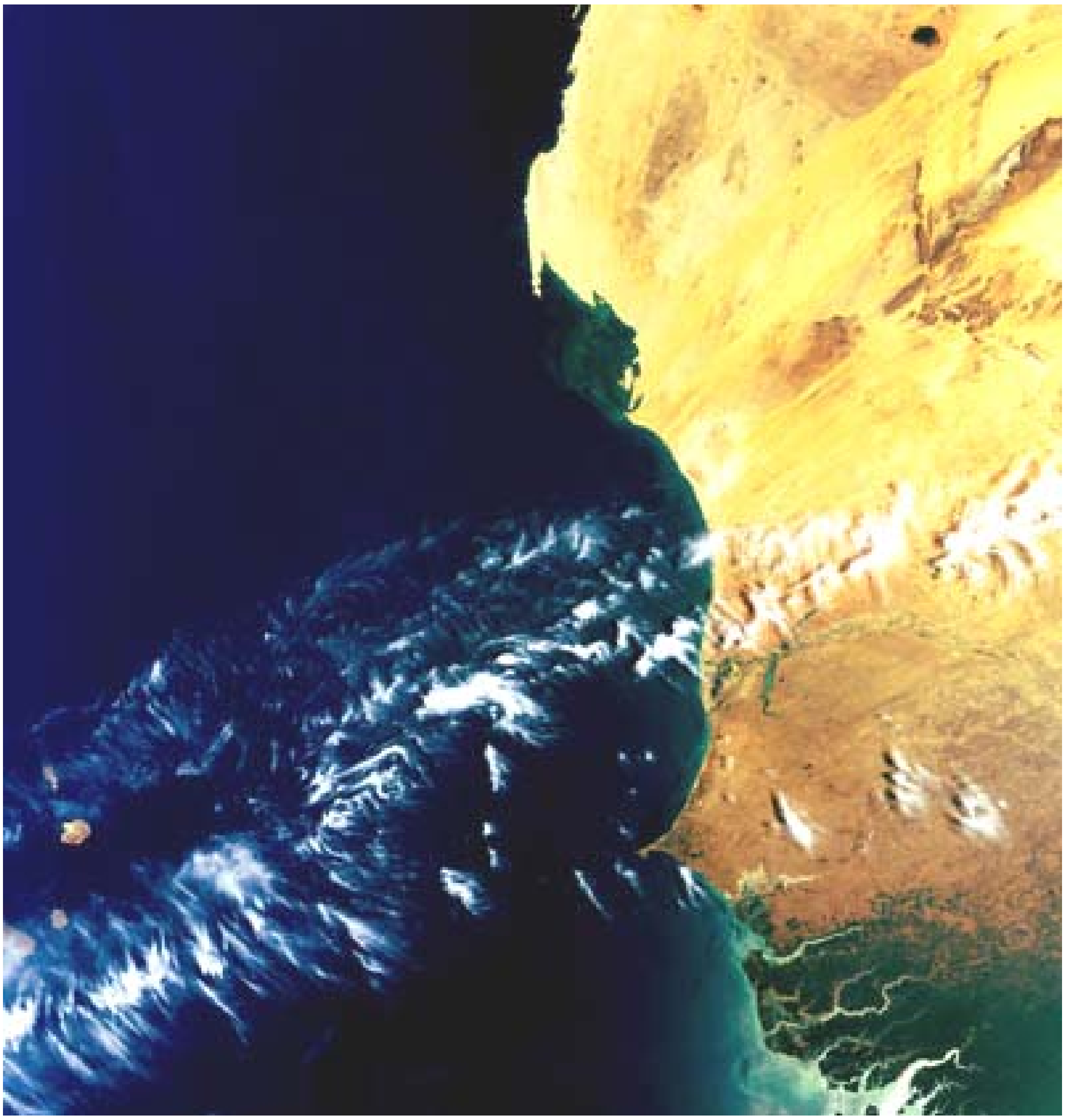
MERIS Product Handbook



European Space Agency – MERIS Product Handbook
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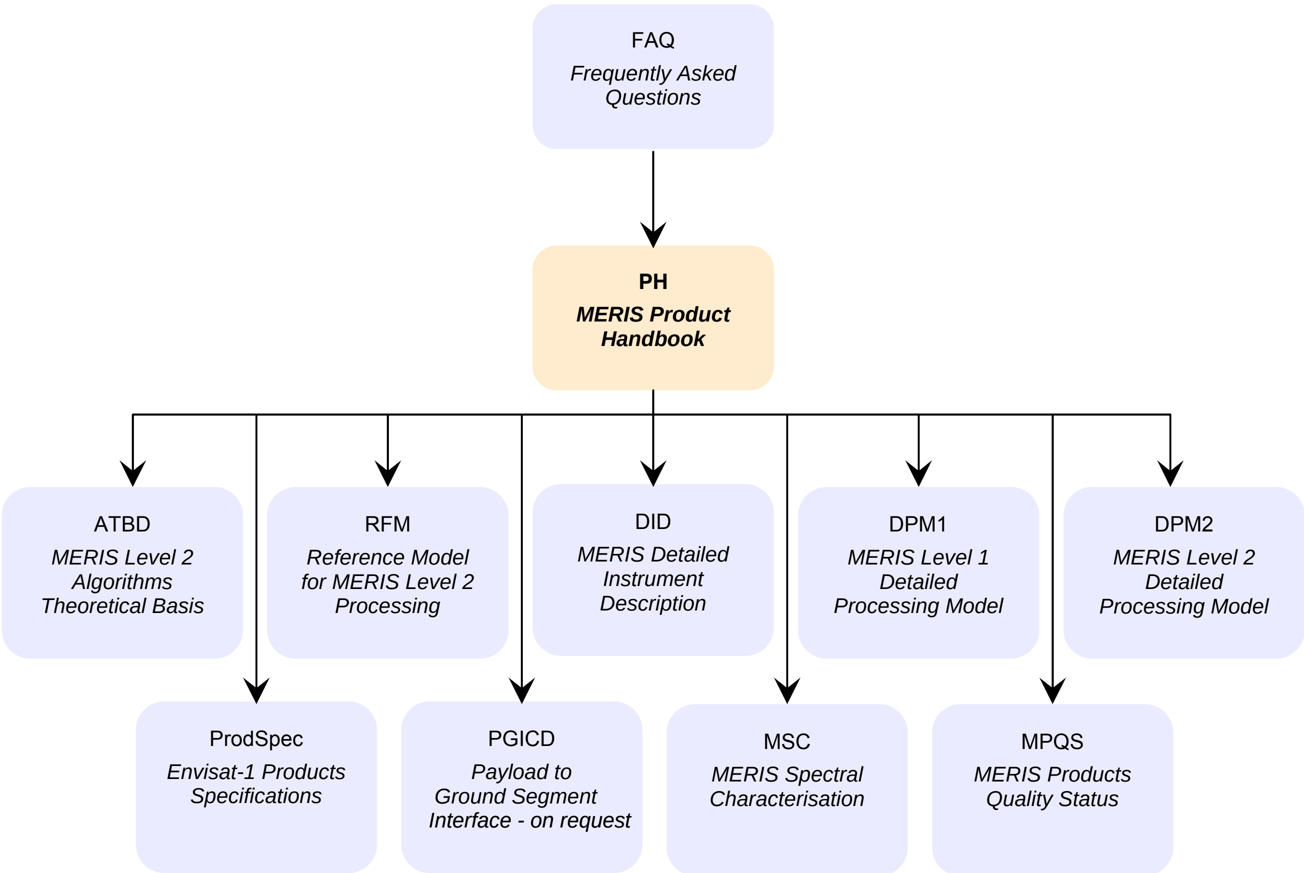
Abstract

This *MERIS Product Handbook* guides users to choose and use MERIS data and explains the way these data are processed and organised.

In order to access faster to the information, another document, the *Frequently Asked Questions* may be used.

Scientists may also get a deeper and more detailed level of information in the documents pointed as reference in this Product Handbook.



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Chapter 1

MERIS User Guide

1.1 How to Choose MERIS Data

The data from the MERIS instrument is capable of retrieving a variety of geophysical information. In order to exploit these effectively, it is necessary to understand exactly:

what variables MERIS measures,

why the instrument has been designed to operate in the way it does,

and how these measurements are made and processed into information.

MERIS data also offer a number of unique properties over data from similar imaging instruments which result in advantages which are highlighted in the following sections.

The result of these properties is data suitable for a wide range of potential applications. A summary of products and applications is provided to assist the user in identifying the most suitable product for his or her particular use.

1.1.1 Geophysical Measurements

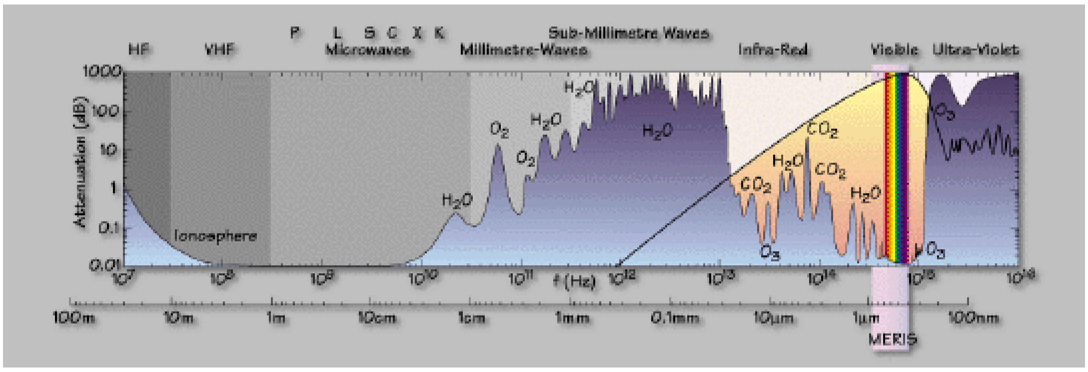


Figure 1.1 - The electromagnetic spectrum indicating the data set measured by MERIS.

The MEdium Resolution Imaging Spectrometer Instrument

MERIS is a 68.5° field-of-view push-broom imaging *spectrometer* that measures the solar radiation reflected by the Earth, at a ground spatial resolution of 300 m, in 15 spectral bands, programmable in width and position, in the visible and near infrared wavelengths. MERIS allows global coverage of the Earth in 3 days.

The MERIS Mission

The primary mission of MERIS is the measurement of sea colour in the oceans and in coastal areas. Knowledge of sea colour can be converted into a measurement of *chlorophyll* pigment concentration, suspended sediment concentration and of atmospheric *aerosol* loads over water.

Why Measure Ocean Colour?

Four applications of ocean-colour data are:

understanding the ocean carbon cycle
understanding the thermal regime of the upper ocean
the management of fisheries
the management of coastal zones
climate studies
ocean dynamic

For more details see http://www.ioccg.org/

What Else Can MERIS Measure?

MERIS is also capable of estimating:

cloud type, top height, and *albedo*
top and bottom of atmosphere *vegetation indices*
photosynthetically available radiation
surface pressure
water vapour total column content for all surfaces
aerosol load over land
vegetation indices
Fractional Absorbed Photosynthetically Active Radiation (FAPAR)

These measurements constitute MERIS' secondary mission.

1.1.2 Scientific Background

1.1.2.1 Heritage

It is believed that the ocean carries between one third to one half of the heat transferred from the Earth's equator to its poles. In fact, it is the existence of this flux that keeps the mid-latitude regions of the Earth habitable. The ocean is the major sink for the constantly increasing human production of carbon dioxide and other "greenhouse gases." Analyses of cores from the ocean floor strongly suggest that during the distant past, when the Earth's climate was very different, the ocean circulation was also radically different.

Therefore, more information is urgently needed on oceanic circulation and changes and the oceanic carbon cycle. Present models of the ocean are inaccurate owing to uncertainties concerning the governing physics, chemistry, and biology, and also due to an inadequate ability to describe the instantaneous state of the system. ENVISAT offers the continuous, global observations of the oceans required to provide data sets for enhanced ocean modelling.

The first observations of ocean colour from space were carried out from 1978 to 1986 by the experimental Coastal Zone Colour Scanner (CZCS) aboard NASA's Nimbus-7 satellite. This instrument provided global and regional data sets which yielded a wealth of new information about the distribution and seasonal variability of primary productivity in oceans. During the period 1986 to 1996, the orderly development of ocean-colour science was hindered by the lack of an operational satellite sensor for the production of ocean-colour data. Although considerable energy was devoted to analysing the results of the then-defunct CZCS, there was no opportunity to conduct new studies in which observations from space could be matched with in situ data observations in near real time.

The picture began to improve in March 1996, when India launched the German sensor *MOS* (Modular Optoelectronic Scanner). Although this device does not provide global coverage, it was important as the first source of new ocean-colour data after a gap of ten years. In August 1996, Japan launched the Japanese sensor *OCTS* (Ocean Colour and Temperature Scanner) and the French sensor *POLDER* (POLarization and Directionality of the Earth's Reflectance) on the *ADEOS* (ADvanced Earth Observation Satellite) mission. This was a very powerful combination, which operated until June 1997, until failure of the satellite's solar panel terminated the mission. In August 1997, the USA launched the *SeaWiFS* (Sea-viewing Wide Field-of-view Sensor), which has been in operation since September 1997. This instrument provides complete global coverage of the oceans about every two days if cloud free.

Over and above these sensors, a number of others have been launched (*MISR*, *MODIS*, *OCI*, *OCM*, *OSMI*, *GLI*, *POLDER*-2) other are planned for launch in the near future. Recent experience has emphasised that a certain controlled redundancy is essential if we are to enjoy an unbroken stream of ocean-colour data into the future.

IOCCG (International Ocean-Colour Coordinating Group) groups together information relative to the various missions and instruments enumerated here above (http://www.ioccg.org/sensors_ioccg.html).

Information may also be directly found at the following URLs:

MOS	http://ceos.cnes.fr:8100/cdrom-00b2/ceos1/satellit/mos/mos.htm
OCTS	http://www.eorc.nasda.go.jp/ADEOS/Project/Octs.html
POLDER	http://smsc.cnes.fr/POLDER/Fr/
ADEOS	http://kuroshio.eorc.jaxa.jp/ADEOS/index.html

SeaWiFS	http://oceancolor.gsfc.nasa.gov/SeaWiFS/
MISR	http://www-misr.jpl.nasa.gov/
MODIS	http://modis.gsfc.nasa.gov/
OCM	http://www.isro.org/programmes.htm
GLI	http://suzaku.eorc.jaxa.jp/GLI/index.html
POLDER-2	http://smsc.cnes.fr/POLDER/Fr/

1.1.2.2 MERIS Level 3 products

Level 3 demonstration products are available at http://envisat.esa.int/level3/ for each month or averaged per year (see figures below).

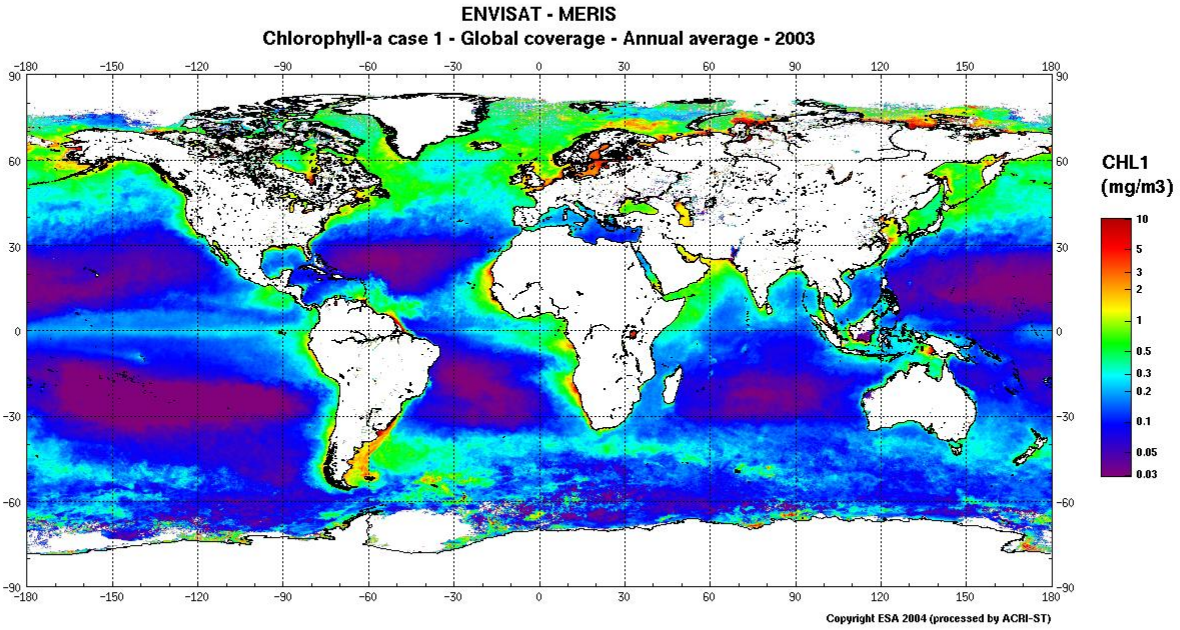


Figure 1.2 - Level 3 product - Chlorophyll-a case 1 – Annual average 2003.

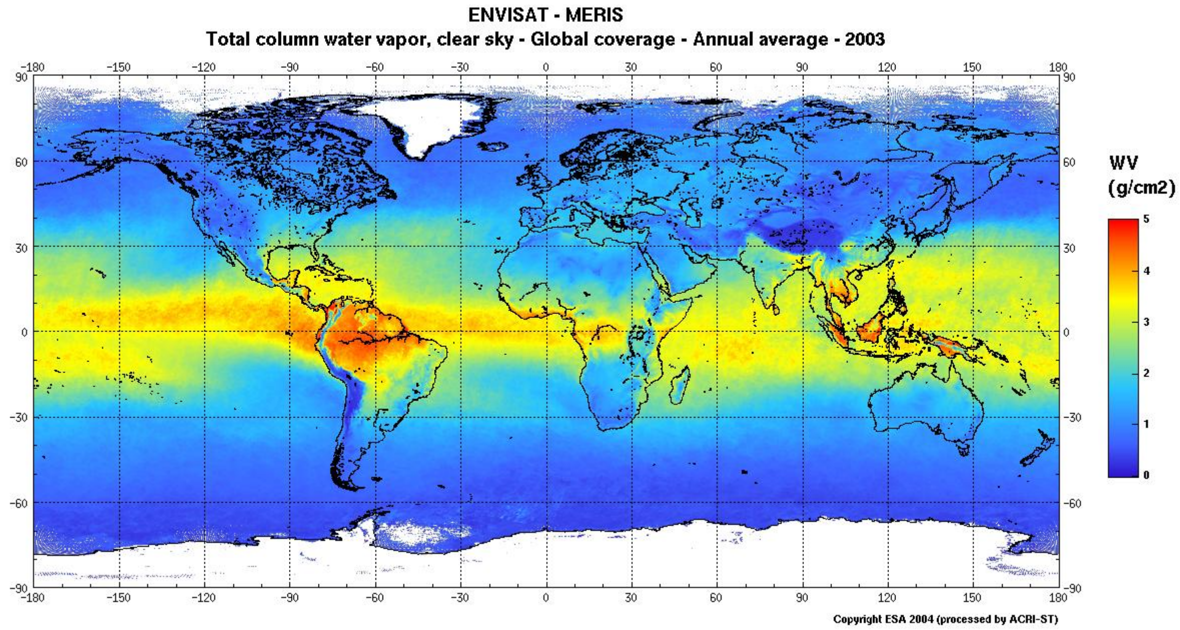


Figure 1.3 - Level 3 product – Total column water vapour, clear sky – Annual average 2003.

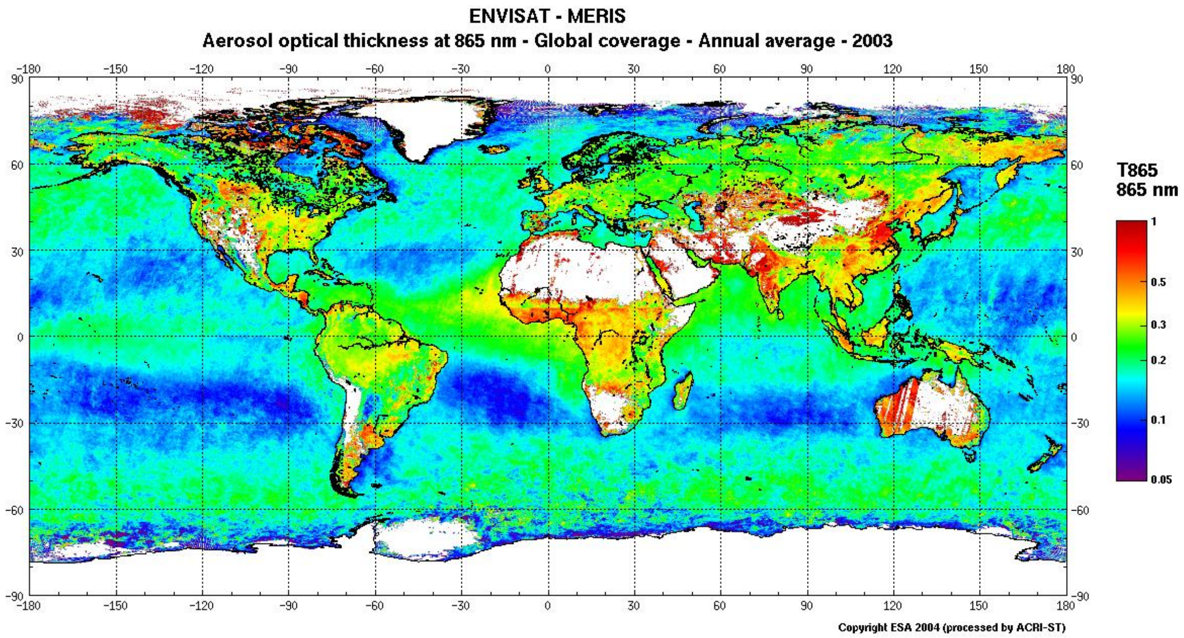


Figure 1.4 - Level 3 product – Aerosol optical thickness at 865 nm – Annual average 2003.

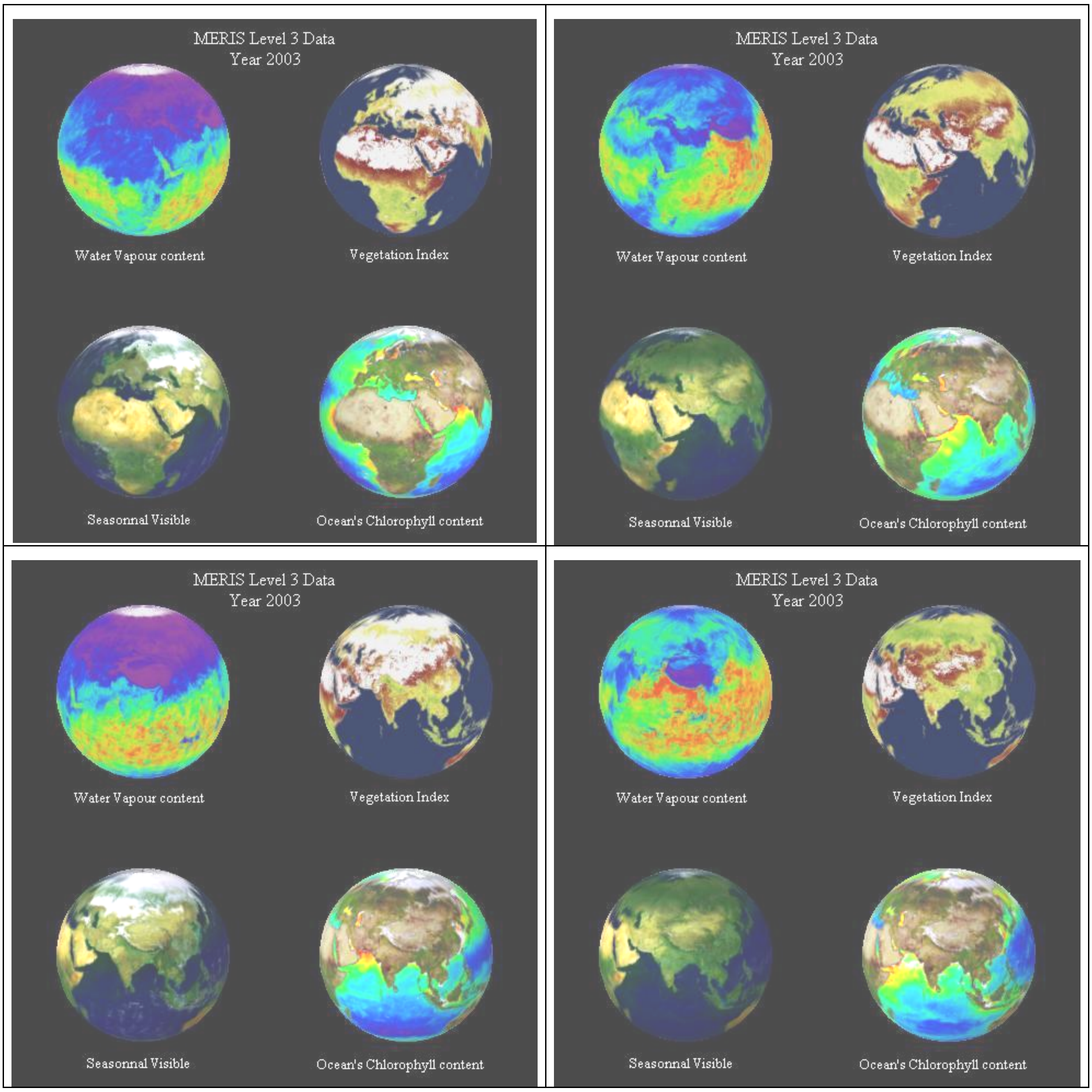


Figure 1.5 - MERIS Level 3 Data – Year 2003

1.1.2.3 Mission Objectives

Ocean Mission

The principal contributions of MERIS data to the study of the upper layers of the ocean are:

- the estimation of photosynthetic potential by detection of phytoplankton (algae);
- the detection of yellow substance (dissolved organic material);
- the detection of suspended matter (particulates and river-borne sediments);

Apart from the above three major observable features, it should also be possible to detect plankton blooms (for example red tides) through their absorption feature near 520 nm. In addition, investigations of water quality, the monitoring of extended pollution areas, and topographic observations (such as coastal erosion), should also be possible.

Atmospheric Mission

The radiation balance of the Earth/atmosphere system is dominated by water vapour, CO_2 and clouds, as well as being dependent on the presence of aerosol. However, the global monitoring of cloud properties and their processes, is not yet sufficiently accurate. MERIS is intended to help redress this balance by providing data on cloud top height and optical thickness, water vapour column content, and aerosol properties.

Land Mission

Questions related to global change include the role of terrestrial surfaces in climate dynamics and biogeochemical cycles. Spatial and temporal models of the biosphere are currently being developed to study the mechanics of such complex systems in order to predict their behaviour under changing environmental conditions. These models are based on physical and biophysical relationships, which need to be estimated on a regular basis using data from spaceborne sensors. Repetitive accurate physical measurements are necessary in order to quantify surface processes and to improve the understanding of vegetation seasonal dynamics and responses to environmental stress.

To achieve these mission goals, the different radiometric and geometric requirements imposed by the various objectives have to be satisfied. With the help of the ESA Science Advisory Group for MERIS, these requirements have been refined, taking into consideration the constraints imposed by a polar orbiting platform and the technical possibilities of an imaging spectrometer.

In advance of the launch of MERIS, the Ground Segment was designed and algorithms were developed for the interpretation of MERIS observations, and dedicated studies are ongoing to establish the means of determining the accuracy of MERIS data products. This is achieved in close cooperation with the European Expert Support Laboratories whose scientists are the main authors for all information estimation algorithms. Wherever possible, the underlying physical models are being evaluated using experience acquired before ENVISAT launch using data provided by airborne or shipborne campaigns and in situ measurements on specially equipped campaign sites.

1.1.3 Principles of Measurement

MERIS is a passive imaging spectrometer, which performs simultaneously spatial and spectral imaging of the Earth, by looking in the nadir direction.

The most outstanding characteristics of MERIS, detailed below, are:

- MERIS is a push-broom instrument.
- The InFOV is 68° +1°/-0.1°, which equates to a swath width of 1150 km centred around the subsatellite point.
- The 15 observed spectral bands are all programmable in position and width.
- Two spatial resolutions can be selected.
- Onboard processing can be performed on the image data.
- The polarisation sensitivity of MERIS is very low.
- MERIS has a high radiometric and spectrometric performance.

The InFOV is divided into five segments, each of which is imaged by one of the corresponding five cameras. A slight overlap exists between the FOVs of adjacent optical cameras. An area Charge-Coupled Device (CCD) detector is used, with an instantaneous detector element FOV of 1.149 arcmin.

Spatial Imaging

Spatial imaging is achieved using the push-broom principle: the across-track sampling is performed electronically and the along-track sampling is made thanks to the satellite motion. (See the figure below.)

A spatially bi-dimensional image is obtained by the gathering and the on-ground processing of subsequent images as ENVISAT moves along track.

MERIS measures the reflected solar radiation from the Earth's surface and clouds, in the visible and near-infrared spectral regions. Therefore, observation is nominally limited to the day side of the Earth, in particular the angular observation range is limited to a Sun zenith angle of less than 80 degrees at the subsatellite point. figure1.5 illustrates the instrument's FOV, swath dimension and camera tracks:

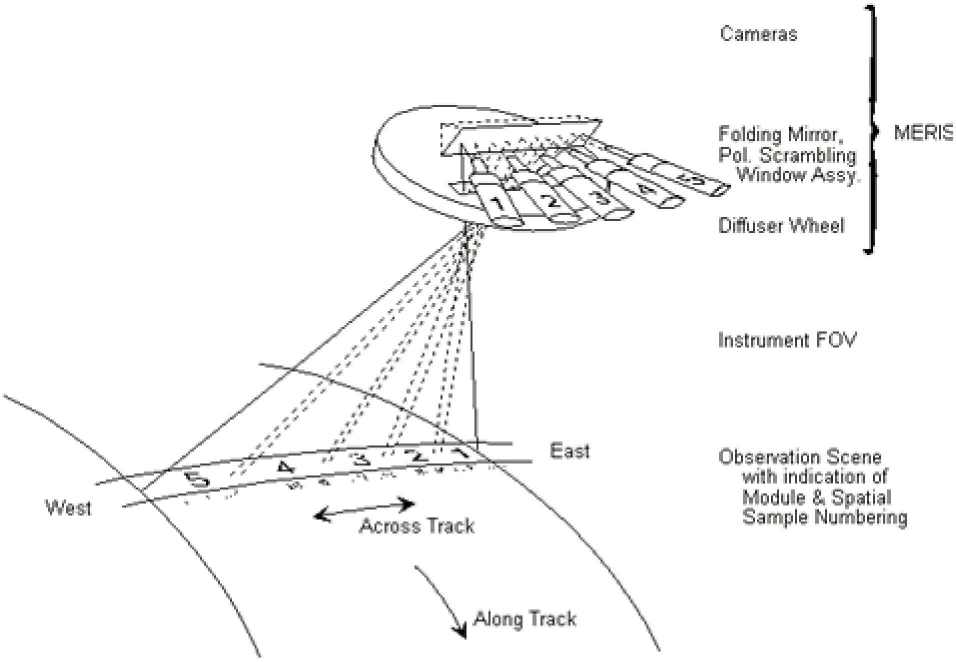


Figure 1.6 - MERIS FOV, camera tracks, pixel enumeration and swath dimension

Spectral Imaging

The observation is performed simultaneously in 15 programmable spectral bands, ranging from the visible to the near infrared (390 nm to 1040 nm). Each of these 15 bands is programmable in position and in width.

Spatial Resolution

MERIS is able to deliver:

- Reduced spatial resolution data
- Reduced and full spatial resolution data simultaneously

These two spatial resolutions, for the nominal orbit are:

- for full spatial resolution: 290 m × 260 m at subsatellite point
- for reduced spatial resolution: 1.2 km × 1.04 km at subsatellite point

An reduced spatial resolution pixel is obtained by averaging the signal of 16 full spatial resolution pixels. More precisely, 4 adjacent pixels across-track for 4 successive pixel lines along-track are used.

1.1.4 Geographical Coverage

MERIS scans the Earth's surface by the so-called push-broom method. CCD arrays provide spatial sampling in the across-track direction, while the satellite's motion provides scanning in the along-track direction. The instrument's 68.5° field of view, nadir pointing, covers a swath width of 1,150 km. at a nominal altitude of 800 km.

Resolutions

MERIS products are available at two spatial resolutions:

Full Resolution (FR) with a resolution at subsatellite point 300 m

Reduced Resolution (RR) with a resolution at subsatellite point 1200 m

Segment Concept

Product partition is performed by segments of 43.5 minutes for the MERIS RR, which consist of that part of the orbit for which the *Sun zenith angle* is below 80°. A MERIS RR segment corresponds to 17,400 km *along track*.

The MERIS FR segment corresponds to the same Sun illumination limitations as for the reduced-resolution mode; however, the acquired data is not necessarily contiguous.

Scene Concept

For the purpose of distribution, the MERIS product is packaged in multiple of scenes of 1,150 km ×1,150 km for the reduced-resolution product; and in scenes of 575 km × 575 km or 296 km × 296 km for the full-resolution products.

RR scenes contain 71 × 71 *tie points* for an 1,150 km × 1,150 km image; FR-1 scenes contain 36 × 36 tie points for an 575 km × 575 km image; FR-2 scenes contain 18 × 18 tie points for an 296 km × 296 km image.

Only a part (called a “Child”) of a acquisition segment could be ordered.

Global Coverage

MERIS's 68.5° field of view allows global coverage to be provided in two to three days, as required by oceanographic, land, and atmospheric investigations. See figure1.5

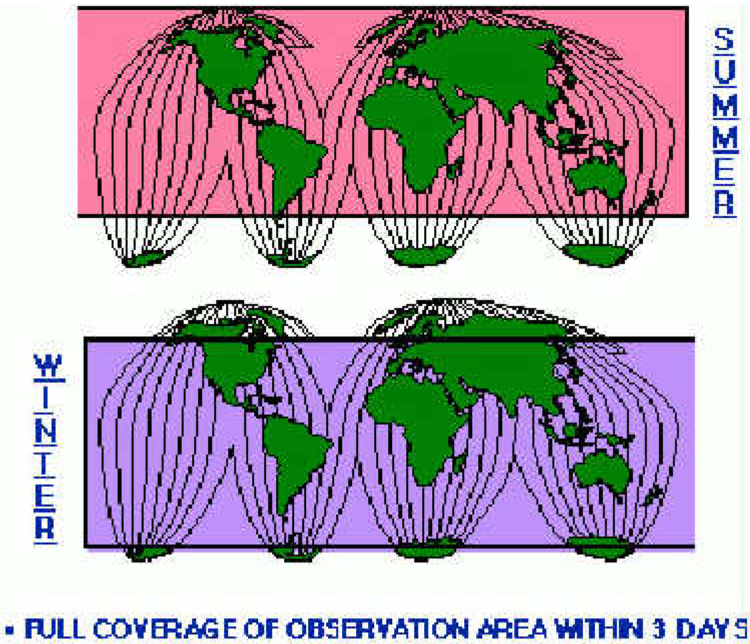


Figure 1.7 - Global coverage

1.1.5 Special Features of MERIS

The global mission of AATSR and MERIS make a major contribution to understanding the role of the oceans and ocean productivity in the climate system, and enhance our ability to forecast change through models. Both sensors offer a large synergistic potential that contributes to climate studies and global change observations in addressing environmental features in a multi-disciplinary way.

