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D8.1: Transformation of MERIS multispectral remote-sensing images to GIS layers

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Abstract (for dissemination)	To support the scientific and the crowdsourcing measurements of water quality a database of water properties derived from satellite observations will be built and transformed into GIS layers. The source of satellite products is the CoastColour ESA funded, project providing the archive of MERIS water surface and optical water properties for specific coastal zones. The Citclops data layers derived from MERIS will include water optical properties, water constituents concentrations, and Forel-Ule maps.
Keywords	GIS layer, CoastColour, MERIS, water properties, coastal water

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1 Introduction

1.1 Context and objectives

The Citclops system will combine information coming from different sources: pictures and measurements taken by citizens with common and cheap adapted devices (smartphones with specific applets, adaptors to measure water samples with smartphones and affordable in-situ sensors.) Citizen measurements will cover increased spatio-temporal scales, yet with a limited quality which will be counterbalanced by the possibility to conduct reference measurements. The satellite data will be the last source providing ocean colour information on large spatial and temporal coverage. Given the coarse resolution of satellite data, these will be cross-compared with in-situ data, and will provide indications on the quality of in-situ data.
The satellite retrieval parameters provide information on water quality: water constituents (phytoplankton, suspended matter, coloured dissolved organic matter (CDOM)), water optical properties (e.g., absorption, fluorescence, scattering). This includes also measurements of water colour by means of the Forel-Ule (FU) scale, which is a simple and robust indicator of water quality. FU observations are used since near one century to compare the colour of oceans and seas and their evolution in time with a standardised and geographically independent scale.

Based on spaceborne ocean colour instruments (MERIS/ENVISAT, and the future OLCI/Sentinel-3), Citclops will disseminate satellite-derived data layers through its webGIS system to the community to help the verification and interpretation of the crowdsourced measurements over the two pilots zones, Alfacs Bay in the NW Mediterranean and the Wadden Sea.

1.2 Rationale

MERIS/ENVISAT is out of order since April 2012, so the near-real time service is not possible anymore. The implementation plan has been revised and it has been decided to build climatology from the long-term MERIS archive, with the aim to support the interpretation of in-situ measurement by scientific instruments or by crowdsourcing methods. The climatology will be composed by temporal statistics of coastal water properties over the two pilot zones, Alfacs Bay (Spain) and the Wadden Sea (Netherlands & Germany) (see Figure 4:).
Once OLCI/Sentinel-3, MERIS successor, is launched, the database will be completed by the products from this new sensor, provided that the data are released by ESA after the Sentinel-3 commissioning phase (launch + 6 months) before the end of Citclops.

The CoastColour product will be used and a selection of relevant parameters is proposed to prepare this database and the GIS web service used to disseminate these products. Some other water properties variables will be processed and will complete the GIS layers.

We chose to exploit an improved dataset of MERIS data coming from the ESA-funded CoastColour Project. The CoastColour project put together specialist of colour water issues and expert of water optical parameters, biology expert and specialist of in-situ measurements.

The selection of CoastColour products rather than direct MERIS product is motivated by the following facts:

- A better radiometry (improved calibration);
- Presence of new and useful additional information like pixel characterization;
- Improved geo-location, land/water mask and coastline.
- Improved processing algorithms for the retrieval of water properties, especially with respect to the retrieval of parameters in turbid coastal zones. The algorithms were inter-compared through a Round Robin validation protocol before the dissemination of the products.
- The CoastColour areas include the Alfacs Bay and the Wadden Sea.
- The CoastColour archive covers the period 2005 to 2012, which is sufficient for elaborating climatology.

Once the climatology is set up, the comparison with the in-situ measurements will be possible: on one hand to help the quality control and on the other hand to make comparisons between the historical variations and the in-situ measurements. The climatology will be a support to the ground measurements rather than a database for the validation.

2 MERIS images to GIS layers

2.1 CoastColour

The ESA manage a long term project to exploit the ocean colour sensors and provide to the community the products relatives to the coastal waters for management and research. The goal is to study the climate change and its importance in the global carbon cycle, the generation of biogenically-active gases and its sensitivity and response to changes in temperature, sea level and water mass distribution.

