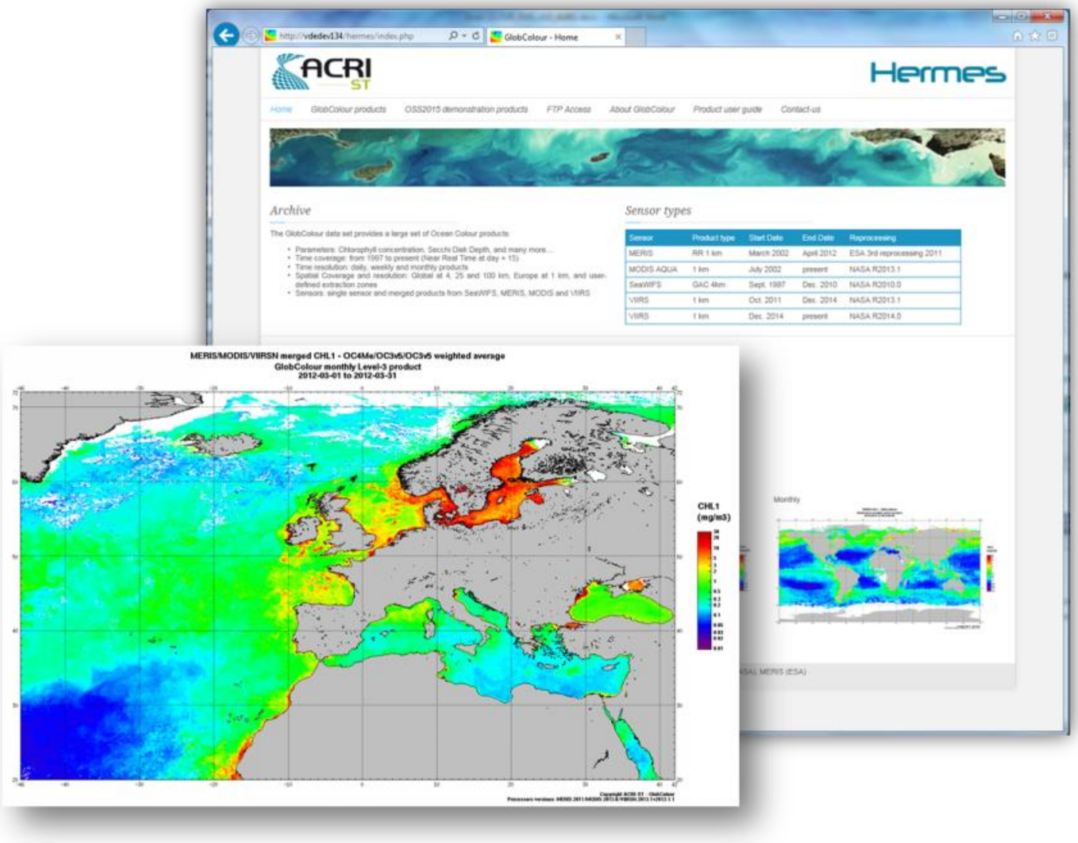
GLOBCOLOUR



Product User’s Guide

Reference: GC-UM-ACR-PUG-01

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Document Signature Table

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Author	ACRI-ST GlobColour Team		ACRI-ST		
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Change record

Issue	Date	Change Log
1.0	17/11/2006	Product User Guide
1.1	22/12/2006	Updated pages
1.2	08/10/2007	Updated pages
1.3	30/01/2009	Updated pages
2.0	08/01/2010	New parameters have been added (to be compliant with MKL3 outputs)
3.0 draft	27/10/2014	GlobColour 2nd reprocessing (draft version)
3.0	05/12/2014	GlobColour 2nd reprocessing
3.1	13/02/2015	Corrected ftp address
3.2	19/10/2015	Update VIIRS to R2014.0 (including new error bars)
4.0	19/11/2015 10/06/2016 14/11/2016 02/03/2017	Update production delivery time Update SeaWiFS to R2014.0 (including new error bars) Update MODIS to R2014.0 Add CHL-OC5, SPM-OC5 and KDPAR-SAULQUIN
4.1	31/08/2017	Add OLCI sensor

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1 Introduction

1.1 Background

The GlobColour project started in 2005 as an ESA Data User Element (DUE) project to provide a continuous data set of merged L3 Ocean Colour products. Merging outputs from different sensors ensures data continuity, improves spatial and temporal coverage and reduces data noise. This allows in particular to process long time series of consistent products (trend analysis, climatology, data assimilation for model hindcast).

Since then, ACRI has maintained the archive and Near Real Time data access services through the Hermes website.

The 2014 reprocessing and the update of the Hermes interface were performed in the framework of the OSS2015 project, with funding from the EU FP7 under grant n°282723.

The GlobColour project has received additional funding from European Union FP7 under grant agreement n° 218812 (MyOcean) and from PACA Region under project RegiColour.

From May 2015, the GlobColour project also contributes to the Copernicus Marine Environment Monitoring Service (CMEMS). A subset of the GlobColour products is disseminated by CMEMS. It concerns at present Chlorophyll, reflectances, Secchi depth, SPM, BBP, KD490 merged products (Near Real Time and the long time series).

In addition, support from NASA regarding access to L2 products is acknowledged.

The GlobColour primary data set has now been delivered as a Group on Earth Observations System of Systems (GEOSS) core data set under reference:

urn:geoss:csr:resource:urn:uuid:4e33fd81-d5cc-dc40-b645-ab961447d9d8.

1.2 Scope of the document

This User Guide contains a description of:

- the products content
  - *the parameters*
  - *the spatial and temporal coverage*
  - *the processing system*
- the products format
- Hermes interface user's guide
- Appendices containing additional information on products and processing

1.3 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
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
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
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
(N)RRSXXX	Fully normalised remote sensing reflectances at xxx nm (sr-1)
NRT	Near-real time
OLCI	Ocean Land Colour Instrument

PAR	Photosynthetic Available Radiation
PC	Plate-Carré projection
PNG	Portable Network Graphics
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

1.4 Brief overview of GlobColour products

1.4.1 Parameters

The parameters of the GlobColour data set are:

- Biological parameters: Chlorophyll (several algorithms), Particulate Organic/Inorganic Carbon, Fluorescence…
- Atmosphere optical parameters: aerosol thickness, cloud fraction, water vapour column…
- Ocean-surface optical parameters: reflectances
- Sub-surface optical parameters: attenuation and back-scattering coefficients, turbidity

The full list of parameters is provided in section 2.1.

For some parameters, several alternative algorithms are proposed. This is the case when no algorithm is clearly superior to the other(s). The relative performance may vary depending on the conditions (water types, regions, sensors…), and users are advised to compare the results on a case-by-case basis.

1.4.2 Spatial Domain

Two spatial domains are covered:

- the global Earth domain:

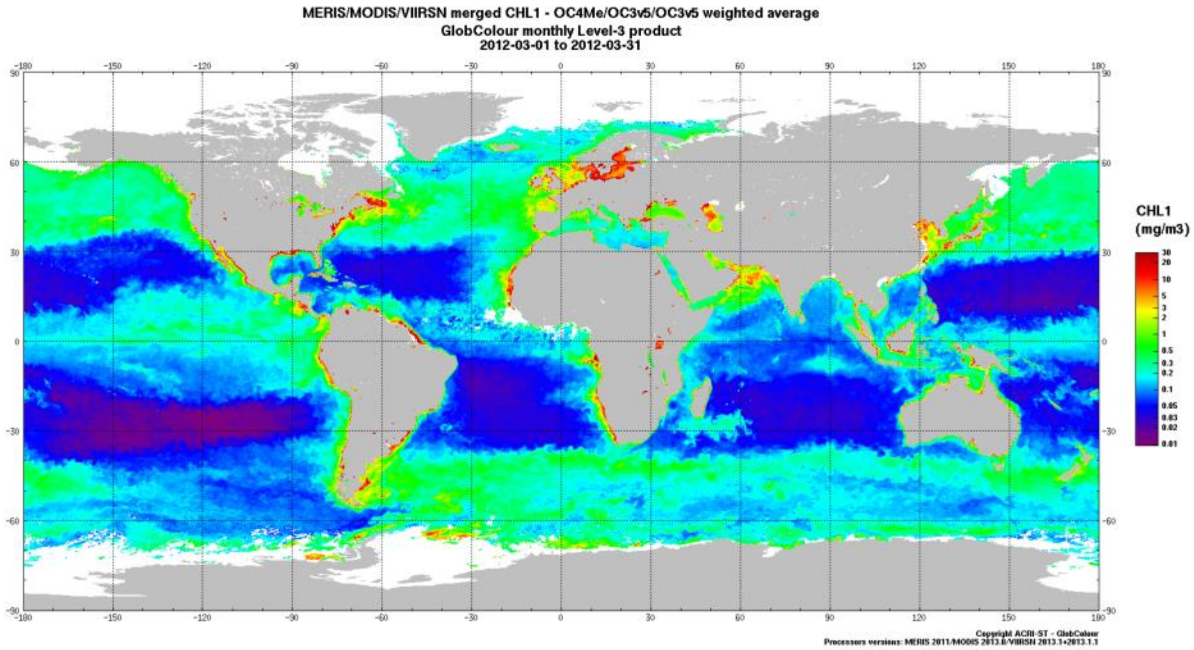


Figure 1-1: A sample GlobColour Global product

- an extended Europe area at full resolution (1km):

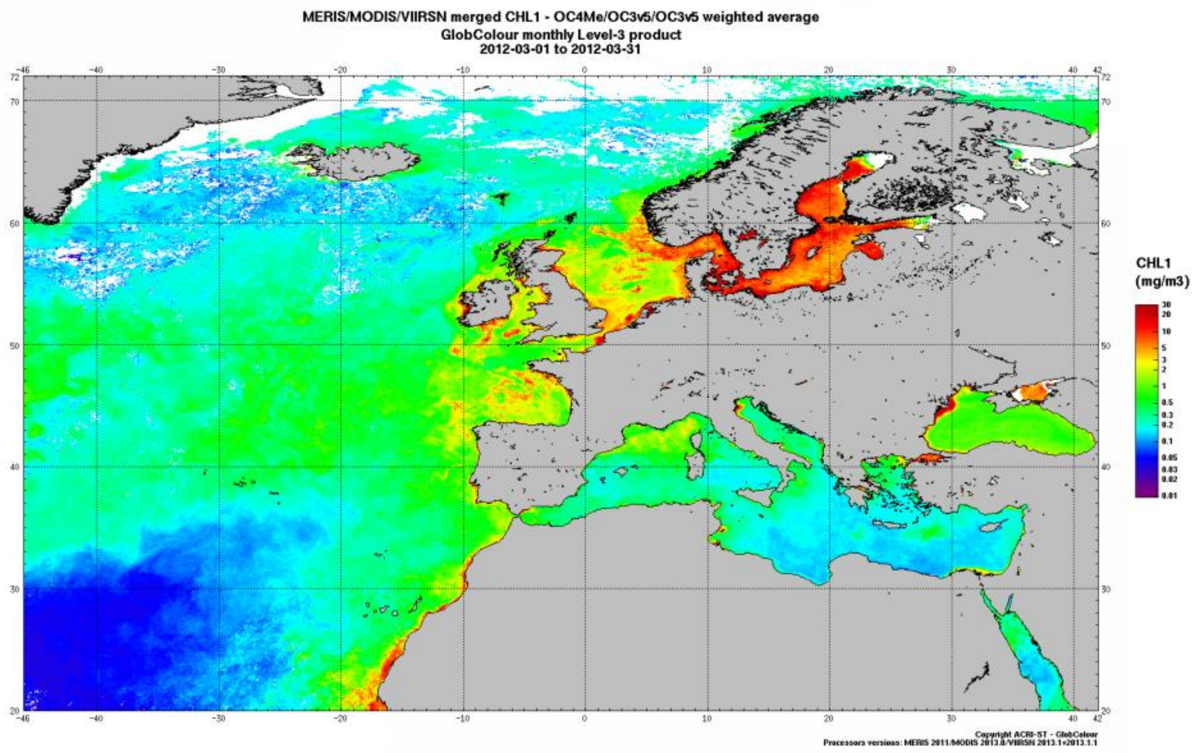


Figure 1-2: A sample GlobColour Europe product

1.4.3 Sensors

The GlobColour data set version 2016.1 is built using the following sensors:

Sensor	Product type	Start Date	End Date	Reprocessing
SeaWIFS	GAC 4km	Sept. 1997	Dec. 2010	NASA R2014.0 (20 Nov 2015)
MERIS	RR 1km	April 2002	April 2012	ESA 3rd reprocessing (1st July 2011)
MODIS AQUA	1km	July 2002	8 June 2014	NASA R2014.0 (June 2015)
MODIS AQUA	1km	9 June 2014	Present	NASA R2014.0.1 (1st Sept. 2016)
VIIRS	1km	Jan. 2012	Present	NASA R2014.0.2 (April 2016)
OLCI-A	RR 1km	July 2012	Present	ESA 06.10 (July 2017)

Table 1-1: Available sensors in the GlobColour data set

Warning: NASA has reported calibration issues for VIIRSN and MODIS-AQUA which can impact the quality of the time series after 2009. This is particularly significant for MODIS since 2012. See this discussion on the NASA forum for details.

The data set includes single-sensor and merged products. Merged products are generated for three merging techniques:

- simple averaging
- weighted averaging
- GSM model

The relative performance of the weighting methods depends on the conditions (water types, region, glint/aerosol conditions…) Users are advised to compare the results on a case-by-case basis as far as possible.

OLCI is not merged with other sensors for the moment.

1.4.4 Spatial and Temporal resolutions

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

Spatial domain	Grid	Temporal domain	Resolution
Global	ISIN	Daily, 8 days, monthly	1/24°
Europe	ISIN	Daily, 8 days, monthly	1/96°
Global	PC	Daily, 8 days, monthly	1/24°, 0.25°, 1.0°
Europe	PC	Daily, 8 days, monthly	0.01°

Table 1-2: Overview of the GlobColour products

Note: SeaWIFS GAC products have a spatial sampling distance of 4 km approximately. Oversampling is used when generating Europe “1 km” products.

2 The products content

2.1 Parameters overview

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).

In the following tables, the following acronyms are used:

AV: simple averaging, AVW: weighted averaging, GSM: GSM model, AN: analytical from other L3 products, STAT: classification statistics.

2.1.1 Biological parameters

The GlobColour biological Parameters are listed in Table 2-1.

Parameter	Description	L3 merging method	Sensor availability				
			MER	MOD	SWF	VIR	OLA
CHL1	Chlorophyll concentration (mg/m^3)	AVW, GSM	✪	✪	✪	✪	✪(1)
CHL-OC5	Chlorophyll concentration (mg/m^3) – OC5 algorithm	AVW	✪	✪	✪	✪	✪(2)
SPM-OC5	Inorganic suspended particulate matter concentration (g/m3) – OC5 algorithm	AVW	✪	✪	✪	✪	✪(2)
CHL2	Chlorophyll concentration (mg/m^3) – Neural Network algorithm	AV	✪				✪
TSM	Total suspended matter concentration (g/m^3)	AV	✪				✪
PIC	Particulate Inorganic Carbon (mol/m^3)	AVW		✪	✪	✪	
POC	Particulate Organic Carbon (mg/m^3)	AVW		✪	✪	✪	
NFLH	Normalised Fluorescence Line Height ($mW/cm^2/microm/sr$)	AV		✪			

Table 2-1: List of GlobColour Biological Parameters

(1): OLCI GSM products are experimental for the moment (we use MERIS uncertainties)
(2): OLCI OC5 products are experimental for the moment (we use MERIS OC5 LUTs)

2.1.2 Atmospheric Optical parameters

Parameter	Description	L3 merging method	Sensor availability				
			MER	MOD	SWF	VIR	OLA
WVCS	Total water vapor column, clear sky (g/cm^2)	AV	✪				✪
T865	Aerosol optical thickness over water (-)	AVW	✪	✪	✪	✪	✪
A865	Angstrom alpha coefficient over water (-)	AVW	✪	✪	✪	✪	✪
T443	Aerosol optical thickness over land (-)	AV	✪				
A443	Angstrom alpha coefficient over land (-)	AV	✪				
T550	Aerosol optical thickness over water+land (-)	AN	✪	✪	✪	✪	✪
A550	Angstrom alpha coefficient over water+land (-)	AN	✪	✪	✪	✪	✪
CF	Cloud fraction (%)	STAT	✪	✪	✪	✪	✪
ABSD	ABSOA_DUST flag statistics (%)	STAT	✪				✪

Table 2-2: List of GlobColour Atmospheric Optical parameters

2.1.3 Ocean Surface Optical parameters

Parameter	Description	L3 merging method	Sensor availability				
			MER	MOD	SWF	VIR	OLA
NRRS400	Fully normalised remote sensing reflectance at xxx nm (sr^{-1})	AV					✪
NRRS412		AVW	✪	✪	✪	✪	✪
NRRS443		AVW	✪	✪	✪	✪	✪
NRRS469		AV		✪			
NRRS490		AVW	✪	✪	✪	✪	✪
NRRS510		AVW	✪		✪		✪
NRRS531		AV		✪			
NRRS547		AV		✪			
NRRS551		AV				✪	
NRRS555		AVW (1)	✪	✪	✪	✪	✪
NRRS560		AV	✪				✪
NRRS620		AV	✪				✪
NRRS645		AV		✪			
NRRS670		AVW	✪	✪	✪	✪	✪
NRRS674		AV					✪
NRRS678		AV		✪			
NRRS681		AV					✪
NRRS709		AV					✪
RRS681	Non normalised remote sensing reflectance at xxx nm (sr^{-1})	AV	✪				
RRS709		AV	✪				
RRS754		AV					✪
RRS779		AV					✪
RRS865		AV					✪
RRS885		AV					✪
RRS1020		AV					✪
EL555	Relative excess of radiance at 555 nm (%)	AN	✪	✪	✪	✪	✪
PAR	Photosynthetically Available Radiation (einstein/m²/day)	AVW		✪	✪	✪	

Table 2-3: List of GlobColour Ocean Surface Optical parameters

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

2.1.4 Ocean Subsurface Optical parameters

Parameter	Description	L3 merging method	Sensor availability				
			MER	MOD	SWF	VIR	OLA
BBP	Particulate back-scattering coefficient at 443 nm (m^{-1})	GSM	✪	✪	✪	✪	✪(1)
CDM	Coloured dissolved and detrital organic materials absorption coefficient at 443 nm (m^{-1})	AV	✪				✪
		GSM	✪	✪	✪	✪	✪(1)
KD490	Diffuse attenuation coefficient at 490 nm (m^{-1}) Algorithms of Morel and Lee	AN (2 methods)	✪	✪	✪	✪	✪(2)
KDPAR	Diffuse attenuation coefficient for the Photosynthetically Available Radiation (m^{-1}) Algorithms of Morel and Saulquin	AN (2 methods)	✪	✪	✪	✪	✪
ZHL	Heated layer depth (m)	AN	✪	✪	✪	✪	✪
ZEU	Depth of the bottom of the euphotic layer (m)	AN	✪	✪	✪	✪	✪
ZSD	Secchi disk depth (m) Algorithms of Morel and Doron	AN (2 methods)	✪	✪	✪	✪	✪

Table 2-4: GlobColour Ocean Subsurface parameters

(1): OLCI GSM products are experimental for the moment (we use MERIS uncertainties)
(2): OLCI has 3 methods for KD490 retrieval

2.1.5 OSS2015 Demonstration Biological Products

This section lists the demonstration products developed in the frame of the OSS2015 project.

All the products are available as merged products (averaging method) at global scale with 25 km resolution.

Archive and product format conventions are not applicable to Third-Party products PP and PHYSAT.

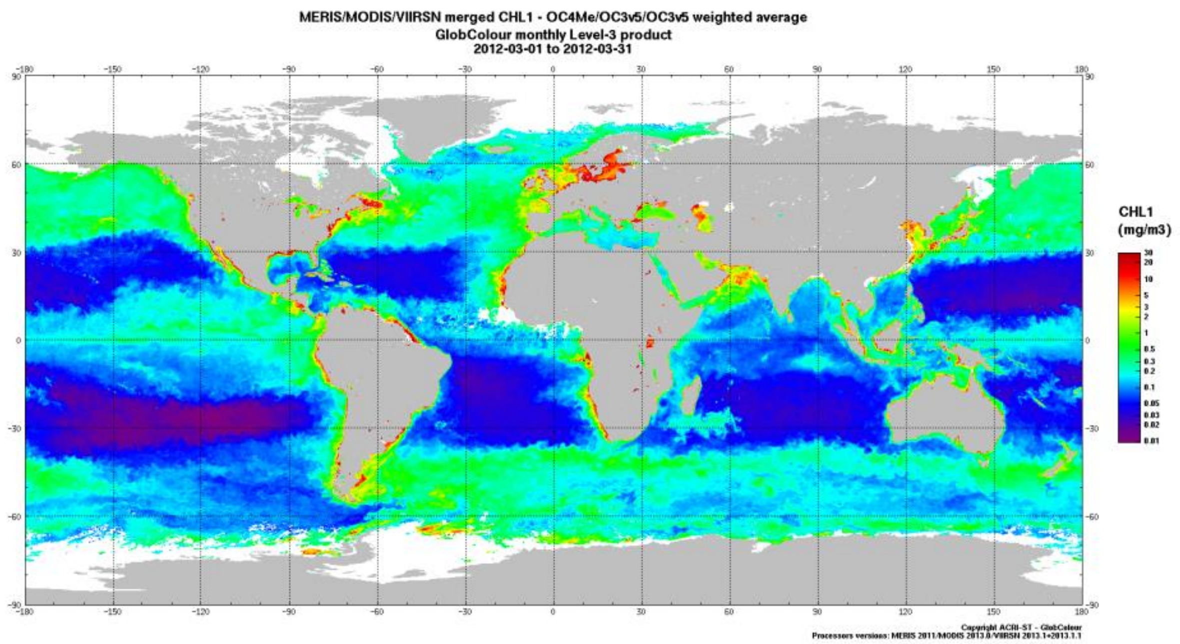
Parameter	Description	Product type
BBP-xxx-LOG	Particulate Back-scattering coefficients at xxx nm (m-1) - LOG algorithm	Monthly analytical
BBPS	Spectral slope of the particulate back-scattering coefficient (-)	Monthly analytical
POC-SURF	Surface Particulate Organic Carbon Concentration (mg/m3)	Monthly analytical
POC-INT	Column-integrated Particulate Organic Carbon Concentration (mg/m2)	Monthly analytical
PSD-XXX	Number concentration of pico, nano and micro particles (#/m3)	Monthly analytical
PP-AM	Primary Production - Antoine- Morel Algorithm	Third party, monthly analytical
PP-UITZ	Primary Production - Uitz Algorithm	Third party, monthly analytical
PHYSAT	Phytoplankton Functional Types	Third party, monthly analytical

2.2 Parameter Detailed Description

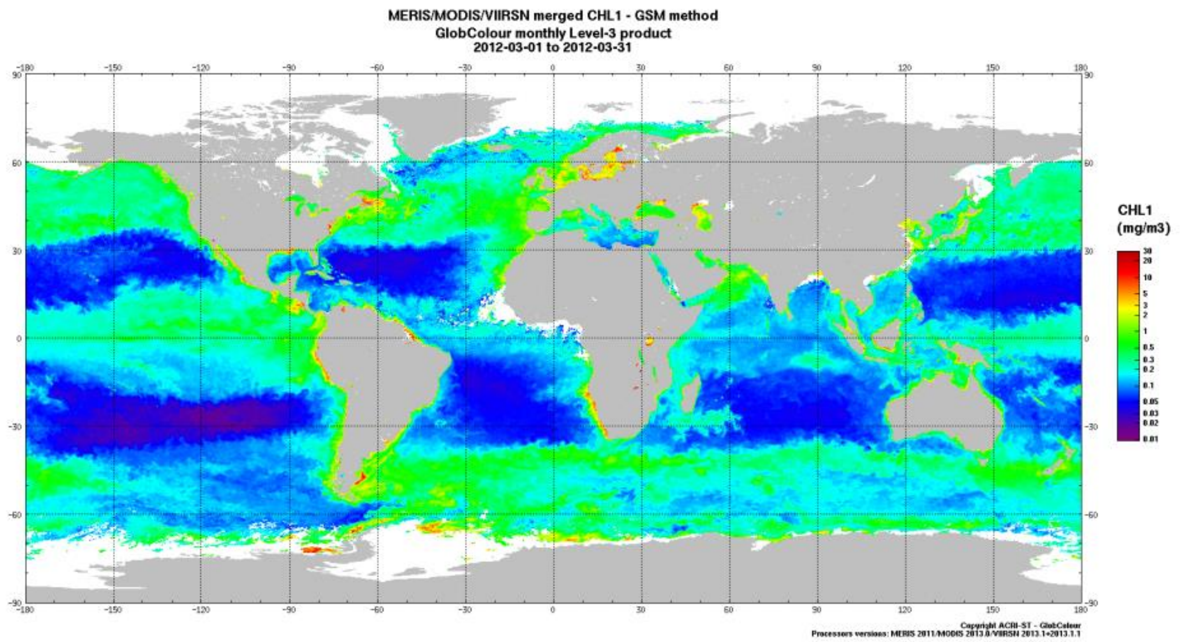
2.2.1 CHL_1

Category	Biological	PARAMETER	CHL1
Description		L3 merging method	Sensor availability
Chlorophyll concentration (mg/m3) for case 1 waters (see below). It is commonly used as a proxy for the biomass of the phytoplankton.		AVW, GSM	MER MOD SWF VIR OLA(1)

AVW



GSM



Algorithm	Reference
SWF: OC4v5	O'Reily et al., 2000
MER: OC4Me	O'Reily et al., 2000
MOD/VIR: OC3v5	O'Reily et al., 2000
OLA: OC4Me	OLCI guide
AVW: weighted average of single-sensor Level 2 CHL1 products	-
GSM: GSM merging of single sensor L3 NRRS. The GSM method uses the normalized reflectances at the original sensor wavelengths, without intercalibration. CHL1 is one of the outputs of the method, in addition to bbp and CDM.	Maritorena and Siegel, 2005

Validity

The CHL1 algorithms are applicable for "case 1" waters, i.e. waters where the phytoplankton concentration dominates over inorganic particles.

References

O Reilly, J.E., and 24 Coauthors, 2000: *SeaWiFS Postlaunch Calibration and Validation Analyses*, Part 3. NASA Tech. Memo. 2000-206892, Vol. 11, S.B. Hooker and E.R. Firestone, Eds., NASA Goddard Space Flight Center.

http://oceancolor.gsfc.nasa.gov/cms/reprocessing/r2009/ocv6

Maritorena, S. and Siegel, D.A. 2005. Consistent Merging of Satellite Ocean Colour Data Sets Using a Bio-Optical Model. *Remote Sensing of Environment*, 94, 4, 429-440.

Maritorena S., O. Hembise Fanton d Andon, A. Mangin, and D.A. Siegel. 2010. Merged Satellite Ocean Color Data Products Using a Bio-Optical Model: Characteristics, Benefits and Issues. Remote Sensing of Environment, 114, 8: 1791-1804.

