DUE CoastColour

Product User Guide

Deliverable DEL-21

Version 2.1

03. June 2011

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Revision History

Version	Date	Change	Author
1	30.10.2010	Initial version	C. Brockmann
1.1	07.11.2010	Chapter 8 Examples added	C. Brockmann
2.0	31.05.2011	Revision to match Demonstration Data set	C. Brockmann, M. Peters
2.1	03.06.2011	Update of Section 6 (Data types, NetCDF content)	M. Peters

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1 SCOPE OF THIS DOCUMENT

This document is the Product User Guide for the ESA DUE CoastColour processing. It is the reference product description, which specifies the products, its content and briefly summarizes the algorithms used to generate it.

The Product User Guide evolves with the project. This is the second version which matches the Demonstration Dataset, provided to users in June 2011.

By construction of the project alternative processing options will be tested during the coming months resulting in the final algorithms and product design. The final version of the document will reflect the final version of the CoastColour processor.

2 INTRODUCTION

To collect synoptic data about the ocean's ecosystem, we need to apply Earth Observation, or remote sensing. There is only one option: visible spectral radiometry, commonly known as ocean colour. No alternative exists for synoptic study of the marine ecosystem, whether we are concerned with the open ocean or, more particularly with coastal ecosystems, where processes tend to operate with higher frequency and shorter spatial scale than offshore.

There are many reasons why one would want to monitor the coastal ecosystem using ocean colour, bearing in mind that the principal deliverable of the method is the bulk seawater concentration of chlorophyll as contained in phytoplankton. The basic anabolic metabolism of phytoplankton is photosynthesis: they are autotrophs and therefore consumers of carbon dioxide. At the global scale, the flux of carbon through marine phytoplankton is about 50 Gigatonnes per annum. Coastal zones are amongst the most productive regions, biologically speaking, in the ocean. Hence, the role of the coastal zone in the planetary carbon cycle is of fundamental importance, and it can be quantified using remotely-sensed data on ocean colour. In other words one can infer from the chlorophyll fields the rate of photosynthesis, amongst the most important of the derived products of ocean colour.

Another characteristic of coastal waters is that, optically, they are complex (compared with the open ocean) and large optical gradients can be found. Such strong optical gradients are favourable for the development and refinement of radiative transfer models of ocean colour: instances can be found where each one of the major optically-active substances (chlorophyll, Gelbstoff, inorganic suspension, organic detritus) dominates. In turn, the bio-optical models so refined can be useful in open-ocean applications, where the optical gradients are often much more subtle.

In coastal regions, the input of sediments from river drainage can have an adverse effect on ecosystem habitat, as can coastal erosion. Ocean colour remote sensing provides an ideal method to monitor sediment movements, providing invaluable information for the aquaculture and fisheries sector. Similarly, the influx into the coastal zone of coloured material in solution through river drainage can be monitored using ocean colour. Coastal zones are under habitat stress because of the large population concentrations over much of the world's coastlines. The delivery of pollutants to coastal waters can be seen directly (if they have a colour signature), or indirectly through their effect on the phytoplankton (if they do not). A good example of the latter is input of inorganic fertilizers from agriculture leading to development of algal blooms, including harmful ones. This is a topic on which the aquaculture industries crave information. More generally, ocean-colour is particularly useful for monitoring water quality at high temporal and spatial resolution, and over extensive areas. This is relevant to the Water Framework Directive of the European Union.

Harvest fisheries can also benefit greatly from the application of ocean-colour data. For at least one hundred years, it has been recognised that we might account for the observed fluctuations between years in exploited fish stocks by studying the fish, in their larval stage. Because the larval stage is usually planktonic, studying this stage means studying a mostly passive component of the pelagic ecosystem and its variable forcing.

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Planktonic stages of fish inhabit an ecosystem in which the communities are, for the most part, microbial. The implication is that the intrinsic turnover times are rapid. The pelagic (micro)flora is on the average about thirty times more active, metabolically, than the terrestrial flora, a consequence of the relative sizes of the organisms concerned. To make sense of the ecological impact of the interannual variability in forcing of the pelagic ecosystem, we must study it on the appropriate scales of time and space. Generally speaking, this is difficult to achieve using ships as the operational platform.

So, with notable exceptions (Cushing), the long-standing hypothesis that the key to variability of fish populations lies in variable forcing of the pelagic ecosystem when the fish are in their larval stage, has proved difficult to test at the relevant time and space scales. However, the advent of remotely-sensed data on visible spectral radiometry of the ocean has radically changed this situation. It is now possible to collect data on the pelagic ecosystem, highly resolved in space (nominally 1 km or better), with rapid repeat coverage (nominally one day), averaged over any area chosen by the investigator. For the first time, we are suitably equipped to test hypotheses about the fisheries implications of ecosystem variability.

We are therefore more adequately equipped than ever before to manage exploited fish stocks (invertebrate as well as vertebrate) on a rational basis. That is, rather than treating the stocks as theoretical entities subject only to the equations of population dynamics, we are now able to consider, on the correct scales, the influence of environmental and ecosystem variability (in particular fluctuations in the availability of food in the critical period of larval stages).

It is clear that the information we now have at our disposal to elucidate fluctuations in the abundance of fish stocks in enormously enhanced over what was available only recently. We could say that, as a consequence, fisheries science stands on the threshold of a renaissance. One of the tasks of ocean-colour scientists is to deliver the relevant information in such a way that it can be exploited to the maximum in the fisheries sector.

More generally, ocean-colour remote sensing proves to be an ideal vehicle for retrieving a broad range of objective indices of ecosystem status and ecosystem health. These are difficult to quantify, but could be characterized using a series of metrics measurable by remote sensing. These so-called ecological indicators provide a compact description of the pelagic ecosystem at a given time and place. The comprehensive information they embody affords an invaluable background to biological oceanographic research, constitutes important ecological intelligence for fisheries management, and for ecosystem-based management of marine resources in the broadest sense. Rational management requires information. Because the ocean is highly dynamic (especially the coastal zone), the information needs to be updated frequently. We cannot hope to accomplish this using ships as the observing platform. Our only hope is through remote sensing. For the ecosystem, our only avenue is via ocean-colour remote sensing.

The European Space Agency has launched the CoastColour project to work towards these objectives by developing, demonstrating, validating and intercomparing different Case 2 algorithms over a global range of coastal water types, identifying best practices, and promoting discussion of the results in an open, public form. CoastColour will fully exploit the potential of the MERIS instrument for remote sensing of coastal zone water. The product requirements have been derived from a user consultation process. These have been translated into algorithm requirements and subsequently in algorithm specification and implementation. A first set of CoastColour products includes a revised Level 1 product and atmospherically corrected coastal products. These are described in this Product User Guide Version 1.

3 COASTCOLOUR APPROACH

The task of retrieving water optical properties and concentrations from reflections spectra in coastal waters is a complex matter. In contrast to case 1 water, where by definition, only 1 component determines the variability of the water leaving radiance reflectance, in all other types of waters, defined as case 2, a large number of factors determines the reflectance, which surmounts the number of independent pieces of information which can be retrieved from the spectra. These factors are various dissolved and suspended water constituents including a variety of phytoplankton species with varying cell size and compositions of absorbing pigments, then bottom effects, stratification and floating material on or close to the surfaces, including Red Tides, Cyanobacteria carpets and foam produced by Phaecystics globosa. Also the atmosphere is more complex in contrast to the deep ocean, with soot containing particles from industry, heating and traffic biomass burning, contrails from aircrafts and desert dust. Considering all of these factors, one can easily come to the conclusion that remote sensing of such areas is not possible. As a consequence as system of procedures is necessary, which reduces the manifold of variables to a number of components, which can be retrieved from reflectance spectra and, at the same time, detects cases, which require special treatments and cases which lead to errors and which have to be flagged. Furthermore, the retrieval uncertainty has to be computed on a pixel to pixel basis.

The general outline of the CoastColour system of procedures is given in Figure 1.

