# Reviewer#1

The comments (bold) are followed by answers, and when applicable, by modifications in the text. Note that extra-modifications are included under section “OTHER COMMENTS”, after sections “GENERAL COMMENTS” and “SPECIFIC COMMENTS”.

## GENRAL COMMENTS

**General Comment1: “Most data seem to have been collected away from coastal zones.”**

**Answer GC1**: Strictly speaking, the coastal waters are indeed legally defined as the part of the ocean within 19.3 km (12 miles) from the coasts. Nevertheless, the CoastColour test sites cover selected coastal zones with extensions towards the open ocean (see map in Ruddick et al., 2010 SPIE proceedings). This enables testing remote sensing algorithms in a wide range of oceanographic waters. Generally, the coastal zones can be defined as the regions in which CDOM is significantly affected by rivers and runoff from terrestrial origins, which induces high spatial/time variability of CDOM (or salinity) in these coastal waters (see details under the answer to Specific Comment3 below). Coastal zones can also include coastal upwelling areas, adjacent to the continental shelf.

As we focus on the coastal area, the MERIS match-up and the *in situ* reflectance datasets retained for the CCRR exercise are generally geographically located within 60 km from the coasts for most of the sites, where the data are mostly confined along the coastal area (< 40 km). This is the case for the sites: Acadia, Benguela (<20 km), Great Barrier Reef region (<20 km), Tasmania (<20 km), Gulf of Mexico, the eastern region of the Indonesian coastal waters, Trinidad and Tobago. For the North Sea and the East China Sea sites, the measurements are more extended because they include all the area around UK/Ireland Islands and the Japan Sea Islands respectively, while the Oregon-Washington and Central California sites are extended over the continental shelf (Juan de Fuca Plate, up to the limit of the Pacific plate) and the Southern California site includes the Channel Islands extending 80 km (50 miles) from the coast.

**General Comment2: “Clearly there are a few datasets from turbid coastal zones but it was difficult to understand how many or what fraction of the data.”**

**Answer GC2**: It is true that exact percentages of CCRR data collected in clear and turbid waters were not provided in the manuscript. This is due to the fact that the parameters measured in the CCRR sites are variable from one site to another (see Table 3a-3b), so there is no information on water turbidity for all the dates and locations of *in situ* measurements (for instance, at the Chesapeake Bay and Oregon-Washington sites, there are no data available for turbidity, TSM, (back)scattering or Secchi depth). Hence, we cannot state the exact percentage of absorption or reflectance measurements in turbid waters when no extra-information on turbidity (associated with these measurements) is provided. Further details are given in the answer to Specific Comment #5 below.

**General Comment3: “The manuscript text (introduction, conclusions) gives the impression that the effort focused on turbid coastal zones. Perhaps this can be better clarified in the**

**abstract, stating the percentage of which type of data really represents turbid or shallow environments."**

**Answer GC3**: We have clearly described the CCRR datasets as being available for coastal waters around the world, not focusing on turbid waters (for instance, there is no mentioning of the words "turbid waters" in the introduction). In the conclusion, we summarized section 3 (which presents, amongst others, TSM, turbidity and CHL distributions in the CCRR datasets), saying that "*The CCRR match-up,* in situ *and simulated datasets form a large database covering a wide range of water types, from oligotrophic to hypertrophic, and from clear to very turbid waters with a high diversity of IOPs."* Hence, there was no focus on turbid waters, but rather on the variability of water types. In the abstract we stated that *"The distribution of the three reflectance datasets are also compared to the simulated and* in situ *reflectances used previously by the International Ocean Colour Coordinating Group (IOCCG, 2006) for algorithm testing, showing a clear extension of the CCRR data which covers more turbid waters."*, which indicates that the CCRR dataset includes waters with larger ranges of turbidity than the IOCCG synthetic dataset.

In the answer to the Specific Comment #5 (see below), we plotted ternary graphs showing the extension CCRR dataset over a wide range of water types.

