit 1) summarises the final cloud flag (result of all cloud tests).

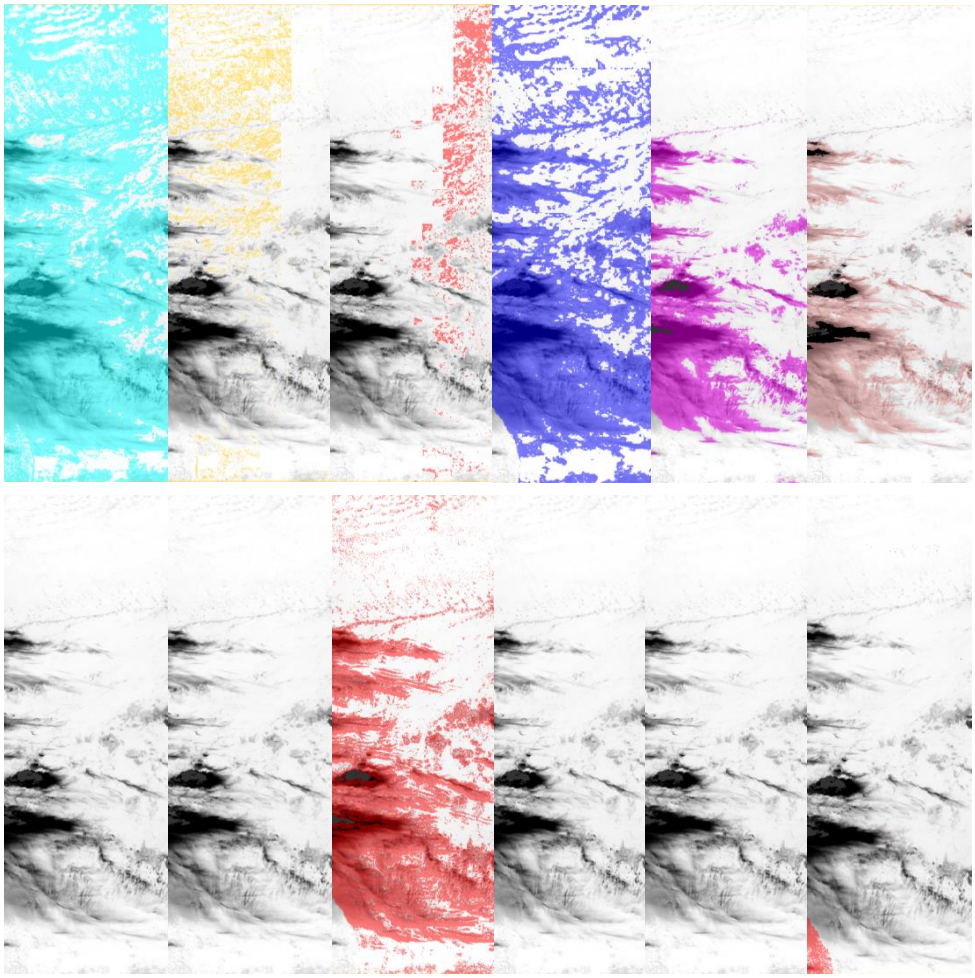

Figure 2-5. The same scene shows how each cloud flag (bit 1 and 3 – 13) is set (left to right, top to bottom).

2.2 Level 2 AATSR Products

The Level 2 products generated by the 3rd Reprocessing were the L2 NR, L2 AR and L2 MET. However, users are requested to note that higher quality Level 2 datasets are now available and recommended for use: the ARC-like L2P (and L3U) products (SST products, see Section 2.2.2) and the UoL LST products (see Section 2.2.3), all of which are in NetCDF format.

2.2.1 AATSR L2 NR Products

The AATSR L2 NR product is the full-resolution geophysical product containing geophysical field data (primarily Sea Surface Temperature (SST) and Land Surface Temperature (LST)) in Envisat format.

There are three MDS in the L2 NR product – the Nadir field, the Combined (dual-view) field and the Confidence word. However, the content of each pixel within the Nadir and Combined fields depend upon the land and cloud flag classifications from the L1B

product, and we say that the L2 NR product is a switchable dataset. It is important, from the point of view of the quality information, to know which physical field is contained in the Nadir and Combined datasets. The following section explains the contents of each field depending on the classification flags.

2.2.1.1 Nadir and Combined field contents

The content of each pixel within the nadir and combined fields depends upon the settings of the land flag and the nadir and forward view cloud flags for that pixel from the L1B product, as follows:

- Check nadir surface classification
  - Check nadir-view cloud flag
    - Fill nadir field contents
    - Ensure nadir field valid flag set appropriately
      i) Check forward-view cloud flag
        - Fill combined field contents
        - Ensure combined field valid flag set appropriately

Table 2-6 shows the contents of the nadir and combined fields, depending on the classification settings for surface and cloud. Note that each pixel within the nadir and combined fields can contain one of three possible physical parameters, and that parameter can be determined by inspecting the surface, cloud and validity flags.

