

README file for ENVISAT MERIS full and reduced resolution level 1 & level 2 data

<i>Field</i>	<i>Content</i>						
<i>Document Title</i>	README file: ENVISAT MERIS full and reduced resolution level 1 & level 2 data						
<i>Reference</i>	QA4EO-BRO-IPF-TSP-4175, issue 1.0, 13/05/2020						
<i>Applicability</i>	This document describes the major fields of improvement in the MERIS Level 1 & Level 2 4 th reprocessing baseline version based on MEGS 9 compared to previous version MEGS 8 which was the equivalent to the operational processor IPF 6.						
<i>ESA Reference Documents</i>	<p>[RD.1] MERIS Sentinel3-like L1 and L2 Product Format Specification – MER4RP-PFS-001-ACR – version 1 – 26/09/2017.</p> <p>[RD.2] 4th MERIS data reprocessing - Evolutions and Validation report – MER4RP Validation Report – Version 1.0 – 01/04/2019</p> <p>[RD.3] MERIS FR 4th REPROCESSING QUALITY ASSESSMENT – Technical Note – version 1.0 – 30/08/2018</p> <p>[RD.4] MERIS RR 4th REPROCESSING QUALITY ASSESSMENT – Technical Note – version 2.0 – 25/07/2019</p> <p>[RD.5] MERIS 4th data reprocessing MEMORANDUM – MER4RP-MM-003-ACR – version 1.0 – 18/01/2019</p> <p>[MRD- 1] ENVISAT-1 PDS Document Change Notice, 2.1 – PO-DN-ESA-GS-428</p> <p>[MAD-1] ENVISAT-1 Product Definition – PO-TN-ESA-GS-0231</p>						
<i>Filled by</i>	MERIS SPPA service team						
<i>Change log</i>	<p>The table below records history and status of this README file.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Issue</th> <th style="text-align: center;">Date</th> <th style="text-align: center;">Major Changes</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1.0</td> <td style="text-align: center;">13.05.2020</td> <td style="text-align: center;">First version</td> </tr> </tbody> </table>	Issue	Date	Major Changes	1.0	13.05.2020	First version
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1 Mission Overview

MERIS mission was the first imaging spectrometer mission with a primary objective for ocean and coastal water colour remote sensor.

MERIS operations was very stable with only very few interruptions and continuously providing data to its users. The data were made available to users in NRT from a rolling archive and through the MERCI system systematically. 4 major reprocessing campaigns took place.

Major events in MERIS operations included:

- First data availability May 2002
- ENVISAT Calibration Workshop in 09.-13.09.2002 (MERIS Presentation)
- Re-Programming of band 11 (761nm, oxygen absorption band) in December 2002 to optimize the cloud top pressure retrieval
- Turning-off the offset control loop (OCL) on 13.12.2004, leading to an unexpected increase of low-level noise. The OCL was turned on again on 09.10.2006. A correction of the data acquired during the OCL-off period was introduced in the 3rd reprocessing which was released in July 2011.
- Reprocessing campaigns:
 - 2004: First reprocessing; applied to the Reduced Resolution data of the year 2003
 - 2005: Second reprocessing: reprocessing of the Reduced Resolution mission archive from 2002 - present (2005)
 - 2011: Third reprocessing: reprocessing of the Reduced Resolution mission archive from 2002 - present (2011)
 - 2014: First bulk reprocessing of the complete Full Resolution Full Mission archive. Same processor configuration as 3rd RR reprocessing
 - 2020: Fourth reprocessing: reprocessing of the Reduced Resolution full mission archive from 2002 – last data take (2012)
 - 2020: Second reprocessing of the complete Full Resolution Full Mission archive. Same processor configuration as 4th RR reprocessing

2 Overview of the MERIS instrument

2.1 Envisat-1 Mission

The ENVISAT-1 mission objectives and payload are described in [MRD-1]. The main characteristics of the orbit are recalled in Table 2-1 below.

Table 1: ENVISAT-1 orbit characteristics

Semi-major axis	7159.5 km
Eccentricity	0.001165
Argument of perigee	90 °
Inclination	98.549°
Period	100.47 mn
Equator Crossing Time	22:00
Repeat cycle	35 days

2.2 MERIS Instrument

MERIS is a medium spatial resolution imaging spectrometer, operating in push-broom mode on a swath width of 1150 km. It provides simultaneously 15 spectral bands selectable in the visible and near-infra-red domain (390 to 1040 nm wavelength at 1.25 nm sampling interval). A reference set of bands is shown in Table 2 below. It should be noted that the finalisation of MERIS bands is the subject of on-going work within the MERIS SAG. The bands in Table 2 below correspond to the three main missions of the instrument:

1. ocean colour;
2. atmosphere aerosols and clouds;
3. land processes.