## SPECIFIC COMMENTS

<u>**Specific Comment1**</u>**: ABSTRACT: "The abstract could provide a brief summary of the performance of the algorithms for a few of the most important water quality parameters, both using *in situ* as well as satellite data. At the moment the abstract simply says that the authors assembled the data and did some comparisons but it doesn't summarize results. The paper really contains more of a very detailed description of various data than a description and test for various water quality parameters. Perhaps thus the language in the Abstract can be refined some to emphasize algorithms less than stated now."**

**Answer SC1**: The Abstract and Introduction parts introduce the CoastColour Round Robin project and the objectives behind setting up the CCRR dataset (to be used in remote-sensing algorithms intercomparison). The scope of this paper is to present the CCRR dataset, in detail, which is now clearly stated in the abstract, to avoid any false expectations on algorithm inter-comparison:

"The use of *in situ* measurements is essential in the validation and evaluation of the algorithms that provide coastal water quality data products from ocean colour satellite remote sensing. Over the past decade, various types of ocean colour algorithms have been developed to deal with the optical complexity of coastal waters. Yet there is a lack of a comprehensive inter-comparison due to the availability of quality checked *in situ* databases. The CoastColour Round Robin (CCRR) project funded by the European Space Agency (ESA) was designed to bring together three reference datasets using these to test algorithms and to assess their accuracy for retrieving water quality parameters. This paper provides a detailed description of these reference datasets that include the Medium Resolution Imaging Spectrometer (MERIS) Level 2 match-ups, *in situ* reflectance measurements and a synthetic data generated by radiative transfer model (HydroLight). These datasets are available from doi.pangaea.de/10.1594/PANGAEA.841950".

The scope of the paper was also given in the introduction: *"This study provides documentation for the publicly available datasets (as detailed in Sect.4) which can be used as benchmarks for oceancolour algorithm testing in coastal waters, to ultimately improve the remote sensing algorithms."*

**Specific Comment3: P 177-15: why is the 709 nm band unique – explain. Figures 1 and 4 (salinity) suggest most samples are actually from areas dominated by marine waters.**

**Answer SC3**: MERIS band 709 nm was unique amongst any other ocean colour mission spectral specifications; with this band, MERIS offered the unique capability to better estimate Chl-a concentration from remote sensing reflectance, since Chl-a algorithms can combine band 709 nm with other bands in/around the phytoplankton absorption peak. Furthermore, the near infra-red and the 709 nm band from MERIS has been used by many (Gower, Gitelson etc) to detect blooms in either high Chl (>30 mg/L) waters or turbid waters also, plus it is also used in FLH (fluorescence).

**Specific Comment4: Figures 1 and 4 (salinity) suggest most samples are actually from areas dominated by marine waters.**

**Answer SC4**: The surface salinity in Figure 6 shows that most of the salinity data (N>220 in Central California, N>24000 in North Sea, N=427 in Oregon-Washington, N=122 in Southern California) with a total of data size exceeding 24 700, have been collected at salinity values ranging from 25 psu to 34 psu. The median values of salinity collected at East China, Florida, GBR region and Tasmania sites range between 33 and 35 psu with only few maxima below 36 psu, whereas minimum values go below 32 psu. The only two sites which are indeed in more "open" waters type are Morocco-W.Md. Sea and Trinidad and Tobago. Furthermore, remote sensing studies usually consider extended coastal waters with salinity < 35 psu e.g. SW Florida coastal waters (Hu et al. 2005, RSE).

**Specific comment5: "Many (most) of the areas shown are not really coastal or Case II. Perhaps authors can clarify how many samples they have that can be classified as Case II. Authors should also state this in the abstract and in the last paragraph of the body, which read as if most of the data are actually from turbid coastal zones – it seems to me that actually most data are not from turbid coastal zones but rather a smaller number of the data – again, please qualify/quantify this for the reader in the abstract, introduction, and in the conclusions, perhaps also making it clearer in the body."**

**Answer SC4**: Due to the divers nature of the CCRR datasets it is impossible to provide this information consistently. CHL, TSM and CDOM measurements are not available for all the stations monitored, which means a ternary plot is possible only for partial dataset (at 182 stations, see Figure 1, upper graph). Similar for absorption budgets (Figure 1, bottom). We could use the salinity but again not all stations have salinity. The *in situ* reflectance, MERIS match-up and simulated data sets could be classified into coastal and more blueish open ocean waters. We could use a simple blue/green ratio test to separate the blue waters. This information is already given in Figure 23 – all those data points with RLw ratio (490:555) < 1 are coastal, and can be used as a simple indicator for "coastal".

