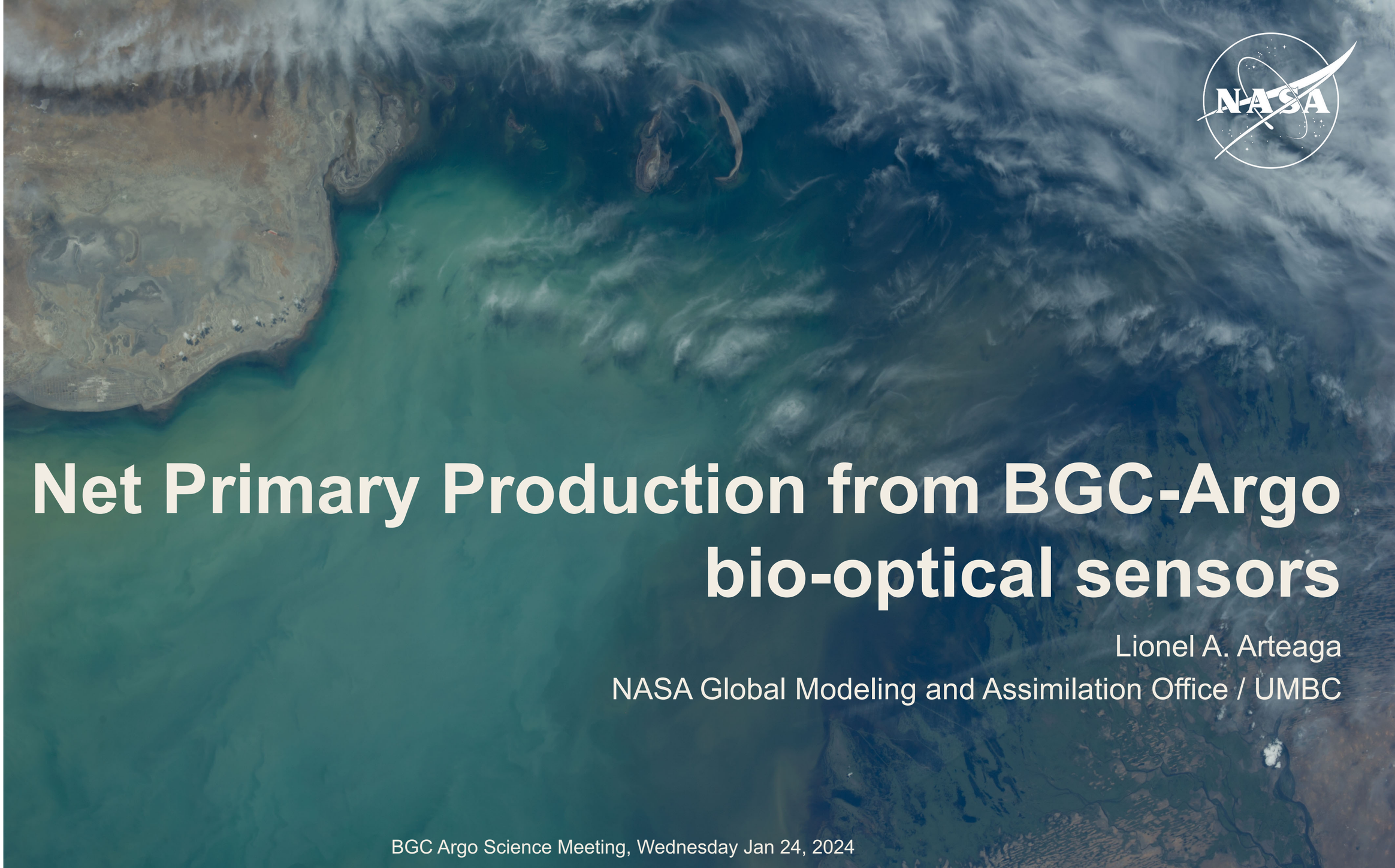


Net Primary Production from BGC-Argo bio-optical sensors

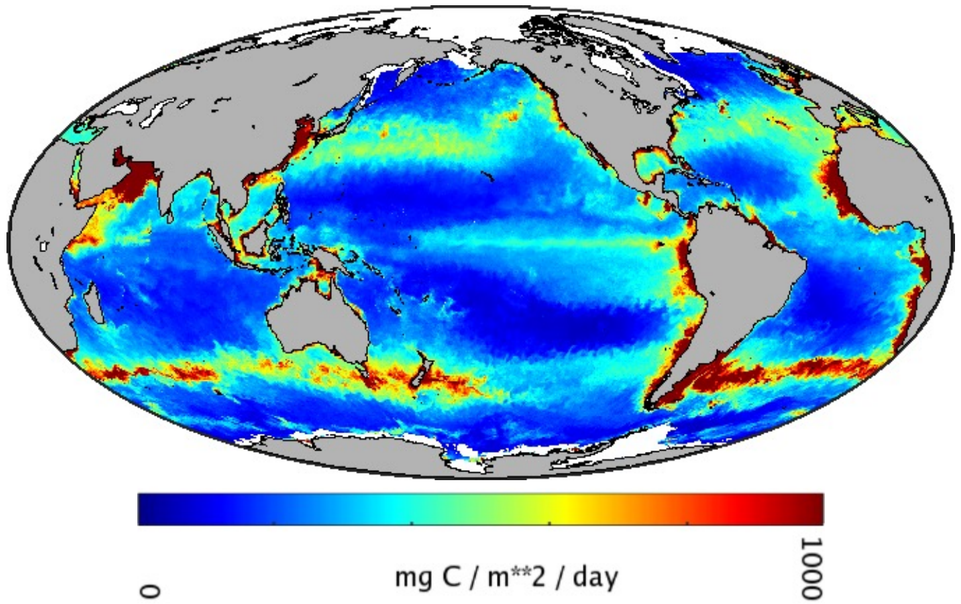
Lionel A. Arteaga
NASA Global Modeling and Assimilation Office / UMBC

BGC Argo Science Meeting, Wednesday Jan 24, 2024

Motivation

1) What about at depth?

NPP February 2015 (VGPM)
(https://sites.science.oregonstate.edu/ocean.productivity/)



2) Validating the carbon cycle in B-SOSE

B-SOSE
Biogeochemical Southern Ocean State Estimate
Data assimilation of carbon and other biogeochemical constraints