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

Related products

Other Chlorophyll-a products: CHL-OC5, CHL2, CHL-CIA (OSS2015 demonstration product)

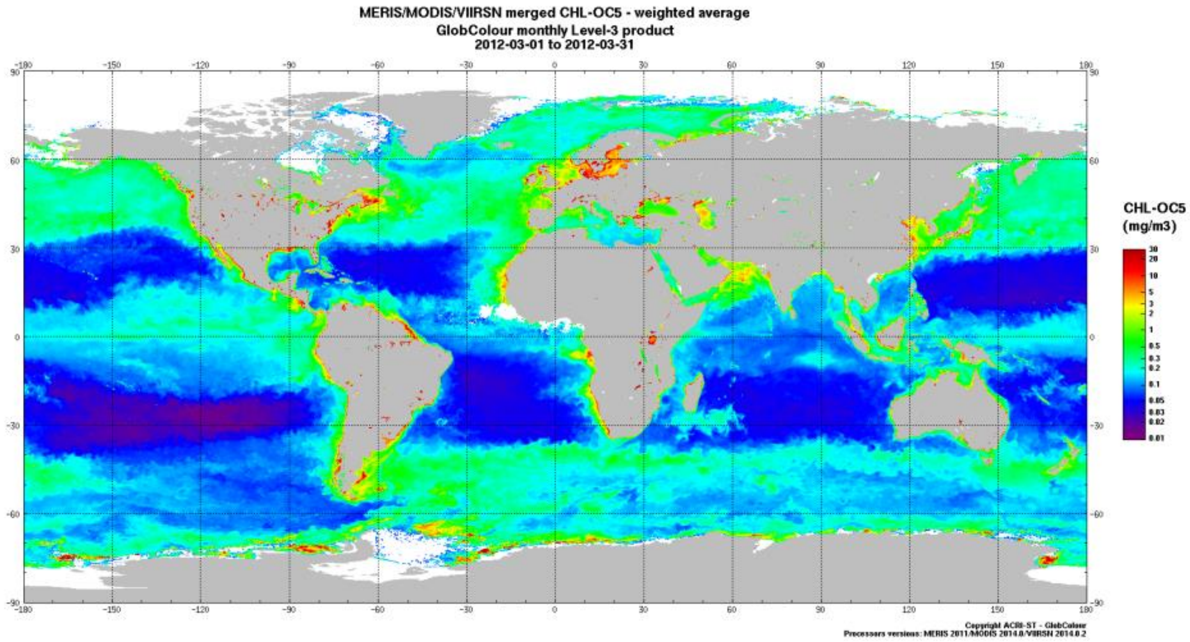
Other GSM algorithm outputs: CDM, BBP

(1): OLCI GSM products are experimental for the moment (we use MERIS uncertainties)

2.2.2 CHL-OC5

Category	Biological	PARAMETER	CHL1

Description	L3 merging method	Sensor availability
Chlorophyll concentration (mg/m3). It is commonly used as a proxy for the biomass of the phytoplankton.	AVW	MER MOD SWF VIR OLA(1)



Algorithm	Reference
OC5	Gohin, F., 2011

References

Gohin, F., Druon, J.N., Lampert, L. (2002). A five channel chlorophyll concentration algorithm applied to SeaWiFS data processed by SeaDAS in coastal waters. International Journal of Remote Sensing, 23, 1639-1661

Gohin, F.: Annual cycles of chlorophyll-a, non-algal suspended particulate matter, and turbidity observed from space and in-situ in coastal waters, Ocean Sci., 7, 705-732, doi:10.5194/os-7-705-2011, 2011. http://www.ocean-sci.net/7/705/2011/os-7-705-2011.pdf

Related products

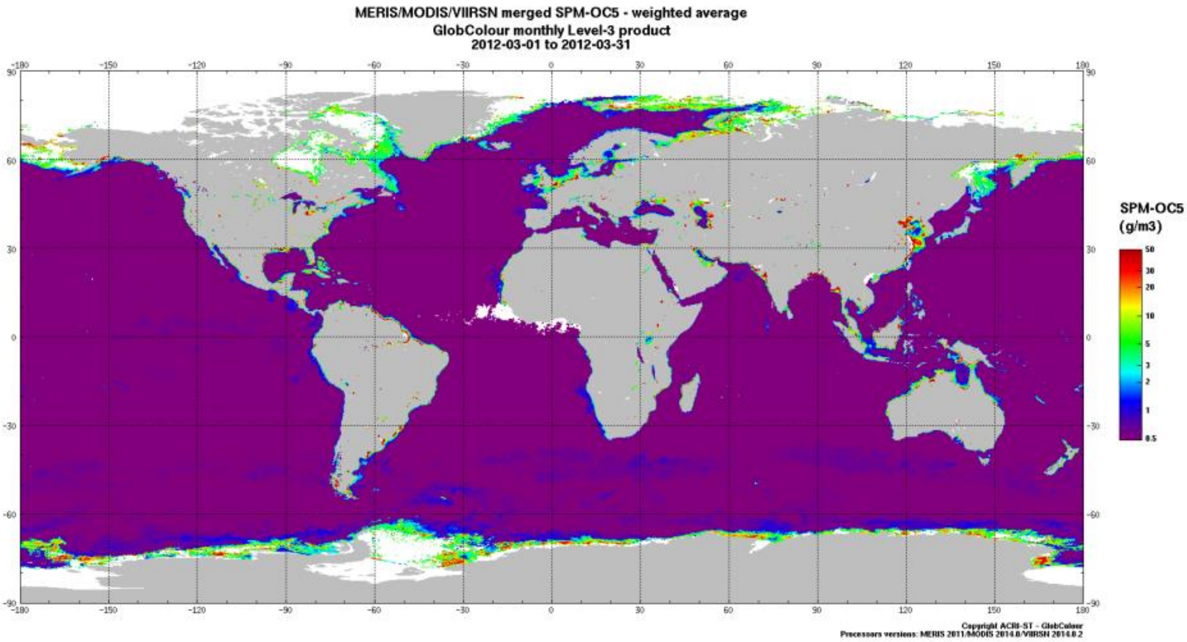
Other Chlorophyll-a products: CHL1, CHL2, CHL-CIA (OSS2015 demonstration product)

Other OC5 algorithm output: SPM-OC5

(1): OLCI OC5 products are experimental for the moment (we use MERIS OC5 LUTs)

2.2.3 SPM-OC5

Category	Biological	PARAMETER	CHL1
Description		**L3 merging method**	**Sensor availability**
Inorganic suspended particulate matter concentration (g/m^3).		AVW	MER MOD SWF VIR OLA(1)



Algorithm	Reference
OC5	Gohin, F., 2011

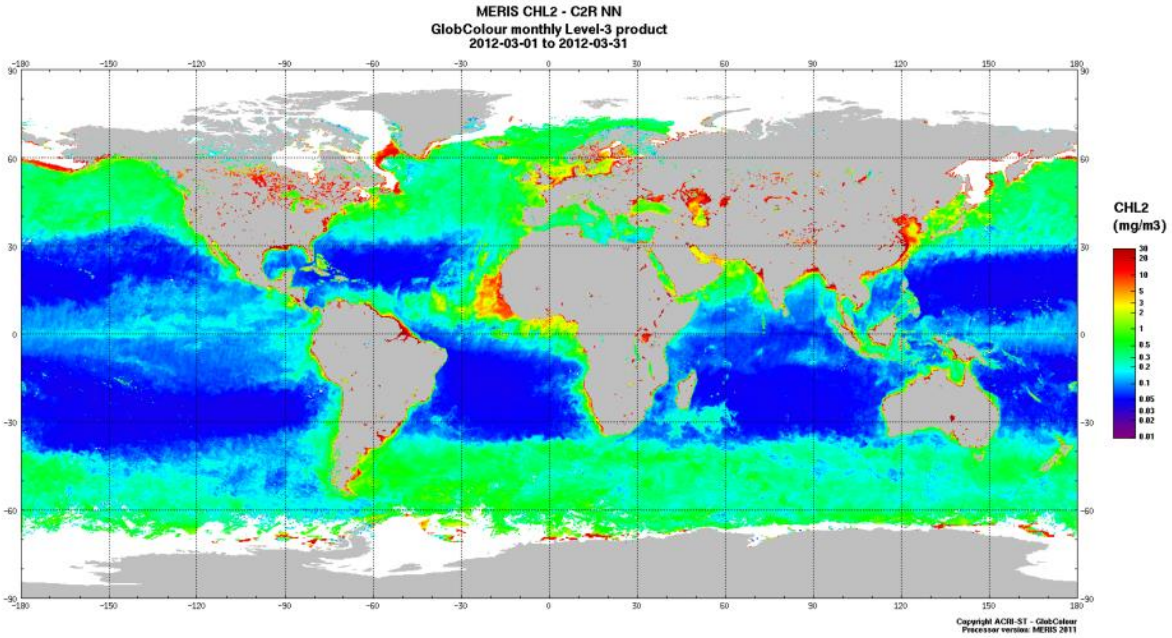
References
Gohin, F.: Annual cycles of chlorophyll-a, non-algal suspended particulate matter, and turbidity observed from space and in-situ in coastal waters, Ocean Sci., 7, 705-732, doi:10.5194/os-7-705-2011, 2011. http://www.ocean-sci.net/7/705/2011/os-7-705-2011.pdf

Related products
Other suspended matter product: TSM, BBP Other OC5 algorithm output: CHL-OC5

(1): OLCI OC5 products are experimental for the moment (we use MERIS OC5 LUTs)

2.2.4 CHL_2

Category	Biological	PARAMETER	CHL2
Description		**L3 merging method**	**Sensor availability**
CHL_2 is the chlorophyll concentration (mg/m^3) for Case 2 waters (see section validity). It is commonly used as a proxy for the biomass of the phytoplankton.		AV	MER OLA



Algorithm	Reference
CHL2 uses the a Neural Network algorithm. Another output of the algorithm is TSM.	Doerffer and Schiller (2007) OLCI guide

Validity

The product is valid for case 2 waters, i.e. waters where inorganic particles dominate over phytoplankton (typically in coastal waters).

References

The MERIS Case 2 water algorithm, R. Doerffer, H. Schiller, International Journal of Remote Sensing, Vol. 28, Iss. 3-4, 2007, doi:10.1080/01431160600821127

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

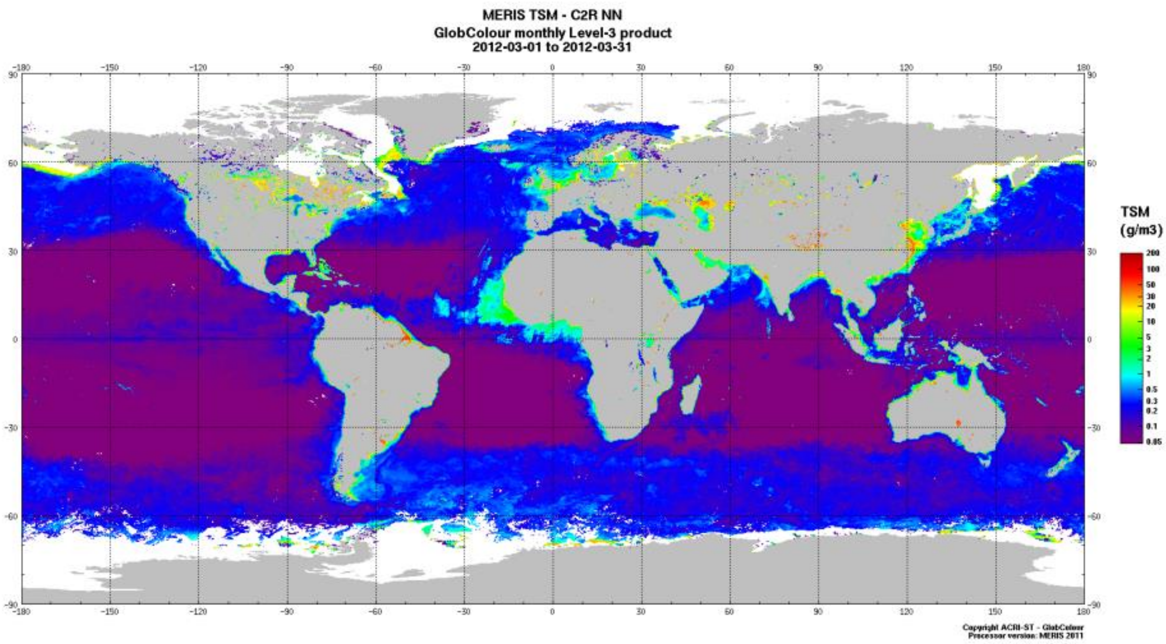
Related products

Other Chlorophyll-a products: CHL1, CHL-OC5, CHL-CIA (OSS2015 demonstration product)

Other MERIS/OLCI Neural Network outputs: TSM, CDM

2.2.5 TSM

Category	Biological	PARAMETER	TSM
Description		L3 merging method	Sensor availability
TSM is the total suspended matter concentration (g/m^3). It is a measure of the turbidity of the water.		AV	MER OLA



Algorithm	Reference
TSM uses a Neural Network algorithm. Another output of the algorithm is CHL2.	Doerffer and Schiller (2007) OLCI guide

Validity

The product is valid for case 2 waters, i.e. waters where inorganic particles dominate over phytoplankton (typically in coastal waters).

References

The MERIS Case 2 water algorithm, R. Doerffer, H. Schiller, International Journal of Remote Sensing, Vol. 28, Iss. 3-4, 2007, doi:10.1080/01431160600821127

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

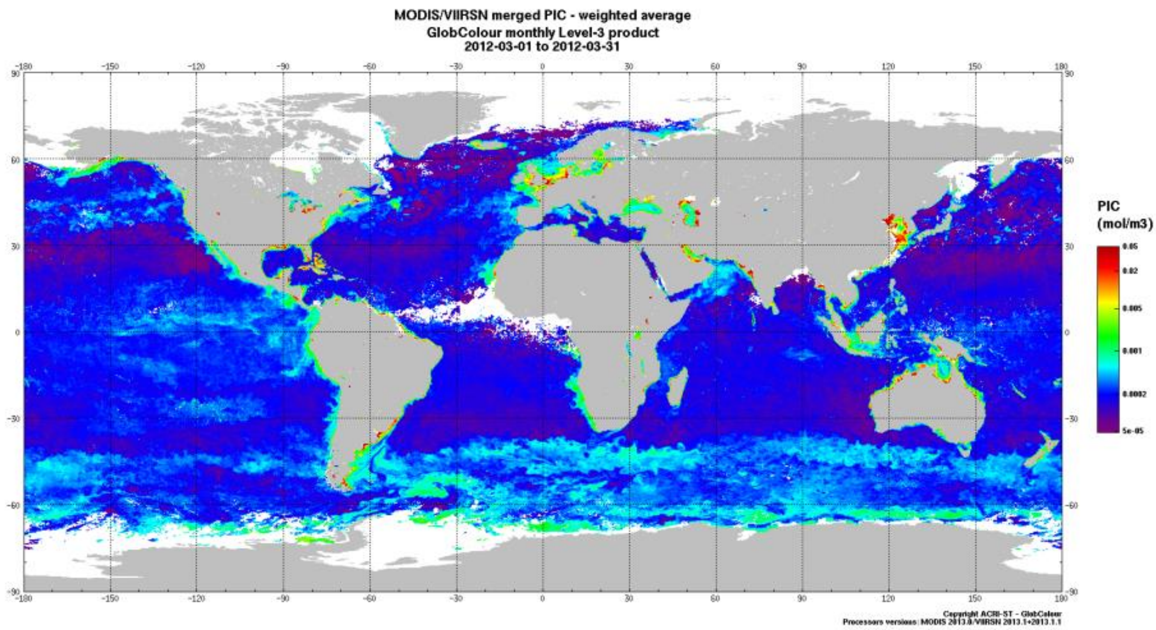
Related products

The MERIS/OLCI TSM product is computed from the back-scattering coefficient at 444 nm using the following assumptions: BP = BBP/0.015, TSM = 1.73*BP. Therefore the BBP variable issued from the GSM algorithm is closely related to TSM. SPM-OC5 provides the inorganic suspended particulate matter, a product closely linked to TSM, according to the OC5 algorithm.

Other MERIS/OLCI Neural Network outputs: CHL2, CDM

2.2.6 PIC

Category	Biological	PARAMETER	PIC
Description		L3 merging method	Sensor availability
PIC is the Particulate Inorganic Carbon or suspended calcium carbonate concentration (mol/m^3). CaCO3 is produced in shallow waters by either coral reefs or macrophytic algae, or in the plankton, by coccolithophores, foraminifera, and pteropods.		AV, AVW	SWF MOD VIR



Algorithm	Reference
PIC uses the original NASA algorithms: 2-band look-up table approach and 3-band algorithm at high concentrations	Bach et al. (2005) Gordon et al. (2001)

References

Balch, W. M., H. R. Gordon, B. C. Bowler, D. T. Drapeau, and E. S. Booth. (2005) Calcium carbonate measurements in the surface global ocean based on Moderate-Resolution Imaging Spectroradiometer data, JGR, Vol. 110, C07001 http://dx.doi.org/10.1029/2004JC002560

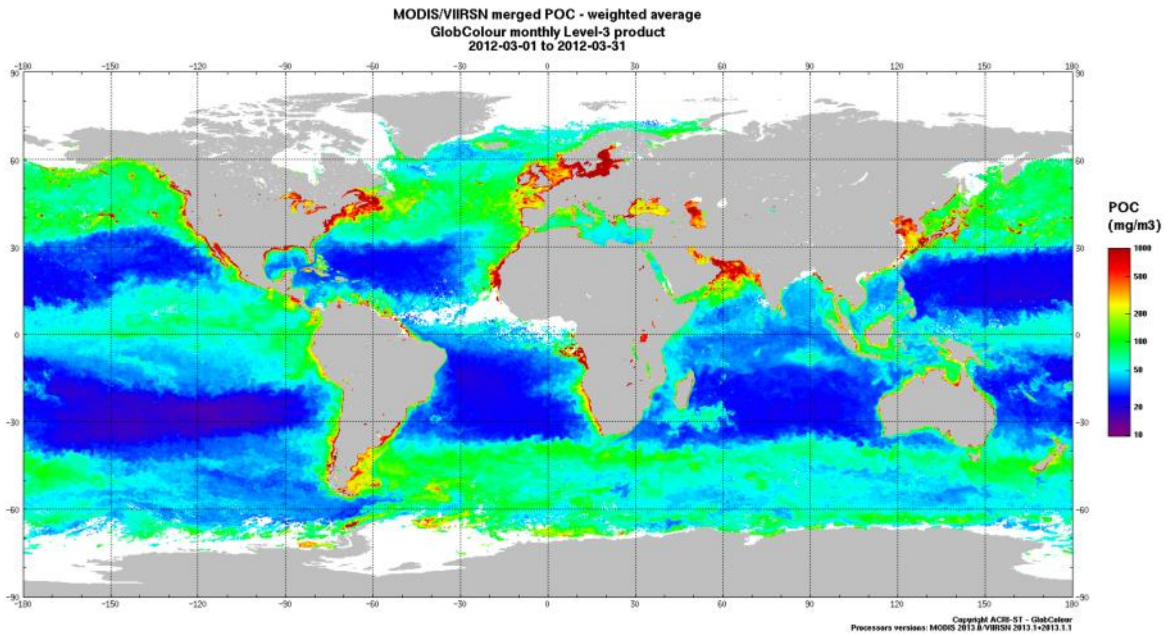
Gordon, Howard R., G. Chris Boynton, William M. Balch, Stephen B. Groom, Derek S. Harbour, and Tim J. Smyth. (2001) Retrieval of Coccolithophore Calcite Concentration from SeaWiFS Imagery. GRL, Vol. 28, No. 8, pp. 1587-1590 http://dx.doi.org/10.1029/2000GL012025

Related products

POC provides the Particulate Organic Concentration

2.2.7 POC

Category	Biological	PARAMETER	POC
Description		L3 merging method	Sensor availability
POC is the Particulate Organic Carbon (mol/m3). POC is an important component in the carbon cycle and serves as a primary food sources for aquatic food webs.		AV, AVW	SWF MOD VIR



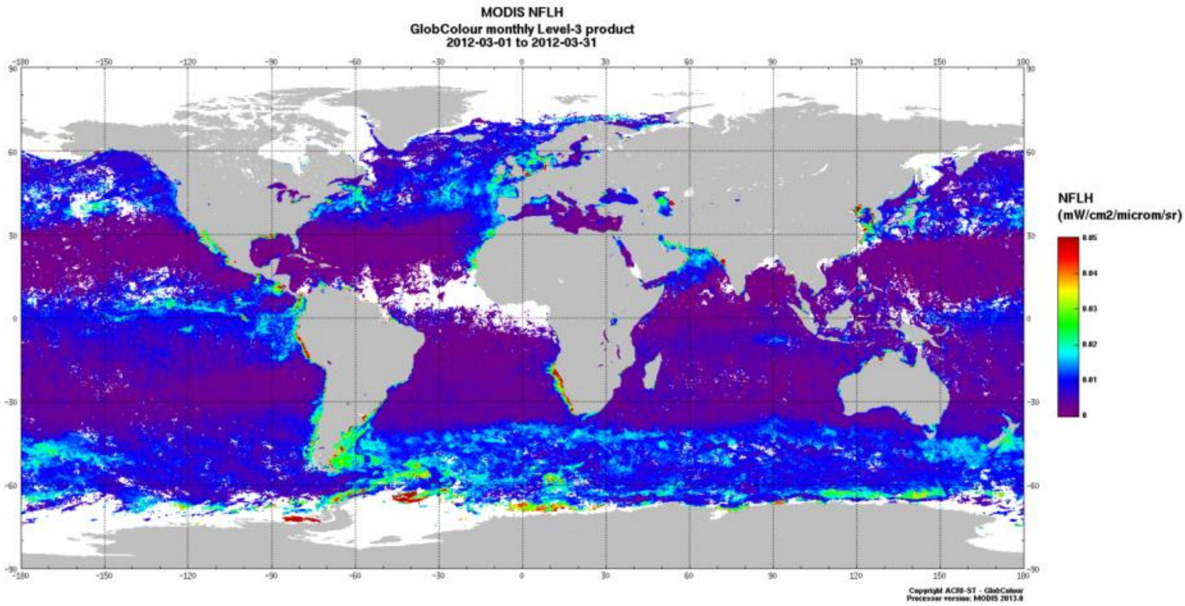
Algorithm	Reference
POC uses the original NASA algorithm (correlation of band ratios).	Stramski et al. (2008)

References

Stramski. D., R.A. Reynolds, M. Babin, S. Kaczmarek, M.R. Lewis, R. Rottgers, A. Sciandra, M. Stramska, M.S. Twardowski, B.A. Franz, and H. Claustre (2008). Relationships between the surface concentration of particulate organic carbon and optical properties in the eastern South Pacific and eastern Atlantic Oceans, Biogeosci., 5, 171-201.
Related products
PIC provides the Particulate Inorganic Concentration The OSS2015 archive includes a similar POC product and a column-integrated POC product.

2.2.8 NFLH

Category	Biological	PARAMETER	POC
Description		L3 merging method	Sensor availability
NFLH is the Normalised Fluorescence Line Height (mW/cm²/microm/sr) at 678 nm. Fluorescence is a marker of the photosynthetic activity of the phytoplankton.		AV	MOD

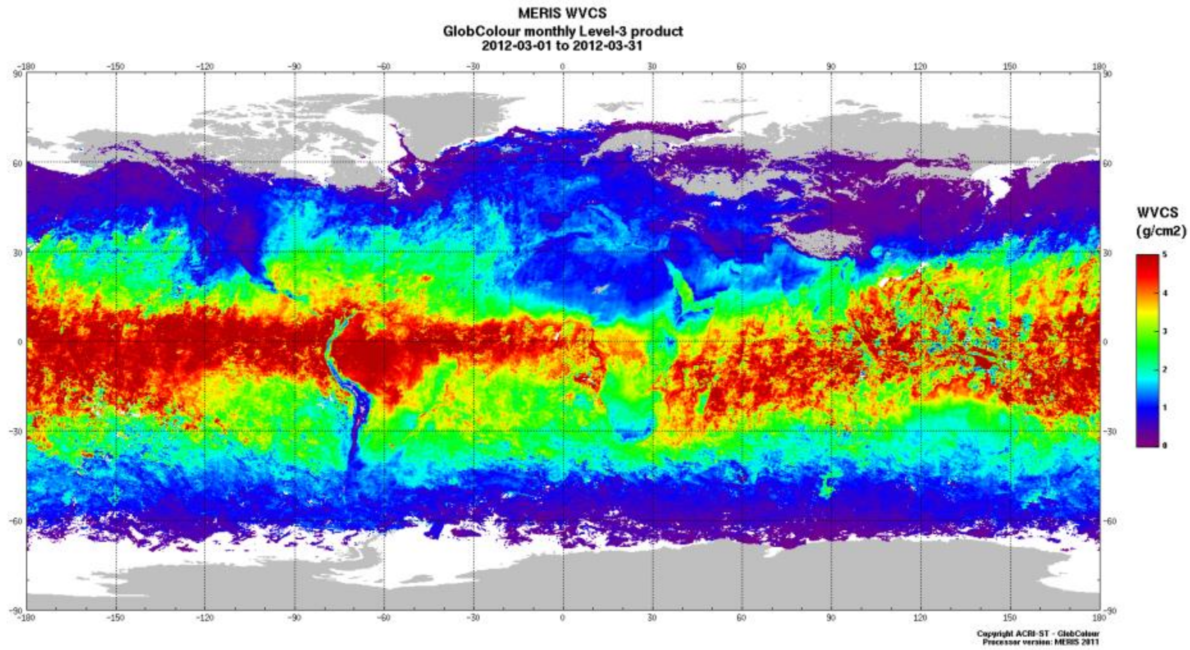


Algorithm	Reference
NFLH is based on the original MODIS L2 product using the spectral band of MODIS at 678 nm.	Berhenfeld et al. (2009)
References	

Behrenfeld, M.J., T.K. Westberry, E.S. Boss, R.T. O Malley, D.A. Siegel, J.D. Wiggert, B.A. Franz, C.R. McClain, G.C. Feldman, S.C. Doney, J.K. Moore, G. Dall Olmo, A. J. Milligan, I. Lima, and N. Mahowald (2009). Satellite-detected fluorescence reveals global physiology of ocean phytoplankton, Biogeosci., 6, 779-794.

2.2.9 WVCS

Category	Atmosphere	PARAMETER	WVCS
Description		L3 merging method	Sensor availability
WVCS is the total water vapor column over clear sky (g/cm²) coming from the MERIS/OLCI L2 data. Water vapour is the most effective greenhouse gas in the atmosphere. It influences weather and climate and is responsible for cloud development, precipitation, and modulates the atmospheric radiative energy transfer.		AV	MER OLA



Algorithm	Reference
WCVS is an average of the corresponding MERIS/OLCI L2 data.	MERIS ATBD OLCI guide

References

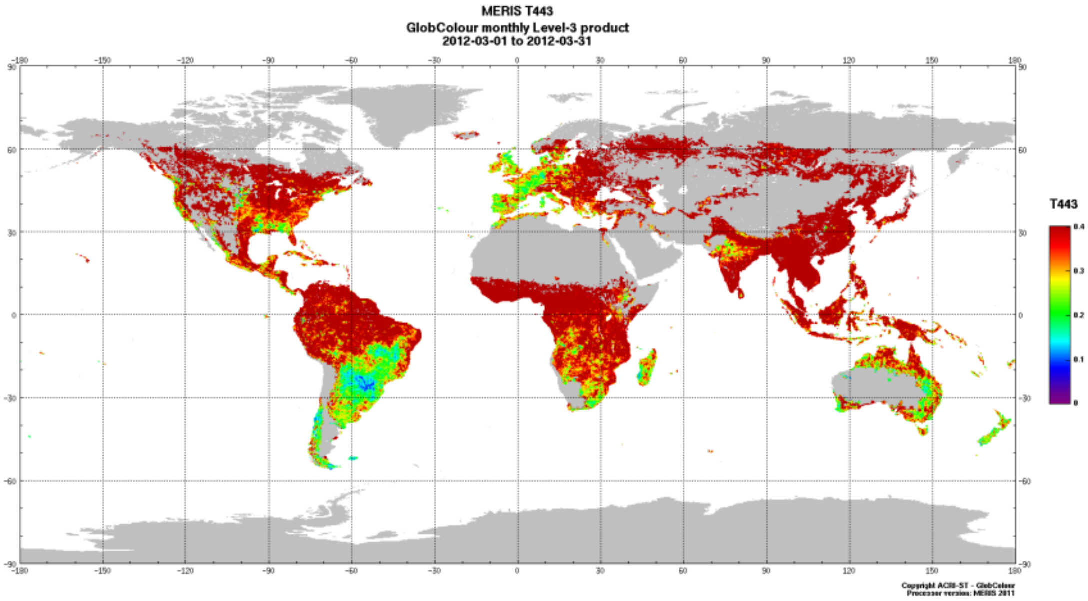
MERIS ATBD: http://envisat.esa.int/handbooks/meris/CNTR2-7.html (accessed October 2016)

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

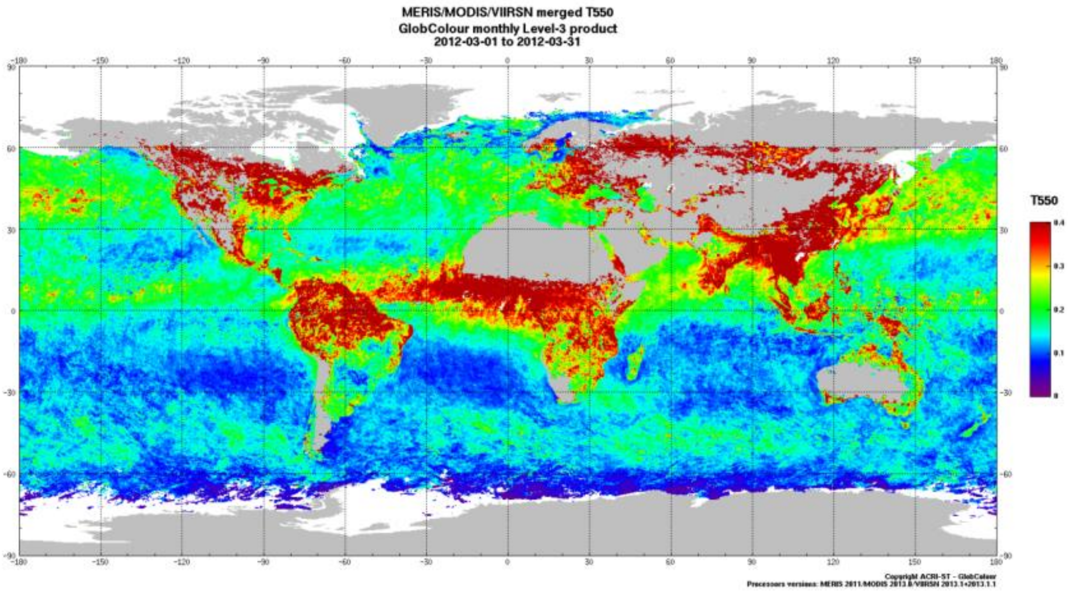
2.2.10 Txxx

Category	Atmosphere	PARAMETER	Txxx
Description		L3 merging method	Sensor availability
Txxx (xxx=443, 550, 865) are the aerosol optical thicknesses at 443 (over land), 550 (over land and water) and 865 nm (over water). The optical thickness is the logarithm of the ratio between the down-welling irradiances and the bottom of the atmosphere.		443: AV 550: AN 865: AVW	MER MER MOD SWF VIR OLA MER MOD SWF VIR OLA

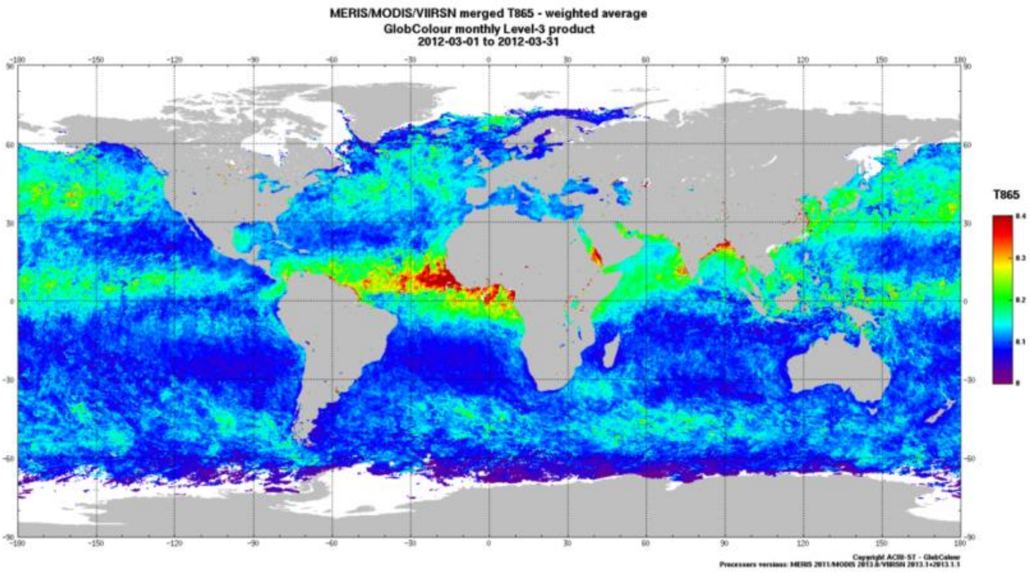
T443 (Land)



T550 (Land + Water)



T865 (Water)



Algorithm	Reference
T443 is computed from the MERIS L2 product. T865 is merged from corresponding L2 products for the various sensors. T550 is extrapolated from the land and water products using the corresponding Angström α exponent: $T550 = Txxx * (550 / xxx)^{-\alpha}$ with α=1 for land (xxx=443) and α=A865 for water (xxx=865)	Gordon, 1997 MERIS ATBD OLCI guide

Validity

The GlobColour merged atmosphere products are not yet validated. The validity of the products is not certified.