Here are the statistics which show how it is difficult to give percentage of coastal waters, case 2 or turbid waters:

- In the MERIS match-up (field) dataset, we consider a subset of 31 506 stations which includes at least one of the following measurements: salinity, TSM, CHL, scattering and backscattering coefficients (at 555 nm), absorption coefficients at 443 nm, for detrital matter, $a_d$, CDOM, $a_g$, phytoplankton, $a_{ph}$, and total particulate matter, $a_p$, water-leaving reflectance at 490 nm and 555 nm, and/or turbidity
- The percentage of stations where salinity is below 32 psu is 19% (with respect to the total number of stations where salinity was available), but we note that percentage of stations where no salinity was provided is 18%
- Percentage of stations where either turbidity or TSM exceeds 10 (NTU, or g $m^{-3}$) is 16% of the total number of stations where these parameters were measured, while percentage of stations with no information on TSM or turbidity is given is very high: 91%
- 57% of stations where $a_d$ was measured show $a_d$(443 nm) > 0.01 $m^{-1}$, but $a_d$ was missing from 98% of the subset
- 72% of stations where $a_p$ was measured show $a_p$(443 nm) > 0.05 $m^{-1}$, but $a_p$ was missing from 98% of the subset
- 64% of stations where *RLw* was measured show *RLw*(490 nm)/ *RLw*(555 nm)< 1, but this ratio was missing from 97% of the subset
- 10% of stations where either $b$ or $b_b$ were monitored show $b$ or $b_b$ exceeding 0.5 $m^{-1}$ and 0.05 $m^{-1}$ respectively. Percentage of stations with no information on $b$ or $b_b$ is 99%
- If we flag all the stations where $a_d$, $a_p$, TSM, turbidity, $b$ or $b_b$ , and *RLw* ratio reach the limits given above, as "turbid waters" (non-blue waters), we obtain the percentage of 36% for turbid water stations, but we need to keep in mind that amongst 31 506 of that CCRR subset, these parameters were provided at only 3 586 stations (4%!)

The ternary plots below show, for the regions indicated, the distributions of

- suspended particulate matter, chlorophyll-a concentration, CDOM absorption,
- absorption coefficients: $a_d$, $a_{ph}$ and CDOM absorption

These plots depict the variability of water types even within a single region e.g. the North Sea. But the plots only give a partial view of the natural variability of water optical properties and bio-geochemical parameters described in the CCRR datasets manuscript.

Therefore, these statistics/graphs are not provided inside the manuscript body, since they do not reflect a complete overview of the water classes actually monitored within the CCRR datasets – but only partial views. However, they will be provided as supplementary materials, and they are now described in the manuscript, at the end of section 3.5 ("Results and discussion"/"Inherent Optical Properties") as the following:

"Concurrent measurements of $a_g$(443), TSM and CHL collected at the GBR region, Tasmania and North Sea sites, and of $a_g$(443), $a_{phy}$(443) and $a_d$(443), measured at the GBR region, Tasmania, Southern California and Florida sites showed large variability of water optical properties and bio-geochemical parameters, covering the case 1 and case 2 waters (see ternary plots in supplementary materials). Note, however, that these plots do not provide an accurate overview of the water masses sampled for this study."