Table 2-6. Contents of the Nadir and Combined data fields in the switchable NR product, depending on the cloud and land flags

Surface	Nadir view	Nadir field contents	Nadir field valid flag	Forward view	Combined field contents	Combined field valid flag
Sea	Not cloudy	**Nadir-only SST**	True	Not cloudy	**Dual-view SST**	True
				Cloudy	**Dual-view SST**	False
	Cloudy	**CTT (11 μm BT)**	True	Not cloudy	**CTH (Zero)**	False
				Cloudy		
Extended Land	Not cloudy	**LST**	True	Not cloudy	**NDVI**	True
				Cloudy		
	Cloudy			Not cloudy		
				Cloudy		

SST: Sea surface temperature
LST: Land surface temperature
NDVI: Normalised difference vegetation index
CTT: Cloud-top temperature, currently the 11 μm BT is used as a placeholder
CTH: cloud-top height, currently set to zero

Note that the best retrieved SST in the L2 NR product is to be found in the combined field and is a dual-view SST. Values can be found as follows:

- For a pixel over sea, and using the combined field, the combined field validity flag is set to **True**. This is the only setting that guarantees both nadir and forward views are cloud-free in the generation of a dual-view SST.

Other points to note are:

1. LST is available in the nadir field over land, but is always generated regardless of cloud settings. This means that users must inspect the cloud flag if they wish to retrieve only cloud-free LST.
2. NDVI is available in the combined field over land, and has the same caveat as the LST. It is only available during daytime.
3. No algorithms have been applied to generate CTT and CTH, and so the fields contain the 11 µm BT as a placeholder for CTT, while CTH is set to zero.

2.2.1.2 Confidence word field contents

The confidence word field of the L2 NR product contains some confidence and classification settings (cloud and land/sea) from the L1B product. The validity flags for the nadir and combined fields are filled once the datasets have been generated and it is known what each pixel contains. Some bits are set depending on whether the SST retrieval uses the 3.7 µm channel.

The contents of the confidence word MDS are shown in Table 2-7. Those taken from the L1B product are marked as such.

Table 2-7. AATSR L2 NR confidence word MDS

Bit	Meaning if set
0	Nadir field is valid (“nadir only SST is valid”)
1	Nadir-only SST retrieval includes 3.7 µm channel
2	Combined field is valid (“dual SST is valid”)
3	Dual-view SST retrieval includes 3.7 µm channel
4	Pixel is over land (from L1B)
5	Nadir-view pixel is cloudy
6	Nadir-view pixel has blanking pulse (from L1B)
7	Nadir-view pixel is cosmetic fill (from L1B)
8	Forward-view pixel is cloudy
9	Forward-view pixel has blanking pulse (from L1B)
10	Forward-view pixel is cosmetic fill (from L1B)
11	One or both views flagged cloudy by 1.6 µm test (daytime only)
12	Cloud flagged by 11 µm /12 µm nadir – forward test
13	One or both views flagged cloudy by infrared histogram test
14 –15	Topographic variance flags for LST retrieval
Note: Bits are numbered from (most significant bit) 15 to (least significant bit) 0	

More detailed information on the flags is given below:

- Bits 0 and 2, the nadir field valid flag and the combined field valid flag, are set as shown in Table 2-6, and are dependent upon the land and cloud flags. Bit 0 is set if

the nadir field contains a valid datum, and bit 2 is set if the combined field contains a valid datum. This is true regardless of the surface type, and so the official label “nadir only SST is valid” is a misnomer, because it implies that the bit is not used if the pixel is not clear sea. Regardless of surface type, the value in the nadir image field contains a valid datum appropriate to the surface type. If the pixel were a land pixel, bit 0 would be set to indicate that the nadir field contains a valid LST. Equally, the bit 2 historical label of “dual view SST is valid” is also misleading.

- Bits 1 and 3 are used only if the pixel is over clear sea and so contains valid nadir-only and dual-view SST values. These bits are set to indicate that the 3.7 µm channel data was used in the retrieval of the corresponding nadir-only or dual-view SST. (Thus typically these bits will be set for night-time data, but not for data measured during the day.)
- Bit 4 is set to indicate a land pixel; it is a copy of the corresponding classification flag from the L1B product and is used in determining the contents of the nadir and combined data fields.
- Bits 5 – 10 are copies of the corresponding nadir and forward view confidence words and classification flags from the L1B product. Bits 5 and 8 are used in determining the contents of the nadir and combined data fields.
- Bits 11 – 13 are derived from the corresponding L1B cloud flags: bit 12 is a copy of the L1B 11 µm/12 µm nadir–forward cloud test, while bits 11 and 13 are the “OR” of the nadir and forward view flags for the 1.6 µm and infrared histogram tests.
- Finally, Bits 14 and 15 form the topographic variance flag for LST. This topographic flag is a two-bit integer representing the standard deviation of the land surface in the half-degree by half-degree cell; the larger the flag value, the more rugged the terrain, and the less reliable the LST retrieval. For more information, see Section 6.6.58 of the AATSR Handbook [RD-1],

2.2.2 AATSR L2P ARC-like Product

The AATSR L2P ARC-like products contain geophysical SST (accompanied by associated SST uncertainty) data in NetCDF4 format. These products have been generated from AATSR L1B products using the ARC_L2P processor, which is based on the processor used to generate the official ARC products (i.e. by the ARC project). For more detailed product information, see the AATSR Product Specifications [RD-2] and ARC_L2P Product Guide [RD-8]. Users may also find reference to the GHRSST Data Specification [RD-9] helpful.