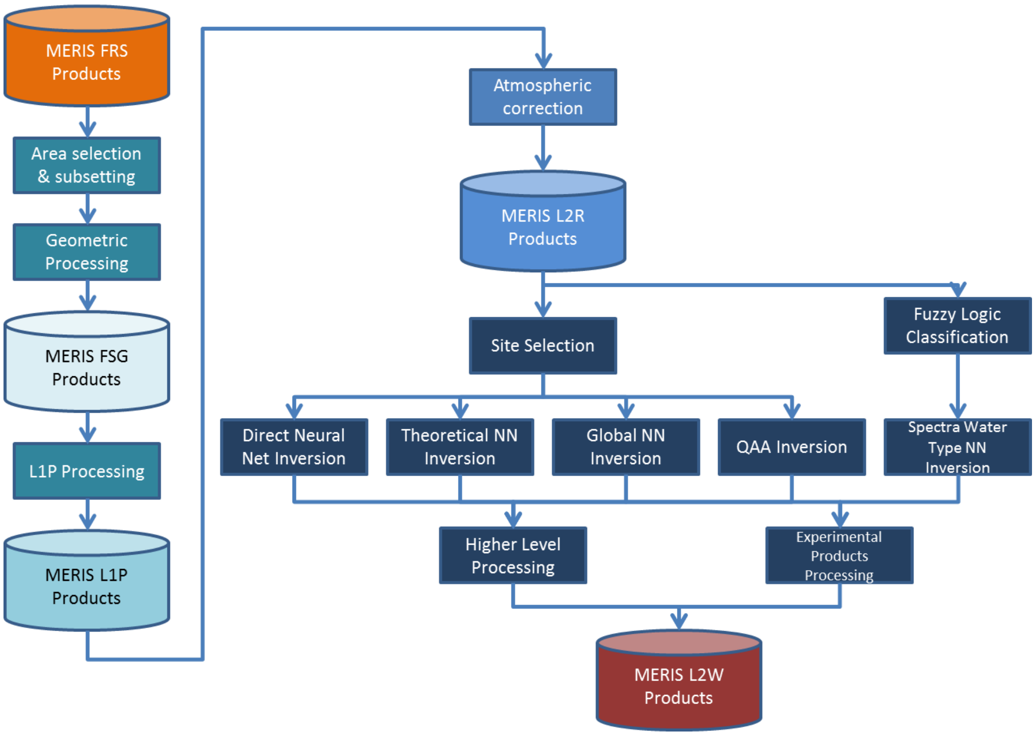

Figure 1: ***General outline of CoastColour processing*.**

Starting point are the MERIS FRS Level 1 products, which include auxiliary data such as surface pressure, ozone, geographical location of pixel, solar and viewing angles, solar flux. A geographical selection is performed in order to detect product which have an overlap with one of the CoastColour sites. Child products are generated and geometrically processed with AMORGOS. The FSG products are further processed by L1P processing, which further cuts the product size horizontally to match the site polygon, performs a radiometric correction, smile correction, equalisation and pixel classification (cloud screening). The results are CoastColour L1P products.

These are input the atmospheric correction, which performs quality checks and generates directional and normalised water leaving reflectances.

The next step classifies a water pixel by using its TOA spectral signature together with available geographical information (5) and applies currently a certain number of different, partially regionally tuned processing that’s all provide IOPs. In the final processing a selection will be made which processing will finally applied. Higher level and experimental products are derived from the IOPs.

4 Level1P Processing

4.1 General Product Description

The Level 1P product is a refined top of atmosphere radiance product compared with the standard Level 1b product. It will provide:

- Improved geolocation
- Improved calibration
- Equalization to reduce coherent noise
- Smile correction
- Pixel characterization information (cloud, snow, …)
- Precise coastline
- Reformatting into NetCDF following Climate Forecast (CF) conventions

The product consists of basically the same type of information as the standard L1b product, namely spectral radiances in 15 bands at top of atmosphere level but with improved radiometry plus additional information including geolocation and geometry, pixel characterisation (flags) and ancillary information such as ECMWF data. The differences with the standard product are

- Changed radiometry in order to improve calibration and remove instrument errors
- Additional pixel characterization flags
- Improved accuracy geolocation at per-pixel level
- Improved land-water mask and coastline
- NetCDF-CF format

The Level 1P product with its bands is described in detail in section 6.

4.2 Methodology and Algorithms

4.2.1 Improved calibration

MERIS standard processing algorithms are revised, and as part of this, the degradation model of the calibration diffusor has been improved, which results in updated gain values per detector. This is applied in L0 to L1 processing. The Reduced Resolution products are currently undergoing a reprocessing (3rd reprocessing) at ESA; however, this applies only to archived RR products, and the Level 1b FRS products available for CoastColour are at 2nd reprocessing quality. The Improved Calibration of CoastColour is reverting the second reprocessing gains and applying the 3rd reprocessing gains, so that that TOA radiances are comparable with the 3rd data.

The radiometric calibration as described below is a non-linear process including several steps. The radiometric gains are the second last step before the L1b are written. However, the last step is the straylight correction which is a non-linear process and not revertible from L1b product. The Improved Calibration of CoastColour is therefore only an approximation. The algorithm is fully defined and implemented. The quality of the Improved Calibration is currently assessed; it is therefore not applied in the CoastColour Preliminary Processing.

The valid MERIS samples are digital counts resulting from the detection and acquisition by MERIS of a bi-dimensional field of spectral radiance in front of the instrument. The objective of the radiometric processing, together with the stray light correction, is to estimate that spectral radiance. An inverse model of the MERIS processing is used for that purpose, using parameters stored in the Characterisation and Radiometric Calibration data bases and the MERIS samples themselves. The MERIS acquisition model may be described as:

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

Where

- M is the camera (or module); b is the spectral band; k is the pixel column; f is a frame (processing unit of number of image lines)
- $X_{b,k,m,f}$ is the MERIS raw sample
- $NonLim_{b,m}$ is a non-linear function, representing the non-linear transformations which take place in the CCD, amplifier and A/D converter; NonLin depends on band and gain settings
- T_f^{VEU} is the temperature of the MERIS amplifiers (VEUs) at the time of frame f
- T_f^{CCD} is the temperature of the MERIS detectors (CCDs) at the time of frame f
- g and g_c are (dimensionless) temperature correction functions
- $AL_{b,k,m}$ the "absolute radiometric gain" in counts/radiance unit; AL depends on band & gain settings
- $L_{b,k,m,f}$ the spectral radiance distribution in front of MERIS
- $Sm_{b,k,m,f}$ the smear signal, due to continuous sensing of light by MERIS
- $C^0_{b,k,m}$ the calibrated dark signal (possibly including an on-board compensation), dependent on band and gain settings
- $G_{b,k,m}$ a linear operator (weighted sum) representing the stray light contribution to the signal. For a given sample, some stray light is expected from all the other samples in the module, spread into the sample by specular (ghost image) or scattering processes
- ε is a random process representative of the noise and measurement errors

This model is inverted during processing: The inverse of the absolute instrument gain $AL_{b,k,m}$ is applied to the valid samples of all bands after dark and smear signal subtraction, with a compensation for the estimated temperature which is expressed as a function of time:

$$R_{b,k,m,f} = \left(AL_{b,k,m}\right)^{-1} \cdot \left\{ \left(X'_{b,k,m,f} - S_{b,k,m,f}\right) \cdot \left[g_0 + g_1(t_f - t_{ref}) + g_2(t_f - t_{ref})^2 \right] - C_{b,k,m,f} \right\}$$

Where $R_{b,k,m,f}$ are the spectral radiances before the straylight correction. The CoastColour Improved calibration is assuming the final straylight corrected radiances as equal to this $R_{b,k,m,f}$. The 2nd reprocessing radiometric gains (AL) are multiplied to R, and then the inverse of the 3rd reprocessing gains are multiplied to give an estimate of the 3rd reprocessing radiances.

4.2.2 Coherent noise equalisation

The MERIS equalization module performs a radiometric equalisation of the MERIS L1b products. It reduces detector-to-detector and camera-to-camera systematic radiometric differences and results into a diminution of the vertical stripping observed on MERIS L1b products. The MERIS swath is imaged by a CCD. The radiance at each pixel of a MERIS L1b products results from the measurements of 5 cameras spread across the swath, each one imaging a part of the swath with 740 so-called detectors in FR (corresponding to 185 mean detectors in RR). This results into 3700 detectors imaging the swath of MERIS FRS product (925 in RR). The response of each one of these detectors is calibrated during the routine operation of the instrument. Residual uncertainties in the calibration process result into detector-to-detector and camera-to-camera systematic radiometric differences. The equalisation corrects for these radiometric differences via a set of detector dependant coefficients correcting for the residual uncertainties in the calibration process. These coefficients are retrieved via a methodology described in Bouvet and Ramino, 2010, based on observations of the Antarctica plateau spread out throughout several years and ideally the MERIS mission lifetime. The coefficients are different for MERIS Reduced and Full Resolution products.

