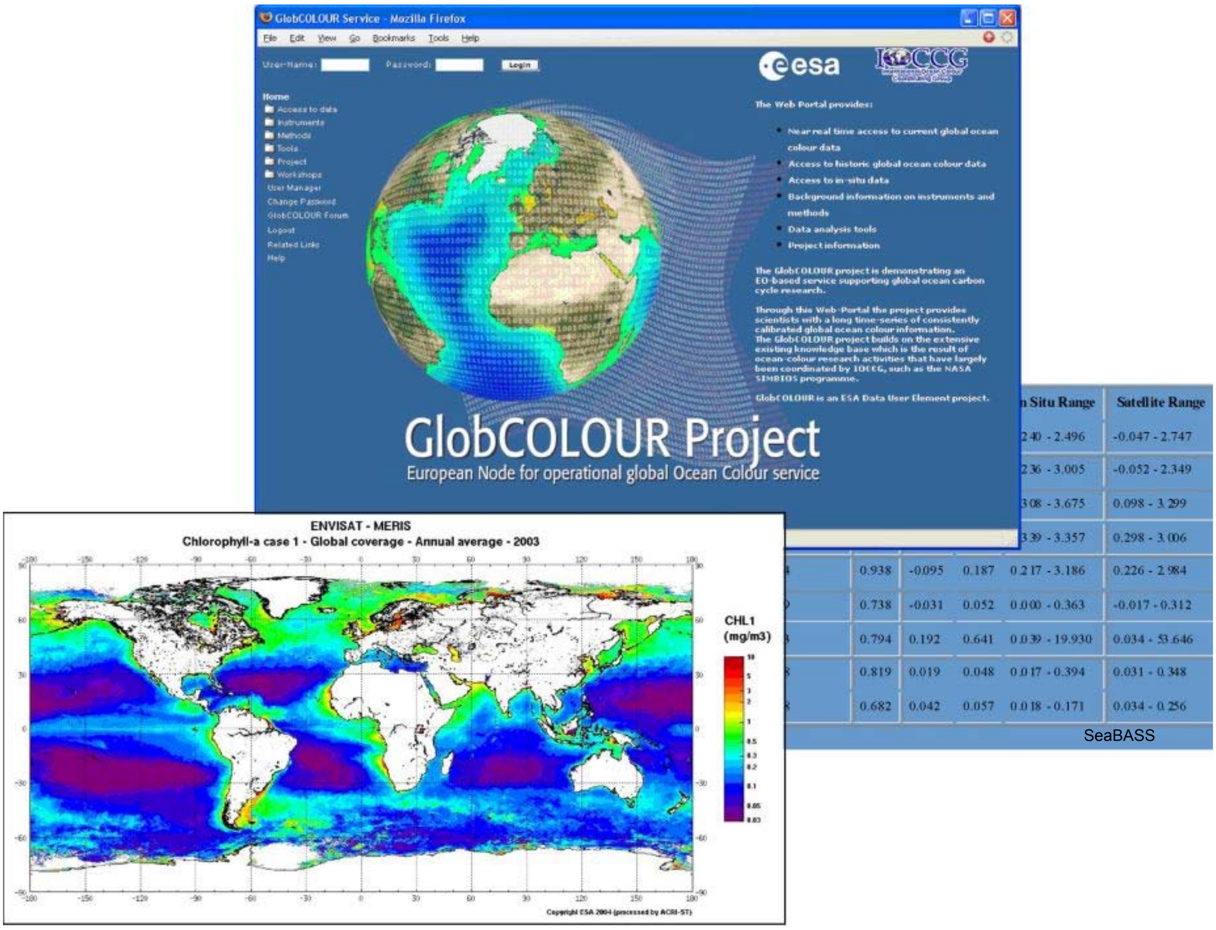
ACRI-ST/LOV, UoP, NIVA, BC, DLR, ICESS consortium

ESA DUE GlobColour
Global Ocean Colour for Carbon Cycle Research



Product User Guide

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1 INTRODUCTION

1.1 Overview

This document is the version 1 of the Product User Guide (PUG) for the GlobColour EO service. It describes the data products content and format available through the GlobColour web site http://www.globcolour.info/.

Figure 1.1: The GlobColour web site

This User Guide contains a description of:

- the products content
  - *the parameters*
  - *the spatial and temporal coverage*
  - *the processing system*
- the products format
- the available tools

1.2 Background of the project

GlobColour is an ESA project contributing to the emerging worldwide dynamic for ocean colour data merging. This kind of technique represents the most likely future solution in the sense that it goes towards rationalisation of space missions and data distribution. Beyond these nice perspectives, it remains that ocean data merging does require critical preliminary steps before its optimal deployment.

The demonstration of feasibility and usefulness of such merged data for the final data users and therefore its acceptance depends very much on the quality of these first steps. The project team has performed the preliminary input data characterisation from several missions, in order to be able to assess the quality of existing merging techniques in confrontation with ground truth.

The immediate result is the qualification of one merging technique to be used in a system and a first production of an ambitious dataset merging 10 years of ocean colour data at global scale and daily, weekly and monthly basis. Moreover, this merging system will be used for testing the capability to produce and deliver merged ocean colour data in Near Real Time to the benefit of operational oceanography.

In summary, the objectives of the GlobColour project are to:

- demonstrate the utility and value of EO-based services to the global ocean colour user community;
- provide a long time-series of ocean-colour information for research on the marine component of the global carbon cycle;
- put in place the capacity to continue production of this time series in the future;
- demonstrate the current state of the art in merging together data streams from different satellite based ocean-colour sensors;
- demonstrate a global NRT ocean-colour service based on merged satellite data.

1.3 Brief overview of GlobColour parameters

The parameters[1] distributed to the end-users are:

- Chlorophyll-a (CHL1 and CHL2)
- Fully normalised water leaving radiances at 412, 443, 490, 510, 531, 550-565, 620, 665-670, 681 and 709 nm (Lxxx)
- Coloured dissolved and detrital organic materials absorption coefficient (CDM)
- Diffuse attenuation coefficient (Kd(490))
- Particulate back-scattering coefficient (b_{bp})
- Total Suspended Matter (TSM)
- Relative excess of radiance at 555 nm (EL555)
- Photosynthetic Available Radiation (PAR)
- Aerosol optical thickness over water (T865)
- Cloud Fraction (CF)

Two spatial domains are covered:

- the global Earth domain.
- local DDS areas (Diagnostic Data Sets areas).

[1] The full description of these parameters can be found later in this document (chapter "The GlobColour parameters")

Products are generated for three merging techniques:

- simple averaging
- weighted averaging
- GSM model

The spatial and temporal resolution of the products distributed to the end-users are:

Spatial domain	Grid	Temporal domain	Resolution	Merging level
Global	ISIN	Daily, 8 days, monthly	1/24°	Merged data
Local	ISIN	Daily, 8 days, monthly	1/24°	Merged data
Global	PC	Daily, 8 days, monthly	0.25° / 1.0°	Merged data
Local	PC	Track	1.0 km	Single instrument
Local	ISIN	Track	1/24°	Single instrument

Table 1.1: Overview of the GlobColour products

1.4 Acronyms

AV	Simple average method
AVW	Weighted average method
b_{bp}	Particulate back-scattering coefficient
BEAM	Basic ERS and Envisat (A)ATSR and MERIS Toolbox
BOUSSOLE	Bouée pour l’acquisition de Séries Optiques à Long Terme
CDL	Common Data Language
CDM	Coloured dissolved and detrital organic materials absorption coefficient
CF	Climate and Forecast
CF	Cloud Fraction
CHL	Chlorophyll-a
CZCS	Coastal Zone Color Scanner
DDS	Diagnostic Data Set
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DPM	Detailed Processing Model
DUE	Data User Element of the ESA Earth Observation Envelope Programme II
EEA	European Environment Agency
EL555	Relative excess of radiance at 555 nm (%)
EO	Earth observation
F_0	Extra-terrestrial solar irradiance
GHRSST-PP	GODAE High Resolution Sea Surface Temperature - Pilot Project
GSM	Garver, Siegel, Maritorena Model

ICESS	Institute for Computational and Earth Systems Science
IOCCG	International Ocean Colour Coordinating Group
IOCCP	International Ocean Carbon Coordination Project
IODD	Input Output Data Definition
ISIN	Integerised SINusoidal projection
LOV	Laboratoire Océanologique de Villefranche-sur-mer
LUT	Look-Up Table
LXXX	Fully normalised water leaving radiances at xxx nm (mW/cm²/µm/sr) where xxx= 412, 443, 490, 510, 531, 550-565, 620, 665-670, 681 and 709 nm
MER	Acronym for the MERIS instrument used in the GlobColour filenames
MERIS	Medium Resolution Imaging Spectrometer
MERSEA	Marine Environment and Security for the European Area – Integrated Project of the EC Framework Programme 6
MOBY	Marine Optical Buoy
MOD	Acronym for the MODIS instrument used in the GlobColour filenames
MODIS	Moderate Resolution Imaging Spectrometer
netCDF	Network Common Data Format
NIVA	Norwegian Institute for Water Research
NRT	Near-real time
PAR	Photosynthetic Available Radiation
PC	Plate-Carré projection
PNG	Portable Network Graphics
POLDER	Polarisation and Directionality of the Earth's Reflectances
PPS	Preliminary Product Set
RD	Reference Document
ROI / RoI	Region of Interest
SeaBASS	SeaWiFS Bio-Optical Archive and Storage System
SeaWiFS	Sea-Viewing Wide Field of View Sensor
SAA	Sun Azimuth Angle
SWF	Acronym for the SeaWiFS instrument used in the GlobColour filenames
SZA	Sun Zenith Angle
TSM	Total Suspended Matter
T865	Aerosol optical thickness over water
UCAR	University Corporation for Atmospheric Research
UoP	University of Plymouth (U.K)
UTC	Coordinated Universal Time
VAA	Viewing Azimuth Angle
VZA	Viewing Zenith Angle

2 The products content

2.1 The GlobColour parameters

This section provides the detailed description of the exhaustive list of all parameters that are available in the GlobColour products.

The GlobColour merged products are generated by different simple averaging techniques (see IOCCG reports N°4 and 5) or by the use of the GSM model (see Maritorena and Siegel, 2005).

The following table summarises which parameters are available.

Parameter	Description	L3 merging method	M
CHL_1	chlorophyll-a concentration (mg/m^3) for case 1 water	averaging methods + GSM model	
CHL_2	chlorophyll-a concentration (mg/m^3) for case 2 water	averaging methods	✪
CDM	Coloured dissolved and detrital organic materials absorption coefficient at 443nm (m^{-1})	averaging methods + GSM model	✪
TSM	total suspended matter concentration (g/m^3)	averaging methods	✪
b_{bp}	particulate back-scattering coefficient at 443 nm (m^{-1})	GSM model	
Kd(490)	diffuse attenuation coefficient at 490 nm (m^{-1})	analytical from merged CHL_1	
Lxxx	fully normalised water leaving radiances at xxx nm (mW/cm²/µm/sr) where xxx= 412, 443, 490, 510, 531, 550-565, 620, 665-670, 681 and 709 nm	averaging methods	
L555	inter-calibrated fully normalised water leaving radiances at 555 nm (mW/cm²/µm/sr)	averaging methods (1)	
EL555	relative excess of radiance at 555 nm (%)	analytical from merged L555 & CHL_1	
PAR	daily photosynthetic available radiation (µEin/m^2)	averaging methods	✪
T865	aerosol optical thickness over water (-)	averaging methods	
CF	cloud fraction (%)	classification & statistical methods	

Table 2.1: GlobColour output parameters

(1): spectral inter-calibration is applied prior to the merging.

✪: averaged data is only available from MERIS data

2.1.1 CHL_1

CHL_1 is the chlorophyll-a concentration (mg/m^3) for case 1 water. As this concentration is computed using a different formulation for each instrument (MERIS, MODIS & SeaWiFS), the quantities read from the level 2 products are intrinsically different. Several PPS products are generated, using different averaging formulations starting from single-instrument chlorophyll-a concentrations and using the GSM model.

2.1.1.1 Averaging from single-instrument chlorophyll-a concentrations

The CHL_1 daily L3 products are generated for each instrument, using the corresponding L2 data. At the beginning of the averaging processes, an inter-calibration correction is applied to the MODIS and SeaWiFS CHL_1 daily L3 products in order to get compatible concentrations with respect to the MERIS sensor:

$$\begin{cases} y = \log_{10}\left[CHL1_{MODIS/SeaWiFS}\right] \\ \log_{10}[CHL1] = 0.03262 + 0.98942 \cdot y + 0.03349 \cdot y^2 + 0.18534 \cdot y^3 + 0.14700 \cdot y^4 + 0.02639 \cdot y^5 \end{cases}$$

Validity limits for this conversion: $0.01 < CHL1_{MODIS/SeaWiFS} < 13$

The merged CHL_1 concentration is then computed as the average of the MERIS, MODIS and SeaWiFS quantities, both as:

- an arithmetic mean
- a weighted average value

A reverse formulation could be applied to the merged CHL_1 products in order to get SeaWiFS-like CHL_1:

$$\begin{cases} y = \log_{10}\left[CHL1_{MERIS}\right] \\ \log_{10}[CHL1_{SeaWiFS}] = -0.02900 + 0.99563 \cdot y - 0.06591 \cdot y^2 - 0.11891 \cdot y^3 - 0.01305 \cdot y^4 + 0.02849 \cdot y^5 \end{cases}$$

Validity limits for this conversion: $0.017 < CHL1_{MERIS} < 50$

2.1.1.2 GSM-derived CHL1 product

Single-instrument daily L3 fully normalised water leaving radiances[2] are used by the GSM model. These radiances are not inter-calibrated before ingestion in the model.

CHL_1 is one of the model outputs.

The next figures present the CHL1 monthly average concentration (simple average method and GSM model output), in July 2002.

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[2] MERIS: 412 nm, 443 nm, 490 nm, 510 nm, 560 nm
MODIS: 412 nm, 443 nm, 488 nm, 531 nm, 551 nm
SeaWiFS: 412 nm, 443 nm, 490 nm, 510 nm, 555 nm

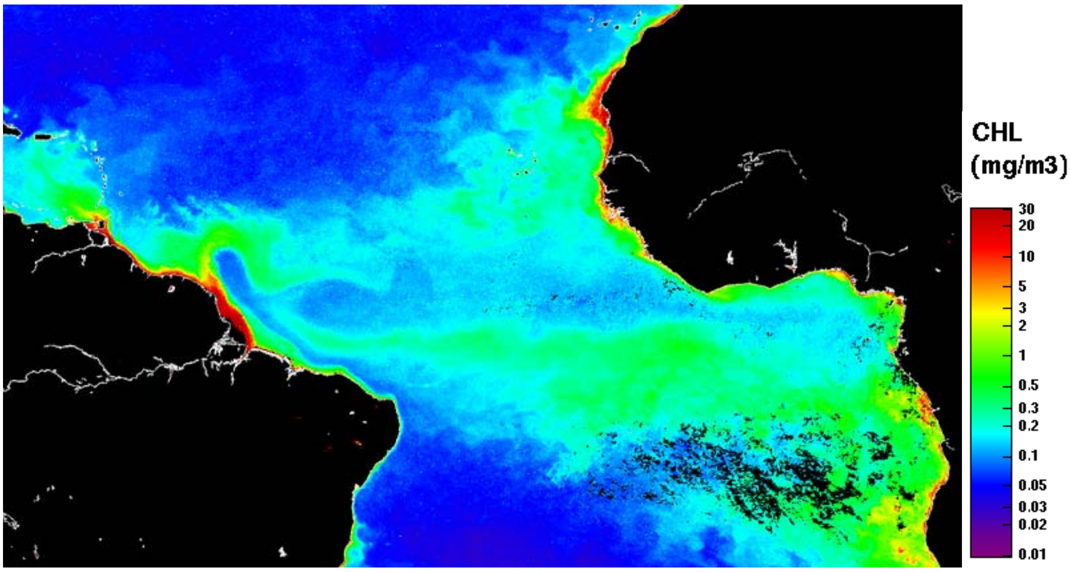

Figure 2.1: CHL1 monthly concentrations in South Atlantic - July 2002 (simple average)

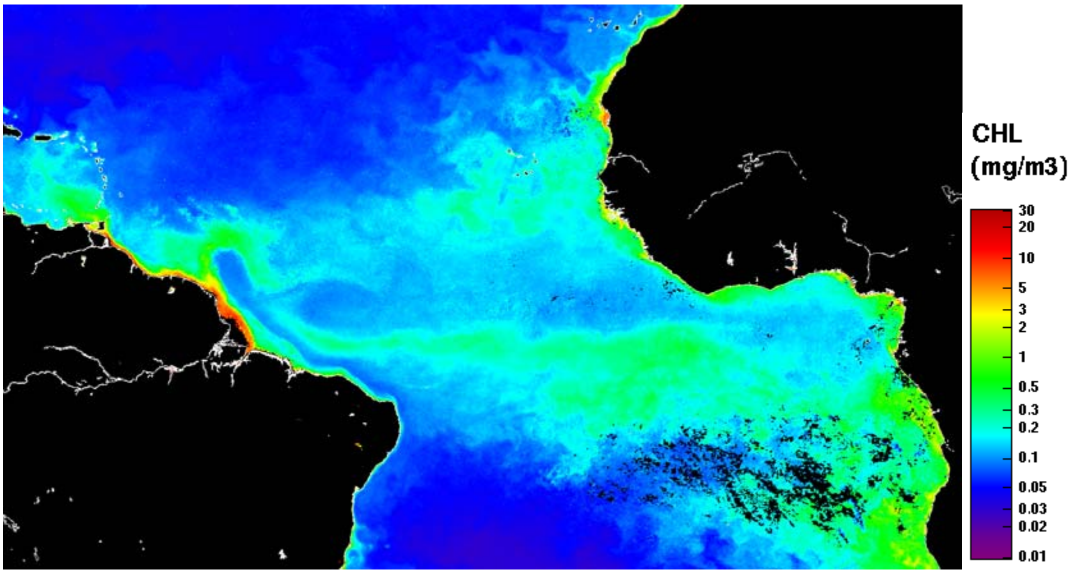

Figure 2.2: CHL1 monthly concentrations in South Atlantic - July 2002 (GSM output)

2.1.2 CHL_2

CHL_2 is the chlorophyll-a concentration (mg/m^3) for case 2 water. This product is only available from the MERIS instrument.