References

Gordon, H.R., 1997. Atmospheric correction of ocean color imagery in the Earth Observing System era. Journal of Geophysical Research - Atmospheres 102 (D14), 17081-17106

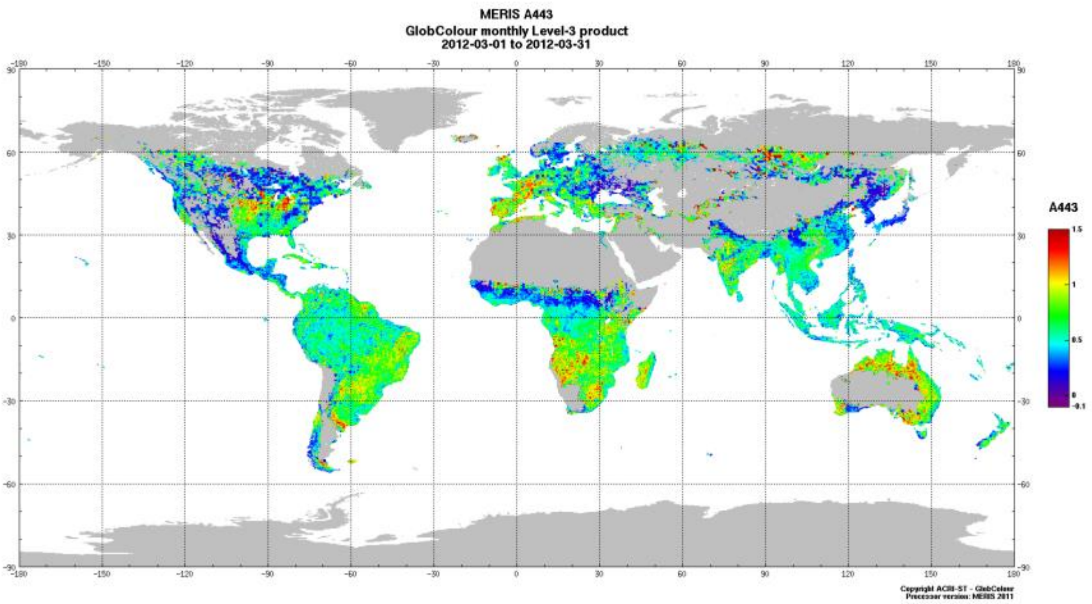
MERIS ATBD: http://envisat.esa.int/handbooks/meris/CNTR2-7.html (accessed October 2016)

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

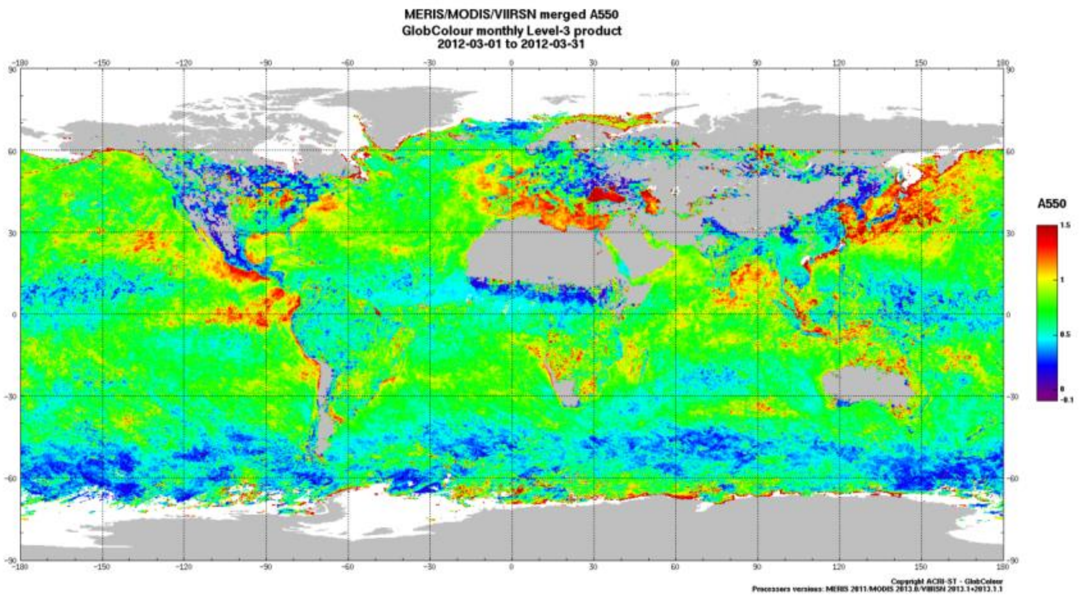
2.2.11 Axxx

Category	Atmosphere	PARAMETER	Axxx
Description		L3 merging method	Sensor availability
Axxx (xxx=443, 550, 865) are the Angstöm exponents at 443 (over land), 550 (over land and water) and 865 nm (over water). The Angström α exponent is related to the aerosol optical thickness τ by $\tau_1/\tau_0 = (\lambda_1/\lambda_0)^{-\alpha}$.		443: AV 550: AN 865: AVW	MER MER MOD SWF VIR OLA MER MOD SWF VIR OLA

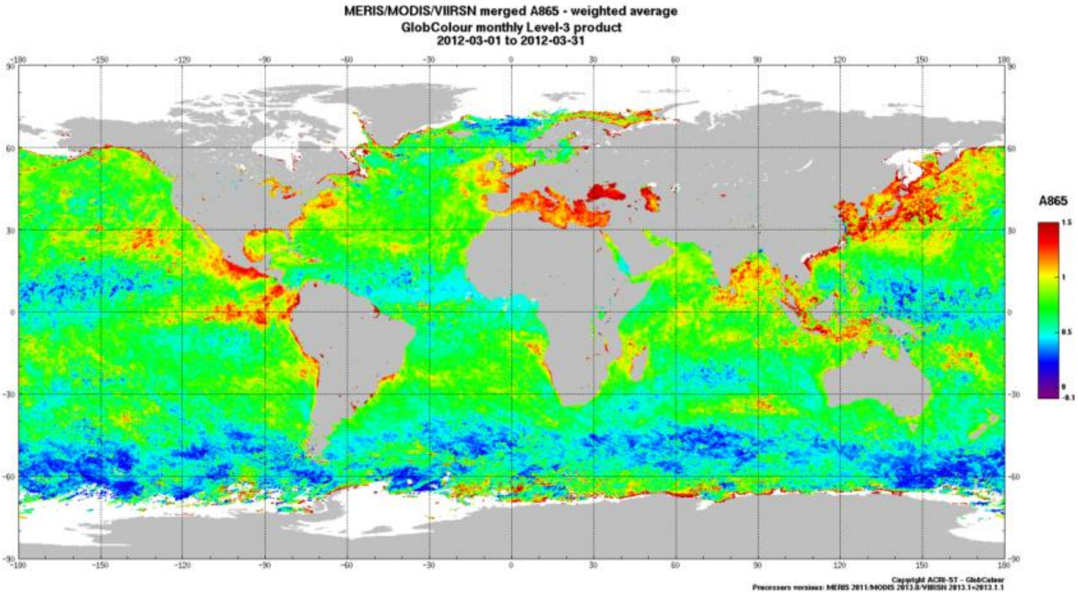
A443 (Land)



A550 (Land + Water)



A865 (Water)



Algorithm	Reference
A443 is computed from the MERIS L2 product. A865 is a weighted average of the corresponding products from all sensors. A550 is obtained by merging A443 (over land) and A865 (over water) products.	MODIS ATBD MERIS ATBD OLCI guide

Validity

The GlobColour merged atmosphere products are not yet validated. The validity of the products is not certified.

References

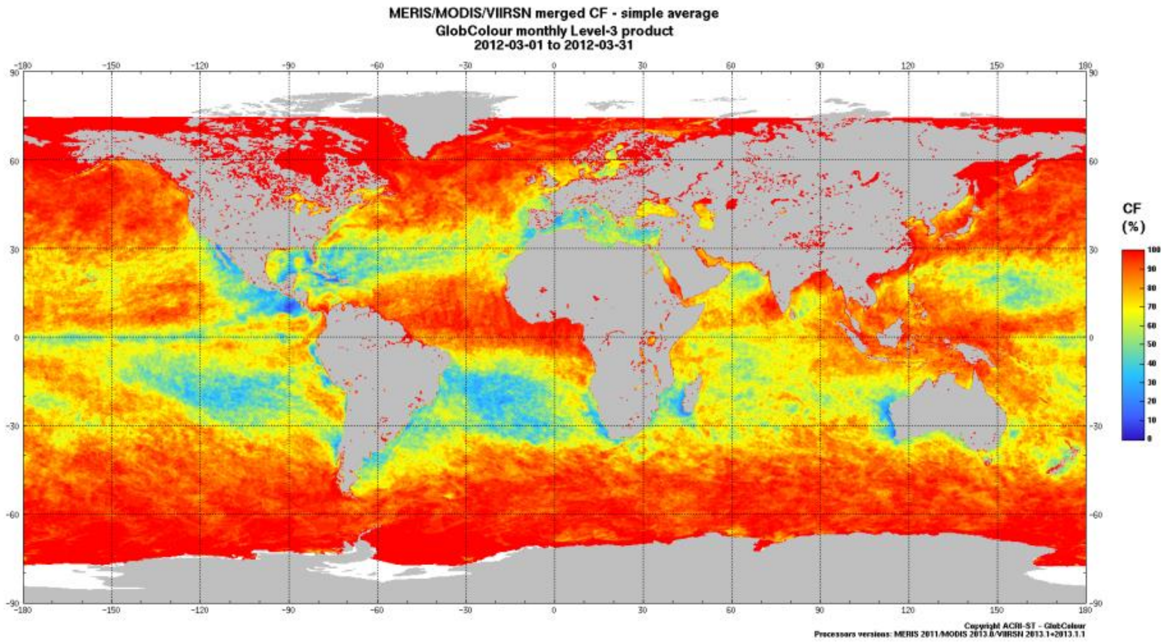
MODIS ATBD: http://modis-atmos.gsfc.nasa.gov/MOD06_L2/atbd.html (accessed December 2014)

MERIS ATBD: http://envisat.esa.int/handbooks/meris/CNTR2-7.html (accessed October 2016)

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

2.2.12 CF

Category	Atmosphere	PARAMETER	CF
Description		**L3 merging method**	**Sensor availability**
CF is the Cloud Fraction (%), i.e. the percentage of pixels with flags Cloud, Ice, or haze per bin.		STAT	MER MOD SWF VIR OLA



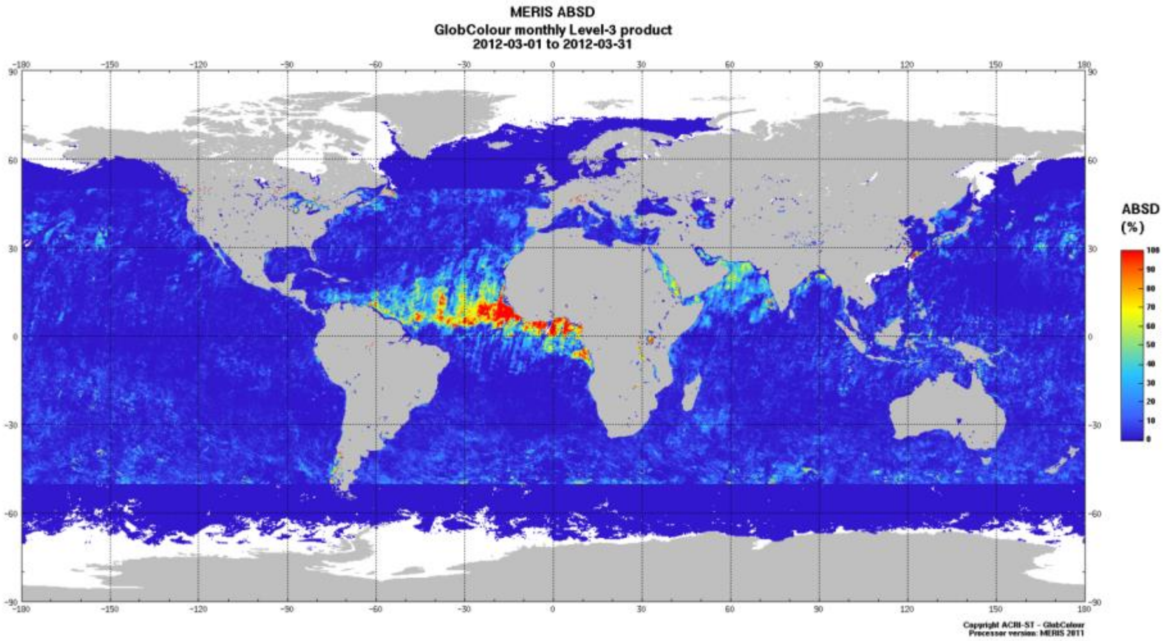
Algorithm	Reference
This parameter is determined by using the following flags: • CLDICE = "Probable cloud or ice contamination" for MODIS, SeaWiFS and VIIRS instruments • "CLOUD or (WATER and ICE_HAZE)" where ICE_HAZE = "Ice or high aerosol load pixel or Cloud" for the MERIS instrument. • "CLOUD or CLOUD_AMBIGUOUS" for the OLCI instrument. 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)	MODIS ATBD MERIS ATBD OLCI guide

References

MODIS ATBD: http://modis-atmos.gsfc.nasa.gov/MOD06_L2/atbd.html (accessed December 2014)
MERIS ATBD: http://envisat.esa.int/handbooks/meris/CNTR2-7.html (accessed October 2016)
OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

2.2.13 ABSD

Category	Atmosphere	PARAMETER	ABSD
Description		**L3 merging method**	**Sensor availability**
ABSD is the MERIS/OLCI L2 ABSOA_DUST flag statistics (%), which is raised to indicate the presence of dust-like absorbing aerosols.		STAT	MER OLA



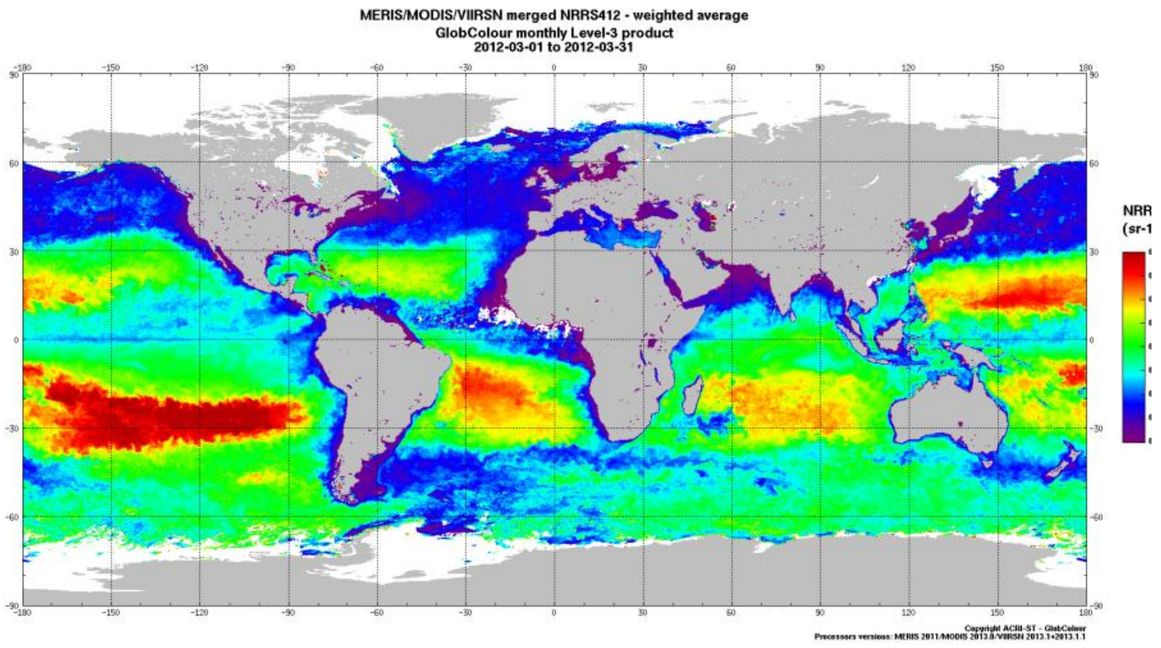
Algorithm	Reference
ABSD is computed from the corresponding MERIS/OLCI L2 product.	MERIS ATBD OLCI guide

References

MERIS ATBD: http://envisat.esa.int/handbooks/meris/CNTR2-7.html (accessed October 2016)
OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

2.2.14 (N)RRSxxx

Category	Ocean Surface Optical	PARAMETER		(N)RRSxxx			
Description		L3 merging method		Sensor availability			
The (N)RRSxxx are the remote sensing reflectances at xxx nm (expressed in sr-1). The remote sensing reflectance is the ratio of the upwelling radiance to the downwelling irradiance at Sea surface. NRRSxxx reflectances are fully normalized. RRSxxx are not normalized. (1) For NRRS 555, an inter-calibration is performed before merging (see algorithm description below).	400	AV					OLA
	412	AVW	MER	MOD	SWF	VIR	OLA
	443	AVW	MER	MOD	SWF	VIR	OLA
	469	AV		MOD			
	490	AVW	MER	MOD	SWF	VIR	OLA
	510	AVW	MER		SWF		OLA
	531	AV		MOD			
	547	AV		MOD			
	551	AV				VIR	
	555	AVW (1)	MER	MOD	SWF	VIR	OLA
	560	AV	MER				OLA
	620	AV	MER				OLA
	645	AV		MOD			
	670	AVW	MER	MOD	SWF	VIR	
	674	AVW					OLA
	678	AV		MOD			
	681	AV	MER				OLA
	709	AV	MER				OLA
	754	AV					OLA
	779	AV					
	865	AV					OLA
	885	AV					OLA
	1020	AV					OLA



Algorithm

MERIS and OLCI normalised water leaving reflectances from the L2 products are initially converted into fully normalised water leaving reflectances (except for the MERIS 681 nm and 709 nm bands and for the OLCI bands ≥ 754 nm).

The NRRSxxx daily L3 products are generated for each instrument, using the corresponding L2 data. The merged NRRSxxx concentration is then computed as the weighted average of all the single-sensor products.

The 547-560 nm 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 an inter-spectral conversion LUT which is a function of the CHL1 concentration (weighted average version):

- MODIS: $NRRS555 = NRRS547 * (0.93573 + 0.0861 * y + 0.01545 * y^2 - 0.00714 * y^3 - 0.00245 * y^4)$
- VIIRS: $NRRS555 = NRRS551 * (0.97979 + 0.03583 * y + 0.0057 * y^2 - 0.00277 * y^3 - 0.00085 * y^4)$
- SeaWiFS: No change as SeaWiFS band is actually at 555 nm
- MERIS/OLCI: $NRRS555 = NRRS560 * (1.02542 - 0.03757 * y - 0.00171 * y^2 + 0.0035 * y^3 + 0.00057 * y^4)$

where y = log10(CHL1).

Validity

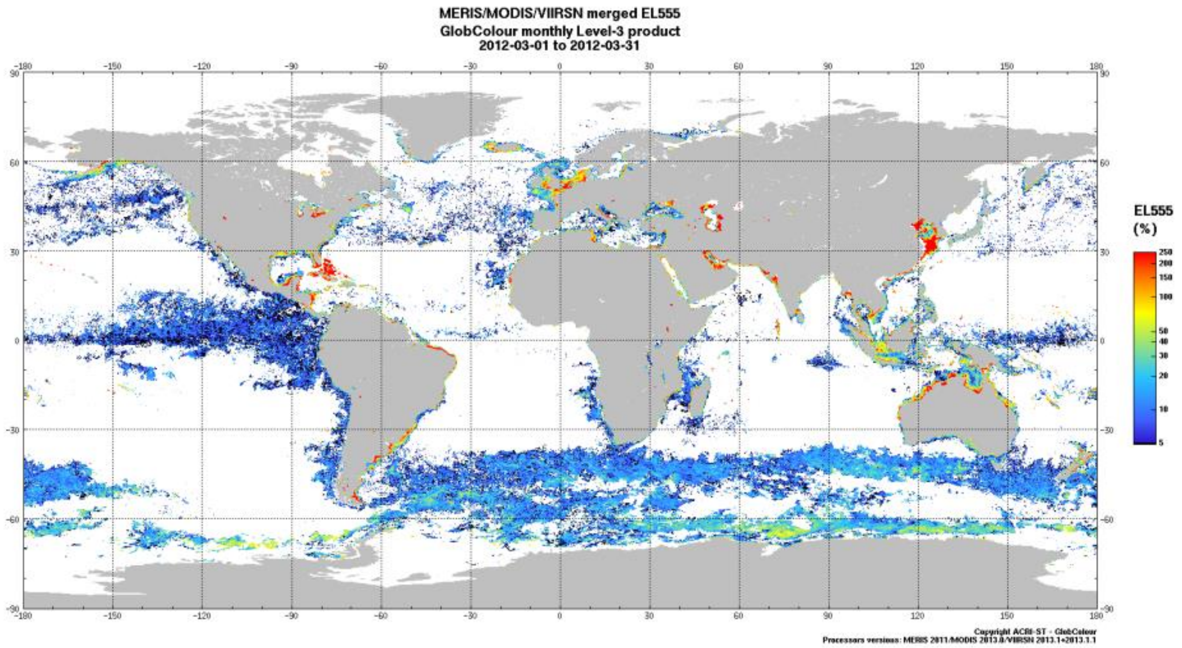
The validity limit for the spectral interpolation method at 555 nm is 0.01 ≤ CHL1 ≤ 30.

References

N/A

2.2.15 EL555

Category	Ocean Surface Optical	PARAMETER	EL555
Description		**L3 merging method**	**Sensor availability**
EL555 is an indicator of an excess of luminance at 555 nm (%) after removal of the chlorophyll contribution in case 1 water. It is an indicator of the quality of the Chlorophyll retrieval and may indicate that the presence of other constituents (especially suspended matter) might have impact the inversion.		AN	MER MOD SWF VIR OLA



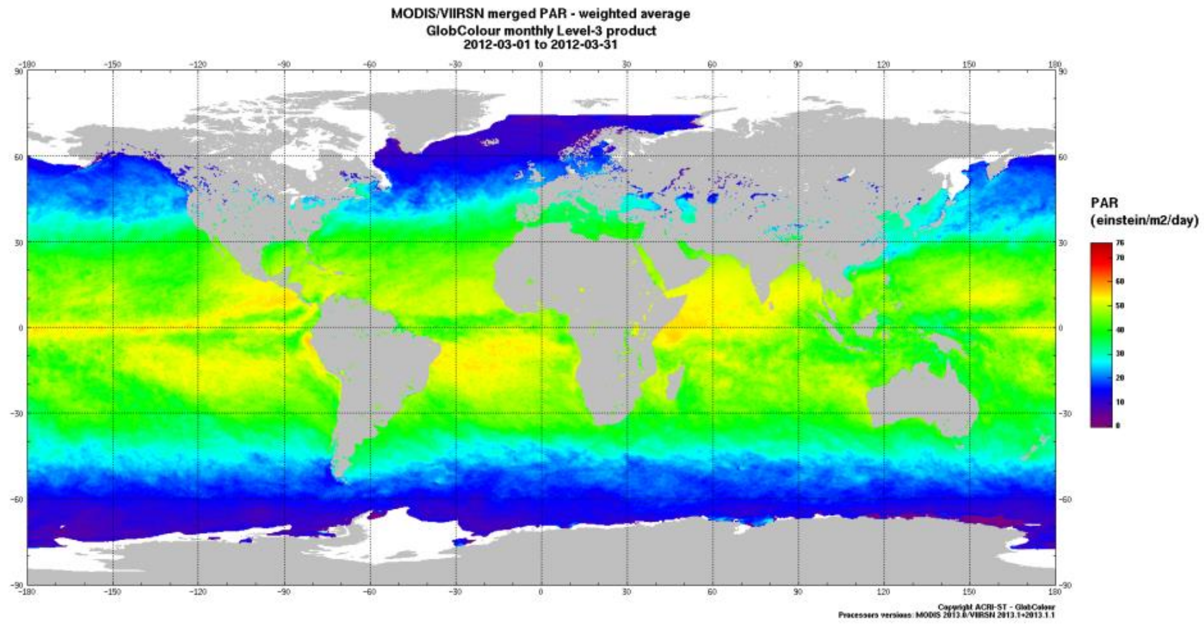
Algorithm	Reference
The parameter is computed from the corresponding merged fully normalised remote sensing reflectance at 555 nm and the CHL1 (weighted method) products, using the following algorithm: If (CHL1 > 0.2) and ($NRRS_{555}$ > Rho_{lim}(CHL1)) then raise the turbid flag for all products EL_{555} = 100. [$NRRS_{555}$ – Rho_{lim}(CHL1)] / Rho_{lim}(CHL1) Endif, where Rho_{lim}(CHL1) is expressed as: $\begin{cases} y = \log_{10}(CHL1) \\ Rho_{lim}(y) = 0.0104 + 0.006665 \cdot y + 0.00099233 \cdot y^2 - 0.0006382 \cdot y^3 \end{cases}$	Morel and Bélanger 2006

References

Morel, A. and S. Belanger, (2006) Improved Detection of turbid waters from Ocean Color information, *Remote Sensing of Environment*, **102**, 237-249.

2.2.16 PAR

Category	Ocean Subsurface Optical	PARAMETER	PAR
Description		L3 merging method	Sensor availability
PAR is the Photosynthetically Available Radiation (einstein/m²/day). It is the mean daily photon flux density in the visible range (400 to 700 nm) that can be used for photosynthesis.		AV, AVW	MOD SWF VIR



Algorithm	Reference
PAR uses the original L2 products.	Frouin et al.