The AATSR L2P product contains a series of surface classification and channel use information flags (per pixel) which are listed in Table 2-8.

Table 2-8. AATSR L2P Flag Words

Bit	Meaning
0	Passive microwave data
1	Land
2	Ice
3	Lake
4	River
5	<Spare>
6	Dual view

Bit	Meaning
7	Three channel

The AATSR L2P product also contains a series of quality information flags (per pixel), each represented by a value (rather than the usual bit setting), which are listed in Table 2-9.

Table 2-9. AATSR L2P Quality Level Flags

Value	Meaning
0	No data
1	Bad data
2	Worst quality
3	Low quality
4	Acceptable quality
5	Best quality

Examples of assigned flags can be seen in Figure 2-6.

There are also AATSR L3U products, derived from the AATSR L2P products, which contain the same information flags that the AATSR L2P products contain.

Note that AATSR L3U products should not be confused with the official ARC AATSR L3 products.

2.2.3 AATSR UoL L2 LST Products

The AATSR L2 LST products (from the University of Leicester, UoL) contain geophysical LST data, accompanied by associated LST uncertainty, as well as additional auxiliary information (e.g. land cover type, fractional vegetation cover, total column water vapour, normalised-difference vegetation index) which is used by the LST retrieval algorithm, in NetCDF4 format. For more detailed product information, see the AATSR LST product (UOL_LST_L2) Level 2 User Guide [RD-10].

UoL's AATSR L2 LST product also contains a series of product quality, cloud and surface classification flags which are listed in Table 2-10.

Table 2-10. UoL L2 LST Product Quality Flags

Bit	Flag name	Meaning if set
0	Night	Solar zenith angle is less than 0º
1	Land including inland & coastal water	Land cover classification is between 1 and 27. The coastal water is defined as within 10 km of the shoreline
2	V1 mask identifies cloud	Standard ESA cloud mask – this is taken directly from bit 1 of the L1B cloud word
3	V2 mask identifies cloud	Aggregation of individual ESA cloud mask with dynamic thresholds
4	V3 mask identifies cloud	Probabilistic approach which utilises simulated radiances at AATSR tie points

Bit	Flag name	Meaning if set
5	Snow	Combination of two snow masking approaches. Where a pixel is identified as snow, LST is retrieved as per land cover classification no. 27

Examples of assigned flags can be seen in Figure 2-6.

There are also UoL LST L3 products, derived from the UoL LST L2 products, which contain the same information flags that the UoL LST L3 products.

2.2.4 Flag examples from SST L2P and UoL LST (NetCDF format)

Using SNAP, Figure 2-6 shows data and flag settings for the following SST L2P and UoL LST products, respectively:

- 20080509040454-UPA-L2P_GHRSST-SSTskin-ARC-AATSR-v02.0-fv01.0.nc
- ATS_LST_2PUUOL20080509_040454_000065272068_00247_32365_5599.nc

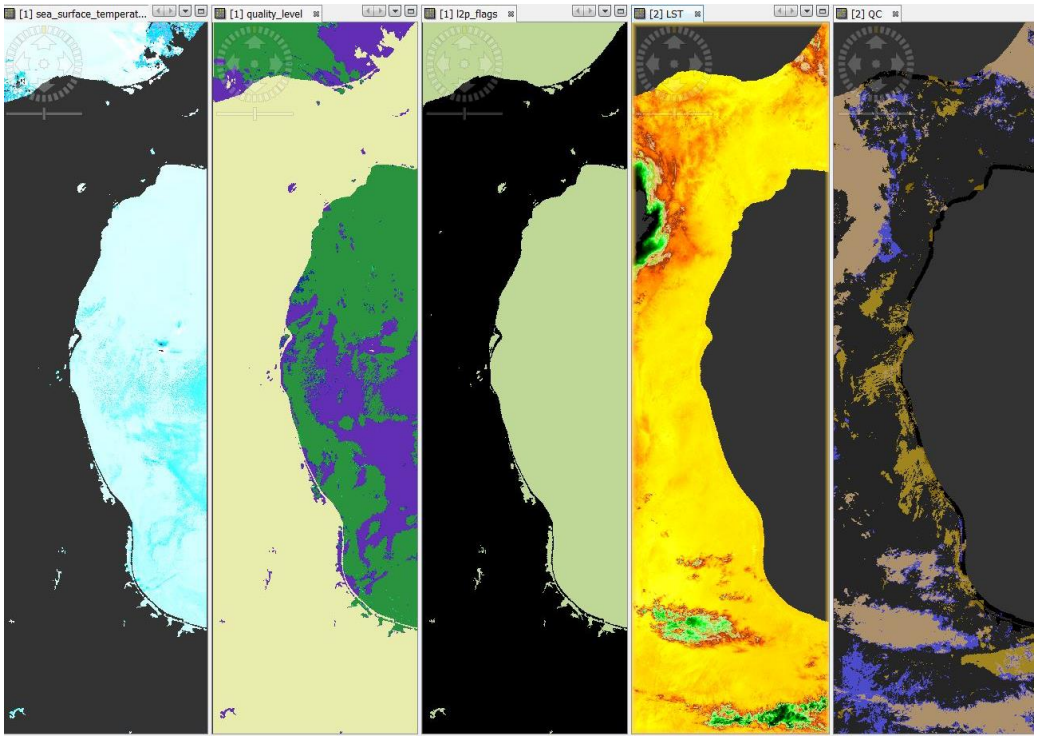

Figure 2-6. Data and flags for L2P SST and UoL LST data. Left-right: L2P SST, L2P SST quality_level flag, L2P SST l2p_flags; UoL LST, UoL LST QC flags. Associated flag colour scales or mask settings are given in Table 2-11.