MERIS daily L3 products are created from MERIS L2 products.

MERIS daily L3 products are eventually converted into the GlobColour merged products format.

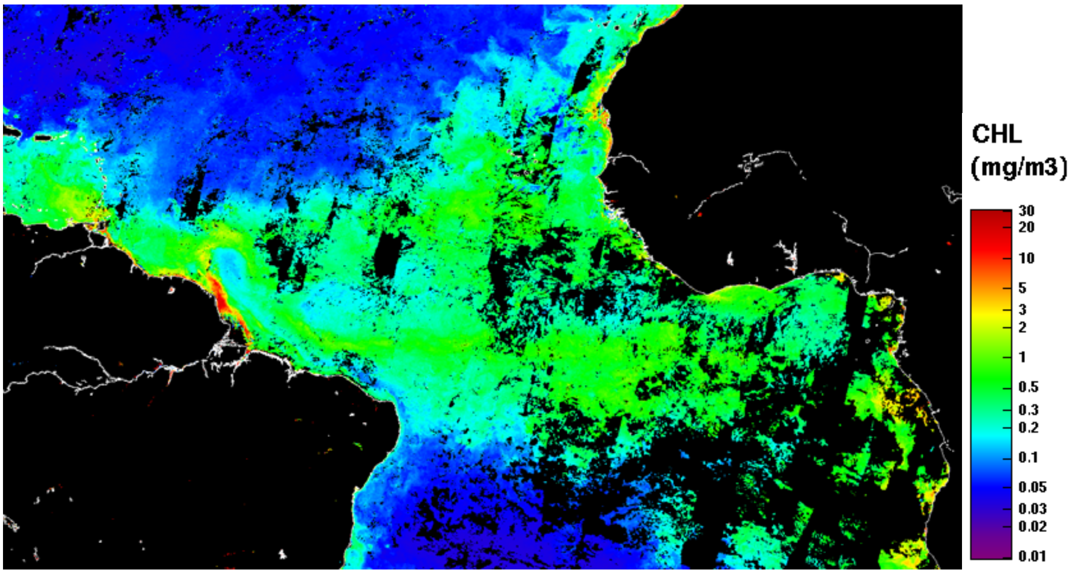

Figure 2.3: CHL2 monthly concentrations in South Atlantic - July 2002 (simple average)

2.1.3 TSM concentration

TSM is the total suspended matter concentration (in g/m^3). This product is only available for MERIS, but could be also computed from the merged GSM BBP product.

MERIS TSM daily L3 products are created from MERIS L2 products, and eventually converted into the GlobColour merged products format.

2.1.4 CDM absorption coefficient at 443nm

CDM is the coloured dissolved and detrital organic materials absorption coefficient (m^{-1}). Two GlobColour products are generated for PPS:

- MERIS-derived CDM product
- GSM-derived CDM product

2.1.4.1 MERIS-derived CDM product

MERIS CDM daily L3 products are created from MERIS L2 products and eventually converted into the GlobColour merged products format.

2.1.4.2 GSM-derived CDM product

The merged CDM absorption coefficient is generated using the GSM model from the MODIS/SeaWiFS/MERIS daily L3 radiance products (Lxxx).

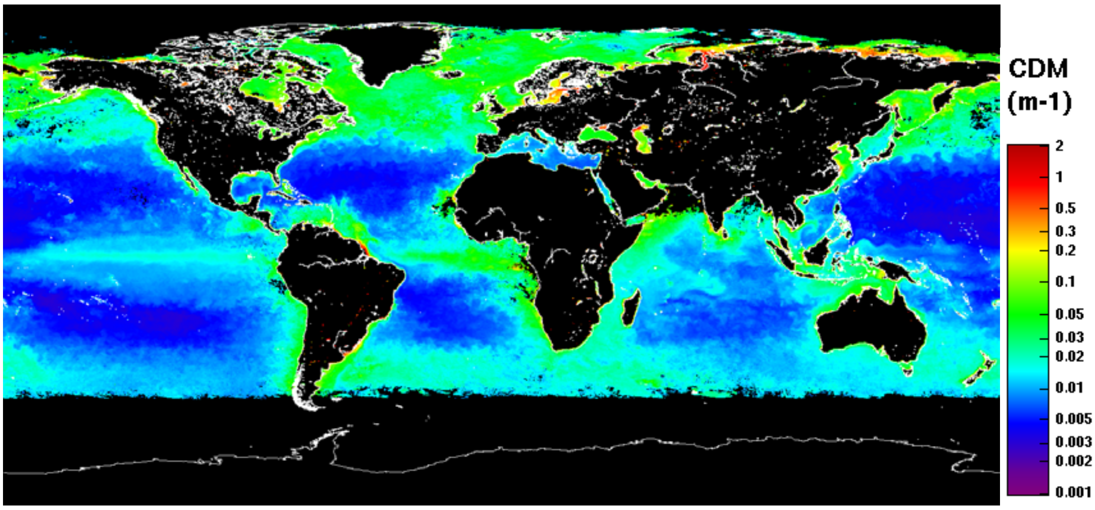

Figure 2.4: CDM monthly average - July 2002 (GSM output)

2.1.5 b_{bp} coefficient at 443nm

b_{bp} is the particulate back-scattering coefficient at the reference wavelength λ_0 = 443nm (in m^{-1}).

The merged b_{bp} coefficient is generated using the GSM model from the MODIS/SeaWiFS/MERIS daily L3 radiance products (Lxxx).

The TSM in standard MERIS L2 product is calculated using the case 2 water neural network. The assumption of the neural network is that there is a constant ratio between total particulate scattering (BP) and particulate back-scattering (BBP): BBP/BP = 0.015. TSM as dry weight of all water constituents is then calculated as TSM ($g.m^{-3}$) = 1.73*BP.

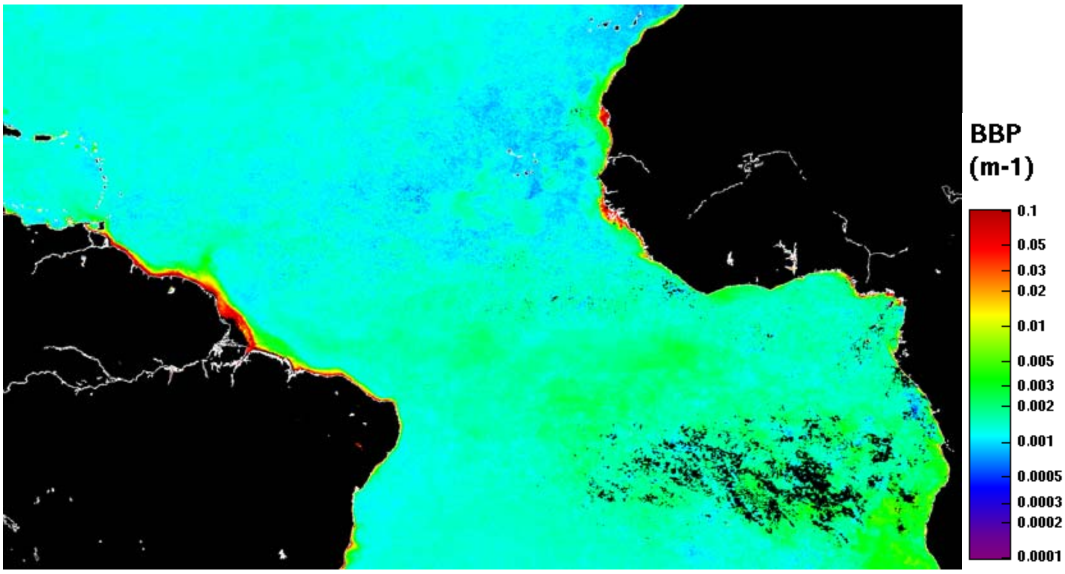

Figure 2.5: b_{bp} monthly average in South Atlantic - July 2002 (GSM output)

From the initial GlobColour BBP merged product, we have therefore the possibility of generating the following products:

1. BP (m^{-1}) = BBP/0.015
2. TSM ($g.m^{-3}$) = 1.73*BP = 1.73*BBP/0.015

2.1.6 K_d(490)

K_d(490) is the diffuse attenuation coefficient at 490 nm (m^{-1}). It is one indicator of the turbidity of the water column. The merged K_d(490) is computed directly from the merged CHL1, using the following equation.

$$K_d(\lambda) = K_w(\lambda) + \chi(\lambda) \cdot chl^{e(\lambda)} \text{ with: } K_w(490) = 0.0166 \text{ m}^{-1}$$

$\chi(490)$ = 0.08349

e(490) = 0.63303

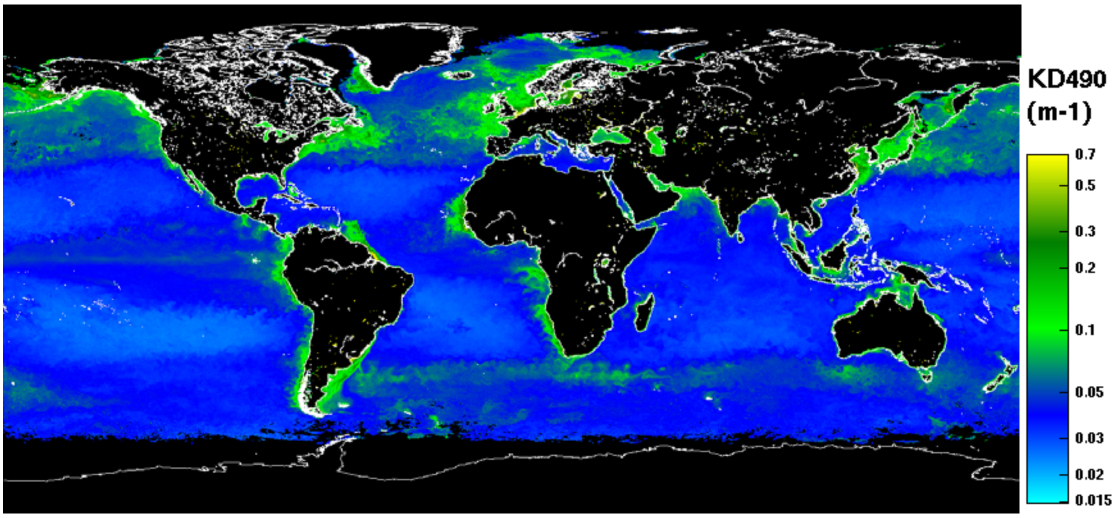

Figure 2.6: KD_{490} monthly average - April 2003 (from CHL1 simple average)

2.1.7 Lxxx

Lxxx is the fully normalised water leaving radiances at xxx nm (expressed in mW/cm²/µm/sr). The list of spectral values is: 412, 443, 490, 510, 531, 550-565, 620, 665-670, 681 and 709 nm. MERIS and Parasol reflectances read from the L2 products are initially converted into fully normalised water leaving radiances (the normalisation is not applied to the MERIS 681 nm fluorescence band and to the 709 nm band.).

Lxxx daily L3 products are generated for each instrument.

- Merged products are created for the bands at 412, 443, 490, 510, 550-565 and 665-670 nm.
- Daily L3 products, created for the MERIS-only bands (620, 681 and 709 nm), are also converted into GlobColour merged product format.
- Daily L3 product, created for the MODIS-only band (531 nm), are also converted into GlobColour merged product format.

The 550-565 bands are submitted to a specific processing just before averaging to prepare a more consistent merging between the instruments. First of all, all bands are spectrally re-affected to 555 nm, using a inter-spectral conversion LUT which is a function of the CHL1 concentration.

MODIS:

$$\begin{cases} y = \log_{10}(CHL1) \\ \dfrac{R_{555}}{R_{551}} = 0.97979 + 0.03583 \cdot y + 0.00570 \cdot y^2 - 0.00277 \cdot y^3 - 0.00085 \cdot y^4 \end{cases}$$

SeaWiFS: No change as SeaWiFS band is actually at 555 nm

MERIS:

$$\begin{cases} y = \log_{10}(CHL1) \\ \dfrac{R_{555}}{R_{560}} = 1.02542 - 0.03757 \cdot y - 0.00171 \cdot y^2 + 0.00350 \cdot y^3 + 0.00057 \cdot y^4 \end{cases}$$

Validity limits for these equations: 0.01 < CHL1 < 30

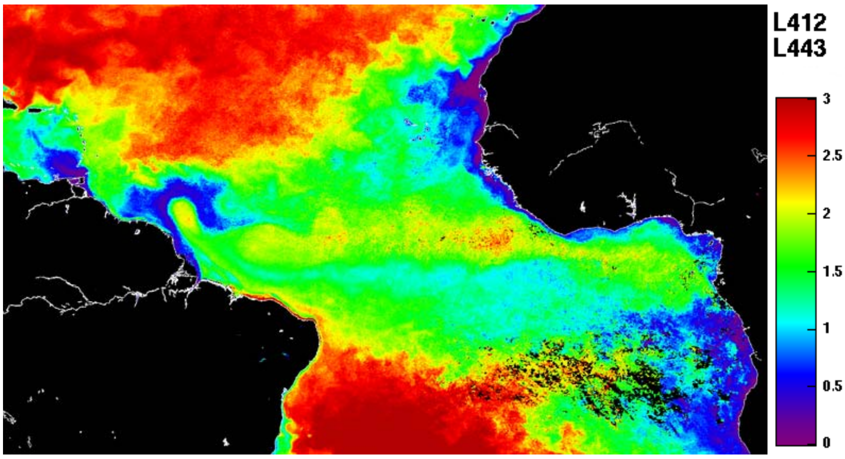

Figure 2.7: L412 monthly average in South Atlantic - July 2002 (simple average)

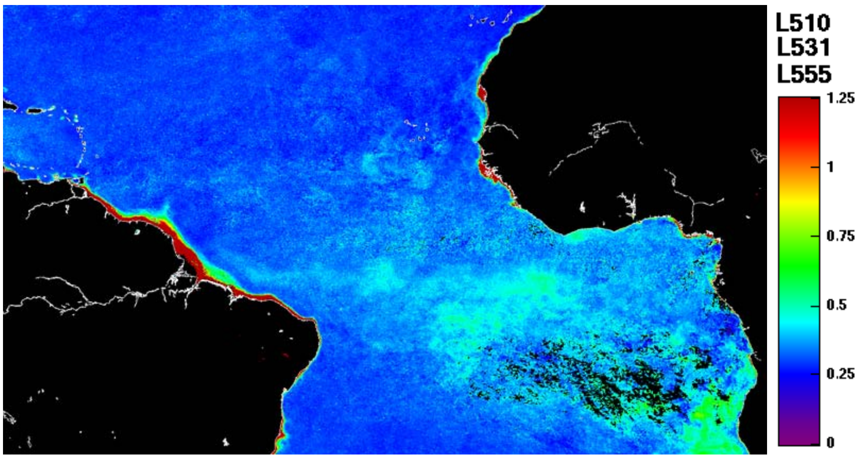

Figure 2.8: L555 monthly average in South Atlantic - July 2002 (simple average)

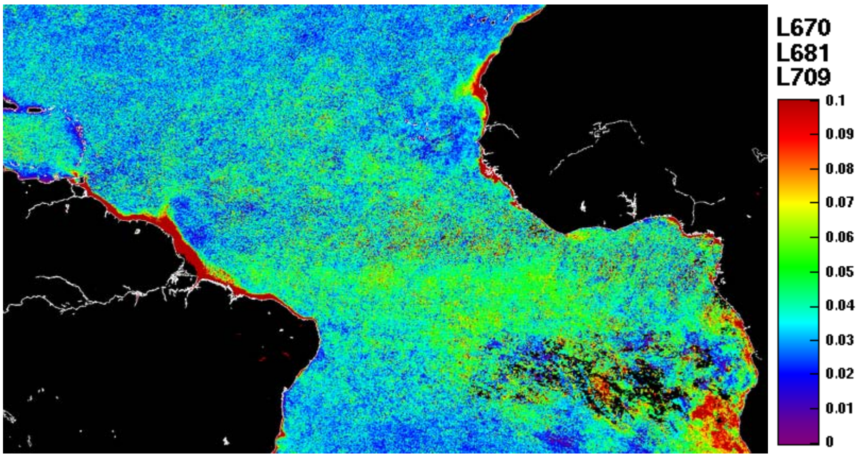

Figure 2.9: L670 monthly average in South Atlantic - July 2002 (simple average)

2.1.8 EL555

EL555 is the relative excess of radiance at 555 nm, expressed in %, above a given threshold.

