Mechanistic Drivers of the Particulate Backscattering-to-Chlorophyll a Relationship and Bias-assessment of Phytoplankton Carbon Algorithms

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The particulate backscattering coefficient ($b_{bp}$) has been suggested to be a good proxy for phytoplankton carbon biomass ($C_{phyto}$) and is used in some NPP global models.

But $C_{phyto}$ data is scarce in space and time, therefore $b_{bp}$-Chl relationships can be used to derive these algorithms.

Problems:

- $b_{bp}$ is a proxy of all particles in the ocean, not only phytoplankton
- Scarce $C_{phyto}$ field data and biased in space and time

We use a global ocean circulation model (MITgcm) with optics embedded in it and the Bgc-Argo data-set to:

- Understand how well does $b_{bp}$ estimate $C_{phyto}$
- Understand $b_{bp}$-Chl relationships and their potential to obtain $C_{phyto}$
Is $b_{bp}$ a good proxy of $C_{phyto}$?

- We use the MITgcm model to investigate $b_{bp}$-$C_{phyto}$ relationship.
- We get an algorithm by fitting a linear regression to the $b_{bp}$-$C_{phyto}$ relationship of the surface pixels of the MITgcm.
- We compare the $C_{phyto}$ estimated by the algorithm relative to the “real” $C_{phyto}$ of the model.

**Results:**
- Algorithm tends to deviate by a factor less than 2 in most regions.
- Worst fits are in winter of high latitudes, in those regions phytoplankton has a very low contribution to $b_{bp}$ (where heterotrophic bacteria and detritus dominate the $b_{bp}$ signal).
Understanding the $b_{bp}$-Chl relationship

- Use the Darwin model to understand the $b_{bp}$-to-Chl relationship
- Use BGC-Argo data to compare trends

Results:

- A linear regression in the linear scale fits relatively well the $b_{bp}$-Chl trend (i.e. we do not get a bi-linear trend in the linear scale as observed in other studies)
  - This is also seen in the Argo data-set

- The bi-linear trend in the log-scale is a visual artifact from having a positive intercept. This positive intercept is mainly driven by a background $b_{bp}$ of NAPs

- Once the background $b_{bp}$ is removed, the trend becomes somewhat linear and a log-log fit seems better. Still, large variability.
Using $b_{bp}$-Chl to get $C_{phyto}$?

Algorithm $b_{bp}$-Chl

Source: Behrenfeld et al. 2005

Algorithm using $b_{bp}$-Chl

- No big differences if Chl-$b_{bp}$ is used compared to $C_{phyto}$-$b_{bp}$
- Chl-$b_{bp}$ relationships can be used to obtain $C_{phyto}$ with similar performance if we had real $C_{phyto}$ data
- The problem is how to convert $b_{bp}$ to $C_{phyto}$...

Biases in $b_{bp}$-based algorithms?

- Assumptions regarding conversions from $b_{bp}$ to $C_{phyto}$ can result in large differences
- Sampling bias in Graff et al. 2005 did not have a strong effect in algorithm performance (tested, but not shown here) → differences in the linear regression across regions might not be that high
Conclusions:

- $b_{bp}$-based algorithm deviates by a factor of 2 in most regions
  - Some regions are heavily overestimated, specially winter high latitudes ($b_{bp}$ signal is dominated by detritus and heterotrophic bacteria)
- No bi-linear trend at linear scale (either in the MITgcm or Argo data):
  - Bi-linear trend in the log scale emerges from having a positive intercept
- Algorithm derived from Argo data is similar to two of the existing algorithms, but assumptions on conversion factors need to be better constrained
- Sampling biases do not have a strong effect on the overall performance of the algorithm.

Knowledge gaps and next steps:

- Clearly, the limiting factor is the lack of $C_{phyto}$ data
- Use the Argo $b_{bp}$-Chl data to see differences across regions/biomes
- Explore what has the largest uncertainty to estimate $C_{phyto} \rightarrow b_{bp}$ or Chl?
  - Uncertainties related to $b_{bp}$ seem similar to the ones driven by differences in Chl:$C_{phyto}$ ratios
  - However, $b_{bp}$ gives a notion of Chl:$C_{phyto}$ ratios