First with MERIS on board ENVISAT then with OLCI on board Sentinel-3 (launch planned for the end of 2014), the products available are the concentration of the water constituents, the inherent optical properties (IOP) of sea water, and other parameters needed to detect the biochemical nature of the species and their response to the variation of the climate due to anthropogenic activities.

From the L1b MERIS product, CoastColour proposes 3 levels of product:

- The L1P is the top of atmosphere (TOA) radiance corrected from the smile effect, geo-located pixels and with a quality mask (surfaces identification, cloudy pixels and other quality flags).
- The water leaving reflectance (L2R) is the TOA radiance corrected from atmospheric effects and from glint and adjacency effect. This is the input to the third level (L2W);
- The L2W concerns the water specific product (concentration, IOPs and other parameters).

These products are available via a web site for 27 coastal zones (see Figure 1:).

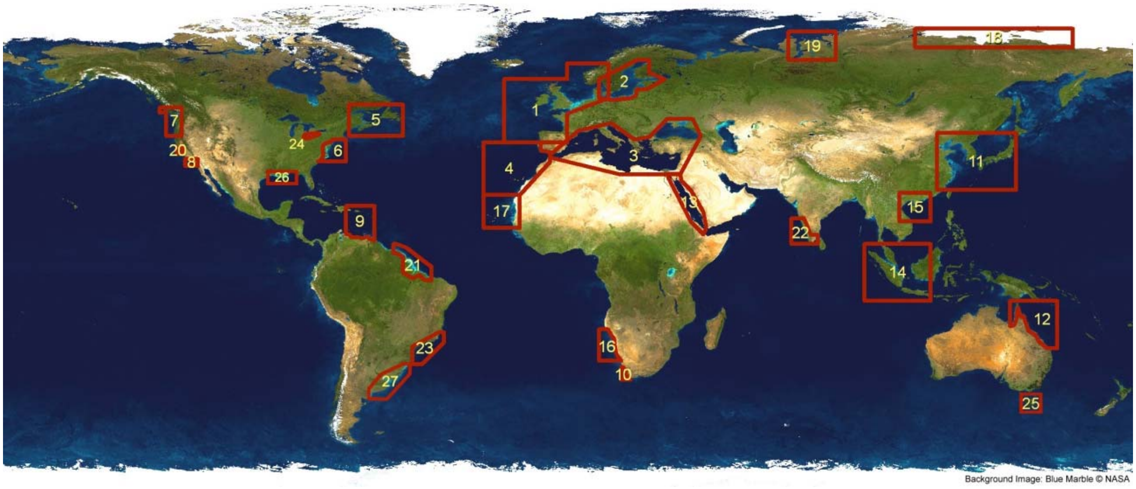

Figure 1: The 27 CoastColour coastal zones: 1: North Sea, English Channel, Bay of Biscay, Celtic Sea; 2: Baltic; 3: Complete Mediterranean & Black Sea; …

2.2 The selection of CoastColour products

2.2.1 The water properties

The relevant CoastColour products for Citclops have been chosen after consulting the consortium partners which are involved in ocean colour research activities (development of algorithms, validation, and development of sensors or measurement platforms). The main objective of these satellite products is to deliver a climatology which will provide typical values to compare and validate the in-situ measurements and observations (in-situ sensors, smartphone, etc…).
The products selected from the CoastColour database come from five groups of variables (Ref. 4):

- RSURF: surface reflectance
- CONC: concentration parameters
- IOPs: inherent optical properties
- OTH: other properties
- FLH: chlorophyll indices

The variables selected in each category are:

- RSURF:
  - The fully normalized water leaving radiance reflectance RLwn
- CONC:
  - Chlorophyll-a concentration Chl
  - Total suspended matter TSM
- IOPs:
  - Total absorption coefficient of all water constituents a_total
  - Total backscattering coefficient of suspended particles bb_spm_443
- Phytoplankton pigment absorption coefficient a_pig_443
- Yellow substance absorption coefficient a_ys_443

- OTH:
    - Spectral downwelling irradiance attenuation coefficient kd_490 and kd_550
    - Turbidity in Formazine Units TFU
- FLH:
    - Fluorescence line height FLH
    - Maximum chlorophyll index MCI

The Figure 2: gives an example of the CoastColour product showing a RGB radiances composite (on the left) and the chlorophyll-a concentration (on the right) for the water off the Spanish and French coasts.