The EL555 parameter is computed from the L555 fully normalised water leaving radiance and the CHL1 products. The daily products are computed for each instrument using the associated daily water leaving radiance and daily CHL1, while the merged product is computed from the merged L555 and the merged CHL1 concentration.

The EL555 parameter is computed from the following formulation:

$rn555 = \pi \; L555 / F_0$

Values of F_0: 560 nm: 180.05, 551 nm: 187.00, 555 nm: 185.84.

If (CHL1 > 0.2) then
  If ($rn555 > Rho_{lim}(CHL1)$) then
    raised the turbid flag for all products
    $EL555 = 100. [rn555 – Rho_{lim}(CHL1)] / Rho_{lim}(CHL1)$
  Endif
Endif

where $Rho_{lim}(CHL1) = \pi . \Re . R_{lim} / Q_0$ (Ref. Morel-Belanger,2006)

is expressed as:

$$\begin{cases} y = \log_{10}(CHL1) \\ Rho_{lim}(y) = 0.0104 + 0.006665 \cdot y + 0.00099233 \cdot y^2 - 0.0006382 \cdot y^3 \end{cases}$$

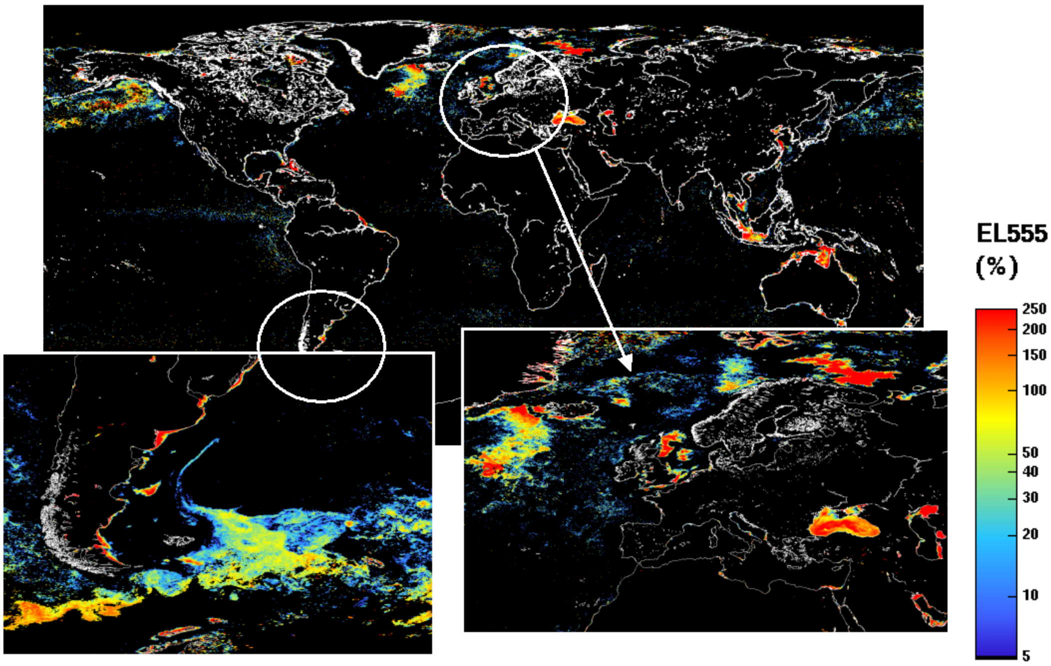

Figure 2.10: EL555 monthly average - July 2002 (from L555 and CHL1 simple average)

2.1.9 PAR

PAR is the daily photosynthetic available radiation (in µEin/m^2). Only MERIS derived PAR is available with the GlobColour processor 0.9i.

2.1.10 T865

T865 is the aerosol optical thickness over water. Merged products are computed from single-instrument daily T865 products, using the arithmetic mean formulation.

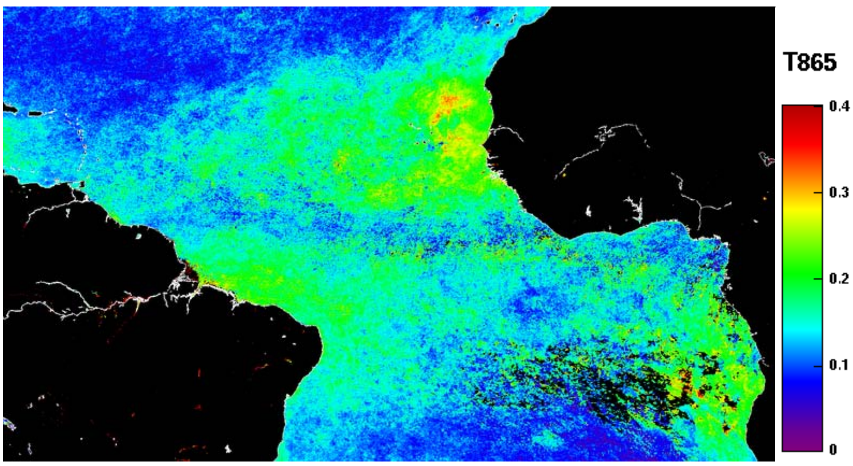

Figure 2.11: T865 monthly average in South Atlantic - July 2002 (simple average)

2.1.11 CF

CF is the cloud fraction (expressed in %).

Note that this parameter is determined by using the following flags: CLDICE = "Probable cloud or ice contamination" for MODIS and SeaWiFS instruments and "CLOUD or (WATER and ICE_HAZE)" where ICE_HAZE = "Ice or high aerosol load pixel or Cloud" for the MERIS instrument. So strictly speaking, CF is actually not only a cloud fraction percentage but takes into account clouds, ice and high aerosol load contamination. This will be clarified in the next version of the GlobColour products.

Two products are available:

- daily products: percentage of input pixels per bin flagged as cloudy in the original level 2 products
- 8-days and monthly products: percentage of merged days per bin where the daily cloud fraction is greater than a specified threshold (50% in current GlobColour processor)

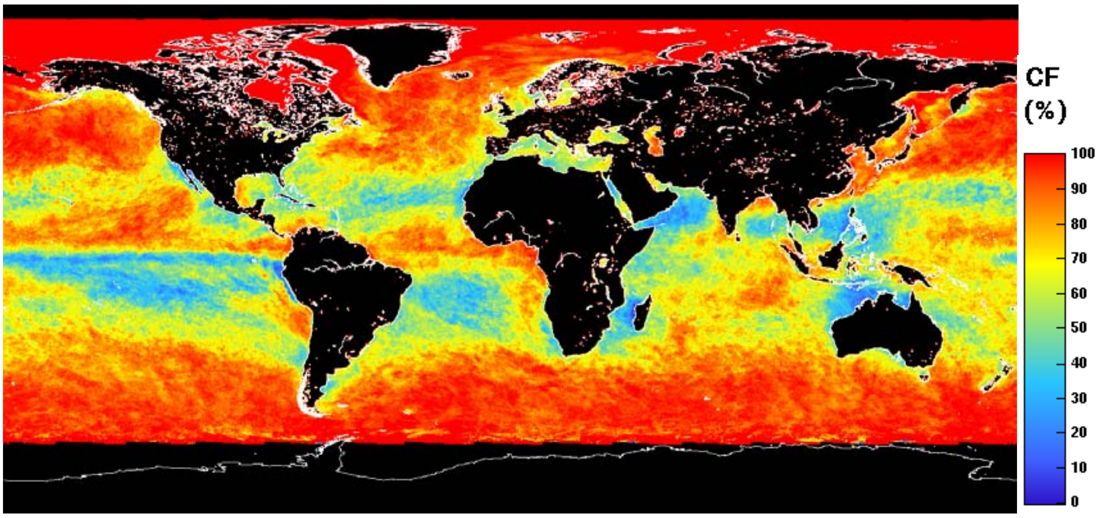

Figure 2.12: CF monthly product - April 2003

2.2 The spatial and temporal coverage

The GlobColour global level-3 binned products have a resolution of 1/24° at the equator (i.e. around 4.63 km) and consist of the accumulated data of all merged level 2 products, corresponding to periods of one day (a data-day algorithm is applied), 8 days and a calendar month. 8-days binning periods are continuous, starting from the first day of each calendar year.

The geographical location and extend of each bin is determined by the so-called Integerized Sinusoidal (ISIN) grid. The complete ISIN grid definition is provided in appendix.

In GlobColour binned ISIN products, bins are always written in sequential order, from the southernmost-westernmost bin to the northernmost-easternmost bin. Only valid bins are written in a binned product. Land bins and bins with no contributions (i.e. uncovered bins) are not contained in the files as well as the covered bins where no valid data has been found. As a result, the actual number of bins cannot exceed an amount of approximately 71% of the total number of bins given above. The spatial resolution of 1/24° yields to the following grid characteristics:

Average bin size:	4.63 km
Average bin area:	21.44 km^2
Total number of rows in the grid:	4320
Number of columns at equator:	8640
Number of columns at poles:	3
Total number of bins in the grid:	23,761,676
Maximum number of bins in a file:	~16,870,000

Table 2.2: Main characteristics of the global ISIN grid

2.2.1 The global mapped products

The GlobColour global level-3 mapped products have a resolution of 0.25° or 1.0° (i.e. respectively around 28 km and 111 km at the equator) and consist of the flux-conserving resampling of the global level-3 binned products. Daily, 8-days and monthly products are available.

Quicklooks of these products are available in PNG format.

2.2.2 The local binned and mapped products

The local products are defined at several specific areas called DDS areas (see the list of GlobColour DDS areas in appendix). DDS areas can be defined at a fixed geographical location or can be defined by the in-situ observation conditions in case of moving stations. In this case, a temporal window is also affected to the DDS.

There are several kinds of DDS products:

- DDS on PC grid, at a resolution of 1 km, computed from the level 2 tracks.
- DDS on ISIN grid, at a resolution of 1/24°, computed from the level 2 tracks.
- DDS on ISIN grid, at a resolution of 1/24°, at daily, 8-days and monthly time scale. They are computed the same way as the global merged level-3 products.

The local ISIN grid is defined to be fully compatible with the global ISIN grid. The numbering of the local DDS bins is computed from the global ISIN grid.

The local ISIN grid is defined to includes the corresponding local PC grid, i.e. the 100x100 km^2 area of the PC grid is fully covered with the local ISIN grid bins.

All DDS products are generated for a set of fixed DDS areas, and also for a set of DDS areas where in-situ measurements are available.

DDS on ISIN grid at daily, 8 days and monthly time scale can be either computed from the DDS on ISIN grid at track level (following the computation path of the global ISIN products) or from the global merged level 3 products.

2.3 The GlobColour system

2.3.1 Overall description of the processor

The GlobColour processor is the computation element of the GlobColour processing system. Its function is the transformation of EO level 2 products (or level 3 products) from independent instrument/missions into a single merged level 3 product.

The level-2 products are transformed after the sensor-specific preprocessing to a global ISIN grid with a resolution of 1/24° at the equator (i.e. around 4.63 km). This binning is separately applied to each level-2 input product for each instrument. Outputs are intermediate spatially binned level-3 products for each instrument, also called level 3 at track level.

The term *binning* refers to the process of distributing the contributions of the level-2 pixels in satellite coordinates to a fixed level-3 grid using a geographic reference system.

When images of different resolutions are to be accumulated together, if the spatial coverage of each pixel is not taken into account, the importance of the image of the highest resolution are largely predominant over the images of smaller resolutions; this may result in introducing a bias in the final product.

Computing a flux value associated to each pixel may solve that problem. Assuming that the data flux for each input pixel is constant, the resampling problem is actually reduced to the problem of finding the set of pixels overlapping each level-3 bin, and then calculating the relative overlapped area.

This approach not only allows to properly mix data of various resolutions together, it also allows to distribute data properly among different level-3 bins as the input image pixel is usually overlapping several of them. This also makes it possible to produce level-3 data at a higher resolution than the input data with no "holes".

Though very attractive, the major drawback to this method is that it is significantly slower than the usual method; different techniques are being investigated to increase the speed of this approach.

The algorithm implemented in the GlobColour processing chain uses the fast Sutherland-Hodgeman area clipping. For more information on the algorithm used refer to ["*A fast flux-conserving resampling algorithm*", available at http://skyview.gsfc.nasa.gov/polysamp/].

The same binning algorithm is applied to each kind of input variables. Only the flags taken into account when filtering the data is different. These flags are listed in the next sub-section.

Following this logic, the GlobColour processor is mainly composed of 4 separate modules, namely:

1. a pre-processor module
2. a spatial binning module
3. a merging module
4. a temporal binning module

For each sensor, a **pre-processing** is foreseen just after extraction of the L2. This pre processor serves for example in the case of MERIS and wherever requested to transform reflectance into normalised water leaving radiance. It could be used also to apply cross calibration LUT to be in position to merge equivalent data.

The complete binning scheme for the production of the GlobColour ocean colour products is a three steps approach comprising **spatial binning**, **data merging** and **temporal binning** as shown in the Figure 2.13.

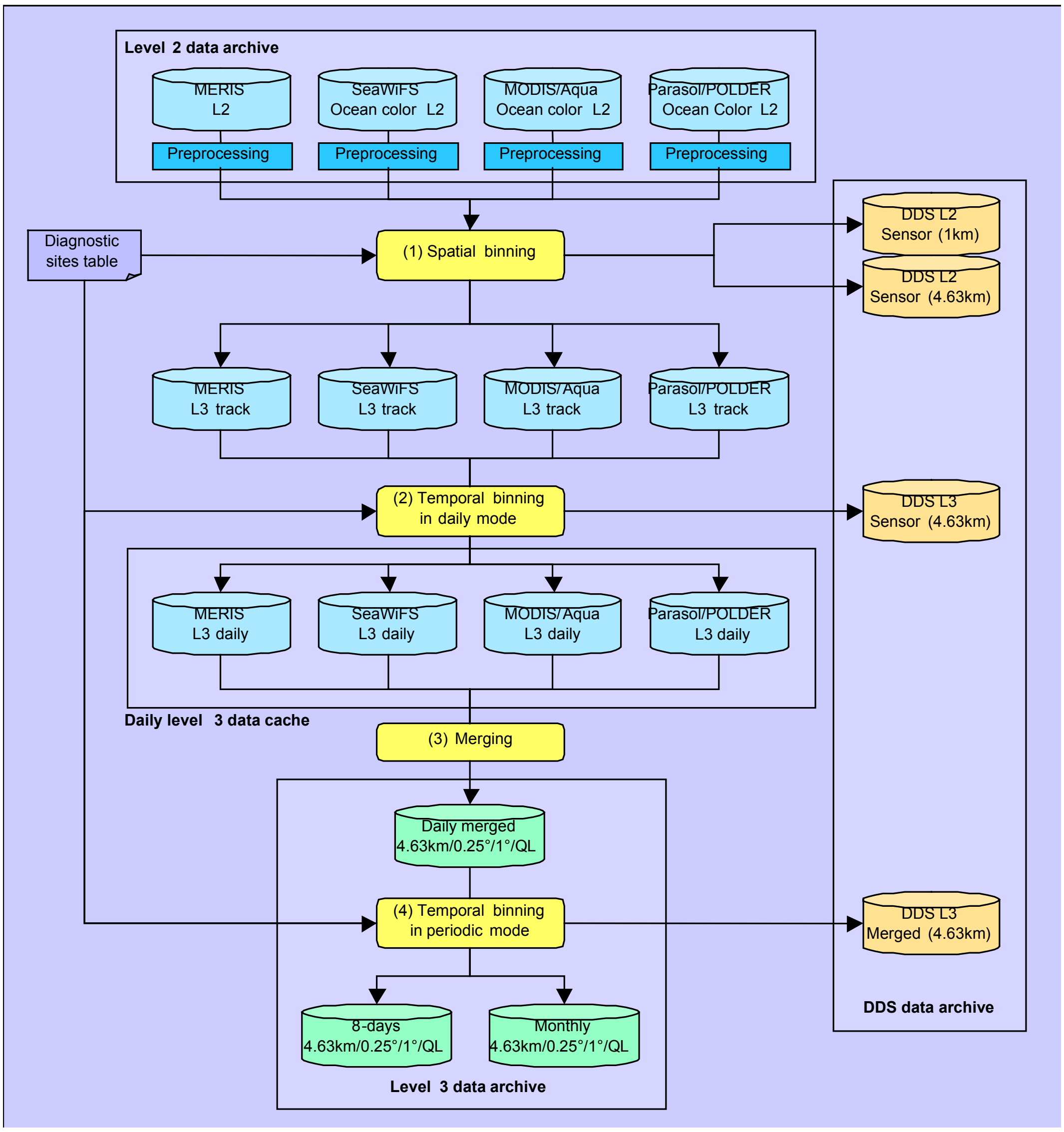

Figure 2.13: The GlobColour processor high-level description

2.3.2 The preprocessor

A preprocessing function is implemented in the processing chain before applying the binning module. This preprocessing is needed to transform some input data read from the level 2 products into the requested variable. For example, the MERIS normalised water-leaving reflectances must be converted into full normalised radiances.

The preprocessing could be a simple equation or a more complex algorithm using several external auxiliary files.

The following table lists the parameters on which a specific preprocessing is applied. The last column indicates which instrument data is affected.