Ariane Verdy, Matt Mazloff

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

GODDARD EARTH SCIENCES

Background

Two ways to estimate NPP from BGC-Argo floats (so far)

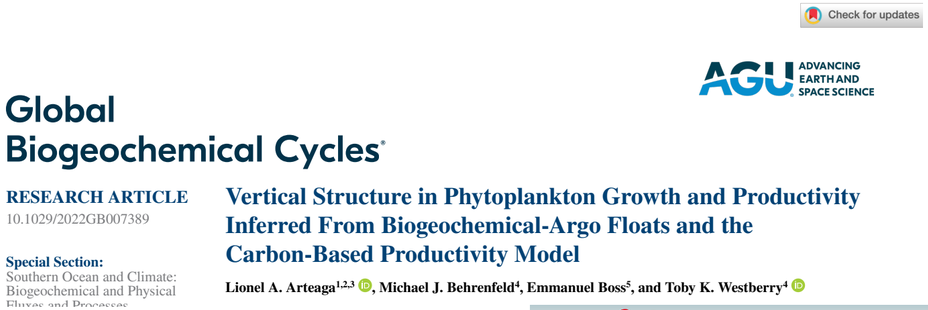
- From oxygen measurements
  - ✓ Perhaps a more direct estimate, with less assumptions.
  - ✗ No depth resolution.

- From bio-optical sensors
  - ✗ A model is needed, less straightforward.
  - ✓ Depth resolution is possible.



Constraint on net primary productivity of the global ocean by Argo oxygen measurements