Reference: Bouvet M., Ramino F. (2010): Equalization of MERIS L1b products from the 2nd reprocessing, ESA TN TEC-EEP/2009.521/MB (available on demand at mbouvet@esa.int)

4.2.3 Smile correction

MERIS is measuring the reflected sun light using CCD technique. A CCD is measuring in one of its dimensions one image line, and in the other dimension the spectrally dispersed radiance for each pixel along the image line. I.e., the spectral measurements of each pixel along an image line is made by it's own set of sensors of the CCD. This causes small variations of the spectral wavelength of each pixel along the image. This is called the "smile effect".

The MERIS instrument is composed of 5 cameras, each equipped with it's own CCD sensor. The variations of the wavelength per pixel are in order of 1nm from one camera to another, while they are in the order of 0.1nm within one camera.

Even though this variation is small compared to the spectral bandwidth of a band, which is typicall 10nm, and can hardly be seen in an image, it can cause disturbances in processing algorithms which require very precise measurements, for example the retrieval of chlorophyll in the ocean. These disturbances can result in visual artefact ("camera borders") or reduced accuracy of the Level 2 products.

Therefore, the MERIS Level 2 processor corrects the smile effect. The Level 1b product is not smile corrected, because this product shall provide the user exactly what the instrument is measuring, and that is in fact the radiance at the given wavelength of each pixel.

The Smile Correction of BEAM is an exact implementation of the Level 2 smile correction, so that the users have a tool to generate smile corrected Level 1b products. While the Level 1b product provides the radiance measurement for individual wavelengths within one spectral band, the smile corrected product has normalised the wavelengths within one spectral band to one reference wavelength. Table 1 provides the reference wavelengths and the reference solar irradiance for this band. Please note that the reference solar irradiance is not corrected for the daily variation.

The smile correction consists of two terms: the irradiance correction and the reflectance correction.

The irradiance correction corrects the variation of the solar irradiance, which is different between the wavelength of the pixel and the reference wavelength:

$$L_{corr,irr}(\lambda_0) = L_{meas,pixel}(\lambda_0) * \frac{F_{0,ref}(\lambda_0)}{F_{0,pixel}(\lambda_0)}$$

The reflectance correction is interpolating along the slope of the reflectances between adjacent wavelengths from the pixel-wavelengths to the reference wavelength:

$$L_{corr,refl}(\lambda_0) = \left[L_{meas,pixel}(\lambda_2) * \frac{F_{0,ref}(\lambda_0)}{F_{0,ref}(\lambda_2)} - L_{meas,pixel}(\lambda_1) * \frac{F_{0,ref}(\lambda_0)}{F_{0,ref}(\lambda_1)} \right] * \frac{(\lambda_{ref} - \lambda_1)}{(\lambda_2 - \lambda_1)}$$

The smile corrected radiance is the sum of the two terms:

$$L_{corr}(\lambda_0) = L_{corr,irr}(\lambda_0) + L_{corr,refl}(\lambda_0)$$

While the irradiance correction can be applied to all 15 bands, it is not possible to define for each band two adjacent bands, which are suitable universally to give a good estimation of the spectral slope within the band. For the bands in absorption lines, i.e. bands 11 and 15, it is totally impossible to find suitable adjacent bands.

4.2.4 Geolocation

The geolocation will be done using the AMORGOS (Accurate MERIS Ortho-Rectified Geo-location Operational Software) tool, available from ESA and developed by ACRI-ST.

AMORGOS is generating accurate geo-location information - longitude, latitude, altitude - for each MERIS pixel, starting from a MERIS Full Resolution product.

If the input product is a Full Swath one, the current version accepts two modes. The first one preserves the organisation of the input product, namely the Level 1b product grid, it is referred to as the FSG (full swath geo-corrected) mode and generates a MER_FSG_1P product. The second one generate results re-organised in the instrument geometry, it is referred to as the FSO (full swath ortho-geolocated) mode and generates a MER_FSO_1P product.

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The FSO mode first restores radiance samples and accompanying flags into Instrument Geometry, un-doing the spatial re-sampling of the Level1 processing, and computes accurate ortho-rectified geo-location using MERIS detectors individual pointing vectors, a High Resolution DEM and accurate spacecraft Orbit and Attitude files.

The FSG mode essentially skips the Instrument Geometry restoration step and computes the same geo-location information for each MERIS detector and each acquisition time but it affects these values to the corresponding MERIS L1B product pixels. It must be noted here that since the MERIS product grid is filled by a nearest neighbour method from the Instrument Acquisition grid with a slight spatial over-sampling, the same instrument sample can be found several times in the same Level 1b product (it is then identified as a DUPLICATE pixel within the Level 1b product flags). Since the additional geo-location information of the MER_FSG_1P product is linked to the source Instrument sample, it will be duplicated the same way than the radiance information.

Ortho-rectified geo-location must be understood as the computation of the intersection of a given sample line of sight with the Earth surface (as represented by the Digital Elevation Model) rather than with the reference ellipsoid as in Level 1b. However, it must be noted that image geometry is either the Instrument one (FSO mode) or the Level 1b one (FSG mode) and thus the output product is not ortho-rectified stricto sensu.

For CoastColour AMORGOS will be run in FSG mode. Further processing of FSO mode products is not possible and not required.

4.2.5 Pixel Characterisation

4.2.5.1. Improved Land-Water Mask and Coastline

If precise latitude and longitude information is available at pixel level (as after processing with Amorgos), a precise geographical database delineating land and water can be queried to provide the land or water attribute at pixel level. If this database is at higher resolution than the MERIS pixel size it is possible to estimate the land and water fraction per pixel.

The SRTM Water Body Database (SWBD) has been used for this purpose. It is a geographical dataset encoding high-resolution worldwide coastline outlines in a vector format, published by NASA and designed for use in geographic information systems and mapping applications. It was created by the US National Geospatial-Intelligence Agency (NGA) as a complementary product during editing of the digital elevation model database of the Shuttle Radar Topography Mission (SRTM). SWBD data covers the Earth's surface between 56° southern latitude and 60° northern latitude. It is distributed in ESRI shapefile format, divided into 12,229 files, each covering one 1°-by-1° tile of the Earth's surface. SWBD data is in the public domain and has been downloaded from NASA.

The Globcover land classification product was used to fill up the SWDB for northern latitudes.

The L1P processing adds two flags to the product:

1) A land flag (true = pixel has 0% water fraction)

2) A coastline flag (true = pixel has 0% < water fraction < 100%)

4.2.5.2. Cloud screening

The L1P processing includes a cloud screening procedure. This is a combination of several tests on features such as brightness, height of the scattering surface and high atmospheric turbidity. The tests take high reflection of sun glint into account.

A risk of sun glint is calculated using the wind speed available at the tie-points to get the Fresnel reflection according to Cox and Munk, in the same way as described in MERIS ATBD 2.13 (envisat.esa.int/instruments/meris/atbd/). Additionally a radiometric test is performed to verify the potential of sun glint. The result of this testing is stored in a flag called sun glint risk. This flag cannot differentiate sun glint from clouds and is therefore true for both, clear sky sun glint and clouds over, where from wind-speed & geometry calculation sun glint is possible.

A cloud buffer of 1 pixel has been put around every cloud pixel. It is available as a separate flag in the L1P product, to be used or ignored in further processing.

A cloud shadow is calculated using the cloud top height, derived by a neural network technique as described in the MERIS ATBD 2.3 Cloud Top Pressure (envisat.esa.int/instruments/meris/atbd/), and the sun illumination geometry. The cloud shadow is also available as a separate flag. Currently this algorithm is in an experimental stage and will be improved for further releases.

Cloud shadow is not calculated for cloud buffer pixels.