Each MERIS pixel has a field of view of 0.019°. Due to the wide instrument field of view (68°), spatial sampling varies in the across track direction, between 0.26 km at nadir and 0.39 km at swath extremities. Along-track sampling is close to 0.29 km.

MERIS has the capability to output data sampled at the Full Resolution (FR) with the spatial sampling described above, and Reduced Resolution (RR) data sub-sampled at 1.2 km.

Table 2: Definition of the MERIS bands

No.	Band centre (nm)	Band width (nm)	Application
1	412.5	10	Yellow substance and detrital pigments
2	442.5	10	Chlorophyll absorption maximum
3	490	10	Chlorophyll and other pigments
4	510	10	Suspended sediment, red tides
5	560	10	Chlorophyll absorption minimum
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption & fluo. reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	708.75	10	Fluo. reference, atmosphere corrections
10	753.75	7.5	Vegetation, cloud
11	760.625	3.75	O2 R- branch absorption band
12	778.75	15	Atmosphere corrections
13	865	20	Vegetation, water vapour reference
14	885	10	Atmosphere corrections
15	900	10	Water vapour, land

MERIS was operating continuously on the day side of the ENVISAT-1 orbit (descending track). RR data was acquired over 43.5 mn in each orbit, i.e. 80% of the descending track, and transmitted directly or via the on-board recorder. FR data was acquired and processed on request for a maximum of 20 mn, in view of X-band stations or DRS (see [MAD-1]).

Radiometric Calibrations were performed periodically at orbital South Pole pass, using on-board dedicated hardware. This allowed the monitoring and / or the update of the calibration Auxiliary data.

Wavelength calibration was performed periodically, using on-board dedicated hardware. This allowed the monitoring and / or the update of auxiliary data.

3 Level 1 & level 2 processor version (MEGS) 9

The MERIS Level 1 and Level 2 processor (MEGS) version 9 was developed introducing both scientific improvements and format updates and was adopted for the reprocessing of the MERIS full-mission data set.

For a full documentation on evolutions and validation see "4th MERIS data reprocessing evolutions and validation report" [RD-2].

3.1 Processor evolution

The new MERIS Level 1 and Level 2 processor (MEGS) Baseline 9 implements software changes and new processing elements discussed in the framework of MERIS QWG activities for the fix or the enhancement of the MERIS Level 0 to 2 processing. The major changes in the algorithms of the new Level 1

and Level 2 version 9, compared to predecessor processor (MEGS) version 8, are reported below:

3.1.1 Product format change

A major evolution of the MER4RP is related to the data formatting: the ENVISAT data format (.N1) is given up in favour to the Sentinel-3 like format. The S3-like format includes multi-file products packages with xml Manifest (descriptive header) and NetCDF data files.

3.1.2 Changes of auxiliary data

- **Meteo data**

The source of the meteo data is now ECMWF Era-Interim

- **Improved a priori masks**

The a priori surface classification masks (land/sea, tidal areas and in-land-waters) are significantly upgraded and are in line with those used by the OLCI data processing.

3.1.3 Level 1 evolution

- **Geolocation**

The geolocation is improved: The MER4RP includes the Amorgos-like ortho-geolocation scheme. Parallax and orographic corrected latitude, longitude and altitude are given per pixel. For detailed information see [RD-2].

- **Level 1 calibration**

The L1 calibration is updated based on a reanalysis of the complete mission in-flight calibration dataset. It includes a revised diffuser ageing methodology accounting also for the ageing of the reference diffuser. For detailed information see [RD-2].

3.1.4 Level 2 evolutions

- **Pre-processing**

New modelling of Rayleigh Optical Thickness: The model of Bodhaine et al. (1999) is selected for the computation of the Rayleigh Optical Thickness in the MERIS spectral bands.

Variation of the barometric pressure with the altitude $P(z)$: The computation of the surface pressure over land and inland waters is improved considering the per-pixel altitude and an improved relationship of barometric pressure with the altitude.

Gaseous correction: The computations of H₂O, O₂ and O₃ transmissions have been revised and the NO₂ absorption has been added in the total gaseous atmospheric transmittance.

Smile correction moved to processing branches: The smile correction is performed through the pressure (or Rayleigh) adjustment by using an equivalent Rayleigh optical thickness. It is separately achieved for the water and the land branch.

