EXPLOITATION OF GLOBCOLOUR DATASET: GLOBAL CHARACTERISATION OF CHLOROPHYLL, ACDM AND BBP UNCERTANTIES AT PIXEL LEVEL

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1. GENERAL INFORMATION

The GlobColour project has been initiated and funded by the ESA Data User Element Programme to develop a satellite based ocean colour data service to support global carbon-cycle research and operational oceanography. It was aiming at satisfy the scientific requirement for a long (10+ year) time-series of consistently calibrated global ocean colour information with the best possible spatial coverage. In order to cover the long time span necessary for climate monitoring purposes, the required ocean colour data set could only be built by merging together observations made with different satellite systems. To that purpose, MERIS products are merged with MODIS and SeaWiFS and a Full Data Set (FPS) covering more than 11 years of observation has been built and made available to the scientific community (www.globcolour.info) and in particular to the key users of the project: IOCCP, IOCCG and UKMO

2. MERGING TECHNIQUE

After comparisons exercise between merging technique, the core of the merging procedure has been based on the semi-analytical ocean color model described by Maritorena et al. (2002), hereafter referred to as the GSM01 model. In this model, a functional relationship between $L_{wN}(\lambda)$ and the component absorption and backscattering coefficients is taken,

$$L_{wN}(l)=\frac{t\,F_0(l)}{n_w^2}\sum_{i=1}^{2} g_i\left(\frac{b_{bw}(l)+b_{bp}(l)}{b_{bw}(l)+b_{bp}(l)+a_w(l)+a_{ph}(l)+a_{cdm}(l)}\right)^i \quad (1)$$

where t is the sea-air transmission factor, F_0 is the extraterrestrial solar irradiance, n_w is the index of refraction of the water and g_i are geometrical factors. The absorption and backscattering, $a(\lambda)$ and $b_b(\lambda)$, coefficients may be partitioned into seawater backscatter ($b_{bw}(\lambda)$) and absorption ($a_w(\lambda)$), particulate backscatter ($b_{bp}(\lambda)$), phytoplankton absorption ($a_{ph}(\lambda)$) and the combined effects of dissolved and detrital particulate absorption $a_{cdm}(\lambda)$ (which is related to CDOM; see Nelson and Siegel, 2002). Pure water optical properties, $b_{bw}(\lambda)$ and $a_w(\lambda)$, are known constants (Morel, 1974; Pope and Fry, 1997) while each of the non-water components of absorption and backscattering is expressed as a known shape function with unknown magnitude:

$$a_{ph}(\lambda) = \mathrm{Chl}\ a_{ph}^{*}(\lambda) \quad (2a)$$
$$a_{cdm}(\lambda) = a_{cdm}(\lambda_o)\exp(-S(\lambda - \lambda_o)) \quad (2b)$$
$$b_{bp}(\lambda) = b_{bp}(\lambda_o)\,(\lambda/\lambda_o)^{-\eta} \quad (2c)$$

For $a_{ph}(\lambda)$, $a_{cdm}(\lambda)$, and $b_{bp}(\lambda)$, the unknown magnitudes are the chlorophyll concentration, Chl, the CDM absorption coefficient, $a_{cdm}(\lambda_o)$, and the particulate backscatter coefficient, $b_{bp}(\lambda_o)$, respectively. The chlorophyll-specific absorption coefficient of phytoplankton, $a_{ph}{*}(\lambda)$, η, S, were determined by tuning the model against a large global in situ data set (Maritorena et al., 2002). The three unknowns, Chl, $a_{cdm}(\lambda_o)$ and $b_{bp}(\lambda_o)$, are retrieved by inverting the model. We apply the Levenberg-Marquardt non-linear least squares technique to find the values of Chl, $a_{cdm}(\lambda_o)$ and $b_{bp}(\lambda_o)$ which best minimizes the mean square difference between the modeled and measured $L_{wN}(\lambda)$. The non-linear fitting technique can also account for uncertainties in the measured $L_{wN}(\lambda)$ by using input and model uncertainty levels ($\sigma_i(\lambda_j)$ and $\sigma_{mod,i}(\lambda_j)$) as weights in the fitting procedure. By conducting this inversion using several satellites (N_{sat}), each with several wavebands (N? i), a metric for least squares minimization (c^2) can be created, or

$$c^2 = \frac{1}{(Nb\_obs - Nb\_param)} \sum_{j=1,sensor1}^{sensorN} \sum_{i=1}^{nband\_j,i} \frac{\left(Lw_{Ngsm\_i} - Lw_{Nsensor\_i,j}\right)^2}{s^2_{sensori,j} + s^2_{gsm\_i}} \quad (3)$$

Values of c^2 measure the degree of misfit of the model (equations 1 and 2) compared with satellite measurements from different missions and for several wavebands weighted by the quality of the input data. In particular, the application of a maximum likelihood approach allows calculation of uncertainties for each of the data products generated following standard non-linear regression methods (e.g., Bates and Watts, 1988; Press et al. 1992; Garver and Siegel, 1997).