References

http://oceancolor.gsfc.nasa.gov/DOCS/seawifs_par_wfigs.pdf

Frouin, R., B. A. Franz, and P. J. Werdell, 2003: The SeaWiFS PAR product. In Algorithm Updates for the Fourth SeaWiFS Data Reprocessing, S. B. Hooker and E. R. Firestone, Editors, CC NASA/TM-2003-206892, Vol. 22, 46-50.

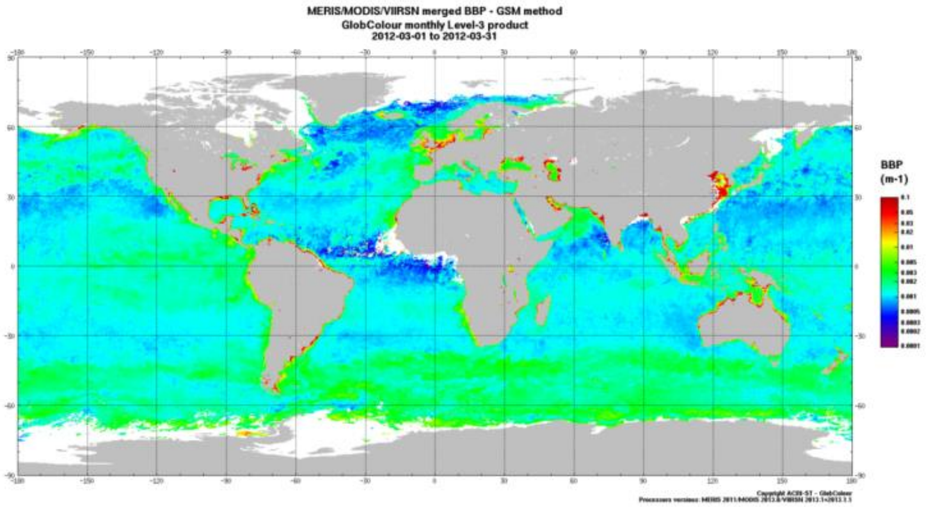
Related products

KdPAR provides the attenuation coefficient of the PAR in the water.

2.2.17 BBP

Category	Ocean Subsurface Optical	PARAMETER	BBP

Description	L3 merging method	Sensor availability
BBP is the particulate back-scattering coefficient (m^{-1}) at the reference wavelength of λ_0 = 443 nm. The back-scattering coefficient can be used as a proxy for the concentration of suspended particles in sea water.	GSM	MER MOD SWF VIR OLA(1)



Algorithm	Reference
BBP is an output of the GSM merging algorithm applied to L3 single-sensors reflectances NRRS.	Maritorena and Siegel, 2005

References

Maritorena, S. and Siegel, D.A. 2005. Consistent Merging of Satellite Ocean Colour Data Sets Using a Bio-Optical Model. Remote Sensing of Environment, 94, 4, 429-440.

Maritorena S., O. Hembise Fanton d Andon, A. Mangin, and D.A. Siegel. 2010. Merged Satellite Ocean Color Data Products Using a Bio-Optical Model: Characteristics, Benefits and Issues. Remote Sensing of Environment, 114, 8: 1791-1804.

Related products

The MERIS/OLCI TSM product is computed from the back-scattering coefficient at 444 nm using the following assumptions: BP = BBP/0.015, TSM = 1.73*BP. Therefore the BBP variable issued from the GSM algorithm is closely related to TSM. SPM-OC5 provides the inorganic suspended particulate matter, a product closely linked to bbp, according to the OC5 algorithm.

The OSS2015 demonstration products include backscattering coefficients at several wavelength computed by the Non-Spectral Algorithm of Loisel et al. 2006.

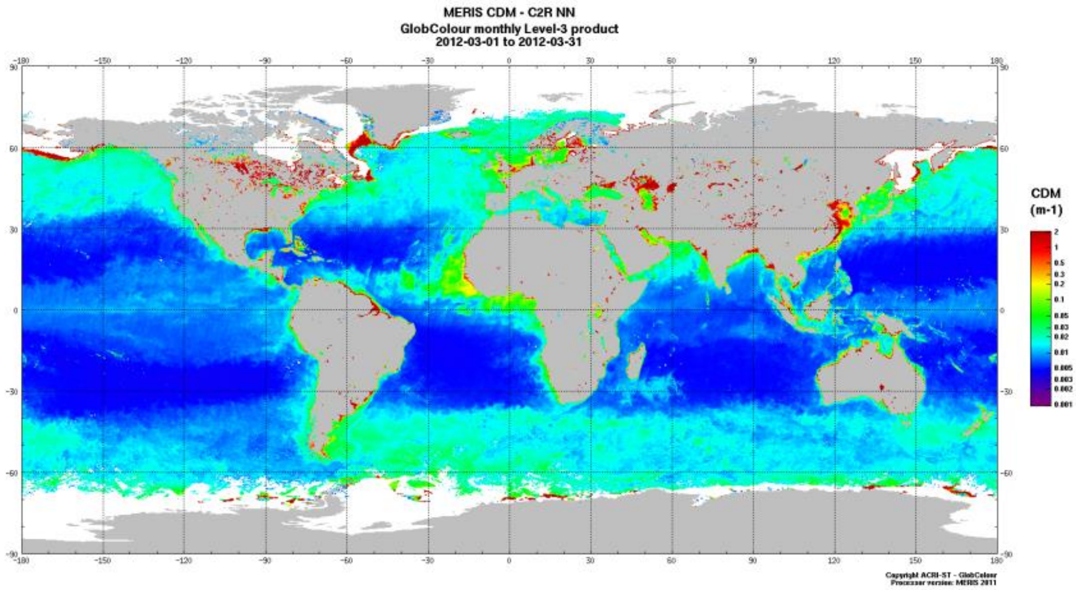
Other GSM algorithm outputs: CHL1 (GSM), CDM

(1): OLCI GSM products are experimental for the moment (we use MERIS uncertainties)

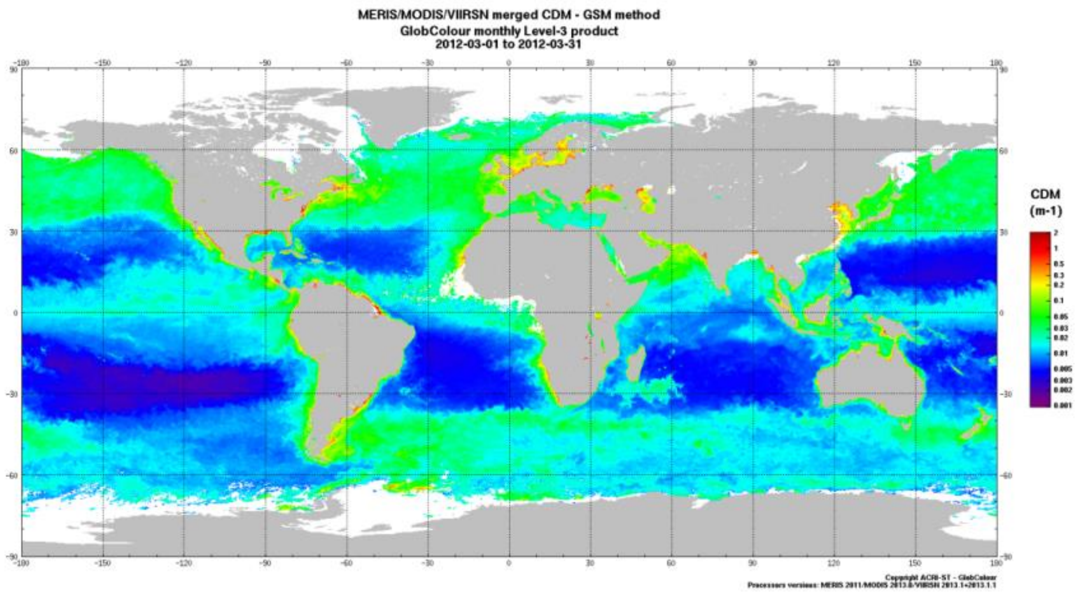
2.2.18 CDM

Category	Ocean Subsurface Optical	PARAMETER	BBP
Description		L3 merging method	Sensor availability
CDM is the absorption coefficient (m^{-1}) of Coloured Dissolved and detrital organic Materials at the reference wavelength of λ0 = 443 nm.		AV GSM	MER OLA MER MOD SWF VIR OLA(1)

MERIS



GSM



Algorithm	Reference
MER: MERIS Neural Network algorithm	Doerffer and Schiller (2007)
OLA: OLCI Neural Network algorithm	OLCI guide
GSM: GSM merging of single sensor L3 NRRS. The GSM method uses the normalized reflectances at the original sensor wavelengths, without intercalibration. CDM is one of the outputs of the method, in addition to BBP and CHL1.	Maritorena et al. 2010

References

The MERIS Case 2 water algorithm, R. Doerffer, H. Schiller, International Journal of Remote Sensing, Vol. 28, Iss. 3-4, 2007, doi:10.1080/01431160600821127

Maritorena, S. and Siegel, D.A. 2005. Consistent Merging of Satellite Ocean Colour Data Sets Using a Bio-Optical Model. Remote Sensing of Environment, 94, 4, 429-440.

Maritorena S., O. Hembise Fanton d Andon, A. Mangin, and D.A. Siegel. 2010. Merged Satellite Ocean Color Data Products Using a Bio-Optical Model: Characteristics, Benefits and Issues. Remote Sensing of Environment, 114, 8: 1791-1804.

OLCI guide: https://earth.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-2/ocean-processing

Related products

Other MERIS/OLCI Neural Network outputs: CHL2, TSM

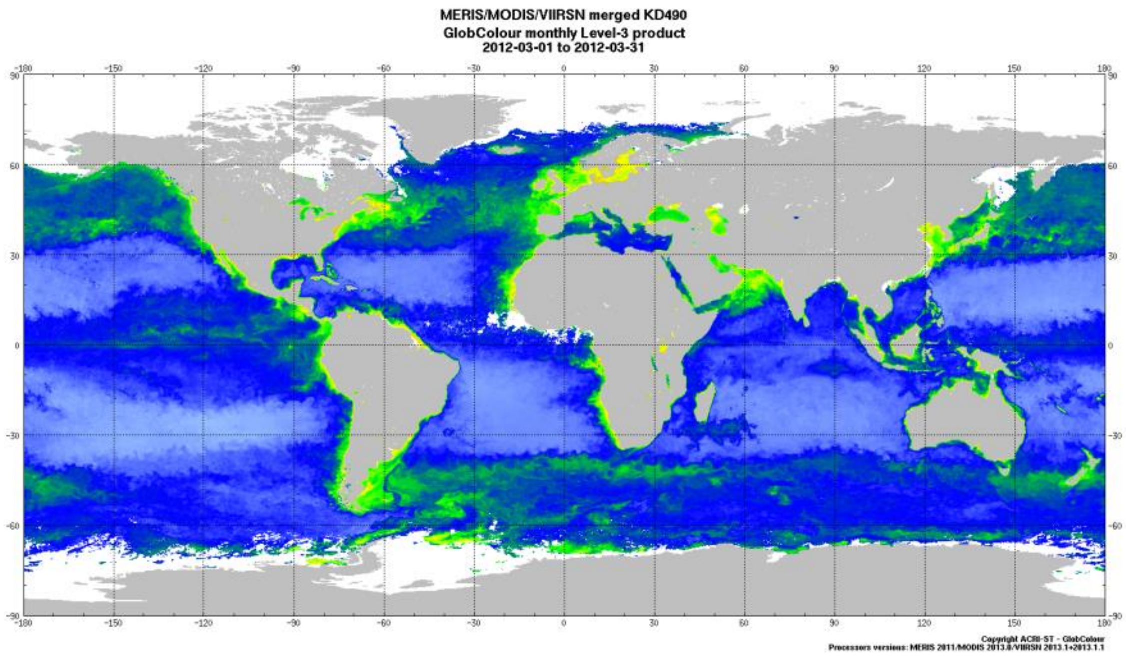
Other GSM algorithm outputs: CHL1 (GSM), BBP

(1): OLCI GSM products are experimental for the moment (we use MERIS uncertainties)

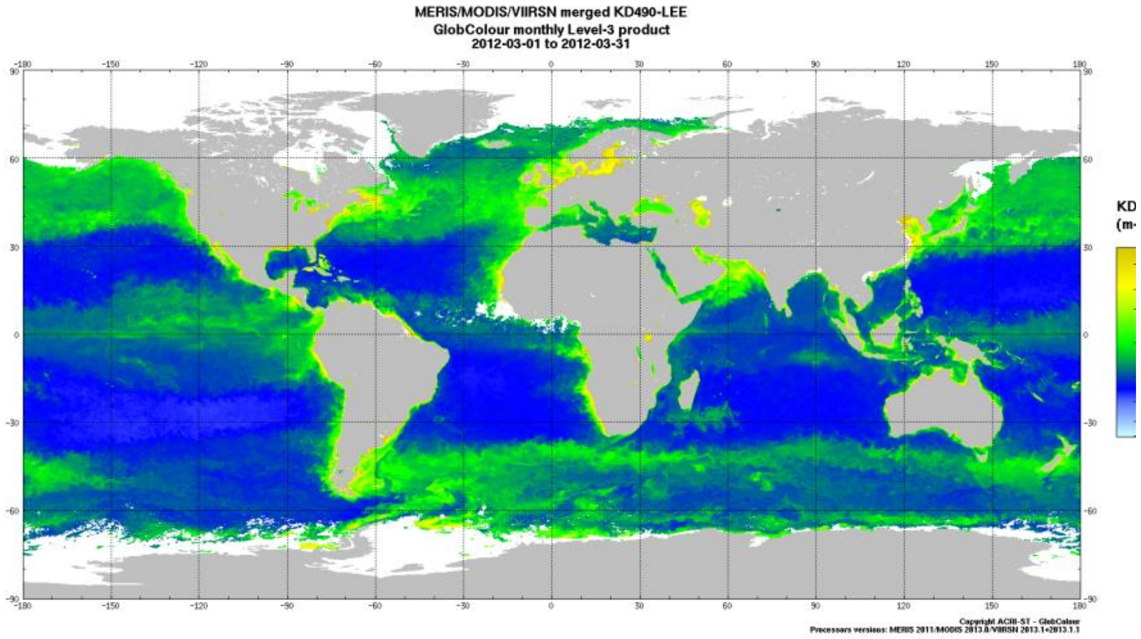
2.2.19 KD490

Category	Ocean Subsurface Optical	PARAMETER	KD490, KD490-LEE
Description		L3 merging method	Sensor availability
Kd(490) is the diffuse attenuation coefficient (m^{-1}) of the downwelling irradiance at 490 nm. It is one indicator of the turbidity of the water column. KD490 is computed according to the Morel algorithm, while KD490-LEE is computed from the Lee and Arnone algorithm.		AN	MER MOD SWF VIR
KD490-M07 is coming from the OLCI Level-2 algorithm.		AV	OLA

KD490 (Morel)



KD490-LEE



Algorithm	Reference
KD490 is computed from the corresponding merged CHL1 products (weighted method), using the following empirical formula: $KD490 = 0.0166 + 0.08349 * CHL1^{0.63303}$ A similar formula with slightly different coefficients is described in Morel et al. (2007).	Morel, 2006
KD490-LEE is computed from the corresponding merged fully normalised remote sensing reflectance products at 443, 490, 555 and 670 nm using the semi-analytical method of Lee and Arnone.	Lee and Arnone, 2005

References

Andre Morel, personnal communication, June 2006.

Andre Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, Remote Sensing of Environment, 111 (2007), 69-88, doi:10.1016/j.rse.2007.03.012

Zhong-Ping Lee, Ke-Ping Du and Robert Arnone (2005) A model for the diffuse attenuation coefficient of downwelling irradiance. JOURNAL OF GEOPHYSICAL RESEARCH. VOL. 110, C02016, doi:10.1029/2004JC002275, 2005

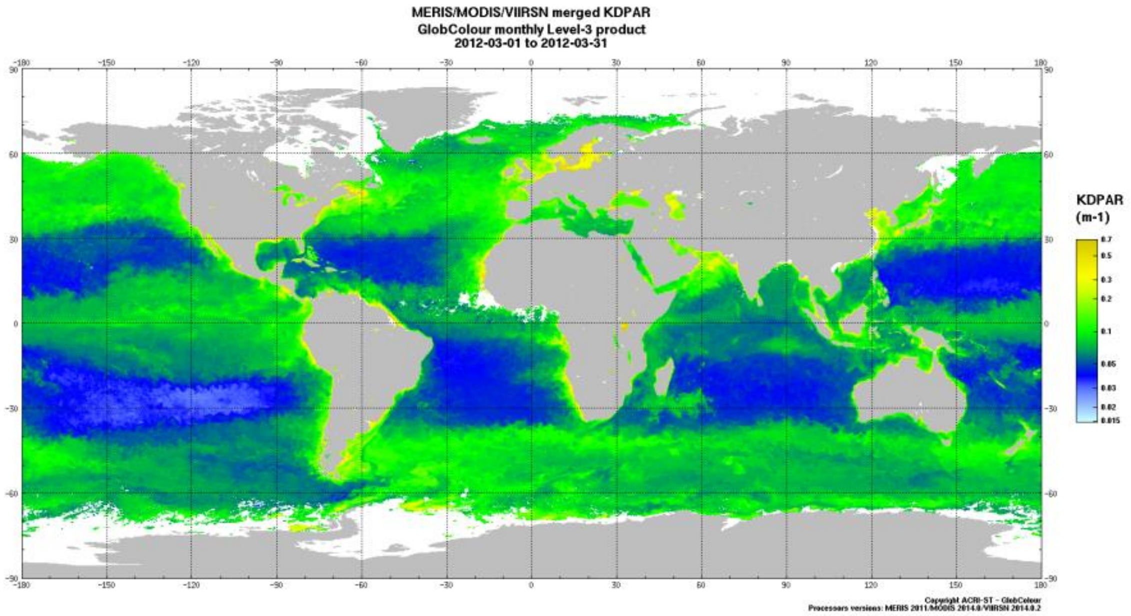
Related products

KDPAR provides the diffuse attenuation coefficient of the Photosynthetically Available Radiation.

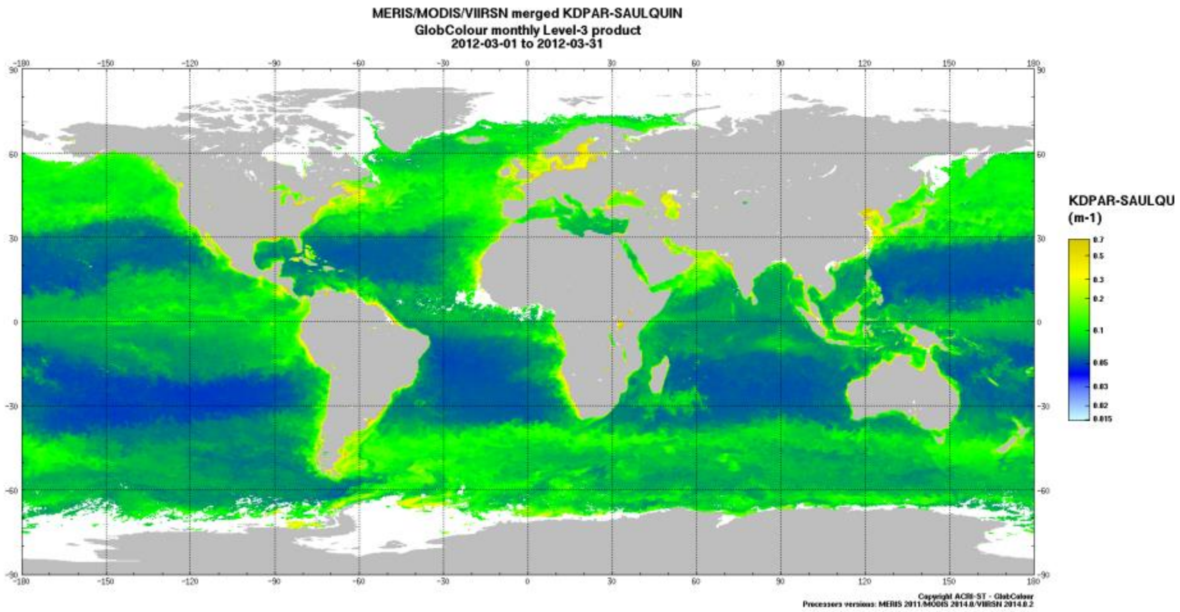
2.2.20 KDPAR

Category	Ocean Subsurface Optical	PARAMETER	KDPAR
Description		L3 merging method	Sensor availability
KdPAR is the diffuse attenuation coefficient (m^{-1}) of the downwelling Photosynthetically Available Radiation in the 400 to 700 nm range. KDPAR is computed according to the Morel algorithm, while KDPAR-SAULQUIN is computed from the Saulquin algorithm.		AN	MER MOD SWF VIR OLA

KDPAR (Morel)



KDPAR-SAULQUIN



Algorithm	Reference
The merged KDPAR (Morel) is computed from the corresponding merged KD490 (Morel) product, using the following equation: KDPAR = 0.0665 + 0.874 * Kd(490) - 0.00121 / Kd(490)	Morel et al. 2007
KDPAR-SAULQUIN is computed from the KD490-LEE product, using the following equations: for KD490-LEE <= 0.115 m-1: KDPAR-SAULQUIN = 4.6051 * Kd(490) / (6.07 * Kd(490) + 3.2) for KD490-LEE > 0.115 m-1: KDPAR-SAULQUIN = 0.81 * $Kd(490)^{0.8256}$	Saulquin, 2013

References

Andre Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, Remote Sensing of Environment, 111 (2007), 69-88, doi:10.1016/j.rse.2007.03.012

Saulquin B., Hamdi A, Gohin F., Populus J., Mangin, A. and Fanton d Andon O., 2013: Estimation of the diffuse attenuation coefficient KdPAR using MERIS and application to seabed habitat mapping. Remote Sensing of Environment, pp. 224-233.

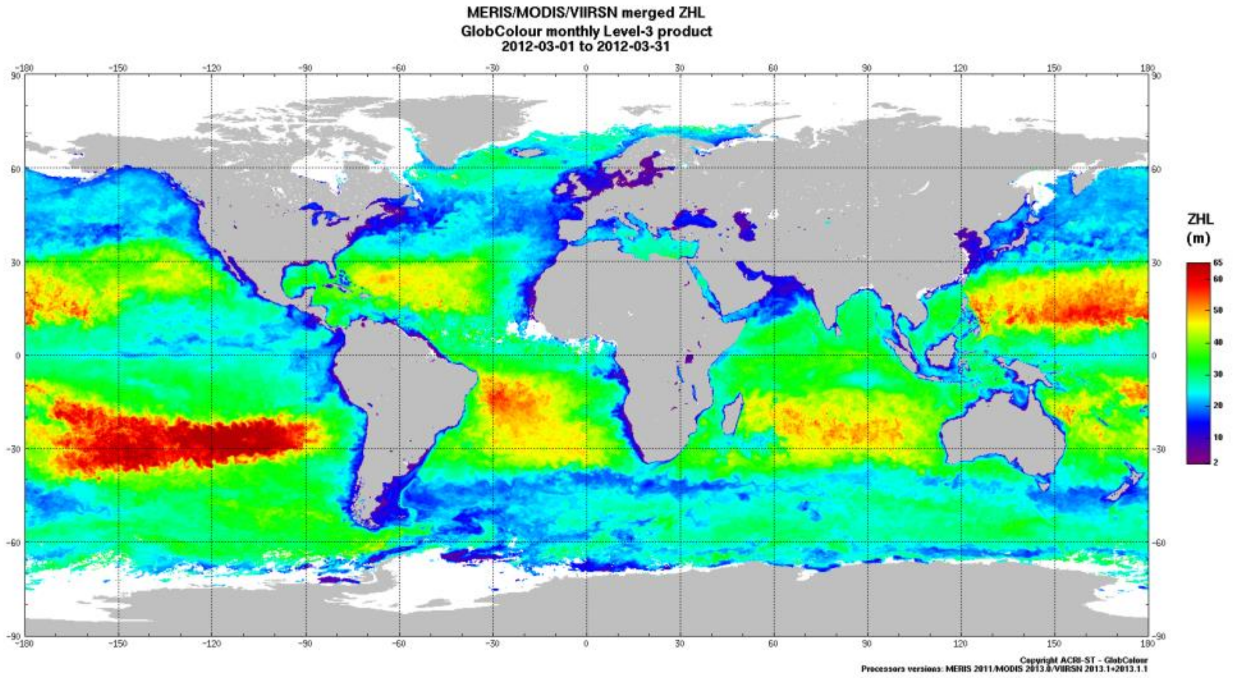
Related products

KDPAR (Morel) is computed from KD490.

KDPAR-SAULQUIN is computed from KD490-LEE.

2.2.21 ZHL

Category	Ocean Subsurface Optical	PARAMETER	ZHL
Description		L3 merging method	Sensor availability
ZHL is the depth of the bottom of the heated layer (m).		AN	MER MOD SWF VIR OLA



Algorithm	Reference
ZHL is computed from the corresponding merged KDPAR MOREL product, using the following equation: ZHL = 2 / KDPAR	Morel et al. 2007

References

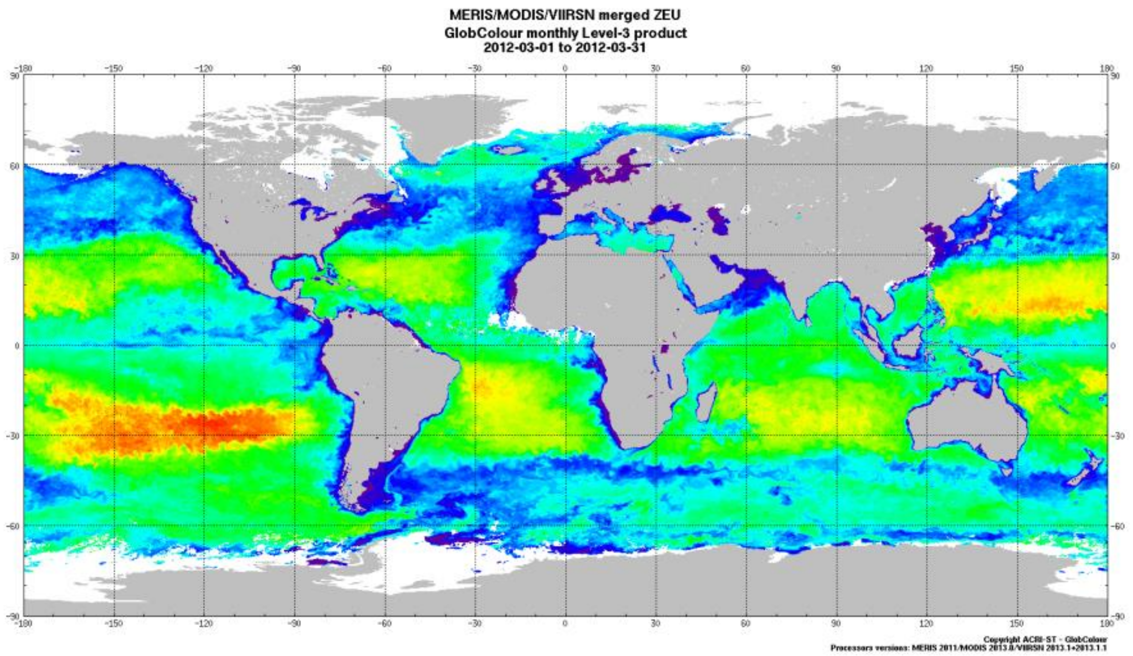
Andre Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, Remote Sensing of Environment, 111 (2007), 69-88, doi:10.1016/j.rse.2007.03.012

Related products

ZHL is computed from KD490.