4.2.5.3. Sea ice/ snow screening

The MERIS Normalised Differential Snow Index MDSI is evaluated to calculate the risk of sea ice (with and without snow cover):

MDSI = (toa_refl_865 – toa_refl_885) / (toa_refl_865 + toa_refl_885)

Ice/Snow is assumed to exist if a pixel is bright and the MDSI exceeds a threshold.

The Ice/Snow test is only applied where an ice climatology has a minimum ice coverage > 0%. The climatology is based on the HadISST data (http://www.hadobs.org/). The result of the test is added to the L1P product as “snow_ice” flag.

4.2.5.4. Land Risk

This flag shall indicate mixed land-water pixels, including floating cyanobacteria blooms. It is currently not derived and always set to false.

5 L2 Processing

As stated in the overview the L2 processing comprises different steps and branches with alternative algorithms and procedures for special user requested tasks.

The first step is the atmospheric correction, which is necessary for almost all further products. Only the fluorescence line height (FLH) and the Maximum Chlorophyll Index (MCI) algorithms can be used with or without atmospheric correction.

After the atmospheric correction we have a network of partly hierarchical organized algorithms available.

5.1 General Product Description

As the result of the user requirements and discussions with the users, a suite of different products will be generated. For some of the products alternative algorithms will be test and the most appropriate one for a task will then be used.

In general the following L2 products will be generated:

Acro	*Product*	*Algorithm*	*Status May 2011*
Level 2R			
RLw	Directional water leaving radiance reflectance	AC neural network	Available
RLwn	Fully normalized water leaving radiance reflectance	Normalisation neural network	Available
tau_lam	aerosol optical depth at three wavelengths (550nm, 779nm,	Aerosol neural network	Available

	865nm)		
ang	Angstrom exponent between 443 and 865nm	Aerosol neural network	Available
Level 2W			
a_total	Total absorption coefficient of all water constituents	Neural network water, QAA	Available
a_pig_443	Phytoplankton pigment absorption coefficient	nnWater, QAA	Available
a_ys_443	Yellow substance absorption coefficient	nnWater, QAA	Available
A_poc_443	Absorption by particulate organic matter	nnWater, QAA	Not available
bb_spm_443	backscattering coefficient of suspended sediment	nnWater, QAA	Available
chl	Chlorophyll a concentration	Conversion from a_pig	Available
tsm	Total suspended matter	Conversion from b_total	Available
kd_490	Downwelling irradiance attenuation coefficient at 490nm	postprocessing of nnWater	Available
k_min	Minimal downwelling irradiance attenuation coefficient	postprocessing of nnWater	Available
Z90_max	Maximal signal depth	postprocessing of nnWater	Available
Z_eu	Depth of euphotic layer	postprocessing of nnWater	Not available
Z_SD	Secchi disc depth	postprocessing of nnWater	Not available
FLH	Fluorescence line height	FLH algorithm	Available, but currently not written to product
MCI	Maximum chlorophyll index	MCI algorithm	Available, but currently not written to product
TFU	Turbidity in Formazine Units	TFU algorithm, postprocessing of nnWater	Available
biomass	Phytoplankton biomass in C units	Conversion from chlorophyll	in development
FL	Sun light induced fluorescence	Derived from nnAC	in development
PPP	Potential primary production	Primary production for standard parameters, PP model	in development

5.2 Methodology and Algorithms

5.2.1 Atmospheric correction

The correction of the influence of the atmosphere (shortly *atmospheric correction, AC*) is the most critical step in ocean colour remote sensing of case 2 water coastal waters.

It is defined here as the determination of the water leaving radiance reflectance spectrum (RLw(λ)) from the top-of-atmosphere radiance reflectance spectrum (RL_toa(λ)). This requires the determination of the radiance backscattered from all targets above the water surface including air molecules, aerosols, thin clouds, foam on the water as well as all radiance which is specularly reflected at the water surface, in particular the sun glint. Furthermore, the transmission of the solar radiance through the atmosphere to the water surface and of the radiance from the water surface to the sensor has to be computed.

In the case of high concentrations of humic matter in the water (gelbstoff) the reflection of the water body can become extremely small so that algorithms fail, which are based on an extrapolation of the path radiance from the red and near infrared bands to the blue-green spectral range. They produce incorrect water leaving reflectance spectra, partly with negative reflectances in the first 1-3 bands. In clear water cases the reflectance in the red bands are very low and unreliable and cause a problem when submitted to the water neural network algorithm. To avoid these problem an atmospheric correction procedure has been developed as an alternative to the standard MERIS correction, which reconstructs the water leaving radiance reflectance from TOA reflectance by using an artificial neural network. It uses 12 MERIS bands, and has been trained with simulated spectra to correct also sun glint contaminated pixels. The procedure is based on 2 ESA contracts, the Case 2 Regional Processor and the Glint correction processor, and is implemented in BEAM. It will be described in detail below.

For both algorithms an adjacency effect correction will be performed for areas close to the coast. A new element is an auto-associative NN, which will be used to determine out of scope spectra.

The atmospheric correction procedure is based on radiative transfer simulations. The simulated radiance reflectances are used to train a neural network, which, in turn, is used for the parametrisation of the relationship between the top of atmosphere radiance reflectances, RL_toa and the water leaving radiance reflectances (RLw). Furthermore it computes (1) the atmospheric path radiances (RL_path), (2) the downwelling irradiance at water level (Ed), (3) the aerosol optical thickness at 550 nm and three other wavelengths and (4) the angstrom exponents of the aerosol optical thickness. The water leaving radiance reflectances (RLw) is then be used as input to another procedure for retrieving the IOPs and concentrations of the water constituents.

The model atmosphere comprises three parts: (1) a standard atmosphere, which includes layers with variable concentrations of different aerosols, cirrus cloud particles and a rough, wind dependent sea surface with specular reflectance, but with a constant air pressure- and ozone profile, (2) a layer on top of the standard atmosphere, which contains only the difference between the standard and real atmosphere concerning air molecules and ozone, and (3) a module to compute the water leaving radiance reflectance.

Of importance is the correction of the sun glint, which is included in the atmospheric correction. It allows using the full swath of a MERIS scene, even for high glint conditions.

Three interfaces are defined: top of the actual atmosphere (TOA), top of standard atmosphere (TOSA) and bottom of atmosphere (BOA).

The atmospheric correction comprises three steps:

1) Calculation of the path radiances and transmittances of the variable "Rayleigh - ozone-layer" by using actual values of sea surface pressure and total ozone content from the ancillary data of MERIS and subtracting them from the standard values. Thus, the path radiance might become negative or the transmittance might become > 1 in cases where the air pressure and ozone con-tent differences are negative. The path radiance and transmittances of this 'correction layer' are used to calculate the downwelling solar irradiance and the upward directed radiance at the top of standard atmosphere (TOSA). The actual pressure regards also the altitude of a lake by including the altitude-pressure formula into the procedure. Furthermore, the correction of a band shift along the cameras

is performed in this module. This band shift is due to small misalignments of the 5 cameras. This has in particular an effect on the actual solar irradiance and the Rayleigh scattering. Both effects are corrected within this module.

Output of this procedure is the radiance reflectance at top of standard atmosphere, RL_tosa.

2) Calculation of the water leaving radiance reflectance, Rlw, by using a forward artificial neural network fwNN. The training of this network is based on the same training data set – computed with Hydrolight radiative transfer model -, which is used to train the backward NN for retrieving the inherent optical properties of water.

3) Calculation of the water leaving radiance reflectance, path radiances reflectance at TOSA, and the downwelling irradiance at bottom of atmosphere (BOA). This calculation is done with the neural network, which is trained with simulated radiances. It includes effects of different aerosols, cirrus clouds, specularly reflected sun and sky radiance and the coupling between all these components and the air molecules.