Acronym	Variable description	Unit	Instruments
L412	Fully normalised water leaving radiances at 412 nm	mW/cm²/µm/sr	MERIS (pp1)
L443	Fully normalised water leaving radiances at 443 nm	mW/cm²/µm/sr	MERIS (pp1)
L490	Fully normalised water leaving radiances at 490 nm	mW/cm²/µm/sr	MERIS (pp1) - Parasol (pp6)
L510	Fully normalised water leaving radiances at 510 nm	mW/cm²/µm/sr	MERIS (pp1)
L555	Fully normalised water leaving radiances at 555 nm	mW/cm²/µm/sr	MERIS (pp1) - Parasol (pp3)
L620	Fully normalised water leaving radiances at 620 nm	mW/cm²/µm/sr	MERIS (pp1)
L670	Fully normalised water leaving radiances at 670 nm	mW/cm²/µm/sr	MERIS (pp1) - Parasol (pp3)
L681	Not normalised water leaving radiances at 681 nm	mW/cm²/µm/sr	MERIS (pp2)
L709	Not normalised water leaving radiances at 709 nm	mW/cm²/µm/sr	MERIS (pp2)
SZA, SAA, VZA, VAA, PRESSURE, WIND	Geometrical characteristics of the observations		MERIS (pp4) - SeaWIFS (pp4) MODIS (pp4) - Parasol (pp4)

Table 2.3: List of variables covered by the GlobColour project

(pp1): MERIS fully normalised water leaving radiances

The MERIS fully normalised water leaving radiances are computed from the normalised water leaving reflectances available in the MERIS level-2 products.

(pp2): MERIS L681, L709 bands exception

No normalisation is applied to the MERIS L681 and L709 bands.

(pp3): Parasol fully normalised water leaving radiances computation

The Parasol fully normalised water leaving radiances are computed from the water leaving reflectances available in the Parasol level-2 products.

(pp4): Geometrical characteristics of the observations

The geometrical characteristics of the observations are provided in the level 2 products for each pixel or every N pixels and frames (e.g. MERIS tie-points). In the latter case, the preprocessing includes the reconstruction of the information for every pixel. For example, in MERIS level 2 products, the geometry observation and some other auxiliary data are stored every 16 pixels and 16 frames. One of the preprocessing task is to rebuild the characteristics of each pixel at each frame by bilinear interpolation.

The following tables list, for each instrument, all variables coming from the preprocessing module, their symbols and their associated validity equation(s). “No data” is written in the validity column if the data is not available for the instrument.

For all sensors we consider that a pixel is invalid if the absolute value of its sun zenith angle is greater or equal to 70°.

MERIS

Acronym	Variable	Symbol	Validity equation
CHL1	Chlorophyll-a concentration. Case 1 water	$Chl_1(m)$	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (WHITE_SCATTERER=0) + **[** ((PCD_15=0) OR (PCD_17=0) **]** + CHL1 ≠ offset_CHL1 + enlarge (CLOUD OR ICE_HAZE) by 2 swath pixels + (CLOUD=0) + (ICE_HAZE=0)
CHL2	Chlorophyll-a concentration. Case 2 water	$Chl_2(m)$	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (WHITE_SCATTERER=0) + (PCD_17=0) + enlarge (CLOUD OR ICE_HAZE) by 2 swath pixels + (CLOUD=0) + (ICE_HAZE=0)
CDM	Coloured dissolved and detrital organic materials absorption coefficient	CDM(m)	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (WHITE_SCATTERER=0) + (PCD_16=0) + enlarge (CLOUD OR ICE_HAZE) by 2 swath pixels + (CLOUD=0) + (ICE_HAZE=0)
TSM	Total suspended matter concentration	$T_{SM}(m)$	Same as CDM
KD490	Diffuse attenuation coefficient	$K_{490}(m)$	Same as CHL1
L412	Fully normalised water leaving radiances at 412 nm	$nLw_{412}(m)$	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (rho[412,…,560]≥0) + **[** (PCD_15=0) OR (PCD_17=0) **]** + (PCD_19=0)
L443	Fully normalised water leaving radiances at 443 nm	$nLw_{443}(m)$	Same as L412
L490	Fully normalised water leaving radiances at 490 nm	$nLw_{490}(m)$	Same as L412
L510	Fully normalised water leaving radiances at 510 nm	$nLw_{510}(m)$	Same as L412
L531	Fully normalised water leaving radiances at 531 nm		No data
L555	Fully normalised water leaving radiances at 555 nm	$nLw_{555}(m)$	Same as L412
L620	Fully normalised water leaving radiances at 620 nm	$nLw_{620}(m)$	Same as L412
L670	Fully normalised water leaving radiances at 670 nm	$nLw_{665}(m)$	Same as L412
L681	Not normalised water leaving radiances at 681 nm	$nLw_{681}(m)$	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (PCD_19=0)
L709	Not normalised water leaving radiances at 709 nm	$nLw_{709}(m)$	Same as L681

EL555	Relative excess of radiance at 555 nm above a given threshold.	$EL_{555}(m)$	Same as L412
PAR	Photosynthetic available radiation	PAR(m)	(WATER=1) + (MEDIUM_GLINT=0) + (ABSOA_DUST=0) + (WHITE_SCATTERER=0) + (PCD_18=0)
T865	Aerosol optical thickness over water	$\tau_a^{865}(m)$	(WATER=1) + (PCD19=0) +(MEDIUM_GLINT=0) + **[** (CASE2_S=1) OR **[** (WHITE_SCATTERER=0) + (CASE2_ANOM=0) **]]** + enlarge (CLOUD OR ICE_HAZE) by 3 track pixels + (CLOUD=0) + (ICE_HAZE=0)
CF	Cloud fraction	$C_F(m)$	(WATER=1) OR (CLOUD=1)

Table 2.4: List of parameters and filters applied to the MERIS level 2 data

The following parameters are included in the geometrical observation condition:

- Sun zenith angle
- Sun azimuth angle
- Viewing zenith angle
- Viewing azimuth angle
- Mean sea level atmospheric pressure
- Surface wind speed

<u>MODIS</u>

Acronym	Variable	Symbol	Validity equation
CHL1	Chlorophyll-a concentration. Case 1 water	$Chl_1(m)$	not ATMFAIL and not LAND and not HILT and not HISATZEN and not STRAYLIGHT and not CLDICE and not COCCOLITH and not LOWLW and not CHLFAIL and not CHLWARN and not NAVWARN and not AXAERITER and not ATMWARN and not NAVFAIL and not FILTER and not HIGLINT.
CHL2	Chlorophyll-a concentration. Case 2 water		No data
CDM	Coloured dissolved and detrital organic materials absorption coefficient		No data
TSM	Total suspended matter concentration		No data
KD490	Diffuse attenuation coefficient	$K_{490}(m)$	Same as CHL1
L412	Fully normalised water leaving radiances at 412 nm	$nLw_{412}(m)$	Same as CHL1
L443	Fully normalised water leaving radiances at 443 nm	$nLw_{443}(m)$	Same as CHL1

L490	Fully normalised water leaving radiances at 490 nm	$nLw_{490}(m)$	Same as CHL1
L510	Fully normalised water leaving radiances at 510 nm		No data
L531	Fully normalised water leaving radiances at 531 nm	$nLw_{531}(m)$	Same as CHL1
L555	Fully normalised water leaving radiances at 555 nm	$nLw_{555}(m)$	Same as CHL1
L620	Fully normalised water leaving radiances at 620 nm		No data
L670	Fully normalised water leaving radiances at 670 nm	$nLw_{665}(m)$	Same as CHL1
L681	Not normalised water leaving radiances at 681 nm		No data
L709	Not normalised water leaving radiances at 709 nm		No data
EL555	Relative excess of radiance at 555 nm above a given threshold.	$EL_{555}(m)$	Same as CHL1
PAR	Photosynthetic available radiation		No data
T865	Aerosol optical thickness over water	$\tau_a^{865}(m)$	Same as CHL1
CF	Cloud fraction	$C_F(m)$	not LAND

Table 2.5: List of parameters and filters applied to the MODIS level 2 data

The following parameters are included in the geometrical observation condition:

- Sun zenith angle
- Sun azimuth angle

<u>SeaWiFS</u>

Acronym	Variable	Symbol	Validity equation
CHL1	Chlorophyll-a concentration. Case 1 water	$Chl_1(m)$	not ATMFAIL and not LAND and not HILT and not HISATZEN and not STRAYLIGHT and not CLDICE and not COCCOLITH and not LOWLW and not CHLFAIL and not CHLWARN and not NAVWARN and not AXAERITER and not ATMWARN and not NAVFAIL and not FILTER.

CHL2	Chlorophyll-a concentration. Case 2 water		No data
CDM	Coloured dissolved and detrital organic materials absorption coefficient		No data
TSM	Total suspended matter absorption		No data
KD490	Diffuse attenuation coefficient	K_{490}(m)	Same as CHL1
L412	Fully normalised water leaving radiances at 412 nm	nLw_{412}(m)	Same as CHL1
L443	Fully normalised water leaving radiances at 443 nm	nLw_{443}(m)	Same as CHL1
L490	Fully normalised water leaving radiances at 490 nm	nLw_{490}(m)	Same as CHL1
L510	Fully normalised water leaving radiances at 510 nm	nLw_{510}(m)	Same as CHL1
L531	Fully normalised water leaving radiances at 531 nm		No data
L555	Fully normalised water leaving radiances at 555 nm	nLw_{555}(m)	Same as CHL1
L620	Fully normalised water leaving radiances at 620 nm		No data
L670	Fully normalised water leaving radiances at 670 nm	nLw_{665}(m)	Same as CHL1
L681	Not normalised water leaving radiances at 681 nm		No data
L709	Not normalised water leaving radiances at 709 nm		No data
EL555	Relative excess of radiance at 555 nm above a given threshold.	EL_{555}(m)	Same as CHL1
PAR	Photosynthetic available radiation		No data
T865	Aerosol optical thickness over water	τ_a^{865}(m)	Same as CHL1
CF	Cloud fraction	C_F(m)	not LAND

Table 2.6: List of parameters and filters applied to the SeaWiFS level 2 data

The following parameters are included in the geometrical observation condition:

- Sun zenith angle
- Sun azimuth angle

POLDER/Parasol

Acronym	Variable	Symbol	Validity equation
CHL1	Chlorophyll-a concentration. Case 1 water	$Chl_1(m)$	bit 31 of the level 2 data quality flag is equal to 0 (bit 31 correspond to the criteria Cloud - local standard deviation threshold of type 3 (0.02))
CHL2	Chlorophyll-a concentration. Case 2 water	$Chl_2(m)$	Same as CHL1
CDM	Coloured dissolved and detrital organic materials absorption coefficient		No data
TSM	Total suspended matter concentration		No data
KD490	Diffuse attenuation coefficient	$K_{490}(m)$	Same as CHL1
L412	Fully normalised water leaving radiances at 412 nm		No data
L443	Fully normalised water leaving radiances at 443 nm	$nLw_{443}(m)$	Not to be used due to strong un-corrigible straylight contamination
L490	Fully normalised water leaving radiances at 490 nm	$nLw_{490}(m)$	Same as CHL1
L510	Fully normalised water leaving radiances at 510 nm		No data
L531	Fully normalised water leaving radiances at 531 nm		No data
L550-565	Fully normalised water leaving radiances at 550-565 nm	$nLw_{555}(m)$	Same as CHL1
L620	Fully normalised water leaving radiances at 620 nm		No data
L665-670	Fully normalised water leaving radiances at 665-670 nm	$nLw_{665}(m)$	Same as CHL1
L681	Fully normalised water leaving radiances at 681 nm		No data

L709	Fully normalised water leaving radiances at 709 nm		No data
EL555	Relative excess of radiance at 555 nm above a given threshold.	$EL_{555}(m)$	Same as CHL1
PAR	Photosynthetic available radiation		No data
T865	Aerosol optical thickness over water	$\tau_a^{865}(m)$	Same as CHL1
CF	Cloud fraction	$C_F(m)$	not LAND

Table 2.7: List of parameters and filters applied to the PARASOL level 2 data

The following parameters are included in the geometrical observation condition:

- Sun zenith angle
- Sun azimuth angle
- Surface wind speed

2.3.3 The spatial and temporal binning schemes

The list of steps for the generation of the whole set of GlobColour products is:

- step 1: L2 to L3 at 1 km (DDS-PC)
- step 2: L2 to L3 at 4.63 km (DDS-ISIN)
- step 3: L2 to L3 track at 4.63 km (global-ISIN)
- step 4: L3 track at 4.63 km to L3 daily for each single instrument (global-ISIN)
- step 5: L3 daily for each single instrument to merged L3 daily (global-ISIN)
- step 6: L3 daily merged to 8days and monthly L3 products (global-ISIN)
- step 7: L3 at 4.63 km at track level to daily/8days/monthly merged products (DDS-ISIN)
- step 8: L3 daily/8days/monthly merged products to 0.25° and 1.0° resolution products (global-PC)
- step 9: generation of the quicklooks (global-PNG)

The information between parenthesis gives the spatial coverage and the sampling grid.

These steps are fully described in appendix.

The temporal binning algorithm is rather simple and the complexity comes from the selection of the input level-3 products to generate the daily products. The simple, obvious, selection of all data measured between 00:00 and 23:59 leads to possible large temporal aliasing in the same region of observation.

The temporal binning process needs the definition of a data-day, as we don't want to mix at the same (or at close geographical locations) pixels observed at too different times. The data-day definition used in the frame of the GlobColour project is fully described in the following sub-chapter.

2.3.4 The GlobColour data-day approach

A new spatial and temporal definition of a data-day has been used in the frame of the GlobColour project. The aim of the data-day definition is to avoid mixing pixels observed at too different times. As for other classic definitions, we accept to increase the duration of a day in order to include the previous and next day data. Then, at the same spatial area we could select the best input, i.e. the one leading to the lowest temporal discrepancies. A data-day therefore may represent data taken over a 24 to 28 hour period.

As the Seastar, Aqua, ENVISAT and POLDER satellites have different orbits, each of them has its own data-day definition.

In the following figures, we have plotted the UTC hour as a function of the pixel longitude for the three instruments for one day in the year. The colour of the dots is proportional to the absolute value of the data latitude (purple-blue for latitude=0° and red-brown for latitude>80°). The idea behind that representation is that if we want to avoid mixing pixels of different hours of the day at the same longitude, something should be visible on this kind of graphic.

We can observe that the data is split in three groups. As expected, the high latitudes of the data cover more longitude values while the equatorial latitudes lead to less scattered longitude values (the orbits are polar). Of course, a bigger width of the instrument track leads to a higher dispersion.

We can also observe that the temporal variation of the pixels of each instrument covers a large period of the day, especially for MODIS and SeaWiFS: if we look at the width of the central set of pixels at any longitude, we can see that this width is equal to 8 hours for MERIS, 20 hours for SeaWiFS and 24 hours for MODIS. This is directly linked to the satellite orbit and the track width. If we avoid pixels above 80°, the temporal variation decreases to: 8 hours for MERIS and SeaWiFS and 16 hours for MODIS. In this new estimation, we have discarded a few valid pixels that belongs to the ascending track (or descending track, depending of the satellite orbit) that are of course far away in longitude with respect to the median part of the track and so will mix with pixels of a previous track, observed several hours before.