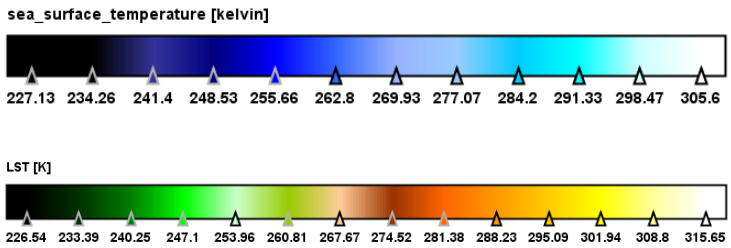

Table 2-11. Colour scales for flags shown in Figure 2-6

Colour scale or mask settings

L2P SST quality_level

Label	Colour	Value	Frequency
no_data		0	61.250%
bad_data		1	29.049%
worst_quality		2	0.000%
low_quality		3	1.438%
acceptable_quality		4	0.078%
best_quality		5	8.185%

L2P SST l2p_flags

	Colour	Description
☑		l2p_flags.microwave
☐		l2p_flags.land
☑		l2p_flags.ice
☑		l2p_flags.lake
☑		l2p_flags.river
☐		l2p_flags.reserved_for_future_use
☑		l2p_flags.dual_view
☑		l2p_flags.three_channel

UoL LST QC

	Colour	Description
☐		night
☐		land_including_inland_coastal_water
☑		cloudy_V1_mask
☑		cloudy_V3_mask
☐		snow

3. 4TH (A)ATSR REPROCESSING

(A)ATSR Level 1 and 2 products from the 4th (A)ATSR Reprocessing are not currently available to users but are expected before the end of 2019. Note that 4th (A)ATSR Reprocessing Level 2 products will be generated independently by relevant expert centres for SST and LST (ESA CCIs for SST and Land Cover).

The product specification for the (A)ATSR L1B product, which is based on the Sentinel-3 SLSTR L1B product specification is given in [RD-3]. This format is different from the Envisat-format products that have been described in previous sections. As not all product parameters are directly transferable between SLSTR, (A)ATSR and Envisat-format products, users may find the 4th (A)ATSR Reprocessing Product Format User Summary [RD-11] document useful as it outlines the main differences that can be found. Notably, channel names are now aligned with SLSTR, and are S1-S3, S5, S7-S9 for the radiance channels through to the infrared. For information, an example 4th Reprocessing L1B file name is given in Annex A.

Note that not all information given below is available for all three instruments, due to improvements over time from 1991 to 2012.

It should also be mentioned that within the 4th Reprocessing product folder are a number of files with the term 'quality' in their name, e.g. S1_quality_in.nc. These files do not contain quality flags as considered here, but channel performance data and instrument operating states that enable estimates of NEΔT or radiance noise to be generated.

3.1 Level 1B (A)ATSR Products

The (A)ATSR L1B products in the new SLSTR-like format include the following items that contain quality and classification information:

- Measurement datasets (MDS) containing radiances and brightness temperatures measured by each channel (at different wavelengths) of the AATSR instrument in the nadir and oblique views. Each MDS contains annotation information concerning data quality; see Section 3.1.1.1.
- An XFDU-format manifest file which contains the product package map, metadata and data object information. This includes information on the quality of the whole product and pixel quality and classification information summaries; see Sections 3.1.1.2 and 3.1.2.3.
- Annotation datasets (ADS) containing ancillary data/information (e.g. quality, global flags, coordinate, solar and satellite geometry and meteorological data) applicable to each channel (at different wavelengths) of the AATSR instrument in either the nadir or oblique views or, across all channels sharing the same view (or no distinction between views). The relevant ADS for this document are the flags ADS (flags_in.nc and flags_io.nc); see Section 3.1.2.

3.1.1 Quality Flags

3.1.1.1 Pixel exception values (MDS)

Pixel exception values are contained within the measurement NetCDF files, the names and contents of which are given in Table 3-1.

Table 3-1. AATSR L1B MDS contents

MDS	Contents
S[1,2,3,5]_radiance_in	Nadir view measurements and exception words in channels 0.55, 0.67, 0.87 and 1.6 μm
S[7,8,9]_BT_in	Nadir view measurements and exception words in channels 3.7, 11 and 12 μm
S[1,2,3,5]_radiance_io	Oblique view measurements and exception words in channels 0.55, 0.67, 0.87 and 1.6 μm
S[7,8,9]_BT_io	Oblique view measurements and exception words in channels 3.7, 11 and 12 μm

The exception words contain quality information for each measurement pixel. The exception words provided in each MDS are listed in Table 3-2 along with the situations when they would usually occur.