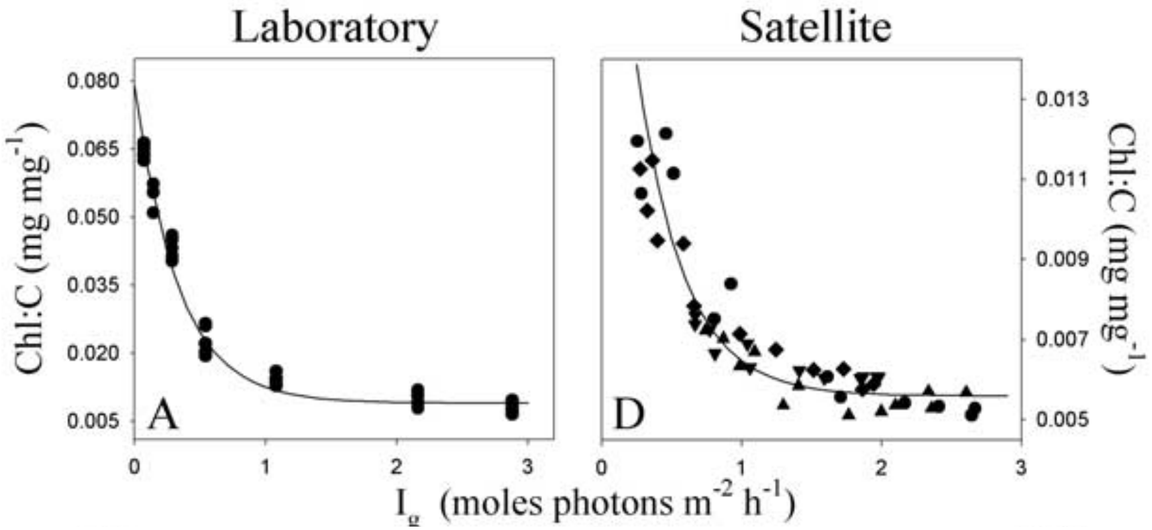
Kenneth S. Johnson ✉ and Mariana B. Bif





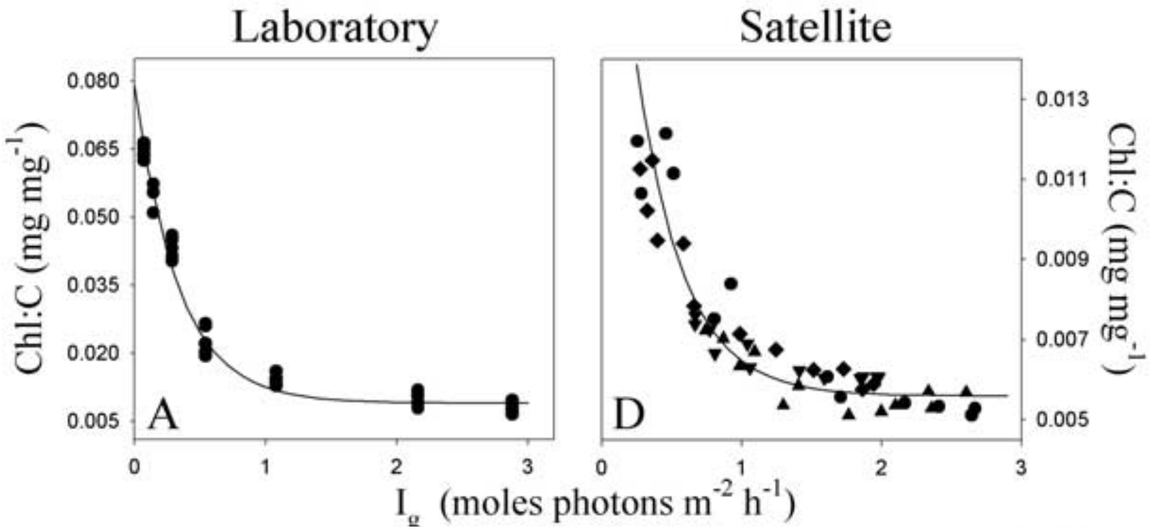
See also Estapa et al. (2019), Yang et al. (2021), Long et al. (2021)