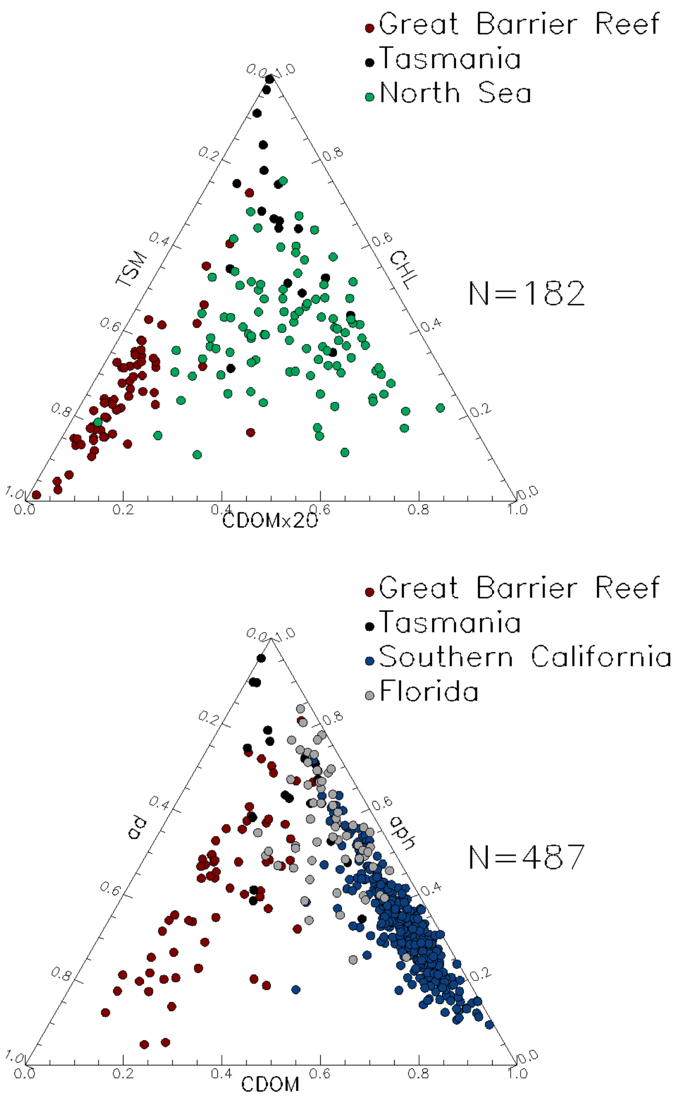



**Figure : Ternary plots for TSM, CHL and CDOM absorption (upper graph) and for absorption coefficients (bottom), collected from the five CoastColour sites indicated in the plots. N is the total number of stations where the three concurrent measurements were available for each graph. Note that these two ternary plots do not provide an accurate overview of the water masses sampled for this study, from the 17 CoastColour sites.**

**<u>Specific comment6</u>: "Can authors explain the extreme values 1000 mg/m3 in Chl a off California? Are these oceanic waters and was there a matchup to satellite data? It would be good to say something about the site."**

**Answer SC6**: Yes, the data have been checked carefully before their publication, and the extreme values briefly explained in the text (page 194-10): *"the variations of Chl a are primarily determined by sea surface temperature and wind-driven coastal upwelling loading nutrient-rich* *waters (Chavez et al., 2002). This site exhibits the widest range of CHL variability (> 6 orders of magnitude).”*

Chl-a value measured from water surface sample off California on 11th Sept 2006 at 18:55 UTC, was extremely high: 1169.728 mg $m^{-3}$. A consecutive measurement at the same location was performed at 19:09 UTC, and at 2 m depth, and also gave a high value of 387.296 mg $m^{-3}$. MERIS match-up reflectance (for both *in situ* measurements) corroborates the *in situ* values, depicting a high phytoplankton absorption peak (see figure 2 below), where RLw at 709 is almost twice the value of RLw at 665 nm.