Table 3-2. Exception word definitions

Bit	Meaning if set	Usual occurrence
0	Scan absent	Often at night
1	Pixel absent	Often at night
2	Not decompressed	Often at night
3	No signal in channel	Over cold cloud; sporadically at night
4	Saturation in channel	Common over cold cloud and bright targets (e.g. desert); sporadically at night
5	Derived radiance outside calibration	Often at night
6	Calibration parameters unavailable	Seldom
7	Unfilled pixel	Seldom
Note: Bits are numbered from (most significant bit) 7 to (least significant bit) 0		

As the definitions associated with these exception words remain unchanged from the 3rd Reprocessing, more detailed explanations can be found in Section 2.1.1.1.

Note that, unlike Envisat-format (A)ATSR products, where confidence flag values were set *irrespective* of the channel the condition originated from, each channel in the 4th Reprocessing L1B product has its own independent exception value.

See Section 3.1.3 for some visual examples.

3.1.1.2 Whole-product quality information (manifest)

The XFDU-formatted manifest file within the product is named xfdumanifest.xml; it contains information on the quality of the whole product, and information on the percentage allocation of individual pixels within the product.

There is a metadataObject ID within this file that is tagged “measurementQualityInformation” and contains a quality product check that is either set to PASSED or DEGRADED. See Figure 3-1 for an example.

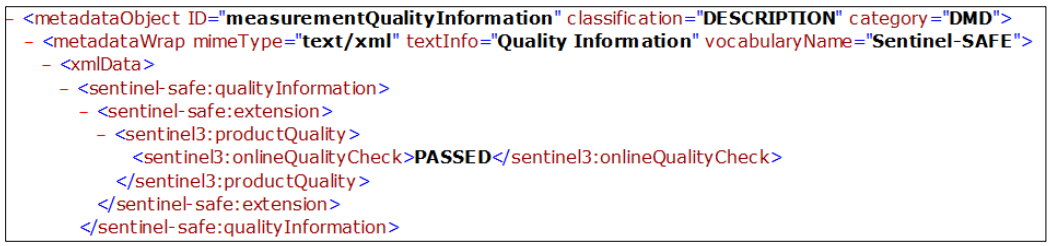

Figure 3-1. Extract from xfdumanifest.xml showing whole product quality information.

A DEGRADED product will contain more information in the manifest file, specifically whether the quality assessment was due to NON_NOMINAL_INPUT or MANOEUVRES.

Ancillary information for the satellite and the instrument was used to determine whether this quality flag should be set; NON_NOMINAL_INPUT describes products that were generated while the instrument was undergoing housekeeping activities or anomalies. See https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/aatsr/mission-operations-overview for some examples for AATSR.

3.1.2 Classification Flags

The flags ADS, named as shown in Table 3-3, contain additional information that have a bearing on quality, as well as cloud and surface classification information.

Table 3-3. AATSR L1B Flags ADS contents

ADS	View
flags_in.nc	Nadir view cloud, Bayesian cloud, pointing and confidence words: all channels
flags_io.nc	Oblique view cloud, Bayesian cloud, pointing and confidence words: all channels

More details are given in the sections below: on the contents of the flags ADS, see Sections 3.1.2.1 (confidence words), 3.1.2.2 (cloud information) and 3.1.2.4 (pointing information).

See Section 3.1.4 for some visual examples of the information in the sections below.

3.1.2.1 Confidence Words (Flags ADS)

The confidence words parameter (see Table 3-4) contains surface classification information flags, details on pixel duplication or cosmetic fill, day/night information. It also includes a summary flag for the cloud and pointing information that are contained in the separate cloud and pointing flags. Each set of confidence words is applicable to all MDS sharing the same view, i.e. separate flags ADS are produced for the nadir and oblique views. They are independent of channel.

Table 3-4. Confidence word definitions

Bit	Meaning if set	Usual occurrence
0	Coastline in field of view	
1	Ocean in field of view	
2	Tidal zone in field of view	
3	Land in field of view	

Bit	Meaning if set	Usual occurrence
4	Inland water in field of view	
5	Unfilled pixel	
6	<spare>	
7	RADAR active	Blanking pulse, often throughout
8	Cosmetic fill pixel	Often throughout the oblique channels, seldom in the nadir
9	Pixel has a duplicate	Duplicate pixel not regridded (orphan pixel exists)
10	Pixel in day light	
11	Pixel in twilight	
12	Sun glint in pixel	
13	Snow	
14	Summary cloud test	
15	Summary pointing	
Note: Bits are numbered from (most significant bit) 15 to (least significant bit) 0		

Further details of the confidence flags list in Table 3-4 are given below:

- Bits 0 – 4: The surface classification flags in 4th reprocessing products are set using pixel latitude and longitude, referencing to the Sentinel-3 Land/Water Masks [RD-7].
- Bits 5 – 8: The same parameters listed in Table 2-3.
- Bit 9: This flag is set if a duplicate pixel is indicated, this means that an extra measurement pixel has been transferred into the orphan dataset. (See [RD-3] for further information.)
- Bit 10: Set if solar zenith angle ≤ 90º
- Bit 11: Set for twilight if 90º < solar zenith angle ≤102º
- Bits 12 – 13: Sunglint and snow are the same as listed in Table 2-5.
- Bit 14: The summary cloud flag is set for a pixel if the presence of cloud has been indicated by separate cloud identification tests (for cloud identification test flags, see Table 3-5).
- Bit 15: The summary pointing flag is set according to the result of the pointing flags raised (see Table 3-7).