Another product produced in addition of the CoastColour product is the c_443 parameter, corresponding to the total attenuation of the suspended particles at 443 nanometers. It will be obtained from the both CoastColour parameters: a_total and bb_spm_443.

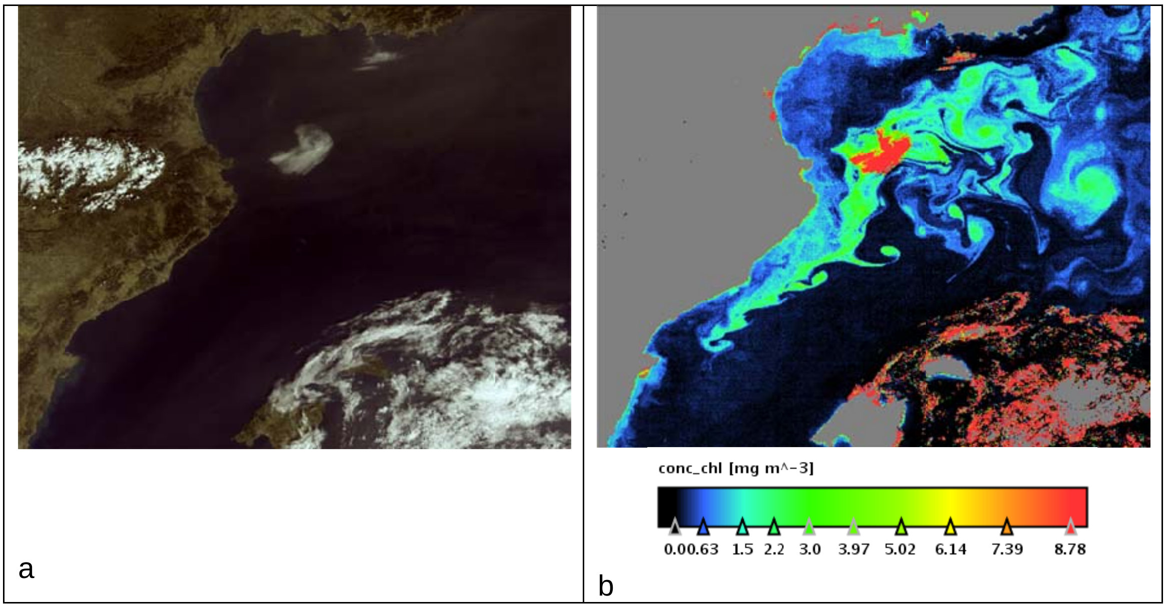

Figure 2: CoastColour map over the Mediterranean sea off the Spanish and French coasts (note the Ebro Delta with Alfacs Bay in the lower left corner of the images) on the 29th march 2012 for (a) the RGB composite TOA radiances and (b) the L2W chlorophyll-a concentration (Chl)

2.2.2 The flags accompanying the water variables

The L2R and L2W products are provided with quality information on the retrieval algorithm, on the confidence of the pixel and on contamination by cloud, glint,…
The best quality mask will be applied to be sure to not take bad or low confident information since the temporal average will compensate the flag filtering by increasing the spatial coverage.
The three level products come with flag from lower level products (L1 flag for the L1P, L1 + L1P flags for the L2R, …) and with the flag of the processed product level. Thus, we have:

- For the L1P : L1flag + L1P flag;

- For the L2R : L1flag + L1P flag + L2R flag;
- For the L2W : L1flag + L1P flag + L2R flag + L2W flag;

We will ensure to take into account the pixel with the most confident flag.

The L1b flags give information on the identification of each pixel: clouds, shadow, land/water, case 1 & 2 waters, coastline, glint risk, snow or ice.
We will prefer the land/ocean flag of the L1P flag than the L1 flag because some pixels are flagged as potential land pixel in the L1P while flagged ocean in the standard level 1. We will discard also the pixels under the glint risk (*L1P flag = 256*) and with a doubt on its surface identity (*potential land: L1P flag = 128*). The cloud mask has four levels to indicate a cloudy pixel or a probably cloud contamination (shadow or edge). We will discard these contaminated pixels.
The quality indicator will also be used to discard low confident pixels.