Input to the neural network are the TOSA radiance reflectances of 12 MERIS bands (412, 443, 490, 520, 560, 620, 665, 681, 708, 756, 778, 865 nm) s. in Figure 5 (1,2) as well as the solar zenith angle, the viewing zenith angles and the difference between viewing and sun azimuth angle (3). Output of the NN are the water leaving radiance reflectances (11), the path radiance reflectance (9) and the transmittance / downwelling irradiance (10), all of the12 MERIS bands, and the aerosol optical thickness at 443, 550, 778, 865 nm (12) from which the angstrom coefficient is computed (13). Further outputs for test purposes, which are not used to generate products, are the total scattering and absorption coefficients of water and the sun glint ratio. The core of the algorithm is a multiple non-linear regression method ("Neural Network"). Its coefficients are determined from a large set of simulated atmospheric and water conditions for the input variables and corresponding output variables. The coefficients of the NN are computed by using a feed forward backpropagation optimisation ("training") technique. The data set for training and testing is produced by radiative transfer simulations using an ocean-atmosphere Monte Carlo photon tracing model, which has been developed at GKSS. This model allows us to label the events, which are photons has encountered. By this it is possible to count photons separately as sun glint photons, which were specularly reflected at the surface and not scattered in the atmosphere. Another model, which has been used recently for computing the training data set, is a modified 6SV code, which is based on the successive order of scattering technique (SOS) and which also includes polarisation.

An alternative atmospheric correction scheme will be tested using an extension of the ICOL processor. Since this processor includes already the determination of aerosol optical properties it can be extended to a full atmospheric correction procedure. This extension will be provided and compared to the NN based AC.

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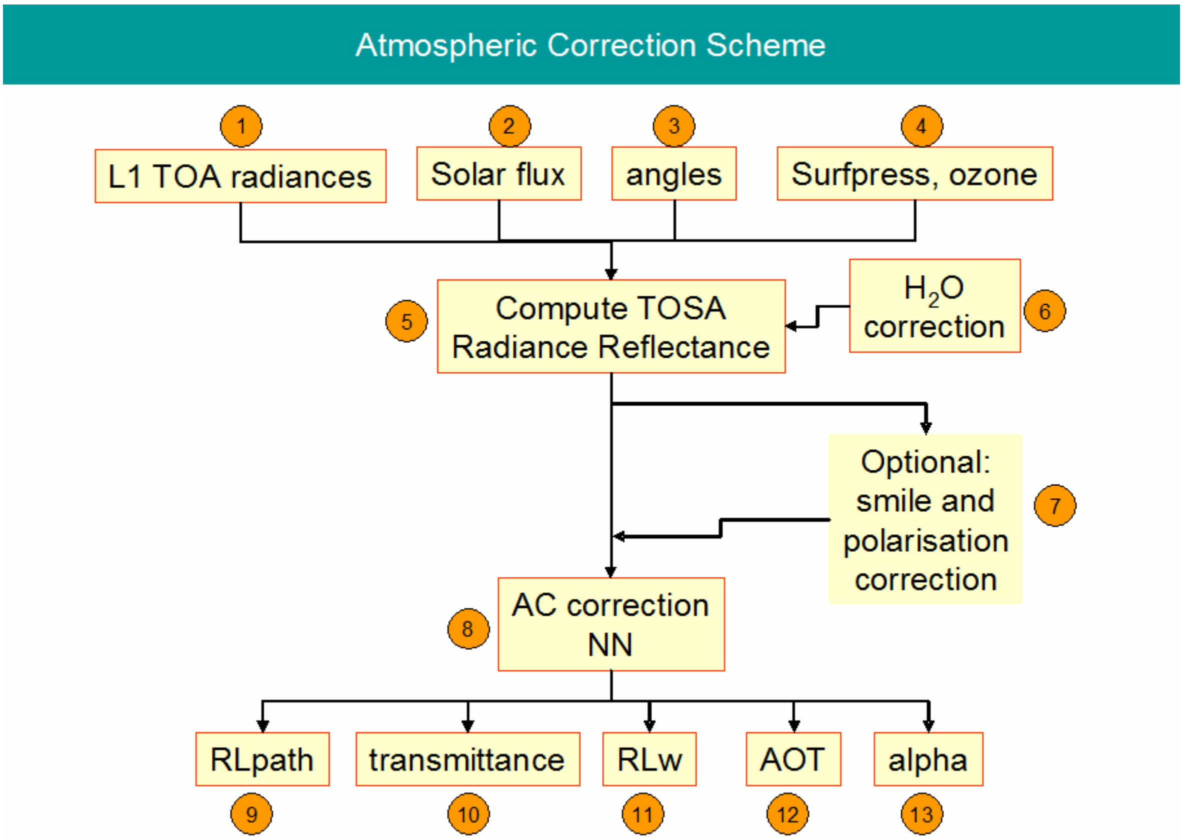

Figure 2: Atmospheric correction scheme

The neural network has the input/output neurons as given in Figure 3.

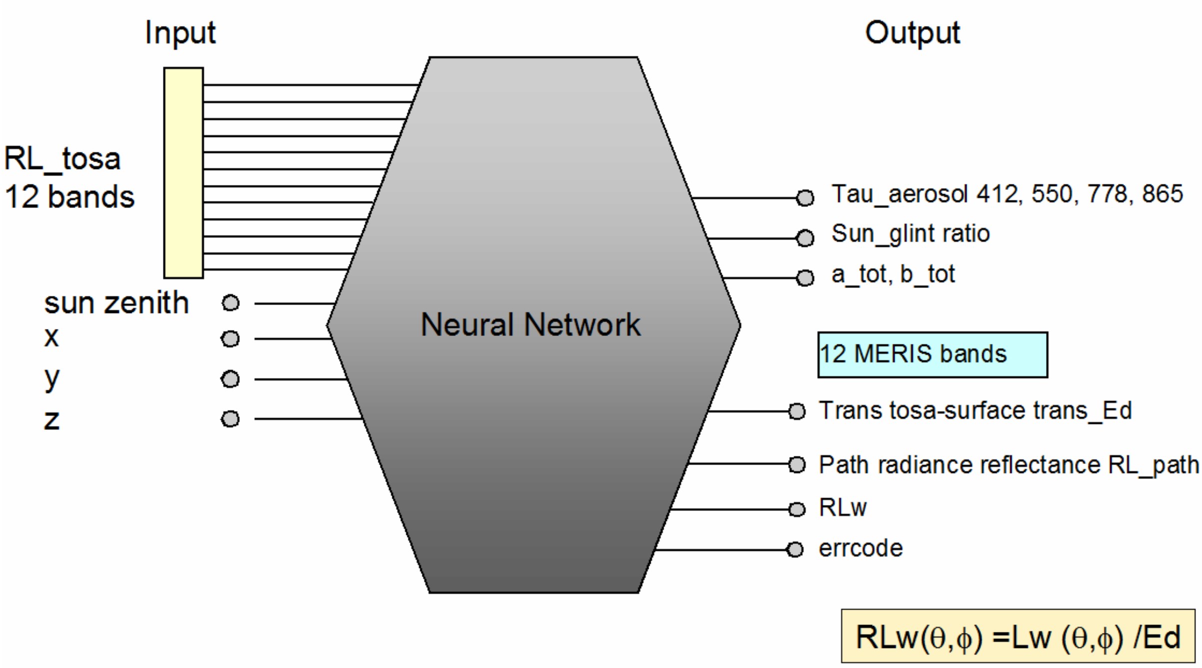

Figure 3 Outline of the neural network to determine the water leaving radiance reflectance RLw.

5.2.2 Water Algorithm

The demonstration products provide in June 2011 to the users have been generated with the neural network inversion technique. The QAA based products will be made available subsequently.

The neural network is used as a multiple non-linear regression technique. It parameterizes the inverse of a radiative transfer model. The model, which will be used to simulate the training and test cases, is Hydrolight, which describes (among others) the directional distribution of the water leaving radiance and the downwelling irradiance, i.e. the bi-directional water leaving radiance reflectance RLw (also called remote sensing reflectance), for a wind dependent rough sea surface.

A large number of cases have been simulated, which define the scope of the algorithm. Input to the NN are the solar and observation angles as well as the bi-directional water leaving radiance reflectances. Outputs are the inherent optical properties of the water constituents, which were defined for the simulations.