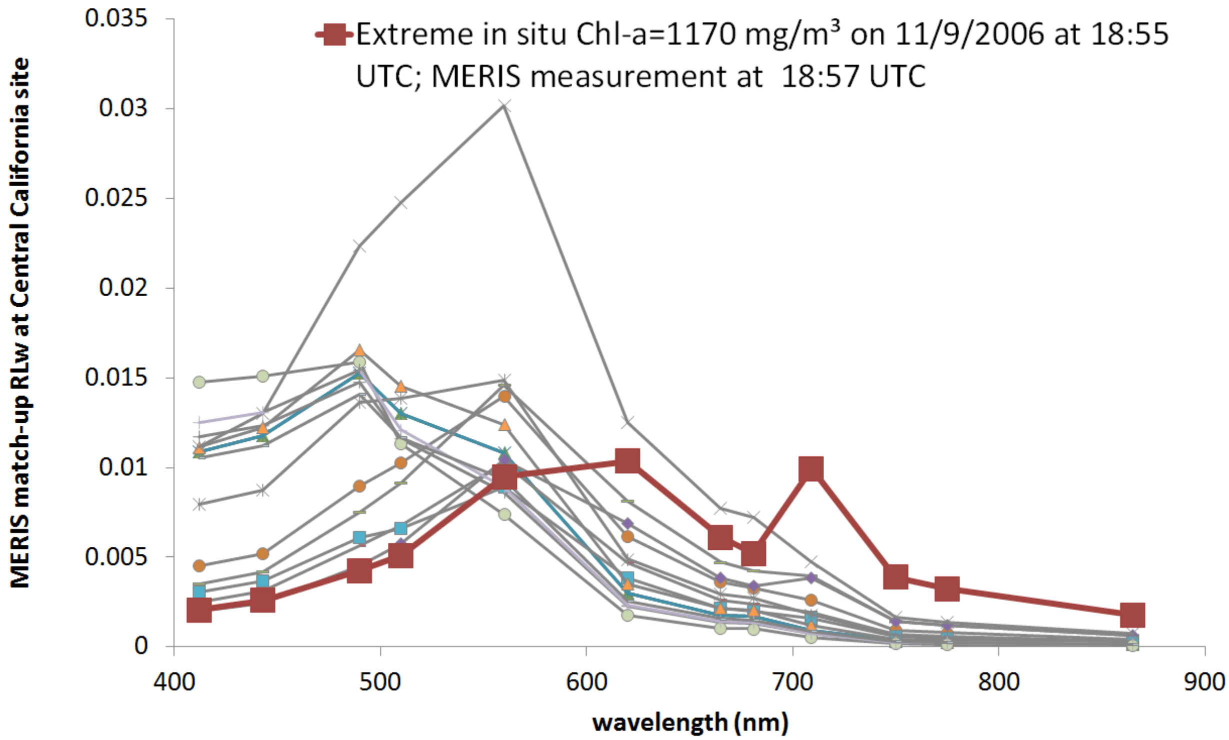



**Figure 2: MERIS RLw reflectances at Central California site, highlighting the extreme phytoplankton absorption peak associated with the extreme *in situ* Chl-a measurements.**

# OTHER COMMENTS

**List of acronyms:**

⇨ ERI acronym is fixed (Earth Research Institute (ERI))

**Absract: specify the *in situ* measurements and simulations are multi- or hyper-spectral.**

⇨ Added in the abstract (highlighted):

"The datasets mainly consisted of 6 484 multispectral or hyperspectral marine reflectance associated with various geometrical (sensor viewing and solar angles) and sky conditions and water constituents"

**Introduction: add definition of Rrs and RLw, as both are used in the text.**

⇨ Added in the introduction (highlighted):

"Three types of data were prepared for the CCRR: a) match-ups: where *in situ* WQ is available simultaneously with a cloud-free Medium Resolution Imaging Spectrometer (MERIS) product; b) *in situ* reflectances: where an *in situ* water-leaving reflectance measurement (denoted by *RLw* which is derived from the remote-sensing reflectance, *Rrs* following $RLw = \pi\ Rrs$)"

**Rectification of data size in section 2.1.1 (carefully checked, now consistent with numbers in Tables 3.a and 3.b).**

⇨ Replaced in the text (as highlighted):

"Metadata including depth, temperature and salinity, exceeded 20 000 for each parameter, whereas the number of bio-geochemical, IOPs and AOPs were much lower: 11 208 chlorophyll-a concentration measurements, 538 TSM measurements, 957 reflectance spectra (the other AOP data do not reach 200 data each), and less than 700 IOP data (for each parameter) except for turbidity (N=2 187)."