MERIS, primarily dedicated to observing oceanic biology and marine water quality through observations of water colour, makes also contributions to atmospheric and land surface related studies. AATSR has, besides its main objective to provide detailed sea surface temperature maps, the capability to measure a range of parameters for cloud microphysics, plus land surface temperature and various vegetation indices over land.

MERIS provides a unique European remote sensing capability for observing oceanic biology and marine water quality through global observations of ocean colour (figure1.6), and provides continuity with other ocean colour sensors such as SeaWiFS and MODIS. AATSR provides continuity with similar ATSR instruments flown on ERS-1 and -2 ensuring the production of a near-continuous 15-year dataset of sea surface temperatures (SST) at an unprecedented accuracy level of 0.3 K or better (figure1.7).

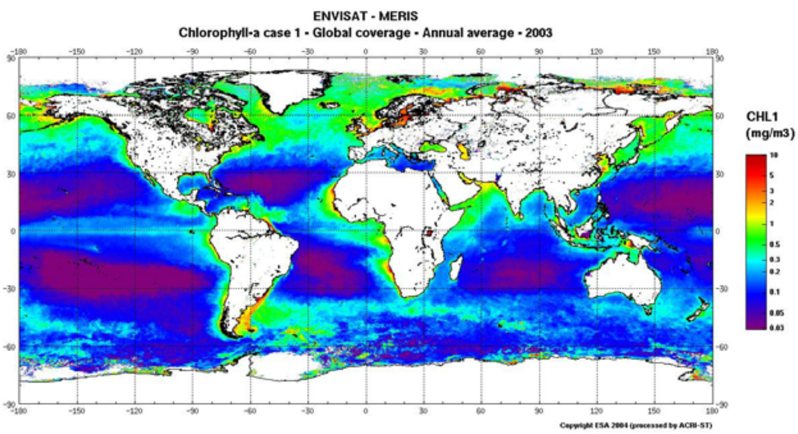


Figure 1.8 - Global ocean colour image

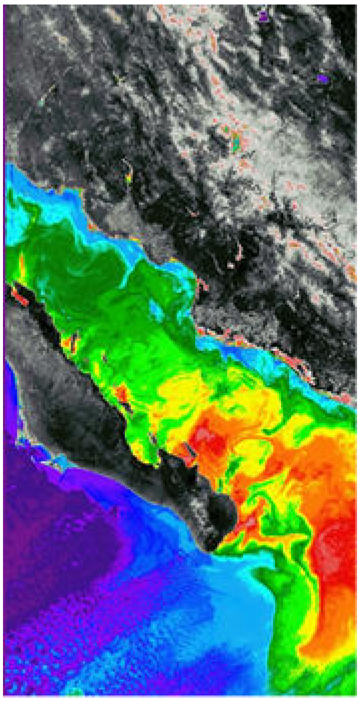


Figure 1.9 - An ATSR-2 11 µm brightness temperature image of the Gulf of California.

The hottest areas (shown in grey) are mostly land. The cooler sea surface temperatures are shown using purple (coolest) to red (warmest). Source: RAL (file: california_sst.gif).

Biogenic material in our oceans accounts for a large portion of their carbon pickup, playing a major role in the Earth's carbon cycle and therefore our climate. Sea surface temperature is one of the most stable of several geographical variables, which, when determined globally, characterize the state of the Earth's climate system. *Phytoplankton* concentrations in the oceans, responsible for the oceans' primary production, need to be known with a high degree of accuracy for their adequate prediction through modelling. Furthermore, the accurate knowledge of marine water constituent concentrations, has become mandatory for the assessment of the water quality in marine ecosystems. In parallel, the precise measurement of small changes in SST provides an indication of significant variations in ocean/atmosphere heat transfer rates and their impact on our physical climate.

AATSR and MERIS are both passive optical imaging instruments measuring radiation reflected and emitted from the Earth's surface. *AATSR* has 4 channels in the visible/near infrared wavelengths and 3 channels in the thermal infrared region. MERIS has 15 channels in the visible and near infrared (see table 1.1 below). The overlap between the instrument bands and the complementary measurements they provide over ocean and land, create novel opportunities for synergetic use of data in many fields of study.

Table 1.1 - MERIS spectral bands and applications.

No.	Band centre (nm)	Band width (nm)	Applications
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 & fluorescence reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	708.75	10	Fluorescence reference, atmosphere corrections
10	753.75	7.5	Vegetation, cloud, O_2 absoption band reference
11	760.625	3.75	O_2 R- branch absorption band
12	778.75	15	Atmosphere corrections
13	865	20	Atmosphere corrections
14	885	10	Vegetation, water vapour reference
15	900	10	Water vapour

This fixed set of bands was recommended by the Science Advisory Group (SAG). The level 2 ESA products have been validated for this set of bands.

The detailed spectral response of each band in each camera is given in document "*MERIS Spectral Characterisation*" (R-10).

1.1.6 Summary of Applications vs. Products

1.1.6.1 Introduction

The following table summarises the MERIS products and gives some examples of how these products can be used for applications. More details of the product formats can be found in the MERIS Products and Algorithms(Chapter 2).

Table 1.2 - MERIS products and applications.

Product ID	Product Name	Application
MER_RR__0P MER_FR__0P MER_CA__0P MER_RV__0P	Reduced Resolution Level 0 Full Resolution Level 0 Calibration Level 0 Reduced Field of View Level 0	Not generally available to users
MER_RR__1P MER_FR__1P	Reduced Resolution Level 1 Full Resolution Level 1	Serve as the basis for level 2 processing Application in atmospheric modelling, land use monitoring, ocean colour monitoring, vegetation indices, and others
MER_RR__2P	Reduced Resolution Geophysical	Ocean, land or atmosphere characterization at 1040 by 1160 m pixel spatial resolution
MER_FR__2P	Full Resolution Geophysical	Climatology, meteorology, environmental monitoring, etc.
MER_LRC_2P	Extracted Cloud Thickness and Water Vapour for Meteorological Users	Intended only for meteorological applications
MER_RRC_2P	Extracted Cloud Thickness and Water Vapour	Intended for meteorological applications
MER_RRV_2P	Extracted Vegetation Indices	Intended for near real time land monitoring
MER_RR__BP	Browse Product	Support queries to a MERIS archive for land, sea, ice or cloud features, to be viewed from a remote user terminal

1.1.6.2 Oceans

The ocean exerts a major influence on the Earth's meteorology and climate through its interaction with the atmosphere. Understanding the transfer of moisture and energy between ocean and atmosphere is therefore a scientific priority. Better observations are needed, to improve the accuracy of weather forecasts of marine conditions and the assessment of climatic change.

Earth observation satellites have revolutionised the study of the ocean. They now provide detailed repetitive measurements over remote areas of the world, where previously there were only a limited number of (isolated) observations from ships and buoys. Microwave instruments, including SARs and radar altimeters, have a remarkable sensitivity to the roughness and height of the ocean surface, enabling the detection of ocean currents, fronts and internal waves, oil slicks and ships, as well as accurate measurement of sea level changes, wave height and wind speed. Optical instruments provide measurements of ocean colour and temperature, which are important indicators of phytoplankton, yellow substance and suspended sediments.

ENVISAT, by including advanced SAR, radar altimeter, ocean colour and ocean temperature instruments together on the same platform, offers particularly exciting opportunities for synergetic measurements over the oceans. It provides an improvement in measurement capability compared with ERS, together with possibilities for many new geophysical measurements. The simultaneous recording of MERIS ocean colour measurements with both AATSR sea surface temperature, and ASAR sea surface roughness offers particularly exciting possibilities.

Ocean Biophysical Properties

There remain major uncertainties about the amount of carbon stored in the ocean and the biosphere, and about the fluxes between these reservoirs and the atmosphere. In particular, there is an important need for better information on the spatial distribution of biological activity in the upper ocean and its temporal variability, especially in the case of oceanic phytoplankton biomass, which has an important role in fixing CO_2 through photosynthesis. In the upper layers of the open ocean, chlorophyll concentration is the most convenient index for phytoplankton abundance and this can be measured using the visible part of the spectrum.

"The remote measurement which has caused the greatest interest within the JGOFS (Joint Global Ocean Flux Study) is the estimation of basin and global-scale variability in the concentration of chlorophyll in the upper ocean. The images of the global distribution of these pigments, derived from data taken by the coastal zone colour scanner (CZCS) onboard the United States' Nimbus-7 spacecraft, have revolutionised the way biological oceanographers view the oceans. For the first time, the blooming of the ocean basins in spring has been observed, as has the extent of the enriched areas associated with the coastal ocean." (International Geosphere-Biosphere Programme [IGBP] A study of Global Change, Report No. 12, 1990).

Although CZCS, launched in 1978, was intended as a one-year proof-of-concept mission, the sensor continued to transmit data over selected oceanic test sites until early 1986. The figures below show examples of CZCS chlorophyll maps of the Earth and the Mediterranean Sea.

Remotely sensed information about global ocean colour is once again available; firstly from the OCTS and POLDER instrument on the Japanese ADEOS mission, from the NASA SeaWiFS satellite launched in August 1997, and from the MOS instrument on IRS-3. MERIS provides data continuity with improved spectral and spatial performance. This results from the use of several near-infrared channels to perform atmospheric corrections, and several narrow visible channels to compute radiance values.

Phytoplankton abundance varies from less than 0.03 mg m^{-3} in oligotrophic waters (i.e., waters poor in nutrients and therefore in phytoplankton), up to about 30 mg m^{-3} in eutrophic waters (i.e., in nutrient rich waters, supporting high biomass). Ocean colour responds in a non-linear way to these large changes in chlorophyll content. It is conveniently depicted by the ratio of blue-to-green radiation backscattered by the ocean, with the ratio that is most sensitive based on wavelengths of 445 and 565 nm. It varies within a range of 1 to 20 for the types of pigments considered, and decreases, almost linearly, with the logarithm of the concentration.

Coastal Waters

The coastal regions are the most populated areas in the world and coastal waters are highly affected by human activities. Marine ecosystems are affected by the influx of large amounts of agricultural and industrial pollutants and sewage from rivers which may inhibit or stimulate marine productivity.

Continuous long-term observation of coastal waters, which cover more than three million square kilometres, is most important for regional climate impact studies and for environmental monitoring. Remote sensing measurements from satellite are the only available means of monitoring such large areas of water.

The major water constituents, which determine the marine and estuarine ecology and the bio-geochemical budget and whose concentration and distribution can be determined by optical remote sensing, are suspended matter, phytoplankton and Gelbstoff.

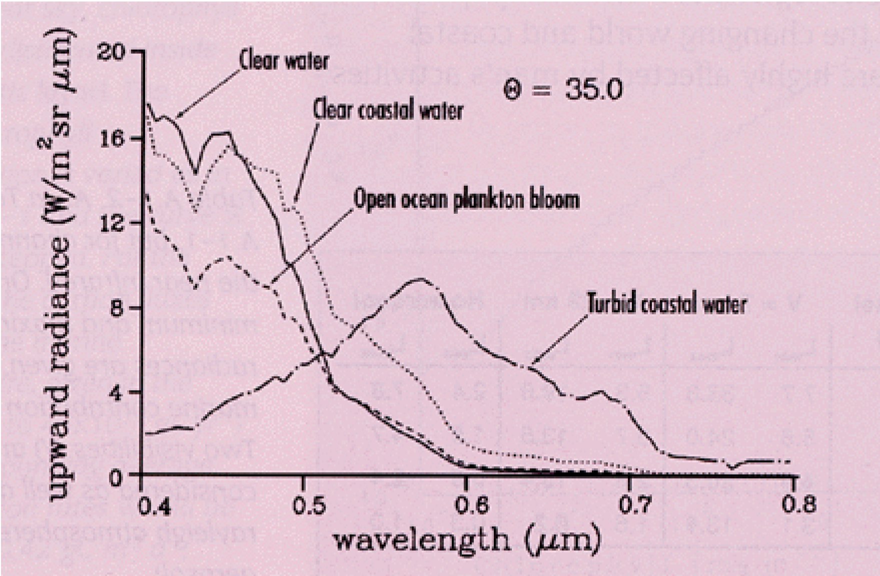


Figure 1.10 - Simulated multispectral radiances for a spectral resolution of 5 nm just above the water surface

Suspended matter is defined as a combination of:

- inorganic particles and *detritus*, present due to re-sedimentation and advection processes
- atmospheric inputs
- dead material of plankton

Gelbstoff consists of various polymerised dissolved organic molecules which are formed by the degradation products of organisms. These originate in brackish and underground water as well as in extraordinary plankton *bloom*s. All these constituents have different optical properties, but there are similarities in their spectral scattering and absorption coefficients.

The upward radiance at any visible wavelength is composed of contributions from all these substances.Figure1.9 above shows simulated multispectral radiances for different ocean waters. Suspended matter usually enhances the upward radiances through reflection within the visible spectrum, while Gelbstoff reduces these radiances mainly in the blue.

To convert from the optical properties of the water constituents, used in the radiative transfer model, to pigment or suspended matter concentration units, robust algorithms have been developed with global applicability. The accuracy of derived oceanic properties depends strongly on the precision of the atmospheric correction procedure.

The development of inverse modelling techniques for the interpretation of MERIS measurements is an ongoing process. For monitoring coastal regions world wide, precise multispectral radiances, with contemporary optical and concentration measurements of the water constituents, are needed. As well as the *chlorophyll* concentration and several atmospheric parameters, planned geophysical products include *total suspended matter* and *yellow substance* concentration.

1.1.6.3 Atmosphere

Satellite remote sensing provides a unique way of monitoring the complex and dynamic processes that occur in the atmosphere. Since the future of the human race is critically dependent on the long term variability of the atmosphere, great efforts are being made to understand the many processes involved. In response to this, researchers develop models of the atmosphere as a mechanism whereby chemical reactions and physical changes in the atmosphere can be placed in context within the overall Earth system.

Such models require large amounts of data describing the spatial and temporal variability of the Earth's atmosphere at different locations and altitudes around the globe, taking account of diurnal, seasonal and longer-term cycles. Sources, reservoirs and sinks of critical trace gases all need to be described. Satellite remote sensing provides a powerful set of techniques for acquiring these data to sustain models of the atmosphere, especially where information is required on a global scale and within a short time span.

Atmosphere Constituents

Many of the factors affecting the global environment are related to changes in the chemical composition of the atmosphere. The results of these changes include: the enhanced greenhouse effect, increase in the levels of ultraviolet-B radiation reaching the Earth's surface, acidification and reduced transparency. The atmosphere is very dynamic, both in terms of chemical composition and associated radiative properties, and also in the way it transports materials around the globe, providing a link between land and ocean. The key role of the atmosphere in the maintenance of the Earth's environment emphasises the need to conduct research, to understand properly the processes involved and to monitor long-term changes.

As a result of man's activities, which have become progressively more significant over the last century, large quantities of carbon, chlorine, nitrogen and sulphur compounds have been injected into the atmosphere and are disrupting the natural equilibrium which had become established. Whilst long-term change has always been a feature of the atmosphere, it has become apparent that it is the increased rate of change, brought about by man's activities, which is having such a potentially detrimental effect on the Earth's system.

The reduction in stratospheric ozone concentrations over Europe since 1960 is the direct result of the use of ozone depleting chemicals such as refrigerants, industrial cleaners, foaming agents and those in fire extinguishers. Conversely, pollution at the Earth's surface has led to increased levels of tropospheric ozone, particularly over industrial areas, with consequent threats to human health. No other chemical in the *troposphere* has a concentration which is so close to being toxic.

The greenhouse effect, shown in figure1.10 below, concerns the warming of the troposphere by increasing concentrations of the so-called greenhouse gases (carbon dioxide, methane, nitrous oxide, ozone and others). This warming occurs because the greenhouse gases are transparent to incoming solar radiation, but absorb infrared radiation from the Earth that would otherwise escape from the atmosphere into space. The greenhouse gases then re-radiate some of this heat back towards the surface of the Earth. The rise in carbon dioxide as a result of industrialisation is primarily responsible for the enhanced greenhouse gas effect. Current carbon dioxide levels are more than double pre-industrial levels and are the focus of international efforts to reduce emissions and offset the consequences of changed climate patterns, sea level rise, effects on hydrology, threats to ecosystems and land degradation.

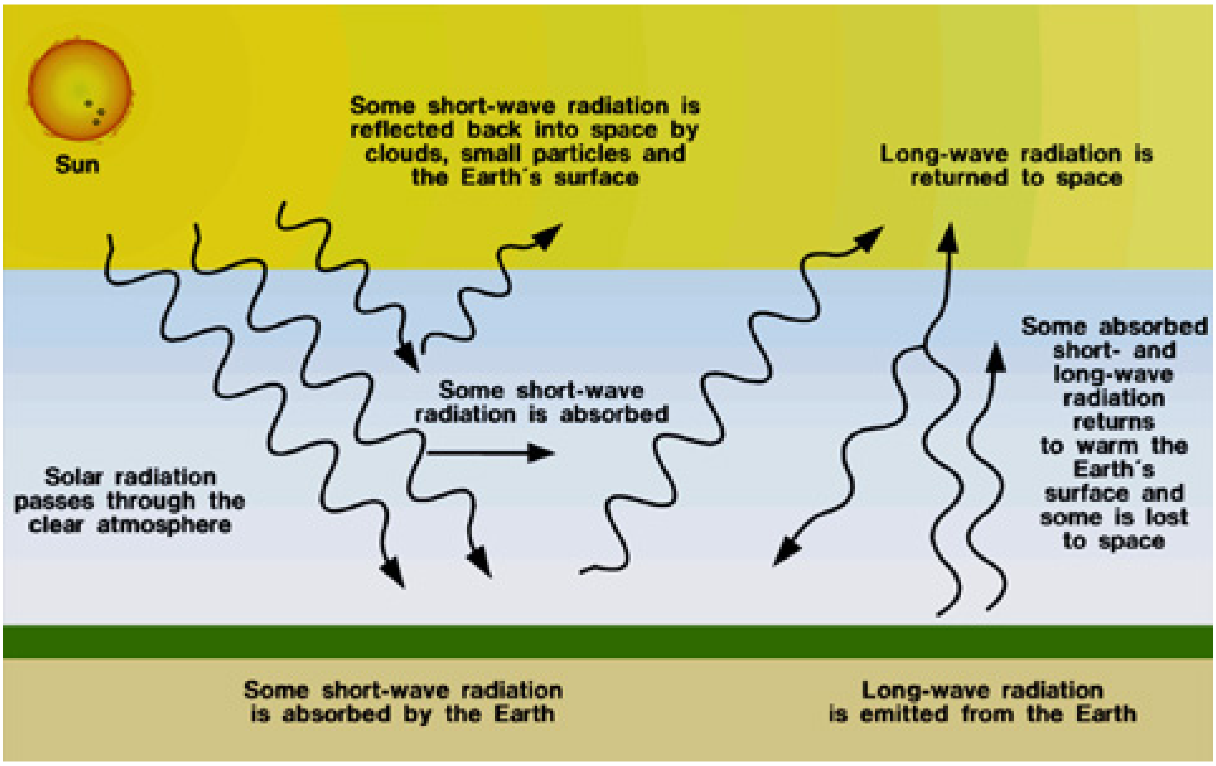


Figure 1.11 - Figure 1.10 The greenhouse effect

Many studies of the effect of greenhouse gases on the climate have and are being carried out. An effective doubling of carbon dioxide concentrations is now predicted for 2030, which is expected to produce an estimated temperature rise of between 1.5° and 4.5°C, but with considerable variations in the rate of warming in different regions. The situation is highly complex due to mechanisms whereby, for example, an increase of sulphur dioxide in the atmosphere, through industrialisation, reduces the greenhouse effect because of an increase in the atmosphere's reflectivity.

While predictions continue to be refined, the overall objective remains as that set out in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), which calls for the stabilisation of greenhouse gas concentrations at a level that prevents dangerous anthropogenic interference with the climate system, and in a time frame that allows ecosystems to adapt naturally.

The amount of water vapour in the atmosphere is an important component of the Earth's climate system. It varies considerably in response to variations in temperature and *relative humidity* and acts as an energy carrier, redistributing energy around the planet. Water vapour has a large radiative effect and is the most important greenhouse gas. Water, in the form of clouds, liquid or ice, modifies the radiation reaching the surface and thereby strongly influences the surface energy flux. The role of clouds in the climate system is poorly understood and this undermines the overall validity of modelling and prediction activities. Research into the influence of water vapour and clouds is needed in order that anthropogenic effects can be isolated from long-term natural climate variations. MERIS contributes to this field by providing the column *water vapour content* over land, oceans, and clouds.

Aerosols

There is evidence to suggest that in recent decades there have been long-term changes in aerosol loading in the *stratosphere*. For example, amounts of sulphate aerosol in the stratosphere increased significantly in 1991 and 1992 as a result of the 1991 eruption of Mount Pinatubo. GOME data has been analysed to produce estimates of SO2 loading of the atmosphere; for example, from the eruption of the Nyamuragira volcano in Zaire. Whilst there is a good relationship between the degree of aerosol loading and volcanic events, an upward trend has been detected in background levels.

The impact of aerosols on the Earth's radiation budget (see below) is both direct, through scattering and absorption, and indirect, through the modification of cloud properties. In both cases, aerosols in the stratosphere seem to have a cooling effect with regard to the Earth's radiation budget. Sulphate aerosol loading in the mid-latitudes has also been correlated with ozone trends in mid-latitude and polar regions, through a modification of the concentration of gases involved in ozone depletion. However, the extent to which aerosols influence the Earth's climate has been difficult to assess since aerosols vary a great deal in terms of size, shape and chemical composition. Satellite-borne sensors have the potential to improve knowledge of the origin, dynamics and fate of aerosols, through their ability to monitor the whole globe within very short data capture repeat cycles. Critical to the determination of aerosol types is the wavelength dependence of extinction coefficients in the visible and near infrared parts of the spectrum.

The use of spaceborne instruments to measure aerosols in the stratosphere is well established. The SAGE (Stratospheric Aerosol and Gas Experiment) series of instruments has demonstrated the concept and share features with the atmosphere sensors onboard ENVISAT; with GOMOS in particular. Several of the instruments onboard ENVISAT are capable of making aerosol measurements with sufficient spectral coverage to determine size distribution and composition. GOMOS and MIPAS make observations of the distribution and structure of the stratospheric aerosol layers. Moreover, the ability of MIPAS to acquire data perpendicularly to its flight direction, strengthens its ability to record aerosol injections into the stratosphere from volcanic eruptions. SCIAMACHY provides further information about aerosols through its ability to make polarisation measurements, and its large spectral coverage. MERIS has the capacity to evaluate tropospheric aerosol properties including optical thickness and type.

Earth Radiation Budget

Processes in the atmosphere which alter the Earth's radiation budget need to be better understood. To achieve this, it is necessary to monitor certain trace gases and other constituents such as aerosols, whose temporal changes affect the Earth's climate by modifying radiative transfer. Long-term global measurements improve current assessments of changes in the abundance of ClOX, HOX, and NOX which are associated with decreases in stratospheric temperatures through their impact on radiative transfer in the atmosphere. Observations on the extent of radiative cooling of the atmosphere can be obtained from measurements of CO_2 and NO in the middle atmosphere.

Of particular interest, in the context of the "greenhouse effect", is the transportation of water vapour from the surface of the Earth into the free troposphere. While climate models have suggested that this is a phenomenon associated with global warming, there is no firm evidence suggesting that the free troposphere is becoming moister and therefore providing the positive feedback necessary to stimulate global warming to the levels being suggested. In terms of radiation budget, water vapour is the most important atmospheric gas in the context of cloud amount, precipitation and evaporation rates. Even small changes in global measurements of cloud albedo have a significant effect on the Earth's radiation budget.

MERIS contributes to this work by providing information on cloud amount, cloud top height, cloud optical thickness, water vapour and cloud albedo, as well as the aerosol information discussed above. Cloud coverage and other parameters, including water/ice discrimination and particle size distribution, are also available from the visible channels on AATSR. The MWR instrument also produces total column measurements of water vapour and liquid water.

1.1.6.4 Land

General

The Earth's land surface is a critical component of the Earth system as it carries over 99% of the biosphere. It is the location of most human activity and it is therefore on land that the human impact on the Earth is most visible. Within the biosphere, vegetation is critical as it supports the bulk of human and animal life and largely controls the exchanges of water and carbon between the land and the atmosphere.

Observations of the land surface by ENVISAT allow the characterisation and measurement of vegetation parameters, surface water and soil moisture, surface temperature, elevation and topography. Global scale measurements (1 km resolution) provide critical data sets for improved climate models, in particular estimates of albedo, vegetation productivity and land surface fluxes.

ENVISAT also provides managers of local natural resources with a capability to monitor their land with detailed (selective) observations on a monthly basis. In particular, ASAR provides 30 m spatial resolution multi-look images for monitoring economically important land units, such as agricultural fields and forest compartments. Natural resources can also be monitored at global and regional scales every few days using the low-resolution imaging of MERIS, AATSR and the ASAR Global Mode.

The relatively high frequency of global coverage provided by ENVISAT is also of great value for hazard monitoring, in which locally infrequent events such as earthquakes, volcanic eruptions, floods and fires, require intensive observation over short periods. The beam steering mode of ASAR (in conjunction with its independence from cloud and illumination conditions) also permits (at least) 3-day repeat observation of certain localised events at high spatial resolution. Although locally rare, certain natural hazards are frequent events on a global scale, thus they can have substantial effects on climate, especially large vegetation fires and volcanic dust clouds. Hazard monitoring is therefore an important component of the ENVISAT mission.

Global Land Cover

A major scientific uncertainty in global change research is the cycling of carbon in the Earth system. It is well known that CO_2 contributes to the greenhouse effect and that over the last few centuries increased human activity, especially the burning of fossil fuels and deforestation, have resulted in an increase in the release of CO_2 into the upper atmosphere. Much of the estimated anthropogenic CO_2 emission cannot currently be accounted for, indeed there is an order of magnitude uncertainty in the global carbon budget.

Critical to this carbon accounting activity is global vegetation monitoring. Figures below show a global land cover product, and a forest map of S.E Asia, both derived from 1 km AVHRR data, The narrow bands of MERIS make it possible to derive more accurate global maps and more effective vegetation indices than have previously been available. From physically based vegetation indices, it is then possible to retrieve key variables in modelling plant productivity (and thus carbon sequestration), surface-atmosphere gas exchanges and energy transfers at the land surface.

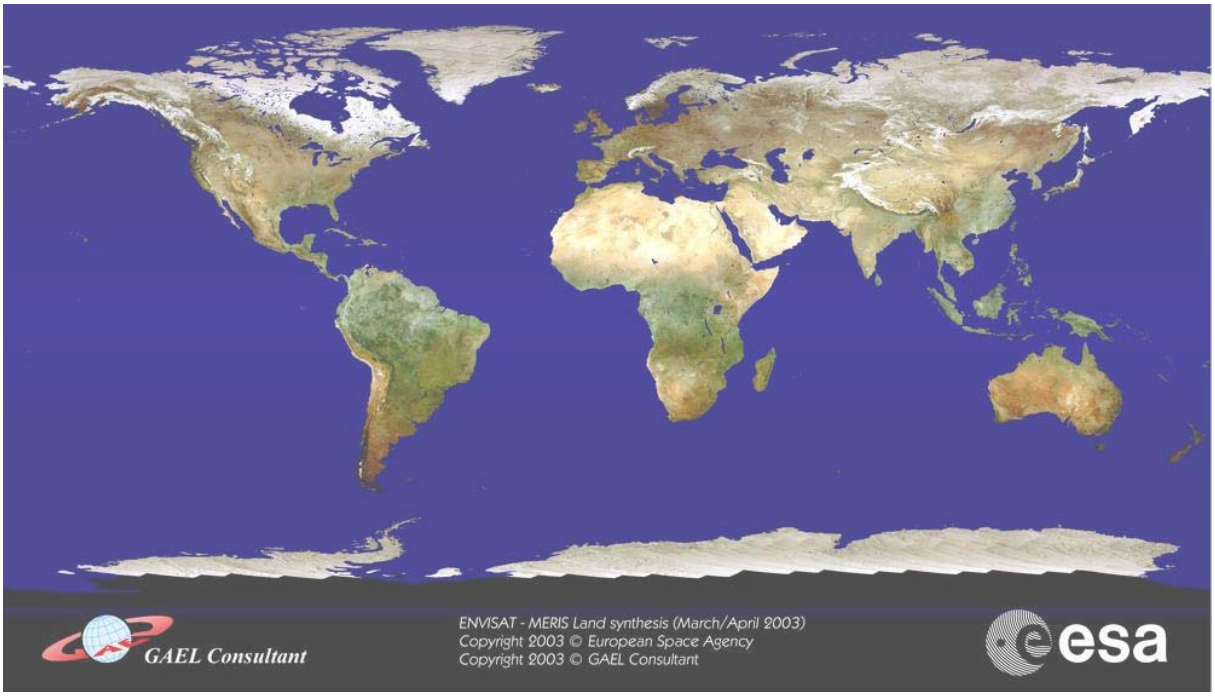


Figure 1.12 - Global MERIS land cover map.

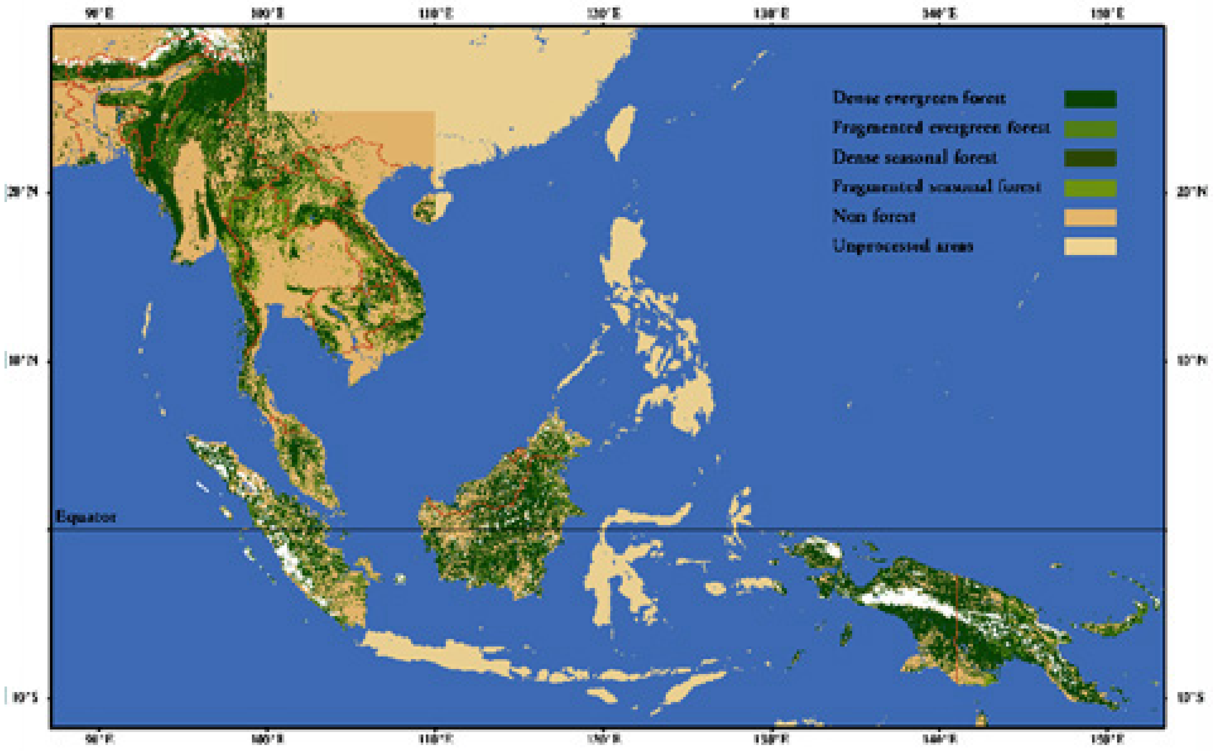


Figure 1.13 - Forest map of Southeast Asia (Acknowledgment: JRC/ESA TREES Project.).

For practical reasons (e.g., obtaining sufficient cloud-free coverage on a seasonal basis), global vegetation monitoring is based on low resolution (1 km) data. However, vegetation products (such as land cover, leaf-area index and *biomass*) at this resolution cannot be validated directly and this is usually done by scaling up data collected at higher resolution on a sample site basis. The availability of contemporary data sets at resolutions of 1000 m from *AATSR*, 300 from MERIS and 30 m from *ASAR*, is thus of key importance in producing and validating global vegetation products.

Agriculture

The control of subsidies at the field level using satellite remote sensing has become an operational activity in Europe. Inventory and estimation of agricultural yields at a national and international level has not been so widely used, but is becoming more operational, particularly in developing countries. *ASAR* provides important data for this, with supporting products also coming from MERIS and *AATSR*.

The *ERS* programme has demonstrated the ability of satellite radars, independent of weather conditions, to identify crops and monitor seasonal land cover changes. Multi-temporal techniques are used, which involve the collection and analysis of *SAR* data on a series of different dates over the period of interest.

figure1.13 below shows a sequence of 9 ERS SAR images (each 3.75 km x 3.75 km) taken over the crop growing season (January to November 1993) in Flevoland, The Netherlands. figure1.14 shows the corresponding *backscatter* temporal profiles for the three winter wheat fields highlighted. Research carried out with ERS data has shown that many crop types have distinctive temporal profiles which can be used successfully for crop classification purposes. ERS data are now being used operationally within major European programmes concerned with agricultural statistics (*MARS STAT*) and the control of agricultural subsidies (*MARS CAP*). Within MARS STAT the use of ERS data has improved the estimation of crop area early in the crop growing season. ERS data are used as a substitute for optical data in the MARS CAP control activity when cloudy conditions are encountered at key times during the crop growing season.