3.1.2.2 Cloud and Bayesian Cloud Words (Flags ADS)

The cloud and Bayesian cloud word parameters contain cloud information flags for each measurement pixel. Each flags ADS contains a set of cloud and Bayesian cloud words that are applicable to all MDS sharing the same view, i.e. separate flags are produced for the nadir and oblique views. The cloud and Bayesian cloud words are listed in Table 3-5 and Table 3-6, respectively.

The definitions associated with the cloud words remain unchanged from the 3rd Reprocessing, with the exception of the order in which they are found, and so detailed explanations of each flag can be found in Section 2.1.2.1. The summary of the cloud word is also included in the confidence word (Section 3.1.2.1).

Table 3-5. Cloud word definitions

Bit	Meaning if set	Usual occurrence/comment
0	Visible channels cloud test	Day time only
1	(not implemented)	Set to 0
2	1.6µm small-scale histogram test	Day time only
3	1.6µm large-scale histogram test	
4	(not implemented)	Set to 0
5	(not implemented)	Set to 0
6	11 µm spatial coherence test	
7	12 µm gross cloud test	
8	11 µm/12 µm thin cirrus test	
9	3.7 µm/12 µm medium/high level test	
10	11 µm/3.7 µm fog/low stratus test	
11	11 µm/12 µm view difference test	Uses both views
12	11 µm/3.7 µm view difference test	Uses both views
13	11 µm/12 µm thermal histogram test	
14	<spare>	
15	<spare>	
Note: Bits are numbered from (most significant bit) 15 to (least significant bit) 0		

The Bayesian cloud parameters contain a series of specialised cloud flags that are based on cloud information generated by the Bayesian cloud-detection algorithms that were originally developed under the University of Reading's *(A)ATSR Reprocessing for Climate* (ARC) project. The Bayesian cloud flags are listed in Table 3-6 along with the level of cloud-clearing that they provide.

Table 3-6. Bayesian cloud word definitions

Bit	Meaning if set	Comment
0	Single view low probability threshold	Climate-quality clearing
1	Single view moderate probability threshold	Operational-quality clearing
2	Dual view low probability threshold	Climate-quality clearing
3	Dual view moderate probability threshold	Operational-quality clearing
4	<spare>	
5	<spare	
6	<spare>	
7	unchecked	Bayesian has not filled in this pixel

The Bayesian cloud flags for pixels over ocean and inland water will be provided by the University of Reading. The University of Leicester will provide similar probabilistic cloud flags for land pixels.

Further cloud information (not flags) will also be included in the flags ADS, e.g. “probability_cloud_single” and “probability_cloud_dual”.

3.1.2.3 Whole-product pixel classification summary (manifest)

The XFDU-formatted manifest file within the product is named xfdumanifest.xml.

There is a tag in the manifest file for “pixelclassificationSummary”, which gives the percentages of pixels within the whole product that are affected by classification and cloud flags. See Figure 3-2 for an example.

```
- <atsr:classificationSummary grid="1 km">
    <sentinel3:salineWaterPixels percentage="63.248123" />
    <sentinel3:landPixels percentage="35.591167" />
    <sentinel3:coastalPixels percentage="0.122512" />
    <sentinel3:freshInlandWaterPixels percentage="1.361874" />
    <sentinel3:tidalRegionPixels percentage="0.234856" />
    <sentinel3:cloudyPixels percentage="76.771228" />
  </atsr:classificationSummary>
```

Figure 3-2. Extract from xfdumanifest.xml showing pixel classification information.

3.1.2.4 Pointing Words (Flags ADS)

The pointing word parameter contains information for each measurement pixel. For AATSR, these words specifically provide users with information pertaining to the existence, or detection, of scan-mirror jitter, where the scan has undergone a non-smooth rotation. Therefore, only bit 4 is expected to be set. The summary of this word is also included in the confidence word as ‘Summary pointing’ (Section 3.1.2.1).

Table 3-7. Pointing word definitions (Flags ADS)

Bit	Meaning if set	Comment
0	(not implemented)	Set to 0
1	(not implemented)	Set to 0
2	(not implemented)	Set to 0
3	(not implemented)	Set to 0
4	Scan mirror integrated error; pixel counter not equal to 2000	
5	(not implemented)	Set to 0
6	(not implemented)	Set to 0
7	Platform mode	Set to 0 if nominal, else 1

3.1.3 Quality Flag Examples

Visual examples using SNAP are given in Figure 3-3 and Figure 3-4, from the 4th reprocessing product ENV_AT_1_RBT____20110107T111532_20110107T130045_20180906T114131_6312_098_166_____TPZ_R_NT_004.SEN3.

3.1.3.1 Exception values

Figure 3-3 shows measurement data from S9_BT_in.nc (left) and S1_radiance_in.nc (right), overlaid with the exception value flag settings. It can be seen that the exception

values within the separate channels S1 and S9 are now independent. So, the area of high cold cloud is shown in pink ('no signal in channel') in S9 (left) but in yellow ('saturation in channel') for S1 (right). Third reprocessing flags did not allow this distinction.