For a detailed description of pre-processing changes see [RD-2].

- **Pixel identification**

Radiometric land/water reclassification: The radiometric land/water reclassification has been revised following upgrades of the a-priori masks: (1) Reclassified pixels outside the tidal areas remain in their original branch; (2) The Flood and Dry Fallen masks have been added.

Cloud screening and snow/ice masking: Cloud screening is improved thanks to the use of Neural Network derived from the ESA Climate Change Initiative (CCI) programme.

Cirrus mask: Cloud screening is enriched with semi-transparent cirrus clouds detection using the O₂ absorption.

For a detailed description of pixel identification changes see [RD-2].

- **Multi-branch processing**

Similarly to the OLCI processing, MER4RP processing is now controlled according to the observed surface type, namely Marine, Land and Cloud. For detailed information see [RD-2].

- **Water vapour processing**

The Water Vapour retrieval has been upgraded using the 1D-var algorithm. For detailed information see [RD-2].

- **Water processing**

Pressure adjustment and smile correction: Handling of the molecular scattering is improved using a new modelling of the ROT, an accurate pixel elevation, a new surface pressure determination, and a new pressure adjustment.

Bright Pixel Atmospheric Correction: The atmospheric correction over coastal waters is better handled thanks to the improvement of the BPAC. The numerical inversion has been totally revised, now based on a spectral matching algorithm (χ^2 minimisation) on five NIR bands, considering input uncertainty at each channel.

Clear water atmospheric correction: A new set of aerosol models, based on a Ahmad et al. (2010), has been included in the Atmospheric Correction LUTs which have been extended to several reference pressure levels for

allowing the application of the atmospheric correction algorithm to the inland waters at significant elevations.

Propagation of radiometric uncertainty: The propagation of TOA radiometric uncertainty through the L2 water processing chain down to BOA has been implemented to provide water-leaving reflectance uncertainties

Vicarious adjustment: Vicarious gains in the VIS region have been recomputed to account for modified L1 calibration, atmospheric correction upgrades and updated in-situ measurement datasets.

Vicarious adjustment in the NIR region (relative to one band) is discarded because the new BPAC is more robust to errors in the NIR domain and spectrally aligns the path reflectance for each pixel.

Case-1 Ocean Colour processing: The Case-1 Ocean Colour algorithm has been upgraded in two main aspects:

1. Introduction of the computation of the diffuse attenuation coefficient at 490 nm $K_d(490)$, according to (Morel et al, 2007)
2. Computation of Ocean Colour products uncertainties by propagation of the radiometric uncertainty through the OC algorithms

Case 2 Ocean Colour processing: The Case-2 Ocean Colour algorithm has been upgraded considering:

1. a new bio-optical model derived from NOMAD data set and extended for Case-2 water with 5 components;
2. an atmospheric correction based on the GEN_TOA Coastcolour atmosphere model, which includes a variable ground pressure;
3. the uncertainties calculation.

For a detailed description of water processing changes see [RD-2].

- **Land processing**

Atmospheric corrections over land: Pressure adjustment and smile correction: Handling of molecular scattering is improved using accurate pixel elevation, better modelling of the relationship between pressure and elevation, better modelling of the Rayleigh optical thickness (Bodhaine et al., 1999) and improved correction of meteorological variation of atmospheric pressure.

Land aerosols remote sensing (AOT at 442 nm (T442) and Angström exponent (A442)): The BRDF model of the Land Aerosol Remote Sensing (LARS) targets has been revised. The aerosol Angstrom exponent climatology has been updated. A new product is introduced T442_ALPHA and a quality index Q.

Land products:

- Uncertainty estimates are now provided for the MGVI
- The MTCI range limit has been extended; the associated flags have been revised and the uncertainty is now estimated.
- New MTCI quality flags

For a detailed description of land processing changes see [RD-2].

- **Flags**

The flags are split into categories and/or branch product; PCDs become Product Confidence “PC” associated to the product.

For detailed information see [RD-2].

3.1.5 LUTs evolutions

The LUTs that either evolved or created for the MER4RP are described in detail in [RD-2]

3.2 Product format evolution

The Envisat data format (.N1) used up to the 3rd MERIS data reprocessing is given up in favour of a Sentinel-3 like format based on a folder of netCDF data files complemented by an xml Manifest file describing the package.