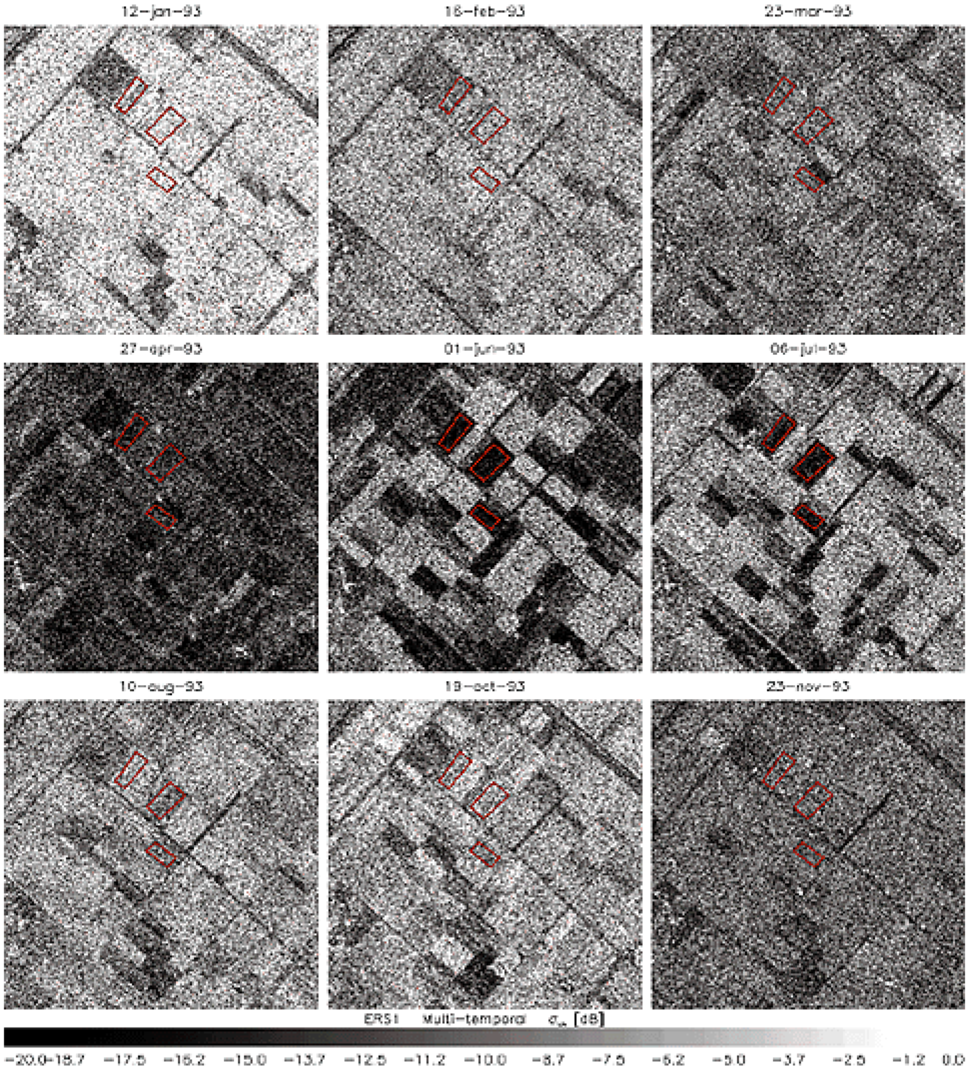


Figure 1.14 - Time Series.

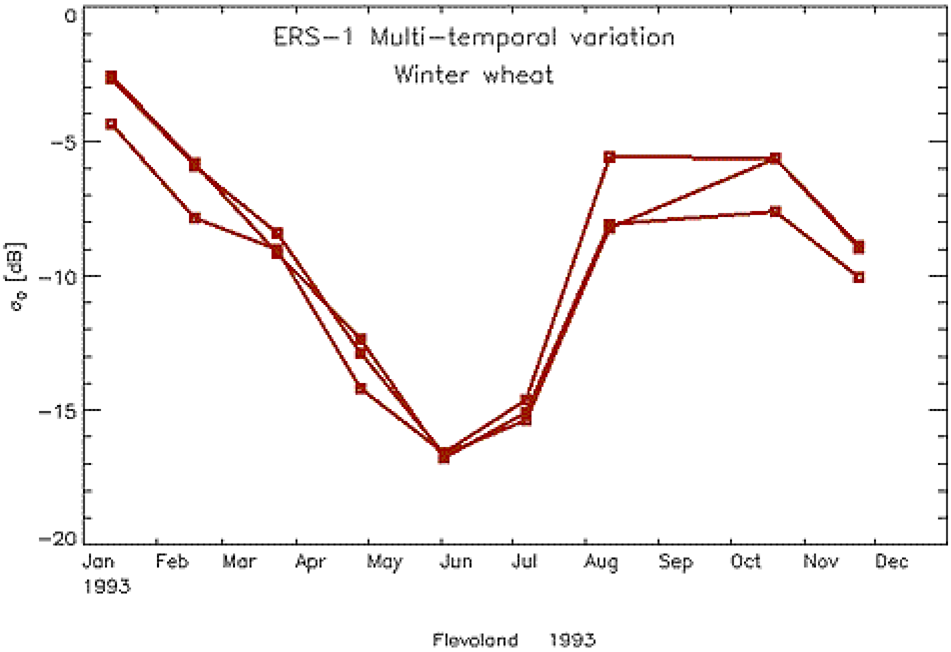


Figure 1.15 - Temporal Backscatter Profiles.

Time series of ERS-1 images covering (a) the crop growing season, and (b) temporal backscatter profiles for the 3 winter wheat fields highlighted, Flevoland, The Netherlands. (Acknowledgment: M. Borgeaud, ESTEC.)

Mapping the area of crops, for the policing of subsidies and crop area inventories, is expected to continue as a primary application to be supported by ENVISAT. However, yield estimation techniques also are improved through the availability of ENVISAT data. Regional yield estimation has been previously accomplished by exploiting the temporal curve of vegetation response obtained from satellite borne instruments such as *AVHRR* which have low spatial resolution but frequent revisit capability. This information is compared with previous years and combined with meteorological data and crop growth modelling to predict year-on-year yield variations.

MERIS greatly improves the quality of the spectral information compared to *AVHRR*, as its spectral bands are narrower and less sensitive to atmospheric effects. MERIS calibration and atmospheric correction is also more accurate than AVHRR, and the spatial resolution is improved while still providing regional revisit every 3 days. Although the *VIS*/NIR bands on *AATSR* are broad, the superior atmospheric correction capability and multi-angle view assist in improving estimates of bidirectional reflectance distribution functions for crop growth modelling. *ASAR* could also contribute to improved crop yield estimates and the identification of stress and disease in crops, particularly in very cloudy areas, but considerable research still needs to be undertaken to prove the potential of *ASAR* data in these areas.

Hydrology

Hydrology in particular benefits from ENVISAT, as detailed spatial and temporal information on a wide range of land surface parameters is required in order to run physically based models and management scenarios. Major variables that can be derived from ENVISAT observations include land surface temperature, vegetation state, soil moisture, surface roughness, and terrain. Much hydrological modelling is based on gridded data at around 1 km. Because of its narrower bands and improved radiometry, MERIS may be better suited to providing vegetation parameters for hydrology than other instruments such as *AVHRR*. Some hydrological applications require information on snow cover distribution and snow-water equivalent. Research is required on how to derive these variables from *ASAR* data at high incidence angles, particularly in mountainous terrain.

Forestry

Forestry information is important as an aid to formulating land use, forest and environment policy, for long-term regional, national and local planning, and for the assessment and monitoring of natural resources, ecosystems and the environment. The qualitative information requirements include vegetation and forest type, species composition, vigour and health, as well as site conditions. The quantitative requirements include area, volume, age and density of forest stands as well as growth forecasts for sustained production. For large parts of the world, and specifically in developing countries, forest maps and statistics are outdated, unreliable, or sometimes nonexistent. For regional inventories, available national maps and statistics are difficult to compare.

Global and regional forest inventory for change detection, particularly of tropical forests is an important aspect of global vegetation mapping to which *ASAR*, *AATSR* and MERIS provide improved capabilities.

1.2 How to Use MERIS Data

This chapter gives guidelines on the usage of MERIS data using various tools.

1.2.1 Software Tools

General tools, such as EnviView, are applicable to all ENVISAT products, including MERIS but with limited capabilities to take the MERIS-specific characteristics into account. Instrument-specific tools are dedicated to the application of MERIS products and support fully the MERIS products and provide tailored functions.

1.2.1.1 General Tools

Users may wish to decode data in the ENVISAT format themselves, to allow subsequent visualisation and further processing in languages such as C, or in commonly available software packages such as IDL, ENVI, PCIWorks and Erdas Imagine. The MERIS and AATSR Toolbox 1.2.1.3. provides functions and C routines for direct ingestion of MERIS data into commercial software or a user's own programmes.

The EnviView tool can also be used to convert ENVISAT data into hdf files. The data can then be automatically read by any software supporting this format.

1.2.1.2 EnviView

EnviView is a software tool, provided free of charge to Envisat data users, that decodes and displays data from any Envisat data file (levels 1b and 2, and auxiliary processor configuration files). It is able to display the value of any field in the data product, and provide limited visualisation capabilities. It is also able to extract and export data to HDF and plain text files.

For further information refer to http://earth.esa.int/services/tools/enviview/.

1.2.1.3 BEAM

Basic Toolbox for ENVISAT (A)ATSR and MERIS

Overview

The Basic Toolbox for ENVISAT (A)ATSR and MERIS (BEAM) is a collection of executable tools and an application programming interface (API) which has been developed to facilitate the utilisation, viewing and processing of ESA MERIS, (A)ATSR and ASAR data. The purpose of the BEAM is not to duplicate existing commercial packages, but to complement them with functions dedicated to the handling of ENVISAT MERIS and AATSR products.

The main components of the BEAM are:

VISAT - A visualization, analysing and processing software, entirely written in Java

A set of scientific tools running either from the command line or invoked by VISAT, also entirely written in Java.

The BEAM Java API provides software frameworks and helpers for application development and new extension modules

ENVISAT MERIS/AATSR Product Access API for ANSI C allowing reading access to these data products using a simple programming model.

The development of the BEAM software is targeted as an open source project and comes with full source code.

More information is available from the EnviSat web site at http://envisat.esa.int/beam or from http://www.brockmann-consult.de/beam/ .

1.3 Image gallery

A gallery of images is available at the following addresses:

MERIS acquisition images
http://earth.esa.int/isc/white.pl?search=&sat=ENVISAT

ESA News : Protecting the environment
http://www.esa.int/esaCP/ESACGIF18ZC_Protecting_0.html

Image of the day
http://www.brockmann-consult.de/ImageOfTheDay/index.htm

Chapter 2

MERIS Products and Algorithms

2.1 Introduction

2.1.1 MERIS products overview

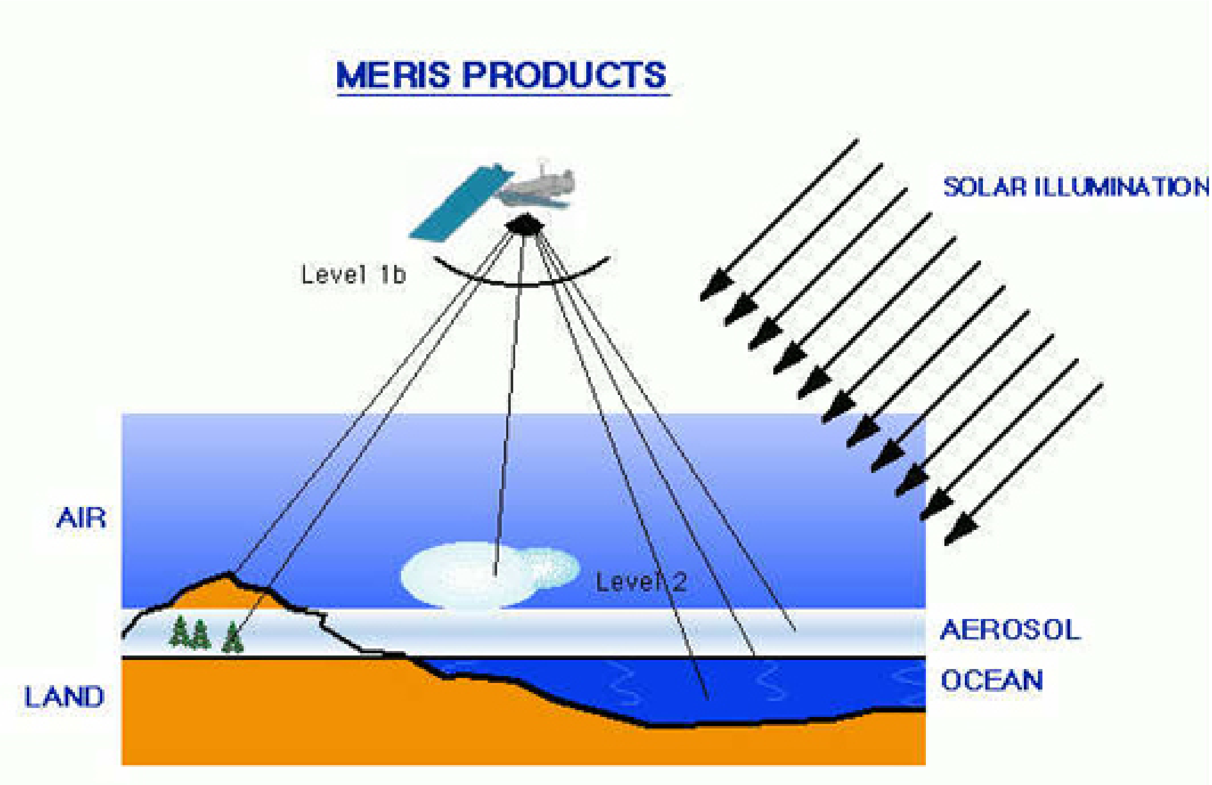


Figure 2.1 - MERIS Products.

2.1.1.1 MERIS product processing levels

The ENVISAT nomenclature of the products delivered to the public describes three types of processing levels:

level 1B – are images resampled on a path-oriented grid, with pixel values having been calibrated to match the Top Of Atmosphere (TOA) radiance.

level 2 – are images deriving from the level1B products, with pixel values having been processed to get geophysical mesurements.

level 3 – are synthesis of more than one MERIS products (and possibly external data) to display geophysical measurements for a time period.

Figure below (see Figure 2.2 -) shows the difference between level 1B and level 2 products. See http://earth.esa.int/showcase/env/North_America/HurricaneIsabel_CTP_MER_RR_Orbit07965_20030908.htm for more information about these images.

Examples of level 3 products are provided in section 1.1.2.2.

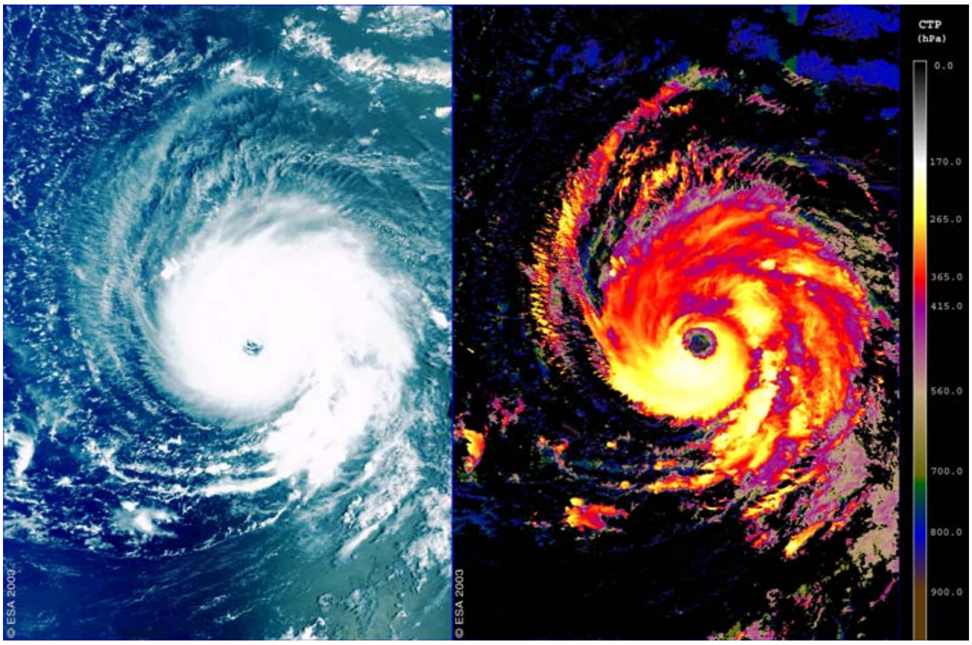


Figure 2.2 - Level 1B RGB composition (left) and Cloud Top Pressure (right) Example of hurricane Isabel acquired on 8th Septembre 2003.

2.1.1.2 Full and reduced resolutions

MERIS data are provided at 3 different levels of processing - Level 0, Level 1, Level 2 - and at 3 different spatial resolutions - Full, Reduced and Low. They may also be sorted and visualised very easily using a browse product (RGB colour coded images of full-resolution data). Child products, including a limited number of measurement data sets, may also be available in reduced and full resolution.

For the same image, a Full-Resolution *(FR)* image has 4 × 4 more points (pixels) than the same image in Reduced Resolution *(RR)*, and an RR image has 4 × 4 more points (pixels) than the same image in Low Resolution (*LR)*. Accordingly, a pixel in an FR image represents an area of 260 m × 290 m, in an RR image an area of 1,040 m × 1,160 m, and in LR an area of 4,160 m × 4,640 m.

The instrument always takes measurements with full resolution; i.e., 260 m × 290 m ground resolution. Onboard averaging generates the RR images, while LR images are generated in the ground processor by further averaging the RR data.

Full-resolution images can be provided either as scenes or as imagettes. A scene is a half-swath square image. An imagette is a quarter-swath square image.

The different MERIS products primarily hold:

- instrument source packets for a Level 0 Product
- Top Of Atmosphere (TOA) radiances measured in the 15 MERIS bands for a Level 1 product
- geophysical quantities varying according to the underlying surface identified (land, ocean, or clouds) for a Level 2 product.

In addition to the core geophysical data, MERIS Level 1 and Level 2 products contain:

- geometric information to allow the user to locate the image on the Earth's surface data describing the Sun and viewing geometry

additional annotation data such as coastline information

terrain height

meteorological data

scaling factors to allow the user to decode the data from numerical counts to geophysical meaningful values

flags that address the quality and the validity of the image

The Level 0 products are generated and archived routinely in both RR and FR, whereas the FR MERIS Level 1b and Level 2 products (scenes or imagettes) are generated on request only.

A reduced resolution product contains data on 1,121 columns (1,165 km) with a number of lines that may vary from product to product. An entire orbit is covered with 15,057 reduced resolution lines. A full-resolution product contains data on 2,241 × 2,241 pixels (i.e., 582 km × 650 km) for a scene and 1,153 × 1,153 pixels (i.e., 300 km × 334 km) for an imagette.

2.1.1.3 MERIS product types

Table 2.1 gives an overview of the MERIS products:

Table 2.1 - MERIS Products.

Instrument/Mode	Product ID	Description
MERIS	MER_CA__0P	MERIS Level 0 Calibration (all calibration modes)
	MER_RR__0P	MERIS Level 0 Reduced Resolution
	MER_RR__1P	Reduced Resolution Geolocated and Calibrated TOA Radiance (Stripline)
	MER_RR__2P	Reduced Resolution Geophysical Product for Ocean, Land and Atmosphere (Stripline)
RR	MER_RRC_2P	Extracted Cloud Optical Thickness and Water Vapour at nominal reduced resolution (Stripline) extracted from MER_RR__2P for NRT distribution

	MER_RRV_2P	Extracted Vegetation Indices (Vegetation indices including atmospheric corrections for selected land regions) at nominal reduced resolution (Stripline) extracted from MER_RR__2P for NRT distribution
	MER_RR__BP	Browse (covers FR and RR requirements) (Stripline)
LR	MER_LRC_2P	Extracted Cloud Optical Thickness and Water Vapour at low resolution (4.8 km, Stripline) for METEO Users generated from MER_RR__2P
FR	MER_FR__0P	MERIS Level 0 Full Resolution
	MER_FR__1P	Full-Resolution Geolocated and Calibrated TOA Radiance
	MER_FR__2P	Full-Resolution Geophysical Product for Ocean, Land and Atmosphere

The MERIS product tree is shown here below.

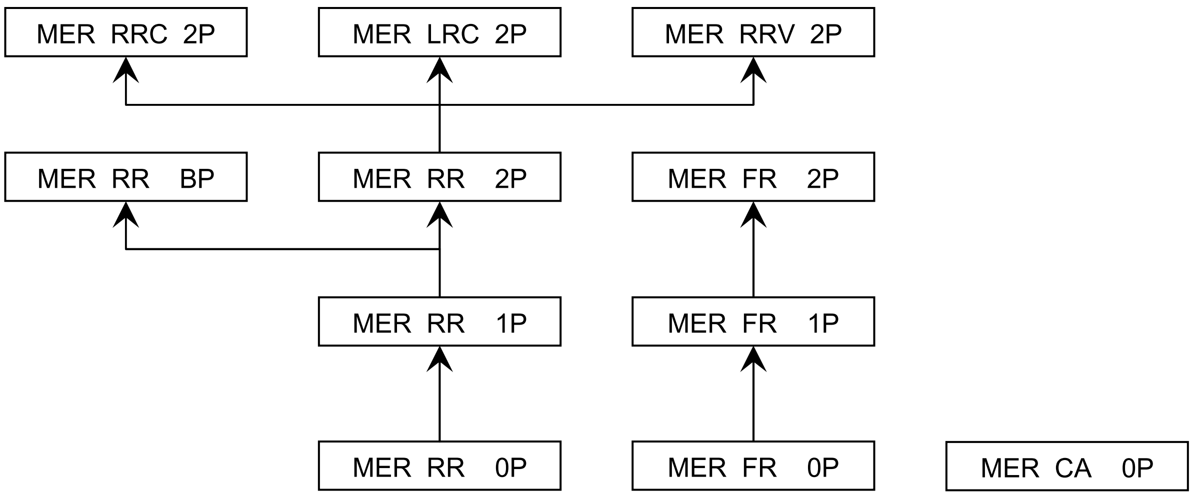


Figure 2.3 - MERIS Product Tree.

2.2 Organisation of Products

2.2.1 File naming convention

2.2.1.1 Product identification scheme

As detailed in the "Envisat-1 Products Specifications - Volume 4 – Product overview" document (R-6), MERIS products are identified according to the following syntax:

MER_XXX_YZ

where

XXX — is the mode (when relevant) or contains letters used to differentiate between several products created at the same processing level (e.g., several Level 2 products. Unused letters are replaced by underscore characters. These codes are instrument specific.

Y — is the product level code:
- 0: Level 0,
- 1: Level 1B,
- 2: Level 2,
- B: Browse

Z — indicates whether the product is a Parent (also called segment for MERIS acquisition) or Child (extracted) product:
- P : Parent Product
- C : Child Product

As listed below, all the MERIS products obey the above syntax.

Table 2.2 - MERIS product names.

MER_CA__0P	MERIS Level 0 Calibration (all calibration modes)
MER_RR__0P	MERIS Level 0 Reduced Resolution
MER_RR__1P	Reduced Resolution Geolocated and Calibrated TOA Radiance (stripline)
MER_RR__2P	Reduced Resolution Geophysical Product for Ocean, Land and Atmosphere (stripline)
MER_LRC_2P	**Extracted Cloud Thickness and Water Vapour for Meteo users. Level 2 Product generated from MER_RR__2P (Cloud thickness and water vapour content for the Meteo at reduced resolution > 5 km) (stripline)**
MER_RRC_2P	Extracted Cloud Thickness and Water Vapour (non-Meteo users). Level 2 product extracted from MER_RR__2P (Cloud thickness and water vapour content at nominal RR resolution) for NRT distribution (stripline)
MER_RRV_2P	Extracted Vegetation Indices. Level 2 product extracted from MER_RR__2P (Vegetation indices including atmospheric corrections for selected land regions) for NRT distribution (stripline)
MER_RR__BP	Browse (covers FR and RR requirements) (stripline)
MER_FR__0P	MERIS Level 0 Full Resolution

MER_FR__1P	Full Resolution Geolocated and Calibrated TOA Radiance
MER_FR__2P	Full Resolution Geophysical Product for Ocean, Land

2.2.1.2 Acquisition identification scheme

As detailed in the “Envisat-1 Products Specifications – Annex A – Product data conventions” document (R-9), the second part (see the first part in the section above) of the MERIS product file names identifies the acquisition context according to the following syntax:

`MER_XXX_YZ`**`pGGGyyyymmdd_HHMMSS_ttttttttPccc_OOOOO_aaaaa_QQQQ.SS`**

Example : `MER_FR__1PNUPA20030921_092217_000000982020_00079_08149_0354.N1`

where

p — is processing stage flag :
- N: Near Real Time product,
- V : fully validated (consolidated) product,
- T : test product,
- S : special product.

GGG — identifies the center which generated the file:
- PDK = PDHS-K
- PDE = PDHS-E
- IEC = IECF
- LRA = LRAC
- PDC = PDCC
- FOS = FOS-ES
- PDA = PDAS-F
- PAM = Matera for NRT production
- UPA = UK-PAC
- DPA = D-PAC
- IPA = I-PAC
- FPA = F-PAC
- SPA = S-PAC
- EPA = E-PAC
- ECM = ECMWF
- ACR = ACRI
- FIN = FINPAC

yyyymmdd — is the start day of the acquisition,
HHMMSS — is the start time of the acquisition,
tttttttt — is the duration (in seconds) of the acquisition,
P — identifies the phase of the mission,
ccc — is the number of the cycle in the mission phase_,
OOOOO — is the relative orbit number within the cycle,
aaaaa — is the absolute orbit number,
QQQQ — is a numerical wrap-around counter for quick file identification. For a given product type the counter is incremented by 1 for each new product generated by the product originator.
SS — identifies the satellite (E1 = ERS-1, E2 = ERS-2, N1 = ENVISAT-1).

2.2.2 MERIS product data structure

The MERIS product is composed of three major groups: two product headers, Main Product Header (MPH) and Specific Product Header (SPH), and several data sets (DS). The structure is as follows:

MPH:

Generic product header

The MPH identifies the product and some of its main characteristics. The Error Message MPH field summarises the errors encountered in processing.

SPH:

The specific product header for MERIS contains information applicable to the complete product.

The SPH contains references to external data files and data set descriptors, as well as general information applicable to the product such as sensor characteristics, Product Confidence Data (PCD), and metrics summary. A large amount of SPH content can be directly derived from the parent L1b product SPH.

DS :

The data sets are composed of an Annotation Data Set (ADS) and a number of Measurement Data Sets (MDS).

ADS :

The annotation data set is a set of equally sized Annotation Data Set Records (ADSR).

SQADS

Summary Quality ADS

This ADS (SQ ADS) contains information on the quality of the product. The annotation data set is composed of one ADSR for every 8 *tie frame*s; i.e., every 128 RR or 512 FR product lines.

GADS

Global ADS

The GADS contains all the data scaling factors and offsets, which are read from an auxiliary data product.

ADS

*Tie point*s location and auxiliary data ADS

This ADS contains information on geolocation, measurement viewing and illumination geometry, and auxiliary environment parameters for a subset of the product pixels: the tie points. One ADSR (ADS Record) includes the set of *tie point*s corresponding to a given satellite location.

ADSR:

The annotation data set record contains the annotation information provided at the *tie point*s. The tie points are associated to the pixels of the measurement product grid at a spacing of 16 pixels for RR and of 64 pixels for FR. The same separation is applied between MDSR (lines).

MDS: The measurement data set is a set of equally sized measurement data set records. The last data set of both the Level 1b and the Level 2 products is the flag measurement data set.

MDSR : The measurement data set records contain the measurement information provided at each product pixel. The size of the pixel content can be different for different data sets.

The detailed description of the organisation of the products can be found in the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" (R-8).

2.3 Definitions and Conventions

2.3.1 Units

Table 2.2 summarises the geophysical units that are used in the MERIS products:

Table 2.3 - MERIS geophysical units.

Product	Unit
Top Of Atmosphere radiance	**$mW.m^{-2}.sr^{-1}.nm^{-1}$** or **LU** (*Luminance* Unit)
Surface reflectance	***dl***
Total water vapour	**$g.cm^{-2}$**
Algal pigment index 1 (Chl_1)	**$mg.m^{-3}$** or **$Log_{10}(mg.m^{-3})$**
Algal pigment index 2 (Chl_2)	**$mg.m^{-3}$** or **$Log_{10}(mg.m^{-3})$**
Total Suspended Matter (TSM) or Suspended Particulate Matter (SPM)	**$g.m^{-3}$** or **$Log_{10}(g.m^{-3})$**
Yellow substance absorption	**m^{-1} or $Log_{10}(m^{-1})$**

Photosynthetic Available Radiation (PAR)	**microEinstein.m^{-2}.s^{-1}** or **10^{-6} mol.photons.m^{-2}.s^{-1}**
Aerosol optical thickness	***dl***
Aerosol angstrom coefficient	***dl***
Top Of Atmosphere Vegetation Index (MGVI)	***dl***
Bottom Of Atmosphere Vegetation Index (MTCI)	***dl***
Surface pressure	**hPa** (hectoPascal)
Cloud top pressure	**hPa** (hectoPascal)
Cloud albedo	***dl***
Cloud optical thickness	***dl***
Cloud type	**-**

Other general quantities have the units shown in table 2.3

Table 2.4 - General quantities and their units.

Quantity	Unit
angles	**degree**
date	**UTC** (Universal Time Coordinate) or **MJD** (Modified Julian Day)
duration	**10^{-6}s** (seconds)
wavelength	**nm** (nanometre)
wind speed	**m.s^{-1}**
ozone	**10^{-3} atm.cm** or **DU** (Dobson Units)
dimensionless quantities (e.g., reflectance, albedo, mixing ratio etc.)	***dl***
no dimension (e.g., a variable used to address an element in a table, cloud type etc.)	***nd***
digital count	if not specified, **nc** (number of counts) or **'-'**
spectral irradiance	**EU** or m**W.m^{-2}.nm^{-1}**
spectral radiance	**LU** or m**W.m^{-2}.sr^{-1}.nm^{-1}**

2.3.2 Product Grid

MERIS is an imaging instrument that produces three-dimensional data sets. The first dimension corresponds to the lines that follow the along-track chronological order - the number of lines is always product-dependent. The second dimension corresponds to the columns of the image; in the Level 0 image columns correspond to the across-track instrument pixels, and in the Level 1b or Level 2 images columns correspond to the across-track product earth pixels. The third and last dimension corresponds to the different geophysical parameters that are produced from a MERIS image.

The MERIS Product grid is intended to:

- be related to the satellite track (assuming nominal pitch and yaw attitude control of the satellite)
- provide quasi-even distance sampling of the parameters on Earth
- provide geolocation and other geophysical annotations as a regular subset of the pixels in order to improve storage efficiency

Resampling is defined on a line basis, with an even spacing grid on Earth with regard to the geoid surface in the across-track direction, it is centred at the subsatellite point as known from orbit prediction, nominal attitude control and modelled attitude perturbations. The along-track sampling is evenly spaced in time and thus provides a quasi-even distance on Earth; possible variations of the along-track sampling step may be due to the orbital motions of the satellite and/or to the ellipsoidal shape of the Earth.

There are different grids used in the MERIS processing, which are summarised below:

- The tie points grid is identical for all products. It has 71 tie points across-track, it is a 16 x 16 sub-grid of the RR product grid, a 64 x 64 sub-grid of the FR product grid, and a 4 x 4 sub-grid of the Browse and LR product grids. Image location and geometrical annotations are only provided at tie points.
- The Reduced-Resolution product grid has 1,121 RR pixels across-track.
- The Full-Resolution product grid has 4 x 4 more points than the RR product grid, in the across-track direction it has 4,481 points.
- The Browse product is obtained by sub-sampling a Level 1b product.

For the various resolutions, the across-track (at nadir) and the along-track distances between two points are shown in table 2.4 :

Table 2.5 - Across-track and along-track distances.

	AC distance at Nadir (m)	AL distance (m)
Low Resolution	4160	4640
Reduced Resolution	1040	1160
Full Resolution (scene or imagette)	260	290

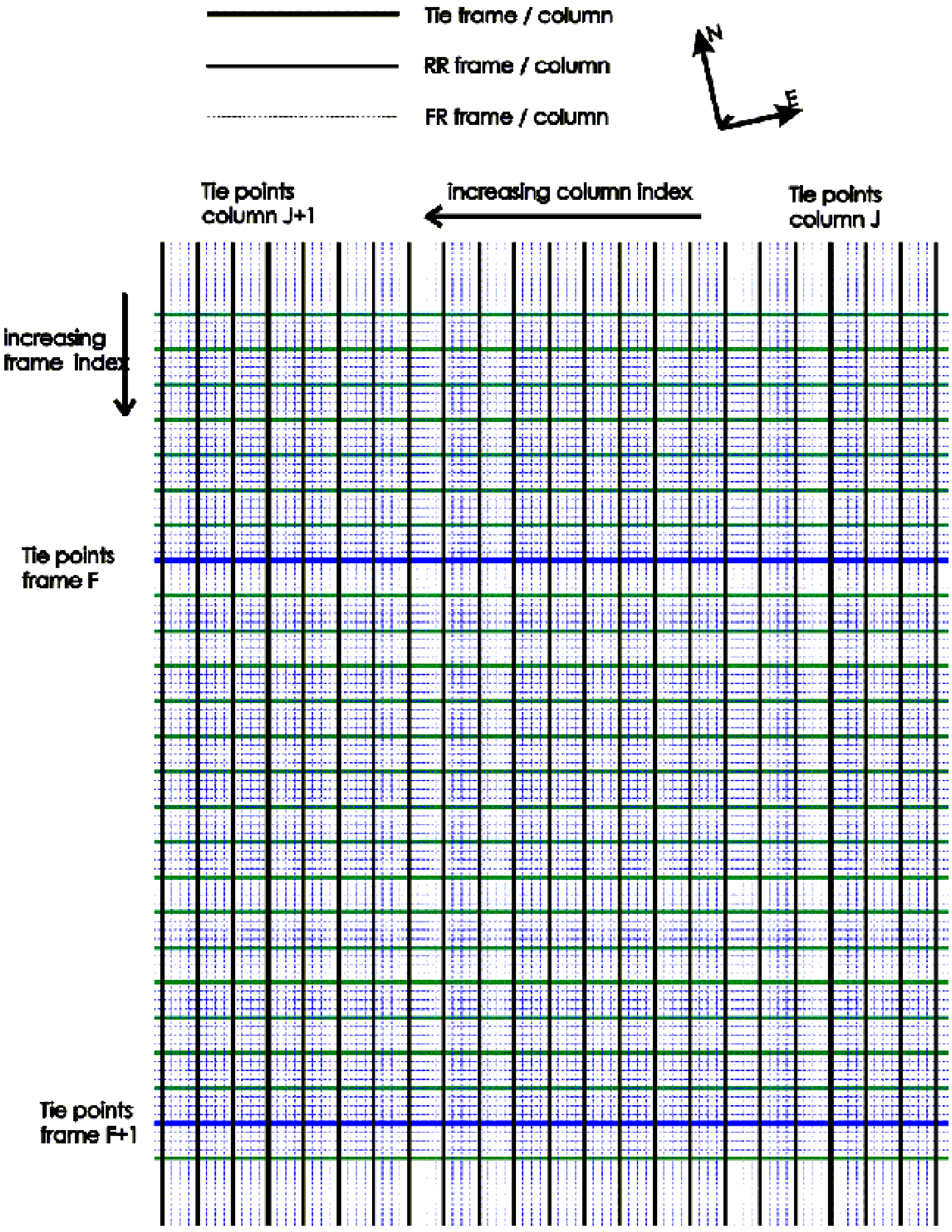


Figure 2.4 - Column and frame index.

The MERIS convention used for indexing column and lines is as follows. Column numbering starts at 1 and increases from east to west, and line numbering starts at 1 and increases from north to south.

The standard tools (BEAM, EnviView…) process and display the image in classical Earth representations.