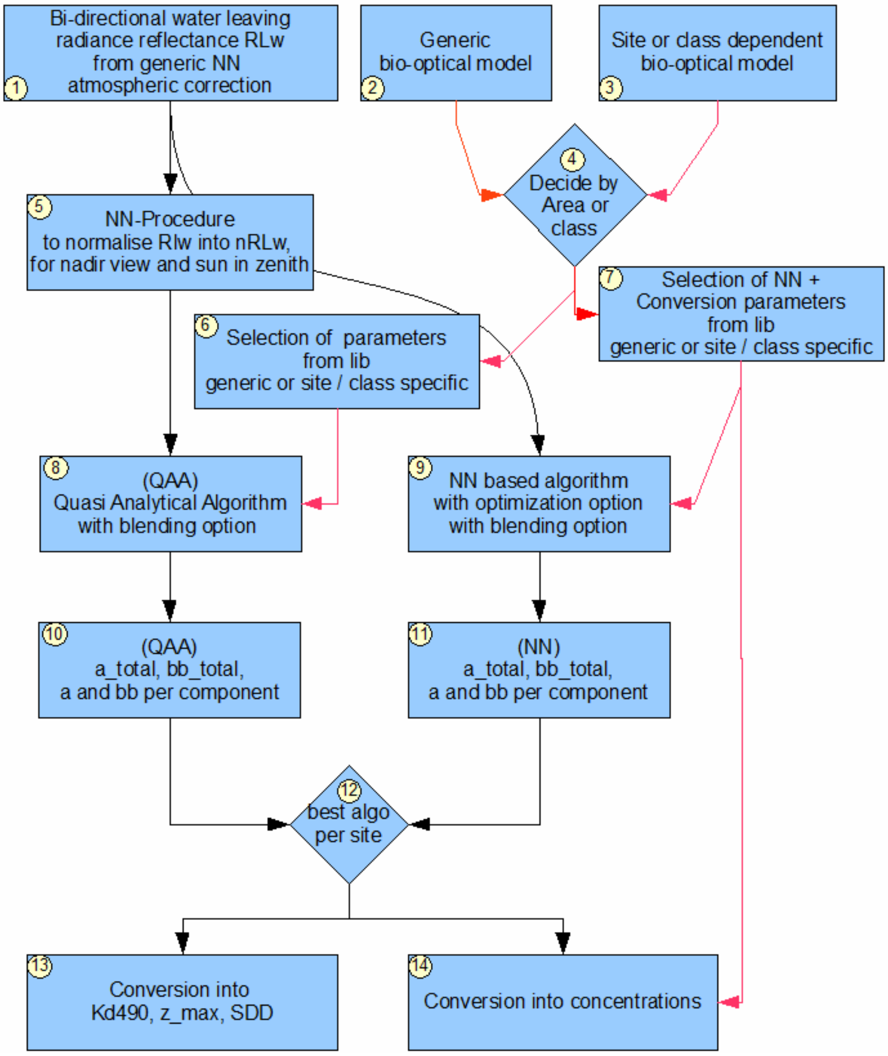

Figure 4 Possible branches of the “normal” water pixel processing (see text)

5.2.3 Validation

The control of the data products and the generation of uncertainty maps is a key issue for the acceptance of RS products for any scientific and operational application. Due to the complexity of coastal waters with respect to water constituents and optical components involved this requirement is a high challenge and we are in some cases at the limit what presently can be done. There are three areas how the quality of the data can be assessed, monitored and documented for the user.

1. The products have to be associated with respective algorithms for recognizing input spectra which are out of scope of that algorithm, and the uncertainty has to be determined for each of the product. These associated quality algorithms will then provide this information in the form of flags and/or quantify the degree as numbers.

2. The products can be verified without any in situ data by tests regarding the noise level, artefacts such as striping or camera boundaries. One important issue is the quality of the atmospheric correction, i.e. the separation of the water leaving radiance reflectance from the TOA reflectance. This can be tested by analysing the water leaving radiance reflectance and the path radiance reflectance along transects with cross strong gradients such as present in river plumes, blooms of coccolithophorids.

3. The data products have to be compared with in situ observations, which require accurate field measurements, the quality of which has also to be assessed and documented.

A large set of in-situ data have been compiled based on the input provided by the CoastColour Champion users. The application of this dataset for validation of the demonstration products has just been started. The feedback provided by the Champion users will contribute to the validation and iterative improvement of the regional algorithms.

6 CoastColour Product File Format

The file format for the L1P, the L2R and L2W products shall ideally be the same in order to reduce specification redundancies and ease data access and software development. Most importantly, the file format shall be

1. self-describing and self-contained,
2. supported by a number of imaging applications and software libraries,
3. well-known and accepted within the EO user community.

Both, the HDF and NetCDF data formats meet these requirements; in fact they have been developed to support scientists, researchers and engineers and are in use in a number of ESA projects such as GlobCover (HDF), GlobColour, Medspiration, GlobAerosol and the Sentinel 3 L1/L2 Product Definition and Proto studies (all NetCDF).

The growing number of ESA projects utilizing the NetCDF format is actually reason enough to go for it. Another major impact is described in the following. Applications reading and writing HDF- and NetCDF-formatted files typically use a dedicated library to do that. HDF and NetCDF libraries are available for a number of programming environments and languages, e.g. C, Java, IDL, MATLAB. In contrast to HDF, a pure Java implementation of the NetCDF 3 and 4 formats is available (which even can read HDF 4 and 5). The HDF Java library actually is a wrapper of the HDF C library and as such uses a shared library binding, which makes it highly dependent on specific hardware architecture (32/64 bit). A pure Java implementation of the file-formatting library is highly desirable as all the processing chains developed in this project will be implemented in Java and compiled against the BEAM Java APIs. Platform and architecture independence is an important issue since it shall be easy to deploy the processing code on different computers in order to parallelize the data processing and address the NRT requirements in this project.

6.1 NetCDF Data Model

In order to specify the product structure, we will use the NetCDF terminology comprising the terms *dataset*, *variable*, *attribute* and *dimension*. A NetCDF file is referred to as *dataset*. A dataset is composed of zero or more named *variables* which store the actual data. The data can be one- or multi-dimensional arrays of primitive data types (integers or floating point numbers). A dataset and also a data variable may be associated with a number of named *attributes*. An attribute has a value which can either be scalar or a 1-dimensional array of a primitive type (including characters). An n-dimensional data variable is also associated with n named *dimensions*. Dimensions establish the index space of data variables by describing the meaning, size and value range of each dimension. Figure 5 illustrates this simple but yet effective data model of NetCDF version 4.

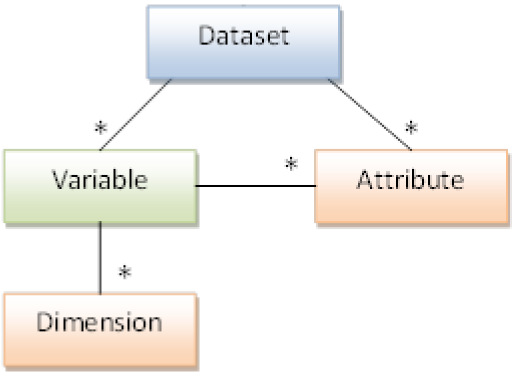

Figure 5: The NetCDF 4 Data Model

6.2 Product Specification

This chapter is applicable to the L1P and L2 products. A dataset is physically represented by one single NetCDF product file. The CoastColour data products are provided as compressed gz files. Most NetCDF reader can directly read this file. Each dataset contains multiple variables. In the following table similar or related variables are grouped in order to give an overview of the product and to describe the contents. In section 6.4.

Table 6-1: Product List

Dataset	Group of Variables	Contents	Status (June 2011)
L1P	TOA	Pre-processed MERIS TOA radiances.	Available
	GEO	Ortho-corrected geo-coding.	Available
	FLAGS	Flags characterising pixels	Available
L2R	RSURF	Contains water leaving reflectances, normalised water leaving reflectances, aerosol optical depth and angstrom exponent. Using the BEAM CoastColour Processor the user can add other variables (currently not publicly available)	Available
	GEO	Ortho-corrected geo-coding.	Available
	FLAGS	Flags characterising pixels	Available
L2W	IOP	IOPs and optical water properties	Available
	CONC	Concentration retrieval products (CHL, TSM, CDOM).	Available
	OTH	Other water properties	Available
	PAR	Photosynthetic active radiation.	Not available
	FLH	Fluorescence line height.	Not available
	EXP	Experimental L2 products	Not available
	GEO	Ortho-corrected geo-coding.	Available
	FLAGS	Flags characterising pixels	Available

6.2.1 Grid

The original MERIS FRS/FSG L1b grids are retained for the L1P and L2 products, specifically the

1. FR grid at pixel resolution and the
2. Tie-point grid located at each 64^{th} pixel in along- and across-track direction.