These groups are attached to three different data-days:

- the pixels belonging to the median group are attached to the current data-day (i.e. the day given by the current UTC date).
- the pixels belonging to the upper group are attached to the next data-day
- the pixels belonging to the lower group are attached to the previous data-day

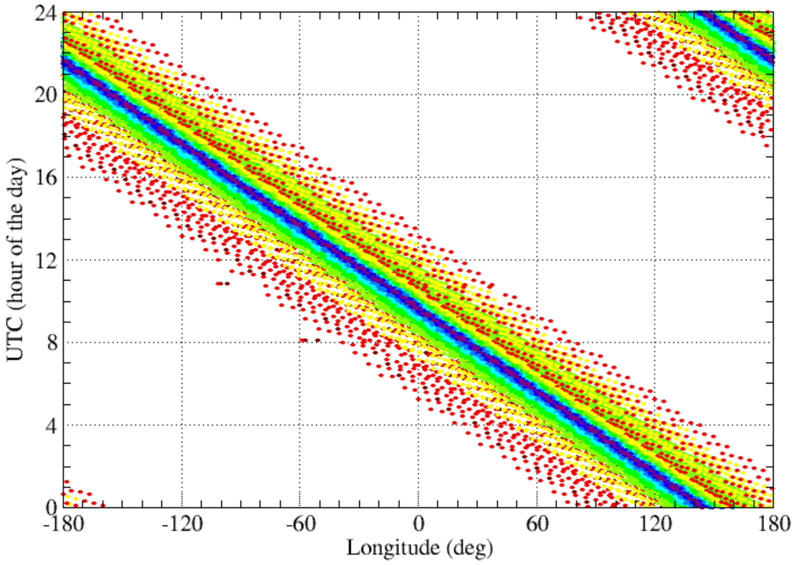

Figure 2.14: MERIS pixels UTC as a function of the pixel longitude (35 days - october 2003)

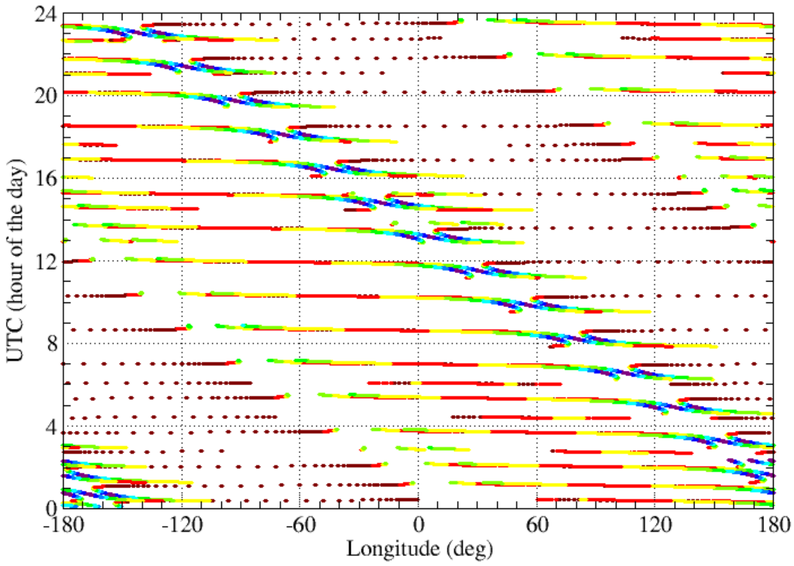

Figure 2.15: MODIS pixels UTC as a function of the pixel longitude (1 day - june 2003)

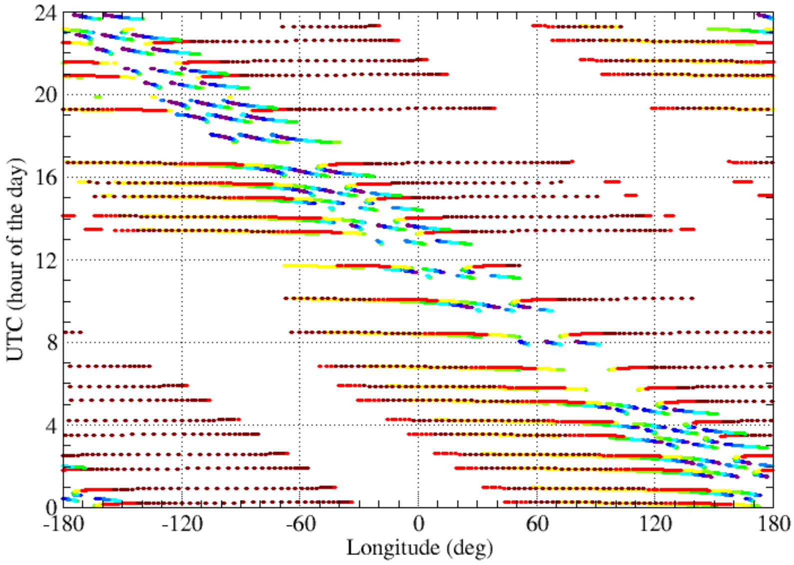

Figure 2.16:SeaWiFS pixels UTC as a function of the pixel longitude (1 day - december 2003)

Obviously, we can see on these graphics that the groups are separated by two regular, more or less large white bands. The slope of these bands is equal to -24/360°. If we plot a line defined by the crossing nodal time of the satellite at -180° and this slope, we can see that this line is almost always located in the white bands and so can be used to distinguish between data of very different day time at the same longitude.

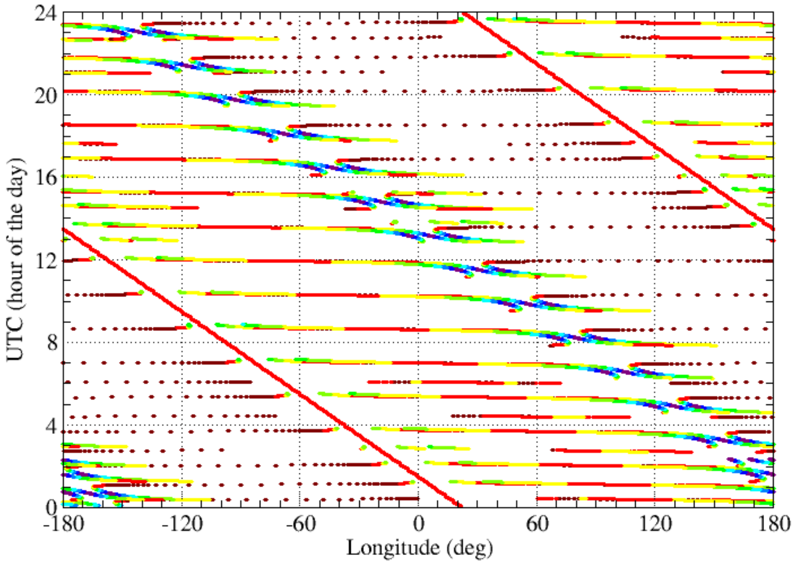

Figure 2.17: Data-day definition line above MODIS pixels UTC versus longitude plot.

As some instrument are able to observe through the pole, there is not always such full discontinuity between the groups. Anyway, this is only true for pixels at very high latitudes (>80°), as shown on the following figure where we have plotted only one SeaWiFS track and the data-day separation line.

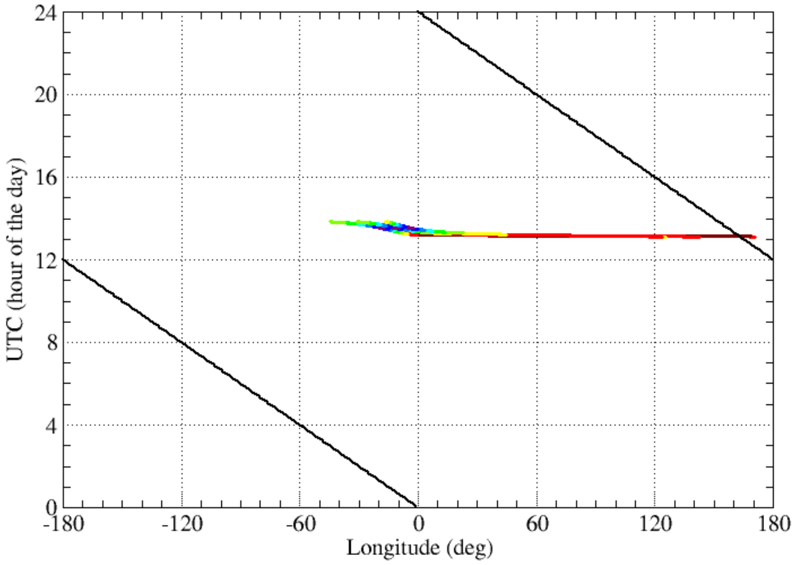

Figure 2.18: Data-day definition line above one SeaWiFS track.

Despite this limitation, there are several reasons to use this data-day separation lines:

- the observation will be probably flagged due to the limitation in sun zenith angle (70°)
- the data is not lost. Only few pixels are shifted to the next of previous data-day
- the coding is very simple

The implementation of this data-day definition is described here:

Input parameters:

Variable	Unit	Description
CNT	hour	crossing nodal time in ascending track
τ	hr/°	slope of the data-day definition lines
d	UTC date	UTC date (day) of the measured pixel
h	UTC hour	UTC date (hour) of the measured pixel
φ	deg	longitude of the measured pixel

Table 2.8: Input parameters for data-day classification

Note: τ has a constant value equal to -24/360.

Instrument	MODIS (Terra)	SeaWiFS (SeaStar)	MERIS (Envisat)
CNT	13.5	12.0	10.0

Table 2.9: CNT of satellites

Algorithm:

if ($h < CNT + (\varphi + 180) * \tau$) then

pixel is attached to data-day (d-1)

else if ($h > CNT + (\varphi + 180) * \tau + 24$) then

pixel is attached to data-day (d+1)

else

pixel is attached to data-day (d)

end if

3 The products format

3.1 General rules

The GlobColour Level-3 binning scheme and its output products have been designed with respect to a number of widely used definitions and de-facto standards:

- MODIS Ocean Color Level-3 products
- GHRSST-PP Level-4 products
- IOCCG Report number 4
- netCDF Climate and Forecast Metadata Conventions CF-1

GlobColour Level-3 output data includes binned, mapped and browse products which are described in the following sections. The binned and mapped products are stored in netCDF files. The netCDF library or third-party tools including netCDF readers must be used to read the GlobColour products. The browse products are written in PNG format.

netCDF (Network Common Data Form) is a machine-independent, self-describing, binary data format standard for exchanging scientific data. The project homepage is hosted by the Unidata program at the University Corporation for Atmospheric Research (UCAR). They are also the chief source of netCDF software, standards development, updates etc. The format is an open standard (see http://www.unidata.ucar.edu/software/netcdf).

The ncdump utility, available on the UCAR server, generates a CDL text representation of a netCDF file on the standard output, optionally excluding some or all of the variable data in the output. The output from ncdump is intended to be acceptable as input to ncgen (also available on the server). Thus ncdump and ncgen can be used as inverses to transform data representation between binary and text representations.

The atomic external types supported by the netCDF-3 interface are (information extracted from the netCDF user's guide):

C name	Storage
NC_BYTE	8-bit signed integer
NC_CHAR	8-bit unsigned integer
NC_SHORT	16-bit signed integer
NC_INT (or NC_LONG)	32-bit signed integer
NC_FLOAT	32-bit floating point
NC_DOUBLE	64-bit floating point

Table 3.1: netCDF external types

There is no primitive “string” type in netCDF-3. Strings must be stored as fixed-length arrays of NC_CHAR.

These types were chosen to provide a reasonably wide range of trade-offs between data precision and number of bits required for each value. These external data types are independent from whatever internal data types are supported by a particular machine and language combination.

These types are called "external", because they correspond to the portable external representation for netCDF data. When a program reads external netCDF data into an internal variable, the data is converted, if necessary, into the specified internal type. Similarly, if you write internal data into a netCDF variable, this may cause it to be converted to a different external type, if the external type for the netCDF variable differs from the internal type.

The separations of external and internal types and automatic type conversion have several advantages. You need not be aware of the external type of numeric variables, since automatic conversion to or from any desired numeric type is available. You can use this feature to simplify code, by making it independent of external types, using a sufficiently wide internal type, e.g., double precision, for numeric netCDF data of several different external types. Programs need not be changed to accommodate a change to the external type of a variable.

The following rules are applied when writing the global binned (ISIN grid) and mapped products (PC grid):

- **each parameter is stored in a single file including metadata and accumulated statistical data.**
- global metadata are stored as global attributes
- accumulated statistical data are stored as variables
- metadata related to statistical data are stored as variable attributes.

The following rules are applied when writing the DDS binned and mapped products (PC grid):

- **all parameters are stored in a single file including metadata and accumulated statistical data.**
- global metadata are stored as global attributes
- accumulated statistical data are stored as variables
- metadata related to statistical data are stored as variable attributes.

3.2 Naming convention

This naming convention is common to all GlobColour products. The file naming convention of the files follows the following rules :

Lzz_date_time_ROI_SR_INS_PRD_TC_nn.ext

where:

- **Lzz** is the product level (L3b for level 3 binned ISIN grid, L3m for level 3 mapped grid)
- **date** is specified in UTC format as yyyymmdd[-yyyymmdd]. The end date is optional for track and daily products.
- **time** is specified in UTC format as hhmmss[-duration]. The time field is needed only for track products. The duration is expressed in seconds.
- **ROI** is the name of the region of interest (e.g. GLOB for global coverage, site name for DDS).
- **SR** indicates the resolution of the grid (e.g. 4 for 1/24° ISIN grid).

- **INS** is the instrument acronym (MER for MERIS, MOD for MODIS, SWF for SeaWiFS or any combinaison of these names for the merged products). For the merged products, the instrument acronym is prefixed with the merging method (AV for simple average, AVW for weighted average, GSM for the GSM model).
- **PRD** is the product type (CHL for chlorophyll...). Note that the various merging algorithms can be indicated in this field using a "-" delimiter (e.g. CHL1-M01, CHL1-M02).
- **TC** is the time coverage (TR for track-level products, DAY for daily, 8D for 8days, MO for monthly, YR for annual products).
- **nn** is a counter. For track products, we store in this counter the data-day in yyyymmdd format.
- **ext** is the file extension (nc for netCDF files, png for PNG files)

The number of field is constant. Missing information leads to two adjacent underscores.

Examples:

```
L3b_20040101_072312-2363_GLOB_4_MER_L555_TR_20040101.nc
L3m_20040401__ZON1_25_MOD_CHL1_DAY_00.nc
L3b_20040401-20040430__GLOB_4_MER_L413_MO_00.nc
L3b_20021001-20021031__GLOB_4_AV-MERMODSWF_T865_MO_00.nc
L3b_20040101-20041231__NMED_9_GSM-MERMODSWF_CDM_YR_00.nc
```

3.3 The global products

A netCDF dataset is made up of three basic components:

- dimensions
- variables
- variables attributes
- global attributes

The variables store the actual data, the dimensions give the relevant dimension information for the variables, and the attributes provide auxiliary information about the variables or the dataset itself.

3.3.1 The binned products

<u>Dimensions</u>

All variables stored in the global ISIN binned product use one of the two dimensions:

Dimension	netCDF Type	Nb of bytes	Parameter Description
bin	NC_LONG	4	Number of bins written in the product
row	NC_LONG	4	Number of useful rows in the global ISIN grid (number of row between northernmost and southernmost bins)

Table 3.2: Dimensions - global binned products

Variables

ISIN grid location variables (only present in ISIN case). Some variable names are prefixed by the name of the parameter (e.g. CHL1_mean, EL555_weight).

Variable Name	netCDF Type	Nb of bytes	Parameter Description
row(bin)	NC_SHORT	2	Latitudinal band index of the bins stored in the product, zero based and beginning at south (1)
col(bin)	NC_SHORT	2	Longitudinal index of the bins stored in the product, zero based and beginning at west (1)
center_lat(row)	NC_FLOAT	4	Center latitude for each useful row (1)
center_lon(row)	NC_FLOAT	4	Center longitude of the first bin (the first bin in the global ISIN grid, not the first valid bin) for each useful row (1)
lon_step(row)	NC_FLOAT	4	Longitude step for each useful row (1)
PRM_mean(bin)	NC_FLOAT	4	Average value of the binned pixels values
PRM_stdev(bin)	NC_FLOAT	4	Standard deviation of the square of the binned pixels values
PRM_count(bin)	NC_SHORT	2	Number of binned pixels
PRM_weight(bin)	NC_FLOAT	4	Sum of the weights of the binned pixels
PRM_flags(bin)	NC_SHORT	2	Flags (3)
PRM_error(bin)	NC_SHORT	2	Error estimation for the geophysical variable (2)

Table 3.3: Variables - global binned products

Note 1: the row(), col(), center_lat, center_lon and lon_step() arrays allow an easier conversion of the bin index into geographical coordinates rather than the global idx() array written in the SeaWiFS and MODIS level 3 products.

Equations to compute center longitude and latitude for a bin *b* are:

index = row(b) – first_row *(first_row is a global attribute)*

lat(b) = center_lat(index)

*lon(b) = center_lon(index) + col(b) * lon_step(index)*

Note 2: the error associated to each bin is computed from representative values of the bin (e.g. arithmetic mean) and observation conditions (e.g. zenith angles) using a LUT read from an external auxiliary file. The error variable is stored only in products where it is significant (i.e. the error bar is not used for simple averaging merging, and so the error is of course not stored). The error bar is stored in 2 bytes integers using the unit 0.01%. The biggest error bar possible in this format is 32767, so if a computed error bar is greater than 32767 is set to 32767.

Note 3: the quality control is available though a flags array (2 bytes), provided for each bin of each product (variability of inputs required for radiance, source of instrument: all, MODIS only..., green reflectance threshold, mostly cloudy pixel, high aerosol optical thickness, etc...). The next table contains the current flags definition. A flag is set if its bit is set to 1. The “Bit” column contains each flag bit number, from the least to the most significant bit of the 2 bytes.

Bit	Flag code	Description
0	NO_MEASUREMENT	Bin not covered by any L2 swaths pixel, valid or invalid (out of swaths)
1	INVALID	Bin covered, but only by invalid pixel(s) (invalid because L2 flags, clouds, land, …)
2	REPLICA	Bin covered by valid or invalid pixel(s), but containing no pixel centre. Only set in case of nearest algorithm for DDS 1km product; for all ISIN products the flag is set to 0.
3	LAND	Bin covered by more than 50% of land. If not set, bin is considered as water. (1) (4)
4	CLOUD1	Cloud fraction (2)
5	CLOUD2	
6	DEPTH1	Water depth (1) (3)
7	DEPTH2	
8	TURBID	Computed from EL555. TURBID flag is raised when EL555 is greater than 0
9		Not yet used
10		Not yet used
11		Not yet used
12		Not yet used
13	SEAWIFS	SeaWiFS valid pixel(s) contribute to the bin value
14	MODIS	MODIS valid pixel(s) contribute to the bin value
15	MERIS	MERIS valid pixel(s) contribute to the bin value

Table 3.4: Flags description

Note 1: computed using a common global land elevation and ocean bathymetry product (data from ESA). This product is computed at 4.63 km on the global ISIN and PC grids.

Note 2: for 8-days or longer periods, cloud fraction flags are not yet defined (flags are currently set to 0). For daily products they define a cloud coverage classification:

(CLOUD2=0) + (CLOUD1=0): CF < 5%

(CLOUD2=0) + (CLOUD1=1): 5% <= CF < 25%

(CLOUD2=1) + (CLOUD1=0): 25% <= CF < 50%

(CLOUD2=1) + (CLOUD1=1): CF >= 50%

Level-2 clouds definition depends on sensor:

MERIS: (WATER=1) + **[** (CLOUD=1) OR (ICE_HAZE=1) **]**
MODIS/SeaWiFS: (LAND=0) + (CLDICE=1)

Note 3: (DEPTH2=0) + (DEPTH1=0): depth < 30m

(DEPTH2=0) + (DEPTH1=1): 30m <= depth < 200m

(DEPTH2=1) + (DEPTH1=0): 200m <= depth < 1000m

(DEPTH2=1) + (DEPTH1=1): depth >= 1000m

Note 4: it is possible that a bin flagged LAND has a valid parameter value on coastal limits.