2.3.3 Notations and Conventions

Illumination and Observation Geometry Convention

The following illumination and observation geometry conventions are used in MERIS processing:

A point on Earth observed by MERIS is taken as a reference.

The Sun zenith angle θ_S is the angle between the local outward normal and the vector from the point towards the Sun.

The view zenith angle θ_V is the angle between the local outward normal and the vector towards the MERIS sensor.

The azimuth difference $\Delta\Phi$ is the angle between the half-plane containing the local normal and the Sun, and the half-plane containing the local normal and MERIS. In the principal plane:

- there may be *specular reflection* of a point source into the MERIS sensor when the azimuth difference is **180°** (and the zenith angles are equal),
- there may be *backscatter* from a point source into the MERIS sensor when the azimuth difference is **0°** (and the zenith angles are equal). In general, we assume that an azimuth difference of N degrees is equivalent with respect to MERIS radiometry, to 360° - N, so that $\Delta\Phi$ ranges from 0° to 180°.

The following figure illustrates these conventions:

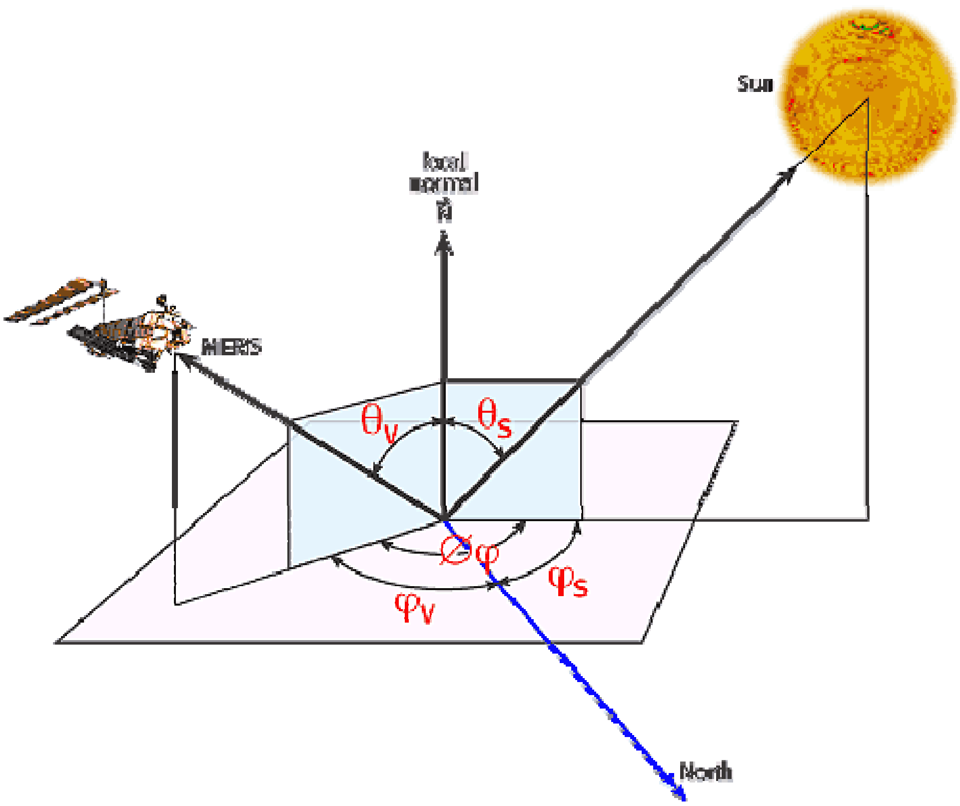


Figure 2.5 - Illumination and observation geometry angles.

2.4 Product Evolution History

A document describing the evolution of the MERIS instrument processing facility may be downloaded at address http://earth.esa.int/pcs/envisat/meris/documentation/MERIS_IPF_evolution.pdf .

2.5 Level 0 Products

There are four MERIS Level 0 products:

MERIS Reduced Resolution Level 0

MERIS Full Resolution Level 0

MERIS Reduced Field of View Level 0

MERIS Calibration Level 0

Level 0 products are generally not available to users.

The reference documents are given in section 4.3. For a description of the content of level 0 products, refer to the PGICD document (*Measurement Data Definition and Format Description for MERIS,R-5*). For a description of the format, refer to PO-RS-MDA-GS-2009 document (*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications, R-8*).

2.6 Level 1b Products and Algorithms

2.6.1 Level 1b Algorithms

Most of the contents of this section has been extracted from the "*MERIS Level 1 Detailed Processing Model*" document (R-1).

The MERIS Level 1b processing is in charge of reading the MERIS Level 0 product; checking the packets; extracting measurement data from the packets; correcting, calibrating and geolocating the Earth imaging data into spectral radiance values at the top of the atmosphere; ingesting ancillary data; creating Level 1 products which include radiances, geolocation and other annotations. On-line quality checks are performed at each processing stage.

The logic of the Level 1b processing algorithm follows the functional breakdown diagram shown in figure 2.19 below. The same logic applies to RR and to FR processing.

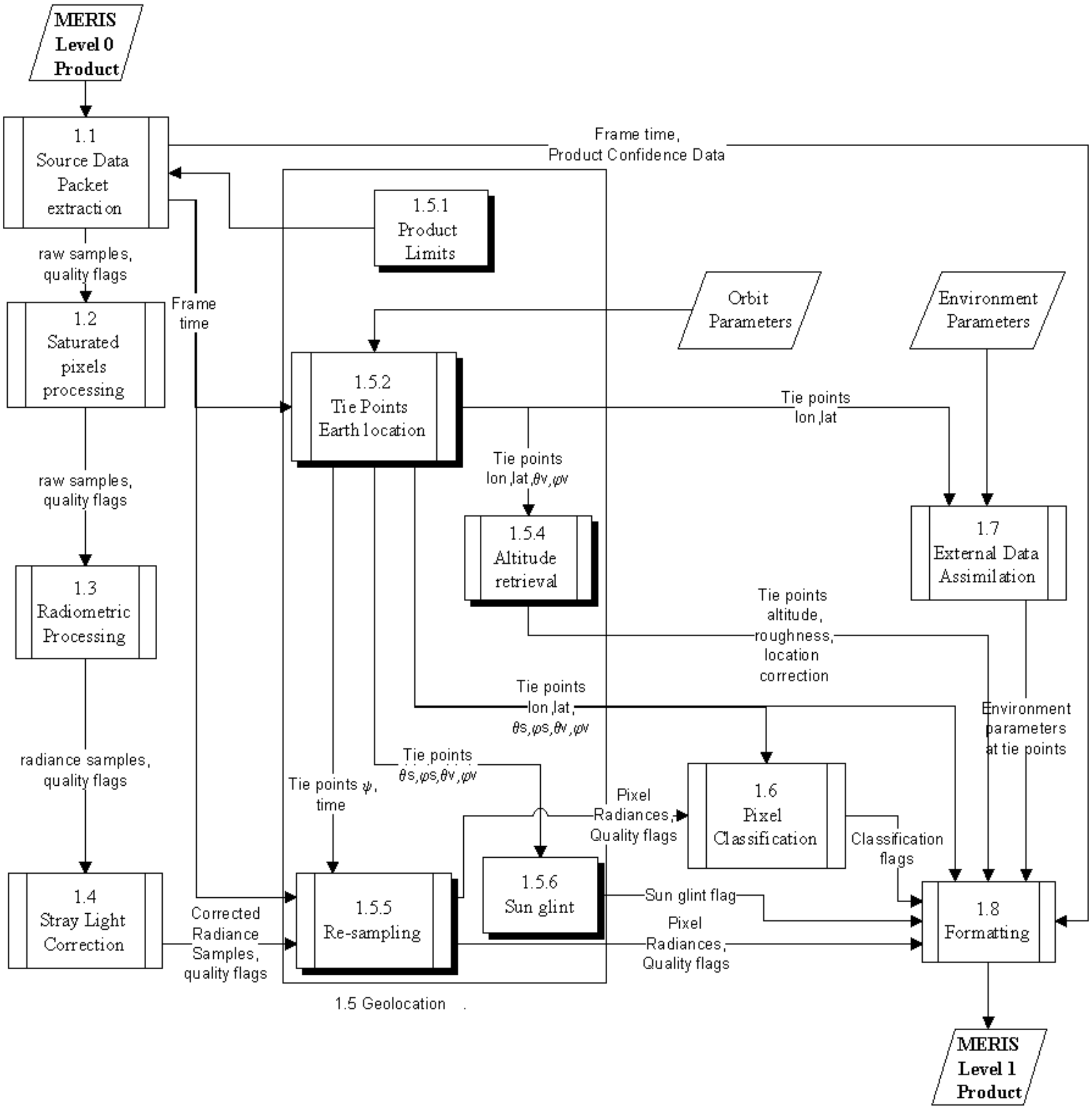


Figure 2.6 - Functional breakdown.

2.6.1.1 Source Data Packet Extraction

MERIS Level 0 processing is assumed to sort packets in the data stream which correspond to the observation modes of MERIS, from those corresponding to onboard characterisation modes.

At the initial stage of Level 1b processing, information in the packet header and data field header is used to detect in the FR or RR stream of packets such anomalies as:

- transmission error
- format error
- sequence error

The onboard time code needs to be converted to Universal Time (UT) for datation of the packets acquisition.

2.6.1.2 Saturated Pixels

MERIS samples may be affected by phenomena outside the range of the useful measurements; i.e., a spectral radiance between 0 and L_{sat}. Such samples are totally invalid, the corresponding cells being affected temporarily or permanently. When possible, invalid pixels should be replaced by a good estimate.

Such phenomena are:

1. Saturation by radiance level above L_{sat} (caused by, e.g., *Sun glint*, cloud, bright land or snow /ice), which affects cells temporarily (typically several columns in several bands over several frames).
2. Recovery from saturation. After saturation, components of the acquisition chain need some time (a few pixel columns) to recover; in the meantime the measurement is affected.
3. Blooming. Samples in bands and columns close to a saturated one may be temporarily affected by photon or photoelectrons diffusing from the saturated pixel.
4. Glitches, high-intensity impacts (e.g., laser) generate isolated high value samples.
5. Dead pixel. Due to manufacturing defects or to ageing in space, the response of some *CCD* cells to light may "die;»I.e., permanently deviate too much (to the extent that gain correction is not usable) from the useful measurement range. Such dead pixels need to be known.

Samples affected by saturation/recovery/blooming (1, 2, 3) are flagged.

Samples corresponding to dead pixels (5) are replaced with a cosmetically interpolated value after radiometric calibration within the radiometric processing step.

Glitches are neither detected nor corrected due to unavailability of a simple model for detection.

2.6.1.3 Radiometric Processing

The valid MERIS samples are digital counts resulting from the acquisition by MERIS of passive optical spectral radiance remote sensing. The objective of the radiometric processing is to estimate the spectral radiance which caused these counts. An inverse model of the MERIS acquisition is used for that purpose, using parameters stored in the Characterisation data base and the MERIS samples themselves. The MERIS acquisition model is described as:

$$X_{b,k,m,f} = \mathrm{NonLin}_{b,m}\left[g(T_f^{VEU}).\left[A_{b,k,m}.\left(L_{b,k,m,f} + G_{b,k,m}(L_{*,*,*,*})\right) + S_{b,k,m,f}\right] + g_c(T_f^{CCD}).\,C^0_{b,k,m}\right] + \varepsilon \qquad \text{eq. 2.6}$$

where:

$X_{b,k,m,f}$ is the MERIS raw sample (not corrected onboard)

$\mathrm{NonLin}_{b,m}$ is a non-linear function

T_f^{VEU} is the amplification unit temperature

T_f^{CCD} is the sensor temperature

$g(T)$ and $g_c(T)$ are temperature-dependent gain terms (close to 1)

$A_{b,k,m}$ is the "absolute radiometric gain"

$L_{b,k,m,f}$ is the spectral radiance distribution in front of MERIS

$S_{b,k,m,f}$ is the smear signal, due to continuous sensing of light by MERIS

$G_{b,k,m}$ is a linear process representing the stray light contribution to the signal. For a given sample, some stray light is expected from:

all the other simultaneous samples in the module, spread into the sample by specular (ghost image) or scattering processes

the samples in the previous and following frames

$C^0{}_{b,k,m}$ is the dark signal (corrected onboard for temperature effects by the Offset Control Loop)

ε is a random process representative of the instrument errors and parasitic processes not accounted for in the other terms of the model.

All terms not indexed by f (frame) do evolve in time due to ageing, but with a much slower rate which allows to represent them, for a given Level 1b product, as fixed quantities retrieved from data bases.

The radiance sensed by MERIS $L_{b,k,m,f}$ is, for a given set of target physical parameters and illumination and observation angles, proportional to the extraterrestrial Sun spectral flux. Because there is no absolute spectral measurement of the Sun *irradiance* simultaneous to MERIS acquisition, all results are produced with reference to a Sun spectral flux model which must be included in the product header.

The term $A_{b,k,m}$ reflects all the amplification gains inside the instrument, which depend on:
instrument programming (band settings, amplification programmable gains)
components ageing
components temperature
power supply voltage

In order to provide for limitation or failure of the onboard temperature regulation, there shall be a residual correction for g(T), GC(T). In normal operation, T depends on the time elapsed since the *Sun zenith angle* has decreased below a threshold (80°) and can be predicted.

2.6.1.4 Stray Light Correction

The stray light term $G_{b,k,m}(L_{*,*,*,*})$ in the MERIS acquisition model above may be strong enough to affect the Least Significant Bits of the raw data. This may happen in particular when MERIS is observing a scene with some high radiance areas (Sun glint patch, partly cloudy ...). As the linear transform $G_{b,k,m}$ is assumed to be known well enough from instrument characterisation, it is possible to compute an estimate of the stray light, and correct for it.

Stray light correction is handled separately from radiometric processing due to the specific nature of the processing in that stage: de-convolution; and to the fact that it can be switched on and off.

2.6.1.5 Geolocation

The geolocation problem encompasses all processing that is directly related to the location on Earth of the MERIS measurement data.

The points where the MERIS radiance samples have been measured are determined by the projection on Earth of the line of sight of every pixel. That projection depends on

the shape of the Earth

the altitude of the sample

the position of the ENVISAT satellite at the time of acquisition

the orientation of the MERIS modules

the optics of each MERIS module

In order to simplify product handling, the MERIS radiance samples are relocated by nearest neighbour interpolation to the MERIS product grid, which has the following characteristics (FR grid):

central column: subsatellite point track on Earth

line orientation: perpendicular to spacecraft velocity, projected on Earth

columns spacing: fixed for one product, 260 m (with very small variations)

number of columns: 4,481

line spacing: variable with time and orbit altitude, fixed by the MERIS frame time of 0.044s (mean ≈ 292 m)

The RR-grid is a 4 x 4 subsampled version of that grid.

The surface of altitude 0 on Earth is approximated by a *geoid* model. The model WGS-84 used by the ENVISAT orbit propagator shall be used.

Knowledge of the ENVISAT platform and attitude relies on:

prediction or estimation of the satellite position and attitude; the ESA CFI software is used:

- po_ppforb or po_interpol for orbit propagation
- pp_target for attitude modelling

accurate datation of the MERIS samples, to the MJD2000 time reference used by the orbit and attitude prediction/estimation.

The interpolation algorithm for resampling MERIS data to the grid may use characterisation data defining the MERIS pixels de-pointing. Neglecting the surface *elevation* causes an error in pixel location, proportional to altitude and to the tangent of the observer zenith angle. That error is estimated at the *tie point*s.

Sun zenith and azimuth angle, observer zenith and azimuth angle, may be computed for any pixel knowing pixel location and Sun direction in a common frame but are stored only at the product *tie point*s.

Sun glint, because of the high radiance values measured there, has an impact on both the direct usage of L1b data and on L2 processing. A first estimate of the affected pixels is performed. The location of the potential Sun glint can be predicted for each pixel, from the illumination and observation geometry.

Geolocation processing is broken down into 5 main algorithm steps:

product limits

tie points Earth location

altitude retrieval

resampling

Sun glint

2.6.1.6 Pixel Classification

In order to make easier the exploitation of *TOA* radiances by further processing (e.g., Level 2, Browse), the Level 1 product contains appended information about the nature of each MERIS pixel. The classification process uses the *a priori* knowledge of a land/ocean map indexed by longitude and latitude, and the information in the *TOA* radiance bands to classify each valid pixel into:

clear sky/ocean

clear sky/land

bright pixel/ocean

bright pixel/land

Bright pixels include clouds, bright sand or soil, ice, snow, *Sun glint*...; the *a priori* known nature of the underlying surface is kept.

Clear sky is to be understood as clear enough to pursue atmospheric corrections.

2.6.1.7 External Data Assimilation

In order to make easier the exploitation of TOA radiances by further processing (e.g., Level 2), the Level 1 product contains appended information about the environmental conditions prevailing at the time and place of the MERIS acquisition. The parameters of interest are:

atmospheric pressure at surface level for prediction of the Rayleigh reflectance, optical thickness

surface wind speed and direction for prediction of Sun glint and *whitecaps*

relative humidity at 850 hPa for verification of the *aerosol* correction

total ozone column contents for atmosphere absorption correction

These parameters are acquired from external source (*ECMWF* data) and are interpolated, space-wise, to the tie points.

2.6.1.8 Formatting

All the data and flags derived in the above algorithm steps are formatted into a file compliant with the Level 1b product description found in the Formats section of this handbook.

2.6.2 Level 1b product definition

This section only contains a high level description of the level 1B products. For more information refer to the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8).

2.6.2.1 Level 1b High-Level Organisation of Products

The MERIS Level 1b product is composed of: the Main Product Header (MPH), the Specific Product Header (SPH), one Global Annotation Data Sets (GADS), two Annotation Data Sets and sixteen Measurement Data Sets. The MPH allows to identify the product and some of its main characteristics.

The SPH contains references to external data files and Data Sets descriptors, as well as general information applicable to the product such as sensor characteristics, *PCD* and metrics summary. The *GADS* contains all the data scaling factors and general information like reference extraterrestrial *solar flux* and some instrument settings which may be useful to analyse results.

The first ADS (LADS for location ADS) contains information on geolocation, measurement viewing and illumination geometry and auxiliary environment parameters for the *tie point*s, a subset of the product pixels.

The second ADS (SQADS for summary quality ADS) contains quality information, aggregated at the level of a group of granules.

The first fifteen MDS are dedicated to top of atmosphere radiance measured in the 15 MERIS spectral bands and the last one to the associated flags: classification and measurement quality indicators.

Information coming either from input Level 0 product, from external data sources, or generated by any processing step are gathered, organised, scaled and coded according to specifications to build the Level 1b product file.

2.6.2.1.1 Reduced Resolution Geolocated and Calibration TOA Radiance

The high-level structure of the product is shown in the table below.

Table 2.6 - Reduced resolution product structure.

MPH
Level 1b - SPH (includes DSDs)
Level 1b Summary Quality ADS (SQ ADS)
Level 1b GADS Scaling Factors and General Info
Level 1b ADS Tie Points Location & Aux. Data (L ADS)
Level 1b MDS (1) TOA Radiance
Level 1b MDS (2) TOA Radiance
Level 1b MDS (3) TOA Radiance
Level 1b MDS (4) TOA Radiance
Level 1b MDS (5) TOA Radiance
Level 1b MDS (6) TOA Radiance
Level 1b MDS (7) TOA Radiance
Level 1b MDS (8) TOA Radiance
Level 1b MDS (9) TOA Radiance
Level 1b MDS (10) TOA Radiance
Level 1b MDS (11) TOA Radiance
Level 1b MDS (12) TOA Radiance
Level 1b MDS (13) TOA Radiance
Level 1b MDS (14) TOA Radiance
Level 1b MDS (15) TOA Radiance
Level 1b MDS (16) Flags and Detector index

2.6.2.1.2 Full Resolution Geolocated and Calibration TOA Radiance

The high-level structure of the product is shown below in the table 2.20

Table 2.7 - Full resolution product structure.

MPH
Level 1b - SPH (includes DSDs)
Level 1b Summary Quality ADS (SQ ADS)
Level 1b GADS Scaling Factors and General Info
Level 1b ADS Tie Points Location & Aux. Data
Level 1b MDS (1) TOA Radiance
Level 1b MDS (2) TOA Radiance
Level 1b MDS (3) TOA Radiance
Level 1b MDS (4) TOA Radiance
Level 1b MDS (5) TOA Radiance
Level 1b MDS (6) TOA Radiance
Level 1b MDS (7) TOA Radiance
Level 1b MDS (8) TOA Radiance
Level 1b MDS (9) TOA Radiance
Level 1b MDS (10) TOA Radiance
Level 1b MDS (11) TOA Radiance
Level 1b MDS (12) TOA Radiance
Level 1b MDS (13) TOA Radiance
Level 1b MDS (14) TOA Radiance
Level 1b MDS (15) TOA Radiance
Level 1b MDS (16) Flags & Detector index

2.6.2.1.3 Main Product Header

Main product header is formatted as described in the "*Envisat-1 Products Specifications - Volume 5 – Product structures*" document (R-7). Only time of first and last frames of the product are input from the processing to the MPH formatting.

The Main Product Header (MPH) identifies the product and its main characteristics. It is an ASCII structure containing information needed for all ENVISAT sensors. It is of fixed length and format for all products. The MPH contains the following major types of information:

Product Identification Information

Information Regarding Data Acquisition and Processing

Information on Time of Data

Information on ENVISAT Orbit and Position

SBT to UTC Conversion Information

Product Confidence Data

Product Size Information

2.6.2.1.4 Specific Product Header

Specific product header is formatted as described in the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8). The PCDs, issued by the previous steps 1.1 to 1.7 (see Figure 2.6 -), as well as the geolocation of first and last *tie frames*, from step 1.5.2, are inputs to the SPH (note that the transmission errors and the format errors counters are transformed into flags set if the mean numbers of errors per packet exceed given thresholds). In the case of the FR Scene Product, for which there is an even number of *tie points*, linear interpolation between the closest *tie points* is considered sufficiently accurate to compute geolocation of the mid sample of first and last frames.

2.6.2.1.5 Global Annotation Data Set

Global Annotation Data Set is formatted as described the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8). Inputs come either from algorithm step 1.6 (solar flux corrected according to day of year) or from auxiliary data bases (gain settings, scaling factors).

2.6.2.1.6 Annotation Data Set "Tie Points Location and corresponding Auxiliary Data"

The annotation data set is composed of one Annotation Data Set Record (ADSR) for every 16 (Reduced Resolution) or 64 (Full Resolution) product frame (time sample), plus one at the last product frame. This leads to 925 ADSR per orbital product in Reduced Resolution (RR) and 36 ADSR per scene product in Full Resolution (FR), or 19 per FR imagette.

Each ADSR is composed of:

MJD, modified Julian Day of time sample

attachment flag: set when the MDSR corresponding to the ADSR are present in the product

one annotation set for every *tie point*: 71 in RR, 36 in FR scene, 19 in FR imagette.

An annotation set includes:

1. *tie point longitude*
2. *tie point latitude*
3. *tie point altitude*
4. *tie point* surface roughness parameter
5. *tie point* longitude correction due to altitude
6. *tie point* latitude correction due to altitude
7. *tie point Sun zenith angle*
8. *tie point Sun azimuth angle*
9. *tie point viewing zenith angle*
10. *tie point viewing azimuth angle*

all the above quantities from Geolocation Processing 2.6.1.5.

11. *ECMWF zonal wind* components
12. *ECMWF meridional wind* components
13. *ECMWF* pressure
14. *ECMWF* total ozone
15. *ECMWF relative humidity*

all the above quantities from External Data Assimilation 2.6.1.7.

Note: for all *tie point*s with a negative altitude, fields 4 to 6 are forced to zero.

2.6.2.1.7 Annotation Data Set "Product Quality"

The annotation data set is composed of one Annotation Data Set Records (ADSR) for every 128 (reduced resolution) or 512 (full resolution) product line, i.e. every 8 *tie frame*s. This leads to 114 ADSR per orbital product in Reduced Resolution (RR) and 5 ADSR per scene product in Full Resolution (FR).

Each ADSR is composed of:

MJD, modified Julian Day of time sample

attachment flag

one "out of range" flag register for the image pixels

one "out of range" flag register for the blank pixels

An "out of range" flag register is composed of one flag per band and per MERIS module. A given flag is set if the number of "out of range»Image or blank band samples for the given module in the region between this Quality Annotation Frame and the next one (or the product end) is above a given threshold (in %). Specific thresholds are used for image pixels and blank pixels.

Note: both "out of range" PCDs are actually linked with MERIS frames instead of Level 1b product's ones. The alignment of the Quality Annotations with the latter is equivalent to a zero *along-track* depointing assumption.

2.6.2.1.8 Measurement Data Sets

There are 16 MDS, 15 for the radiances of the 15 MERIS bands and 1 for the associated flags, with the same record structure : an MDS is composed of one Measurement Data Set Record (MDSR) by product time sample.

The radiance MDSR contains:

MJD, modified Julian Day of time sample

quality flag: set to 0 when all data in the MDSR are invalid.

one (scaled) radiance value per pixel (1121 in RR, 2241 in FR, 1153 in FR imagette).

Radiances are expressed in counts using the scaling factor stored in the SPH. Each value is stored in a two bytes unsigned integer.

The flag MDSR contains:

MJD, modified Julian Day of time sample

quality flag: set to 0 when all data in the MDSR are invalid.

one flag set (one byte) per pixel (1121 in RR, 2241 in FR, 1153 in FR imagette).

The flag set contains 8 binary values meaning:

Table 2.8 - Flag set.

Flag Name	Bit	1	0
cosmetic	0	cosmetic pixel	fully measured pixel
duplicated	1	duplicated pixel value	not duplicated pixel value
glint risk	2	glint risk	no glint risk
suspect	3	suspect pixel	not suspect pixel
land/ocean	4	land	ocean
bright	5	bright	clear sky
coastline	6	coastline	not coastline
invalid	7	invalid	valid

Each value is coded on 1 bit of the same byte, from least significant bit for flag 1 to most significant bit for flag 8.

The "land/ocean", "bright" and "coastline" flags are direct inputs from Pixel Classification 2.6.1.2.6. ; the "duplicate" flag is a direct input of the Radiance Resampling 2.6.1.2.5. ; the "glint risk" flag is a direct input from Geolocation 2.6.1.2.5. ; they are stored without further processing and do not need new definitions.

The "invalid" flag is a direct input, logically recombined with other flags, in order to gather all pixels satisfying any one of the following conditions:

samples of all bands are saturated;

out-of-swath product pixels;

pixels added at the end of the product to reach the last *tie frame*;

pixels added to fill a transmission gap of more than sixteen packets.

The "cosmetic" flag coming from the processing chain is a per band flag; the "suspect" flag is a new flag gathering pixels with diverse internal flags configurations; they are defined below:

are considered "cosmetic" those pixels for which at least one radiance sample has been replaced by interpolation from neighbours;

are considered "suspect" those pixels satisfying one of the following conditions:

– for any pixel, if it is flagged "stray light risk";

– for a "clear sky" and "ocean" pixel, at least one of the radiance samples is "saturated" or "dubious";

– for a "clear sky" and "land" pixel, at least one of the radiance samples of the bands dedicated to "land»Is "saturated" or "dubious" (list of "land" bands a processing parameter).

2.6.2.2 Level 1b Accuracies

Accuracies for Level 1b products are given in the table below.

Table 2.9 - Accuracies for Level 1b products.

Product ID	Product Name	Geometric Accuracy/ Absolute Localisation Accuracy	Radiometric Accuracy
MER_RR__1P	Reduced Resolution Level 1	localisation error less than 2000 m	from 400 to 1050 nm < 4%
MER_FR__1P	Full Resolution Level 1	localisation error less than 212 $\pm$ 22 metres.	from 400 to 1050 nm < 4%

2.6.2.3 Level 1b Engineering Quantities

The MERIS Level 1b product is given in radiance units [LU] after scaling.

The in-band reference *irradiances* for the 15 MERIS bands are computed by averaging the in-band solar irradiance of each pixel. The in-band solar irradiance of each pixel is computed by integrating the reference solar spectrum with the band-pass of each pixel.

The 15 Sun spectral flux values provided in the "*GADS* Scaling" record of the Level 1b products are the in-band reference *irradiances* adjusted for the Earth-Sun distance at the time of measurement.

The band-pass of each pixel is derived from on-ground and in-flight characterisation via an instrument model.

The values "Band wavelength" and "Bandwidth" provided in the SPH of the Level 1b products are the averaged band-pass of each pixel over the instrument field of view. The centre wavelength of each pixel as characterised on ground is shown in figure2.43 below for a sample *CCD* row pertaining to band 11. Band 11 is dedicated to the observation of oxygen absorption and an accurate knowledge of its central wavelength is crucial for the retrieval of atmospheric pressure.

The detailed information can be found in document R-10. This workbook contains 9 data sheets:

1. the central wavelengths of each FR pixel for each band (pixel 1 is East, pixel 3700 is west)
2. corresponding in-band irradiances (derived using above wavelengths, computed instrument response functions and reference irradiances from sheet 4, scaled to Sun-Earth distance for MERIS reference day of year 95)
3. FWHM (full width at half modulation) of the instrument response functions for each band of each camera (each camera has 740 FR pixels – there is no FWHM variation for a given band within a given camera FOV -; camera 1 is east, camera 5 is west)
4. sheet 4 contains the reference Irradiance at 1 AU adopted for ENVISAT (*Thuillier, G., M. Hersé, P. C. Simon, D. Labs, H. Mandel, D. Gillotay, and T. Foujols, The solar spectral irradiance from 200 to 2400 nm as measured by the SOLSPEC spectrometer from the ATLAS 1-2-3 and EURECA missions, Solar Phys., submitted, 2002.*)
5. sheets 5 to 9 hold the instrument response functions for cameras 1 to 5 (hence 5 sheets), for each band, computed at centre of FOV (between pixels 370 & 371). Each function is scaled to max=1.

All wavelengths and widths are expressed in nm, irradiances in $mW.m^{-2}.nm^{-1}$.

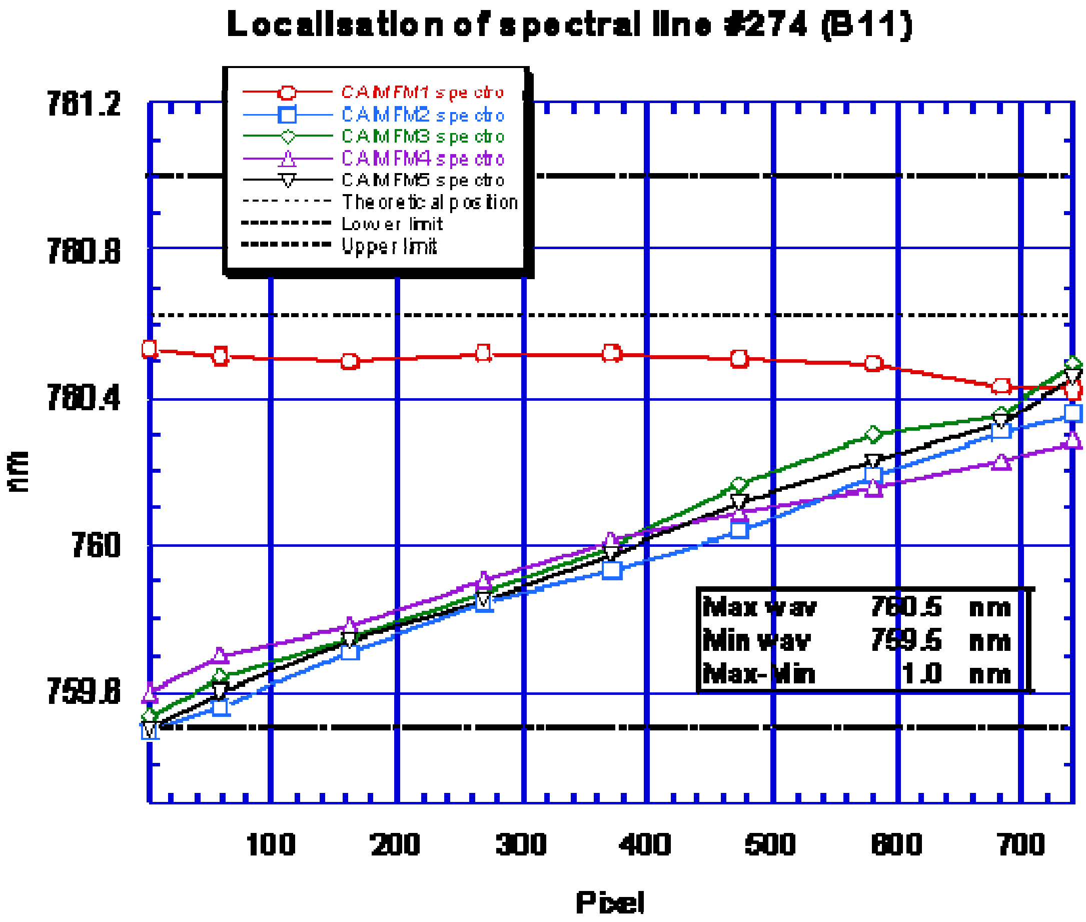


Figure 2.7 - Sample CCD row for band 11.

Corrections

The instrument response can be computed by including, or not, a non-linearity and stray light corrections.

The non-linearity correction consists of transforming a 16-bit telemetry word into a floating point value before any offset and smear corrections (see Science Data Processing Subsystem 3.1.2.6.) are applied in order to account for the non-linear response of the *CCD* output amplifier. With the correction switched on, both the calibration and measurement signals are corrected before the instrument gains are computed or applied, respectively.

The stray light correction consists of the de-convolution of the signal with a stray light kernel. The kernels are shift invariant *across-track* and include for each spectral band a contribution from different spectral regions of the *CCD*. (See Stray Light Correction Algorithm 2.6.1.2.4. .)

With the correction switched on, both the calibration and measurement signals are corrected after the instrument gains are computed/applied. During calibration processing, an iterative process is used to return the instrument gains, corrected for stray light.

2.6.2.4 Level 1b Essential Product Confidence Data

Flags are provided on a pixel-by-pixel basis and are listed below:

Bright clouds - based on a radiometric test in the blue part of the spectrum.

Coastline - based on an a priori atlas.

Land/sea - based on an a priori atlas.

Sun glint risk - determined by the solar elevation angle at *tie point*s.

Invalid.

Suspect - due to transmission errors.

Cosmetic - filling of defective detection elements.

Duplicated - due to resampling using the nearest-neighbour method.

2.6.2.5 Browse Products

Quicklooks are enhanced RGB images created from MERIS level 1b swath products. The enhancement is obtained using a local histogram equalisation algorithm:

for each pixel of the swath, an histogram equalisation is done considering only surrounding pixels (a square window centred on the current pixel). The continuity of the output image is obtained from the overlapping of the window considered for each pixel.

To obtain an enhance RGB both on water and lands (using the level 1b flag masks), different wavelength bands are respectively used:

- water pixels are handle in a way main oceanic structure are usually visible (ratio of bands 560/442) and displayed as blue tint,
- for lands and clouds is applied a combination of bands to create a pseudo RGB image.

The output image is the merge of the two previous complementary images. The result provide a very good enhancement for each image. The drawback are the discontinuities which are created by the two algorithms, especially for invalid cloud flags or when clouds over water become transparent. Note that due to the definition of the MERIS flags, there is no overlap between the water and land/cloud maps.