The MERIS L1 and L2 products available in S3-like format are summarized in Table 3:

Table 3: MERIS products tree

Product type	Description	Level
ME_1_FRG_	Full Resolution top of atmosphere radiance	Level 1
ME_1_RRG_	Reduced Resolution top of atmosphere radiance	Level 1
ME_2_FRG_	Full Resolution Water, Land, Cloud & Atmosphere geophysical products	Level 2
ME_2_RRG_	Reduced Resolution Water, Cloud, Land & Atmosphere geophysical products	Level 2

The names of the MERIS products are based on the Sentinel-3 file naming convention with some adaptations to handle Envisat platform and MERIS sensor.

Details can be found in the latest issues of the product specification document [RD-1].

3.3 Product format and tools

MERIS products generated with MEGS 9 have a new format (SEN3 like, see 3.2). Owing to this SNAP and the Sentinel-3 toolbox have been updated. Other previous tools usable with the 3rd reprocessing data (BEAM, AMROGOS, ODESA) are no longer supported with the 4th reprocessing data. BEAM and ODESA currently do not support the SEN3 format. There are no plans for BEAM to support the new format in the future. AMORGOS like correction is already applied to the 4th RP data (see 3.1.3).

4 Data quality of 4th reprocessing data

The data quality of the MERIS 4th reprocessing data has been analysed during a dedicated quality assessment (QA). This QA was done on Level 1 data using MERCI.

The main goal of this activity was to make a quality assessment (QA) of MERIS RRG L1b data in SEN3 like format, to ensure a good quality of the reprocessed data. The quality assessment is based on three steps:

1. Evaluation of processing reports provided by the processing facility.
2. Evaluation of the MERCI quality tests.
3. Random check of products already segregated during 3rd reprocessing.

One systematic issue with cosmetic filling of FR products was found during QA, which is briefly described in section 5.

4.1 Level 1 & Level 2 FR data

The three steps quality analysis has shown that the overall quality of the products seems to be good. A few products have been identified (below 1%) that need to be separated due to cosmetic filling and dubious flagging. Another 1528 products (around 1.7%) need to be segregated as the quality cannot be guaranteed and the issues of 3rd RP have not been completely solved. Nevertheless, during the visual inspection of products, a few products have been found with geolocation issues due to cosmetic filling that could not be found by any of the conducted quality tests. For details see section 5

Detailed insights of the QA of RR data are given in the MERIS FR 4th reprocessing quality assessment technical note [RD.3]. As the QA was only done on L1 data. The results were applied also to L2 data.

4.2 Level 1 & Level 2 RR data

The three steps quality analysis has shown that the overall quality of the products seems to be good. No products could be found that showed any quality constraints.

Detailed insights of the QA of RR data are given in the MERIS FR 4th reprocessing quality assessment technical note [RD.4]. As the QA was only done on L1 data. The results were applied also to L2 data.

5 Known Processing Issues

During the QA of MERIS FR Level 1 products, an issue was found in a MER4RP Level-1 product:

ENV_ME_1_FRG____20061101T084658_20061101T085904_____0726_052_322____DSI_R_NT____SEN3

The symptom: Some cosmetic filling in the 4th RP led to geolocation issues, which have not been present in the 3rd RP.