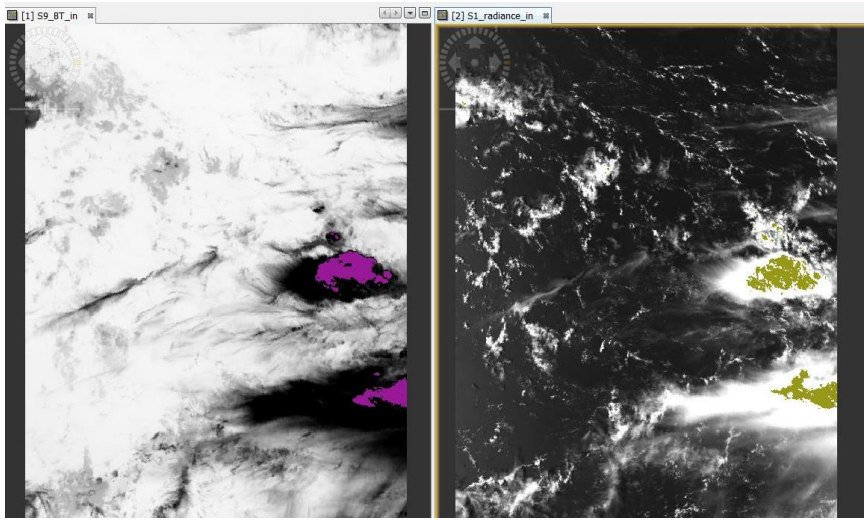

Figure 3-3. SNAP display of S9_BT_in.nc (left) and S1_radiance_in.nc (right). Quality flag settings are as shown in Table 3-8.

Table 3-8. Quality flag settings for exception values for Figure 3-3

Flag parameters	Masking details
S9_exception_in S1_exception_in	Name ... Colour ISP scan absent pixel absent not decompressed no signal in channel saturation in channel radiance outside calibration calibration parameters unavailable unfilled pixel

Figure 3-4 shows measurement data from files S9_BT_in.nc (left) and S1_radiance_in.nc (right) overlain with exception value flag settings during nighttime. It is known that noise in the visible channels at night can mimic the exception value settings, and this can be seen in Figure 3-4, where all exception values are set. Note that in the 4th reprocessing products, these false exception values are not carried over into the BT channels.

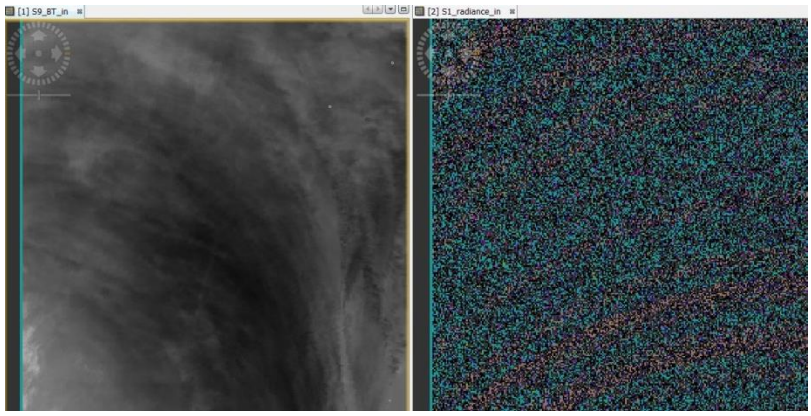

Figure 3-4. SNAP display of S9_BT_in.nc (left) and S1_radiance_in.nc (right) Quality flag settings are as shown in Table 3-9.

Table 3-9. Quality flag settings for exception values in Figure 3-4

Parameters inside S9_BT_in and S1_radiance_in	Masking details
S9_exception_in S1_exception_in	Name ... Colour ISP scan absent pixel absent not decompressed no signal in channel saturation in channel radiance outside calibration calibration parameters unavailable unfilled pixel

3.1.4 Classification Flag Examples

A visual example using SNAP is given in Figure 3-5, from flags_in.nc from the 4th Reprocessing product ENV_AT_1_RBT____20110107T111532_20110107T130045_20180823T135851_6312_098_166_____TPZ_R_NT_004.SEN3.

3.1.4.1 Cloud, confidence and pointing

Figure 3-5 shows the following parameters from the flags_in.nc file: (left-right) cloud_in, confidence_in, pointing_in, with flags set as shown in Table 3-10.

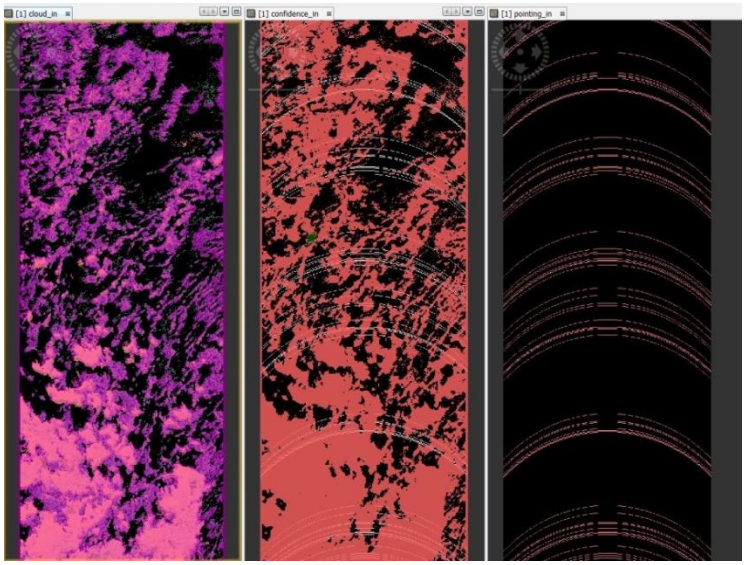

Figure 3-5. SNAP display of flags_in.nc. Left to right: cloud, confidence, pointing, with the coloured settings as shown in Table 3-10.