Variables attributes

The following table lists the variable attributes used in the GlobColour project. These attributes are commonly used to annotate variable in netCDF files and their usage is strongly encouraged by the CF-1 metadata conventions.

Attribute Name	netCDF type	Attribute Description
long_name	string	A descriptive name that indicates a variable's content. We set it to the "Parameter Description" of the previous table
_FillValue	same type as variable	A value used to indicate array elements containing no valid data
units	string	Text description of the physical units, preferably S.I. Some variables (row, col, count, flags, …) don't have any units attribute
pct_characterised_error	NC_FLOAT	Characterised error, expressed in %

Table 3.5: Variables attributes - global binned products

Global attributes

This section presents the metadata that are written in the main product file. Metadata is stored as global attributes in the netCDF file.

General product information

Attribute Name	netCDF type	Attribute Description
Conventions	string	Indicates compatibility with the Climate and Forecast (CF) netCDF convention. "CF-1.0"
title	string	A high-level descriptive title for the product
product_name	string	The name of the product without path.
product_type	string	Temporal binning period: e.g. "track", "day", "week", "8-day", "month", "year"
product_version	string	Version of the product format
product_level	NC_SHORT	Product level: 3
parameter_code	string	Parameter short name (e.g. "CHL1")
parameter	string	Parameter long name (e.g. "Chlorophyll-a case 1 water")
site_name	string	Name of the region of interest, or name of the site for which the DDS granule was created
sensor_name	string	Instrument short name, e.g. "MERIS" In case of merged product, this field is an acronym of the merging algorithm applied.

sensor	string	Instrument full name, e.g. "MEdium Resolution Imaging Spectrometer Instrument" In case of merged product, this field describes the merging algorithm applied.
sensor_name_list	string	List of all input data sensors (comma delimiter)
software_name	string	Name of the processing software
software_version	string	Version string of the processing software
institution	string	Processing centre where the product has been generated
processing_time	string	UTC time of generation of the product; concatenated digits for year, month, day, hours, minutes and seconds in the format of yyyymmddhhmmss
netcdf_version	string	The netCDF file format version
DPM_reference	string	Reference to a document describing the model used to generate the data
IODD_reference	string	Reference to a document describing the content and format of the product
references	string	Published or web-based references that describe the data or methods used to produce it
contact	string	A free text string giving the primary contact for information about the data set
history	string	Provides an audit trail for modifications to the original data. Well-behaved generic netCDF filters will automatically append their name and the parameters with which they were invoked to the global history attribute of an input netCDF file. We recommend that each line begin with a timestamp indicating the date and time of day that the program was executed
input_files	string	List of the input products that were used to generate this product (comma delimiter)

Table 3.6: Global attributes - global binned products (1/3)

Temporal information

Attribute Name	netCDF type	Attribute Description
start_time	string	UTC date and time of the first measurement valid or invalid falling in the product in the format yyyymmddhhmmss
end_time	string	UTC date and time of the last measurement valid or invalid falling in the product in the format yyyymmddhhmmss
duration_time	NC_LONG	Duration in seconds between the first and last measurement valid or invalid falling in the product
period_start_day	string	UTC start day of the binning period in the format yyyymmdd
period_end_day	string	UTC end day of the binning period in the format yyyymmdd
period_duration_day	NC_LONG	Duration in days of the binning period

Table 3.7: Global attributes - global binned products (2/3)

Note: the binning period is not identical to the period resulting from the effective time period of the contributing data. And due to the data-day temporal splitting of the data, the binning period could be included in the effective time period.

Grid information

Attribute Name	netCDF type	Attribute Description
grid_type	string	Grid used to project the data: “Equirectangular” or “Integerized Sinusoidal Grid”
spatial_resolution	NC_FLOAT	Spatial resolution of the product in km
nb_equ_bins	NC_LONG	Number of equatorial bins (used to built the sinusoidal grid)
registration	NC_LONG	Location of characteristic point within bin (5: centre)
straddle	NC_LONG	Indicates if a longitudinal band straddle the equator (0: no and 1: yes; only present in ISIN case)
first_row	NC_SHORT	First useful row, zero based and beginning at south (only present in ISIN case)
lat_step	NC_FLOAT	Latitude step
lon_step	NC_FLOAT	Longitude step (only present in PC case)
earth_radius	NC_DOUBLE	Earth radius in kilometres (used to built the sinusoidal grid)
max_north_grid	NC_FLOAT	Northernmost latitude of the grid (range: -90° to +90°) (1)
max_south_grid	NC_FLOAT	Southernmost latitude of the grid (range: -90° to +90°) (1)
max_west_grid	NC_FLOAT	Westernmost longitude of the grid (range: -180° to +180°) (1)
max_east_grid	NC_FLOAT	Easternmost longitude of the grid (range: -180° to +180°) (1)
northernmost_latitude	NC_FLOAT	Latitude in degrees of the northernmost side of the northernmost valid bin (range: -90° to +90°)
southernmost_latitude	NC_FLOAT	Latitude in degrees of the southernmost side of the southernmost valid bin (range: -90° to +90°)
westernmost_longitude	NC_FLOAT	Longitude in degrees of the westernmost side of the westernmost valid bin (range: -180° to +180°)
easternmost_longitude	NC_FLOAT	Longitude in degrees of the easternmost side of the easternmost valid bin (range: -180° to +180°)
nb_grid_bins	NC_LONG	Total number of bins of the grid
nb_bins	NC_LONG	Total number of bins saved in the product
pct_bins	NC_FLOAT	(nb_bins * 100) / nb_grid_bins
nb_valid_bins	NC_LONG	Number of valid bins in the product (i.e. bins not equal to _FillValue)
pct_valid_bins	NC_FLOAT	(nb_valid_bins * 100) / nb_bins

Table 3.8: Global attributes - global binned products (3/3)

Note 1: these attributes define the product coverage. In global products (ISIN or mapped) cases, this is –180/90 to 180/-90, and in DDS products it defines the region of interest.

3.3.2 The mapped products

The global mapped product is the level 3 binned product projected on a Plate-Carré grid with a low resolution (also called level 3 low resolution product). This product is created by a re-projection of the level 3 binned data using an equal-angle latitude-longitude projection.

Land bins and missing data are represented by a "no-data" value (values identified by the netCDF global _FillValue attribute).

There is a one-to-one correspondence between the level 3 binned products and the level 3 low resolution products. The averaging periods are the same as for the binned products: daily, 8-days and monthly.

The following table gives the grid size as a function of the spatial resolution:

Angular resolution:	0.25°	1.0°
Longitudinal grid size	1440	360
Latitudinal grid size	720	180

Table 3.9: Dimensions of the grid - global mapped products

A PNG representation of the level 3 low resolution product is distributed. The format of the PNG file is not described here. The colour scale table is also provided.

The layout of the mapped products is similar to the layout of the binned products. Most of the global attributes and variable attributes are identical. The differences are listed below.

<u>Dimensions</u>

Due to their rectangular grid layout, the mapped products include two dimensions for each variable (instead of a single one for the binned products). The naming of the dimensions refers to the "Independent latitude, longitude, vertical and time axes" definition of the CF-10 convention.

Dimension	**Value**	**Description**
lon	720 or 180	Number of pixels in the longitudinal axis of the map grid. A corresponding variable named lon contains the actual longitude values.
lat	1440 or 360	Number of pixels in the latitudinal axis of the map grid. A corresponding variable named lat contains the actual latitude values.

Table 3.10: Dimensions - global mapped products

With respect to the binned products, the mapped product includes variables to specify the geolocation of the map pixels (for the binned products, the geolocation of the bins shall be recomputed from formulas and parameters provided in the product or read in a specific file).

Variable Name	netCDF Type	Nb of bytes	Parameter Description

lon(lon)	NC_FLOAT	4	Center longitude of each column of the grid, beginning at west. Following the CF 1.0 conventions, the attributes of this variable are:
			`long_name = "longitude"`
			`unit      = "degrees_east".`

lat(lat)	NC_FLOAT	4	Center latitude of each row of the grid, beginning at north. Following the CF 1.0 conventions, the attributes of this variable are:
			`long_name = "latitude"`
			`unit      = "degrees_north".`

Table 3.11: Variables - global mapped products (1/2)

The definition of the variables is also modified by the fact that 2D maps are written in the products instead of 1D vectors of bins. Note also that the row and col variables needed to locate the bin in the sinusoidal grid is no more needed as all the map is stored in the file.

Variable Name	netCDF Type	Nb of bytes	Parameter Description
PRM_mean(lat,lon)	NC_FLOAT	4	Average value of the binned pixels values
PRM_stdev(lat,lon)	NC_FLOAT	4	Standard deviation of the square of the binned pixels values
PRM_count(lat,lon)	NC_SHORT	2	Number of binned pixels
PRM_weight(lat,lon)	NC_FLOAT	4	Sum of the weights of the binned pixels
PRM_flags(lat,lon)	NC_SHORT	2	Flags
PRM_error(lat,lon)	NC_SHORT	2	Error estimation for the geophysical variable

Table 3.12: Variables - global mapped products (2/2)

3.4 The DDS products

3.4.1 The binned products

The DDS binned products have two different origins. The first one is the spatial binning of level 2 products on the local 4.63 km ISIN grids. The second one is the extracted of merged data from the daily, 8 days and monthly merged level 3 products.

Parent Product Type	Spatial Grid	Spatial Resolution	Frequency	Resampling
Level-2	ISIN	4.63 km	orbit-wise	flux-conserving binning
Level-3	ISIN	4.63 km	daily, 8-day, monthly	none (data extraction)

Table 3.13: Local binned products

<u>Variables</u>

Level-2 DDS granules consist of input data for each instrument resampled from the level-2 products.

As all parameters are written in a single netCDF file, the name of the variable is prefixed with the name of the parameter (e.g. CDM_mean, CHL1_flags, KD_error).

Level-3 DDS granules are created from Level-3 binned products. Each Level-3 granule contains the statistics for all generated geo-physical variables and all available quality data.

<u>Global attributes</u>

Where applicable, the global attributes of the parent products are found in the DDS granules as well. The following additional attributes exist only in DDS granules:

Attribute Name	netCDF type	Attribute Description
site_id	string	The unique identifier of the site for which the DDS granule was created.
site_latitude	NC_FLOAT	Latitude of the centre of the region of interest (this parameter is useful only for DDS products) (range: -90° to +90°)
site_longitude	NC_FLOAT	Longitude of the centre of the region of interest (this parameter is useful only for DDS products) (range: -180° to +180°)
site_row	NC_SHORT	Zero-based y-coordinate of grid cell (pixel) containing the in-situ site's centre coordinate (1)
site_col	NC_SHORT	Zero-based x-coordinate of grid cell (pixel) containing the in-situ site's centre coordinate (1)

Table 3.14: Global attributes - local binned products

Note 1: these coordinates are global in the ISIN case.

3.4.2 The mapped products

The DDS mapped products are generated by the spatial binning of level 2 products on a local PC grid.

Parent Product Type	Spatial Grid	Spatial Resolution	Frequency	Resampling
Level-2	PC	1.00 km	orbit-wise	flux-conserving binning

Table 3.15: Local mapped products

Variables

Level-2 DDS granules consist of input data for each instrument resampled from the level-2 products.

As all parameters are written in a single netCDF file, the name of the variable is prefixed with the name of the parameter (e.g. CDM_value, CHL1_flags).

Variable Name	netCDF Type	Nb of bytes	Parameter Description
PRM_value(lat,lon)	NC_FLOAT	4	Nearest measurement data
PRM_flags(lat,lon)	NC_SHORT	2	Flags built from the existing level 2 flags (see dedicated chapter)

Table 3.16: Variables - local mapped products

Global attributes

Where applicable, the global attributes of the parent products are found in the DDS granules as well. The following additional attributes exist only in DDS granules:

Attribute Name	netCDF type	Attribute Description
site_id	string	The unique identifier of the site for which the DDS granule was created.
site_latitude	NC_FLOAT	Latitude of the centre of the region of interest (this parameter is useful only for DDS products) (range: -90° to +90°)
site_longitude	NC_FLOAT	Longitude of the centre of the region of interest (this parameter is useful only for DDS products) (range: -180° to +180°)
site_row	NC_SHORT	Zero-based y-coordinate of grid cell (pixel) containing the in-situ site's centre coordinate (1)
site_col	NC_SHORT	Zero-based x-coordinate of grid cell (pixel) containing the in-situ site's centre coordinate (1)

Table 3.17: Global attributes - local mapped products

Note 1: these coordinates are local in the PC case.

4 The available tools

Tools to browse and view the content of the GlobColour products are available on the web site:
http://www.globcolour.info/

"Data tools"

DDS tools	The DDS Tools support the validation of the data products generated in GlobColour. The current set of tools are developed as plug-ins for BEAM 3.6.
Export Pin-Pixels	This plug-in allows to export the pixel data of a rectangular region around all or the selected pin
BEAM	BEAM is the Basic ERS & Envisat (A)ATSR and MERIS Toolbox and is a collection of executable tools and an application programming interface (API) which have been developed to facilitate the use, viewing and processing of data of various sensors. BEAM is used for the validation of the GlobColour data in conjunction with the DDS Tools

Table 4.1: Available tools

5 How-to ?

5.1 Access the GlobColour data

Load the following link to any browser and click on "Data Access"

http://www.globcolour.info/

5.2 Download the data from the GlobColour ftp server

The GlobColour project maintains a ftp site from where the products can be downloaded. Read the information provided by the GlobColour web site ("Data Access" section) to get the latest news about this service.

The current ftp access is

```
ftp server: ftp://ftp.fr-acri.com
login: globcolour_data
password: fgh678
```

The distribution structure of the FPS data is:

```
/parameter type (CHL1, L412, EL555, CF...)
     /MERGED
          /merging mode (SIMPLE | WEIGHTED | GMS)
               /year (1997-2006)
                    /binning period (DAILY, 8DAYS, MONTHLY)
                         /products (L3b*, L3m*)
```

Note that the low resolution products (0.25° and 1°) as well as the associated quicklooks are stored in the same directory as their parent products.

The distribution structure of the DDS data is similar:

For L3 DDS 1 or 4 km created from the level 2 products:

```
/region of interest (DDS acronyms)
     /INPUT
          /instrument (MERIS, MODIS, SEAWIFS)
               /year (1997-2006)
                    /TRACK
                         /products (L3m*)
```

For L3 DDS 4 km extracted from L3 binned products:

```
/region of interest (DDS acronyms)
     /MERGED
          /merging mode (SIMPLE | WEIGHTED | GMS)
               /year (1997-2006)
                    /binning period (DAILY, 8DAYS, MONTHLY)
                         /products (L3b*)
```

A convenient way to download the products is to use the Unix wget command. This command is also available in the cygwin package for Windows systems. wget is particularly efficient to download specific files from scattered sub-directories. It can be used also to check for new products - mirroring (already downloaded files are not transferred, updated products on the server are transferred).

Here is an example for downloading all the MERIS CDM binned products. You can adapt this command to your specific needs. The specification of the GlobColour products filenames is useful to use the correct wildcarding included in the wget commands.

```
wget -r -l10 -t10 -A "L3b*_4_*MER_CDM*.gz" -w3 -Q1000m \
      ftp://globcolour_data:fgh678@ftp.fr-acri.com/FPS/CDM ./
```

Another example to download all the CHL1 monthly quicklooks at 25 km resolution.

```
wget -r -l10 -t10 -A "L3m*_25_*CHL1_MO*.gz" -w3 -Q1000m \
      ftp://globcolour_data:fgh678@ftp.fr-acri.com/FPS/CHL1 ./
```

The products will be stored in a local directory called ftp.fr-acri.com using the same structure as on the ftp server. All options of the wget command are described here.

`-w3` is specified to pause the process 3s after each download to decrease our server load by making the requests less frequent. Please keep it to share the bandwidth with other users.

`-Q1000m` limits the amount of data you can retrieve in one command (1 Gb). Please, keep this option too.

5.3 Read the data

Specific browser and utilities are available on the GlobColour web site (see dedicated chapter "The available tools")). However, the products may be also read using the netCDF library or any third-party tool reading netCDF files. The format of the data is provided in a dedicated chapter ("The Products format").

5.4 Plot the data

The GlobColour binned products are provided on a ISIN grid that cannot be displayed immediately. A resampling of the data on any regular grid must be performed prior to any plot command.

The BEAM tool available on the GlobColour web site performs automatically a resampling of the original data on a Plate-Carré grid before plotting it.

5.5 How to plot GlobColour data using Google Earth™ ?

First of all, you need to have Google Earth installed on your system. Next, you need to have downloaded one GlobColour quicklook (better ones are available at a resolution of 0.25°).

There are two easy ways to ingest GlobColour quicklook data in Google Earth.

The first one is to use the Add / Image Overlay function. In the "Link" field, write the name of the QL (or use the "Browse..." utility). In the "Title" field, write any title you want (this title is used to identify your image in the menus). In the "Location" panel, gives the lon-lat range of the image (i.e. -180° to +180° in longitude and -90 to +90° in latitude). Transparency can be adjusted using the transparency slide.