**Section 2.1.1 TSM data have been removed from the CSIC data:**

In the CSIC dataset, TSM measurements are not correlated to Chl-a in the Morocco-W. Md. Sea site, at the Guadalquivir estuary flow and offshore, because of light limitation for phytoplankton (due to high TSM concentrations frequently observed at this site). However, the quasi-constant values measured between 30 and 45 mg/l, are probably due to the measuring protocol with no sufficient rinsing of filters. Isabel Caballero de Frutos (CSIC) was about to redo new measurements in this region during year 2015. No results yet.

⇨ In the meanwhile, the TSM and PIM data from CSIC were removed from the paper. **Figures 8** and **10** were updated accordingly and the text too (see below).

**Figure 8 (Morocco-W.Md. Sea site TSM data removed):**

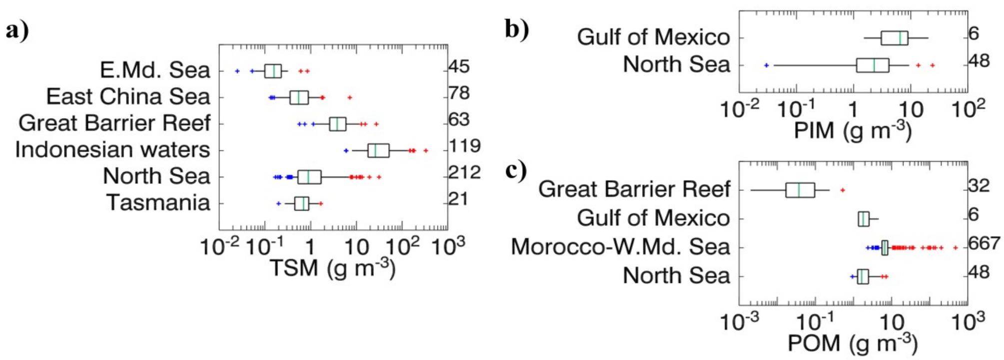
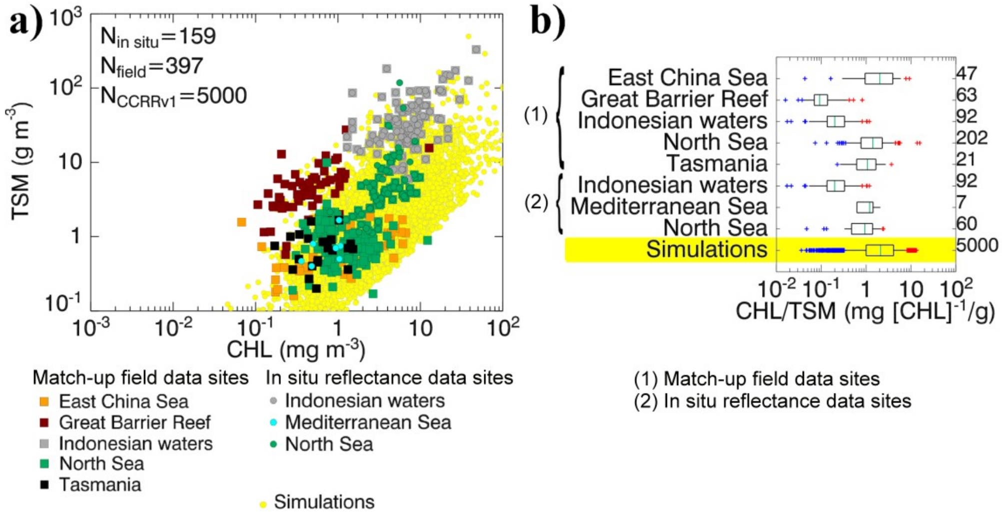


**Figure 10 (Morocco-W.Md. Sea site TSM data removed):**




⇨ The paragraph on CSIC data was updated (see highlighted) as:

"The CSIC dataset contains 736 Chl-a and 667 POM measurements collected in the Gulf of Cadiz (southwest Iberian Peninsula) within the Morocco-W. Md. Sea site. The measurements were taken in the nearshore area (<30 km) of the Guadalquivir estuary from 2005 to 2007, and offshore during 2008 with slightly lesser measurements during the periods June-August (19% of the data). Chlorophyll analysis was conducted by filtering samples of 500 ml through Whatman GF/F glass fiber filters (0.7 µm pore size), extracting in 90% acetone, and measuring chlorophyll-a by standard fluorometric methods using a Turner Designs Model-10 following JGOFS protocols (IOC/UNESCO, 1994). TSM concentrations were measured gravimetrically on pre-weighted Whatman GF/F (0.7 µm pore size) after rinsing with distilled water, following JGOFS protocols (IOC/UNESCO 1994). Organic matter lost on ignition was determined by reweighting the filters after 3 hours in the oven at 500°C, giving the concentrations of PIM and POM (by subtraction). TSM and PIM measurements were contaminated by salt (filters not correctly rinsed) and showed low variability of TSM and PIM, with 90% of TSM measurements comprised between 31.1 and 48.3 g $m^{-3}$. Therefore, only Chl-a and POM measurements were retained from the initial CSIC dataset."

**Section 2.1.1: CSIRO dataset: remove an outlier in $a_{phy}$**

- ⇨ The $a_{phy}$ outlier was removed, Table 3.b updated (62 measurements at the GBR site, and 681 from all sites)
- ⇨ Figure 13 was replotted for GBR region: 62 $a_{phy}$ spectra instead of 63.
- ⇨ All figures in Figure 15 were updated.

**Section 2.1.1: add reference to Ifremer dataset.**

⇨ Added in the text (highlighted):

"The Ifremer dataset consisted of 975 Chl-a measurements collected at 30 different locations within the Armorican Shelf (north-west of France), from 2005 to 2009. Data were available from the French phytoplankton surveillance network (REseau PHYtoplankon, REPHY, Gohin 2011)."

**Section 2.1.1: minor corrections, NOMAD dataset (Chl, IOPs and AOPs).**

⇨ Replaced in the text (as highlighted):

"The NASA SeaWiFS Bio-optical Archive and Storage System (SeaBass, (Werdell et al., 2003)), the source of the NOMAD dataset, includes both the HPLC and fluorometric methods."

"The spectral backscattering coefficient provided in NOMAD dataset was obtained using HOBI Labs HydroScat-2 and HydroScat-6 sensors, WET Labs *ECO*$b_b$ and *ECO*VSF sensors, and Wyatt Technology Corporation DAWN photometers. The details on $b_b$ data processing are given in Werdell (2005).

"From the NOMAD database, *Lw* and *Es* measurements were extracted for the match-up locations between 2005 and 2010, and converted to *RLw* spectra. Various instruments were used for the measurements of the remote-sensing reflectance, *Rrs*, in the NOMAD dataset (Werdell and Bailey, 2005), including in-water profiling or above-water measurements. All in- and above-water data from various instruments and data providers were consistently processed to Rrs, with the methods described in Werdell and Bailey (2005)."

**Section 2.1.1: complete description of USCB measurements (Southern California site)**

The methods and instruments of ERI/USCB data were updated in Table 6 (for RLw measurements), and in the text for RLw, backscattering and absorption measurements (see the two paragraphs below):

"The USCB *RLw* measurements in the Southern California region were obtained using above-water radiometric measurements of one Dual FieldSpec spectrometer (ASD) instrument and under-water measurements of a Biospherical Instruments (San Diego, California) profiling reflectance radiometer (PRR-600), as described by Toole et al.,(2001). Sea-surface radiance, *Ls*, at viewing zenith angle of 45°, sky radiance (that would be reflected into *Ls*), *Lsky* and spectralon upwelling radiance, *Lspec* were measured by the ASD. The above water reflectance was estimated following Toole et al. (2000): the above-water irradiance was calculated from spectralon measurements according to $Ed = \pi\ Lspec/\rho_{spec}$ where $\rho_{spec}$ is the reflectance of the plaque, the water-leaving reflectance was calculated as $RLw = \pi\ (Ls - \rho\ Lsky)/Ed$ - residual(750), where residual(750) corrects for any residual reflected sky radiance, assuming zero water-leaving radiance at 750 nm. Underwater downwelling irradiance, $Ed^-$, and upwelling radiance, $Lu^-$ were measured along vertical profiles using the Biospherical PRR-600, then interpolated to above water radiance and irradiance respectively, leading to a new estimate of *RLw* spectra which were merged with ASD relectances (see Toole et al. (2000) for details)."