Table 3-10. Flag settings for Figure 3-5

Parameter inside flags_in.nc	Masking details
cloud_in	visible channels cloud test (day only) 1.6 um small-scale histogram test (day only) 1.6 um large-scale histogram test (day only) 11 um spatial coherence test 12 um gross cloud test 11 um 12 um thin cirrus test 3.7 um 12 um medium-high level test 11 um 3.7 um fog low-stratus test 11 um 12 um view difference test 3.7 um 11 um view difference test 11 um 12 um thermal histogram test
confidence_in	coastline ocean tidal land inland water unfilled spare blanking_pulse cosmetically filled pixel has duplicate day twilight sunglint snow summary_cloud summary_pointing
pointing_in	jitter platform_mode_not_ok

Points to note:

1. The transfer of the summary of the cloud test information from cloud_in to the summary_cloud flag in confidence_in. That is, where any cloud test has flagged cloud, the pixel is determined to be cloudy. Therefore the summary_cloud flag in the confidence word is now set and coloured red.
2. Land pixels in confidence_in are coloured green.
3. The transfer of the jitter flag in pointing_in to the summary_pointing flag in confidence_in. (Not actually set in this example, but it can be observed as the corresponding white lines inside confidence_in.)

3.1.4.2 Cosmetic fill

To complement the information in Section 2.1.3.2, Figure 3-6 shows the visualisation in SNAP of the cosmetic fill flag, contained within the confidence word in flags_in.nc and flags_io.nc. The flags shown in yellow are cosmetically filled pixels, and it can be seen that a large number of pixels in the oblique view are flagged, compared with a very small number in the nadir view.

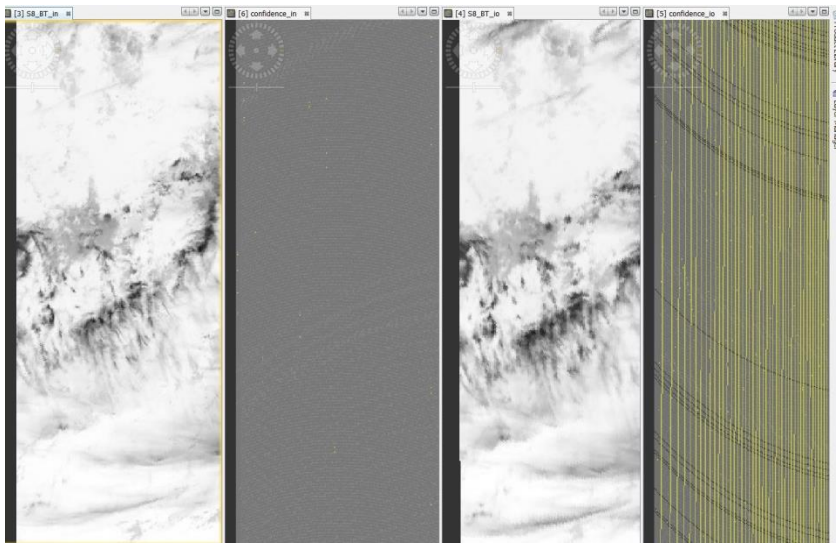

Figure 3-6. SNAP display of (left-right): S8_BT_in.nc, confidence_in, S8_BT_io.nc, confidence_io. The cosmetic fill flag is shown in yellow.
(From product ENV_AT_1_RBT____20110107T111532_20110107T130045_20180906T114131_6312_098_166_____TPZ_R_NT_004.SEN3)

3.2 Level 2 AATSR Products

4th Reprocessing L2 products will come from other ESA projects in order to benefit from the best available science. Note product generation will be conducted in accordance with each project's own plans.

Therefore, SST users will eventually be directed to the L2 (and L3) SST products from ESA's CCI SST project (http://www.esa-sst-cci.org/).

The L2 LST products will come from expertise from ESA's GlobTemperature project (http://www.globtemperature.info/ now covered by the Land Cover CCI https://www.esa-landcover-cci.org/).

4. ANNEX A

Table 4-1 gives example file names for different product types for the 3rd and 4th reprocessings.

Table 4-1. Example file names for different product types

Product type	Example product filename	Section
Third Reprocessing		
L1B	ATS_TOA_1PUUPA20040101_101845_000065272023_00036_09609_3015.N1	2.1
L2 NR	ATS_NR__2PUUPA20040101_101845_000065272023_00036_09609_3015.N1	2.2.1
L2P ARC	20040101101845-UPA-L2P_GHRSST-SSTskin-ARC-AATSR-v02.0-fv01.0.nc	2.2.2
L2 LST	ATS_LST_2PUUOL20050524_202516_000065272037_00314_16901_0507.nc	2.2.3
Fourth Reprocessing		
L1B	ENV_AT_1_RBT____20060928T065948_20060928T074242_20171205T052845_2574_051_335_____TVUK_R_NT_004.SEN3	3.1