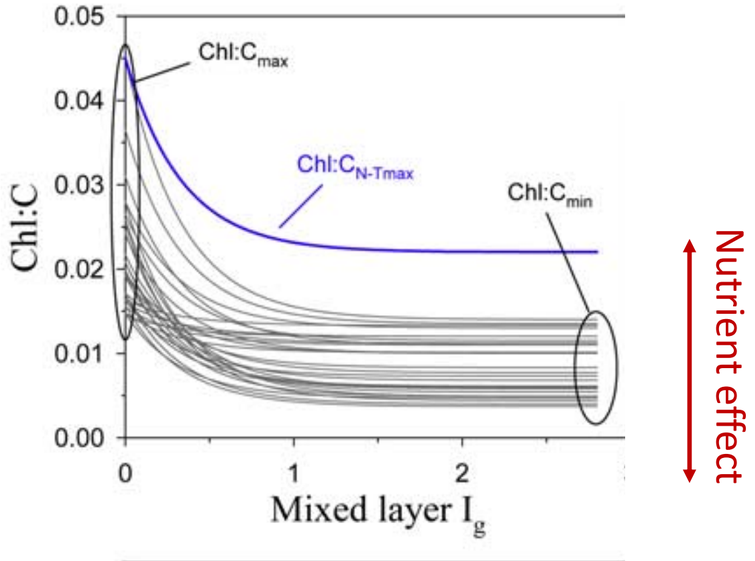
Basics: Chl:C

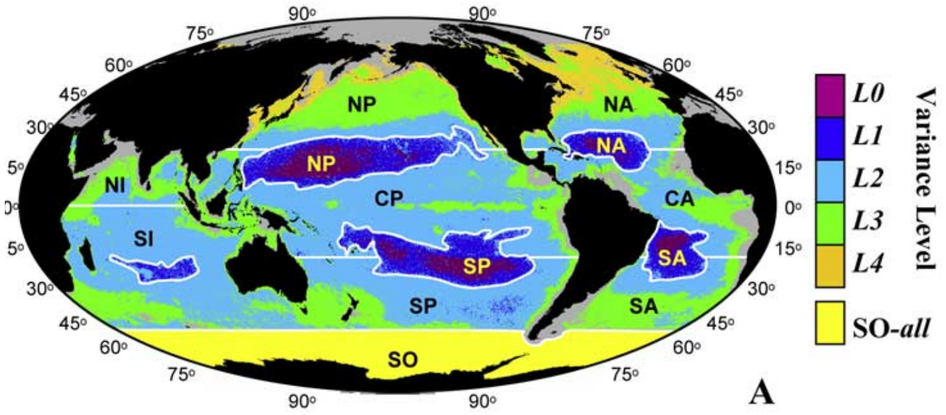


CbPM I: Behrenfeld et al. (2005)

Basics: Chl:C





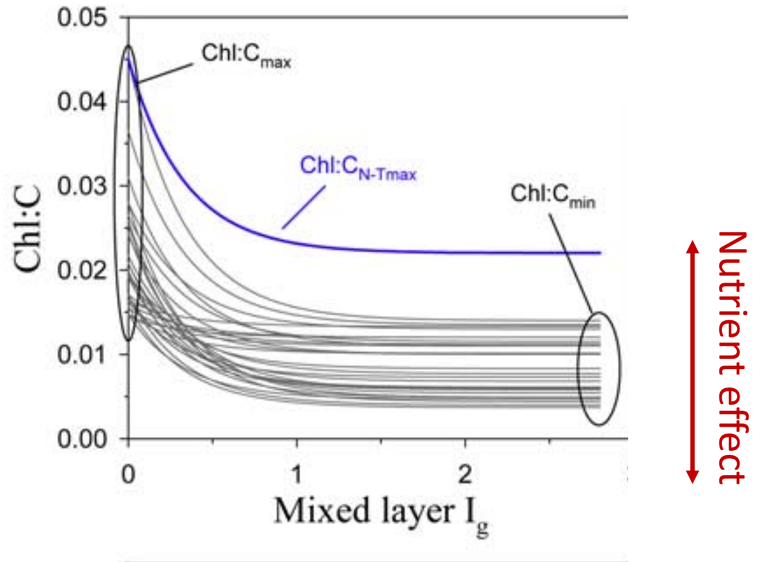


CbPM I: Behrenfeld et al. (2005)