2.2.22 ZEU

Category	Ocean Subsurface Optical	PARAMETER	ZEU
Description		L3 merging method	Sensor availability
ZEU is the depth of the euphotic layer (m), i.e. the depth for which the down-welling irradiance is 1% of its value at the surface. It characterizes the upper layer of the ocean which can support phytoplankton photosynthesis. It depends on the turbidity of the water.		AN	MER MOD SWF VIR OLA



Algorithm	Reference
ZEU computed from the corresponding merged CHL1 products (weighted method), using the following empirical equation: $ZEU = 10^{1.524-0.436y-0.0145y^2+0.0186y^3}$ with $y = \log_{10}(CHL1)$	Morel et al. 2007

References

Andre Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, Remote Sensing of Environment, 111 (2007), 69-88, doi:10.1016/j.rse.2007.03.012

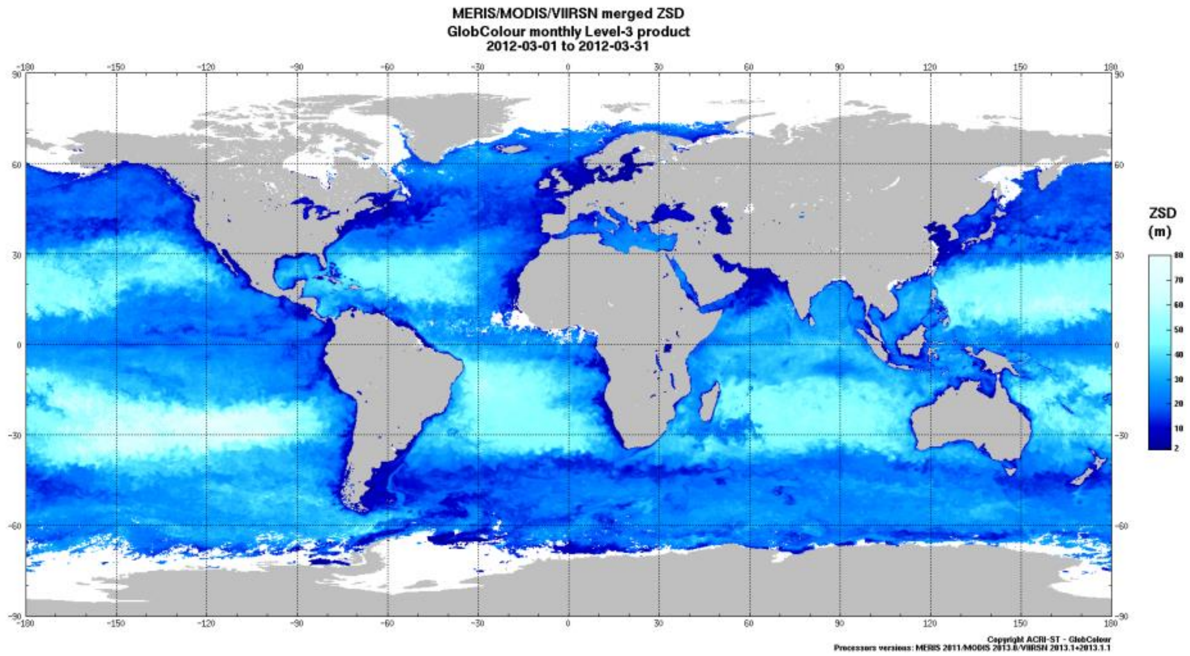
Related products

ZHL is computed from KD490.

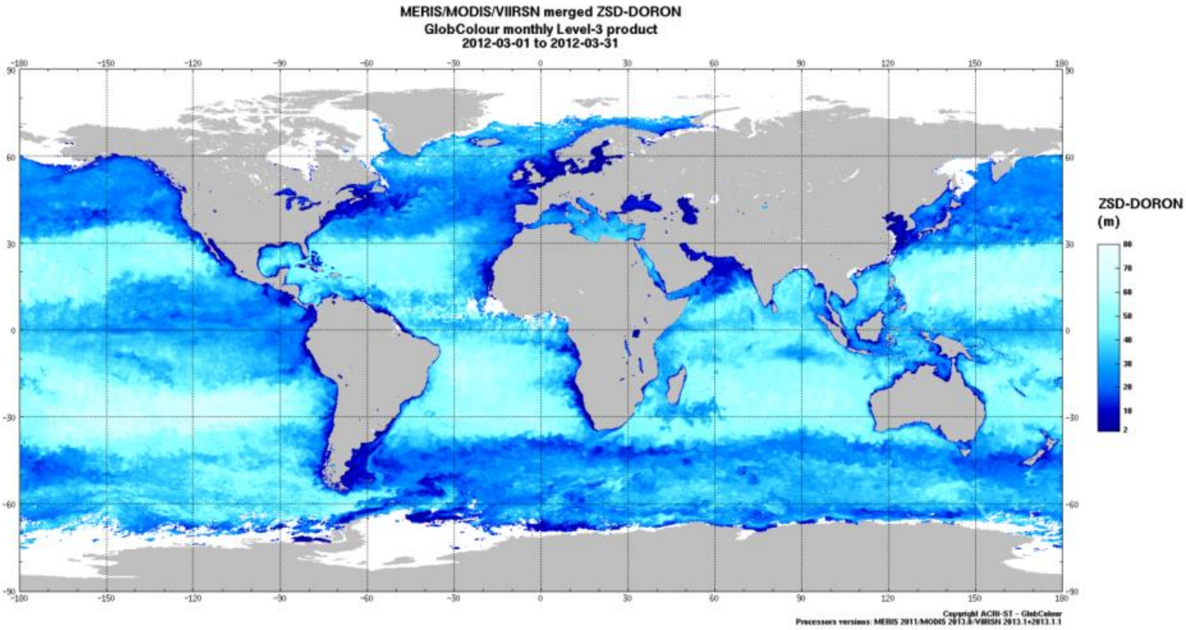
2.2.23 ZSD

Category	Ocean Subsurface Optical	PARAMETER	ZSD, ZSD-DORON
Description		L3 merging method	Sensor availability
ZSD is the Secchi Disk depth (m). It represents the maximum depth at which a calibrated black and white disk (the so-called Secchi disk) is still visible from the surface. As such, it is a good indication of the maximum depth of underwater vertical visibility. Two algorithms are available. ZSD is computed according to the Morel et al. algorithm, and ZSD-DORON according to Doron et al.		AN	MER MOD SWF VIR OLA

ZSD (Morel et al.)



ZSD-DORON (Doron et al.)



Algorithm	Reference
ZSD is computed from the corresponding merged CHL1 products (weighted method), using the following empirical equation: $ZSD = 8.5 - 12.6y + 7.36y^2 - 1.43y^3$ with $y = \log_{10}(CHL1)$	Morel et al. 2007
The merged ZSD DORON is computed from the corresponding merged fully normalised remote sensing reflectance products at 490 and 555 nm using the DORON method.	Doron et al.

References

Andre Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, Remote Sensing of Environment, 111 (2007), 69-88, doi:10.1016/j.rse.2007.03.012

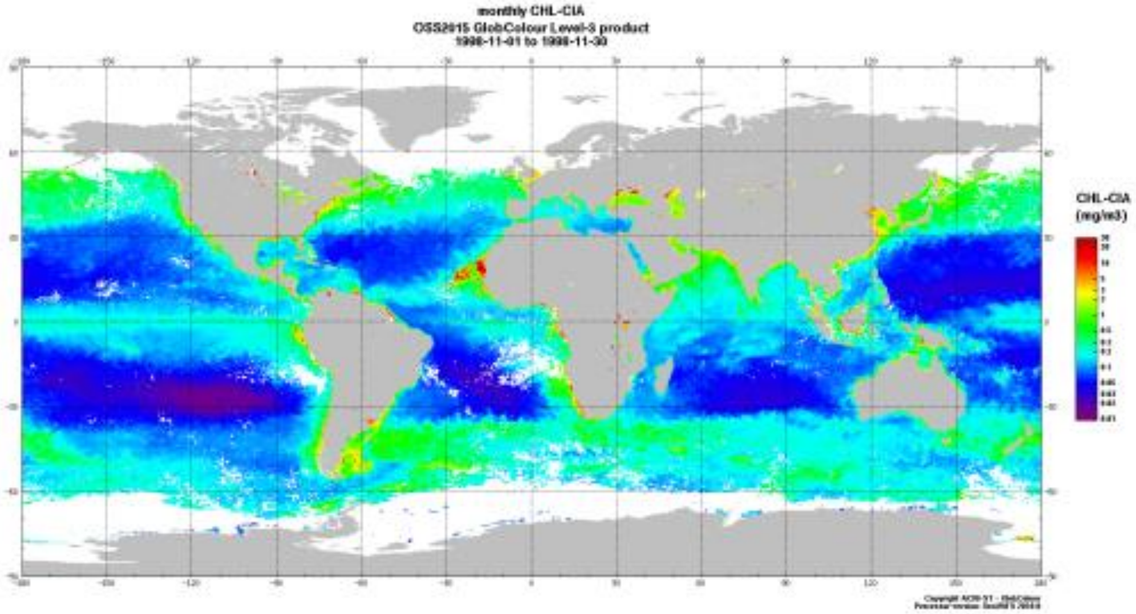
Doron, M., Babin, M., Mangin, A. and O. Fanton d Andon (2006). Estimation of light penetration, and horizontal and vertical visibility in oceanic and coastal waters from surface reflectance. Journal of Geophysical Research, volume 112, C06003, doi: 10.1029/2006JC004007.

Related products

Another parameter linked to light penetration is the euphotic layer depth ZEU.

2.2.24 CHL-CIA

Category	Demonstration Biochemical	PARAMETER	CHL-CIA
Description		L3 merging method	Sensor availability
Chlorophyll concentration (mg/m3) according to Color Index Algorithm (see below). It is commonly used as a proxy for the biomass of the phytoplankton.		AN	MER MOD SWF VIR



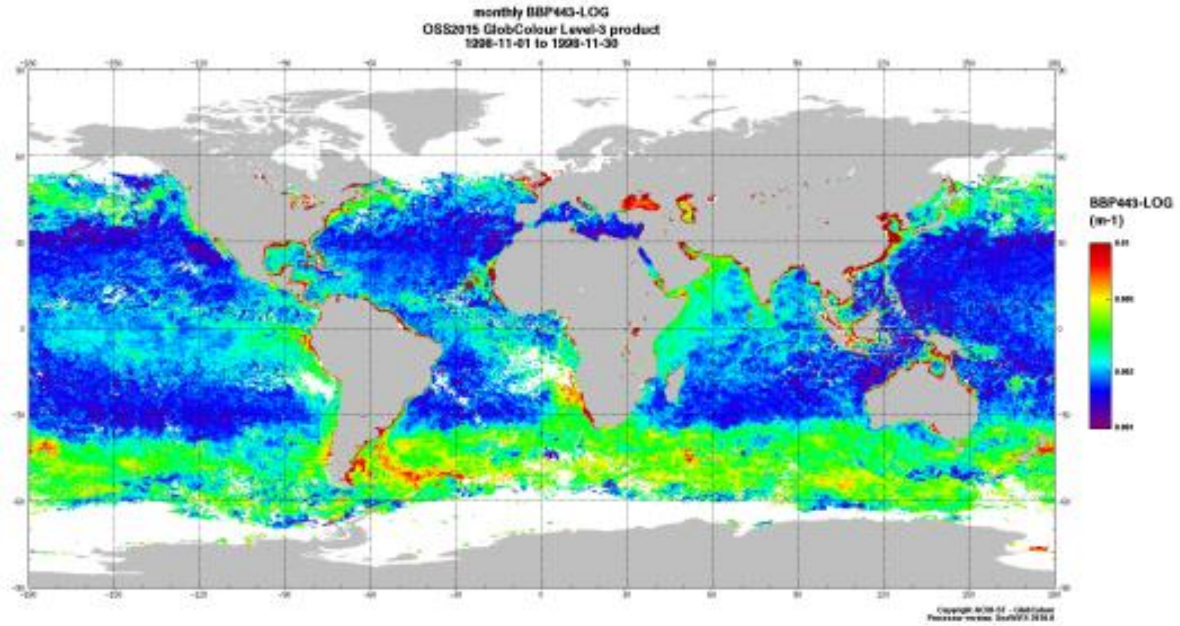
Algorithm	Reference
CHL-CIA is computed from L3 monthly merged products CHL1 (AVW) and NRRS using the Color Index band ratio algorithm. For chlorophyll concentrations higher than 0.3 mg/m^3, CHL-CIA is equal to CHL1. A linear interpolation between the Color Index band ratio algorithm and CHL1 is performed in the range 0.25 to 0.3 mg/m^3.	Hu et al. 2012

References
Hu, C., Lee, Z., and Franz, B., 2012. Chlorophyll a algorithms for oligotrophic oceans: A novel approach bases on three-band reflectance difference. Journal of Geophysical Research, 117, doi:10.1029/2011JC007395.

Related products
Other chlorophyll products available in the GlobColour data set: CHL1 (weighted average and GSM), CHL-OC5, CHL2

2.2.25 BBPxxx-LOG

Category	Demonstration Optical Subsurface	PARAMETER	BBPxxx-LOG
Description		L3 merging method	Sensor availability
BBPxxx-LOG is the particulate back-scattering coefficient (m^{-1}) at wavelengths xxx = 443, 490, 510 and 555 nm. The bbp provide information on the particulate concentration and size distributions.		AN	MER MOD SWF VIR



Algorithm	Reference
BBPxxx-LOG uses the Non Spectral Algorithm, based on a Neural Network approach. The product is computed from the monthly merged L3 reflectances NRRSxxx.	Loisel et al. 2006

References

H. Loisel, J.-M. Nicolas, A. Sciandra, D. Stramski, and A. Poteau. 2006. Spectral dependency of optical backscattering by marine particles from satellite remote sensing of the global ocean, Journal of Geophysical Research, 111, C09024, doi:10.1029/2005JC003367

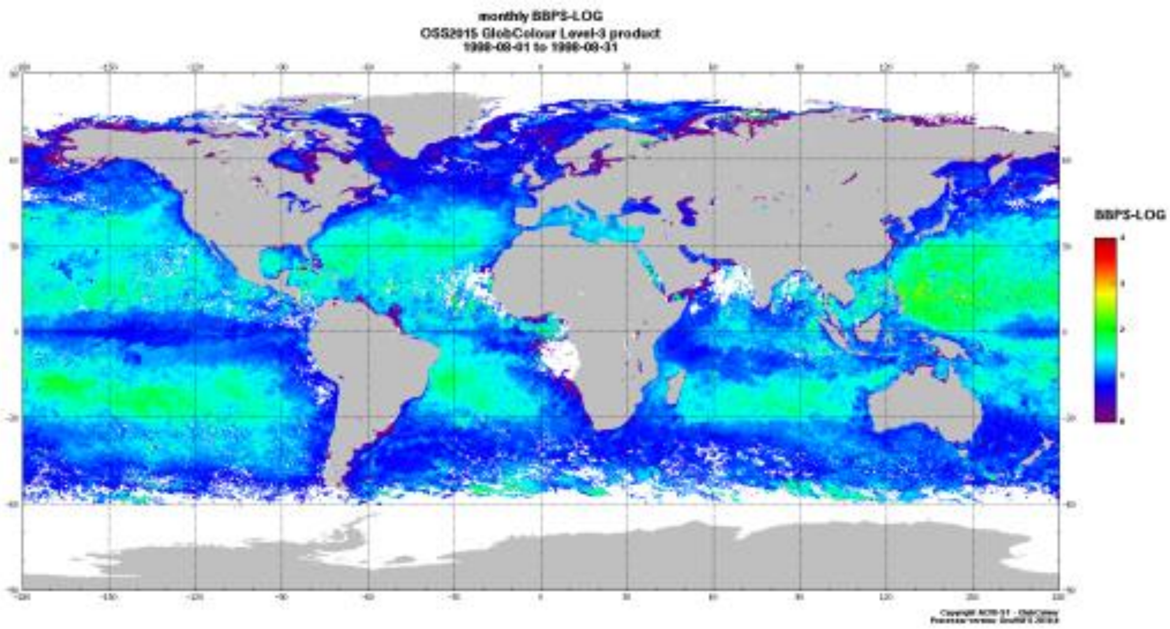
Related products

The GlobColour BBP product provides the backscattering coefficient at 443 nm determined from the GSM approach. TSM provides the total suspended matter, a product closely linked to bbp, according to the MERIS/OLCI Neural Network algorithm. SPM-OC5 provides the inorganic suspended particulate matter, a product closely linked to bbp, according to the OC5 algorithm.

The OSS2015 products BBPS and PSD are computed from the BBPxxx-LOG.

2.2.26 BBPS-LOG

Category	Demonstration Optical Subsurface	PARAMETER	BBPS-LOG
Description		L3 merging method	Sensor availability
BBPS-LOG provides the spectral exponent (logarithmic slope) of the particulate back-scattering coefficient. BBPS provides information about the size distribution of particles.		AN	MER MOD SWF VIR



Algorithm	Reference
BBPS-LOG is computed by linear regression of log(BBPxxx-LOG) at 443, 490, 510 and 555 nm.	Loisel et al. 2006

References

H. Loisel, J.-M. Nicolas, A. Sciandra, D. Stramski, and A. Poteau. 2006. Spectral dependency of optical backscattering by marine particles from satellite remote sensing of the global ocean, Journal of Geophysical Research, 111, C09024, doi:10.1029/2005JC003367

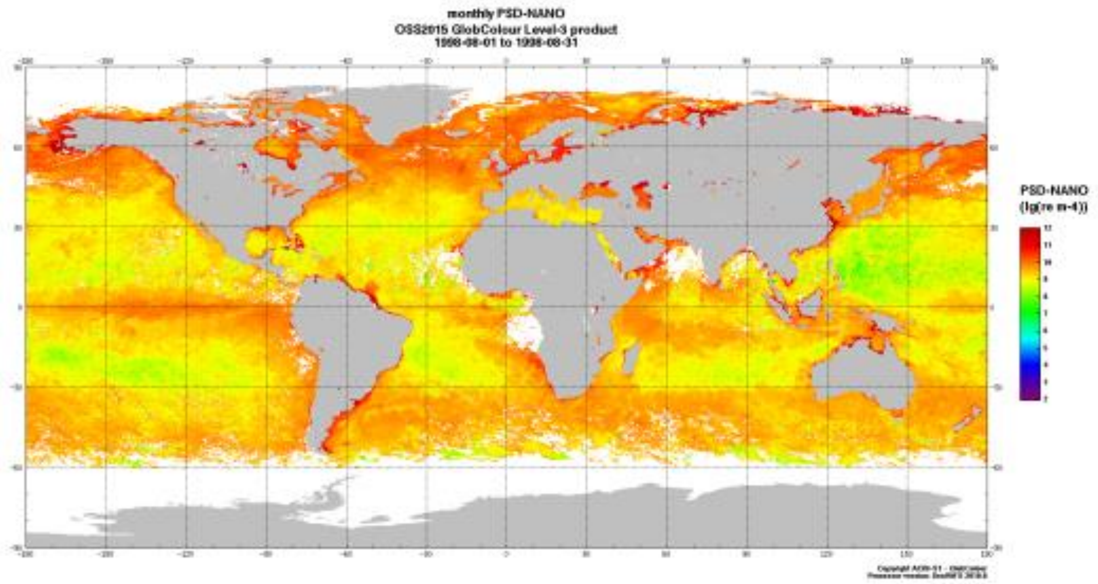
Related products

See the BBPxxx-LOG info sheet for more information on the product.

BBPS-LOG is used to determine the particle size distributions PSD-XXX

2.2.27 PSD-XXX

Category	Demonstration Biochemical	PARAMETER	PSD-XXX
Description		L3 merging method	Sensor availability
PSD-XXX (Particle Size Distribution) provide the number density of micro-, nano- and pico-plankton (#/m3) particles in the Ocean, with the following definitions: • Micro: 20 and 50 µm • Nano: between 2 and 20 µm • Pico: between 0.5 and 2 µm		AN	MER MOD SWF VIR



Algorithm	Reference
The PSD products are computed from the BBPS-LOG according to a semi-analytical formula based on the Mie theory.	Loisel et al. 2006 Kostadinov et al. 2009

References

H. Loisel, J.-M. Nicolas, A. Sciandra, D. Stramski, and A. Poteau. 2006. Spectral dependency of optical backscattering by marine particles from satellite remote sensing of the global ocean, Journal of Geophysical Research, 111, C09024, doi:10.1029/2005JC003367

Kostadinov, T.S., D.A. Siegel, and S. Maritorena. 2009. Retrieval of the Particle Size Distribution from Satellite Ocean Color Observations. Journal of Geophysical Research, VOL. 114, C09015, doi:10.1029/2009JC005303.

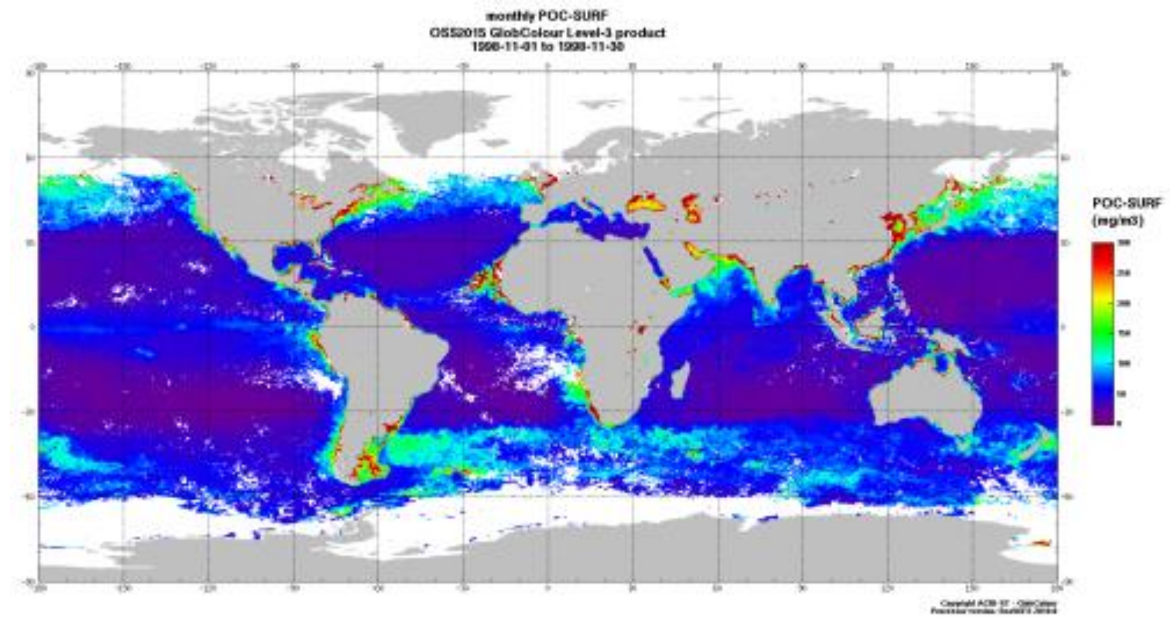
Related products

BBPS-LOG is used to determine the particle size distributions PSD-XXX

Another classification of phytoplankton (according to the functional types) is provided by the PHYSAT product.

2.2.28 POC-SURF

Category	Demonstration Biochemical	PARAMETER	POC-SURF
Description		L3 merging method	Sensor availability
POC-SURF is the Particulate Organic Carbon (mol/m^3) at sea surface. POC is an important component in the carbon cycle and serves as a primary food sources for aquatic food webs.		AN	MER MOD SWF VIR



Algorithm	Reference
POC-SURF is computed from monthly merged L3 reflectances NRRS using a band ratio algorithm.	Stramski et al. 2008

References

Stramski. D., R.A. Reynolds, M. Babin, S. Kaczmarek, M.R. Lewis, R. Rottgers, A. Sciandra, M. Stramska, M.S. Twardowski, B.A. Franz, and H. Claustre (2008). Relationships between the surface concentration of particulate organic carbon and optical properties in the eastern South Pacific and eastern Atlantic Oceans, Biogeosci., 5, 171-201.

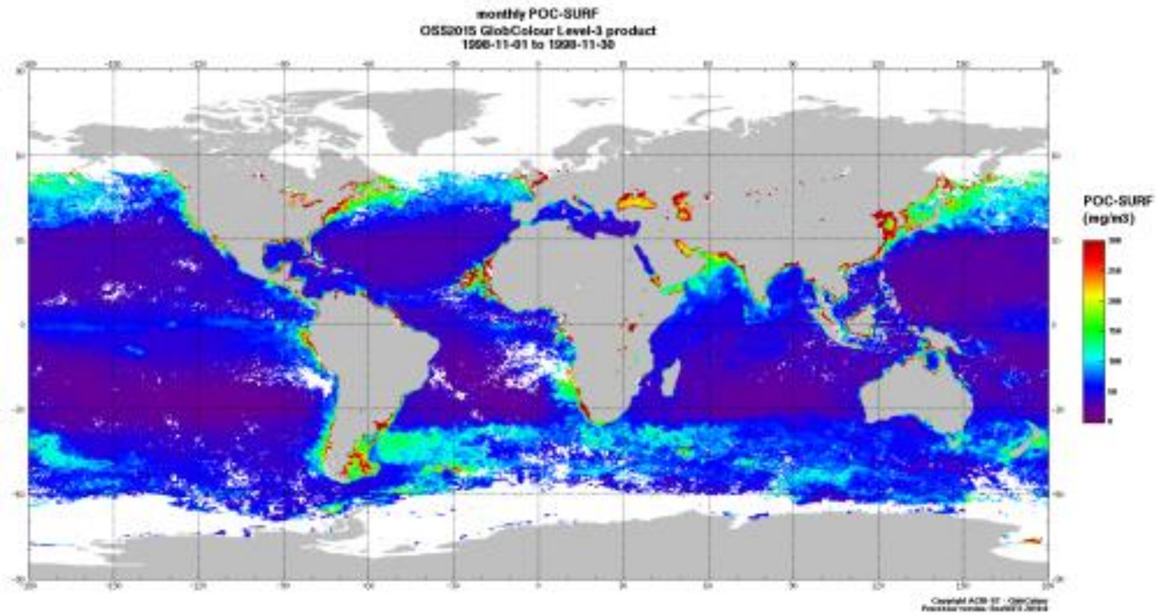
Related products

The OSS2015 product POC-SURF is equivalent to the GlobColour POC product but it is computed in a different way (from monthly merged reflectances). POC-SURF uses data from MERIS.

POC-SURF is used to compute the column integrated product POC-INT.

2.2.29 POC-INT

Category	Demonstration Biochemical	PARAMETER	POC-INT
Description		L3 merging method	Sensor availability
POC-INT is the Particulate Organic Carbon integrated over the vertical water column (mol/m^2). POC is an important component in the carbon cycle and serves as a primary food sources for aquatic food webs.		AN	MER MOD SWF VIR



Algorithm	Reference
POC-INT is computed from POC-SURF and from the Mixed Layer Depth World Ocean Atlas Climatology, using an empirical formula.	Duforêt-Gaurier et al. (2010),

References

Duforet-Gaurier L., Loisel H., Dessailly D., Nordkvist K., Alvain S., 2010. Estimates of particulate organic carbon over the euphotic depth from in situ measurements. Application to satellite data over the global ocean. Deep-Sea Research, I 57 (2010) 351-367.

Monterey, G., Levitus, S., 1997. Seasonal Variability of Mixed Layer Depth for the World Ocean. NOAA Atlas NESDIS, vol. 14. U.S. Government Print Office, Washington, DC, 96pp.

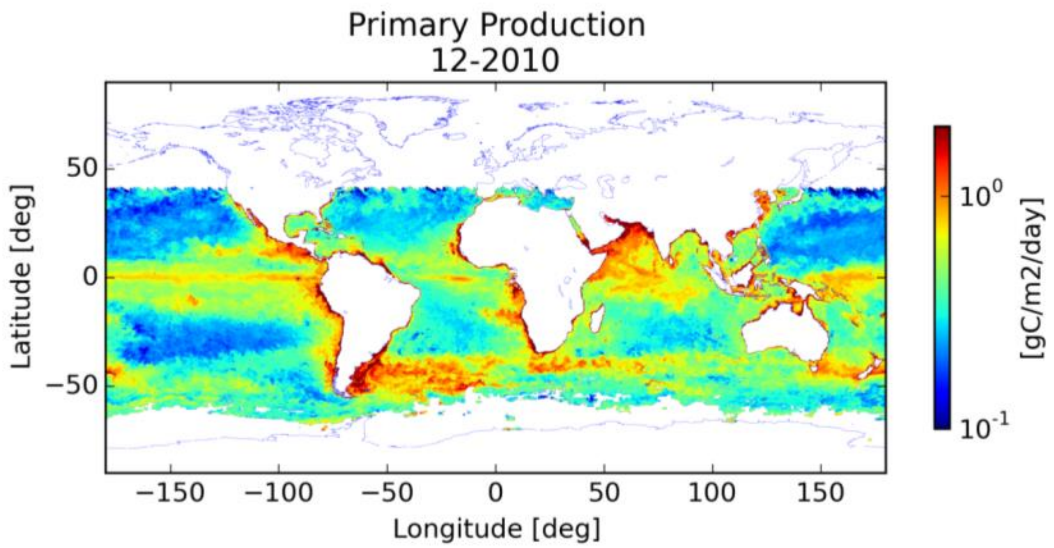
Related products

See the POC-SURF datasheet for information on this product.