2.7 Level 2 Products and Algorithms

2.7.1 Level 2 Algorithms

2.7.1.1 Level 2 Physical Justification

The MERIS mission is concerned with three broad classes of applications associated respectively to three types of surfaces: ocean, land, and clouds.

These different types of surfaces lie below the stratosphere, which can introduce perturbations to the observations. Only two of them are considered significant enough to justify correction: absorption by ozone and the presence of volcanic aerosols.

When this initial correction has been applied, the next task is to attribute pixels to the three types of surfaces. This classification of pixels is based on a combination of radiometric thresholds, spectral slopes and several pressure estimates that can all be derived from the information contained in the MERIS bands.

When the classification has been performed, each pixel is treated with algorithms appropriate to achieve the MERIS mission objectives. For the oceanic pixels, the main objective is to derive the water constituents, which necessitates a complex atmospheric correction. For cloud pixels, atmospheric correction is not necessary to retrieve cloud optical properties. For land pixels atmospheric correction is considered possible only over dense dark vegetation.

The physical justification of all the algorithms used in the Level 2 ground segment processing can be found in the series of MERIS Algorithm Theoretical Basis Documents (ATBDs). Table 2.23 contains the chapters of the ATBDs stored at the address on ENVISAT web site. They can be viewed with the Adobe Acrobat Reader, free software available on the Adobe web site (http://www.adobe.com/products/acrobat/readstep.html) which allows users to view, navigate, and print PDF files on all major computing platforms.

Table 2.10 - MERIS ATBD references.

No	Title	Author	PDF size
2.0	Introduction (http://envisat.esa.int/instruments/meris/pdf/cover.pdf)	ACRI	36 kb
2.1 (& 2.2)	Cloud Albedo and Cloud Optical Thickness (http://envisat.esa.int/instruments/meris/pdf/atbd_2_01.pdf)	FUB	526 kb
2.3	Cloud Top Pressure (http://envisat.esa.int/instruments/meris/pdf/atbd_2_03.pdf)	FUB	1323 kb
2.4	Retrieval of Total Water Vapour Content from MERIS Measurements (http://envisat.esa.int/instruments/meris/pdf/atbd_2_04.pdf)	FUB	155 kb
2.5	Case 2 Turbid Waters Flag (http://envisat.esa.int/instruments/meris/pdf/atbd_2_05.pdf)	PML	245 kb

2.6	Case 2 (Sediment) Bright Water Atmospheric Correction http://envisat.esa.int/instruments/meris/pdf/atbd_2_06.pdf)	PML	308 kb
2.7	Atmospheric Correction over the Ocean (Case1 Waters) (http://envisat.esa.int/instruments/meris/pdf/atbd_2_07.pdf)	LPCM	4662 kb
2.8	Case 2 Anomalous Scattering and Gelbstoff Water Flags (http://envisat.esa.int/instruments/meris/pdf/atbd_2_08.pdf)	PML	924 kb
2.9	Pigment Index Retrieval in Case 1 Waters (http://envisat.esa.int/instruments/meris/pdf/atbd_2_09.pdf)	LPCM	614 kb
2.10	MERIS global vegetation Index (http://envisat.esa.int/instruments/meris/pdf/atbd_mgvi_jrc.pdf)	JRC-EC	1502 kb
2.11	Correction of volcanic aerosols		
2.12	Pigment index, sediment and gelbstoff retrieval from directional water-leaving radiance reflectances using inverse modelling technique (http://envisat.esa.int/instruments/meris/pdf/atbd_2_12.pdf)	GKSS	697 kb
2.13	Sun Glint Flag Algorithm (http://envisat.esa.int/instruments/meris/pdf/atbd_2_13.pdf)	ACRI	110 kb
2.14	Whitecaps Algorithm		
2.15	Atmospheric corrections over land (http://envisat.esa.int/instruments/meris/pdf/atbd_2_15.pdf)	PAMOC	535 kb
2.16	Cloud Reflectance (http://envisat.esa.int/instruments/meris/pdf/atbd_2_16.pdf)	FUB	37 kb
2.17	Pixel Identification (http://envisat.esa.int/instruments/meris/pdf/atbd_2_17.pdf)	LISE	274 kb
2.18	Photosynthetically Available Radiation (PAR) (http://envisat.esa.int/instruments/meris/pdf/atbd_2_18.pdf)	PML	18 kb
2.19	ATMOSPHERIC CORRECTION OVER LAND: CORRECTION OF DIRECTIONAL EFFECTS OVER DDV (http://envisat.esa.int/instruments/meris/pdf/atbd_2_19.pdf)	LISE	3377 kb
2.20	Cirrus cloud detection	LISE	
2.21	Adjacency effects in coastal areas	LISE	
2.22	MERIS Terrestrial Chlorophyll Index (http://envisat.esa.int/instruments/meris/pdf/atbd_2_22.pdf)	Univ. Southampton	

2.7.1.2 Level 2 Algorithm Description

This chapter provides a description of the MERIS processing in terms of algorithms. It describes data processing to be applied to the MERIS pixels, in order to derive the MERIS Level 2 Reference Products, in Reduced Resolution as well as in Full Resolution. For a more detailed information, please refer to the "MERIS level 2 Detailed Processing Model".

The Level 2 processing is in charge of processing *TOA* radiance measurements into geophysical parameters.

These parameters depend on the observed pixel (water, land, cloud) and provide information on:

the surface properties:

normalised reflectance at surface, chlorophyll and other water constituent concentration (ocean); reflectance at surface, vegetation indices (land);

the properties of the atmosphere above the surface:

aerosol type and optical thickness, water-vapour column content, cloud top height, optical thickness and albedo.

The general structure of Level 2 processing and products is presented in the following flow chart. The box numbers refer to the different step numbers of the MERIS Level 2 processing breakdown presented. Note that, in the diagram below, the paths labelled in Arial type indicate the main control flow, according to pixel type; those labelled in Times italic indicate the product flow. Please take note of the definitions on this page 2.3.3. . Click on the algorithm name in the diagram for a detailed description of the algorithm.

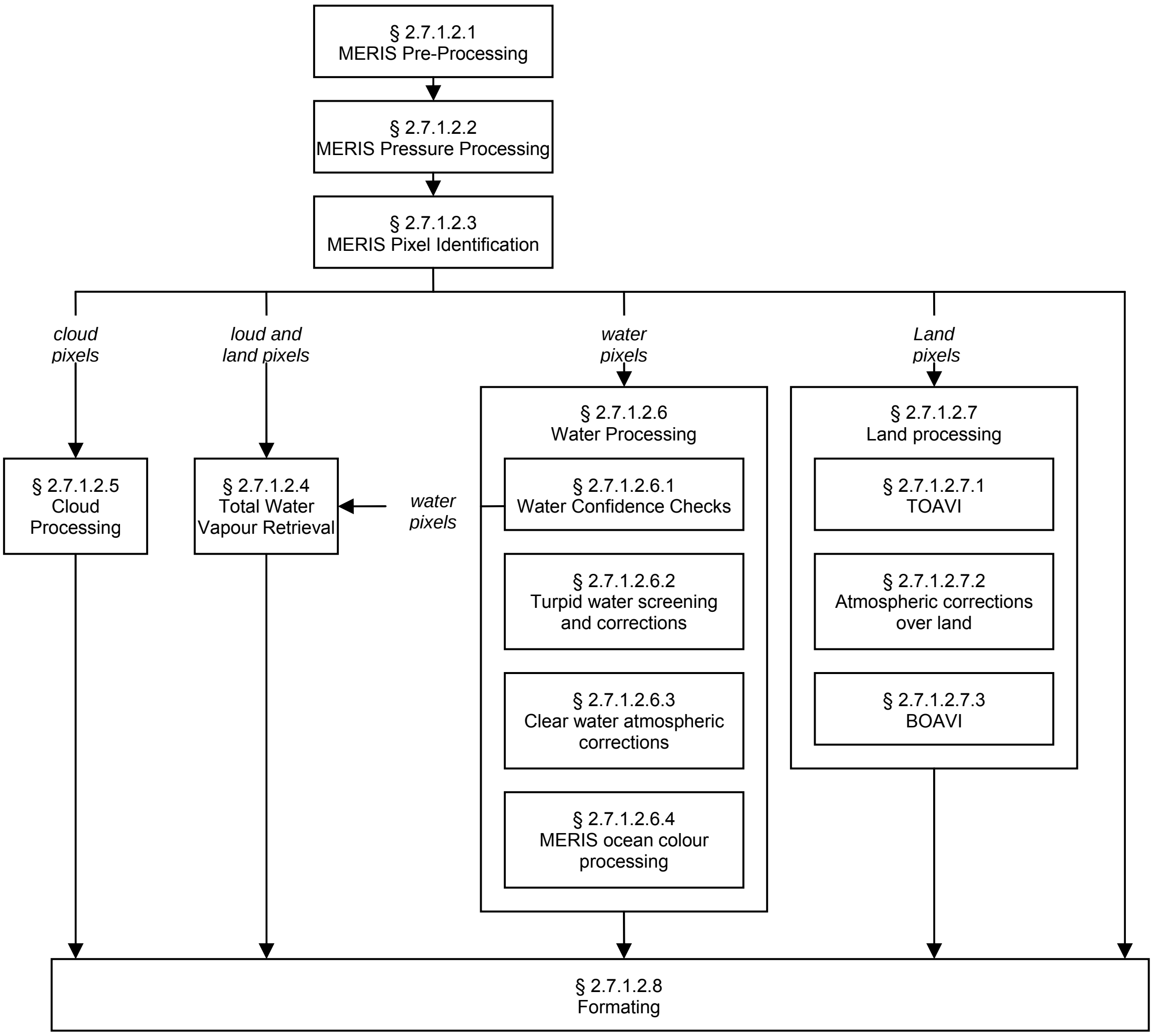


Figure 2.8 - General structure of Level 2 processing.

The detailed descriptions of the algorithms are contained in the following subsections (see index).

2.7.1.2.1 MERIS Pre-processing

2.7.1.2.1.1 Level 1b product check

If one or more band within the Level 1b product is not one of those in table 2-1, the product shall not be processed to Level 2.

If the Solar irradiance in the Level 1B product (GADS scaling factors) is 0 in any band, the product shall not be processed to Level 2.

2.7.1.2.1.2 Pre processing step

Pre-processing for geometry and meteorological parameters (step 2.1.0)

This step is done in order to derive geometry and meteorological parameters (pressure, wind) at each pixel, including invalid ones, from those provided at each tie point of the Level 1b annotation product.

Level 1b pixel classification screening (step 2.1.11)

The Level 2 pixel identification starts with the reading of the INVALID flag of the Level 1b product. If it is set to TRUE, then no further processing of the current pixel is done, the L2 product shall contain fixed values for all MDS (see section 10 below), with the "Invalid" flag set, and the next pixel is examined ; otherwise, the processing of the current pixel is pursued.

Pixel extraction and reflectance conversion (step 2.1.4)

If the Level 1b pixel is not flagged INVALID, the other L1B flags and the Top Of Atmosphere radiances at all bands are extracted from the L1B product. Radiances are converted to reflectances, using the Sun zenith angle cosine interpolated at the pixel and the Sun spectral flux read from the L1B product annotations.

2.7.1.2.2 MERIS Pressure Processing

2.7.1.2.2.1 Atmospheric pressure estimate (steps 2.1.5, 2.1.12)

The pressure is estimated for each pixel from the MERIS bands 10: 753.75 nm and 11: 760.625 nm, following two methods in parallel :

"cloud top pressure" that uses a Neural Network algorithm, and

"surface pressure" that uses a polynomial algorithm.

Spatial registration of the instrument has to be taken into account. A spectral shift index is computed from annotations of the L1B product and look-up-tables.

To retrieve the Cloud Top Pressure, P_{top},a neural net (NN) approach is used. The MERIS signals in channel 10, 11, the surface albedo $_{surf}$ and the geometry (sun zenith angle, viewing zenith angle and azimuth angle) are used as input of the Neural Network. The net produces the cloud Top pressure P_{top}. Depending on the surface albedo two different neural nets are used (one for surface albedo equal to zero, one for non-zero surface albedo). Neural Nets are selected according to spectral shift index.

The Neural Nets apply generic Neural Net functions to specific auxiliary parameters and inputs, to obtain the required outputs..

Each pressure estimate produces Product Confidence Data (PCD).

2.7.1.2.2.2 Atmospheric pressure confidence tests (steps 2.1.2)

A surface pressure test is performed (step 2.1.2). This test compares the difference between pressure estimates from MERIS measurements (step 2.1.12, 2.1.5 above) and pressure derived from ECMWF data (stored in Level1 data product annotations) to thresholds (function of θ_s, θ_v and surface type -

LAND_F). Furthermore, the difference of the two estimates is tested against a confidence interval width.

2.7.1.2.3 MERIS Pixel Identification

2.7.1.2.3.1 Cloud screening (steps 2.1.2, 2.1.7, 2.1.8)

For pixels identified as LAND, tests are performed on the ratio of Rayleigh-corrected reflectance at several wavelengths (step 2.1.7). The coarse Rayleigh correction uses a algorithm to compute the reflectance due to Rayleigh scattering.

This algorithm enables setting the following Boolean parameters:

1. Bright pixel flag: set if the Rayleigh-corrected reflectance at a specified band (nominally 442.5nm) is higher than a threshold : BRIGHT_F;
2. Low pressure estimate from neural net : LOW_POL_F;
3. Low pressure estimate from polynomial :LOW_NN_F
4. Product confidence flag from neural net : PCD_NN_F;
5. Product confidence flag from polynomial : PCD_POL_F;
6. Consistency between the two pressure estimates : P_CONFIDENCE_F;
7. Rayleigh-corrected reflectance ratio 1: SLOPE_1_F;
8. Rayleigh-corrected reflectance ratio 2: SLOPE_2_F;

These parameters are used to index a decision table which provides the CLOUD_F flag (step 2.1.8).

2.7.1.2.3.2 Stratospheric Aerosol Correction (step 2.1.9)

When the switch to perform stratospheric aerosol corrections is set, all valid pixels are corrected for stratospheric aerosol transmission and scattering. Correction applies to all TOA reflectance bands, and to the TOA radiance bands used in further processing steps :

753.75nm; 761.25nm; 775 nm; 865 nm; 885 nm; 900 nm

The correction algorithm is similar to the one described in section "Atmospheric Correction Over Land" below; the stratospheric aerosol parameters are read from auxiliary parameters sets. The algorithm runs on a 4x4 pixels window.

2.7.1.2.3.3 Gaseous absorption corrections (step 2.6.12)

Gaseous correction processing is organised in three steps, O_3, O_2 and H_2O correction. Input is the TOA reflectance for the MERIS channels, corrected for stratospheric aerosols when applicable: (b, j, f). Its output is the reflectance corrected for gaseous absorption (ρ_{ng}*). All three algorithms apply polynomial expressions using LUT technique. In step 2.6.12.1 the O_3 transmittance is estimated over a 4*4 pixel window. In step 2.6.12.2 and 2.6.12.3 the O_2 and H_2O transmittances are estimated for each land pixel. Because the signals used are weak, an average of radiances is performed on water pixels to compute the transmittances.

2.7.1.2.3.4 Land Identification (step 2.6.26) and Smile Effect Correction (step 2.1.6)

The purpose of this classification is to identify using geo-physical data, land from water pixels in cases where the Level1b *a priori* classification leads to ambiguities which may occur from:

geo-location error;

land /ocean atlas error: uncharted land or water, etc.;

transient emerged land: tidal flats, etc.

This cases are identified using the Surface Confidence Map, an atlas identifying zones of low-confidence in the *a priori* land/water classification map used in the level1b. When the Surface Confidence Map indicates high confidence classification, the Land Identification radiometric tests are by-passed and the *a priori* classification is kept.

Inland water

First, a test on the reflectance corrected for gaseous absorption at 665 nm is performed to identify the darkest pixels. The TOA reflectance at 665 nm is compared to a threshold interpolated from a LUT.

For the pixels having a reflectance smaller than this threshold, a second test is made to compare the TOA reflectance at 665 nm with the TOA reflectance at 865 nm ; if the TOA reflectance at 665 nm is greater than the reflectance at 865 nm, the pixel is classified as water.

Land in water

The purpose of this test is to identify pixels of emerged land, flagged as "water" in the L1B product. It is the opposite of the Inland water test.

The purpose of the Smile Effect Correction is to correct TOA reflectance (already corrected for stratospheric aerosols and gaseous absorption) for small scale variations due to non-constant central wavelength of a given band across the field of view. Correction is made only for a subset of bands for which those variations can induce severe distortions after corrections based on fixed wavelength scheme (e.g. Rayleigh diffusion correction). This subset of bands, which is specific to each land and water surface type, should ensure smoothness of reflectance local variations with wavelength and allow a good estimation of the reflectance derivative using neighbour bands.

2.7.1.2.4 Total Water Vapour Retrieval

This algorithm is applied to land, water and cloud pixels. It is based on a differential absorption method using two spectral bands close to each other (one within the absorption band and the other outside the absorption band). The algorithm consists in a polynomial of the logarithm of the ratio of TOA radiance at band 15 (900 nm, within the water vapour absorption region) to TOA radiance at band 14 (885 nm, outside water vapour absorption).

Above land surfaces, TOA radiances are corrected for the spectral slope of the surface albedo prior to applying the algorithm. Above water surfaces, the algorithm takes into account the aerosol optical depth, except when Sun glint is significant.

Polynomial coefficients depend on illumination and viewing geometry, surface type, presence of glint (above water), cloud properties (above clouds), for any given pixel. That dependence is coded in look-up tables.

The spectral bands centred at 885 nm and 900 nm have proven to be the best suited for the retrieval of water vapour over all surfaces. The total water vapour is computed in two steps. In a first step, depending on the type of pixel: land or glint, water, cloud, polynomial coefficients are read from LUT. The ratio of TOA radiances (corrected for stratospheric aerosols if needed) at 885nm and 900nm may be corrected. The second step is a simple polynomial applicable to all surfaces.

2.7.1.2.4.1 Water vapour retrieval over land surfaces (step 2.3.1)

A correction is made for the surface albedo slope between 885 and 900nm. The polynomial coefficients take surface pressure into account.

2.7.1.2.4.2 Water vapour retrieval over water surfaces (steps 2.3.2, 2.3.5)

Outside the Sun glint region, the retrieval of the total water vapour over water surfaces is more difficult than over land surfaces because of the larger influence of aerosols. The polynomial coefficients take into account aerosol influence. Also in order to improve noise performance, 4x4 pixel averaging is performed as a pre-processing step.

In the Sun glint region, the same algorithm as above land is applied.

2.7.1.2.4.3 Water vapour retrieval over clouds (step 2.3.3)

Polynomial coefficients take into account the cloud optical thickness and the albedo of the underlying surface.

2.7.1.2.4.4 Range checks (steps 2.3.0, 2.3.6)

Range checks are performed on radiance at the algorithm input. Out of range radiance result in an exception, water vapour is not processed. When processed, the water vapour is also checked for range, the product is kept but a flag is raised when out of range.

2.7.1.2.4.5 Water vapour polynomial (function)

The algorithm consists in a second-degree polynomial equation using the logarithm of the ratio of TOA radiance at 885 and 900 nm and coefficients. All polynomial parameters are provided by steps 2.3.1, 2.3.2, 2.3.3 depending on the type of pixel.

2.7.1.2.5 Cloud Processing

Pixels output from the Pixel Identification module (step 2.1) and flagged as cloudy (CLOUD_F = true) are processed in order to retrieve the cloud albedo (step 2.4.1) and the cloud optical thickness (step 2.4.3). Cloud top pressure is already known from step 2.1. From the optical thickness and top pressure, the cloud type index is computed (step 2.4.8). It should be noted that cloud reflectance, written in the L2 product, is the TOA reflectance (corrected for stratospheric aerosol if needed) (b, j, f), computed at step 2.1.

2.7.1.2.5.1 Cloud Albedo processing (step 2.4.1)

The cloud albedo processing relates the cloud albedo α_c to the MERIS radiance in channel 10 (753.75 nm) using a polynomial regression technique. The polynomial coefficients are read from a Look Up Table as a function of geometry (sun zenith angle, viewing angle and azimuth angle) and estimated surface albedo.

2.7.1.2.5.2 Cloud Optical Thickness processing (step 2.4.3)

To retrieve the cloud optical thickness τ_c , the same technique is used as for retrieving the cloud albedo. A polynomial expression relates the cloud optical thickness τ_c as a function of the MERIS radiance in channel 10. The polynomial coefficients are read from a Look Up Table as a function of geometry and estimated surface albedo.

2.7.1.2.5.3 Cloud type processing (step 2.4.8)

The algorithm uses a simple classification table indexed by the cloud optical thickness and cloud top pressure, to provide a cloud type index.

2.7.1.2.6 Water Processing

The processing of water pixels is intended to provide the following Level 2 products:

a) quantitative

normalised water-leaving reflectance at bands 412.5, 442.5, 490, 510, 560, 620, 665, 681.25, 705, 753, 775, 865, 885 nm
algal pigment index 1
algal pigment index 2
total suspended matter
yellow substance absorption at 442.5nm
photosynthetically available radiance (PAR)

aerosol optical thickness at 865nm
aerosol Angström exponent (775, 865)

b) qualitative

turbid case 2 water;
yellow substance loaded case 2 water;
water with excessive scattering;
continental absorbing aerosol;
desert dust absorbing aerosol;

as well as flags relevant to the quality of all products.

2.7.1.2.6.1 Water Confidence Checks (step 2.6.5)

Water confidence checks include processing of Sun glint, and flagging of low pressure and whitecaps. These steps use the wind and pressure provided in the L1B product annotations. All water confidence checks apply to water pixels within a 4x4 pixels window.

2.7.1.2.6.1.1 Glint processing (step 2.6.5.1)

Glint processing applies only to water pixels

Glint estimation

The Sun glint reflectance ρ_g is calculated (step 2.6.5.1.1) by interpolation in LUT produced using the Cox and Munk model (1954) as a function of geometry, wind speed modulus and direction. An estimate of glint reflectance is produced. Wind speed modulus and wind direction are computed from the W_u and W_v annotations.

Note: Sun glint reflectance is now an input to current step as its computation a been moved to section "Pixel identification" (step 2.1c).

Glint classification (low, medium or high glint ?)

This glint reflectance is compared to a low glint threshold (step 2.6.5.1.3). If the glint reflectance is below this low glint threshold then no glint correction for this pixel is applied. If the pixel is not bright then it is further processed by step 2.6.5.3. If bright, it is flagged as ice or high aerosol load.

If the glint reflectance is above the low glint threshold then the glint reflectance is compared to a medium glint threshold (step 2.6.5.1.4).

If the glint reflectance is below the medium glint threshold then a medium glint flag is raised and the pixel is corrected for glint reflectance in step 2.6.5.1.7.

If the glint reflectance is above the medium glint threshold then no correction is applied and the pixel is flagged as uncorrected sun glint (step 2.6.5.1.5).

In addition, a specific glint threshold is used to derive a second "high glint" flag dedicated to Water Vapour Processing over water (step 2.6.1.5.1.9): As a matter of fact, when the Glint reflectance is very high, total water vapour over water surface is best determined using the Water Vapour Over Land algorithm, best suited for bright underlying surfaces.

Glint correction in case of medium glint (step 2.6.5.1.7)

The glint reflectance at surface level is transferred to the Top Of Atmosphere by applying a direct atmospheric transmission term (including Rayleigh scattering on both sun-surface and surface sensor paths). The Top Of Atmosphere glint reflectance ρ_g* is then subtracted from the TOA reflectance.

Note : step 2.6.5.1.8, because of its simplicity, is only shown in the corresponding equation section.

2.7.1.2.6.1.2 Low pressure water flagging (step 2.6.5.2)

Surface pressure (from ECMWF annotation) is compared with a threshold in order to flag low pressure, typically high altitude inland waters. Above such waters, the results of the atmosphere correction are disturbed.

2.7.1.2.6.1.3 Whitecaps Flagging (step 2.6.5.3)

The modulus of the wind speed is compared to a threshold. Above that threshold a whitecap flag is raised because white caps are likely to disturb the performance of the atmosphere correction.

2.7.1.2.6.1.4 Reflectance threshold on reflectance at 412 nm (step 2.6.5.4)

An additional “bright” pixels screening, specific to water pixels, is performed by comparison of the Glint corrected reflectance at 412 nm with a pre-computed threshold. It is intended to further sort out and flag those pixels affected by sea-ice, partial clouds or very high aerosol load.

2.7.1.2.6.2 Turbid water screening and corrections (steps 2.6.8, 2.6.10)

This section describes the algorithms used

1. in step 2.6.8, to detect Case 2 turbid waters based on radiometry (reflectance corrected for stratospheric aerosol, gaseous absorption, Sun glint); in the process, Rayleigh reflectance above water is computed;
2. in step 2.6.10, to compute the water-leaving reflectance for Case 2 turbid waters at 510, 705, 775 and 865 nm, needed before entering the atmospheric corrections processing over Case 1 waters (step 2.6.9) and provide an estimate of the total suspended matter used in turn to identified sediment dominated case 2 waters through a dedicated flag.

2.7.1.2.6.2.1 Rayleigh correction 1 (step 2.6.8.1)

This correction requires to estimate the Rayleigh reflectance in all useful bands, which will be re-used for further ocean pixels processing. The Rayleigh reflectance is interpolated in a LUT (RD 7, 3.6.1) as a function of pixel geometry, wind speed and wavelength.

The Rayleigh correction consists in subtracting the Rayleigh reflectance, corrected for atmosphere pressure in this step, from the total reflectance (already corrected for stratospheric aerosol, gaseous absorption and sun glint) in each band (RD 8, 2.7, 3.1.1.4.2).

2.7.1.2.6.2.2 Turbid water and White Scatterers identification (step 2.6.8.2)

Turbid water identification

The TOA marine reflectance is computed at 705 nm (channel 9) from Rayleigh corrected reflectances at 775 nm (channel 12) and 865 (channel 13) using the Angström exponent method. Then this TOA marine reflectance at 705 nm is compared to a threshold (interpolated in a LUT as a function of geometry). If it exceeds the threshold then the turbid water flag (Case2_S) is raised.

White scatterer identification

An estimate of the spectral slope of marine basckscatter is computed using Rayleigh corrected reflectance and pure water specific absorption. This estimated spectral slope is compared to a threshold below which the White Scatterer Flag is raised.

2.7.1.2.6.2.3 Turbid water correction (step 2.6.10)

When a water pixel has been detected as contaminated by a water signal in the infra-red by test 2.6.8, the algorithm called bright pixel procedure performs an estimate of the water-leaving reflectance at four bands used later by the atmosphere corrections above water (see 8.3 below). The algorithm is based on optical properties of the water and performs an iterative procedure with a combination of:

- single scattering aerosol reflectance;
- water-leaving reflectance;
- Suspended Particular Matter concentration.

The atmospheric attenuation of water-leaving reflectance is taken into account.

2.7.1.2.6.3 Clear water atmospheric corrections (step 2.6.9)

The objective of the clear water atmosphere correction is to identify and subtract from the TOA reflectances (corrected for stratospheric aerosols, gaseous absorption and Sun glint), the contribution of the atmosphere, which consists of molecular (Rayleigh) and particulate (aerosol) scattering and extinction. The correction is performed in order to provide normalised water-leaving reflectances.

A secondary objective is to estimate aerosol products: type and optical thickness.

The principle of the clear water atmosphere correction is to identify aerosol models which, together with a tabulated model of the molecular scattering and assumptions on the surface reflectance, fit the observed glint-corrected reflectance in the infra-red part of the spectrum (bands 705, 775, 865nm) and in a visible band (510nm).

The assumptions for Case 1 waters are that reflectance is null at all wavelengths beyond 700nm, and that reflectance at 510nm is nearly constant.

The output of the turbid water atmosphere correction (step 2.6.10, see section 7.3.4.2 above) provides as input estimates of the water reflectance at the bands used by the algorithm.

The algorithm provides one or two aerosol models and their properties in the visible and NIR wavelength domain, which allow to perform a correction of the atmosphere contribution and compute water-leaving reflectances.

The water-leaving reflectances output by the atmosphere corrections above water are normalised in order to remove dependency of the signal upon atmosphere conditions. The normalised water-leaving reflectance product ρ'_w is defined as follows:

$$\rho'_w = \frac{\pi . L_w}{E_d(0^+)}$$

where L_w is the water-leaving radiance and $E_d(0^+)$ the down-welling irradiance.

The water-leaving reflectance is used by other sub-steps and provided to the Product formatting (step 2.10). This step is applied to all pixels where ACFAIL_F is FALSE.

2.7.1.2.6.3.1 Path reflectance estimate (step 2.6.9.1)

When starting the atmospheric correction, we dispose of the (measured) total glint corrected reflectance ROGC, and of $\rho_R(\lambda)$ for each wavelength. When turbid case 2 water has been detected by a previous step, we also have an estimate of the marine reflectance at TOA, $t\rho_w$_C2.

Atmospheric corrections need an estimate of the contribution of the sky to the total reflectance, or path reflectance, at four wavelengths.

In Case 1 waters, the Infra-Red (IR) contribution of water to the signal is neglected, so that we have, at 775 and 865nm:

$$\rho_{path}(\lambda) = ROGC(\lambda).$$

This is also performed at band 510nm, even though the water contribution is not negligible in the visible. That estimate will be useful in the MERIS aerosol model (see below).

In turbid Case 2 water, we subtract the water contribution so that

$$\rho_{path}(\lambda) = ROGC(\lambda) - t\rho_w\_C2(\lambda)$$

2.7.1.2.6.3.2 MERIS aerosol model (step 2.6.9.2)

When starting the aerosol correction, we dispose on one hand of the path reflectance ρ_{path} at four wavelengths, and of the TOA reflectance ROGC(λ) and Rayleigh reflectance $\rho_R(\lambda)$ for each wavelength, and on the other hand of tabulated relationships linking the ratio ρ_{path} /ρ_R to the aerosol optical thickness $\tau_a(\lambda)$, for N aerosol models.

The central problem is the selection, among a set of aerosol models, of the two models that most closely bracket the actual aerosol. The principle is to rely on the look-up tables, which should allow :

- To calculate the values of $\tau_a(865)$ from the $\rho_{path}(865)/\rho_R(865)$ ratio, for several aerosol models,
- To extrapolate τ_a from 865 to 775 nm, for each aerosol model,
- To obtain the ($\rho_{path}(775)$ / $\rho_R(775)$) ratios from $\tau_a(775)$, for each aerosol model. These ratios computed from aerosol model, will be noted $\zeta(\lambda)$ in the following.
- To select a couple of aerosol models, by comparing the actual ($\rho_{path}(775)$ / $\rho_R(775)$) ratio, and the various $\zeta(775)$ ratios as obtained at the previous step.
- To estimate the $\zeta(\lambda)$ ratio in the visible bands from the knowledge of the spectral behaviour of this couple of aerosol models.

The successive steps of such a correction scheme are as follows. For a given pixel, and thus for a given geometry (θ_s, θ_v, $\Delta\phi$):

(1) The ratio $\rho_{path}(\lambda)$ / $\rho_R(\lambda)$ is computed at 865 and 775 nm, $\rho_R(\lambda)$ being taken in tabulated values (at these wavelengths, and for oceanic Case 1 waters, ρ_{path} = ROGC).

(2) A first set of N aerosol models is selected, which, in principle, is representative of clear oceanic atmospheres. For these N aerosol models, N $\tau_a(865)$ values are calculated from the ($\rho_{path}(865)$ / $\rho_R(865)$) ratio.

(3) N values of $\tau_a(775)$ are computed for the N aerosol models, from the knowledge of their spectral optical thicknesses (normalised by their values at 865 nm; tabulated values).

(4) N values of $\zeta(775)$ are computed from the N values of $\tau_a(775)$ for the N aerosol models, from the tabulated relationships between both quantities.

(5) The actual ($\rho_{path}(775)$ / $\rho_R(775)$) is then compared to the N individual values of $\zeta(775)$ obtained at step (4), and the 2 that most closely bracket the actual one indicate the two candidate aerosol models.

(6) 2 values of $\tau_a(\lambda)$ are calculated for bands at 510 nm and 705 nm from the normalised spectral optical thicknesses of the 2 “bracketing” aerosol models. Step (2) is now inverted, to calculate two $\zeta(\lambda)$ ratios from the two $\tau_a(\lambda)$ at 510 nm and 705 nm.

(7) The following step lies on the assumption that the actual ($\rho_{path}(\lambda)$ / $\rho_R(\lambda)$) ratio falls between the two $\zeta(\lambda)$ ratios calculated at step (6), proportionally, in the same manner as it does at 775 nm. $\rho_{path}(\lambda)$ is now estimated for bands at 510 nm and 705 nm.

(8) By making an assumption on the normalised water-leaving reflectance at 510 nm, the error in the atmospheric correction at 510 nm, $\Delta\rho_{510}$, can be assessed.

(9) A test is then made on this $\Delta\rho_{510}$ value, if a number of conditions are met. If those conditions are not met, the correction is continued at step (10). Otherwise, depending on the test result, either the correction is continued at step (10), or it is carried out once more from step (2), by selecting however a different set of N' aerosol models. In the latter situation, the correction is actually carried out for several aerosol databases, so that steps 2-8 are carried out several times; several couples of aerosol models are then selected (one at each time steps 2-8 are done), and the one which is retained at the end is the one that leads to the lowest $\Delta\rho_{510}$.

(10) For every wavelength λ of the visible domain, 2 values of τ_a are calculated from the knowledge of the spectral scattering coefficients of the 2 "bracketing" aerosol models.

(11) Step (2) is now inverted, to calculate two $\zeta(\lambda)$ ratios from the two $\tau_a(\lambda)$ for the visible bands, and then to obtain $\rho_{path}(\lambda)$ (see step 7).

2.7.1.2.6.3.3 Correction (step 2.6.9.3)

At then end of the MERIS model step, we now have an estimate of the path reflectance and aerosol optical parameters at all visible and NIR wavelengths where the atmospheric correction is required.

The water-leaving reflectance at the instrument level is then obtained as :

$$t_u(\lambda).t_d(\lambda).\rho'_w(\lambda) = ROGC(\lambda) - \rho_{path}^*(\lambda)$$

The following step consists in calculating the diffuse transmittance, downward $t_d(\lambda)$ and upward $t_u(\lambda)$, in order to retrieve the normalised water-leaving reflectance at surface level $\rho'_w(\lambda)$.

2.7.1.2.6.4 MERIS Ocean Colour Processing (step 2.9)

This chapter describes the processing to be applied to surface reflectances produced by the atmospheric corrections above water (see section 2.7.1.2.6.3 above) in order to derive ocean bio-optical parameters.

Different algorithms are used as shown in flow chart 8.5.2-1.