For bb and a-measurements:

"Backscattering coefficients provided by USCB were estimated from profiled measurements of the total volume scattering function β at 140°, using a HobiLabs HydroScat-6, collected at the Southern California site. These measurements were corrected for light attenuation along the photon path to the instrument detector (σ-correction of Maffione and Dana, 1997) using concurrent absorption spectra (Kostadinov et al. 2007) for measurements up to 2005, and concurrent beam attenuation and absorption modelled from the diffuse attenuation coefficient for downwelling irradiance and the irradiance reflectance (see Antoine et al. (2011) for details). A total of 269 backscattering spectra initially measured at 442, 470, 510, 589 and 671 nm were interpolated at 412, 470, 510 and 589 nm assuming a $\lambda^{-1}$ spectral dependency of the backscattering coefficient. USCB absorption spectra up to 2005 were obtained using vertical profiles of WET Labs ac-9 measurements, after application of pure water calibration, and standard temperature, salinity and scattering corrections (WET Labs ac-9 Protocol, 2003). Surface absorption values were derived from the upper 15 m absorption spectra, after filtering incomplete, negative or extreme values; spectra were linearly interpolated at 412, 443, 490, 510, 530, 555, 620 and 665 nm (Kostadinov et al., 2007). Measurements of $a_{phy}$ , $a_g$ and $a_d$ spectra were obtained using a Shimadzu UV2401-PC spectrophotometer. CDOM samples were filtered on 0-2µm Poretics membranes, while GF/F filters were used to retain total particulate matter for $a_p$ measurement, corrected for pathlength effects following Guillocheau (2003). Pigment extraction was performed in 100% methanol."

**Acknowledgements**

CSIR Data Providers are now duly acknowledged:

- Stewart Bernard, Hayley Evers-King, Mark Mattews and Lisl Robertson for processing the CSIR dataset over the Benguela region, with the support of the Department of Agriculture, Forestry and Fisheries, DAFF.

CSIRO:
The CSIRO measurements were funded by the CSIRO Wealth from Oceans Flagship and the Australian Integrated Marine Observing System (IMOS).
REPHY Data Providers duly acknowledged:

- Francis Gohin, Catherine Belin and Alain Lefèbvre for the Ifremer (REPHY phytoplankton network) dataset

**New references**

New references were added (instruments/methods of Ifremer)

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

New references were added (instruments/methods of the USCB)

Guillocheau, N.: β-Correction Experiment Report, ICESS, University of California, Santa Barbara, CA, 2003.

Kostadinov, T. S., Siegel, D. A., Maritorena, S., and Guillocheau, N.: Ocean color observations and modeling for an optically complex site: Santa Barbara Channel, California, USA, Journal of Geophysical Research, 112, C07011, 1-15, 2007. doi: 10.1029/2006JC003526

Maffione, R. A., and Dana, D. R.: Instruments and methods for measuring the backward-scattering coefficient of ocean waters, Applied Optics, 36, 24, 6057-6067, 1997.

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WET Labs ac-9 Protocol, revision H (2003), WET Labs, Inc. Philomath, OR, 42 pp.

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# References (in the responses to reviewer)

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*Gower, J. et al., 2005. Detection of intense plankton blooms using the 709 nm band of the MERIS imaging spectrometer. International Journal of Remote Sensing 26, 2005–2012.*

Hu, C. M., F. E. Muller-Karger, C. Taylor, K. L. Carder, C. Kelble, E. Johns, and C. A. Heil. (2005). Red tide detection and tracing using MODIS fluorescence data: A regional example in SW Florida coastal waters. Remote Sensing of Environment 97:311-321.


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