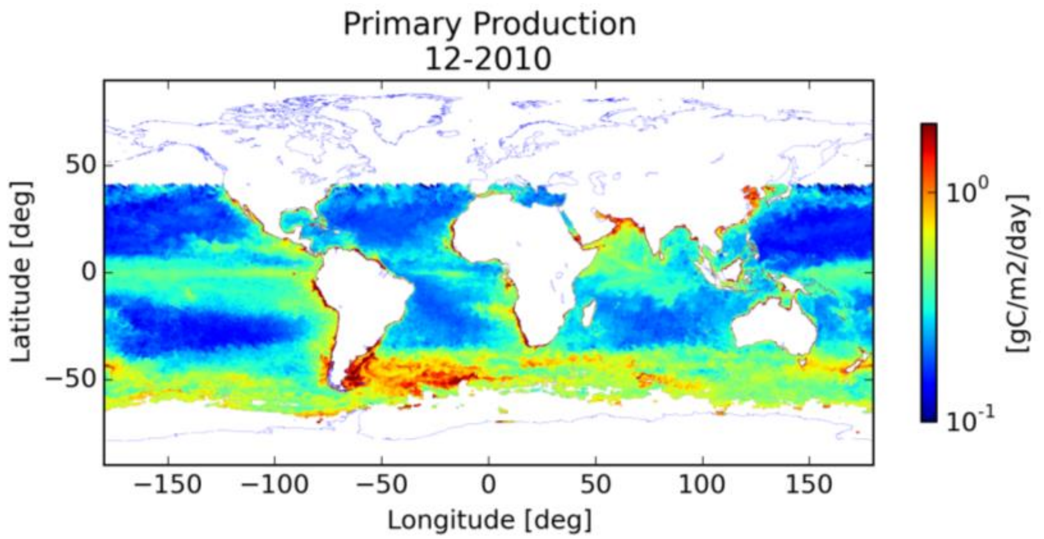
2.2.30 PP-AM, PP-UITZ

Category	Demonstration Biochemical	PARAMETER	PP-AM, PP-UITZ
Description		L3 merging method	Sensor availability
PP is the primary production (gC/m^2/day) of the biomass. Two algorithms are available PP-AM (Antoine and Morel) and PP-UITZ (Uitz et al.) PP-AM and PP-UITZ are available only from the GlobColour ftp server.		AN	MER MOD SWF VIR

PP-AM



PP-UITZ



Algorithm	Reference
PP-AM and PP-UITZ are computed from merged monthly L3 products using the respective algorithms.	Antoine and Morel 1996 Uitz et al. 2008

References

Antoine D. and A. Morel (1996). Oceanic primary production: 1. Adaptation of a spectral light-photosynthesis model in view of application to satellite chlorophyll observations. Global Biogeochemical Cycles, 10: 43-55

Uitz J., Y. Huot, F. Bruyant, M. Babin, and H. Claustre (2008). Relating phytoplankton photophysiological properties to community structure on large scales. Limnology and Oceanography, 53: 614\u2013630

2.2.31 PHYSAT

Category	Demonstration Biochemical	PARAMETER	PHYSAT

Description

PHYSAT is a data set of Phytoplankton functional types.

The freq-xxx products contain the detection frequency of group xxx (0 < freq-xxx < 1):

- 0 = group never detected;
- 1 = all valid pixels are associated with the group

The xxx code refers to the phytoplankton groups:

- Nan: Nanoeucaryotes (group 1)
- Pro: Prochloroccocus (group 2)
- Slc: Synechococcus (group 3)
- Dia: Diatoms (group 4)
- Pha: Phaeocystis-like (group 5)

The GlobalMapOfMonthlyDominantsGroups product contains a map of the dominant (highest detection frequency) group for each month, using the numbering convention defined above.

The PHYSAT data set is available from the GlobColour Ftp server only.

References

Ben Mustapha Z., Alvain S., Jamet C, Loisel H. and D. Dessailly. Automatic classification of water-leaving radiance anomalies from global SeaWiFS imagery: Application to the detection of phytoplankton groups in open ocean waters, RSE-08794, 2014

2.3 The spatial and temporal coverage

2.3.1 The binned products

The GlobColour level-3 binned products have a resolution of 1/24° at the equator (i.e. around 4.63 km) for global products and of 1/96° (i.e. around 1.16 km) for Europe products. They 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. 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. The spatial resolutions of global and Europe products yield to the following grid characteristics:

Area	GLOBAL	Europe
Average bin size:	4.63 km	1.16 km
Average bin area:	21.44 km^2	1.35 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	28,307,867

Table 2-5: Main characteristics of the ISIN grids

2.3.2 The mapped products

The GlobColour level-3 mapped products have a resolution of 1/24°, 0.25° or 1.0° (i.e. respectively around 4.63 km, 28 km and 111 km at the equator) for global products and of 0.015°x0.01° for Europe products. They 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.

3 The GlobColour system

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 the global and Europe ISIN grids. 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 are 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 preprocessor 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 preprocessor serves for example in the case of MERIS/OLCI and wherever requested to transform the L2 normalised water leaving reflectances into fully normalised remote sensing reflectance. 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 3-1.

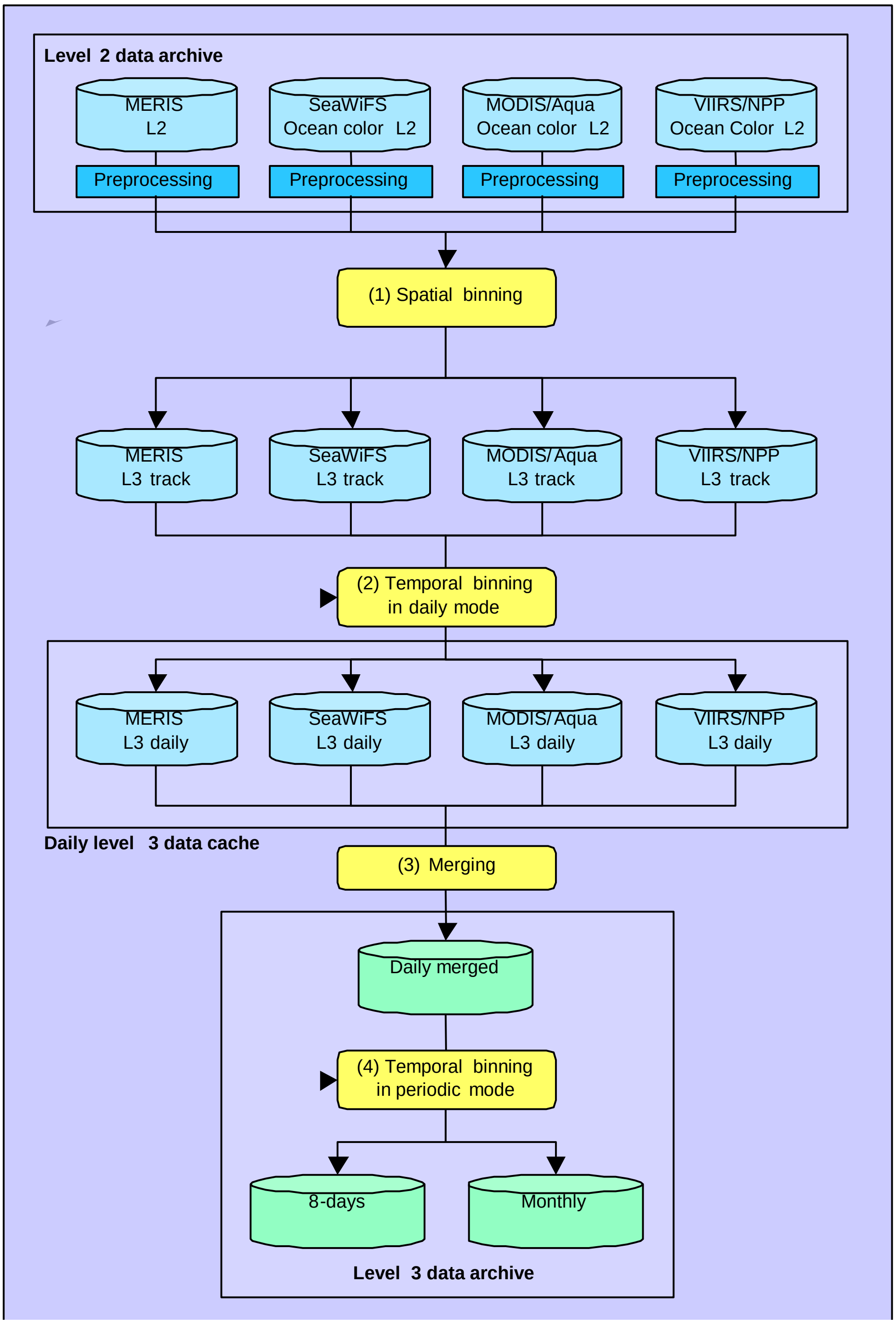


Figure 3-1: The GlobColour processor high-level description

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/OLCI normalised water leaving reflectances must be converted into fully normalised remote sensing reflectances.

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
NRRS400	Fully normalised remote sensing reflectance at 400 nm	sr-1	OLCI (pp1)
NRRS412	Fully normalised remote sensing reflectance at 412 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS443	Fully normalised remote sensing reflectance at 443 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS490	Fully normalised remote sensing reflectance at 490 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS510	Fully normalised remote sensing reflectance at 510 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS560	Fully normalised remote sensing reflectance at 560 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS620	Fully normalised remote sensing reflectance at 620 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS670	Fully normalised remote sensing reflectance at 670 nm	sr-1	MERIS (pp1) - OLCI (pp1)
NRRS674	Fully normalised remote sensing reflectance at 674 nm	sr-1	OLCI (pp1)
NRRS681	Fully normalised remote sensing reflectance at 681 nm	sr-1	OLCI (pp1)
NRRS709	Fully normalised remote sensing reflectance at 709 nm	sr-1	OLCI (pp1)
RRS681	None normalised remote sensing reflectance at 681 nm	sr-1	MERIS (pp2)
RRS709	None normalised remote sensing reflectance at 709 nm	sr-1	MERIS (pp2)
RRS754	None normalised remote sensing reflectance at 754 nm	sr-1	OLCI (pp2)
RRS779	None normalised remote sensing reflectance at 779 nm	sr-1	OLCI (pp2)
RRS865	None normalised remote sensing reflectance at 865 nm	sr-1	OLCI (pp2)
RRS885	None normalised remote sensing reflectance at 885 nm	sr-1	OLCI (pp2)
RRS1020	None normalised remote sensing reflectance at 1020 nm	sr-1	OLCI (pp2)
LON, LAT, SZA, SAA, VZA, VAA, PRESSURE, WIND	Geometrical characteristics of the observations		MERIS (pp3) - OLCI (pp3)
SZA, SAA	Geometrical characteristics of the observations		MODIS (pp4) - SeaWiFS (pp4) - VIIRS (pp4)

Table 3-1: List of variables with a specific preprocessing

(pp1): MERIS/OLCI fully normalised remote sensing reflectances

The MERIS/OLCI fully normalised remote sensing relfectances are computed from the normalised water leaving reflectances available in the MERIS/OLCI level-2 products.

(pp2): MERIS/OLCI none normalisation remote sensing reflectances.

(pp3): 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/OLCI 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 tasks is to rebuild the characteristics of each pixel at each frame by bilinear interpolation.

(pp4): MODIS, SeaWiFS and VIIRS L2 products now provide LAT/LON for each pixel but SZA and SAA are not available so the preprocessor recomputed them from pixel position and date/time.

The following tables list, for each instrument, all variables coming from the preprocessing module, their symbols and their associated validity equation(s).

For all sensors we consider that a pixel is invalid if the absolute value of its sun zenith angle is greater than 70° (excepting for OC5 products).

Convention: ***FFFF_enlargedX* = *FFFF* flag enlarged by X swath pixels (flag neighbouring pixels at a distance <= X)**

3.2.1 MERIS

For all MERIS products we discard input Level-2 pixels with packed value equal to 0 (except for the flags band).

Convention: CLOUD_HAZE = CLOUD or ICE_HAZE

<table>
<tr><th>Acronym</th><th>Variable</th><th>Validity equation</th></tr>
<tr><td>NRRSxxx
RRSxxx</td><td>Fully (or None) normalised remote sensing reflectance at xxx nm</td><td>WATER
and not (PCD_19_WHITECAPS15 [Note 1]
or CLOUD_HAZE_enlarged2
or HIGH_GLINT_enlarged2
or ABSOA_DUST)</td></tr>
<tr><td>CHL1</td><td>Chlorophyll concentration (from OC4Me)</td><td>WATER
and not (PCD_15_WHITECAPS15 [Note 1]
or CLOUD_HAZE_enlarged2
or HIGH_GLINT_enlarged2
or ABSOA_DUST
or WHITE_SCATTERER)</td></tr>
<tr><td>CHL2</td><td>Chlorophyll concentration (from Neural Net)</td><td rowspan="3">WATER
and not (PCD_17 for CHL2 or PCD_16 for CDM/TSM
or CLOUD_enlarged2
or HIGH_GLINT_enlarged2
or ice from climatology)</td></tr>
<tr><td>CDM</td><td>Coloured dissolved and detrital organic materials absorption coefficient (from Neural Net)</td></tr>
<tr><td>TSM</td><td>Total suspended matter concentration (from Neural Net)</td></tr>
<tr><td>CHL-OC5</td><td>Chlorophyll concentration (from OC5)</td><td>WATER
and not (HIGH_GLINT
or ABSOA_DUST</td></tr>
</table>

SPM-OC5	Inorganic suspended particulate matter (from OC5)	or COSMETIC or SUSPECT) and use 78° as maximum sun zenith angle and specific noise filter
WVCS	Total water vapor column over clear sky	(WATER or LAND) and not (PCD14 or CLOUD_HAZE_enlarged2 or TOAVI_CSI_enlarged2 or HIGH_GLINT_enlarged2)
T865	Aerosol optical thickness over water	WATER and not (PCD_19_WHITECAPS15 [Note 1] or CLOUD_HAZE_enlarged3 or HIGH_GLINT_enlarged2) and **[** CASE2_S or not (WHITE_SCATTERER or CASE2_ANOM) **]**
A865	Angstrom alpha coefficient over water	
T443	Aerosol optical thickness over land	LAND and not (PCD19 or CLOUD_enlarged3 or TOAVI_CSI_enlarged3) and [Note 2]
A443	Angstrom alpha coefficient over land	
CF	Cloud fraction	WATER or CLOUD
ABSD	ABSOA_DUST flag statistics	WATER and not (PCD_19_WHITECAPS15 [Note 1] or HIGH_GLINT) and **[** CASE2_S or not (WHITE_SCATTERER or CASE2_ANOM) **]**

Table 3-2: List of parameters and filters applied to the MERIS level 2 data

Note 1: PCD_15_WHITECAPS15 and PCD_19_WHITECAPS15 are respectively recomputed PCD_15 and PCD_19 flags modified to accept wind speed modulus up to 15 m/s instead of 10 (WHITECAPS is an intermediary internal L2 processing flag raised when the wind speed modulus is greater than the threshold). Detailed definition:

- PCD_15_ WHITECAPS15 = PCD_18 or CASE2ANOM or CASE2Y or (T865 > 0.6)
  or (wind speed modulus > 15)
- PCD_19_ WHITECAPS15 = PCD_18 or (wind speed modulus > 15)

Note 2: Santer & Vidot aerosol over land algorithm implementation:

- discard pixel if A865 (with scale/offset applied) not in [0, 2.5]
- apply a standard deviation filter on T865 (with scale/offset applied) on a 9x9 box: discard the pixel if it is not in [mean – max(2*stddev, scale), mean + max(2*stddev, scale)], with mean and stddev computed using all T865 valid pixels. The term max(2*stddev, scale) allows to handle homogeneous areas (we don't want discard all pixels if stddev is very small).

3.2.2 OLCI

OLCI parameters validity equations are based on The Sentinel-3A Product Notice – OLCI Level-2 Ocean Colour

Conventions:

CLOUDS = CLOUD or CLOUD_AMBIGUOUS or CLOUD_MARGIN

COMMON_FLAGS = CLOUDS or INVALID or COSMETIC or SATURATED or SUSPECT
or HIGHGLINT or SNOW_ICE or AC_FAIL or WHITECAPS
or ANNOT_ABSO_D or ANNOT_MIXR1 or ANNOT_DROUT or ANNOT_TAU06
or RWNEG_O2..O8

Acronym	Variable	Validity equation
NRRSxxx RRSxxx	Fully (or None) normalised remote sensing reflectance at xxx nm	(WATER or INLAND_WATER) and not COMMON_FLAGS
CHL1	Chlorophyll concentration (from OC4Me)	(WATER or INLAND_WATER) and not (COMMON_FLAGS or OC4ME/KDM_FAIL)
KD490-M07	Diffuse attenuation coefficient (from M07)	
CHL2	Chlorophyll concentration (from Neural Net)	(WATER or INLAND_WATER) and not (OCNN_FAIL or INVALID or COSMETIC or SATURATED or SUSPECT or CLOUDS or HIGHGLINT)
CDM	Coloured dissolved and detrital organic materials absorption coefficient (from Neural Net)	
TSM	Total suspended matter concentration (from Neural Net)	
CHL-OC5	Chlorophyll concentration (from OC5)	(WATER or INLAND_WATER) and not (HIGHGLINT or ANNOT_ABSO_D or COSMETIC or SUSPECT) and use 78° as maximum sun zenith angle and specific noise filter
SPM-OC5	Inorganic suspended particulate matter (from OC5)	
WVCS	Total water vapor column over clear sky	(WATER or INLAND_WATER or LAND) and not (WV_FAIL or CLOUDS or MEGLINT)
T865	Aerosol optical thickness over water	(WATER or INLAND_WATER) and not COMMON_FLAGS
A865	Angstrom alpha coefficient over water	
CF	Cloud fraction	WATER or INLAND_WATER or CLOUD
ABSD	ABSOA_DUST flag statistics	(WATER or INLAND_WATER) and not (COMMON_FLAGS *excepting ANNOT_ABSO_D* or ANNOT_ACLIM)

Table 3-3: List of parameters and filters applied to the OLCI level 2 data

3.2.3 MODIS/SeaWiFS/VIIRS

Acronym	Variable	Validity equation
NRRSxxx	Fully normalised remote sensing reflectance at xxx nm	not (ATMFAIL or LAND or HILT or HISATZEN or STRAYLIGHT or CLDICE or COCCOLITH or LOWLW or CHLFAIL or CHLWARN or NAVWARN or MAXAERITER or ATMWARN or NAVFAIL or FILTER or HIGLINT)
CHL1	Chlorophyll concentration	
POC	Particulate Organic Carbon	
T865	Aerosol optical thickness over water	
A865	Angstrom alpha coefficient over water	
PIC	Particulate Inorganic Carbon	not (ATMFAIL or LAND or HISATZEN or STRAYLIGHT or CLDICE or LOWLW or NAVWARN or ATMWARN or NAVFAIL or FILTER or HIGLINT)
CHL-OC5	Chlorophyll concentration (from OC5)	not (ATMFAIL or HILT or CLDICE or LOWLW or NAVWARN or MAXAERITER or ATMWARN or NAVFAIL or HIGLINT or ATMFAIL) and use 78° as maximum sun zenith angle and specific noise filter
SPM-OC5	Inorganic suspended particulate matter (from OC5)	
NFLH	Normalised Fluorescence Line Height	*(same as for CHL1)* and not(PRODWARN or MODGLINT)
PAR	Photosynthetically Available Radiation	Not (LAND or NAVFAIL or FILTER or HIGLINT)
CF	Cloud fraction	not LAND

Table 3-4: List of parameters and filters applied to the MODIS/SeaWiFS/VIIRS level 2 data

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 track on ISIN grid
- step 2: L3 track to L3 daily for each single instrument
- step 3: L3 daily for each single instrument to merged L3 daily
- step 4: L3 daily merged to 8days and monthly L3 products
- step 5: L3 daily/8days/monthly merged products to mapped products on PC grid
- step 6: generation of the quicklooks

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.

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 NPP 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, SeaWiFS and VIIRS: 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

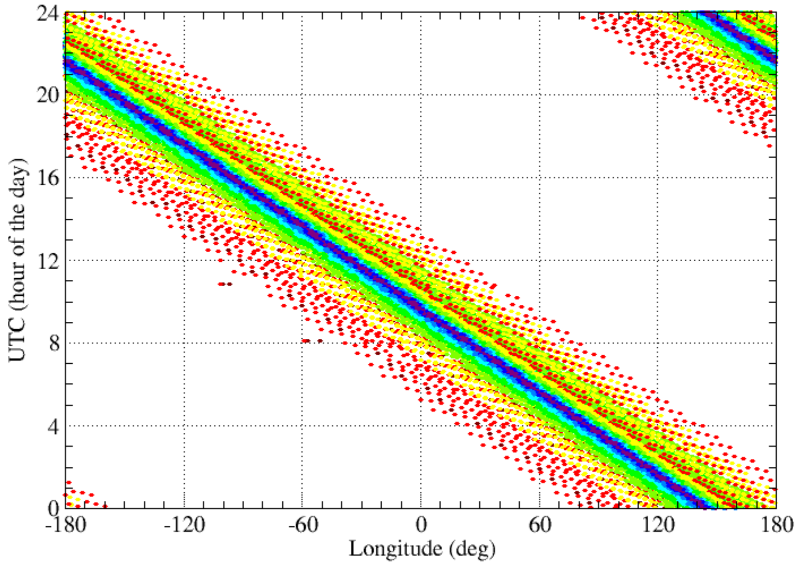


Figure 3-2: MERIS pixels UTC as a function of the pixel longitude (35 days - October 2003)

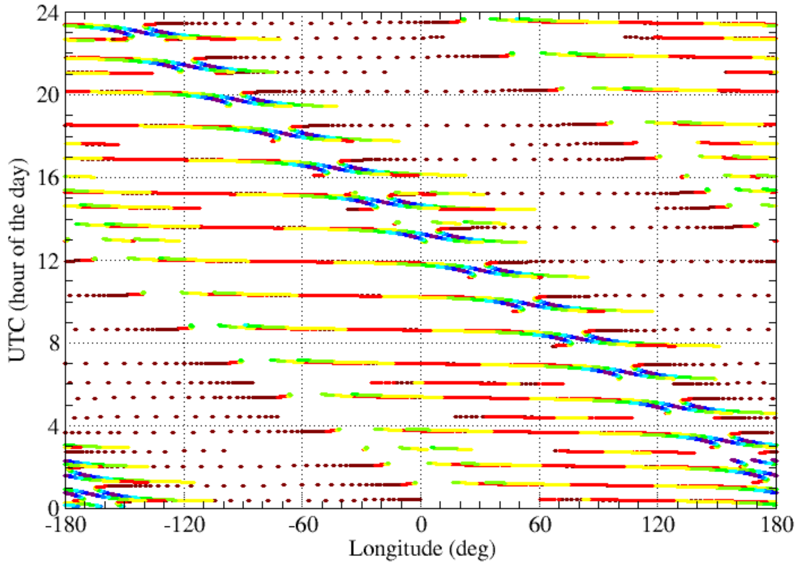


Figure 3-3: MODIS pixels UTC as a function of the pixel longitude (1 day - June 2003)

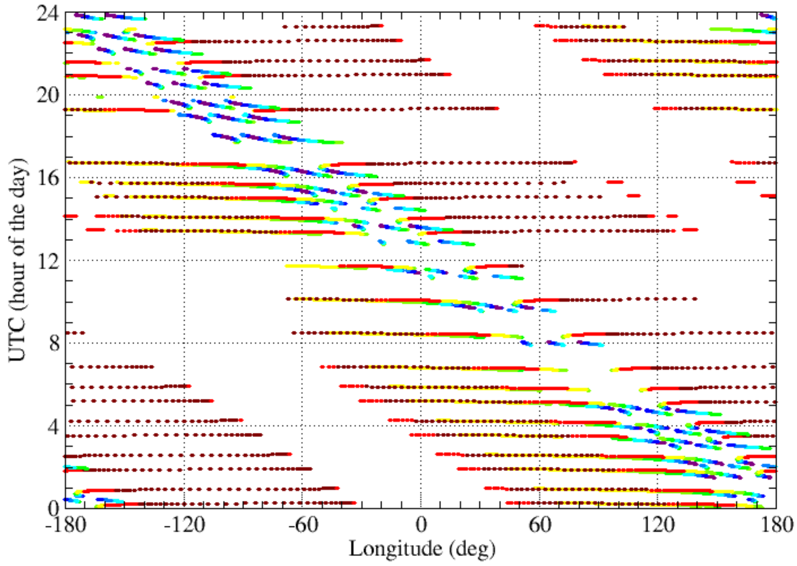


Figure 3-4:SeaWiFS pixels UTC as a function of the pixel longitude (1 day - December 2003)

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.

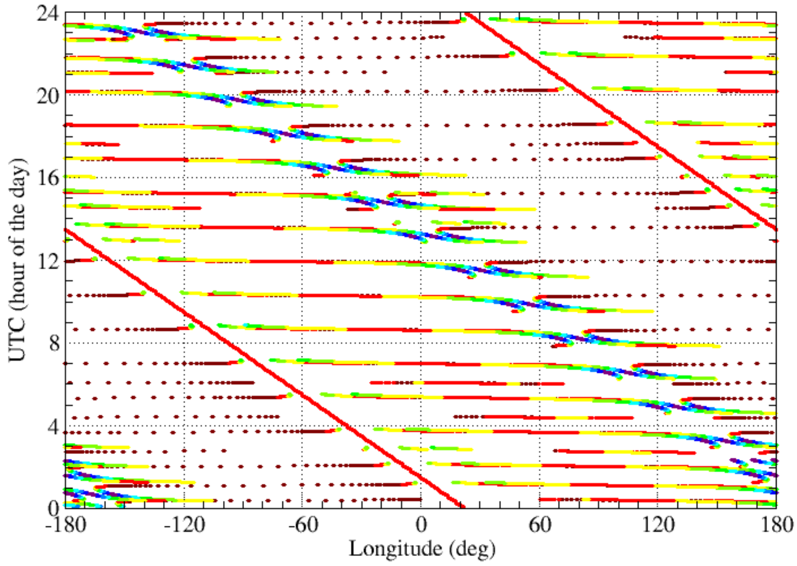


Figure 3-5: Data-day definition line above MODIS pixels UTC versus longitude plot.

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.

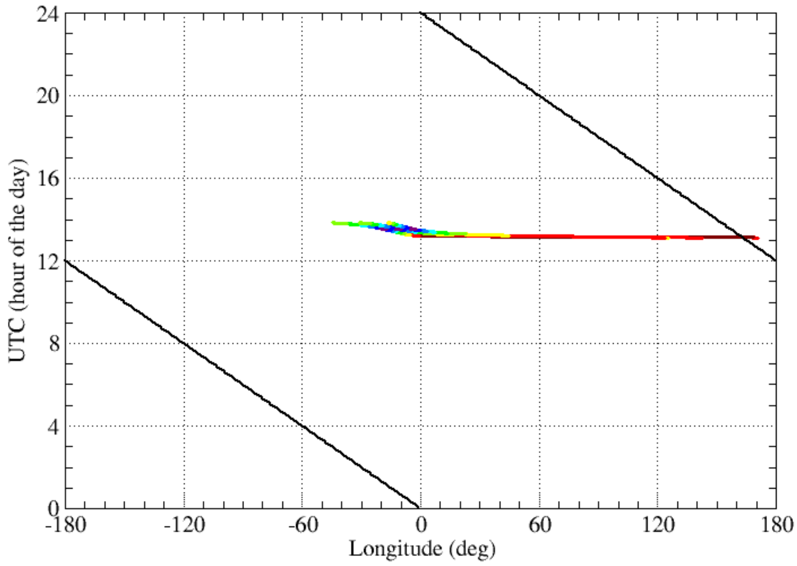


Figure 3-6: Data-day definition line above one SeaWiFS track.

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 3-5: Input parameters for data-day classification

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

Instrument	MODIS (Aqua) VIIRS (NPP)	SeaWiFS (SeaStar)	MERIS (Envisat) OLCI (Sentinel-3)
CNT	13.5	12.0	10.0

Table 3-6: CNT of satellites

Algorithm:

if (h < CNT + (φ +180)*τ) then
    pixel is attached to data-day (d-1)
else if (h > CNT + (φ +180)*τ + 24) then
    pixel is attached to data-day (d+1)
else
    pixel is attached to data-day (d)
end if

4 The products format

4.1 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:

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

GlobColour Level-3 output data includes binned, mapped and quicklook products which are described in the following sections. The binned and mapped products are stored in netCDF-4 files. The netCDF-4 library or third-party tools including netCDF-4 readers must be used to read the GlobColour products. The quicklook 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 version 4 of the netCDF format provides new features which are used for GlobColour products: chunking and internal compression. These two features allow us to distribute files with reduced compressed size and optimized random access: reading a small window on a product needs only to read and decompress the chunks covering it, without decompressing the whole file. Other new feature of netCDF-4 like new unsigned data types and groups are not used for GlobColour products to keep compatibility with the netCDF-3 data model: existing netCDF-3 tools could be easily re-used without any other modification than re-linking the program with the version 4 of the library. Note that the netCDF-4 format is now based on the widely supported HDF5 scientific data format, which means that any HDF5 tool will be also able to read the GlobColour products.

The following rules are applied when writing the 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.