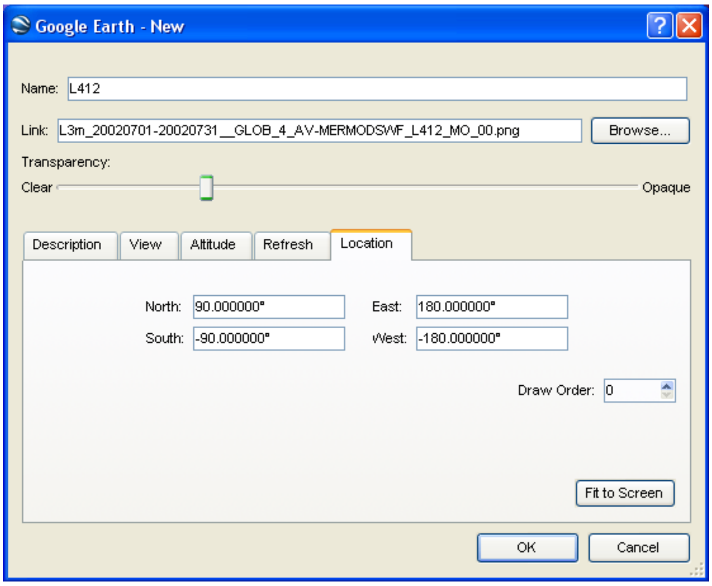

Figure 5.1: Google Earth image overlay menu

Click on OK to finish. All Google Earth functions can be used (zoom, rotations...).

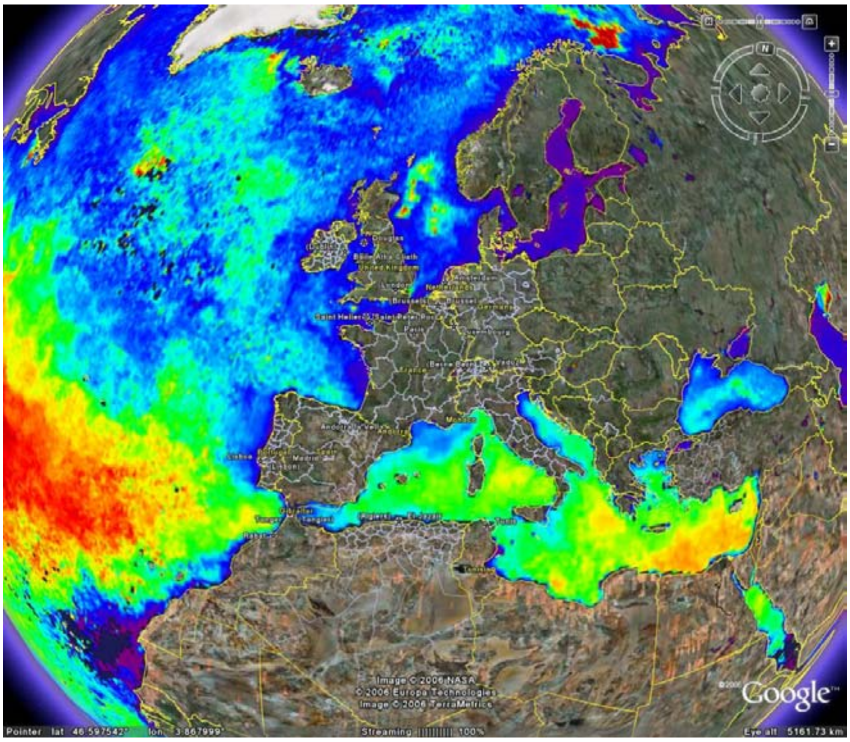

Figure 5.2: GlobColour image displayed in Google Earth (manual)

The second way is to write a Google Earth script file (KML file). Here is an example of such file.

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.0">
<Folder>
<LookAt>
  <longitude>-30</longitude>
  <latitude>10</latitude>
  <range>1.e+7</range>
  <tilt>0</tilt>
  <heading>0</heading>
</LookAt>
<GroundOverlay>
  <description>GlobColour - CHL1 - Monthly average 10/2002</description>
  <name>Global</name>
  <visibility>1</visibility>
  <color>ffffffff</color>
  <TimeSpan>
    <begin>2002-10-01T00:00:00Z</begin>
    <end>2002-10-31T23:59:59Z</end>
  </TimeSpan>
  <drawOrder>1</drawOrder>
  <Icon>
    <href>L3m_20020701-20020731__GLOB_4_AVW-MERMODSWF_CHL1_MO_00.png</href>
  </Icon>
  <LatLonBox>
    <west>-180</west> <east>180</east>
    <south>-90</south> <north>90</north>
    <rotation>0</rotation>
  </LatLonBox>
</GroundOverlay>
</Folder>
</kml>
```

You can load the kml file in Google Earth using the File / Open function... to obtain the following figure.

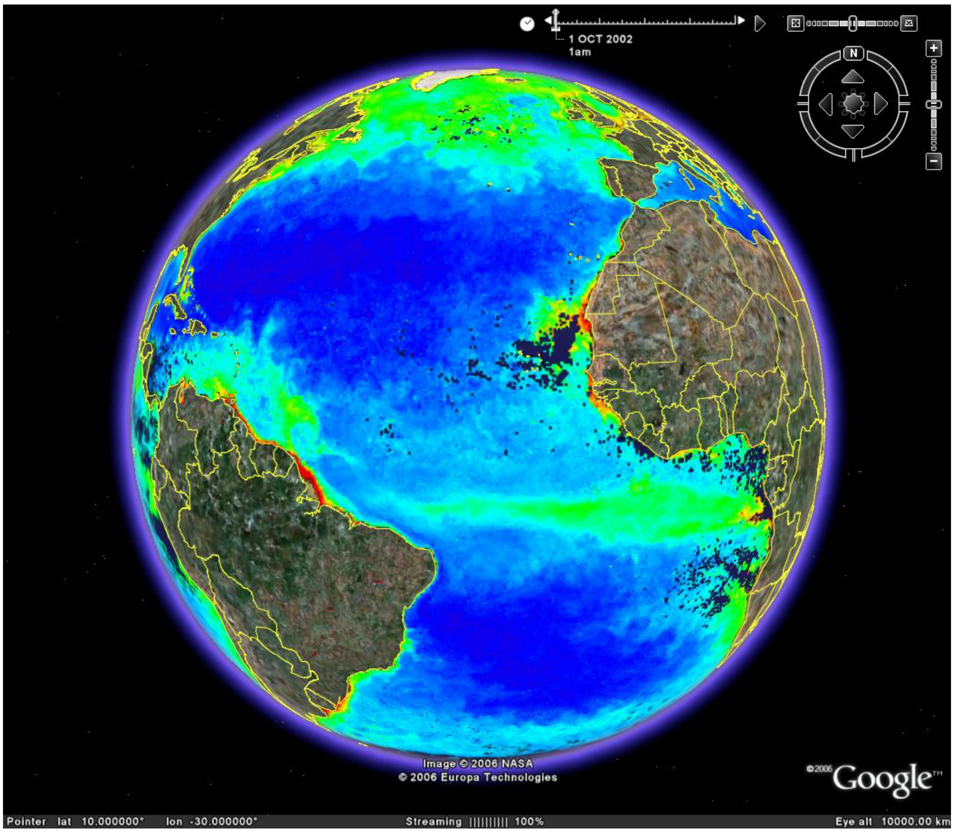

Figure 5.3: GlobColour image displayed in Google Earth (kml file)

KML tags are fully detailed in http://earth.google.com/kml/kml_tags.html.

6 Appendices

6.1 List of DDS sites

DDS areas are defined by a reference point and a half-window size. The DDS areas are centred around the reference point. The half-window size is fixed to 50 km.

In PC grid, at 1 km resolution, the reference point is located in the middle of the 51-th cell in both X (longitude) and Y (latitude) directions.

The following table shows the default GlobColour list of DDS.

Site-ID	Site-Name	Location	Latitude	Longitude
1	MOBY	Hawaii	20.8	-157.2
2	BOUSSOLE	Ligurian Sea	43.37	7.9
3	VeniceTower	Adriatic Sea	45.31	12.51
4	BATS	Sargasso S.	32	-64.5
5	CARIACO	Carib.Sea	11	-65
6	CALCOFI	California	35	-125
7	GulfOfMaine	USA-Canada	43	-69
8	LEO15	New Jersey	39	-74
9	Benguela	South Africa	-32.5	17.4
10	Helgoland	North Sea	54	7.5
11	Channel	English Ch.	50	-3
12	Sopot	Baltic Sea	55.2	19
13	Palmer	Antarctic	-65	-65
14	RapaNui	S. Pacific	-23	-118
15	Concepcion	Chile	-36.5	-73
16	TaiwanStr	China	22.5	118
17	YellowSea	China	35	122
18	AbuAlBukhoos	Persian (Arabian) Gulf	25.5	53.15
19	GustavDalenTower	Baltic Sea	58.59	17.47
20	HelsinkiLighthouse	Gulf of Finland	59.95	24.93
21	MVCO	Cape Cod (or the Vineyard)	41.3	-70.55
22	COVE	Chesapeake Lighthouse-Virginia	36.9	-75.71
23	NIVAFerryBox	Skagerrak	58.5 (1)	10.5 (1)
24	Azores	N. Atlantic	38.53	-28.63
25	CapeVerde	N. Atlantic	16.73	-22.94
26	*Reserved*	…	…	…
27	Barbados	N. Atlantic	13.17	-59.5
28	Tahiti	S. Pacific	-17.57	-149.61
29	Nauru	Eq Pacific	-0.52	166.92
30	Okinawa	N. Pacific	26.35	127.77
31	MidwayIsland	N. Pacific	28.21	-177.38
32	DongshaIsland	S. China Sea	20.71	116.72
33	Goa	Arabian Sea	15.45	73.81
34	AmsterdamIsland	S. Indian	-37.81	77.57

Table 6.1: List of the DDS sites

(1): The site **NIVAFerryBox** use the format: "Site-ID Site-Name Location Lat.C Lat.A Lat.B Lon.C Lon.A Lon.B" with:

- **C** corresponds to the reference location of the DDS
- **A** corresponds to the top left corner of the DDS
- **B** corresponds to the bottom right corner of the DDS

23	NIVAFerryBox	Skagerrak	**58.5**	**60**	**57**	**10.5**	**10**	**11**

6.2 Global ISIN grid definition

The following formulas shall clarify the ISIN grid definition.

Earth radius (km)	$R_e = 6378.145$
Total number of latitude rows	$N_{lat} = 4320$ (*)
Latitudinal bin width (km)	$d_r = \frac{\pi \cdot R_e}{N_{lat}}$
Latitudinal angular discretisation (radians)	$\Delta\phi = \frac{\pi}{N_{lat}}$
Centre latitude of each row n (radians)	$\phi_n = -\frac{\pi}{2} + n \cdot \Delta\phi + \frac{\Delta\phi}{2}$ (**)
Longitudinal length of each row n i.e. local perimeter (km)	$p_n = 2 \cdot \pi \cdot R_e \cdot \cos(\phi_n)$
Number of columns in row n	$N_{lon}(n) = \text{nearest}\left(\frac{2 \cdot \pi \cdot p_n}{d_r}\right)$
Effective longitudinal bin width for row n (km)	$d_e^{lon}(n) = \frac{2 \cdot \pi \cdot p_n}{N_{lon}(n)}$
Effective longitudinal angular discretisation for row n (radians)	$\Delta\varphi_n = \frac{2 \cdot \pi}{N_{lon}(n)}$
Total number of bins in the grid	$N_{tot} = \sum_{n=0}^{N_{lat}-1} N_{lon}(n)$

Table 6.2: Global ISIN grid definition

(*) we fix here the number of latitude rows to set the bin size to 1/24° (i.e. a latitudinal dimension close to 4.63 km).

(**) index n varies from 0 to N_{lat}-1

6.3 Summary of products content

The next table lists all products generated in the frame of GlobColour and their content (only the variable fields, not the metadata).

- θ_n : set of observation geometrical conditions (e.g. solar and viewing zenith angles, solar and viewing azimuth angles, wind speed, sea-level pressure).
- error: error estimate. This can be a theoretical computation using external LUT, variable value and observation conditions or the output of the merging model.
- count(n): is the number of binned pixels that contribute to the computation of mean and stdev

The green cells identify the variables stored in the products.

<table>
<tr><th></th><th></th><th></th><th>mean</th><th>stdev</th><th>θ_n</th><th>error</th><th>weight</th><th>count</th><th>flags</th></tr>
<tr><td>**DDS**</td><td>**1 km**</td><td>**PC**</td><td>(8)</td><td>(1)</td><td>x</td><td rowspan="3">(2)</td><td></td><td></td><td>x</td></tr>
<tr><td>**DDS**</td><td>**4.63 km**</td><td>**ISIN**</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>**Global track/daily**</td><td>**4.63 km**</td><td>**ISIN**</td><td>x</td><td>x</td><td rowspan="5"></td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>**Global merged**</td><td>**4.63 km**</td><td>**ISIN**</td><td>x</td><td rowspan="4">(3)</td><td>(4)</td><td rowspan="4"></td><td rowspan="4">(5)</td><td>x</td></tr>
<tr><td>**Global 8days/monthly**</td><td>**4.63 km**</td><td>**ISIN**</td><td>x</td><td>(6)</td><td>x</td></tr>
<tr><td>**Global low resolution**</td><td>**0.25°/1°**</td><td>**PC**</td><td>x</td><td>(4)</td><td>x</td></tr>
<tr><td>**DDS**</td><td>**4.63 km**</td><td>**ISIN**</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>**Global quicklook**</td><td>**0.25°**</td><td>**PC**</td><td colspan="7">(7)</td></tr>
</table>

Table 6.3: Summary of products content

(1): stdev is not computed in the nearest neighbour interpolation process

(2): before merging step, error is not provided pixel-wise, but the global relative error (%) coming from the characterisation is saved in metadata

(3): stdev is not defined at the output of the merging module. Only error is estimated.

(4): error is the output of the weighted average or GSM merging models. Only products merged using these methods contain the error pixel-wise field; other products does not contain this field.

(5): for merged daily, 8-days and monthly products, count is not the number of L2 binned pixels, but the number of days contributing to the bin. So for merged daily products, it is always set to 1.

(6): for the moment there is no associated error bar in the 8-days and monthly L3 products.

(7): quicklook product does not contain any geophysical variable

(8): for DDS PC 1km, the variable is named value instead of mean because this is the direct L2 value.

6.4 The main characteristics of the products

The following lists summarises the main characteristics of the different products generated in the frame of the GlobColour project. Note that not all these products are available to external users (internal products are written in dark blue).

Level 3 DDS at 1 km (DDS-PC):

- computed from the level 2 products
- single instrument product
- one product per DDS site
- all variables are stored in the same file
- nearest neighbour interpolation, one single pixel per bin
- use a specific flag REPLICA to identify bins that contain no input L2 pixel centre
- no stdev, weight and count fields
- observation geometry is taken from the nearest neighbour pixel
- the global relative error (%) coming from the characterisation is stored in the variable attribute pct_characterised_error
- the whole grid is written in the output product

Level 3 DDS at 4.63 km (DDS-ISIN):

- computed from the level 2 products
- single instrument product
- one product per DDS site
- all variables are stored in the same file
- binning flux-conserving algorithm
- each parameter defining the observation geometry is also computed with a flux-conserving algorithm
- the global relative error (%) coming from the characterisation is stored in the variable attribute pct_characterised_error
- mean and stdev are computed from the input pixel values
- weight is the sum of each binned pixel area (only the pixel area intersecting the bin)
- count is the number of binned pixels
- the whole local ISIN grid is written in the output product

Level 3 track global at 4.63 km (ISIN grid):

- same as for the level 3 DDS at 4.63 km (DDS-ISIN grid), except:
- global product
- one variable per file
- no observation geometry
- only valid bins are written in the product

Level 3 daily global at 4.63 km (ISIN grid):

- computed from the level 3 track global products
- same as for the level 3 track global at 4.63 km (ISIN grid), single instrument product, except:
- temporal binning algorithm using GlobColour data-day definition
- weight is the sum of weight at track level

Level 3 DDS daily single-instrument at 4.63 km (DDS-ISIN grid):

- extracted from the level 3 daily global products
- one product per DDS site
- all fields are copied with no modification
- the whole local ISIN grid is written in the output product

Level 3 merged global at 4.63 km (ISIN grid):

- computed from the level 3 daily global products using one merging method
- multi-instruments product
- same format as for the level 3 daily global products, except:
- no weight and stdev fields
- the "mean" field is an output of the merging model
- only the weighted average and GSM model merging method provides the pixel-wise error (stored in the "error" field)
- parameters with no characterised error are not merged using the weighted average method
- the global relative error (%) is stored in the variable attribute pct_characterised_error. It is actually set to the maximum of the global relative characterised errors for each input sensor.
- for merged daily, 8-days and monthly products, count is not the number of L2 binned pixels, but the number of days contributing to the bin. At this step it is always set to 1.

Level 3 8-days/monthly global at 4.63 km (ISIN grid):

- computed from the level 3 merged daily products
- temporal binning algorithm applied

Level 3 DDS at 4.63 km (DDS-ISIN grid):

- same processing chain as for the global products, except that only the bins covered by the DDS areas are taken into account.
- one product per DDS site (all parameters are included in one single file)
- the whole local ISIN grid is written in the output product

Level 3 daily/8-days/monthly merged global low resolution at 0.25°/1° (PC grid):

- computed from the corresponding level 3 merged products
- mean and error are computed from the parent products fields using of a flux-conserving algorithm to reproject the 4.63 km bins onto the 0.25°/1° PC grid
- the whole grid is written in the output product

Level 3 daily/8-days/monthly merged global quicklook at 0.25° (PC grid):

- computed from the corresponding level 3 merged low resolution 0.25° PC products
- PNG RGB lossless format
- the quicklook image is computed using the mean field of the low resolution product

6.5 The steps of the binning and merging schemes

The list of steps for the generation of the whole set of GlobColour products is:

- step 1: L2 to L3 at 1 km (DDS-PC)
- step 2: L2 to L3 at 4.63 km (DDS-ISIN)
- step 3: L2 to L3 track at 4.63 km (global-ISIN)
- step 4: L3 track at 4.63 km to L3 daily for each single instrument (global-ISIN)
- step 5: L3 daily for each single instrument to merged L3 daily (global-ISIN)
- step 6: L3 daily merged to 8days and monthly L3 products (global-ISIN)
- step 7: L3 at 4.63 km at track level to daily/8days/monthly merged products (DDS-ISIN)
- step 8: L3 daily/8days/monthly merged products to 0.25° and 1.0° resolution products (global-PC)
- step 9: generation of the quicklooks (global-PNG)

The information between parenthesis gives the spatial coverage and the sampling grid.

We describe here below the way to accumulate information for each of these steps and the corresponding means to account for error bars, taking into account the way the information is stored at the end of each step.

It is assumed here that the quality of the data is characterised, so that we know the standard deviation of a single measurement (through DDS analysis or available characterisation). The error bars are provided in appendix.

6.5.1 Step 1: L2 to L3 at 1 km (DDS-PC)

A simple nearest neighbour algorithm is used to fill the DDS 1km PC grid with the L2 pixels. Output bins covered by L2 input pixels but which do not contain any L2 pixels centre are flagged with the REPLICA flag.

6.5.2 Step 2: L2 to L3 at 4.63 km (DDS-ISIN)

The L3 grid (either sinusoidal or geographical regular) is not aligned with the satellite swath, so the first action is to determine the fraction of each L3 bin impacted by the projection of L2 pixel. Let $F_{i,j}$ be the fraction of bin L3 number j impacted by the pixel L2 number i.

The final output of the binning of the L2 pixels on the L3 grid is given by:

$$T_j = \frac{\sum_{N_j} \left(F_{i,j} \cdot P_i\right)}{\sum_{N_j} F_{i,j}}$$

in which N_j is the number of L2 pixels that effectively impact the L3 bin number j; P_i is the value of the parameter at pixel i, T_j is the value of the parameter for the bin number j.

The standard deviation of T_j is given by:

$$\sigma(T_j) = \sqrt{\frac{\sum_{N_j}(F_{i,j} \cdot P_i^2)}{\sum_{N_j} F_{i,j}} - T_j^2}$$

The weight of Tj is given by:

$$W_j = \sum_{N_j} F_{i,j}$$

The quantities stored in the L3 products at track level are:

T_j, $\sigma(T_j)$, W_j and N_j

6.5.3 Step 3: L2 to L3 track at 4.63 km (global-ISIN)

This step is the same than the previous Step 2 but on a global grid instead of on the local DDS ROI.

6.5.4 Step 4: L3 track at 4 km to L3 daily for each single instrument (global-ISIN)

The output D_j of the temporal accumulation of the L3 at track level for the L3 daily product generation is computed as:

$$D_j = \frac{\sum_{M_j}\left[\sum_{N_j}(F_{i,j} \cdot P_i)\right]}{\sum_{M_j}\left[\sum_{N_j}(F_{i,j})\right]}$$

in which M_j is the effective number of L3 at track level bins used for the temporal accumulation for the bin number j.

As we must be able to compute these quantities using the values written in the L3 products at track level, we have to express them as:

$$D_j = \frac{\sum_{M_j}[T \cdot W_j]}{\sum_{M_j}[W_j]}$$

The daily standard deviation is expressed from the quadratic sum of the L3 bin variances at track level:

$$\sigma(D_j) = \sqrt{\frac{\sum_{M_j}(\sigma^2(T_j))}{M_j}}$$

The total daily weighting factor is given by:

$$\overline{W_j} = \sum_{M_j} \left[W_j \right]$$

The total daily number of L2 pixels that effectively impact the L3 bin is given by:

$$\overline{N_j} = \sum_{M_j} \left[N_j \right]$$

The quantities stored in the daily L3 products are:

D_j, $\sigma(D_j)$, $\overline{W_j}$ and $\overline{N_j}$

6.5.5 Step 5: L3 daily for each single instrument to merged L3 daily (global-ISIN)

At this stage, we use only single instrument daily bins which have a weight greater than 10%, and discard the others.

Let's introduced $\tilde{N}_j$, which is the effective number of valid instruments for the L3 bin (could be for example 2 if only MERIS and MODIS dailies cover at least 10% of the L3 bin), and $\tilde{N}_d$, which is the number of days in the temporal binning period. For the merging step, $\tilde{N}_d$ is always set to 1 because we merge one day.

Simple average:

$$\tilde{D}_{j-SIMPLE} = \frac{\sum_{\tilde{N}_j} D_j}{\tilde{N}_j}$$

The quantities stored in the daily merged L3 products when using simple averaging are:

$\tilde{D}_{j-SIMPLE}$ and $\tilde{N}_d$

Weighted average:

Here we compute the relative error for each sensor $\varepsilon(D_j)$ by applying the error bars (%) of each sensor on the result of the simple averaging $\tilde{D}_{j-SIMPLE}$:

$$\varepsilon(D_j) = \frac{ErrorBar \cdot \tilde{D}_{j-SIMPLE}}{100}$$

Then, the weighted mean is given by:

$$\tilde{D}_{j-WEIGHTED} = \frac{\sum_{\tilde{N}_j} \frac{D_j}{\varepsilon(D_j)^2}}{\sum_{\tilde{N}_j} \frac{1}{\varepsilon(D_j)^2}}$$

The corresponding error bar is given by:

$$\varepsilon(\tilde{D}_{j-WEIGHTED}) = \sqrt{\frac{1}{\sum_{\tilde{N}_j} \frac{1}{\varepsilon(D_j)^2}}}$$

This error is translated into relative error in 0.01% to be saved in the product:

$$\Delta\left(\tilde{D}_{j-WEIGHTED}\right) = 10000 \cdot \frac{\varepsilon\left(\tilde{D}_{j-WEIGHTED}\right)}{\tilde{D}_{j-WEIGHTED}}$$

The quantities stored in the daily merged L3 products when using weight averaging are:

$$\tilde{D}_{j-WEIGHTED},\ \Delta\left(\tilde{D}_{j-WEIGHTED}\right) \text{ and } \tilde{N}_d$$

<u>GSM method</u>

Inputs of the GSM minimisation process are the fully normalised water leaving radiances Lxxx (D_j individually computed for each band) and their associated error bars. The outputs of the GSM model are: CHL1, CDM and BBP and their associated error bars.

The GSM output error bars are translated into relative error in 0.01% using the same equation than for the weighted average method.

The quantities stored in the daily merged L3 products when using the GSM method are:

$$\tilde{D}_{j-GSM},\ \Delta\left(\tilde{D}_{j-GSM}\right) \text{ and } \tilde{N}_d$$

6.5.6 Step 6: L3 daily merged to 8-days and monthly L3 products (global-ISIN)

Let's introduced $\hat{N}_d$, which is the number of effective valid daily bins during the binning period.

The 8-days or monthly parameter is computed as the arithmetic mean of the daily merged data.

$$\hat{D}_j = \frac{\sum_{\hat{N}_d} \tilde{D}_j}{\hat{N}_d}$$

For the moment there is no associated error bar in the 8-days and monthly L3 products (and then the error netCDF variable is not present in the products).

The quantities stored in the daily L3 products are:

$$\hat{D}_j \text{ and } \hat{N}_d$$

6.5.7 Step 7: L3 at 4.63 km at track level to daily/8days/monthly merged products (DDS-ISIN)

Same processing chain as for the global level 3 products, except that only the bins covered by the DDS area are computed and written in the products.

6.5.8 Step 8: L3 daily/8days/monthly merged products to 0.25° and 1.0° resolution products (global-PC)

Re-projection of the corresponding L3 ISIN product on the PC grid using a flux-conserving algorithm.

Let $\breve{F}_{i,j}$ be the fraction of the L3 PC bin number j impacted by the L3 ISIN bin number i.

The final output of the binning of the L3 ISIN bins on the low resolution PC grid is given by:

$$\breve{D}_j = \frac{\sum_{\breve{N}_j} \left(\breve{F}_{i,j} \cdot \ddot{D}_i \right)}{\sum_{\breve{N}_j} \breve{F}_{i,j}}$$

in which $\breve{N}_j$ is the number of L3 ISIN bins that effectively impact the L3 low resolution PC bin number j; $\ddot{D}_i$ is the value of the parameter at ISIN bin i, $\breve{D}_j$ is the value of the parameter for the PC bin number j.

When the input ISIN product contains an error bar variable, the corresponding error bar in the low resolution PC product is given by:

$$\varepsilon(\breve{D}_j) = \sqrt{\frac{\sum_{\breve{N}_j} \breve{F}_{i,j}{}^2 \cdot \varepsilon(\ddot{D}_i)^2}{\sum_{\breve{N}_j} \breve{F}_{i,j}{}^2}}$$

in which $\varepsilon(\ddot{D}_i)$ is the absolute error bar of the ISIN bin i recomputed using the relative error bar $\Delta(\ddot{D}_i)$ of the ISIN L3 product:

$$\varepsilon(\ddot{D}_j) = \frac{\Delta(\ddot{D}_i) \cdot \ddot{D}_i}{10000}$$

The quantities stored in the daily L3 products are:

$\breve{D}_j$ and when available $\varepsilon(\breve{D}_j)$

6.5.9 Step 9: generation of the quicklooks (global-PNG)

No special processing, the mean field of the 0.25° low resolution product is used to create the image.

6.6 The error bars

The next table presents the standard deviation of a single measurement. This information is used by the merging and temporal binning module in weighted average and GSM model cases.

	MERIS from GlobColour	**MODIS-A** from GlobColour	**SeaWiFS** from GlobColour
L412	31.74	22.19	19.91
L442	19.55	n/a	n/a
L443	n/a	15.58	14.68
L488	n/a	10.73	n/a
L490	14.83	n/a	12.62
L510	17.09	n/a	12.19
L531	n/a	16.6	n/a
L551	n/a	9.44	n/a
L555	n/a	n/a	15.13
L560	16.73	n/a	n/a
L620	53.43 ? ❖	n/a	n/a
L665	31.61	n/a	n/a
L667	n/a	30.06	n/a
L670	n/a	n/a	32.44
L681	333.74	n/a	n/a
Chl1	53.04	44.08	35.77
Chl2	71.3	n/a	n/a
K_d(490)	15.23	11.53	16.27
CDM	66.79 ? ❖	n/a	n/a
T865	61.53	68.1	57.66

Table 6.4: Characterised error bars

Error bars are expressed in %

❖: insufficient data points

n/a: the parameter is not available for the instrument

6.7 The GlobColour color-bars

The colorbars used for the GlobColour quicklooks are:

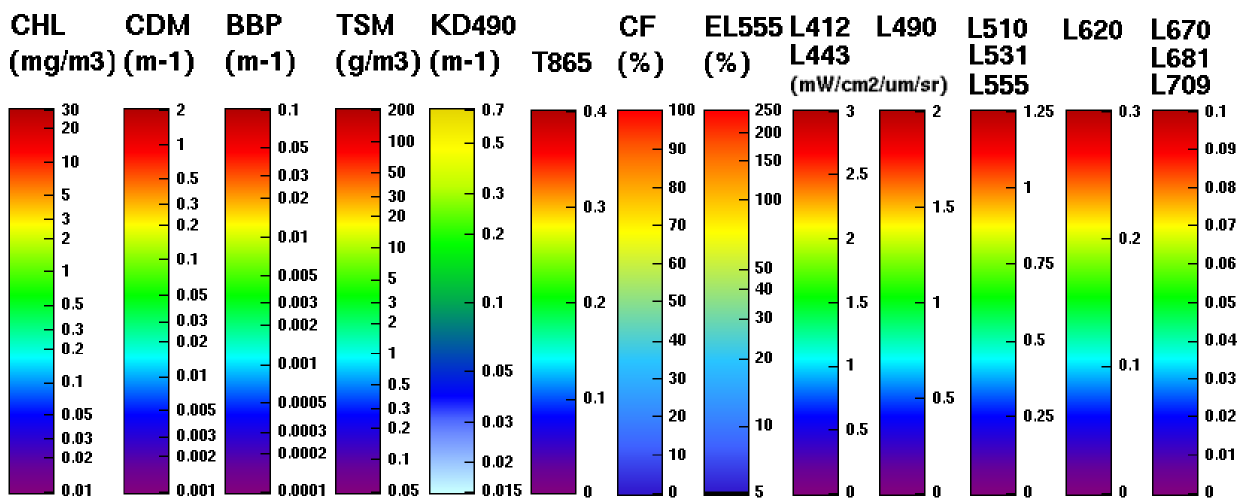

Figure 6.1: The GlobColour color bars

6.8 CDL

CDL representation of a global binned level-3 product (example for a daily global MERIS single-instrument level 3 product).