We will use the L2R flag which has a level making the combination of the pixel quality indicator and the cloud mask.
The L2R flags will give information about the quality of the atmospheric correction to obtain the water-leaving radiances. The ranges of the Top of Atmosphere (TOA) and Top of Standard Atmosphere (TOSA), coming from after the gaseous absorption and scattering correction, pixels are evaluated and classified. The largest solar zenith angles are also flagged.

Finally, the L2W mask will be used thanks to the information giving on the quality of the retrieval properties.
It includes the result of the out of training range evaluation for the water leaving reflectances and the water constituents. A risk for the white caps is also flagged. Some flags concerning the retrieval algorithms (negative values, imaginary number) are interesting and will be used.

Based on a combination of such flags, an automatic system will be applied on the L2R and L2W selected products to make the climatology as confident as possible. Adapted to each product, the most stringent choices will be done on the flags to discard the discrepancy pixels and the out of range values.

2.3 The Forel-Ule product

The Forel-Ule colour scale (Ref. 1 ; Ref. 2) is a colorimetric scale ranging from indigo blue for the open ocean to brownish-green for coastal water and even brown for humid-acid dominated waters (Ref. 3). This scale is used to compare water colour around the world and the data collected since one century can be compared with the present measurement (Ref. 5). A recent perspective has been to transform the satellite spectral measurements (radiances) into the Forel-Ule (FU) scale and thus to compare with the in-situ FU data and make global and historic statistics on the ocean colour to study their time evolution.

In the frame of the WP8, the description of the algorithm for the MERIS transformation into FU scale developed by the NIOZ (M. Wernand) will be described in the D8.2 report.

The FU-MERIS product will be integrated as a GIS layer in the Citclops database.
An example of the MERIS Forel-Ule map is shown on the Figure 3: for the Madagascar channel.

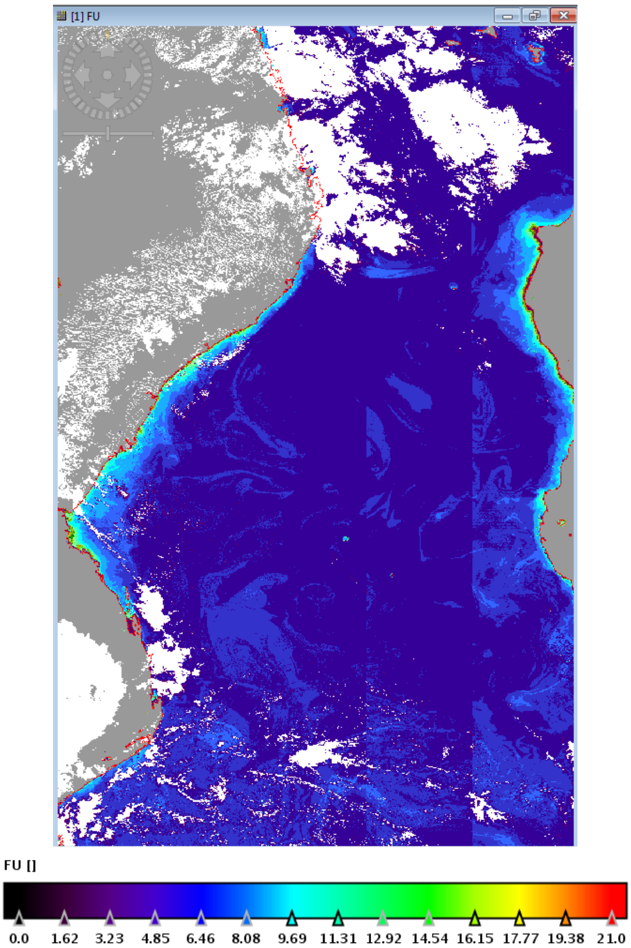

Figure 3: The MERIS Forel-Ule map for the Madagascar channel and the colour scale legend.