The grids are kept because remapping of the L1P to another grid incorporates several issues which can be avoided by sustaining the original MERIS FR grids. Typical issues are

- Interpolating (non-nearest-neighbour) resampling methods distort the original measurement of spectra.
- Introduction of many no-data pixels due to re-projection will increase product size.
- Duplication of pixels due to oversampling, especially true for Plate Carrée at high and low latitudes, will increase amount of data to be processed and therefore processing time.

6.3 Metadata

Attributes and dimensions are used to realize the self-describing nature of NetCDF files. In order to utilize these attributes in software, associate datasets and variables with meta-data. The NetCDF group defines a number of standard attributes for annotating datasets. These are for example the attributes `units`, `long_name`, `value_range` , `_FillValue`, `title` and `history`. Whenever applicable, these standard attributes are used.

The NetCDF standard attributes provide basic metadata for the interpretation of data variables but they don't tell much about the spatial and temporal properties of the data. The *NetCDF Climate and Forecast (CF) Metadata Convention* (brief CF Convention) defines metadata that provide a definitive description of what the data in each variable represents.

The file format for **L1P** product and the final **L2** product are **NetCDF**. The metadata associated with the NetCDF datasets and its variables will be fully compliant with the **CF Conventions**.

6.4 Variable Definition

6.4.1 Annotation Data

Annotation data is provided within the tie-point grid and will be provided in all L1P and L2 datasets. The annotation data comprises the original tie-point grids from the MERIS L1B product. These tie-point grids contain geographic coordinates and ECMWF derived geophysical data.

Table 6-2: Common Annotation Data

Variable name	Description	Unit	Type	Size (W×H)
latitude	Latitude of intersection of line of sight with WGS84 ellipsoid.	deg	fl	4/1024
longitude	Latitude of intersection of line of sight with WGS84 ellipsoid.	deg	fl	4/1024
dem_alt	Altitude at intersection of line of sight with WGS84 ellipsoid taken from DEM.	M	fl	4/1024
dem_rough	Roughness at intersection of line of sight with WGS84 ellipsoid taken from DEM.	-	fl	4/1024
sun_zenith	Sun zenith angle	deg	fl	4/1024
sun_azimuth	Sun azimuth angle	deg	fl	4/1024

view_zenith	View zenith angle	deg	fl	4/1024
view_azimuth	View azimuth angle	deg	fl	4/1024
zonal_wind	ECMWF zonal wind	m/s	fl	4/1024
merid_wind	ECMWF meridional wind	m/s	fl	4/1024
atm_press	ECMWF atmospheric pressure at sea level	hPa	fl	4/1024
ozone	ECMWF ozone concentration	DU	fl	4/1024
rel_hum	ECMWF relative humidity	g/cm²	fl	4/1024
				$\frac{13}{256}$

6.4.2 GEO Variables

This group of variables comprises the ortho-geolocation information generated by the AMORGOS tool and is common to all L1P and L2 products.

Table 6-3 Common Geolocation Data

Variable name	Description	Unit	T	Size (W×H)
`lon`	Ortho-corrected longitude. (The normally existing stripes of invalids at the left and right border are filled with values from the longitude tie-point grid)	deg	fl	4
`lat`	Ortho-corrected latitude. (The normally existing stripes of invalids at the left and right border are filled with values from the latitude tie-point grid)	deg	fl	4
`altitude`	DEM altitude (from GETASSE30)	m	ss	2
				10

In the current CoastColour products also corr_latitude and corr_longitude variables are included. These are the variables directly generated by AMORGOS. They will be removed from the products of the next processing, because they contain redundant information.

6.4.3 L1P TOA Variables

The L1P TOA variables comprise the 15 MERIS radiance bands, the MERIS detector index and flags.

Table 6-4 L1P TOA Data

Variable name	Description	Unit	T	Size (W×H)
`radiance_<i>`	TOA radiances in the 15 MERIS bands		us	15 × 2
`detector_index`	Index of the MERIS pixel		ss	2
				30

6.4.4 L1P FLAGS Variables

The L1P FLAGS variables comprise the flags of the MERIS L1B product and also the flags of the CoastColour L1P pre-processing.

Table 6-5 L1P Flag Data

Variable name	Description	Unit	T	Size (W×H)
l1_flags	MERIS L1b flags (copy from M1b product)		ub	2
l1p_flags	Flags set by pre-processing (e.g. cloud screening, land/water classification …)		ss	2
				6

6.4.5 L2R RSURF Variables

The L2R RSURF variables comprise data related to the atmospheric correction. This includes normalised and bidirectional water leaving radiance reflectances, aerosol optical thickness, and the angstrom exponent.

Table 6-6 L2R RSURF Data

Variable name	Description	Unit	T	Size (W×H)
norm_reflec_<i>	Normalised water leaving radiance reflectances.	-	fl	12 × 4
reflec_<i>	Bidirectional water leaving radiance reflectances.	-	fl	12 × 4
atm_tau_550	Aerosol optical thickness at 550 nm	-	fl	4
atm_tau_778	Aerosol optical thickness at 778 nm	-	fl	4
atm_tau_865	Aerosol optical thickness at 865 nm	-	fl	4
ang_443_865	Aerosol angstrom exponent between 443 and 865nm	-	fl	4
detector_index	Index of the MERIS pixel		ss	2
				112

6.4.6 L2R FLAGS Variables

The L2R FLAGS variables comprise the flags of the MERIS L1B product, the flags of the CoastColour L1P and the flags of the L2R processing.

Table 6-7 L2R Flag Data

Variable name	Description	Unit	T	Size (W×H)
l1_flags	MERIS L1b flags (copy from M1b product)		ub	2
l1p_flags	Flags set by pre-processing (e.g. cloud screening, land/water		ss	2

	classification ...)			
l2r_flags	Flags specific to atmospheric correction	-	us	2
				8

6.4.7 L2W IOP Variables

The L2W IOP variables comprises the inherent optical properties of the water.

Table 6-8 L2W IOP Data

Variable name	Description	Unit	T	Size (W×H)
iop_a_total_443	Total absorption coefficient of all water constituents	m^{-1}	fl	4
iop_bb_spm_443	Total scattering or backscattering coefficient	m^{-1}	fl	4
iop_a_pig_443	Phytoplankton pigment absorption coefficient	m^{-1}	fl	4
iop_a_ys_443	Yellow substance absorption coefficient	m^{-1}	fl	4
				16

6.4.8 L2W CONC Variables

The L2W CONC variables comprise the data of chlorophyll and total suspended matter contrations.

Table 6-9 L2W Concentrations Data

Variable name	Description	Unit	T	Size (W×H)
conc_chl	Chlorophyll-a concentration	g/m^3	fl	4
conc_tsm	Concentration of total suspended matter	mg/l	fl	4
				8

6.4.9 L2W OTH Variables

The L2W OTH variables comprise other water properties and the quality indicator for the IOP retrieval.

Table 6-10 L2W Other Data

Variable name	Description	Unit	T	Size (W×H)
chiSquare	Quality indicator of the IOP retrieval	-	fl	4
Kd_<i>	Spectral downwelling irradiance attenuation coefficient	m^{-1}	fl	8 x 4
K_min	Minimum downwelling irradiance at-	m^{-1}	fl	4

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	tenuation coefficient.			
Z90_max	Maximal signal depth	m	fl	4
Turbidity_index	Turbidity in formazine units	FNU	fl	4
				48

6.4.10 L2W FLAGS Variables

The L2W FLAGS variables comprise the flags specific to the retrieval of water properties and the flags of the lower levels.

Table 6-11 L2W Flags data

Variable name	Descrip-tion	Unit	T	Size (W× H)
l1_flags	MERIS L1b flags (copy from M1b product)	-	ub	1
l1p_flags	Flags set by pre-processing (e.g. cloud screening, land/water classification ...)	-	us	2
l2r_flags	Flags specific to atmos-pheric correction	-	us	2
l2w_flags	Flags specific to retriev-al of water IOPs	-	ub	1
				6

6.5 CoastColour NetCDF Format Specification

The provided CoastColour products are in line with the NetCDF CF-convention. Beside the used attributes defined by CF-convention we have defined some extra attributes. These attributes were introduced on the one hand to reduce the size of the resulting NetCDF files and on the other hand to provide more information about the product to the user.