I. A band-ratio algorithm **optimised** for open ocean clear waters (so-called "Case 1") yields a geophysical quantity :
   Algal Pigment Index 1

II. **Robust** band-ratio algorithms valid for all water types, including yellow substance dominated (so-called Case 2 (y)) and waters with excessive back-scattering. These algorithms yield the following Product Confidence Data :
   flag for anomalous scattering waters
   flag for yellow substance-dominated waters

III. A **robust** algorithm based on the Inverse Modelling Technique (IMT), that can be applied to all water types, yields the following geophysical quantities :
   Algal Pigment Index 2 ($mg.m^{-3}$)
   Yellow substance absorption (m^{-1})
   Sediment load ($g.m^{-3}$)

IV. An algorithm to estimate the instantaneous value of the Photosynthetically Available Radiation (PAR)

Three different flags indicating the type of water sensed are used as they have an influence on processing quality:
   turbid waters (described in Section 7 of this document)
   yellow substance dominated waters
   anomalous scattering

Furthermore, range checks on input and output parameters are applied for quality control.

2.7.1.2.6.4.1 Case 2 (Yellow substance dominated) flag (step 2.9.4)

The presence of Case 2 water is flagged by Yellow substance (CASE2Y_F) flag (step 2.9.4). Input data are normalised water-leaving reflectance $\rho'_w(b, j, f)$. A LUT technique is applied for the retrieval. The procedure is described in RD8 (2.8).

2.7.1.2.6.4.2 Case 1 waters processing - Algal pigment index 1 (Chl1) retrieval (step 2.9.7)

Case 1 waters processing is based on a band ratio algorithm. Inputs are normalised water-leaving reflectance $\rho'_w(b, j, f)$ and ancillary data. The theory of data processing is described in RD8 (2.9). Processing is performed in two steps:

1. a band ratio estimate of Chl1 is selected among up to three possible ones, according to ratio value
2. an iterative procedure eliminates the influence of bi-directionality (parameter f_over_q1) on Chl1 estimate.

2.7.1.2.6.4.3 Case 2 anomalous scattering water flags (step 2.9.6)

The presence of Case 2 water is flagged by the Anomalous scattering (CASE2ANOM_F) flag (step 2.9.6). Input data are normalised water-leaving reflectance $\rho'_w(b, j, f)$ and algal pigment index 1. A LUT technique is applied for the retrieval. The procedure is described in RD8 (2.8).

2.7.1.2.6.4.4 Case 2 waters processing - Inverse modelling technique (IMT) (step 2.9.11)

IMT (RD 8, 2.12) uses an Inverse Radiative Transfer Model-Neural Network (IRTM-NN) to estimate the concentration of algal pigment index 2 (Chl2), yellow substance absorption (ODOC), and suspended particulate matter (SPM) concentration for Case 1 and Case 2 waters from normalised water-leaving reflectance at MERIS bands b442 to b665, b705, θ_s, θ_v and $\Delta\varphi$. In this approach, Case 1 waters are treated as a special case of the Case 2 water algorithm. The IMT considers the complex nature of the water leaving reflectance and its parameterisation avoids any iterative procedures. The multiple non-linear regression method in this approach leads to high reduction in computing time and is therefore fast enough for operational mass production of Level 2 products, but it requires a careful and elaborate determination of the multiple coefficients (training phase). The IRTM-NN procedure is already programmed and requires only data input. The data output from this algorithm are Chl2 concentration, ODOC absorption, SPM concentration and a confidence flag.

The Neural Network applies generic Neural Network functions, as specified in AD 6, to specific auxiliary parameters and inputs, to obtain the required outputs. All specific aspects of the application are specified in section 8.5.5.4 below.

2.7.1.2.6.4.5 Photosynthetically Available Radiation (step 2.9.8)

Instantaneous Photosynthetically Available Radiation (PAR) is derived from the irradiance above each water pixels, under a tabulated relationship. This step is applied to all pixels where ACFAIL_F(j, f) is FALSE.

2.7.1.2.7 MERIS Land Pixels Processing

This chapter describes the algorithms to be applied to the MERIS Top Of Atmosphere reflectance in order to compute the MERIS land level 2 products:

a) quantitative

Top Of Atmosphere Vegetation Index (TOAVI);
Surface reflectances in bands 412 to 885nm;
Aerosol optical thickness and alpha above DDV
Bottom Of Atmosphere Vegetation Index (BOAVI);

b) qualitative

Dense Dark Vegetation (DDV) flag;

as well as flags relevant to the quality of all products.

2.7.1.2.7.1 MERIS Top Of Atmosphere Vegetation Index (TOAVI) (step 2.2)

The TOA Vegetation Index computation algorithm takes as input the Top Of Atmosphere Reflectance output by step 2.1 .

Before computing TOAVI, a spectral test is done on every Land pixels in order to flag any pixels that are not vegetated. Then, on the vegetated pixels, TOAVI or MERIS Global Vegetation Index (MGVI) is estimated in two steps. First, the information contained in the blue band at 442 nm is combined with that in the bands at 681 and 865 nm traditionally used to monitor vegetation, in order to generate "rectified channels" at these latter two wavelengths. The "rectification" is done in such a way as to minimise the difference between those rectified channels and the spectral reflectances that would be measured at the top of the canopy under a standard geometry of illumination and observation. The proposed algorithm assumes that ratios of polynomials are appropriate to generate both the "rectified channels" and the final spectral index, MGVI.

The MGVI has been optimised to assess the presence on the ground of healthy live green vegetation. The optimisation procedure has been constrained to provide an estimate of the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) in the plant canopy, although the index is expected to be used in a wide range of applications.

2.7.1.2.7.2 Atmospheric correction over land (step 2.6.23)

This scheme is detailed in RD 8, sections 2.15, 2.17. The input of the algorithm are TOA reflectances, corrected for gaseous absorption and stratospheric aerosols, above all valid land pixels. The outputs of the algorithm are:

Rayleigh corrected reflectances for all pixels;
Dense Dark Vegetation (DDV) flag for all pixels;
aerosol model index and Angström exponent for pixels flagged as DDV;

Processing of the atmospheric correction over land is performed in 13 MERIS bands (basic set of 15 bands described in section 2, minus the O_2 absorption band at 761.25 nm (band 11) and H_2O absorption band at 900 nm (band 15)).

2.7.1.2.7.2.1 Rayleigh Correction Processing (step 2.6.15)

Rayleigh correction processing is organised in several steps. First the Rayleigh reflectance is computed for every 4x4 pixels window. Then, Rayleigh transmittance and Rayleigh spherical albedo are computed for every 4x4 pixels window. Then, the TOA apparent reflectance corrected for gaseous absorption ρ^*_{ng} is corrected for Rayleigh contributions for each pixel in order to derive the top of aerosol reflectance ρ_{top}. The 4x4 pixels windows do not overlap.

2.7.1.2.7.2.2 Dense Dark Vegetation (DDV) Screening (step 2.6.13)

DDV screening consists in flagging pixels identified as DDV by comparing a spectral index, the Atmosphere Robust Vegetation Index (ARVI), to a tabulated threshold which depends on Earth location and on the date of data acquisition. The ARVI is built using MERIS bands 3 (442 nm), 7 (665 nm) and 13 (865 nm).

2.7.1.2.7.2.3 Aerosol above DDV (step 2.6.17)

Aerosol type and optical thickness are estimated for DDV pixels. The same set of aerosol models is used for all pixels in a 32x64 pixels window (both in RR and FR); these windows do not overlap.

Using the aerosol parameters, we can estimate the aerosol reflectance ρ_a at MERIS bands 12 (775nm) and 13 (865nm), and the corresponding optical thicknesses. The alpha product expresses the spectral dependence of the optical thickness: $\tau(\lambda) = \tau(\lambda_0) \cdot \left(\frac{\lambda}{\lambda_0}\right)^{-\alpha}$.

2.7.1.2.7.3 MERIS Bottom Of Atmosphere Vegetation Index (BOAVI) (step 2.8)

The processing of the BOA Vegetation Index computation is only applied to land pixels. The algorithm is the MERIS Terrestrial Chlorophyll Index (MTCI).

The products delivered by the atmospheric corrections processing are used as input to the BOAVI algorithm.

2.7.1.2.8 MERIS Level 2 Product Formatting Algorithm

MERIS processed data samples corresponding annotations and flags are collected from previous steps and formatted according to Level 2 product description in R-8.

Each MERIS Level 2 geo-physical product is derived from a MERIS Level 1B product (herein after called "parent L1B product") and auxiliary parameter files specific of the MERIS Level 2 processing.

The MERIS Level 2 product is composed of : the Main Product Header (MPH), the Specific Product Header (SPH), one Summary Quality Annotation Data Sets (SQ ADS)), one Global Annotation Data Sets (GADS), one Annotation Data Sets and twenty Measurement Data Sets.

The MPH allows to identify the product and some of its main characteristics.

The SPH contains references to external data files and Data Sets descriptors, as well as general information applicable to the product such as sensor characteristics, PCD and metrics summary. A large amount of SPH contents can be directly derived from the parent L1B product SPH.

The first ADS (SQ ADS) contains information on the quality of the product.

The GADS contains all the data scaling factors.

The second ADS contains information on geo-location, measurement viewing and illumination geometry and auxiliary environment parameters for a subset of the product pixels: the tie-points. One ADSR includes the set of tie points corresponding to a given satellite location. It is the same as in the parent Level 1B product.

The Measurement Data Sets (MDS) contain geo-physical parameters derived by the L2 processing. The products are distributed in order to obtain

- maximum homogeneity of the information: the "reflectance" bands, for instance, contain reflectance whatever the underlying surface is;
- maximum storage efficiency: the bytes allocated for a given pixel will be used to store different parameters, relevant to the surface observed.

The Flags MDS (20) contains all information needed to decode and check for quality the distributed pixel information.

One MDSR includes the parameters for all pixels corresponding to a given time sample of MERIS. The term "product line" will be used hereafter to name the MDSRs of the different MDS for the same time sample, i.e. with the same MDSR index.

Information coming either from parent Level 1B product, from external data sources, or generated by any processing step are gathered, organised, scaled and coded according to the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8) to build the Level 2 product file.

2.7.1.2.8.1 Main Product Header

Main product header is formatted as described in the "*Envisat-1 Products Specifications - Volume 5 – Product structures*" document (R-7). The Error Message MPH field summarises the errors encountered in processing.

2.7.1.2.8.2 Specific Product Header

Specific product header is formatted as described in the "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8).

2.7.1.2.8.3 Annotation Data Set "Summary Product Quality"

The annotation data set is composed of one Annotation Data Set Records (ADSR) for every 8 tie frames, i.e. every 128 (Reduced Resolution) or 512 (Full Resolution) product lines.

Each ADSR, following "*Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*" document (R-8) is composed of :

Start time of the measurement or MJD, modified Julian Day of time sample
Attachment Flag
% of water pixels having absorbing aerosols (wrt water pixels)
% of water, % of DDV land, % of land, % of cloud pixels (wrt valid pixels);
% of pixels w/ low polynomial pressure (wrt valid pixels);
% of pixels w/ low Neural Network pressure (wrt valid pixels);
% of pixels w/ out of range inputs for water vapour processing (wrt valid pixels);
% of pixels w/ out of range outputs for water vapour processing (wrt valid pixels);
% of pixels w/ out of range inputs for Cloud processing (wrt cloud pixels);;
% of pixels w/ out of range outputs for Cloud processing (wrt cloud pixels);
% of pixels w/ out of range inputs for Land processing (wrt land pixels);
% of pixels w/ out of range outputs for Land processing (wrt land pixels);
% of pixels w/ out of range inputs for Water processing (wrt water pixels);
% of pixels w/ out of range outputs for Water processing (wrt water pixels);
% of pixels w/ out of range inputs for Case 1 processing (wrt water pixels);
% of pixels w/ out of range outputs for Case 1 processing (wrt water pixels);
% of pixels w/. out of range inputs for Case 2 processing (wrt water pixels);
% of pixels w/. out of range outputs for Case 2 processing (wrt water pixels);

The counters are accumulated according to every pixel in the time interval between a Q-ADSR (included) and the following one (excluded) and dumped to the Q-ADSR. The last Q-ADSR of the product may relate to a smaller number of product lines than the others.

2.7.1.2.8.4 Global Annotation Data Set - Scaling Factors

Global Annotation Data Set is formatted as described in R-8. Scaling factors and offsets are read from an auxiliary data product.

2.7.1.2.8.5 Annotation Data Set "Tie Points Location and corresponding Auxiliary Data"

Annotation Data Set "Tie Points Location and corresponding Auxiliary Data" is the same as found in the parent L1B product.

2.7.1.2.8.6 Measurement Data Sets

There are 20 MDS:

MDS 1 to 13 for the Normalised Reflectance for any valid pixel, at those MERIS bands not dedicated to gaseous absorption measurements: b412, b442, b490, b510, b560, b620, b665, b681, b705, b753, b775, b865, b885;
MDS-14 for total water vapour for any valid pixel;

MDS-15 for Algal Pigment Index I (water pixels) or TOAVI (land pixels) or Cloud Top Pressure (cloud pixels);
MDS-16 for Yellow Substance and Total Suspended Matter (water pixels);
MDS-17 for Algal Index II (water pixels) or BOAVI (land pixels);
MDS-18 for PAR (water pixels) or Cloud Albedo (cloud pixels) or surface pressure (land and bright pixels);
MDS-19 for Aerosols Angström exponent and optical thickness (water, land pixels) or cloud type and Optical Thickness (cloud pixels);
MDS-20 for the associated flags for any pixel;

with the same record structure : an MDS is composed of one Measurement Data Set Record (MDSR) by product time sample. The structures are specified in R-8.

The normalised surface reflectance MDSR contains, according to R-8 :
start time of sample in MJD2000 format;
quality indicator (0 if nominal, -1 if no data are available; in such a case the data field of the MDSR is filled with zeroes);
one (scaled) normalised surface reflectance value per pixel (1121 in RR, 2241 in FR, 1153 in FR imagette, 4481 in FR FullSwath).

Geo-physical parameters are expressed in counts using the scaling factor and offset stored in the GADS. Each value is stored in one or two bytes.

The flag MDSR contains :
start time of sample in MJD2000 format;
quality indicator
one flag set (three bytes) per pixel (1121 in RR, 2241 in FR, 1153 in FR imagette, 4481 in FR FullSwath).

The coding of flags is specified in R-8.

2.7.1.3 Level 2 Accuracies

Accuracies for Level 2 products are given in table 2.24 .

Table 2.11 - Accuracies for Level 2 products.

Product ID	**Product Name**	**Geometric Accuracy/ Absolute Localisation Accuracy**	**Radiometric Accuracy**
MER_RR__2P	Reduced Resolution Geophysical Product	> 2000 m	Surface reflectance (ocean) <2 x 10 –4 Surface reflectance (Land) < 5% Chlorophyll retrieval < 15 % Yellow substance < 30 % Suspended matter < 15 % Water vapour < 20% Cloud albedo < 2 % Cloud optical thickness ~ 10% Cloud top pressure ~ 40 hPa
MER_LRC_2P	Extracted Cloud Thickness and Water Vapour for Meteo Users	N/A	Water vapour < 20% Cloud optical thickness ~ 10%

MER_RRC_2P	Extracted Cloud Thickness and Water Vapour (non-Meteo Users)	> 2000 m	Water vapour < 20% Cloud optical thickness ~ 10%
MER_RRV_2P	Extracted Vegetation Indices	> 2000 m	N/A
MER_FR__2P	Full Resolution Geophysical Product	> 2000 m	Surface reflectance (ocean) <2 x 10 –4 Surface reflectance (Land) < 5% Chlorophyll retrieval < 15 % Yellow substance < 30 % Suspended matter < 15 % Water vapour < 20% Cloud albedo < 2 % Cloud optical thickness ~ 10% Cloud top pressure ~ 40 hPa MERIS Vegetation Index:-N/A

2.7.2 Level 2 Products

2.7.2.1 Level 2 High-Level Organisation of Products

2.7.2.1.1 Reduced Resolution Geophysical Product

The high-level structure of the product is shown below in the table 2.25 .

Table 2.12 - Reduced Resolution Geophysical Product high-level structure.

MPH
Level 2 - SPH (includes DSDs)
Level 2 ADS Summary Quality ADS (SQ ADS)
Level 2 GADS Scaling Factors and General Info
Level 2 ADS Tie Points Location & Aux. Data (L ADS)
Level 2 MDS (1)
...
Level 2 MDS (13)
Level 2 MDS (14)
Level 2 MDS (15)
Level 2 MDS (16)

Level 2 MDS (17)
Level 2 MDS (18)
Level 2 MDS (19)
Level 2 MDS (20) Flags

2.7.2.1.2 Extracted Cloud Thickness and Water Vapour

The high-level structure of the product is shown below in the table 2.26 .

Table 2.13 - Extracted Cloud Thickness and Water Vapour high-level structure.

MPH
Level 2 - SPH (includes DSDs)
Level 2 Summary Quality ADS (SQ ADS)
Level 2 GADS Scaling Factors and General Info
Level 2 ADS Tie Points Location & Aux. Data (L ADS)
Level 2 MDS Cloud Optical Thickness
Level 2 MDS Total Water Vapour
Level 2 MDS Flags

2.7.2.1.3 Extracted Cloud Thickness and Water Vapour for Meteo Users

The high-level structure of the product is shown below in the table 2.27 .

Table 2.14 - Extracted Cloud Thickness and Water Vapour for Meteo Users high-level structure.

MPH
Level 2 - SPH (includes DSDs)
Level 2 Summary Quality ADS (SQ ADS)
Level 2 GADS Scaling Factors and General Info
Level 2 ADS Tie Points Location & Aux. Data (L ADS)
Level 2 MDS Cloud Optical Thickness
Level 2 MDS Total Water Vapour
Level 2 MDS Flags

2.7.2.1.4 Extracted Vegetation Indices

The high-level structure of the product is shown below in the table 2.28 .

Table 2.15 - Extracted Vegetation Indices high-level structure.

MPH
Level 2 - SPH (includes DSDs)
Level 2 ADS Summary Quality ADS (SQ ADS)
Level 2 GADS Scaling Factors and General Info
Level 2 ADS Tie Points Location & Aux. Data (L ADS)
Level 2 MDS TOA Vegetation Index
Level 2 MDS BOA Vegetation Index
Level 2 MDS Flags

2.7.2.1.5 Full Resolution Geophysical Product

The high-level structure of the product is shown below in the table 2.29 .

Table 2.16 - Full Resolution Geophysical Product high-level structure.

MPH
Level 2 - SPH (includes DSDs)
Level 2 ADS Summary Quality ADS (SQ ADS)
Level 2 GADS Scaling Factors and General Info
Level 2 ADS Tie Points Location & Aux. Data (L ADS)
Level 2 MDS (1)
...
Level 2 MDS (13)
Level 2 MDS (14)
Level 2 MDS (15)
Level 2 MDS (16)
Level 2 MDS (17)
Level 2 MDS (18)
Level 2 MDS (19)
Level 2 MDS (20) Flags

2.7.2.2 Level 2 Geophysical Products

The MERIS Level 2 product are a distributed mixture of geophysical products and reflectances.

The product format is called distributed because the geophysical quantity found in the different data sets changes according to the different surfaces measured. The different product groups are: ocean colour products, land and cloud products.

The classification between the different product groups, ocean, land and cloud is made on a pixel by pixel basis by using the a priori determination of Level 1b further consolidated by the use of radiometric tests at level 2. The Level 2 classification information is provided on a pixel by pixel basis in the flag measurement data set.

The scientific background to the MERIS products can be found in a MERIS special issue of the International Journal of Remote Sensing Volume 20, Number 9, 15th June 1999.

2.7.2.2.1 Product description

For each measurement data set, the products will be distributed according to the table below.

Table 2.17 - Distributed product Table.

MDS	Data set	Ocean	Land	Cloud
1	2 bytes	RS 412.5	RS 412.5	RS 412.5
2	2 bytes	RS 442.5	RS 442.5	RS 442.5
3	2 bytes	RS 490	RS 490	RS 490
4	2 bytes	RS 510	RS 510	RS 510
5	2 bytes	RS 560	RS 560	RS 560
6	2 bytes	RS 620	RS 620	RS 620
7	2 bytes	RS 665	RS 665	RS 665
8	2 bytes	RS 681.25	RS 681.25	RS 681.25
9	2 bytes	RS 705	RS 705	RS 705
10	2 bytes	RS 753.75	RS 753.75	RS 753.75
11	2 bytes	RS 775	RS 775	RS 775
12	2 bytes	RS 865	RS 865	RS 865
13	2 bytes	RS 890	RS 890	RS 890
14	1 byte	Water vapour content	Water vapour content	Water vapour content
15	1 byte	Algal pigment I (see image below)	MGVI	Cloud top pressure

16	2 byte	SM - YS *	BOAVI	Spare
17	1 byte	Algal pigment II	Spare	Spare
18	1 byte	FPAR	Surface pressure	Cloud albedo
19	2 bytes	Aerosol optical thickness at 865 nm & Angström	Aerosol optical thickness at 442.5 nm & Angström	Cloud t & type
20	3 bytes	Flags	Flags	Flags

SM - YS: Suspended Matter & Yellow Substance
MGVI: MERIS global vegetation index
PAR: Photosynthetically Active Radiation for chlorophyll fluorescence applications
Aerosol t & e: Aerosol optical Thickness & Aerosol Angström factor
RS: Normalised water leaving radiance/reflectance

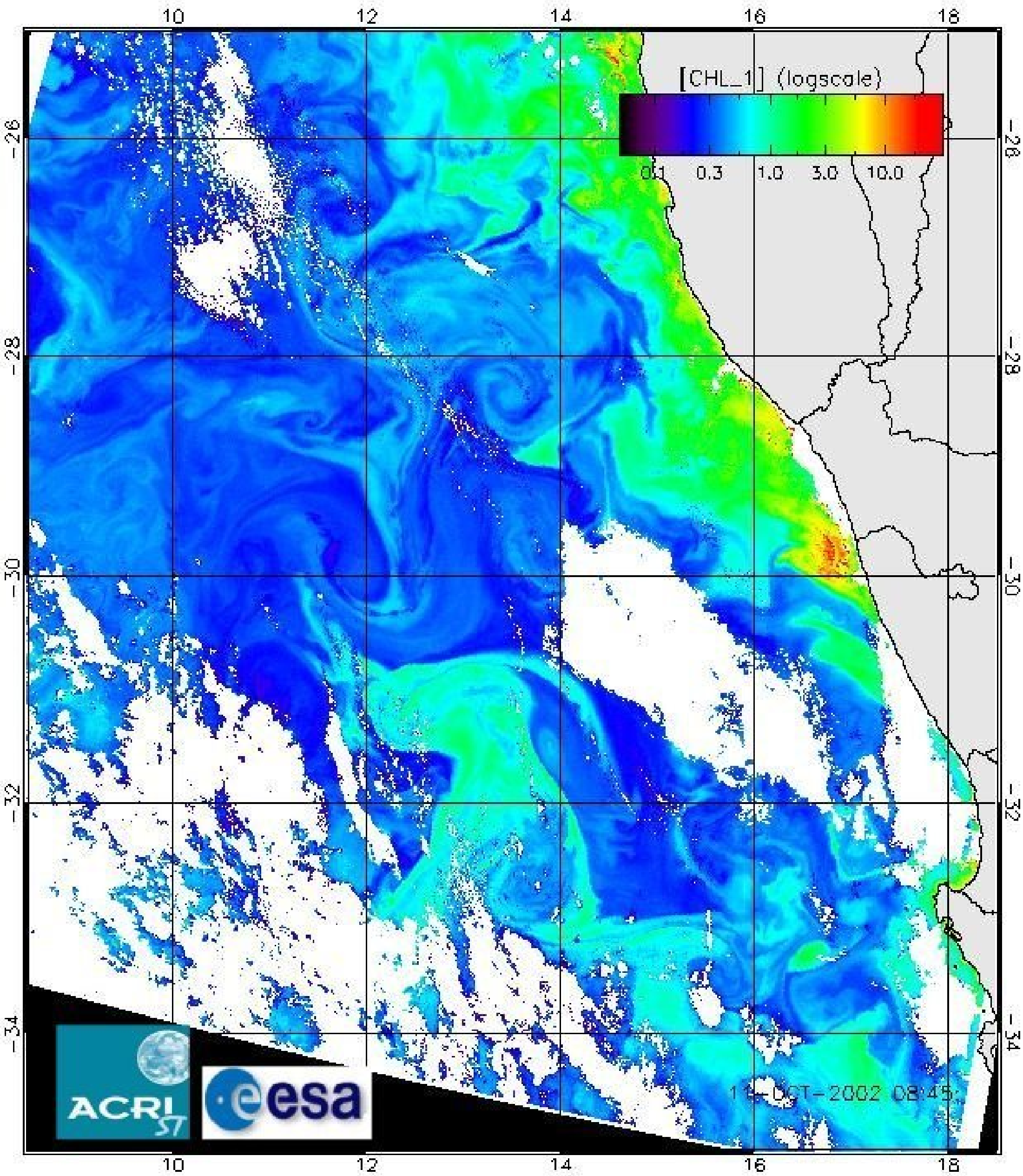


Figure 2.9 - Chlorophyll Map of Western coast of South Africa.

The open ocean data products consists of chlorophyll concentrations and several atmospheric parameters. In coastal zones more products are produced such as Total Suspended Matter and Yellow Substance Concentration. The land surface product contains MERIS global Vegetation Index (MGVI) and atmospheric parameters. In addition, surface reflectances will be made available, allowing the user to derive further products. Three cloud products are foreseen: cloud top height, cloud optical thickness and cloud albedo.

The next sections briefly present the MERIS Level 2 products.

2.7.2.2.2 Ocean products

2.7.2.2.2.1 Normalized water leaving radiance / reflectance

The MERIS Level 2 radiometric unit is atmospherically corrected water leaving reflectance. The atmospheric correction applied assumes that the water is absorbing in the NIR, and include a correction for those sediment loaded waters where this assumption fails.

For more information, see ***ATBD 2.7***, and ***ATBD 2.6*** for the bright water correction.

2.7.2.2.2.2 Algal Pigment Index I

The MERIS algal pigment index is a measurement of the concentration in $Log_{10}(mg/m^3)$ of phytoplankton (algae) in the water. The concentration is derived by the direct relationship between the ratio of the blue and green signal leaving the water surface and the concentration of algal pigments. The relationship, based on published data, is valid over clear waters and spans a concentration range from mg/m^3 to tens of g/m^3.

For more information, see ***ATBD 2.9***.

2.7.2.2.2.3 Algal Pigment Index II

The second MERIS algal pigment index is also a measurement of the concentation in $Log_{10}(mg/m^3)$ of phytoplankton (algae) in the water but, is part of a suite of oceanic products derived by inverting a model of the optical properties of the ocean by the use of a neural network. The other oceanic products are suspended matter and yellow substance.

For more information, see ***ATBD 2.12.***

2.7.2.2.2.4 Suspended matter

The MERIS suspended matter products is a measurement of the suspended sediments concentration in $Log_{10}(g/m^3)$. As described above, it is derived by inverting a model of the optical properties of the ocean by the use of a neural network. The model describe suspended matter as a scattering particle with very little absorption for which a more appropriate name would be "total suspended mineralic matter concentration.

For more information, see ***ATBD 2.12***.

2.7.2.2.2.5 Yellow substance

The MERIS yellow substance product is a measurement of the Gelbstoff absorption in m^{-1}. As described above, it is derived by inverting a model of the optical properties of the ocean by the use of a neural network. The model describes yellow substance as non-scattering absorbing matter. Yellow substance or "Gelbstoff" is decayed organic material that has been dissolved in the marine waters and is usually transported into the sea by rivers.

For more information, see ***ATBD 2.12***.

2.7.2.2.2.6 Photosynthetically Active Radiation (PAR)

The MERIS PAR product is a measurement the amount of radiation in $mEinstein.m^2$ available to the Photosynthetically Active oceanic flora. It will be computed from atmospherically corrected irradiances using the method proposed by Calder et al. This product is intended for the study of chlorophyll fluorescence and should be used with the 681.25 nm band selected for this purpose.

For more information, see ***ATBD 2.18***.

2.7.2.2.2.7 Aerosol optical thickness

The MERIS aerosol optical thickness is a measurement the opacity of the aerosol layers at 865 nm. It is measured by assuming that the ocean is a black surface in the NIR (see Normalized water leaving radiance / reflectance).

For more information, see ***ATBD 2.7***.

2.7.2.2.2.8 The MERIS Aerosol Angström Coefficient

The MERIS aerosol Epsilon factor is a description of the aerosol assemblage detected over water bodies. It is expressed as the spectral slope of the Aerosol Reflectance in the near Infra Red, complemented by two flags which identifies whether they are absorbing or not.

To be consistent with the land aerosol product, the epsilon factor is converted into an Angström coefficient.

For more information, see ***ATBD 2.7***.

2.7.2.2.3 Cloud products

2.7.2.2.3.1 Cloud optical thickness

The MERIS cloud optical thickness is a measurement the opacity of the cloud.

For more information, see ***ATBD 2.1***.

2.7.2.2.3.2 Cloud albedo

The MERIS cloud albedo is a measurement the amount of radiation reflected by clouds.

For more information, see ***ATBD 2.2***.

2.7.2.2.3.3 Cloud top pressure

The MERIS cloud top pressure is a measurement of pressure in hPa based on the absorption of solar radiation by oxygen. It is derived by inverting a model of the optical properties of the atmosphere and clouds by the use of a neural network.

One example of Cloud Top Pressure image is shown in Figure 2.2 - .

For more information, see ***ATBD 2.3***.

2.7.2.2.3.4 Cloud Type

The MERIS cloud type product is determined by using a simple relationship between the cloud properties - optical thickness and height - and its type, as established by the International Satellite Cloud Climatology Project (ISCCP).

2.7.2.2.3.5 Cloud reflectance

The MERIS Level 2 cloud radiometric unit will consist of top of the atmosphere reflectance only.

For more information, see ***ATBD 2.16*** .

2.7.2.2.4 Land products

2.7.2.2.4.1 Reflectance

The MERIS Level 2 land radiometric unit will consist of Rayleigh corrected reflectance. The atmospheric corrections over land does not include a correction for the aerosols contribution.

For more information, see ***ATBD 2.15***.

2.7.2.2.4.2 Aerosol optical thickness

The MERIS cloud optical thickness is a measurement the opacity of the aerosol layers at 865 nm. It is measured by assuming that Dense Dark Vegetation has a known dependent standard reflectance value in the visible.

For more information, see ***ATBD 2.15***.

2.7.2.2.4.3 Aerosol Angström Coefficient

The Angström coefficient describes the dependance of the aerosol optical thickness between the blue and the red spectral bands.

For more information, see ***ATBD 2.15***.

2.7.2.2.4.4 Meris Global Vegetation Index

The MERIS Global vegetation index is a measurement of the presence of healthy live green vegetation. It has been optimised to be robust to atmospheric conditions and surface reflectance and constrained to provided an estimate of the fraction of absorbed photosynthetically active radiation.

For more information, see ***ATBD 2.10***.

2.7.2.2.4.5 Meris Terrestrial Chlorophyll Index

The MERIS Global vegetation index is a measurement of the presence of healthy live green vegetation. It has been optimised to be robust to atmospheric conditions and surface reflectance and constrained to provided an estimate of the fraction of absorbed photosynthetically active radiation.

For more information, see ***ATBD 2.10***.

2.7.2.2.5 Water Vapour products

The MERIS water vapour product is a measurement of the concentration in $g.m^{-2}$ of water vapour found in the total atmospheric column. This product is of particular interest over land where the signal is high, but it will also be provided over water surfaces and clouds.

For more information, see ***ATBD 2.4.***

The MERIS Level 2 products are coded in such a way as to take the full advantage of the storage space allocated to them. As a consequence, in order to convert the data to geophysical units, an offset and gain correction shall be applied.

In addition to the level 2 reference product which contains all data sets of the distributed product table, three smaller extracted products are available:

Reduced resolution (1.2 km) column water vapour content product.

Reduced resolution (1.2 km) vegetation product.

Low resolution (4.8km) column water vapour content product.

2.7.2.2.6 Flags

Flags are provided on a pixel by pixel basis.

The list of flags is as follows:

Surface Classification :

land pixel
cloud pixel
water pixel

Product Confidence :

validity for MDS 1 to 13
validity for MDS 14
validity for MDS 15
validity for MDS 16
validity for MDS 17
validity for MDS 18
validity for MDS 19

Flag meaning :

Coastline: From Level 1b
Cosmetic: From Level 1b
Suspect: From Level 1b
Continental absorbing aerosol
Dust-Line absorbing aerosol
Turbid water
Anomalous scattering water
Yellow substance loaded water
Ice or high aerosol load
Corrected for glint
Contaminated by glint
Dense dark vegetation
Cloud Top Pressure and Surface pressure do not match.
Pressure product Lower than ECMWF pressure over land or bright scattering over sea.

2.7.2.2.7 Annotation data set

Annotation data provided in the Level 2 product are identical to those of the Level 1b product.

All annotation data will be provided at equally spaced tie points every 16 by 16 pixels in Reduced Resolution and every 64 by 64 Full Resolution pixels, which is equivalent to a 19km by 19 km grid on ground.

The following meteorological data provided by ECMWF will be resampled to the tie point grid: :

Mean sea level atmospheric pressure
Surface wind speed
Relative Humidity
Total column ozone

The following geographical information will be provided with respect to the Earth reference model WGS84:

Latitude, Longitude
Altitude and topographically corrected localisation
Bathymetry

The following geometrical information will be provided with respect to the Earth reference model WGS84 :

Solar illumination zenithal angle
Solar illumination azimuthal angle
Viewing zenithal angle
Viewing azimuthal angle

The annotation data povided in the near real time products will consist of meteorological forcasts and, geographical and geometric information computed using a predicted satellite orbit state vector.

The annotation data povided in the off-line (consolidated) products will consist of meteorological analysis data and, geographical and geometric information computed using a restituted satellite orbit state vector.

For further details regarding the MERIS Level 2 data products see Product Spreadsheets.

2.8 MERIS-Specific Topics

Band Set

MERIS is operated with a fixed set of bands, recommended by the Science Advisory Group (SAG) and frozen before launch. The Level 2 ESA products have been developed and are validated for this set of bands.

It is possible to use alternative band sets for experimental campaigns of a few weeks duration. Initial requirements for such campaigns can be submitted through the Announcement of Opportunity.

Acquisition Modes

MERIS measurements are always taken in full resolution (FR). These are averaged onboard to reduced resolution (RR). RR and FR data from areas, which are not in the visibility need to be recorded onboard. The capacity of the onboard recorder for FR data is limited to 20 min.

The background mission defines which data is stored and transmitted to the receiving station. The background mission foresees that RR data is available from every location worldwide, while FR data are available from European land surfaces and all coastal areas, but not from open ocean areas. Requests for FR data can be submitted to mission planning and overwrite the background mission.

2.9 Auxiliary Files

2.9.1 Summary of Auxiliary Datasets

2.9.1.1 MERIS Instrument Data File

This data file contains all the parameters needed for processing MERIS data in any band configurations. Therefore, it also contains the data needed for geolocation and resampling.

FILE ID: MER_INS_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(2,898 bytes) + DSs (approx. 2.936 MBytes) =2,940,344 Bytes

2.9.1.2 MERIS Level 1b Control Parameters Data File

This file contains processing parameters used during the generation of the Level 1b products.

