PACE Ocean Products

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HRH Chlorophyll



Phytoplankton carbon fixation via photosynthesis $(CO_2 \text{ uptake and release of } O_2)$



Phytoplankton carbon fixation via photosynthesis (CO₂ uptake and release of O₂)



HRH Chlorophyll

- Blend between OC3/OC4 (OCx) band ratio algorithm (O'Reilly and Werdell 2019) and the color index (CI) of Hu et al. (2019)
- CI=Rrs(λgreen)-[Rrs(λblue)+(λgreen-λblue)/(λred-λblue)*(Rrs(λred)-Rrs(λblue))]

where: chlor_a=10^(aci1+aci2*Cl)

- $\log_{10}(\text{chlor}_a) = a_0 + \sum_{i=1}^4 a_i \left(\log_{10} \left(\frac{Rrs(\lambda(blue))}{Rrs(\lambda(green))} \right) \right)^i$
- If chlorophyll < 0.15 mg m⁻³, the CI algorithm is used. If chlorophyll > 0.2 mg m⁻³, the OCx algorithm is used. If chlorophyll is > 0.15 & <0.2

 $chlor_a = \frac{chlor_a_{CI} (t2 - chlor_a_{CI})}{(t2 - t1)} + \frac{chlor_a_{OCx} (chlor_a_{CI} - t1)}{(t2 - t1)}$



Figure 1. Scatterplot to show the CI2 algorithm. For comparison, the original CI algorithm (CI1) is also presented. The red circle highlights the difference between CI2 and CI1 for low-Chl waters. Hu et al. 2019

Chlorophyll is not the only pigment in the ocean (and waters)



Carbon is the currency of life



Siegel et al, ARMS accepted PACE



Deriving IOPs (Inherent optical properties)

IOPs (absorption and scattering coefficients) shape the underwater light field.





Radiative transfer schematic: Kirk (1983)

NASA IOP Processor: GIOP algorithm

- Generalized Inherent Optical Properties algorithm (GIOP; Werdell et al. 2013)
- Default Configuration (DC):
 - Gordon (1988) forward reflectance model
 - *a_{ph}*: Bricaud et al (1998)*
 - ads_s: fixed at 0.018
 - bbp_s: dynamic Lee et al (2002)
 - Levenberg-Marquart solution method
 - T-S dependent b_{bw} (Zhang et al. 2009)
 - Raman scattering correction (McKinna et al. 2016)
 - Uncertainties (McKinna et al. 2019)
 - L3 run with SeaWiFS-like bands



GIOP algorithm schematic



WATER QUALITY Light attenuation (Kd)

Units: m⁻¹

Ζ

- Spectral diffuse attenuation (Kd) of downwelling irradiance (Ed) at multiple wavelengths between 350 and 700-nm.
- Index of water clarity and light penetration, needed for NPP models.



Past approaches:

- Empirical, Rrs band ratios
- Semi analytical (Lee et al. 2005)

UVA, https://www.windcheckmagazine.com/

WATER QUALITY Suspended Particulate Matter (SPM)



Applications: water clarity, water quality, sediment transport, marsh health, dredging, oyster aquaculture

Balasubramanian et al. 2020

Total Suspended Solids (TSS)



Carbon stocks + carbon fluxes





Siegel et al, ARMS accepted PACE⁵

Carbon stocks

- CONCENTRATION OF PARTICULATE ORGANIC CARBON (POC)
 - CONCENTRATION OF PHYTOPLANKTON CARBON (only organic Cphyto)
- CONCENTRATION OF PARTICULATE INORGANIC CARBON (PIC)
 - ≥0.2 μm **(0.2 0.7)**
- CONCENTRATION OF DISSOLVED ORGANIC CARBON



PARTICULATE ORGANIC CARBON



Stramski et al 2022

Similar to Chlorophyll – blend approach MBR (Maximum Band Ratio)-OC4 cubic polynomial function and BRDI (Band Ratio Difference Index) quintic polynomial function



Phytoplankton carbon



Phytoplankton carbon distribution (mg m⁻³), MODIS A, April 2020.





PHYTOPLANKTON

Many shapes, colors and sizes.. ...that define their role in marine ecosystem and oceanic carbon cycle



Pigment composition (Phytoplankton community composition) – open ocean







BUT ... I WANT MY CARBON.

Phytoplankton community composition - open ocean



Fig. 9. Aqua-MODIS monthly composites (October 2014) showing cell abundances (cells ml^{-1}) of **a**) *Prochlorococcus*, **b**) *Synechococcus* and **c**) autotrophic picoeukaryotes at the sea surface.



Chase et al 2022 – Diatom carbon NN combo of Chl + SSS + SST





Carbon Fluxes: Primary productivity

Units: mg Carbon m⁻² time⁻¹



Primary productivity (all over the place)





Primary productivity

Add something about physiology (happiness of cells)?

Units: mg Carbon m⁻² time⁻¹



Normalized Fluorescent Line Height (nFLH)

Estimate of phytoplankton fluorescence: physiology, health, excess energy = Observed nLw(red edge) – linearly interpolated nLw(red edge)



nLw = normalized water leaving radiance







Carbon stocks (kinda check) + carbon fluxes (tiny check)



Siegel et al, ARMS accepted PACE

Earth system models disagree on the projected response of the global export flux to climate change, with estimates ranging from -41% to +1.8%.



Henson et al, 2022

In simple words **PACE Ocean** products will tell you a story about:

- WHAT IS THE COLOR OF THE OCEAN (awesome Rrs)
- WHAT/WHO IS THERE (phytoplankton composition, SPM)
- HOW MUCH OF IT IS THERE (chlorophyll concentration, particulate/phytoplankton carbon etc
- ARE THEY SHINY/COLORFUL??? (IOPs)
- HOW MUCH LIGHT IS THERE (PAR/Kd)
- WHAT ARE THEY DOING (Primary productivity)
- HOW ARE THEY DOING (Fluorescence Line Height)