2.4 The GIS layers

2.4.1 The product selected

The product available in the Citclops project defined as GIS layers are listed in the table 1.

parameters	description	unit	Origin
Norm_reflect	Fully normalized water leaving radiance reflectance (13 bands from 412 to 864 nm)	sr^{-1}	Direct CoastColour L2R
Chl	Chlorophyll-a concentration	mg/m^3	Direct CoastColour L2W
TSM	Total suspended matter	g/m^3	Direct CoastColour L2W
Kd *@ 490nm & 550 nm*	Spectral downwelling irradiance attenuation coefficient	m^{-1}	Direct CoastColour L2W

TFU	Turbidity in Formazine Units	FNU	Direct CoastColour L2W
a_total	Total absorption coefficient of all water constituents	m^{-1}	Direct CoastColour L2W
bb_spm_443	backscattering coefficient of suspended sediment	m^{-1}	Direct CoastColour L2W
a_pig_443	Phytoplankton pigment absorption coefficient	m^{-1}	Direct CoastColour L2W
a_ys_443	Yellow substance absorption coefficient	m^{-1}	Direct CoastColour L2W
FLH	Fluorescence line height		Derived CoastColour L2W
MCI	Maximum chlorophyll index	$mW/m^2.sr.nm$	Derived CoastColour L2W
FU	Forel-Ule		Citclops processed
c_443	Total attenuation of suspended matter		Citclops processed

Table 1 : Variable of CoastColour database used in the Citclops GIS layers.

2.4.2 The GIS layers

The GIS layers will consist of climatology of the CoastColour product on the two regions of interest. The temporal re-sampled images will be the monthly, yearly and seasonal averages and statistics will be produced (minimum, maximum, standard deviation, 10 and 90 percentiles). Besides the arithmetic average, the geometric average will be processed which is a less sensitive measure to extreme values (Ref. 6).
The monthly and annual averages will be based on the civil calendar. The monthly average will be made from the first day to the last day of the month (28, 29, 30 or 31). Information about the representativeness of the average for each pixel will be added.

The period for the seasonal average has been defined and based on the astronomically simple classification of the meteorological calendar:
3 months per season:

winter = December + January + February,
spring = March + April + May,
summer = June + July + Aug,
autumn = September + October + November.

The no-data pixel will not be compensated and a zero value will be assigned.

Two large geographical zones have been defined including the two ROI, Alfacs Bay and Wadden Sea. The limits are given below as images (Figure 4:). The limits for the Alfacs Bay zone are [38°-42°N] and [2°W – 6°E] and for the Wadden Sea are [50° - 56°N] and [0° - 10°E].
Since MERIS CoastColour data are produced with two different spatial resolutions and since the OLCI swath will be different from MERIS, we will produce the GIS layers on a reference grid with fixed geographical coordinates on which the MERIS and future ocean colour sensors will be projected. A possibility to zoom-in will be implemented.

Each of the ocean colour parameter will be mapped on the reference grid. A fixed colour scale will be defined for each parameter and adapted to the ROI. The definition of the colour bars (range and extreme values) will be done with the Citclops partners involved in ocean colour research activities and will be based on published studies giving typical values on the two pilot regions (Ref. 7).

