Derived products from optical measurements of SOCCOM floats

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The SOCCOM floats are embedded with one of two models of bio-optical sensors: the WET Labs ECO FLBB with a fluorometer (EX/EM 470/695 nm) and backscatter ($\lambda = 700$nm, $\theta = 140°$) which are mounted on the majority of the floats, or the WET Labs MCOMS, present on three floats, which includes a fluorometer (EX/EM 470/695 nm), a backscatter ($\lambda = 700$nm, $\theta = 150°$) and another fluorometer (EX/EM 370/460 nm). The measurements of these sensors are used as a proxy to estimate concentrations of chlorophyll a (chl_a), particulate organic carbon (POC), phytoplankton carbon biomass (C_{phyto}) or colored dissovled organic matter (CDOM).

1 Chlorophyll a fluorescence

Chlorophyll a fluorescence is computed from the raw signal with the dark count and slope coefficient from the manufacturer by MBARI. The dark is re-estimated with the following procedure. For every profile, a $dark_{profile}$ is computed which corresponds to the median of the 10 minimum values of the profile. The dark of the float $dark_{dynamic}$ is equal to the median of the 10 minimum $dark_{profile}$ of all the profiles available at the time of computation. The slope is estimated with the empirical relationship between the first profile of the SOCCOM floats and HPLC values taken at time of deployment of the float during cruises P16S, PS89, and IN2015v1. To date the slope coefficient is $1 \div 6.56$.

$$chl_a = (signal - dark_{dynamic}) \times slope$$

The chla fluorescence is corrected for non-photochemical quenching (NPQ) with an average of Sackmann et al. (2008) and Xing et al. (2012) if the sun elevation is over 10. The mixed layer depth used for those corrections was estimated with a fixed density threshold criterion of 0.005 $\mathrm{kg\,m^{-3}}$. MODIS and VIIRS reflectance data and Chl near each float surfacing is archived and will be used, at the end a sensor life, to evaluate drift.

2 Angular scatterance β

The angular scatterance β is computed from the raw signal with the dark count and the slope coefficient of the manufacturer by MBARI. Darks are replaced by the one measured before deployment if available.

$$\beta = (signal - dark) \times slope$$

2.1 Particulate backscattering b_{bp}

The backscattering coefficient of particles b_{bp} is commonly estimated from measurement of scattering at a single angle in the backward hemisphere $\beta(\theta)$. Sensors embedded have: $\lambda = 700$ nm and $\theta = 140°$ (ECO-FLBB) or 150° (MCOMS).

$$\beta_p(\theta) = \beta(\theta) - \beta_{sw}(\theta)$$
$$b_{bp} = 2 \times \pi \times \chi(\theta) \times \beta_p(\theta)$$

$\beta_{sw}(\theta, \lambda)$ is the angular scatterance of sea water and is estimated with Zhang and Hu (2009) and $\chi(\theta)$ is a conversion coefficient from Sullivan et al. (2013).

2.2 Particulate organic carbon (POC)

Particulate organic carbon is leanearly proportional to particulate backscattering, an emprirical relationship built for the SOCCOM floats based on the relationship between the first profile of the floats and *in-situ* measurements taken during deployement (cruises: PS89, P16S and IN2015v1). Note that the results are similar to previous studies listed in Cetinić et al. (2012).

$$POC = 3.23 \times 10^4 \times b_{bp}(700) + 2.76$$

with POC in $\mathrm{mg\,m^{-3}}$ and b_{bp} in $\mathrm{m^{-1}}$

2.3 Phytoplankton carbon biomass C_{phyto}

Phytoplankton carbon biomass C_{phyto} is estimated from $b_{bp}(440)$ with an empirical relationship described in Graff et al. (2015) based on MODIS product.

$$b_{bp}(440) = b_{bp}(700) \left(\frac{440}{700}\right)^{-\gamma}$$
$$C_{phyto} = 12128 \times b_{bp}(440) + 0.59$$

with b_{bp} in $\mathrm{m^{-1}}$, C_{phyto} in $\mathrm{mg\,m^{-3}}$ and $\gamma = 0.78$ from Boss et al. (2013)

References

Emmanuel Boss, Marc Picheral, Thomas Leeuw, Alison Chase, Eric Karsenti, Gabriel Gorsky, Lisa Taylor, Wayne Slade, Josephine Ras, and Herve Claustre. The characteristics of particulate absorption, scattering and attenuation coefficients in the surface ocean; Contribution of the Tara Oceans expedition. *Methods in Oceanography*, 7:52–62, 2013. ISSN 22111220. doi: 10.1016/j.mio.2013.11.002. URL http://dx.doi.org/10.1016/j.mio.2013.11.002.

Ivona Cetinić, Mary Jane Perry, Nathan T. Briggs, Emily Kallin, Eric a. D'Asaro, and Craig M. Lee. Particulate organic carbon and inherent optical properties during 2008 North Atlantic bloom experiment. *Journal of Geophysical Research: Oceans*, 117(6), 2012. ISSN 21699291. doi: 10.1029/2011JC007771.

Jason R. Graff, Toby K. Westberry, Allen J. Milligan, Matthew B. Brown, Giorgio Dall'Olmo, Virginie van Dongen-Vogels, Kristen M. Reifel, and Michael J. Behrenfeld. Analytical phytoplankton carbon measurements spanning diverse ecosystems. *Deep-Sea Research Part I: Oceanographic Research Papers*, 102:16–25, 2015. ISSN 09670637. doi: 10.1016/j.dsr.2015.04.006. URL http://dx.doi.org/10.1016/j.dsr.2015.04.006.

B. S. Sackmann, M. J. Perry, and C. C. Eriksen. Seaglider observations of variability in daytime fluorescence quenching of chlorophyll-a in Northeastern Pacific coastal waters. *Biogeosciences Discussions*, 5(4):2839–2865, 2008. ISSN 1810-6285. doi: 10.5194/bgd-5-2839-2008.

James M. Sullivan, Michael S. Twardowski, J. Ronald V Zaneveld, and Casey C. Moore. *Measuring optical backscattering in water*. 2013. ISBN 978-3-540-25315-0. doi: 10.1007/3-540-37672-0. URL http://www.springerlink.com/index/10.1007/3-540-37672-0.

Xiaogang Xing, H Claustre, and S Blain. for in vivo chlorophyll fluorescence acquired by autonomous platforms: A case study with instrumented elephant seals in the Kerguelen region (Southern Ocean. *Limnol. Oceanogr. ...*, pages 483–495, 2012. ISSN 15415856. doi: 10.4319/lom.2012.10.483. URL http://www.aslo.org/lomethods/locked/2012/0483.pdf.

Xiaodong Zhang and Lianbo Hu. Scattering by pure seawater at high salinity. *Optics express*, 17(15):12685–12691, 2009. ISSN 1094-4087. doi: 10.1364/OE.17.012685.