3. DERIVATION OF ERROR BARS

The potential of this inversion technique for providing error bars has been extensively explored during GlobColour and some consolidated results are presented below.
The requested qualification of inputs (as well as model uncertainties) has been done during the first phases of GlobColour.

4. UNCERTANTIES OF THE WATER-LEAVING RADIANCE SPECTRA (σ_{sensor})

Statistical figures from match-up analyses between satellite and in situ NLw(λ) observations were used to determine the expected level of error for each band by using the original NOMAD data set (Werdell and Bailey, 2005) plus data from the NASA SeaBASS archive (Werdell & Bailey, 2002), the BOUSSOLE buoy (Antoine et al., 2008a, b) and above-water radiometric measurements (Hooker et al., 2004; Zibordi et al., 2006a, b), the normalized water-leaving radiances from each of the sensors were compared to in situ data for each of the bands in the visible through match-up plots and regression statistics.

5. MODEL ERRORS (σ_{gsm}(i, j))

To evaluate the errors caused by the GSM01 model, the input radiance spectra from the NOMADv1 data set were compared to the GSM01 radiance spectra that correspond to the best fit obtained during the inversion (or, in other words, the reconstructed radiance spectra when the model is used in the forward mode and produces a radiance spectrum given a set of Chl, CDM and BBP values).

6. UNCERTANTIES ON OUTPUTS

Propagation of error through Levenberg-Marquardt minimisation procedure has allowed production of reliable error bars at least for Chl-a and for bbp. For CDM the propagation of uncertainties has proven to be less reliable and points toward a requested adaptation of the reference reflectance spectrum.
Illustrations below (figure 1) figure out the results for all three parameters (see the three first panels) of the retrieved error estimates wrt to actual error obtained through matchup analysis. Scatter plots for which (visually) two third of the actual error is under the 1/1 line of error estimates, indicate a satisfactory estimates of the error (as assumed to follow a normal probability function). The three normalised distribution function have been reported on the fourth panel (right-below) and theoretically should be comparable to the normalised centred density probability function which is also sketched. Good correlation between this theoretical shape and the ones obtained for Chla and bbp (while CDM deserves some attention) indicates that this approach is the one to be followed for the implementation of the OLCI L2 processing.