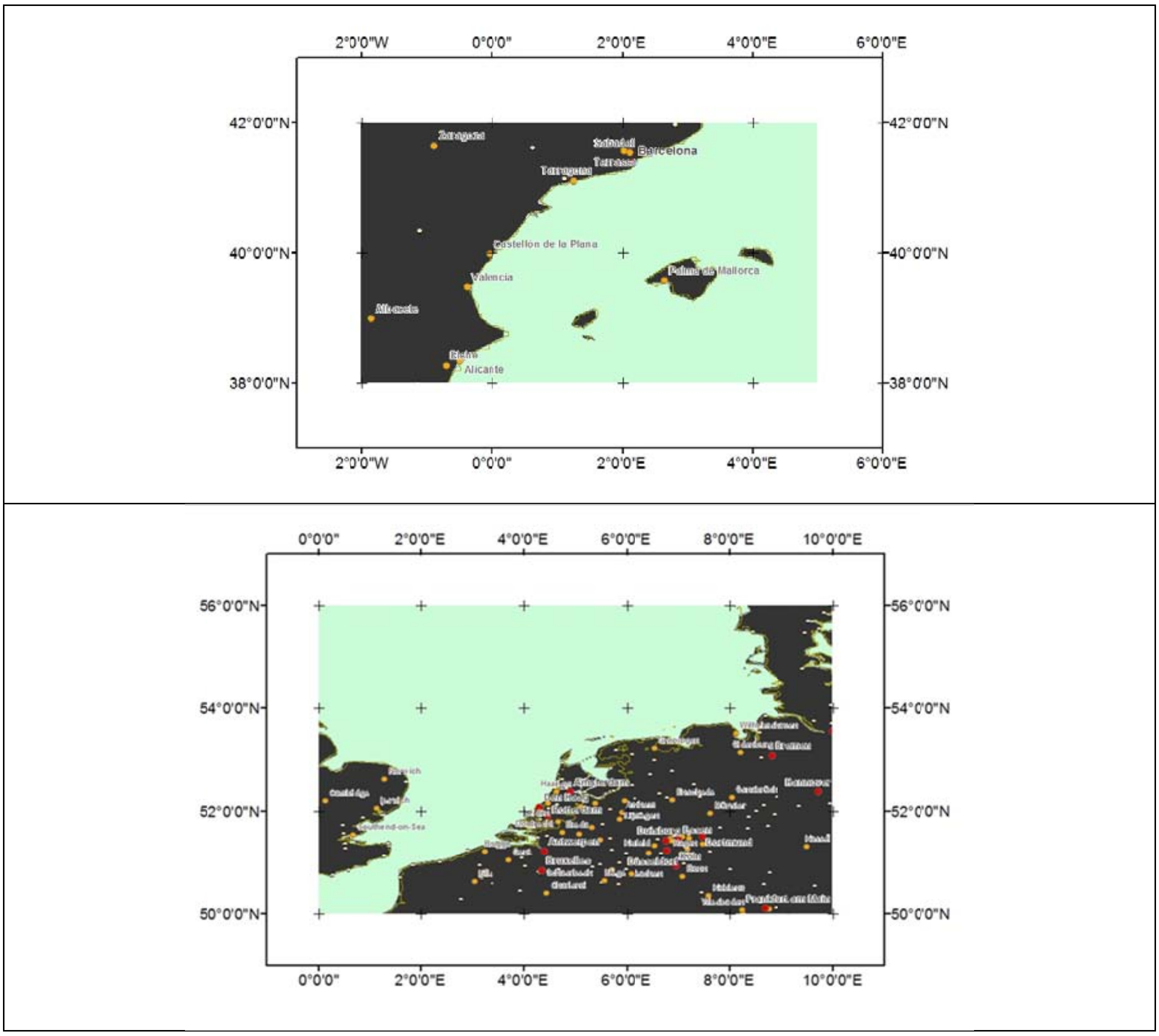

Figure 4: The two geographical zones of the GIS layers defined by Citclops partners including the two ROIs: Alfacs Bay (A) and the Wadden Sea (B)

3 References

Ref. 1 Forel F. A., "Une nouvelle forme de la gamme de couleur pour l'étude de l'eau des lacs" in Archives des Sciences Physiques et Naturelles/Société de Physique et d'Histoire Naturelle de Genève, 6, 25 (1890).

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Ref. 6 Eleveld, M. A; Pasterkamp R.; van der Woerd, H. J.; Pietrzak J. D., “Remotely sensed seasonality in the spatial distribution of sea-surface suspended particulate matter in the southern North Sea”, in Estuarine, Coastal and Shelf Science, 80, 103-113, 2008

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4 List of Key Words/Abbreviations

CDOM	Coloured Dissolved Organic Matter
FU	Forel-Ule
IOP	Inherent Optical Properties
L1B	Level 1B
L1P	Level 1P
L2R	Level 2 Reflectance
L2W	Level 2 Water
MERIS	MEdium Resolution Imaging Spectrometer
OLCI	Ocean and Land Colour Instrument
ROI	Region of Interest
TOA	Top of Atmosphere