In the following table the the CoastColour specific attributes are list and their purpose is described.

6-12 CoastColour Specific Attributes

NetCDF Element	Description
tp_x	Width of the tie-point grids (Annotation Data).
tp_y	Height of the tie-point grids (Annotation Data).
offset_x	The x-coordinate of the first (upper-left) tie-point in pixel coordinates (Annotation Data).
offset_y	The y-coordinate of the first (upper-left) tie-point in pixel coordinates (Annotation Data).
subsampling_x	The sub-sampling of the tie-point grid in x-direction given in pixel coordinates (Annotation Data).
subsampling_y	The sub-sampling of the tie-point grid in y-direction given in pixel coordinates (Annotation Data).

metadata	Contains metadata information (MPH, SPH, ...) from the MERIS product and information about the processing chain
valid_pixel_expression	Attribute used for a variable to store an expression identifying valid pixels (optional).
bandwidth	The bandwidth of a spectral band (optional).
wavelength	The wavelength of a spectral band (optional).
product_type	The type (identifier) of the product. One of MER_FSG_CCL1P, MER_FSG_CCL2R, or MER_FSG_CCL2W (contained in the global attributes).
metadata_profile	The value is 'beam'. Identifying the NetCDF file as one with special BEAM extensions (contained in the global attributes).
metadata_version	The version of the content contained in the metadata variable (contained in the global attributes).
auto_grouping	Value used within BEAM to group bands by the given pattern (contained in the global attributes).

7 Tools

CoastColour NetCDF formatted products can be opened with all NetCDF compatible software packages. We recommend specifically using the BEAM toolbox, which is specifically developed by ESA for the exploitation of MERIS and other Earth Observation data products.

The tie-point grid and the product grid have different resolutions. With BEAM these are automatically mapped. MERIS product specific data, such as flags, are interpreted with BEAM and offered as bitmasks.

BEAM is open source and free available from earth.esa.int/beam.

NASA provides free of the charge the Panoply data viewer: www.giss.nasa.gov/tools/panoply

8 Known Issues and planned upgrade

8.1 Common to all Products

- Products contain corr_latitude and corr_longitude variables, these will be removed in a next version.

8.2 Level 1P Processing and Products

- Clouds over land are only roughly identified; it is not the objective of CoastColour to provide a perfect cloud mask over land.
- The cloud shadow flag is often not matching the visible cloud shadow, has visible artifacts and is often missing at all. We are investigating this. Currently the cloud shadow flag is only a warning and is not stopping further processing
- The snow and cloud flags can be set both under certain circumstances. This is a bug and will be corrected.
- The LandRisk flag is not yet used and always set to FALSE.

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8.3 Level 2R Processing and Products

- There are currently no known issues.
- An adjacency correction is currently under investigation. This may become part of the atmospheric correction in a next version.
- Currently a fixed set of aerosol models has been used. In parallel a set of coastal aerosols has been compiled. In a future release of the atmospheric correction we may use region specific coastal aerosol models.

8.4 Level 2W Processing and Products

- There are currently no known issues.
- A fuzzy logic classification of marine spectra is available. We are currently investigating linking this with regional (=spectrum specific) water processing.
- The regionalisation of the QAA is currently under investigation.
- The experimental products are not yet available on a large basis but only for single products for testing purpose and within the CoastColour team.

ACRONYMS AND ABBREVIATIONS

AATSR	Advance Along Track Scanning Radiometer
AC	Atmospheric Correction
AMORGOS	Accurate MERIS ortho-rectified geolocation operational software
ANN	Artificial neural network
AOI	Area of interest
AOP	Apparent optical properties
API	Application Programming Interface
ATBD	Algorithm theoretical basis document
BC	Brockmann Consult
BEAM	Basic Envisat AATSR and MERIS toolbox
BOA	Bottom of Atmosphere
BRF	Bidirectional Reflectance Factor
CC	CostColour
CDOM	Coloured dissolved organic matter
CEOS	Committee on Earth Observation Satellites
Chl	Chlorophyll
ChloroGIN	Chlorophyll Global Integrated Network
CO	Centre of Oceanography of the University Lisbon
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CZCS	Coastal Zone Colour Scanner
DDS	ESA's satellite data distribution system
DEL	Delivery
DJF	Design justification file
DPM	Detailed Processing Model
DPQR	Demonstration products and qualification report
DQWG	Data quality working group
DUE	Data User Element of the ESA Earth Observation Envelope Programme
ECSS	European Co-operation for Space Standardisation
EE	Earth Explorer (Mission)
ENVISAT	Environmental Satellite (http://envisat.esa.int)
EO	Earth observation
EOLI	ESA Earth Observation Link
ERS	European Remote Sensing satellite
ESA	European Space Agency
ESRIN	European Space Research Institute (http://www.esa.it/export/esaCP/index.html)
FFH	Flora Fauna Habitat Directive
FR	Full resolution (300m resolution MERIS products)
FRS	Full resolution full swath
FTP	File transfer protocol
FLH	Fluorescence Line Height
fwNN	forward artificial neural network
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GIOP	Generic IOP algorithm
GMES	Global Monitoring for Environment and Security
GOCI	Geostationary Ocean Colour Imager
HAB	Harmful Algal Bloom
ICOL	Improve Contrast between Ocean and Land

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IDE	Integrated development environment
IGBP	Geosphere Biosphere Program
INPE	National Institute for Space Research
IOCCG	International Ocean Colour Coordinating Group
IOP	Inherent optical properties
IPF	Instrument Processing Facility
ITT	Invitation to tender
IVM	Institute of Environmental Studies
JAI	Java advanced imaging
JIIO	Java image input/output
JRC	Joint Research Centre
Kd(490)	Diffuse absorption coefficient at 490 nm
KO	Project kick-off
KORDI	Korea Ocean Satellite Center
L1, L2	Level 1, Level 2
L1P	A pre-processed version of the standard Level-1 data products.
L2R	Advanced atmospherically corrected L1P data
LISE	University of the Littoral Opal Coast
LOICZ	Land Ocean Interaction in the Coastal Zone
LTO	Linear tape open
LUT	Look Up Table
MEGS	MERIS Ground Segment Data Processing Prototype
MERCI	MERIS Catalogue and Inventory
MERIS	Medium Resolution Imaging Spectrometer (ESA instrument)
MODIS	Moderate Resolution Imaging Spectrometer (NASA instrument)
MUMM	Management Unit of the North Sea Mathematical Models
NASA	National Aeronautics and Space Administration
NIR	Near InfraRed
NRT	Near-real time
OCM	Ocean Colour Monitor
OLCI	Ocean and Land Colour Instrument
OSSD	Open Source Software Development
PAR	Photosynthetically active radiation
PM	Progress meeting
PML	Plymouth Marine Laboratory
POGO	Partnership for Observation of the Global Oceans
PUG	Product User Guide
Q4	4th quarter of the year (October-December)
QA4EO	Quality Assurance Framework for Earth Observation data
QAA	quasi-analytical algorithm
RB	Requirements baseline
RD	Reference document
REVAMP	Regional Validation of MERIS chlorophyll Product
RID	Review item discrepancy
RH	relative humidity
ROI IOCCG	Regional bio-Optical algorithms Initiative
RLw	water leaving radiance reflectances
RR	Reduced resolution (1km resolution MERIS products)
RRob	Round Robin
SAFARI	Societal Applications in fisheries and Aquaculture using Remotely-sensed Imagery

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SAG	Science advisory group
SDD	Secchi disk depth
SeaWiFS	Sea-viewing Wide Field-of-view Sensor (GeoEye/NASA instrument)
SoW	Statement of work
SPH	Specific Product Header
SPM	Suspended particulate material
SUM	System User Manual
SW	Software
TOA	Top of atmosphere
TOSA	top of standard atmosphere
TS	Technical specification
TSM	Total suspended matter
UCM	User consultation meeting
UML	Universal modelling language
VISAT	Visualisation and analysis tool
WFD	Water Framework Directive
WP	Work package
WPD	Work package description
XP	Extreme programming