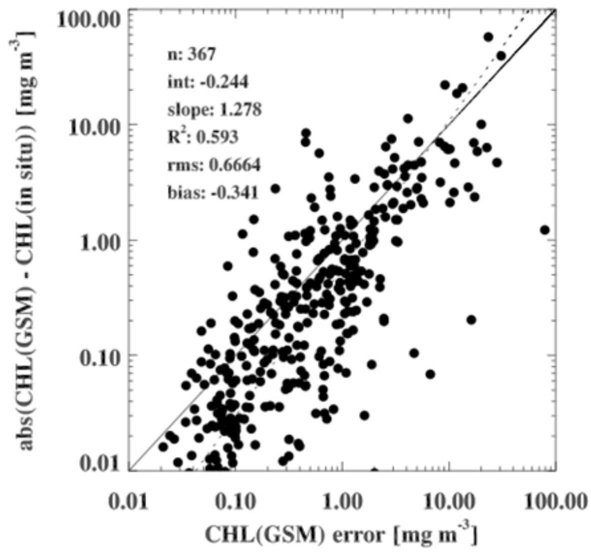

Figure 1a

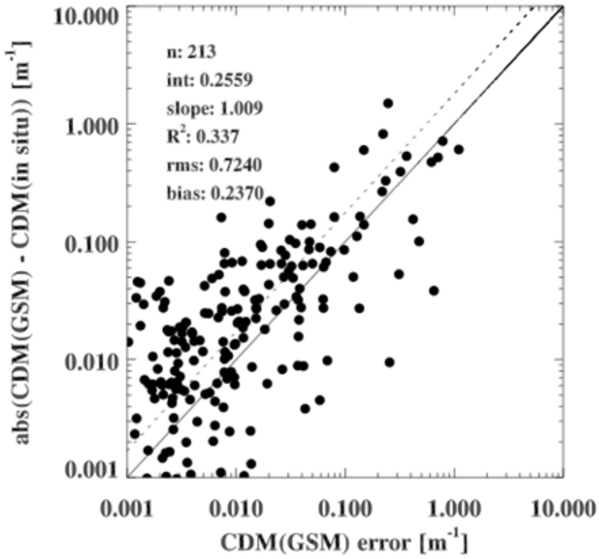

Figure 2b

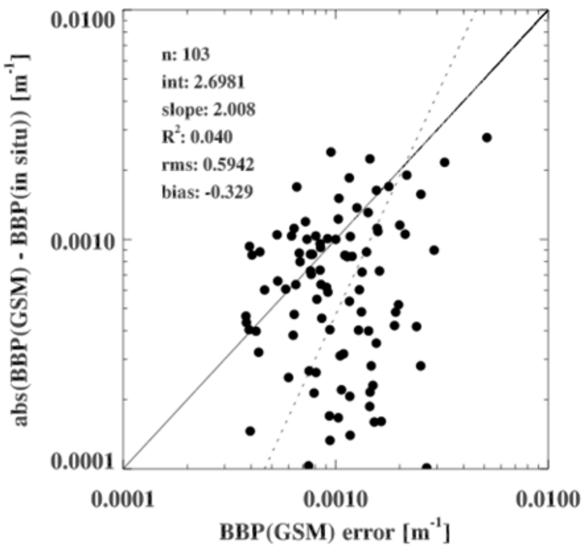

Figure 3c

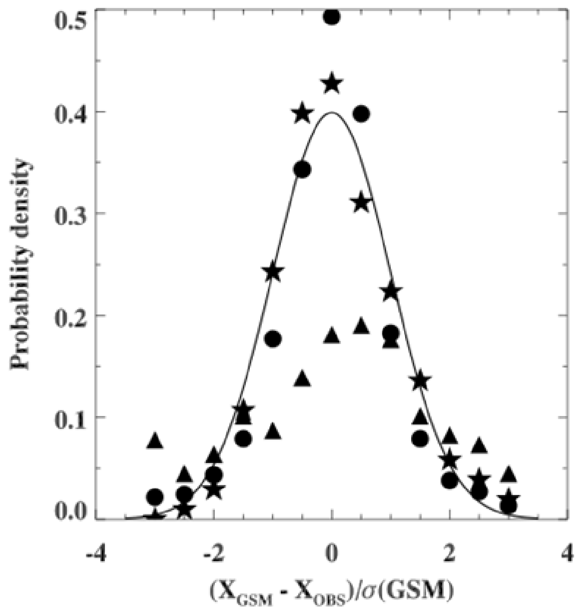

Figure 4d

Figure 5: Adapted from Fig. 9 of Maritorena et al. 2009. Comparisons of the predicted and actual uncertainties using the NOMAD data set (1a: CHL; 1b: CDM; 1c: BBP. If the predicted uncertainties are accurate, about 2/3 of the data points should be below the 1:1 line. The centered variables (retrieval/error; lower right panel) show a normal distribution for CHL (circles) and BBP (stars) while the CDM (triangles) distribution departs from normal (curve).

7. CONCLUSIONS PERSPECTIVES

The GlobColour service distributes global daily, 8-day and monthly data sets at 4.6 km resolution for, chlorophyll-a concentration, normalised water-leaving radiances (412, 443, 490, 510, 531, 555 and 620 nm, 670, 681 and 709 nm), diffuse attenuation coefficient, coloured dissolved and detrital organic materials, total suspended matter or particulate backscattering coefficient, turbidity index, cloud fraction and quality indicators. New demonstration products are available online too: Photosynthetic Available Radiation, Depth of the Heated Layer, Secchi Disk Depth. Error statistics from the initial sensor characterisation are used as an input to the merging methods and propagate through the merging process to provide error estimates on some output merged products namely: Chlorophyll-a concentration, backscattering of suspended matter and absorption of coloured dissolved and detrital organic materials, which appeared to be reliable (at least clearly for the two first) and open the route to derivation of errors bars on by-products (e.g. Secchi depth, DHL, …). These error estimates are a key component of GlobColour as they are invaluable to the users; particularly the modellers who need them in order to assimilate the ocean colour data into ocean simulations.

The NRT service was started mid-2008, with a global daily delivery of merged MERIS and MODIS ocean colour data to primarily support operational oceanography. The GlobColour service has begun to feed in the European Community funded Marine Core Service, MyOcean, which starts to provide, in 2009, a suite of services to support Europe's decision makers. GlobColour's merged ocean colour dataset are provided by the Global Ocean Colour Thematic Assembly Centre (http://www.myocean.eu.org/repository/full_catalogue_v0.pdf) whose main objective is to bridge the gap between space agencies providing ocean colour data and Global Monitoring for Environment and Safety (GMES) marine applications.

The exploitation of the GlobColour dataset gives access to the spatial and temporal variability of the Chlorophyll, aCDM and bbp uncertainties at global and regional scales. Results of this characterisation will be presented and discussed.

8. ACKNOWLEDGEMENT

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