FILE ID: MER_CP1_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(5,138 bytes) + DSs(12,872 bytes) = 19,257 bytes

2.9.1.3 Radiometric Calibration Data File

FILE ID: MER_RAC_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Nominally every 2 weeks
SIZE: MPH(1,247 bytes) + SPH(2,338 bytes) + DSs(2,166,097 bytes) = 2,169,682 bytes

2.9.1.4 Digital Roughness Model Data File

FILE ID: MER_DRM_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(658 bytes) + DSs(approx. 37 MB) = approx. 37.3 MB

2.9.1.5 Coastline/Land/Ocean Data File

The Land/Sea Mask file classifies points on the Earth's surface as Land/Sea or Coastline.

FILE ID: AUX_LSM_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Infrequently.
SIZE: MPH(1,247 bytes) + SPH(1,778 bytes) + GADS(approx. 12.3 MB) = approx. 13 MB

2.9.1.6 Aerosol Climatology Data File

FILE ID: MER_AER_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(1,498 bytes) + GADSs (1,233,444 bytes) = 1,236,189 bytes

2.9.1.7 Level 2 Control Parameters Data File

FILE ID: MER_CP2_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(1,498 bytes) + DSs(13,083 bytes) = 15,828 bytes

2.9.1.8 Atmosphere Parameters Data File

FILE ID: MER_ATP_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(2,898 bytes) + DSs(1,133,289) = 1,137,434 bytes

2.9.1.9 Water Vapour Parameters Data File

FILE ID: MER_WVP_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(1,778 bytes) + GADSs(33,437,320 Bytes) = 33,440,345 Bytes

2.9.1.10 Ocean Aerosols Parameters Data File

FILE ID: MER_OAP_AX
TYPE: Auxiliary
USE: Level 2 processing

UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(2,338 bytes) + DSs(47,535,994 bytes) = 47,539,579 bytes

2.9.1.11 Land Aerosols Parameters Data File

FILE ID: MER_LAP_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(4,018 bytes) + DSs(2,203,548 bytes) = 2,207,813 bytes

2.9.1.12 Ocean I Parameters Data File

FILE ID: MER_OC1_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(1,778 bytes) + DSs(2,634,189 bytes) = 2,637,214 bytes.

2.9.1.13 Ocean II Parameters Data File

FILE ID: MER_OC2_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(1,778 bytes) + DSs(19,727,376) = 19,730,401 bytes

2.9.1.14 Cloud Measurement Parameters Data File

FILE ID: MER_CMP_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(2,058 bytes) + DSs(5,415,011 bytes) = 5,418,316 bytes

2.9.1.15 Land Vegetation Index Parameters Data File

FILE ID: MER_LVI_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Once a year
SIZE: MPH(1,247 bytes) + SPH(378 bytes) + GADS(209 bytes) = 1,834 bytes

2.9.1.16 Surface Confidence Map File

The Surface Confidence Map file provides a Boolean flag which indicates for any location on Earth, whether the land/water classification provided by the Land/Sea Mask file is fully asserted or not.

FILE ID: MER_SCM_AX
TYPE: Auxiliary
USE: Level 2 processing
UPDATED: Infrequently.
SIZE: MPH(1,247 bytes) + SPH(938 bytes) + GADS(7,608,256 bytes) = 7,610,441 bytes

2.9.1.17 ENVISAT Orbit Data Files

The instrument ground processing software uses the CFI orbit propagator software module and an orbit state vector as input to calculate the satellite position all along the orbit. The following describes the product structure of the FOS predicted and restituted orbit state vector files.

FILE_ID: FOS Predicted: AUX_FPO_AX
FOS Restituted: AUX_FRO_AX
USE: Used during ground processing
UPDATED: Once per day
SIZE:
AUX_FPO_AX: One MDSR per orbit, file covers 6 days (86 MDSRs). Size = 1,247 (MPH) + 378 (SPH) + 129 * 86 MDSRs = 12,719 bytes.
AUX_FRO_AX: One MDSR per minute, file covers 1 day, with 60 minute overlap (1,500 MDSRs). Size = 1,247 (MPH) + 378 (SPH) + 129 * 1,500 = 195,125 bytes.

2.9.1.18 ECMWF Data Files

ECMWF data files contain meteorological information. They are ingested into the Payload Data Segment (PDS) ground segment on a regular basis and are used by various instrument processors during the generation of products.

There are two kinds of ECMWF data: Forecast data and analysis data. Forecast data is used in NRT processing, while analysis data is used during OFL product generation. Both forecast data and analysis data files have the same format.

FILE ID: AUX_ECF_AX - ECMWF Forecast data
AUX_ECA_AX - ECMWF Analysis data
TYPE: Auxiliary
USE: Level 1b processing, Level 2 processing
UPDATED: ECMWF files enter the PDS every 6 hours. There are 4 analysis files and 4 forecast files, each valid for a 12 hour time period.
SIZE: MPH(1,247 bytes) + SPH(378 bytes) + DSs(approx. 8.7 MB) = approx. 8.7 MB

2.9.1.19 Digital Elevation Model

This file contains a world Digital Elevation Model (DEM). The GADS of this file contains the elevation values on a regular grid. The coverage of the grid is from 180+1/24 W to 180 - 1/24 E degrees in longitude and from -90 + 1/24 to 90 -1/24 degrees in latitude. The resolution of the grid is 1/12 degree in longitude and 1/12 degree in latitude. One value is recorded at each grid point.

FILE ID: AUX_DEM_AX
TYPE: Auxiliary
USE: Level 1b processing
UPDATED: Infrequently
SIZE: MPH(1,247 bytes) + SPH(658 bytes) + DSs(37,325,059 bytes) = approx. 38 MB

2.9.2 Auxiliary Datasets for Level 1b Processing

The following table shows the auxiliary datasets used in Level 1b processing.

Table 2.18 - Level 1 auxiliary datasets.

Description	Auxiliary File ID
Instrument data file	MER_INS_AX
Radiometric calibration data	MER_RAC_AX
Digital elevation data	AUX_DEM_AX
Digital Roughness Model	MER_DRM_AX
Processing Level-1b control parameters data	MER_CP1_AX
ECMWF Forecast data or ECMWF Analysis data	AUX_ECF_AX AUX_ECA_AX
Land-ocean-coastline data	AUX_LSM_AX
Attitude Data File	AUX_ATT_AX
Orbit state vectors	AUX_FRO_AX DOR_NAV_0P DOR_POR_AX DOR_VOR_AX

2.9.3 Auxiliary Datasets for Level 2 Processing

The following table shows the auxiliary datasets used in Level 2 processing.

Table 2.19 - Level 2 auxiliary datasets.

Description	Auxiliary File ID
Cloud measurement parameters data	MER_CMP_AX
Land aerosols parameters data	MER_LAP_AX
Ocean aerosols parameters data	MER_OAP_AX
Ocean I parameters data file	MER_OC1_AX
Ocean II parameters data file	MER_OC2_AX
Atmospheric parameters data	MER_ATP_AX
Processing Level-2 control parameters data	MER_CP2_AX
Land vegetation index parameters data	MER_LVI_AX
Aerosol Climatology Data file	MER_AER_AX

Water Vapour Parameters	MER_WVP_AX
Surface Confidence Map data	MER_SCM_AX

2.9.4 2.9.4 Common Auxiliary Datasets

The following table shows the common auxiliary datasets used by other instruments as well as MERIS.

Table 2.20 - Common auxiliary datasets.

Description	Auxiliary File ID
Digital elevation data	AUX_DEM_AX
ECMWF Forecast data or ECMWF Analysis data	AUX_ECF_AX AUX_ECA_AX
Land-ocean-coastline data	AUX_LSM_AX
Attitude Data File	AUX_ATT_AX
Orbit state vectors	AUX_FPO_AX AUX_FRO_AX DOR_NAV_0P DOR_POR_AX DOR_VOR_AX

2.10 Latency, Throughput and Data Volume

The following table shows:

the time between acquisition and availability to end-users

measurements per orbit and product throughput

product size

for each MERIS product.

Table 2.21 - MERIS product details.

Product ID	Description	Delivery Time	Throughput	Product size
MER_RR_0P	Level 0 Reduced Resolution Product	The product is produced systematically and the NRT version of the product	1 product per orbit. Satellite data generation at 1.6 Mbps	max. 522 MB/product (43.5 min. × 1.6 Mbit/s).

		is available within 3 hours of data acquisition from the PDHS. The OFL (fully consolidated) version of the product is available from the LRAC 2 weeks after acquisition.		
MER_FR__0P	Level 0 Full Resolution Product	NRT version of the product is available within 1 day of data acquisition from the PDHS. The OFL (fully consolidated) version of the product available from the PAC 2 weeks after acquisition.	Variable as data is acquired upon request. Satellite data generation at 24 Mbps. Up to 12.5 minutes/orbit to PDHS-K, 20, minutes / orbit to PDHS-E, and 12.5 minutes /orbit to PDAS.	max. 3600 MB/orbit [24 Mbit/s for 20 minutes] to PDHS-E, or max. 2250 MB for 12.5 minutes per orbit at PDHS-K. Max file size is 2 GB, thus when larger, product divided across several files, each with own MPH and SPH
MER_CA__0P	MERIS Calibration Level 0 Product	NRT version of the product is available within 3 hours of data acquisition from the PDHS. The OFL (fully consolidated) version of the product is available from the LRAC 2 weeks after acquisition	performed on demand at a weekly to monthly rate. Calibration sequence takes approximately 160 seconds. Satellite data generation at 1.6 Mbps.	approx. 160 s × 1.6 Mbit/s = 32 MB/product.
MER_RR__1P	MERIS Reduced Resolution Geolocated and Calibrated TOA Radiance Product	NRT version is available from the PDHS 3 hours after data acquisition. The OFL (fully consolidated) version is available 2 weeks after acquisition from the LRAC.	1 per orbit	approx 40 MB per 1165 by 1300 km scene (1121 pixels × 1121 lines × 32 bytes/pixel)up to 521 MB/orbit (1165 km × 17400 km × 15 bands + 1 annotation band + auxiliary information appended)
MER_FR__1P	MERIS Full Resolution Geolocated and Calibrated TOA Radiance Product	NRT version available 1 day after data acquisition, OFL (fully consolidated	Variable as data is acquired upon request. Up to 12.5 minutes/orbit to PDHS-K, 20,	161 MB/scene; 41 MB/imagette.

		version) available 2 weeks after acquisition.	minutes/orbit to PDHS-E, and 12.5 minutes/orbit to PDAS.	
MER_RR__2P	MERIS Reduced Resolution Geophysical Product	NRT version of the product is available from the PDHS 3 hours after data acquisition. The OFL (fully consolidated) version is available from the LRAC 2 weeks after data acquisition	1 product per orbit	max. 621 MB/ 43.5 min product, approx. 46 MB per 1165 km by 1300 km floating scene
MER_FR__2P	MERIS Full Resolution Geophysical Product	NRT version available 1 day after data acquisition, OFL (fully consolidated version) available 2 weeks after acquisition.	Variable as data is acquired upon request. Up to 12.5 minutes/orbit to PDHS-K, 20, minutes/orbit to PDHS-E, and 12.5 minutes/orbit to PDAS.	186 MB/scene typically (582 km × 650 km). 50 MB per imagette (300 km × 334 km).
MER_LRC_2P	MERIS Extracted Cloud Thickness and Water Vapour for Meteo Users	This product is available in NRT form only, from the PDHS, 3 hours after data acquisition	1 product per orbit.	Max. 9 MB/product
MER_RRC_2P	MERIS Extracted Cloud Thickness and Water Vapour	This product is available in NRT form only, from the PDHS, 3 hours after data acquisition	1 product per orbit.	Max. 108 MB/product
MER_RRV_2P	MERIS Extracted Vegetation Indices	This product is available in NRT form only, from the PDHS, 3 hours after data acquisition	1 product per orbit.	Max. 91 Mb/product
MER_RR__BP	MERIS browse image (for both FR and RR products)	NRT product available from PDHS within 3 hours from data acquisition	1 product per orbit	max 4 MB (full orbit)

Chapter 3

MERIS Instrument

3.1 Instrument Description

A detailed description of the MERIS instrument is provided in document R-11.

3.1.1 The MERIS instrument

MERIS is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. Fifteen (15) spectral bands can be selected by ground command, each of which has a programmable width and a programmable location in the 390 nm to 1040 nm spectral range.

The instrument scans the Earth's surface by the so called 'push broom' method. CCDs arrays provide spatial sampling in the across track direction, while the satellite's motion provides scanning in the along-track direction.

MERIS is designed so that it can acquire data over the Earth whenever illumination conditions are suitable. The instrument's 68.5° field of view around nadir covers a swath width of 1150 km. This wide field of view is shared between five identical optical modules arranged in a fan shape configuration (see Figure 3.3 -). In the calibration mode, correction parameters such as offset and gain are generated, which are then used to correct the recorded spectra. This correction can be carried out either on board or on the ground.

The Earth is imaged with a spatial resolution of 300 m (at nadir). This resolution is reduced to 1200 m by the on board combination of four adjacent samples across track over four successive lines.

The scene is imaged simultaneously across the entire spectral range, through a dispersing system, onto the CCD array. Signals read out from the CCD pass through several processing steps in order to achieve the required image quality. These CCD processing tasks include dumping of spectral information from unwanted bands, and spectral integration to obtain the required bandwidth. On-board analogue electronics perform pre-amplification of the signal and correlated double sampling and gain adjustment before digitisation. The on-board digital electronics has three major functions: it completes the spectral integration, performs offset and gain corrections in full processed mode, and creates the reduced-resolution data when required.

The calibration of MERIS is performed at the orbital South pole, where the calibration diffuser is illuminated by the Sun by rotating a calibration mechanism.

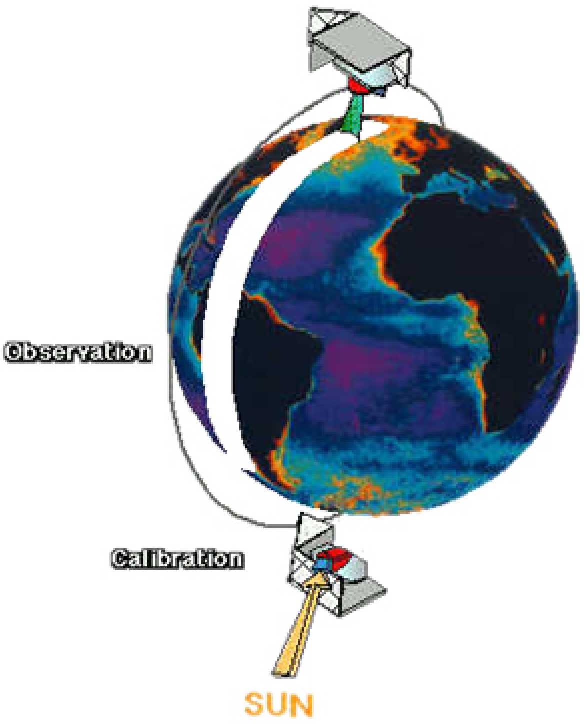


Figure 3.1 - Observation / calibration cycle.

The engineering requirements on the instrument, which have been derived from the Envisat mission requirements, are as follows:

Spectral range: 390 nm to 1040 nm

Spectral resolution: 1.8 nm
Band transmission capability: Up to 15 spectral bands, programmable in position and width
Band-to-band registration: Less than 0.1 pixel
Band-centre knowledge accuracy: Less than 1 nm
Polarisation sensitivity: Less than 0.3%
Radiometric accuracy: Less than 2% of detected signal, relative to sun
Band-to-band accuracy: Less than 0.1%
Dynamic range: Up to albedo 1.0
Field of view: 68.5°
Spatial resolution: 300 m at nadir

3.1.2 Instrument Concept

The instrument acquisition and processing chain can be separated into four sub systems:

The Instrument Optics
The Detection Focal Plane
The Video Electronic Unit
The Digital Processing Unit

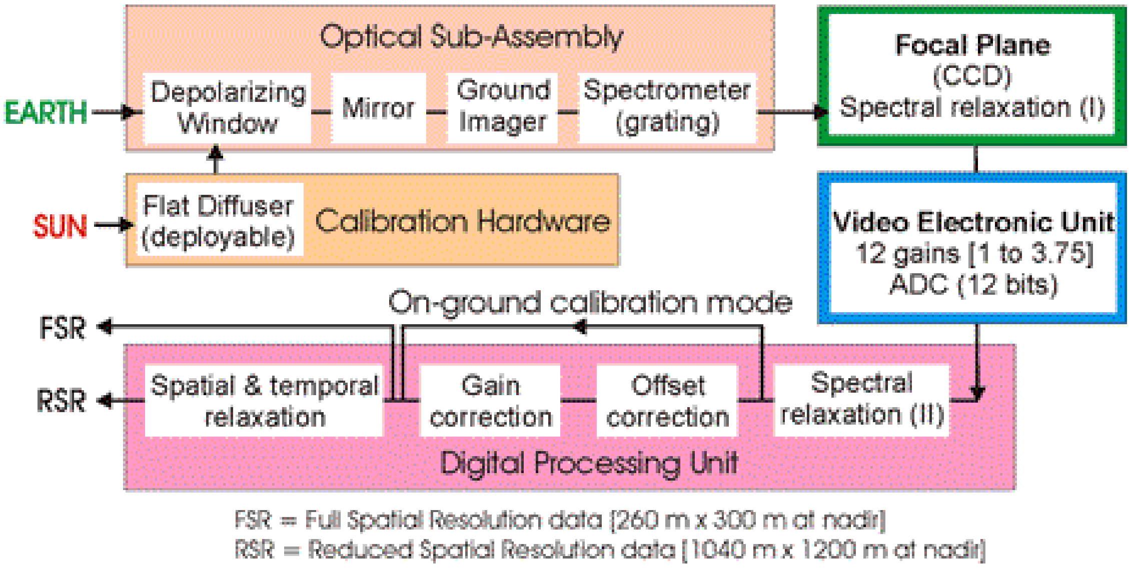


Figure 3.2 - Instrument Concept.

3.1.2.1 Instrument optics

The instrument has a field of view of 68.5° divided between five identical cameras, each having a field of view of 14°. The cameras are arranged in a fan shape configuration in which the fields of view overlap slightly (see Figure 3.3 -). The modular design has been specifically selected for MERIS to ensure high optical image quality over a large field of view. The output of each camera is processed separately in an analogue and digital processing unit.

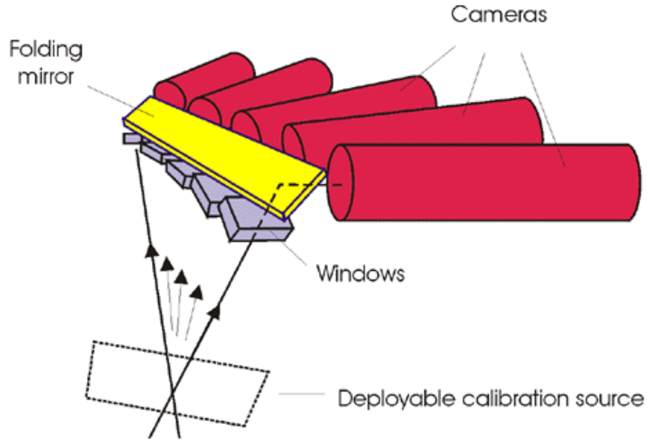


Figure 3.3 - Arrangement of optical modules, folding mirror and Earth viewing windows.

The MERIS optics consists of an external window, a folding mirror, an off axis catadioptric ground imager and a spectrometer. A window scrambles the incident polarised light coming from the Earth, making the instrument less sensitive to changes in light polarisation. The window also plays the role of protecting the rest of the optical elements.

The ground imager consists of a three lenses aperture group, a concave primary mirror, a convex secondary mirror cemented on the third aperture lens, and a field lens cemented on the spectrometer. The dispersive element of the spectrometer is a low grooves density concave reflecting holographic grating. A blocking filter is inserted in the corrector block to suppress the second order of the grating.

3.1.2.2 Detection Focal Plane

The camera's detectors are CCD arrays specifically developed for MERIS. Thinned back side illuminated CCDs have been selected which offers the required responsivity in the blue part of the spectral range. The camera swath is imaged along the CCD line while the light dispersion takes place along the CCD column. Each pixel is 22.5 micron square. The CCD covers the spectral range with a nominal 1.25 nm spectral sampling interval. The CCD basic layout is illustrated in **Error! Reference source not found.**. The CCDs operate in a frame transfer mode. The frame period is 44 ms. After integration, the charges are rapidly transferred from the imaging zone to the storage zone. A frame transfer is followed by a new integration period in the imaging zone, while the store zone is read out.

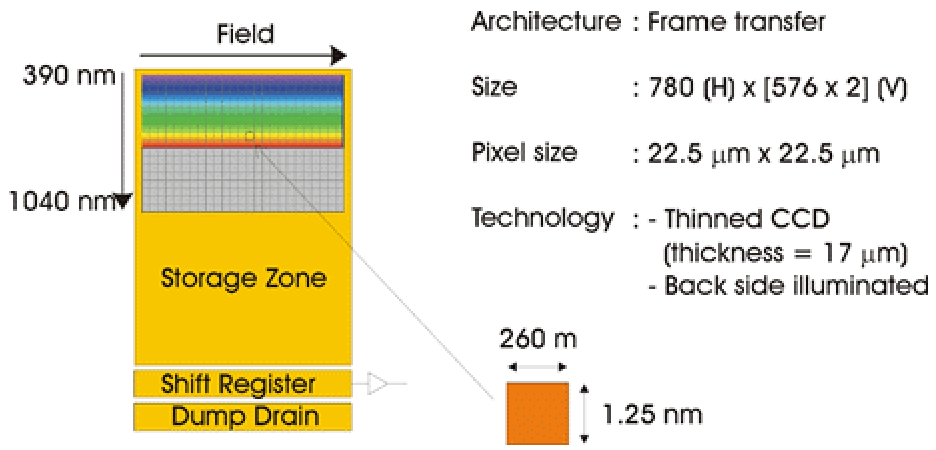


Figure 3.4 - Basic layout of the CCD.

The programmed spectral width is obtained by summing the necessary number of CCD lines in the shift register. This process is termed spectral relaxation. The CCD lines which fall outside the 15 selected spectral bands are dumped at shift register level.

The width and position of the MERIS spectral bands can be modified in-flight by programming the CCD. Apart from allowing the selection of different sets of spectral bands during the mission, the CCD programming also serves the purpose compensating for any spectral drift occurring during launch or in flight.

3.1.2.3 Video Electronic Unit

Each camera has a dedicated image processing chain. The analogue processing is undertaken by the Video Electronic Unit, whose functions are:

To extract the useful signal in 15 selected bands

To compensate the offset variation by using the dark reference pixels

To amplify the signal

To digitize the video signal on 12 bits

The signal amplification is done by selecting one of the 12 fixed gains defined in the range 1 to 3.75. The selection of the amplification gain is done separately for each spectral bands. Thus the saturation level of any band can be optimised for the purpose of the band. For instance a spectral band used only for ocean applications can saturate over clouds, leaving the full 12 bit digitisation for the useful dynamic range.

3.1.2.4 Digital processing Unit

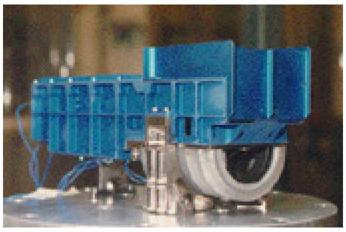
The digital output of the Video Electronic Unit is subsequently processed by the Digital Processing Unit in three major steps:

Complete the spectral relaxation up to the required bandwidth

Subtract the offset components and correct the gains in full processed mode

Reduce the spatial resolution of the data to 1200 m for the global mission

Offset and gain correction are based on coefficients computed during the calibration sequences. These coefficients are stored on board as well as sent to the ground. The instrument design offers the flexibility to have these corrections applied either on board or on ground. In the latter case offset, smear and gain correction are bypassed in the on board processing flow. The overall instrument acquisition and on board processing is illustrated in Figure 3.5 - .



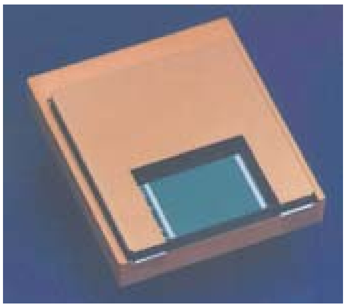


Figure 3.5 - MERIS instrument: camera (left) – spectro-imager camera (centre) – CCD (right).

The CCD is coupled to a Peltier cooler stabilizing the CCD temperature to -22°C.

3.1.3 Instrument model philosophy

The MERIS instrument development philosophy is based on a three-model approach:

The structural model (StM);

The engineering model (EM);

The flight model (FM).

The objectives of the StM are mainly the qualification of the instrument structure and the verification of dynamic behaviour.

The EM is to be used for a prequalification of the instrument design. The model will, among others:

verify the instrument performances (limited to one camera);

verify the internal and external interfaces;

verify electromagnetic compatibility (EMC);

qualify the functional operation aspects including the software and hardware/software compatibility;

qualify the instrument thermal control;

validate all ground support equipments (GSE).

The Flight Model (FM) will undergo a full acceptance test programme.

All three models are deliverables for integration on the Polar Platform.

MERIS has been developed under the leadership of ALCATEL Space Industries

3.2 Characterisation and Calibration

3.2.1 Calibration Modes

The calibration is performed at the orbital south pole, where the calibration diffusers are illuminated by the Sun by rotating a calibration mechanism. Two identical diffusers are available.

There are two types of calibration and associated operational scenarios.

1. Radiometric calibration is performed every two weeks using diffuser one. A monitoring of the degradation of the *BRDF* of diffuser one is performed every three months by deploying diffuser two and comparing the results.
2. Spectrometric calibration is performed every three months by first performing a radiometric calibration with an appropriate band settings for the spectral calibration under consideration, and deploying the erbium-doped diffuser with the same band settings on a second orbit. Two erbium spectral absorption features are used, one in the green and one in the NIR Additionally, a high-precision spectrometric calibration for the O_2A absorption bands is performed by exploiting the shape of the absorption band.

3.2.2 Onboard Calibration Hardware

One of the most severe requirements on MERIS is posed by calibration. A very accurate band-to-band calibration relative to the solar spectral *irradiance* is required for ocean colour applications. The imaging principle of MERIS imposes, in addition, a need for detector elements to be accurately normalised.

The basic hardware requirements for an onboard calibration system offering both a uniform reference signal over a large field of view and a stable absolute spectral reference signal has led to the preferred solution which utilises diffuser plates illuminated by the Sun.

The calibration hardware is implemented on a selection disk. A stepper motor allows the selection of any of the five positions of the disk as required by the instrument mission requirements.

Earth Observation

A diaphragm is introduced in the field of view.

Radiometric Gain Calibration

A Sun-illuminated white diffuser plate is inserted into the field of view of MERIS at the cross-over point of the five cameras' fields of view. The diffuser provides a reflectance standard across the entire spectral range and field of view. In this way a full aperture instrument calibration which follows the same optical path as in the observation modes is realised. During the calibration the signal is recorded for 512 frames. Each frame is corrected for offset and smear components. The averaged signal is then divided by the *BRDF* of the diffuser obtained from on-ground characterisation and stored onboard, yielding the absolute radiometric gains. If the on-ground calibration mode has been selected, the onboard processing is limited to the averaging over the 512 frames. The gain coefficients are calculated on ground.

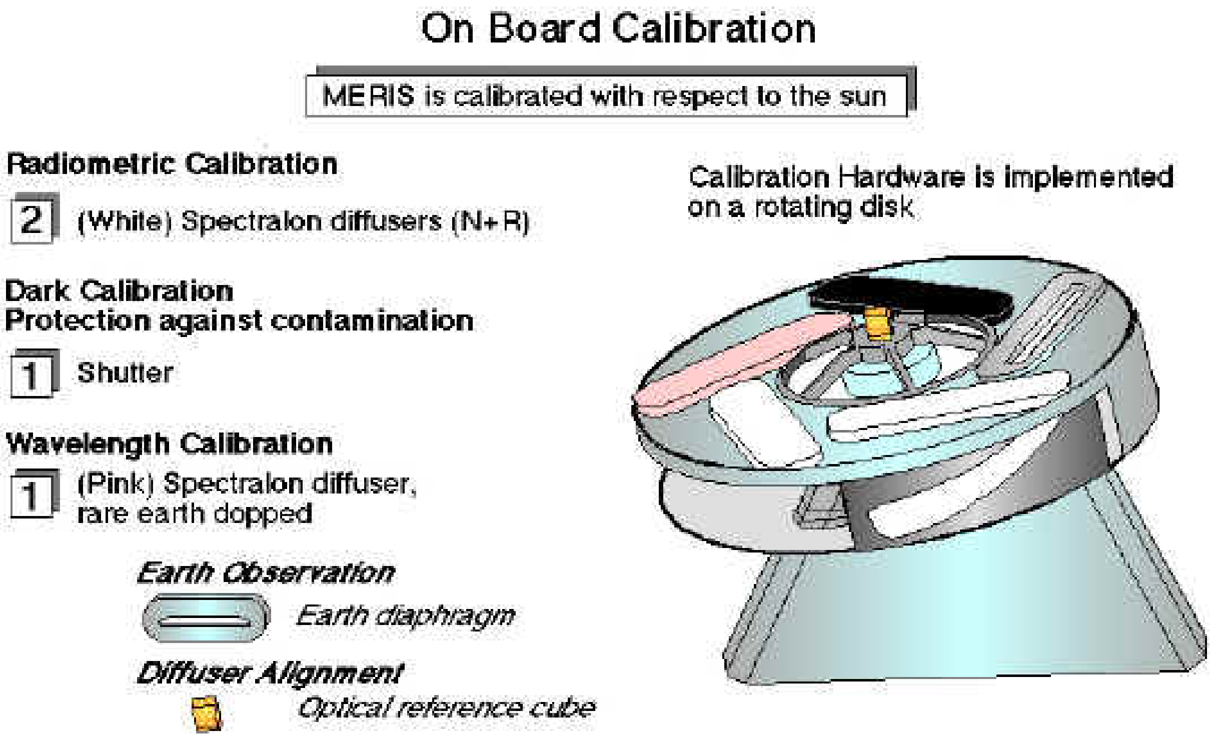


Figure 3.6 - Calibration hardware.

Diffuser Degradation Monitoring

The radiometric diffuser is exposed to the Sun for a cumulated period of about 1 hour during the MERIS lifetime. Some limited degradation caused by radiation exposure may be expected. A second diffuser is therefore provided to evaluate changes in the BRDF of the commonly used diffuser. This diffuser is used infrequently and thus does not degrade as quickly as the first diffuser. The ageing of the radiometric diffuser is monitored by comparing the data acquired with both diffusers.

Spectral Calibration

This is achieved by using the wavelength diffuser featuring well-characterised absorption minima. MERIS is reprogrammed to sample adequately the absorption features. As a result, the spectral distribution law is obtained, which relates spectral bands to their wavelengths. It is also envisaged to use as an alternative the solar Fraunhoffer line absorption seen when observing the radiometric diffuser. The wavelength diffuser is inserted into the field of view of MERIS. A precise wavelength calibration of the O2A absorption band is performed by comparing the diffuser measurements of the O2A band, normalised by a baseline through adjacent bands, with pre-calculated values.

Dark Calibration

The Earth and Sun optical paths are blocked by a shutter.

Following extensive environmental tests, SpectralonTM has been selected as the diffuser material. Diffusers manufactured with this material offer the required uniformity over the field of view and a remarkable stability. A diffuser plate doped with a rare Earth oxide is used for the spectral calibration.

The onboard calibration sequence calculates the calibration coefficients for all FR pixels of the 15 spectral bands, stores them on board for further use during full processed observation mode.

3.3 Instrument Characteristics and Performance

3.3.1 Instrument characteristic

The MS Excel document "MERIS_Wavelenghts_and_Irradiances_2005.xls" can be found at address http://earth.esa.int/pcs/envisat/meris/documentation/

This document gives :

the central wavelengths of each FR pixel for each band (pixel 1 is East, pixel 3700 is West),

corresponding in-band irradiances (derived using above wavelengths, computed instrument response functions and reference irradiances from sheet 4, scaled to Sun-Earth distance for MERIS reference day of year 95),

FWHM (Full Width at Half Modulation) of the instrument response functions for each band of each camera (each camera has 740 FR pixels – there is no FWHM variation for a given band within a given camera FOV -; camera 1 is east, camera 5 is west),

sheet 4 contains the reference Irradiance at 1 AU adopted for ENVISAT (*Thuillier, G., M. Hersé, P. C. Simon, D. Labs, H. Mandel, D. Gillotay, and T. Foujols, The solar spectral irradiance from 200 to 2400 nm as measured by the SOLSPEC spectrometer from the ATLAS 1-2-3 and EURECA missions, Solar Phys., submitted, 2002.*),

sheets 5 to 9 hold the instrument response functions for cameras 1 to 5 (hence 5 sheets), for each band, computed at centre of FOV (between pixels 370 & 371). Each function is scaled to max=1.

3.3.2 MERIS Quality Status

The product quality status is reported in the document "MERIS Products Quality Status Report" dated March 2006. It can be found at http://earth.esa.int/pcs/envisat/meris/documentation/.

This report can change with time and evolution of products and algorithms.

Chapter 4

MERIS Glossary and reference documents

4.1 Acronyms and Abbreviations

Table 4.1 - Acronyms and Abbreviations.