```
netcdf L3b_20020702_010017-532_GLOB_4_MER_CHL1_TR_20020701 {
dimensions:
    bin = 19 ;
    row = 39 ;
variables:
    short row(bin) ;
        row:long_name = "Lat. band index of the bins stored in the product, zero
                based and beginning at south" ;
    short col(bin) ;
        col:long_name = "Long. index of the bins stored in the product, zero
                based and beginning at west" ;
    float center_lat(row) ;
        center_lat:long_name = "Center latitude for each useful row" ;
        center_lat:units = "degrees_north" ;
    float center_lon(row) ;
        center_lon:long_name = "Center longitude of the first left bin (the first
                bin in the global ISIN grid, not the first valid bin) for each
                useful row" ;
        center_lon:units = "degrees_east" ;
    float lon_step(row) ;
        lon_step:long_name = "Longitude step for each useful row" ;
        lon_step:units = "degrees" ;
    float CHL1_mean(bin) ;
        CHL1_mean:long_name = "Chlorophyll-a concentration. Case 1 water - Mean
                of the binned pixels" ;
        CHL1_mean:_FillValue = -999.f ;
        CHL1_mean:units = "mg/m3" ;
        CHL1_mean:pct_characterised_error = 31.f ;
    float CHL1_stdev(bin) ;
        CHL1_stdev:long_name = "Chlorophyll-a concentration. Case 1 water -
                Standard deviation of the binned pixels" ;
        CHL1_stdev:_FillValue = -999.f ;
    short CHL1_count(bin) ;
        CHL1_count:long_name = "Chlorophyll-a concentration. Case 1 water -
                Total number of binned pixels" ;
        CHL1_count:_FillValue = -32768s ;
    float CHL1_weight(bin) ;
        CHL1_weight:long_name = "Chlorophyll-a concentration. Case 1 water -
                Sum of the weights of the binned pixels" ;
        CHL1_weight:_FillValue = -999.f ;
    short CHL1_flags(bin) ;
        CHL1_flags:long_name = "Chlorophyll-a concentration. Case 1 water - Flags" ;
        CHL1_flags:_FillValue = 0s ;

// global attributes:
        :Conventions = "CF-1.0" ;
        :title = "GlobColour Level-3 Binned Data" ;
        :product_name = "L3b_20020702_010017-532_GLOB_4_MER_CHL1_TR_20020701.nc" ;
        :product_type = "track" ;
        :product_version = "0.9h" ;
        :product_level = 3s ;
        :parameter_code = "CHL1" ;
        :parameter = "Chlorophyll-a concentration. Case 1 water" ;
```

```
        :site_name = "GLOB" ;
        :sensor_name = "MERIS" ;
        :sensor = "MEdium Resolution Imaging Spectrometer Instrument" ;
        :sensor_name_list = "MER" ;
        :start_time = "20020702010017" ;
        :end_time = "20020702010908" ;
        :duration_time = 532 ;
        :period_start_day = "20020701" ;
        :period_end_day = "20020701" ;
        :grid_type = "Integerized Sinusoidal Grid" ;
        :spatial_resolution = 4.638312f ;
        :nb_equ_bins = 8640 ;
        :registration = 5 ;
        :straddle = 0 ;
        :first_row = 3971 ;
        :lat_step = 0.04166667f ;
        :earth_radius = 6378.137 ;
        :max_north_grid = 90.f ;
        :max_south_grid = -90.f ;
        :max_west_grid = -180.f ;
        :max_east_grid = 180.f ;
        :northernmost_latitude = 77.08334f ;
        :southernmost_latitude = 75.45834f ;
        :westernmost_longitude = -111.6434f ;
        :easternmost_longitude = -94.74664f ;
        :nb_grid_bins = 23761676 ;
        :nb_bins = 19 ;
        :software_name = "globcolour_l2_spatial_binning" ;
        :software_version = "0.9h" ;
        :institution = "ACRI" ;
        :processing_time = "20061013160522" ;
        :netcdf_version = "3.5.1 of Mar 15 2005 16:28:41 $" ;
        :DPM_reference = "GC-UD-ACRI-PUG" ;
        :IODD_reference = "GC-UD-ACRI-PUG" ;
        :references = "http://www.globcolour.info" ;
        :contact = "service@globcolour.info" ;
        :input_files = "MER_RR__2PQACR20020702_010017_000026402007_00203_01760_0000.N1";
}
```

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