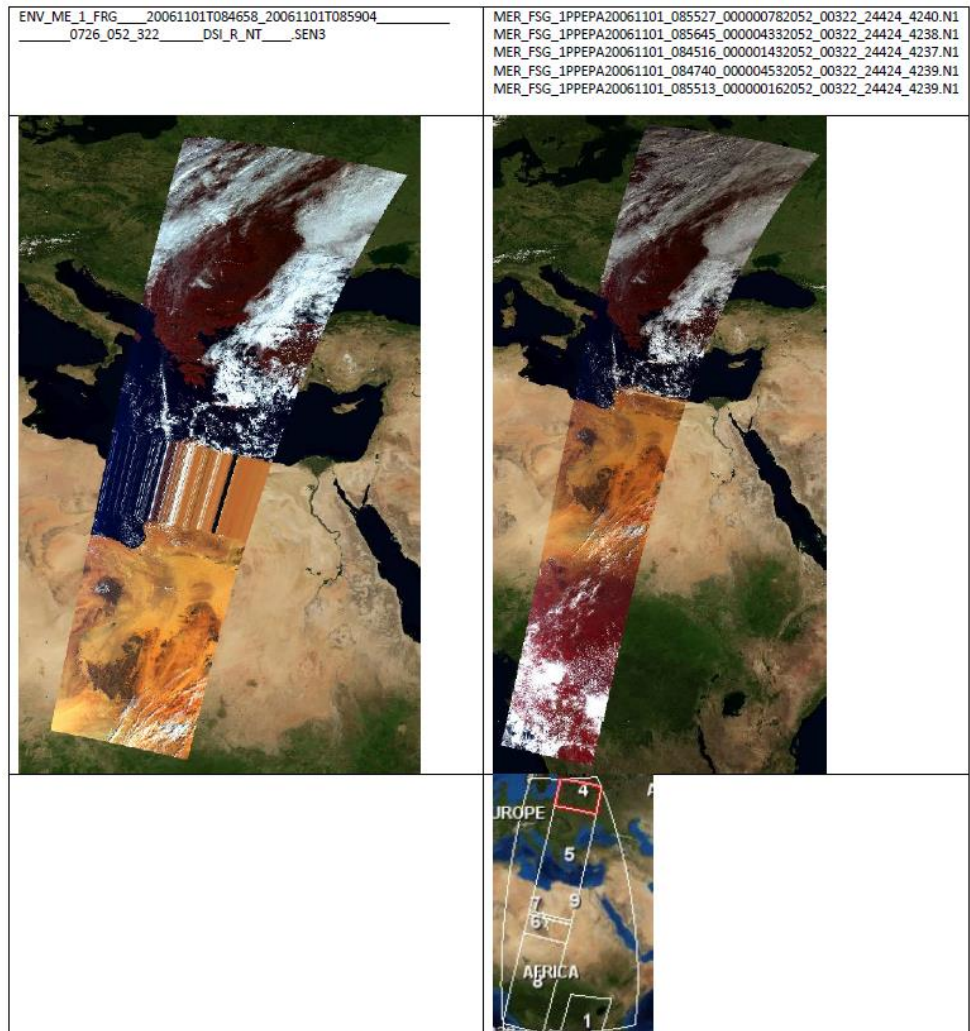


Figure 1: Comparison between single part 4th RP (left) and multi product 3rd RP(right) (Source: [RD.3] & [RD.5])

Not visible in the figure, but in the 3rd RP there was a short data gap, that has not been filled. This data gap might have caused the issue in the 4th RP.

It is important to know that 3rd RP and 4th RP products are not generated from the same L0 products: there are several 3RP Level 1 products for the same orbit, generated from a set of Level 0s while the 4RP version is generated from a single Level 0, by a single processor run:

- 3rd RP Level 0 products:
 - MER_FR__OCNPK20061101_084517_000001832052_00322_24424_1154.N1
 - MER_FR__OCNPDE20061101_085558_000004802052_00322_24424_2974.N1
 - MER_FR__OCNIPA20061101_084658_000006352052_00322_24424_0303.N1

These products have not been archived and are not available anymore

- 4th RP Level 0 product:
 - MER_FR__OPNIPA20061101_084658_000006342052_00322_24424_0303.N1

This product is likely the result of Level 0 consolidation from various input L0 products.

The 4RP input Level 0 has been analysed in terms of Instrument Source Packets relevance, in order to assess if the conditions required for processing to Level 1 are met.

The analysis came to the following conclusion:

Corrupted data, incorrectly filtered by the acquisition ground station, are present in the Level 0 product, with anomalous time stamps values. These anomalies introduce large discontinuities in the data time stamping with negative time steps that are not handled by the processor as such cases were explicitly excluded from the design process by the definition of the Level 0 product.

For detailed information please see MERIS 4th data reprocessing memorandum [RD.5].

6 Transient data quality degradation events

MERIS operations was very stable with only very few interruptions and continuously providing data to its users.

Major events in MERIS operations included:

- First data availability May 2002
- ENVISAT Calibration Workshop in 09.-13.09.2002 (MERIS Presentation)
- Re-Programming of band 11 (761nm, oxygen absorption band) in December 2002 in order to optimize the cloud top pressure retrieval
- Turning-off the offset control loop (OCL) on 13.12.2004, leading to an unexpected increase of low level noise. The OCL was turned on again on 09.10.2006. A correction of the data acquired during the OCL-off period was introduced in the 3rd reprocessing which was released in July 2011.

	Major events of the instrument operations can be found at https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/meris/mission-operations-overview
<i>Acronyms</i>	<p>FR Full Resolution</p> <p>MER4RP MERIS 4th reprocessing</p> <p>MERIS Medium Resolution Imaging Spectrometer</p> <p>QA Quality Assessment</p> <p>RP Re-Processing</p> <p>RR Reduced Resolution</p>