AATSR	Advanced Along-Track Scanning Radiometer
AC	ACross track
ADC	Analogue to Digital Conversion
ADEOS	ADvanced Earth Observation Satellite

ADS	Annotation Data Set
ADSR	Annotation Data Set Record
AISP	Annotated Instrument Source Packet
AIT	Acceptance, Integration, and Testing
AL	ALong track
AOCS	Attitude and Orbit Control System
ARVI	Atmosphere Robust Vegetation Index
ASAR	Advanced Synthetic Aperture Radar
ASIC	Application Specific Integrated Circuit
ASW	Application SoftWare
ATBD	Algorithm Theoretical Basis Document
AU	Astronomical Unit
AVHRR	Advanced Very High Resolution Radiometer
BIC	Bus Interface Controller
BOA	Bottom Of Atmosphere / Begin Of Acquisition
BOAVI	Bottom of Atmosphere Vegetation Index
BPA	Bleached Particle Absorption
BRDF	Bi-directional Reflectance Distribution Function
CA	Corrective Action / Cloud Albedo
Cal/Val	Calibration/Validation
CCD	Charge-Coupled Device
CFI	Customer-Furnished Item
CM	Calibration Mechanism
COSA	Camera Optics SubAssembly
CPU	Central Processing Unit
CZCS	Coastal Zone Colour Scanner
DAPB	Data Acquisition and Processing Block
DB	Detection Box
DBI	Digital Bus Interface
DBU	Digital Bus Unit
DDV	Dense Dark Vegetation
DEM	Digital Elevation Model
DORIS	Doppler Orbitography and Radio-positioning Integrated by Satellite

DPC	Digital Processing Chain
DPM	Detailed Processing Model
DRM	Digital Roughness Model
DR	Digital Relay
DS16	Digital Serial via 16 bits words
DSD	Data Set Descriptor
DSL	Depointing Signal Line
DSP	Digital Signal Processor
DSR	Data Set Record
DSU	Detection Supply Unit
DU	Detection Unit (dB + FPA)
ECMWF	European Centre for Medium-term Weather Forecast
EDAC	Error Detection And Correction
ENVISAT	ENVIronment SATellite
EQSOL	EQuipment Switch Off Line
ERS	European Remote-sensing Satellites
ESA	European Space Agency
ESRIN	European Space Research INstitute
FM	Flight Model
FME	Folding Mirror Element
FOV	Field Of View
FPA	Focal Plane Assembly
FPAR	Fractional Photosynthetically Active Radiation
FR	Full Resolution
FSR	Full Spatial Resolution
GADS	Global Annotation Data Set
GLI	GLobal Imager
GOME	Global Ozone Monitoring Experiment
GOMOS	Global Ozone Monitoring by Occultation of the Stars
HSM	High Speed Multiplexer
H/W	HardWare
ICU	Instrument Control Unit
ID	IDentifier

IFOV	Instantaneous Field Of View
IGBP	International Geosphere-Biosphere Programme
IMT	Inverse Modelling Technique
InFOV	Instrument Field Of View
I/O	Input/Output
IOCCG	International Ocean-Colour Coordinating Group
IOP	Inherent Optical Properties
IPF	Instrument Processing Facility
IR	InfraRed
IRS	Indian Remote Sensing Satellite
IRTM-NN	Inverse Radiative Transfer Model - Neural Network
ISLSCP	International Satellite Land Surface Climatology Project
JGOFS	Joint Global Ocean Flux Study
L1B	Level 1B
L2	Level 2
LANDSAT	LAND observation SATellite
LBR	Low Bit Rate
LR	Low Resolution
LRAC	Low Rate Reference Archive Centre
LSB	Least Significant Bit
LU	Luminance unit ($mW.sr^{-1}.m^{-2}.\ m^{-1}$)
LUT	Look Up Table
LVI	Land Vegetation Index
MARS	Monitoring Agriculture by Remote Sensing
MARS CAP	Monitoring Agriculture by Remote Sensing Common Agricultural Policy
MARS STAT	Monitoring Agriculture by Remote Sensing STATistics
MBR	Medium Bit Rate
MCMD	MacroCoMmanD
MDS	Measurement Data Set
MDSR	Measurement Data Set Record
MERIS	MEdium Resolution Imaging Spectrometer
MIPAS	Michelson Interferometer for Passive Atmospheric Soundings
MISR	Multi-angle Imaging SpectroRadiometer

MGVI	MERIS Global Vegetation Index
MJD	Modified Julian Day
MJD2000	Modified Julian Day 2000
ML16	Memory Load via 16 bits words
MMU	Memory Management Unit
MODIS	MODerate resolution Imaging Spectrometer
MOS	Modular Optoelectronic Scanner
MOMO	Matrix Operator MOdel
MPH	Main Product Header
MTF	Modulation Transfer Function
MWR	MicroWave Radiometer
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NDVI	Normalised Differential Vegetation Index
NEDL	Noise Equivalent Differential Luminance
NIR	Near Infra-Red
NN	Neural Network
NRT	Near Real Time
N/S	Non Significant
OBDH	OnBoard Data Handling
OBT	OnBoard Time
OCL	Offset Control Loop
OCI	Ocean Colour Imager
OCM	Ocean Colour Monitor
ODOC	Optical Dissolved Organic Compounds (synonyms: Yellow substance, Gelbstoff)
OCTS	Ocean Colour and Temperature Scanner
OFL	OFf-Line
OS	Operating System
OSMI	Ocean Scanning Multispectral Imager
PAR	Photosynthetically Available Radiation
PC	Peltier Cooler
PCD	Product Confidence Data
PDF	Portable Document Format

PDHF	Payload Data Handling Facility
PDHS	Payload Data Handling Station
PDS	Payload Data Segment
PDU	Power Distribution Unit
PF	Processing Facility
PF-HS	Processing Facility - Host Structure
PM	Payload Module
PMC	Payload Management Computer
POLDER, POLDER-2	POLarization and Directionality of the Earth's Reflectance
PPDU	Payload Power Distribution Unit
PPF	Polar PlatForm
PROM	Programmable Read Only Memory
PS	Power Supply (inside DSU)
RAM	Random Access Memory
RBI	Remote Bus Interface
RGB	Red Green Blue
ROM	Read Only Memory
RR	Reduced Resolution
RSR	Reduced Spatial Resolution
SAG	Science Advisory Group
SAGE	Stratospheric Aerosol and Gas Equipment
SAR	Synthetic Aperture Radar
SCIAMACHY	SCanning Imaging Absorption Spectrometer for Atmospheric Cartography
SDPSS	Science Data Processing SubSystem
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SL16	Serial Link via 16 bits words
SP	SPectral (dimension of the sensor)
SPH	Specific Product Header
SPM	Suspended Particulate Matter (equivalent to TSM)
SQADS	Summary Quality Annotation Data Set
SRDF	Spectral Region Distribution Function
SSI	Spectral Sampling Interval

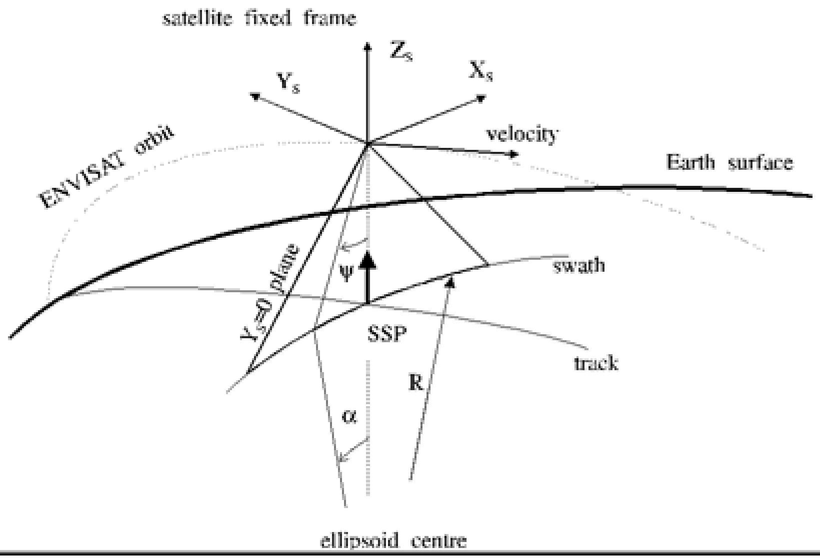
SST	Sea Surface Temperature
S/W	SoftWare
SWSA	Scrambling Windows SubAssembly
SWE	Scrambling Window Element
TBC	To Be Confirmed
TBD	To Be Defined
TOA	Top Of Atmosphere
TOAR	Top Of Atmosphere Radiance
TOAVI	Top Of Atmosphere Vegetation Index
TSM	Total Suspended Matter (equivalent to SPM)
TSP	Total Suspended Particulates
UNFCCC	United Nations Framework Convention on Climate Change
UT	Universal Time
UV	UltraViolet
VC	Video Chain
VEU	Video Electronic Unit
VIS	VISible
WGS84	World Geodetic Standard 1984
YS	Yellow Substance

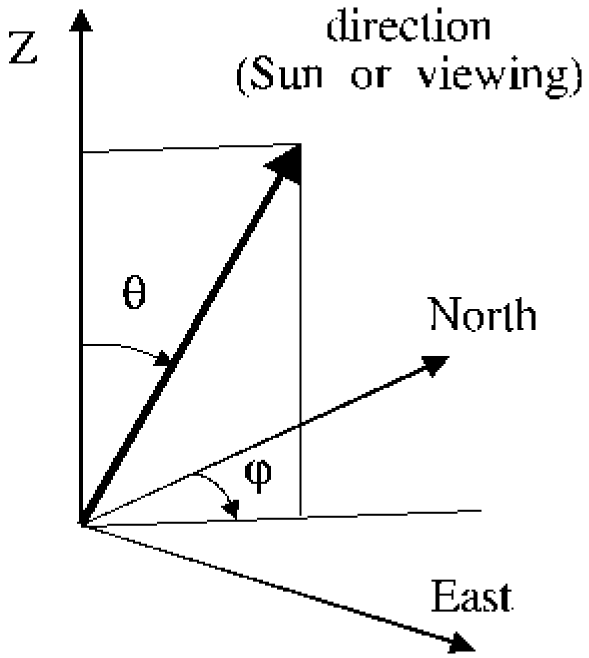
4.2 Glossary

4.2.1 Geometry Glossary

Table 4.2 - Geometry Glossary.

azimuth angle	Horizontal direction measured clockwise from the meridian plane.
elevation	The vertical distance of a point or object above or below a reference surface or datum (usually mean sea level). Also referred to as altitude or height.
geodesy	Science concerned with the measurement and mathematical description

	of the size and shape of the earth and its gravitational fields. Geodesy also includes the large-scale, extended surveys for determining positions and elevations of points, in which the size and shape of the Earth must be taken into account.
geoid	Figure of the Earth visualised as a mean sea level surface extended continuously through the continents. It is a theoretically continuous surface that is perpendicular at every point to the direction of gravity (the plumb line).
latitude	Angular distance, in degrees, minutes, and seconds of a point north or south of the Equator.
longitude	Angular distance, in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.
nadir	Point on the ground directly in line with the remote sensing system and the centre of the Earth.
pointing direction	Angle between a look direction lying in the (Y_S=0) plane in the satellite fixed coordinates system, and the $-Z_S$ axis of that system. Positive around Y_S.
satellite fixed coordinate system	Z_S points in the direction of the Earth outward local normal. X_S is perpendicular to the satellite orbit plane. Y_S completes the right-handed system and is the direction of the opposite of the satellite velocity. This coordinate system is defined and referred to as the "Satellite Relative Actual Reference" system. 
Sun zenith angle	The vertical direction of the Sun relative to the zenith expressed in degrees.
viewing angle	The angle measured from a position on the earth ellipsoid pointing towards the satellite. It is defined by its zenith θ and azimuth ϕ angles as shown in the following diagram:

	
WGS84 geoid	The Earth geoid model referred to as a "reference ellipsoid".
zenith angle	Angle between a look direction in the topocentric coordinate system and the zenith axis of that system (zenith angle + elevation angle = 90°).

4.2.2 Atmosphere Glossary

Table 4.3 - Atmosphere Glossary.

aerosol	Non-gaseous microscopic particles and droplets floating in the atmosphere that have a climate forcing effect, which can be derived from natural and artificial sources, with the most abundant ones being particles of mineral dust, sulphuric acid, ammonium sulphate, biological material-like pollens, and carbon or soot.
aerosol optical thickness	The factor by which the aerosol reduces optical transmission.
boundary layer	The part of the troposphere that is directly influenced by the presence of the Earth's surface, and responds to surface forcings with a timescale of an hour or less.
exosphere	Region of the atmosphere beyond 400 km. that fades into interplanetary space.
glitter	The reflection of sunlight from a rough water surface.
mesosphere	Region of the atmosphere, between approximately 50 to 100 km, in which temperature decreases with altitude.

Rayleigh scattering	Dominant form of light scattering in the upper atmosphere, which produces the blue colour of the sky. It is caused by atmospheric particulates that have very small diameters relative to the wavelength of the light, such as dust particles or atmospheric gases like nitrogen and oxygen.
solar flux	The energy or photon flow rate from the Sun.
stratosphere	Portion of the atmosphere between the tropopause, at approximately 8 to 15 km, and 50 km in altitude, depending upon latitude, season, and weather.
Sun glint	Specular reflection of solar flux on ocean surface.
thermosphere	Region of the atmosphere in which temperature increases with altitude. Located at approximately 100 to 400 km.
troposphere	Lowest region of the atmosphere, defined by a steady decrease in temperature with altitude. Extends to approximately 15 km above Earth's surface.

4.2.3 Cloud Glossary

Table 4.4 - Cloud Glossary.

cloud albedo	The ratio of the radiation reflected from the cloud's surface to the total amount incident upon it, for a particular portion of the spectrum.
cloud optical thickness	The factor by which the cloud reduces optical transmission.
cloud top pressure	The atmospheric pressure at the altitude of the top of the cloud.

4.2.4 Meteorology Glossary

Table 4.5 - Meteorology Glossary.

meridional wind	The wind that corresponds to the northward wind, or the wind that blows along a meridian.
ozone content	A naturally occurring trace gas, chemical formula O_3. In the stratosphere, it serves to absorb many harmful solar UV rays.
relative humidity	The relative humidity is the percent of saturation humidity, generally calculated in relation to saturated vapour density. $\text{Relative Humidity} = \frac{\text{actual vapor density}}{\text{saturation vapor density}} \times 100\%$

water vapour content	Water in gaseous form, esp. when evaporated below the boiling temperature.
zonal wind	The movement of air in a dominant west-east or east-west direction.

4.2.5 Neural Network Glossary

Table 4.6 - Neural Network Glossary.

activation / initialisation function	The time-varying value that is the output of a neuron.
backpropagation (generalised delta-rule)	A name given to the process by which the Perceptron neural network is "trained" to produce good responses to a set of input patterns. In light of this, the Perceptron network is sometimes called a "back-prop" network.
bias	The net input (or bias) is proportional to the amount that incoming neural activations must exceed in order for a neuron to fire.
connectivity	The amount of interaction in a system, the structure of the weights in a neural network, or the relative number of edges in a graph.
pattern recognition	The act of identifying patterns within previously learned data. This can be carried out by a neural network even in the presence of noise or when some data is missing.
epoch	One complete presentation of the training set to the network during training.
input layer	Neurons whose inputs are fed from the outside world.
learning algorithms (supervised, unsupervised)	An adaptation process whereby synapses, weights of neural network's, classifier strengths, or some other set of adjustable parameters is automatically modified so that some objective is more readily achieved. The backpropagation and bucket brigade algorithms are two types of learning procedures.
Learning rule	The algorithm used for modifying the connection strengths, or weights, in response to training patterns while training is being carried out.
layer	A group of neurons that have a specific function and are processed as a whole. The most common example is in a feedforward network that has an input layer, an output layer and one or more hidden layers.
Monte-Carlo method	The Monte-Carlo method provides approximate solutions to a variety of mathematical problems by performing statistical sampling experiments on a computer.
multilayer-perceptron (MLP)	A type of feedforward neural network that is an extension of the perceptron in that it has at least one hidden layer of neurons. Layers are updated by starting at the inputs and ending with the outputs. Each neuron computes a weighted sum of the incoming signals, to yield a net input, and passes this value through its sigmoidal activation function to yield the neuron's activation value. Unlike the perceptron, an MLP can

	solve linearly inseparable problems.
Neural Network (NN)	A network of neurons that are connected through synapses or weights. Each neuron performs a simple calculation that is a function of the activations of the neurons that are connected to it. Through feedback mechanisms and/or the non-linear output response of neurons, the network as a whole is capable of performing extremely complicated tasks, including universal computation and universal approximation. Three different classes of neural networks are feedforward, feedback, and recurrent neural networks, which differ in the degree and type of connectivity that they possess.
neuron	A simple computational unit that performs a weighted sum on incoming signals, adds a threshold or bias term to this value to yield a net input, and maps this last value through an activation function to compute its own activation. Some neurons, such as those found in feedback or Hopfield networks, will retain a portion of their previous activation.
output neuron	A neuron within a neural network whose outputs are the result of the network.
perceptron	An artificial neural network capable of simple pattern recognition and classification tasks. It is composed of three layers where signals only pass forward from nodes in the input layer to nodes in the hidden layer and finally out to the output layer. There are no connections within a layer.
sigmoid function	An S-shaped function that is often used as an activation function in a neural network.
threshold	A quantity added to (or subtracted from) the weighted sum of inputs into a neuron, which forms the neuron's net input. Intuitively, the net input (or bias) is proportional to the amount that the incoming neural activations must exceed in order for a neuron to fire.
training set	A neural network is trained using a training set. A training set comprises information about the problem to be solved as input stimuli. In some computing systems the training set is called the "facts" file.
weight	In a neural network, the strength of a synapse (or connection) between two neurons. Weights may be positive (excitatory) or negative (inhibitory). The thresholds of a neuron are also considered weights, since they undergo adaptation by a learning algorithm.

4.2.6 Ocean Colour Glossary

Table 4.7 - Ocean Colour Glossary.

attenuation	A term that describes the loss of electromagnetic energy (solar radiation) as it passes through the atmosphere owing to absorption and scattering by atmospheric particles and molecules.

biogenous	Biogenous sediment is derived from living organisms, normally plankton organisms, that have shells which are resistant to dissolution or destruction. The most common shell materials for plankton are calcite ($CaCO_3$ or calcium carbonate) and opal (SiO_2 or silica).
bloom	A population burst of phytoplankton that remains within a defined part of the water column.
case 1 waters	Those oceanic or coastal waters where the ocean colour is determined by algal pigments.
case 2 waters	All oceanic or coastal waters which are not case I waters.
chlorophyll	Pigments found in plant cells that are active in harnessing energy during photosynthesis.
coccolith	A small round body found in chalk formations.
detritus	Particulate material that enters into a marine or aquatic system.
diatom	A major phytoplankton group characterised by cells enclosed in silicon frustules, or shells.
euphotic zone	In the ocean, the sunlit layer consisting of the upper 100 m or so in which most of the primary productivity takes place. The depth varies geographically and seasonally and can range from a few metres in turbid waters near the shore to 120 m in the Sargasso Sea. It is a zone with sharp gradients in illumination, temperature and salinity, and is the upper of three vertical zones that comprise the pelagic part of the ocean, the other two being the middle mesopelagic and the lower bathypelagic zones. It is also known as the photic zone.
eutrophic waters	Water bodies or habitats having high concentrations of nutrients.
fluorescence	The re-emission of light energy at a lower frequency by an absorber illuminated with optical energy. The response is usually immediate and on order 1 to 3% of the incident intensity.
Gelbstoff	Dissolved material in sea water that is resistant to bacterial attack. Its name comes from the yellow colour it imparts to the water. Brown algae, the principal algae group growing in coastal waters of temperature and higher latitudes, excrete phenolic compounds. These polyphenols are converted into a brown polymer by secondary reactions with carbohydrates and proteins of algal origin. The properties of the resulting substance are identical with Gelbstoff. Its concentration in sea water is around 1 mg/l and it is removed mainly by precipitation since its phenolic nature renders it resistant to bacterial attack. This is also known as yellow substance or gilvin.
gilvin	See **Gelbstoff**.
halocline	A layer in water where the salinity changes rapidly.
heterotrophic	Refers to the ability of an organism to manufacture its own food. It must obtain it from other organisms, living or dead, and it is said to depend on external nourishment.
mesotrophic waters	A state of a water body within a soil which is intermediate in character between an eutrophic and an oligotrophic state, as far as its nutrients are concerned.

mixed layer	In oceanography, a nearly isothermal surface layer of around 40 to 150 m depth caused by wind stirring and convection.
oligotrophic waters	Refers to water bodies or habitats with low concentrations of nutrients.
packaging effect	The optical properties of a water sample varies if suspended particles gather in groups (are "packed") or divide (cell growth).
particulate organic matter	The suspended particle load that controls the chemistry of the oceans. The physical and chemical properties of the particles control how rapidly a chemical species is removed from solution and incorporated in sediment.
photosynthesis	The process in plants by which carbon dioxide is converted into organic compounds using the energy of light absorbed by chlorophyll, which in all plants except some bacteria involves the production of oxygen from water.
phytoplankton	One of two groups into which plankton are divided, the other being zooplankton. Phytoplankton comprise all the freely floating photosynthetic forms in the oceans, i.e., they are free-floating microscopic plants which, having little mobility, are distributed by ocean currents.
pigment	A substance giving colour to animal or vegetable tissues.
radiance	The radiation energy per unit time coming from a specific direction and passing through a unit area perpendicular to the direction.
reflectance	In radiation transfer, the fraction of incoming radiation that is reflected from a medium. The sum of this, the transmittance, and the absorption must equal unity.
Secchi Disc	A white target lowered from a vessel and viewed from above the surface in full solar illumination to estimate the attenuation in the water column.
thermocline	Depth zone within which temperature gradient is at a maximum.
total suspended matter	Particulates ranging in size from less than 0.1 micrometre to 50 micrometres are called Total Suspended Particulates (TSP).
turbidity	The weight of particulate matter per unit volume of sea water.
upwelling	The movement of nutrient-rich water from a specified depth to the surface.
whitecaps	The air/water emulsion occurring at the top of ocean surface waves under high winds.
yellow substance	See ***Gelbstoff*** .
zooplankton	Animal members of the plankton family.

4.2.7 Water Vapour Glossary

Table 4.8 - Water Vapour Glossary.

water vapour pressure	The atmospheric pressure which is exerted by water vapour (water in its gaseous state). It is one way of measuring the humidity of the air. At a given temperature, an increase of water vapour in the air corresponds to an increase in the humidity of the air. Water vapour is supplied to the atmosphere by evaporation of water from oceans, lakes, wet land surfaces or from vegetation (transpiration). Water vapour absorbs the Sun's radiation. As a result, the sunlight received at the earth's surface will be more intense in a dryer atmosphere.

4.2.8 Vegetation Glossary

Table 4.9 - Vegetation Glossary.

biomass	The amount of living material existing at a given instant of time in a unit volume or area.
biome	An area on the Earth's surface that has a certain set of characteristics. There are seven kinds of biomes in the world: tundra, taiga, temperate forest, tropical rainforest, desert, grassland, and ocean.
canopy	The layers of vegetation above the level of the ground, formed by the leaves of the plants.
phytosphere	The layer of ocean in which the phytoplankton is found.
vegetation index	The reduction of multispectral scanning measurements to a single value for predicting and assessing vegetative characteristics. Examples of such characteristics include plant leaf area, total biomass, fresh and dry above-ground phytomass, chlorophyll content, plant height, percent ground cover by vegetation, grain or forage yield and general plant stress and vigour.

4.2.9 Optics Glossary

Table 4.10 - Optics Glossary.

absorption	A measure of the ability of a surface to absorb incident energy, often at specific wavelengths.

albedo	The ratio of the radiation reflected from an object to the total amount incident upon it, for a particular portion of the spectrum.
backscatter	In radar, the portion of the microwave energy scattered by the terrain surface directly back toward the antenna.
detector index	Index of the CCD detector (1 to 15).
irradiance	The density of the radiant flux that is incident on a surface per unit of wavelength.
luminance	The quantitative attribute of light that correlates with the sensation of brightness and is the evaluation of radiance by means of the standard luminosity function.
Mie Scatter	A form of atmospheric scatter that occurs when radiation interacts with atmospheric particles whose diameter is approximately equal to the wavelength of the radiation.
Monte-Carlo method	Probabilistic method allowing to trace the path of each photon knowing the inherent (scattering and absorption) characteristics of the medium.
optical density	The logarithm to base 10 of the inverse of the transmittance.
photon	A photon is a particle of light (or other electromagnetic radiation).
radiance	A measure of the energy radiated by the object together with the frequency distribution of that radiation.
radiative transfer equation	The equation which describes the radiation passage through a scattering and absorbing medium.
radiometer	An instrument for quantitatively measuring the intensity of electromagnetic radiation in some band of wavelengths in any part of the electromagnetic spectrum. Usually used with a modifier, such as an infrared radiometer or a microwave radiometer.
Raman Scatter	Raman scatter arises when the incident light excites molecules in the sample which subsequently scatters the light. While most of this scattered light is at the same wavelength as the incident light, some is scattered at a different wavelengths . This inelastically scattered light is called Raman scatter. It results from the molecule changing it's molecular motions.
Rayleigh scattering	A form of atmospheric scattering that is caused when radiation interacts with particles whose diameter is much smaller than its wavelength. It therefore affects shorter wavelengths.
reflectance	Ratio of the intensity of reflected radiation to that of the incident radiation on a surface.
scattering	The process in which a wave or beam of particles is diffused or deflected by collisions with particles of the medium which it traverses.
scattering phase function	The angular function which describes the directional scattering probability as a photon interacts with a scattering particle.
Snell's law	Gives the quantitative change of direction of a ray of light in passing from one medium to another. The product n sin z is the same on both sides of a plane interface between two media, where n is the local refractive index, and z is the local angle the ray makes with the normal to the interface.

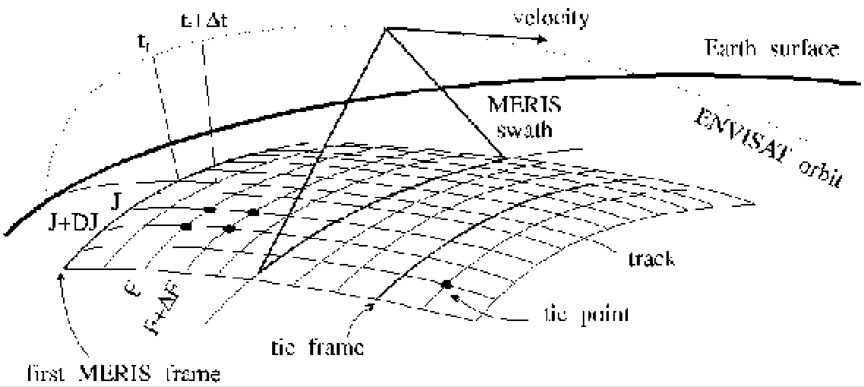
spectrometer	A device used to measure radiant intensity or to determine the wavelengths of various radiations.

4.2.10 Product Glossary

Table 4.11 - Product Glossary.

across track	The direction on the ground perpendicular to the satellite path.
along track	The direction on the ground of the satellite path.
Annotation Data Set	A data set that contains data other than instrument measurements.
auxiliary product	Data other than the instrument measurements which are necessary to the processing. Auxiliary data may come from the satellite itself, sources external to the PDS, or be created by instrument processing facilities within the PDS.
Browse product	Browse products are produced for AATSR, ASAR and MERIS. They are severely decimated images which can be ordered from the ENVISAT inventory. These products are very small to support electronic transmission while querying the catalogues. They may be further reduced in size through the use of standardised data compression algorithms. Browse products are generated systematically and contains image lines derived from a data segment (up to a full orbit of data).
column	A column of pixels follows the along track direction, its numbering starts from one and increases from East to West.
Data Set	A collection (one or more) of data set records in mixed binary/ASCII format.
Data Set Descriptor (DSD)	Data Set Descriptors are used to describe an attached Data Set or to provide reference to external files relevant to the current product (e.g. auxiliary data used in processing but not included with the product). There must be one DSD per Data Set or per reference to an external file.
frame	The set of product pixels corresponding to a given satellite position
full resolution	The full resolution grid has 4x4 more points than the reduced resolution grid, in the across track direction it has 4481 points.
pixel geometry	A set of angles (Sun zenith angle, viewing zenith angle and azimuth difference angle) specifying how the pixel is seen from the instrument and from the Sun.
level 0 data	Level 0 is the lowest level product in the ENVISAT PDS. Raw data is retrieved from the instrument data stream that holds measurements in numerical counts.

level 1b data	Level 1b products are geolocated products in which data has been converted into engineering units, auxiliary data has been separated from measurements, and selected calibrations have been applied to the data. These products are the foundation from which higher level products are derived. Level 0 products are transformed into Level 1b products by application of algorithms and calibration data to form a baseline "engineering product."
level 2 data	The level 2 product is a geolocated geophysical product. The Level 1b product is transformed into one or more Level 2 products through higher-level processing to convert engineering units into geophysical quantities and to form a data set that is easier to interpret.
line	A line of pixels follows the across track direction, its numbering starts from one and increases from North to South
location	Coordinates (geodetic latitude, longitude) of a point on the geoid, expressed in the Earth-fixed coordinate system.
low resolution	The low resolution grid has 4x4 less points than the reduced resolution grid.
Main Product Header (MPH)	The Main Product Header is in ASCII format and contains information which is common to all ENVISAT instruments.
Measurement Data Set (MDS)	The Measurement Data Set consist of a series of Annotated Instrument Source Packets (AISPs).
MERIS frame	A set of simultaneously acquired MERIS measurements; by extension the time when that set is acquired. The actual MERIS pixels are located at the known lines of sight of the MERIS pixel centres at the MERIS sampling instants. These are characterised by a pointing angle yk,m and an along-track offset from the (YS=0) plane, noted dqk,m. Considering the small variability of the along-track sampling distance along the orbit that offset is taken to be directly expressed in frames. As MERIS sensor elements have a nearly even angular spacing, the distance between their projections on Earth increases from centre to end of frame.
MERIS swath	Projection on the geoid of the sector between the extreme look directions of MERIS in the (YS=0) plane, at a given time.
Product Confidence Data	A flag that simultaneously provides surface type information (land, water or cloud), additional scientific information relevant to the product interpretation (dark vegetation, turbid waters, absorbing aerosols etc.), and confidence information for each product.
product pixel	Product pixels are a matrix of points where 1) lines (frames) correspond to the MERIS sampling instants and cope with the swath at those instants; 2) columns correspond to regular subdivisions of the interval between two adjacent columns of the tie points matrix, i.e. product columns are sampling the swath at constant distance.

product swath	The arc on the geoid between the two extreme product pixels at a given time. The product swath is wider than the widest possible MERIS swath. 
raw data	Raw data is recorded from the X and Ka band demodulator output interfaces and stored on High-Density Data Tapes (HDDTs). The Raw Data is not considered a product.
reduced resolution	The reduced resolution grid has 4x4 less points than the full resolution grid.
scene	A square, full resolution MERIS image containing 4481 x 4481 pixels.
Specific Product Header (SPH)	The SPH is in ASCII format and contains information which describes the specific product as a whole. It varies between instruments and between different products for each instrument. The SPH also contains Data Set Descriptors (DSDs). DSDs are used to point to and describe the various Data Sets which make up a product.
swath angle	An angle sub-tending the arc between swath centre and a point on the swath.
swath width	The distance between the two extreme pixels (Eastern and Western most pixels) of the same frame.
tie frame	A set of tie points corresponding to a given time and location of the satellite.
tie point	Tie points for a given product are a matrix of Earth points, where 1) lines (tie frames) correspond to regularly spaced (time-wise) instants tf, origin at the first frame of the product. Tie points are located at successive projections at instants tf of the (YS=0) plane in the satellite fixed frame (XS, YS, ZS); 2) the central tie point is at the swath centre, i.e. the projection on the geoid of the axis ZS; 3) tie points at a given instant are spaced at even distance (the same for all tie frames) along the swath.
unconsolidated	This is the Level 1b product produced in NRT using available NRT auxiliary data (i.e. may not be the most precise orbit vectors or calibration information).

4.3 Reference documents

An accurate description of the MERIS products and algorithms may be found in the following reference documents.

R-1 PO-TN-MEL-GS-005 — *MERIS Level 2 Algorithms Theoretical Basis Document*
Issue 4, Revision 0 – 05/12/1997
ACRI ST – ESA.
..\..\A001_VISIOTERRA_REFERENCE_DOCUMENTS\ENVISAT\PO-TN-MEL-GS-0005_issue_4-0_atbd_full.pdf

R-2 PO-TN-MEL-GS-0026 — *Reference Model for MERIS Level 2 Processing*
Issue 4, Revision 1 – 13/07/2001
ACRI ST – ESA.
..\..\A001_VISIOTERRA_REFERENCE_DOCUMENTS\ENVISAT\PO-TN-MEL-GS-0005_issue_4-0_atbd_full.pdf

R-3 PO-TN-MEL-GS-002 — *MERIS Level 1 Detailed Processing Model - Parameters Data List*
Issue 7, Revision 0 – 30/06/2005
ACRI ST – ESA
http://earth.esa.int/pub/ESA_DOC/ENVISAT/MERIS/reference_model_i4r1.pdf

R-4 PO-TN-MEL-GS-006 — *MERIS Level 2 Detailed Processing Model*
Issue 7, Revision 2 – 30/06/2005
ACRI ST – ESA
../reference_documents/mail_20050720_Bourg_DPM1_DPM2_Erbium_fromACRI/DPML2_i7r2/Dpm01_02.doc

R-5 *PGICD - Vol. 7* — *Measurement Data Definition and Format Description for MERIS*
Issue 6– 15/01/2001
Astrium GmbH.
..\..\A001_VISIOTERRA_REFERENCE_DOCUMENTS\ENVISAT\PO-ID-DOR-SY-0032_08pgicd.pdf

R-6 PO-RS-MDA-GS-2009 (4) — *Envisat-1 Products Specifications - Volume 4 – Product overview*
Issue 3, Revision C – 28/11/2000
ESA – ALCATEL SPACE
http://envisat.esa.int/support-docs/productspecs/
http://earth.esa.int/pub/ESA_DOC/ENVISAT/vol04_3c.products_overview.pdf

R-7 PO-RS-MDA-GS-2009 (5) — *Envisat-1 Products Specifications - Volume 5 – Product structures*
Issue 3, Revision C – 16/10/1997
ESA – ALCATEL SPACE
http://envisat.esa.int/support-docs/productspecs/
..\..\A001_VISIOTERRA_REFERENCE_DOCUMENTS\ENVISAT\PO-RS-MDA-GS-2009_Product_Specifications\vol05_products_structure_3c.pdf
http://earth.esa.int/pub/ESA_DOC/ENVISAT/vol05_3c.product_structures.pdf

R-8 PO-RS-MDA-GS-2009 (11) *Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications*
Issue 4, Revision A – 04/11/2004
ESA – ALCATEL SPACE
http://envisat.esa.int/support-docs/productspecs/
..\reference_documents\mail_20050517_Goryl_Vol11_Meris_4a.pdf
http://earth.esa.int/pub/ESA_DOC/ENVISAT/MERIS/Vol11_Meris_4a.pdf
http://earth.esa.int/pub/ESA_DOC/ENVISAT/Vol11_Meris_4a.pdf

R-9 PO-RS-MDA-GS-2009 (A) *Envisat-1 Products Specifications – Annex A – Product data conventions*
Issue 3, Revision E – 20/06/2005
ESA – MDA
http://envisat.esa.int/support-docs/productspecs/
http://earth.esa.int/pub/ESA_DOC/ENVISAT/AnnexA_Data_Convention_3e.pdf

R-10 *MERIS Spectral Characterisation*
Issue 1, Revision 0 – December 2005
ESA – ACRI
MERIS_Wavelenghts_and_Irradiances_2005.xls

R-11 MERIS-DID *MERIS Detailed Instrument Description*
Issue 01, Revision 00 – 13/02/2006
ESA – VisioTerra
VT-P017-DOC-004-E-01-00_meris.DetailedInstrumentDescription.1_0.pdf

R-12 MERIS-FAQ *MERIS Frequently Asked Questions*
Issue 01, Revision 00 – 13/02/2006
ESA – VisioTerra
VT-P017-DOC-005-E-01-00_meris.faq.1_0.pdf

Chapter 5

MERIS Data Formats Products

A detailed description of the MERIS products is given in the following documents:

R-6 *Envisat-1 Products Specifications - Volume 5 – Product structures,*

for the description of the Main Product Header (MPH), and giving information regarding the generic structure of the Specific Product Header (SPH) and Data Set Descriptors (DSD).

R-7 *Envisat-1 Products Specifications - Volume 11 – MERIS Products Specifications,*

for the description of the Specific Product Header (SPH), Measurement Data Sets (MDS), and Annotation data Sets (ADS) of all the MERIS products (levels 0, 1 and 2).

Chapter 6

MERIS Credits

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	Canada Centre for Remote Sensing Director General's Office 588 Booth Street , Room 330 Ottawa , Ontario K1A 0Y7 Tel: +1-613-947-1393 Fax: +1-613-947-1382 Contact: Mr. Edryd Shaw E-Mail: Ed.Shaw@GeoCan.NRCan.gc.ca
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