4.2 Naming convention

This naming convention is common to all GlobColour products (but not to OSS2015 third-party 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, EURO for Europe area).
- **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, VIR for VIIRS, OLA for OLCI-A, or any combination 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 parameter algorithms can be indicated in this field using a "-" delimiter (e.g. CHL1-OC5, KD490-LEE).
- **TC** is the time coverage (TR for track-level products, DAY for daily, 8D for 8days, MO for monthly).
- **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_NRRS555_TR_20040101.nc
L3m_20040401__EURO_1_MOD_CHL1_DAY_00.nc
L3b_20040401-20040430__GLOB_4_MER_NRRS413_MO_00.nc
L3b_20021001-20021031__GLOB_4_AV-MERMODSWF_T865_MO_00.nc
```

4.3 The binned 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.

<u>Dimensions</u>

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

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

Table 4-1: Dimensions - 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 or NC_INT (3)	2 or 4 (3)	Latitudinal band index of the bins stored in the product, zero based and beginning at south (1)
col(bin)	NC_SHORT or NC_INT (3)	2 or 4 (3)	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 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 (4)
PRM_error(bin)	NC_SHORT	2	Error estimation for the geophysical variable (2)

Table 4-2: Variables - 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 % packed into a 2 bytes integers using a scale factor of

0.01 (this kind of data packing is standard in netCDF). The biggest error bar possible in this format is 327.67, so if a computed error bar is greater than 327.67 then it is set to 327.67.

Note 3: these variables type could be NC_SHORT or NC_INT depending on the ISIN grid resolution.

Note 4: the quality control is available through a flags array (2 bytes), provided for each bin of each product (source of instrument: all, MODIS only..., green reflectance threshold, mostly cloudy pixel, 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. The flags definition is also stored in the product itself following the netCDF “CF” (Climate and Forecast) convention.

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	OLCI_A	OLCI(A) valid pixel(s) contribute to the bin value
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	ICE	Bin covered by ice. Computed from an ice climatology.
10	TROPHIC1	Trophic classification (5)
11	TROPHIC2	
12	VIIRS_N	VIIRS(N) valid pixel(s) contribute to the bin value
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 4-3: 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 based on the value of the CF product:

(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%

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 near the coastline.

Note 5: (TROPHIC2=0) + (TROPHIC1=1): Oligotrophic water
(TROPHIC2=1) + (TROPHIC1=0): Mesotrophic water
(TROPHIC2=1) + (TROPHIC1=1): Eutrophic water

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 metadata conventions (excepting for pct_characterised_error which is GlobColour specific).

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
standard_name	string	If available, a CF standard name that references a description of variable's content
_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 4-4: Variables attributes - 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-1.4"
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"
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”)
parameter_algo_list	string	List of the algorithms name that were used to generate this parameter or input data (comma delimiter, e.g. “OC4Me,OC3v5”)
site_name	string	Name of the region of interest (e.g. “GLOB” or “EURO”)
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 in the ISO 8601 yyyymmddThhmmssZ standard format
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
copyright	string	Copyright of the product
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)
input_files_reprocessings	string	List of the reprocessings versions of each input product when available (comma delimiter). The reprocessing version is given by the MPH SOFTWARE_VER attribute for MERIS, by the global netCDF "processing_version" attribute for MODIS, SeaWiFS and VIIRS, and by the global netCDF "source" attribute for OLCI.

Table 4-5: Global attributes - binned products (1/3)

Temporal information

Attribute Name	netCDF type	Attribute Description
start_time	string	UTC date and time of the first valid or invalid measurement falling in the product, in the ISO 8601 yyyymmddThhmmssZ standard format
end_time	string	UTC date and time of the last valid or invalid measurement falling in the product, in the ISO 8601 yyyymmddThhmmssZ standard format
duration_time	NC_LONG	Duration in seconds between the first and last valid or invalid measurement falling in the product, in the ISO 8601 PTxxxS standard format
period_start_day	string	UTC start day of the binning period in the ISO 8601 yyyymmdd standard format
period_end_day	string	UTC end day of the binning period in the ISO 8601 yyyymmdd standard format
period_duration_day	NC_LONG	Duration in days of the binning period in the ISO 8601 PxxxD standard format

Table 4-6: Global attributes - 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 or NC_INT	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 build 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

Attribute Name	netCDF type	Attribute Description
		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 4-7: Global attributes - binned products (3/3)

4.4 The mapped products

The mapped product is the level 3 binned product projected on a Plate-Carrée. 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 and mapped 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:

Area	EURO	GLOB		
Angular resolution	1/96°	1/24°	0.25°	1.0°
Longitudinal grid size	5867	8640	1440	360
Latitudinal grid size	5201	4320	720	180

Table 4-8: Dimensions of the grid - mapped products

A PNG representation of the level 3 mapped 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 convention.

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

Table 4-9: Dimensions - 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 convention, 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 convention, the attributes of this variable are:
			`long_name = "latitude"`
			`unit      = "degrees_north".`

Table 4-10: Variables - 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 4-11: Variables - mapped products (2/2)

5 How to…?

5.1 Access the GlobColour data

5.1.1 The HERMES interface

The GlobColour products are also available through the HERMES web interface:

http://hermes.acri.fr

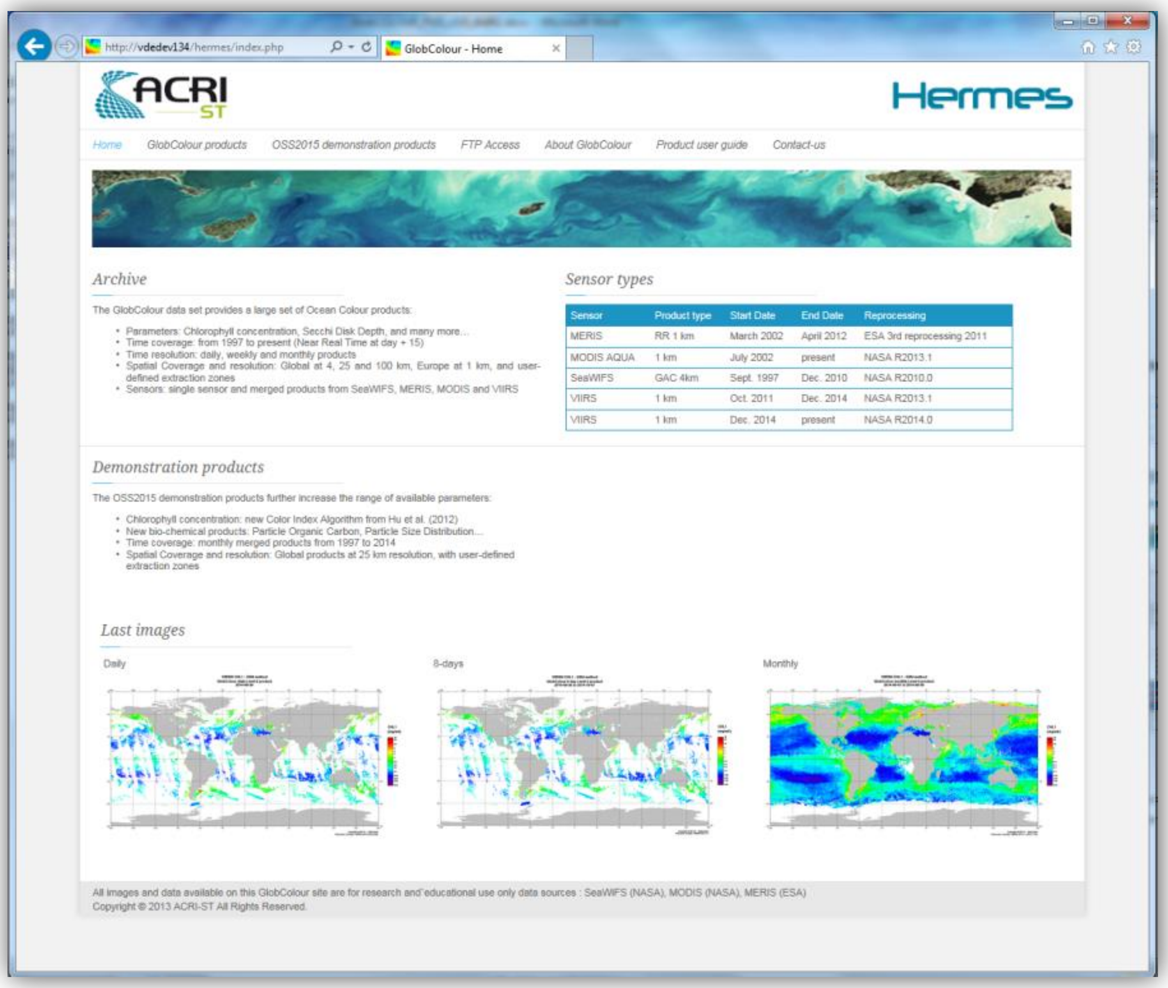


Figure 5-1: the HERMES Interface

HERMES provides the following access:

- GlobColour Data Set

  The GlobColour data set consists of daily, 8-days and monthly Level-3 ocean colour products generated in near real time at day+1 and consolidated at day+20. The archive data is based on the merging of MERIS, SeaWiFS, MODIS, VIIRS and OLCI level-2 data over the whole globe and the Europe area, with data extraction capability over user-defined regions of interest.

Single-sensor products are also available. OLCI is not merged with other sensors for the moment.

- OSS 2015 Demonstration products

The OSS2015 new EO products are available from a dedicated page.

5.1.2 Ordering GlobColour Products

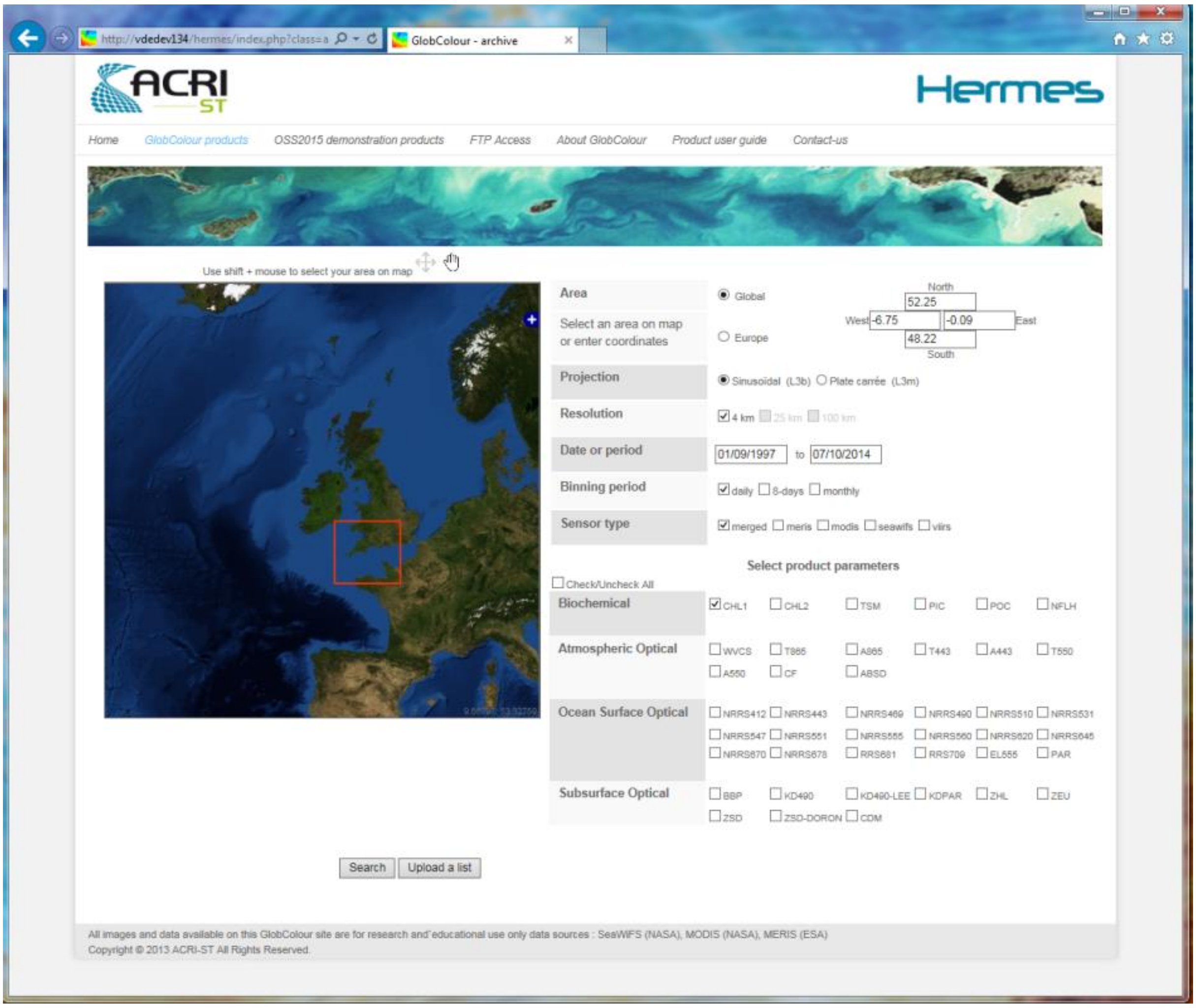


Figure 5-2: GlobColour Data Access interface

The GlobColour Data Access interface is depicted in Figure 5-2.

The selection of the spatial coverage is performed by:

- Selecting Global (4/25/100 km products) or Europe (1 km) products

- Selecting an extraction zone (optional) through the interactive map or the coordinate boxes. Use shift+click to select a rectangle on the map. Use to resize the selection zone, and to navigate on the map.

The map overlays can be changed by clicking on the "+" button, see figure below.

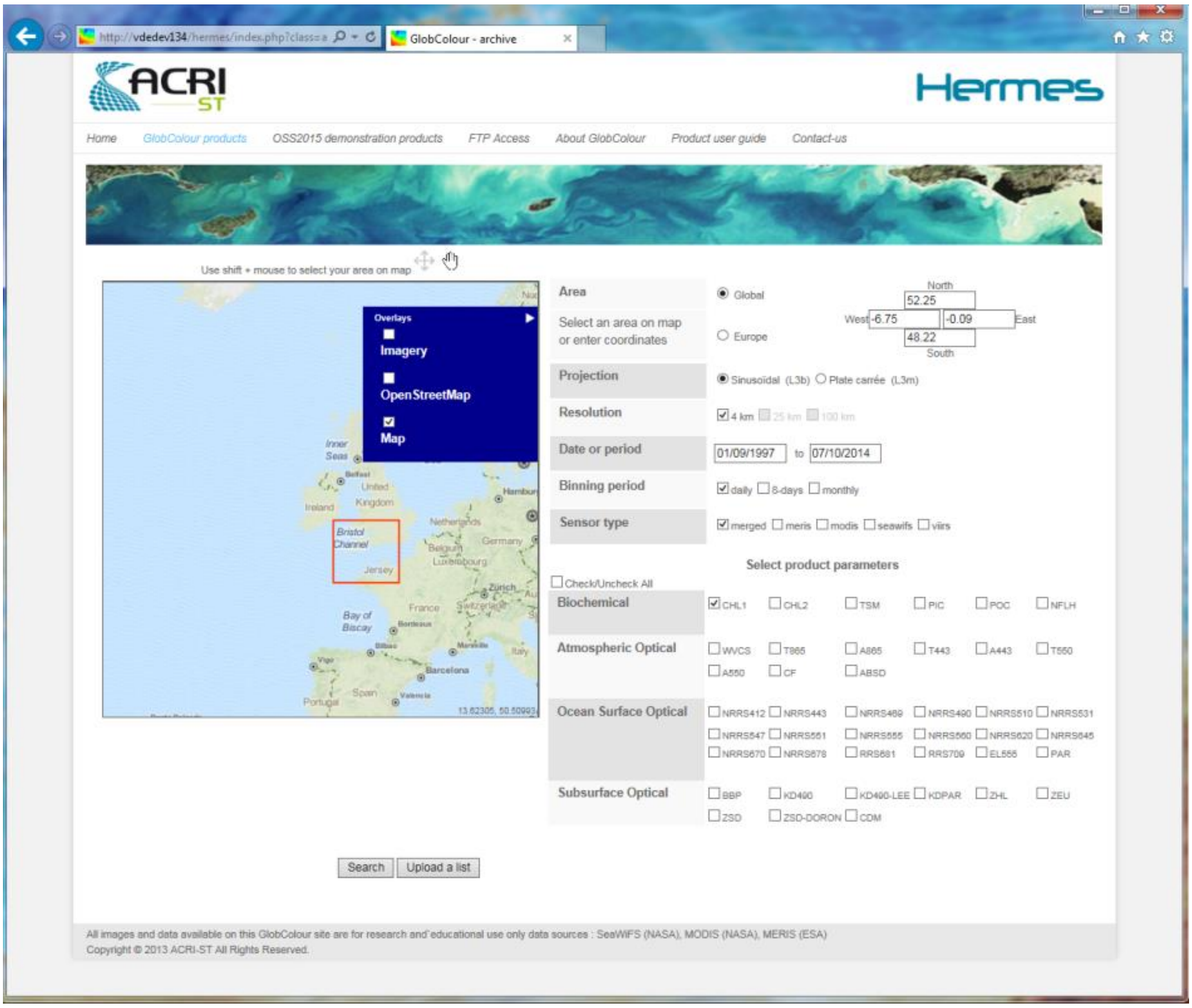


Figure 5-3: Selection of the map overlays

Check boxes allow selecting:

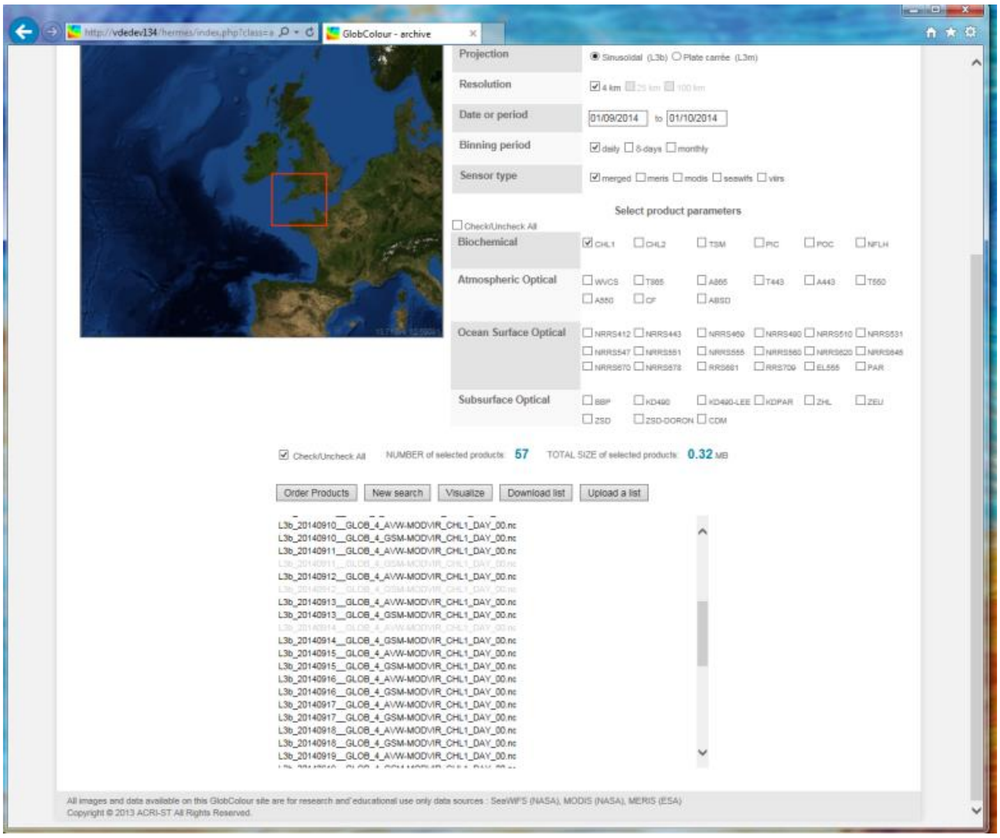
- Grid type (sinusoidal L3b or Plate-Carrée L3m)
- Spatial resolution
- And temporal resolution (binning period).

The temporal coverage is adjusted through the interactive calendar.

Finally the products selection is performed by checking the corresponding boxes.

Once the product order is finished, click on Search to retrieve the products of the database corresponding to the order. A list of products appears on the screen. Products can be de-selected or re-selected by clicking on their name in the list. The number of selected products and the estimated size of the order are refreshed automatically.

A pre-visualisation of the selected images is possible by clicking on the “Visualize” button.



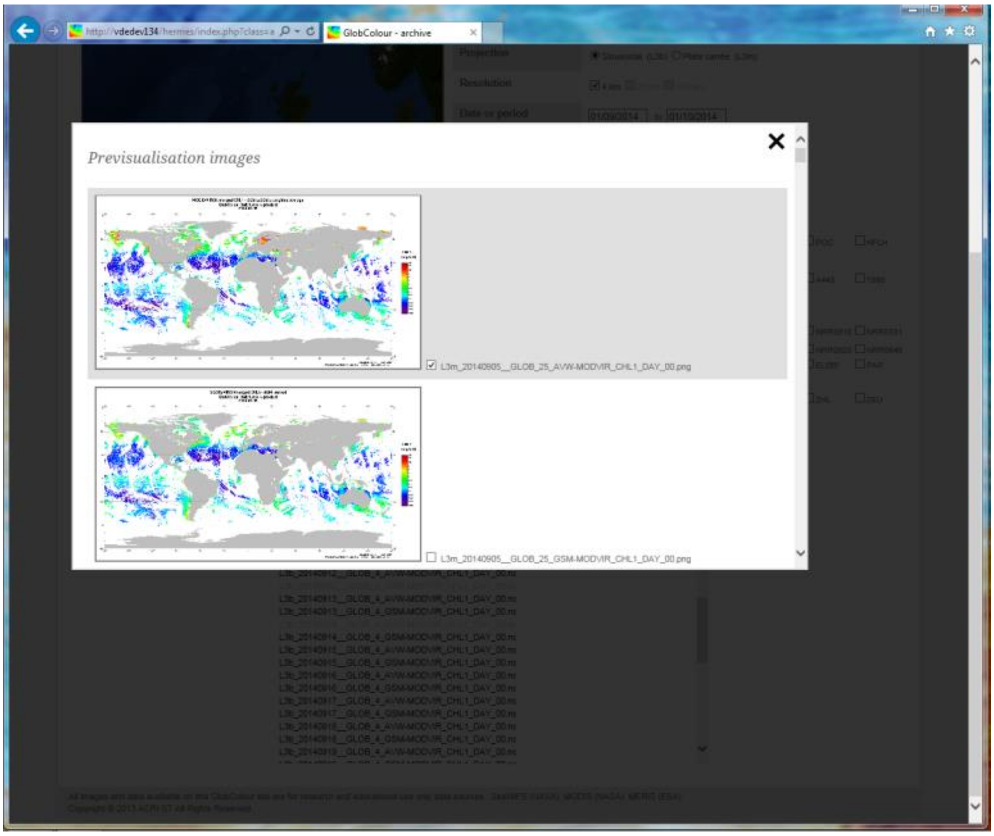


Figure 5-4: Selected products list and previsualisation screen

5.1.3 Ordering OSS2015 demonstration products

OSS2015 products can be accessed using a similar but different interface, see Figure 5-5.

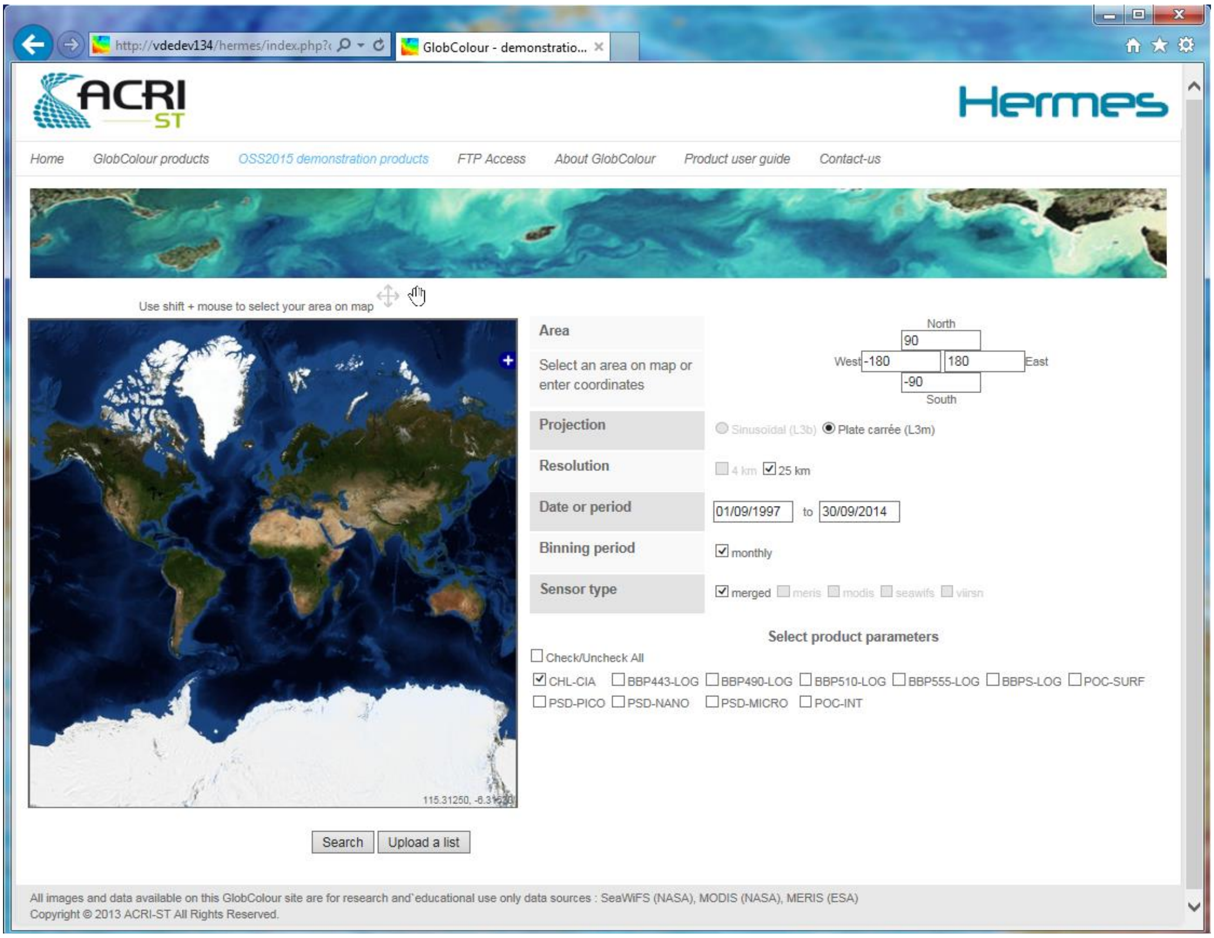


Figure 5-5: OS2015 products data access

5.1.4 Ordering a list of products

The products can also be ordered by uploading a list of products in a text file (comma separated). This functionality can be used to generate automatically a list of products using the naming convention. Clicking on the “Upload List” button opens a file browser to select the file.

5.1.5 Retrieving the data

After completion of the order, the user is asked to provide his/her e-mail address. Once the order has been processed, an email is sent to the user providing directions to retrieve the data on the GlobColour ftp server.

5.2 Download the data from the GlobColour ftp server

The GlobColour project maintains an 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 server is `ftp://ftp.hermes.acri.fr`

Login and passwords can be obtained by filling the request on-line on the hermes page "FTP access".

The distribution structure of the ftp archive is:

/*zone* **(GLOB|EURO)**
/*sensor* **(seawifs|meris|modis|viirsn|olcia|merged)**
/*binning period* **(day|8-day|month)**
/yyyy/mm/dd

Each directory contains the netCDF products **(L3b*.nc|L3m*.nc)** as well as the associated "quicklook" images.

The ftp also delivers the third party products (NPP and PFT).

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*.nc" -w3 -Q1000m \
      ftp://GlobColour_data:fgh678@ftp.acri.fr/GLOB/meris/ ./
```

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

```
wget -r -l10 -t10 -A "L3m*_25_*CHL1_MO*.nc" -w3 -Q1000m \
      ftp://GlobColour_data:fgh678@ftp.acri.fr/GLOB/merged ./
```

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 at:

http://www.gnu.org/software/wget/manual/wget.html

The following options are recommended:

`-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

The products may be 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 Visualize the data

GlobColour mapped products ("L3m") can be visualized using tools accepting NetCDF format, such as BEAM / Visat[1] (Figure 5-6) and ncview[2] (Figure 5-7).