Basics: Chl:C

$$\mu \approx \mu_{max}\, f(N)\, f(L)$$

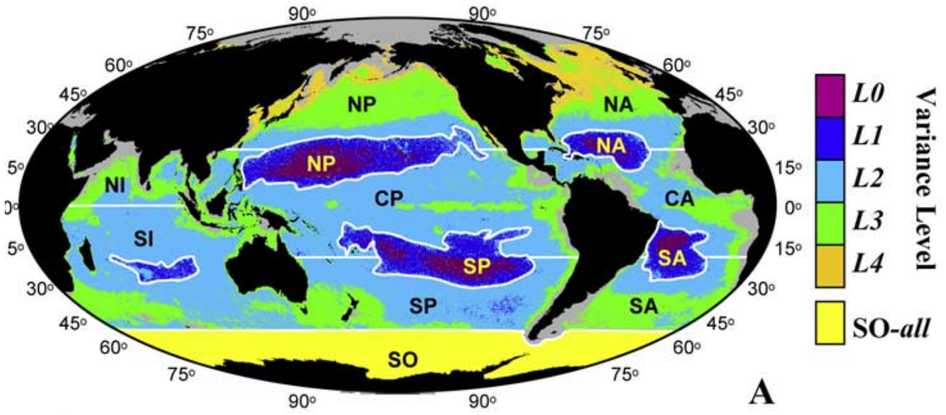
$$f(N) \approx \frac{Chl{:}\,C}{Chl{:}\,C_{max}(light)}$$



CbPM equations in BGC-Argo talk

&

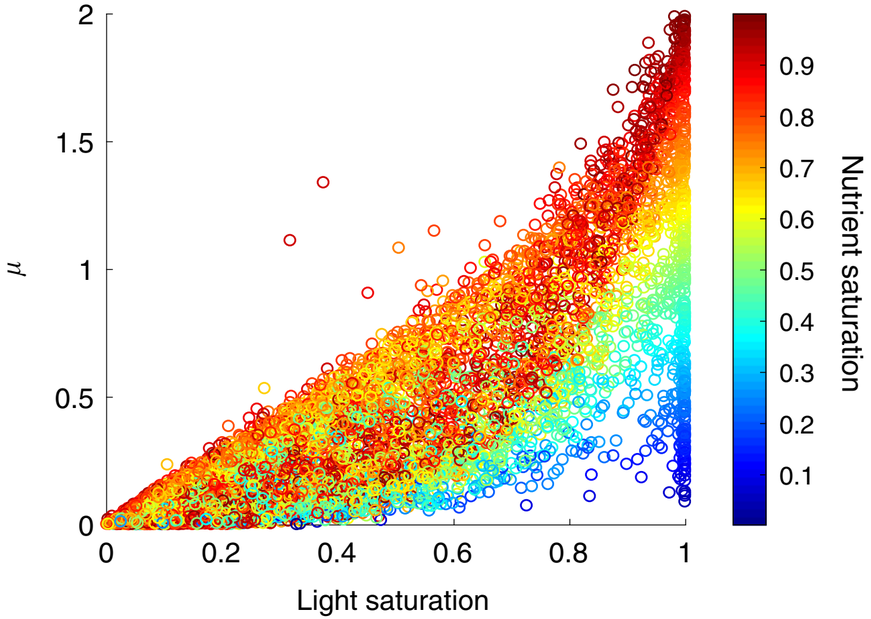
Section 2.3 of Arteaga et al. (2022)



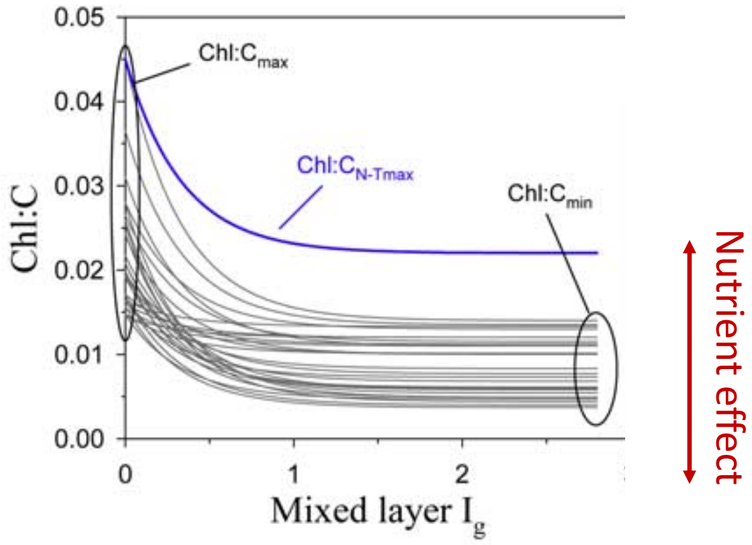
CbPM I: Behrenfeld et al. (2005)