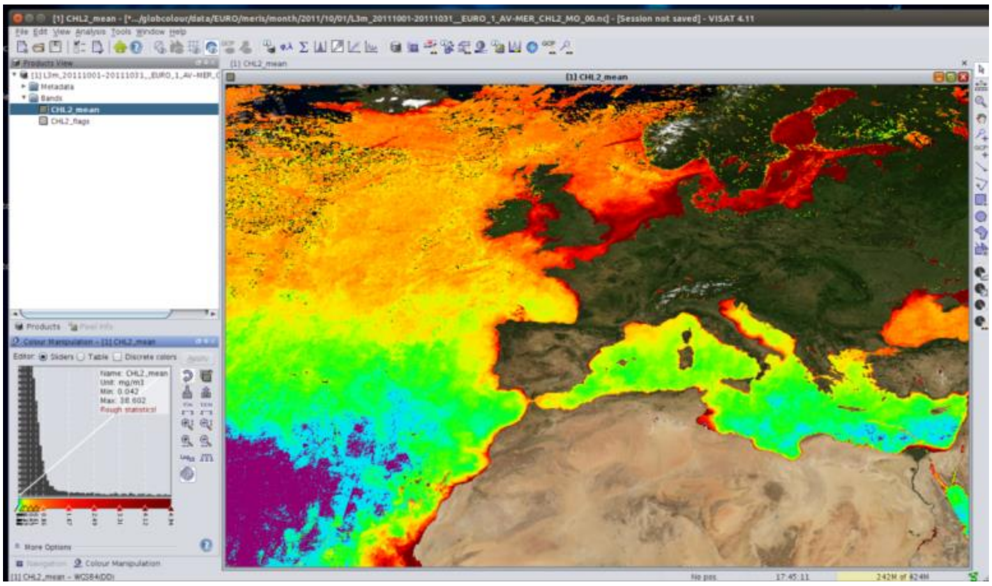


Figure 5-6: Visualization of a GlobColour L3m product using Visat

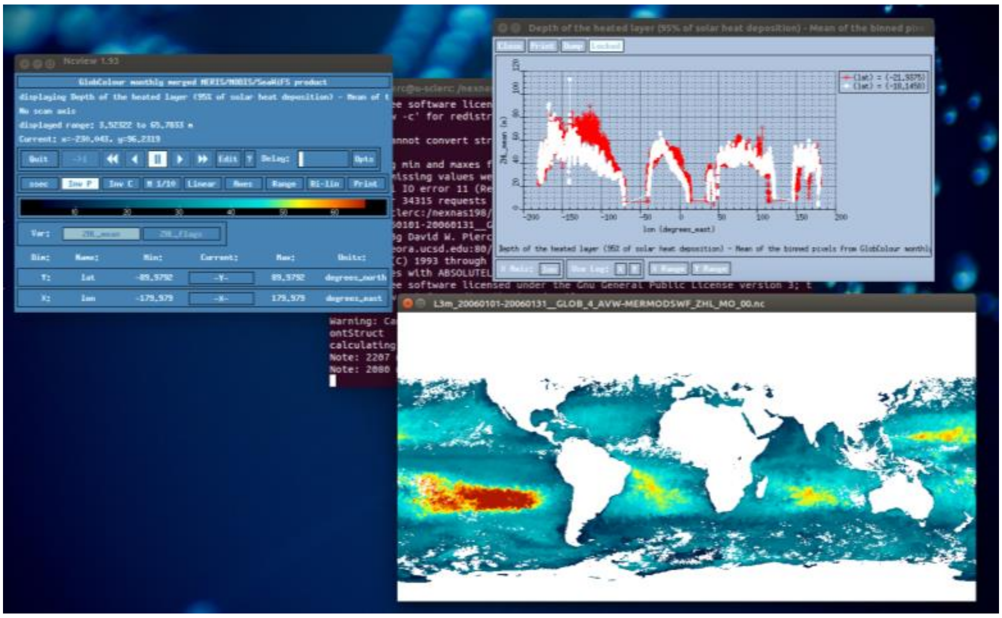


Figure 5-7: Visualization of a GlobColour L3m product using ncview.

The following example shows how the "Land" flag can be used to depict the Earth mask with matplotlib (http://matplotlib.org/index.html).

[1] http://www.brockmann-consult.de/cms/web/beam/

[2] http://meteora.ucsd.edu/~pierce/ncview_home_page.html

```
import matplotlib.pyplot as plot
from matplotlib.colors import LogNorm
import pylab
import numpy as np
import netCDF4 as nc

# settings for Chlorophyll
infile = 'L3m_20050101-20050131__GLOB_4_AVW-MERMODSWF_CHL1_MO_00.nc'
cmap='jet'
norm=LogNorm()
vmin , vmax = 0.01,100

# open dataset
ncfile=nc.Dataset(infile,'r')

# get grid
longitudes = ncfile.variables['lon'][:]
latitudes  = ncfile.variables['lat'][:]
extent = [longitudes.min(), longitudes.max(), latitudes.min(), latitudes.max()]

# get parameter
varname = getattr(ncfile,u'parameter_code')+'_mean'
thevar  = ncfile.variables[varname]
label   = getattr(ncfile,'parameter')+' ['+thevar.getncattr('units')+']'
var_val = thevar[:].data
var_mask= thevar[:].mask
var     = np.ma.MaskedArray(var_val,mask=var_mask)
var[var_mask] = np.nan

# get Earth mask
flagsname = getattr(ncfile,u'parameter_code')+'_flags'
earth = (ncfile.variables[flagsname][:]&8==0)
earthmasked = np.ma.MaskedArray(earth,mask=earth)
earthmasked[earth]=np.nan

#--- Plot -------------------------------------------
# Plot Earth Mask
plot.imshow(earthmasked,cmap='gray',vmin=-1,vmax=1,extent=extent)
plot.hold(True)

# Plot variable
CS=plot.imshow(var, cmap=cmap, vmin=vmin,vmax=vmax,extent=extent,norm=norm)

# colorbar
plot.colorbar(CS,orientation='horizontal',aspect=30,label=label)

# axes labels
plot.xlabel('Longitude [deg]')
plot.ylabel('Latitude [deg]')

# save file
outfile = infile[:-3]+'.png'
pylab.savefig(outfile,dpi=300)
plot.close()
```

Figure 5-8: Visualizing GlobColour products with matplotlib

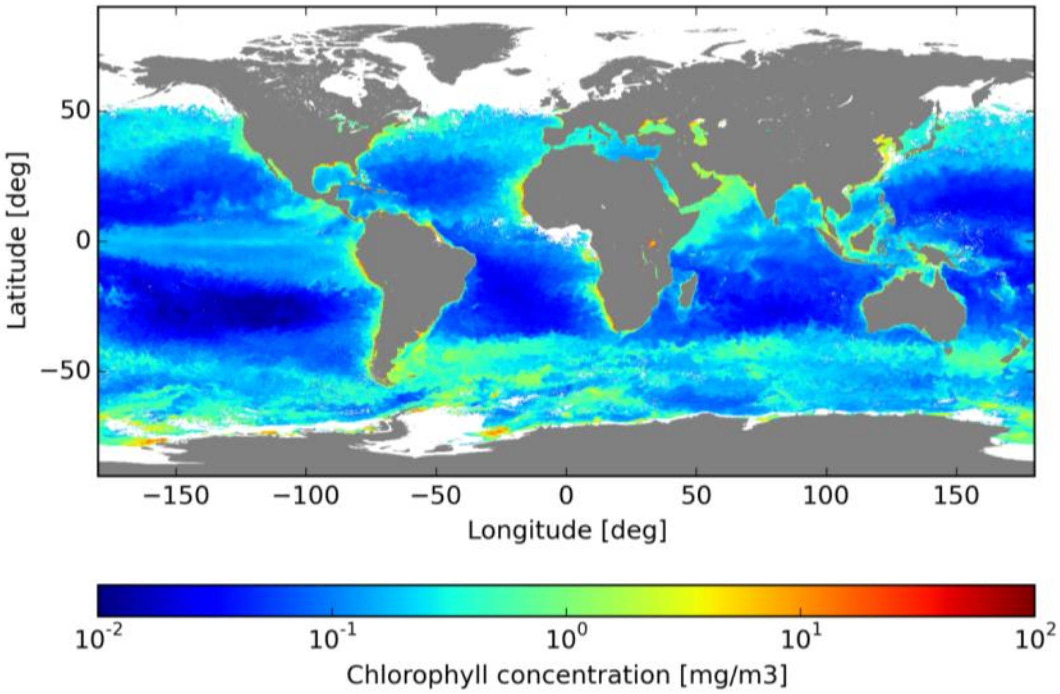


Figure 5-9: Generated image

6 Appendices

6.1 Global ISIN grid definition

The following formulas shall clarify the ISIN grid definition.

Earth radius (km)	$R_e = 6378.137$
Total number of latitude rows	$N_{lat} = 4320$ for GLOB area
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	$N_{lon}(n) = \text{nearest}\left(\frac{p_n}{d_r}\right)$
Effective longitudinal bin width for row n (km)	$d_e^{lon}(n) = \frac{p_n}{N_{lon}(n)}$
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 6-1: ISIN grid definition

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

6.2 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).

- 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>L3 type</th><th>grid</th><th>mean</th><th>stdev</th><th>error</th><th>weight</th><th>count</th><th>flags</th></tr>
<tr><td>track</td><td>ISIN</td><td>x</td><td>x</td><td>(2)</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>daily</td><td>ISIN</td><td>x</td><td rowspan="3">(3)</td><td>(4)</td><td rowspan="3"></td><td rowspan="2">(5)</td><td>x</td></tr>
<tr><td>8days/monthly</td><td>ISIN</td><td>x</td><td>(6)</td><td>x</td></tr>
<tr><td>mapped</td><td>PC</td><td>x</td><td>(4)</td><td></td><td>x</td></tr>
<tr><td>quicklook</td><td>PC</td><td colspan="6">(7)</td></tr>
</table>

Table 6-2: Summary of products content

(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

6.3 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 track global at 4.63 km (ISIN grid):

- 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 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 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
- "Quicklook" image in PNG RGB lossless format
- the quicklook image is computed using the mean field of the low resolution product

6.4 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 track at 4.63 km
- step 2: L3 track to L3 daily for each single instrument
- step 3: L3 daily for each single instrument to merged L3 daily
- step 4: L3 daily merged to 8days and monthly L3 products
- step 5: L3 daily/8days/monthly merged products to mapped products
- step 6: generation of the quicklooks

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 available characterisation). The error bars are provided in appendix.

6.4.1 Step 1: L2 to L3 track

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

6.4.2 Step 2: L3 track to L3 daily for each single instrument

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:

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

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

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

The quantities stored in the daily L3 products are:

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

6.4.3 Step 3: L3 daily for each single instrument to merged L3 daily

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:

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

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

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

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 $\tilde{D}_{j\text{-SIMPLE}}$:

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

Then, the weighted mean is given by:

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

The corresponding error bar is given by:

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

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

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

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

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

GSM method

Inputs of the GSM minimisation process are the fully normalised remote sensing reflectances NRRSxxx (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 packed % 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:

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

6.4.4 Step 4: L3 daily merged to 8-days and monthly L3

Let's introduce $\hat{N}_d$, 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:

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

6.4.5 Step 5: L3 daily/8days/monthly merged products to mapped products

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 mapped PC grid is given by:

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

in which $\breve{N}_j$ is the number of L3 ISIN bins that effectively impact the L3 mapped PC bin number j; $\dddot{D}_i$ 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 mapped PC product is given by:

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

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

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

The quantities stored in the daily L3 products are:

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

6.4.6 Step 6: generation of the quicklooks

No special processing, the mean field of the mapped product is used to create the image.

6.5 The error bars

The following table details the error bars assumed for the computation of weighted average products. When a characterized error is available from comparison with in-situ measurements, this value is used. Otherwise, an arbitrary value is selected in order to obtain a consistent data set.

Parameter	MERIS	MODIS	SeaWiFS	VIIRS
CHL1	38.46	32.06	33.79	43.31
CHL-OC5	50(1)	50(1)	50(1)	50(1)
SPM-OC5	50(1)	50(1)	50(1)	50(1)
PIC	–	50(1)	50(1)	50(1)
POC	–	18.78	17.27	18.78(1)
T865	39.26	68.1(2)	57.66(2)	68.1(2)
A865	1312.8	50(1)	50(1)	50(1)
NRRS412	9,63	16.17	18.28	7.38
NRRS443	9.08	12.01	16.36	6.79
NRRS490	9.23	9.15	14.21	6.34
NRRS510	10.99	–	14.93	–
NRRS547-560	15.58	13.08	17.58	10.50
NRRS670	80.89	31.39	46.9	23.69
PAR	8.21(1)	3.92(2)	8.21	8.21 (1)

Table 6-3: Error Bars used to generate Weighted Average products

(1) Arbitrary value
(2) Value from the first reprocessing

6.6 Common Data Language description

CDL representation of a global mapped level-3 daily merged product:

```
netcdf L3m_20120301-20120331__GLOB_4_AVW-MERMODVIR_CHL1_MO_00 {
dimensions:
	lat = 4320 ;
	lon = 8640 ;
variables:
	float lat(lat) ;
		lat:long_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:axis = "Y" ;
	float lon(lon) ;
		lon:long_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:axis = "X" ;
	float CHL1_mean(lat, lon) ;
		CHL1_mean:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water" ;
		CHL1_mean:long_name = "Chlorophyll concentration - Mean of the binned pixels" ;
		CHL1_mean:_FillValue = -999.f ;
		CHL1_mean:units = "mg/m3" ;
		CHL1_mean:pct_characterised_error = 43.31f ;
	short CHL1_flags(lat, lon) ;
		CHL1_flags:long_name = "Chlorophyll concentration - Flags" ;
		CHL1_flags:_FillValue = 0s ;
	short CHL1_error(lat, lon) ;
		CHL1_error:long_name = "Chlorophyll concentration - Error estimation" ;
		CHL1_error:_FillValue = -32768s ;
		CHL1_error:units = "%" ;
		CHL1_error:scale_factor = 0.01f ;

// global attributes:
		:Conventions = "CF-1.4" ;
		:title = "GlobColour monthly merged MERIS/MODIS/VIIRSN product" ;
		:product_name = "L3m_20120301-20120331__GLOB_4_AVW-MERMODVIR_CHL1_MO_00.nc" ;
		:product_type = "month" ;
		:product_level = 3s ;
```

```
:parameter_code = "CHL1" ;
:parameter = "Chlorophyll concentration" ;
:parameter_algo_list = "OC4Me,OC3v5,OC3v5" ;
:site_name = "GLOB" ;
:sensor_name = "WEIGHTED_AVERAGING" ;
:sensor = "Merged data - weighted mean" ;
:sensor_name_list = "MER,MOD,VIR" ;
:start_time = "20120229T214722Z" ;
:end_time = "20120401T025400Z" ;
:duration_time = "PT2696799S" ;
:period_start_day = "20120301" ;
:period_end_day = "20120331" ;
:period_duration_day = "P31D" ;
:grid_type = "Equirectangular" ;
:spatial_resolution = 4.638312f ;
:nb_equ_bins = 8640 ;
:registration = 5 ;
:lat_step = 0.04166667f ;
:lon_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 = 74.41666f ;
:southernmost_latitude = -76.25001f ;
:westernmost_longitude = -180.f ;
:easternmost_longitude = 180.f ;
:nb_grid_bins = 37324800 ;
:nb_bins = 37324800 ;
:pct_bins = 100.f ;
:nb_valid_bins = 19406411 ;
:pct_valid_bins = 51.99334f ;
:software_name = "globcolour_l3_reproject" ;
:institution = "ACRI" ;
:processing_time = "20140724T080509Z" ;
:netcdf_version = "4.1.3 of Sep  5 2011 16:53:33 $" ;
:DPM_reference = "GC-UD-ACRI-PUG" ;
:IODD_reference = "GC-UD-ACRI-PUG" ;
:references = "http://www.globcolour.info" ;
:contact = "service@globcolour.info" ;
```

:history = "20140724T080509Z: globcolour_l3_reproject.sh -inlist globcolour/data/merged/month/2012/03/01 -outdir globcolour/data/merged/month/2012/03/01 -startdataday 20120301 -enddataday 20120331 -resolution 0.041666666666666664 -resolutioncode 4 -tmpdir /work/scratch" ;

:input_files = "…"

:input_files_reprocessings = "…"

:product_version = "2014.0" ;

:software_version = "2014.0" ;

:copyright = "Copyright ACRI-ST - GlobColour. GlobColour has been originally funded by ESA with data from ESA, NASA, NOAA and GeoEye. This reprocessing version has received funding from the European Community's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement n° 282723 [OSS2015 project]." ;

}

6.7 References

6.7.1 GlobColour products references

Antoine, D., André J.M. and A. Morel (1996). Oceanic primary production: II. Estimation at global scale from satellite (Coastal Zone Color Scanner) chlorophyll, Global Biogeochemical Cycles, 10, 57-69.

Bailey, S.W., McClain, C.R., Werdell, P.J. and Schieber, B.D. (2000) Chapter 7: Normalised Water-Leaving Radiance and Chlorophyll a Match-Up Analyses. *NASA Tech. Memo. 206892*, Vol. 10, S.B. Hooker, and E.R. Firestone, Eds., NASA Goddard Space Flight Center, Greenbelt, Maryland, pp 45-52.

Doron, M., Babin, M., Mangin, A. and O. Fanton d'Andon (2006). Estimation of light penetration, and horizontal and vertical visibility in oceanic and coastal waters from surface reflectance. Journal of Geophysical Research, volume 112, C06003, doi: 10.1029/2006JC004007.

Feldman, G.C. (2005b) MODIS/Aqua Ocean Reprocessing 1.1 http://oceancolor.gsfc.nasa.gov/REPROCESSING/Aqua/R1.1/. Accessed December 2005.

Feldman, G.C. (2005c) SeaWiFS Ocean Reprocessing 5.1: http://oceancolor.gsfc.nasa.gov/REPROCESSING/SeaWiFS/R5.1/. Accessed December 2005.

Feldman, G.C. (2005d) MSl12: The Multi-Sensor Level-1 to Level-2 Code http://oceancolor.gsfc.nasa.gov/DOCS/MSL12/. Accessed January 2006.

Feldman, G.C. (2006) Oceancolor Products. http://oceancolor.gsfc.nasa.gov/PRODUCTS/. Access January 2006.

IOCCG (1998) Minimum Requirements for an Operational, Ocean-Colour Sensor for the Open Ocean, *IOCCG Report Number 1*, 50 pp.

IOCCG (1999). Status and Plans for Satellite Ocean-Colour Missions: Considerations for Complementary Missions. Yoder, J. A. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 2, IOCCG, Dartmouth, Canada. ISSN: 1098-6030

IOCCG Report No. 4, Guide to the creation and use of ocean-colour, Level-3, binned data products, D. Antoine (ed.), 2004. http://www.ioccg.org/reports_ioccg.html

IOCCG (2006). Ocean Colour Data Merging. Gregg, W.W. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 5, IOCCG.

Maritorena, S. and Siegel, D.A. 2005. Consistent Merging of Satellite Ocean Colour Data Sets Using a Bio-Optical Model. *Remote Sensing of Environment*, 94, 4, 429-440.

Maritorena S., Siegel, D.A. and Peterson, A. (2002) Optimization of a Semi-Analytical Ocean Colour Model for Global Scale Applications. *Applied Optics*, 41, 15, 2705-2714.

MODIS (2005) http://oceancolor.gsfc.nasa.gov/DOCS/MODISA_processing.html. Accessed December 2005.

André Morel, Yannick Huot, Bernard Gentili, P. Jeremy Werdell, Stanford B. Hooker, Bryan A. Franz, "Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach", *Remote Sensing of Environment*, **111** (2007), 69-88, doi:10.1016/j.rse.2007.03.012

Morel, A. and S. Bélanger, (2006) Improved Detection of turbid waters from Ocean Color information, *Remote Sensing of Environment*, **102**, 237-249

Morel, A. and Antoine, D. (2000) Pigment Index Retrieval in Case 1 Waters, *MERIS ATBD 2.9*, Issue 4, Revision 2, 26 pp.

Morel, A., Antoine, D. and Gentilli, B. (2002) Bidirectional reflectance of oceanic waters: accounting for Raman emission and varying particle scattering phase function, *Applied Optics*, 41, 6289-6306

Morel, A., Huot, Y., Gentili, B., Werdell, P.J., Hooker, S.B. and B.A. Franz (2007). Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach. Remote Sensing of Environment, 111, 69-88.

Orbimage Inc. (2005) http://www.orbimage.com/prods/orbview_2_prodinfo.htm. Accessed December 2005.

Frouin, R., B. A. Franz, and P. J. Werdell, 2003: The SeaWiFS PAR product. In Algorithm Updates for the Fourth SeaWiFS Data Reprocessing, S. B. Hooker and E. R. Firestone, Editors, CC NASA/TM-2003-206892, Vol. 22, 46-50.

Morel, A. and Gentili, B.: A simple band ratio technique to quantify the colored dissolved and detrital organic material from ocean color remotely sensed data, Remote Sens. Environ., 113, 998–1011, 2009a.

Zhong-Ping Lee, Ke-Ping Du and Robert Arnone (2005) A model for the diffuse attenuation coefficient of downwelling irradiance. *JOURNAL OF GEOPHYSICAL RESEARCH.* VOL. 110, C02016, doi:10.1029/2004JC002275, 2005.

Saulquin, B., Hamdi, A., Gohin, F., Populus, J., Mangin, A., & d'Andon, O. F. (2013). Estimation of the diffuse attenuation coefficient K_{dPAR} using MERIS and application to seabed habitat mapping. *Remote Sensing of Environment*, *128*, 224-233.

Gohin, F.: Annual cycles of chlorophyll-a, non-algal suspended particulate matter, and turbidity observed from space and in-situ in coastal waters, Ocean Sci., 7, 705-732, doi:10.5194/os-7-705-2011, 2011. http://www.ocean-sci.net/7/705/2011/os-7-705-2011.pdf

6.7.2 References for OSS2015 demonstration products

Antoine, D. and A. Morel (1996). Oceanic primary production : I. Adaptation of a spectral light-photosynthesis model in view of application to satellite chlorophyll observations, Global Biogeochemical Cycles, 10, 43-55.

Claustre, H., Sciandra A., and D. Vaulot (2008), Introduction to the special section Bio-optical and biogeochemical conditions in the South East Pacific in late 2004: the BIOSOPE program. *Biogeosciences*, 5, 679-691.

Claustre H., Morel A., Babin M., Cailliau C., Marie D., Marty J. C., Talliez D., Vaulot D., 1999. "Variability in particle attenuation and chlorophyll fluorescence in the tropical Pacific: Scales, patterns and biogeochemical implications". Journal of Geophysical Research, 104, pp. 3401-3422.

Campbell, J.W., Blaisdell, J.M., and Darzi, M., (1995).SeaWIFS Technical Report Series, NASA Vol. 32, Level-3 SeaWIFS Data Products: Spatial and Temporal Binning Algorithms. Edited by Hooker, S.B., Firestone, E.R., and Acker, J.G.

Carton, J. A. and B. S. Giese, 2008: A Reanalysis of Ocean Climate Using Simple Ocean Data Assimilation (SODA), Mon. Weather Rev., 136, 2999-3017.

de Boyer Montégut C., Madec G., Fischer A., LazarA., Ludicone D., 2004."Mixed layer depth over the global ocean: an examination of profile data and profile-based climatology". Journal of Geophysical Research, 108(C7),C12003,doi:10.1029/ 2004JC002378.

Duforêt-Gaurier L., Loisel H., Dessailly D., Nordkvist K., Alvain S., 2010. " Estimates of particulate organic carbon over the euphotic depth from in situ measurements". Application tosatellite data ove r the global ocean". Deep-Sea Research, I 57 (2010) 351–367.

Eppley, R. W., Temperature and phytoplankton growth in the sea, Fish. Bull., 70, 1063-1084, 1972.

Garver, S.A., and Siegel, D., 1997. " Inherent optical property inversion of ocean color spectra and its biogeochemical interpretation 1. Time series from the Sargossa Sea". J. Geophys. Res. 102: 18607-18625.

Gordon, H. R., Brown, O. B., Evans, R. H., Brown, J. W., Smith, R. C., Baker, K. S. and Clark, D. K., 1988. " A semianalytic radiance model of ocean color"? J. of Geoph. Res. 93(D9), 10909-10924.

Hu, C., Lee, Z., and Franz, B., 2012. " Chlorophyll a algorithms for oligotrophic oceans: A novel approach bases on three-band reflectance difference". Journal of Geophysical Research, 117, doi:10.1029/2011JC007395.

IOCCG, 2006. Remote sensing of inherent optical properties: fundamentals, tests of algorithms, and applications. In: Lee, Z. P. (Ed.), Reports of the International Ocean Color Coordinating Group, Vol. 5, IOCCG, Darthmouth, Canada, pp. 145.

Knap A., Michaels A., Close A., Ducklow H., Dickson A., 1996. "Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements". JGOFS Report Nr. 19 (Reprint of the IOC Manuals and Guides no. 29, UNESCO, Paris, 1994), 170pp.

Kostadinov, T.S., D.A. Siegel, and S. Maritorena. 2009. Retrieval of the Particle Size Distribution from Satellite Ocean Color Observations. Journal of Geophysical Research, VOL. 114, C09015, doi:10.1029/2009JC005303.

Lee, Z., and K. L. Carder (2000), Band-ratio or spectral-curvature algorithms for satellite remote sensing, Appl. Opt.,39, 4377–4380, doi:10.1364/AO.39.004377.

H. Loisel and D. Stramski. 2000. Estimation of the inherent optical properties of natural waters from irradiance attenuation coefficient and reflectance in the presence of Raman scattering. Applied Optics. 39 : 3001-3011

H. Loisel, J.-M. Nicolas, A. Sciandra, D. Stramski, and A. Poteau. 2006. Spectral dependency of optical backscattering by marine particles from satellite remote sensing of the global ocean, Journal of Geophysical Research, 111, C09024, doi:10.1029/2005JC003367

Maritorena, S., Siegel, D. A., and Peterson, A. R., 2002. " Optimization of a semi-analytical ocean color model for global-scale applications". Applied Optics 41:2705-2714.

Maritorena S., Siegel, D.A. and Peterson, A. (2002) Optimization of a Semi-Analytical Ocean Colour Model for Global Scale Applications. Applied Optics, 41, 15, 2705-2714.

Morel, A., Antoine, D., Babin, M., and Y. Dandonneau (1996). Measured and modeled primary production in the Northeast Atlantic (EUMELI JGOFS program): The impact of natural variations in photosynthetic parameters on model predictive skill. Deep-Sea Research I, 43, 1273-1304.

Morel, A., and J.F. Berthon (1989). Surface pigments, algal biomass profiles, and potential production of the euphotic layer: Relationships reinvestigated in view of remote-sensing applications, Limnology and Oceanography, 34, 1545-1562.

Mobley, C. D. 1994. "Light and Water: Radiative Transfer in Natural Waters". (Academic, San Diego, Calif., 1994

Monterey, G., Levitus, S., 1997. Seasonal Variability of Mixed Layer Depth for the World Ocean. NOAA Atlas NESDIS, vol. 14. U.S. Government Print Office, Washington, DC, 96pp.

Morel A., Maritorena S., 2001. "Bio-optical properties of oceanic waters: a reappraisal". Journal of Geophysical Research. 106 (C4), 7163–7180.

Report of the International Ocean-Colour Coordinate Group, IOCCG Report Number 4, (2004).Edited by David Antoine.

Reynolds, R.W., N.A. Rayner, T.M. Smith, D.C. Stokes, and W. Wang, 2002: An improved in situ and satellite SST analysis for climate. J. Climate, 15, 1609-1625.

O'Reilly, J., S. Maritorena, B. G. Mitchell, D. Siegel, K. L. Carder, S. Garver, M. Kahru and C. McClain, 1998. " Ocean color chlorophyll algorithms for SeaWiFS", J. Geophys. Res. 103, 24, 937-24, 53.

O'Reilly, J. E. et al., 2000. " SeaWiFS postlaunch calibration and validation analyses", Part 3, NASA Tech. Memo., NASA, TM-2000-206892, vol. 11, 49 pp.

Stramska M., 2009. Particulate organic carbon in the global ocean derived from SeaWiFS ocean color. Deep-Sea Research. I 56 (9), 1459–1470.

Stramski D., Reynolds R.A., Babin M., Kaczmarek S., Lewis M.R., Rottgers R., Sciandra A., Stramska M., Twardowski M., Franz, B, Claustre, H., 2008. "Relationships between the surface concentration of particulate organic carbon and optical properties in the eastern South Pacific and eastern Atlantic Oceans". Biogeosciences 5, 171–201.

Twardowski M, Boss E., Macdonald J., Pegau W., Barnard, A., Zaneveld, J., 2001. "A model for bulk refractive index from the optical backscattering ratio and the implications for understanding particle composition in case I and case II waters". Journal of Geophysical Research. 106 (C7), 14129–14142.

Uitz J., Claustre H., Morel A., Hooker S.B., 2006. "Vertical distribution of phytoplankton communities in open ocean: an assessment based on surface chlorophyll". Journal of Geophysical Research. 111, C08005, doi: 10.1029/2005JC003207.

Uitz, J., Claustre, H., Gentili, B. and D. Stramski (2010). Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations. Global Biogeochemical Cycles, Vol. 24, No. 3, GB3016, doi: 10.1029/2009GB003680.

Uitz, J., Huot, Y., Bruyant, F., Babin, M. and H. Claustre (2008) Relating phytoplankton photophysiological properties to community structure on large scale, Limnology and Oceanography, 53(2), 614-630