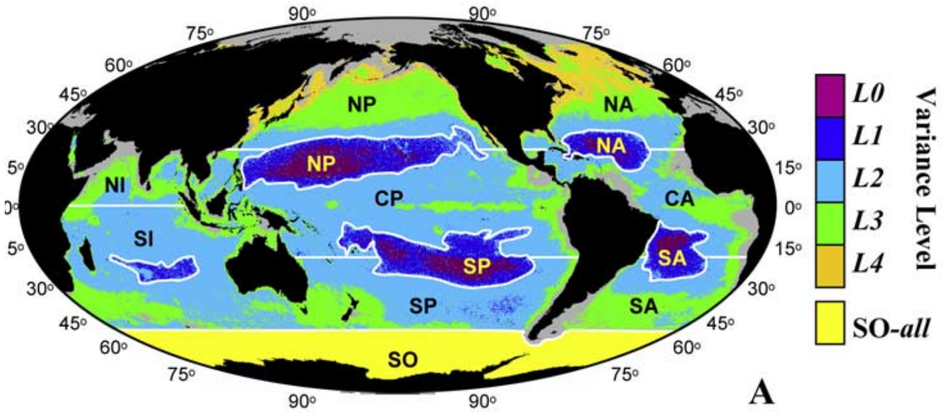
Basics: Chl:C

Relationship between division rates (u) and light and nutrient limitation in the Southern Ocean



Arteaga et al. (2020)



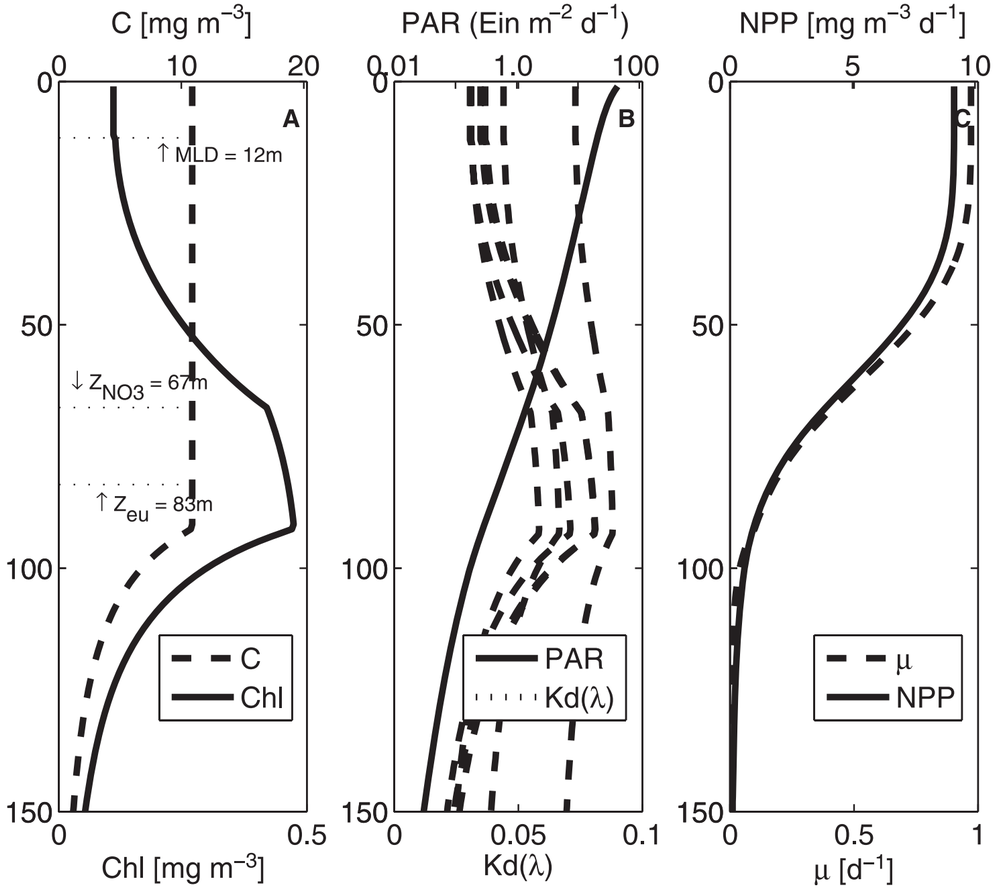


CbPM I: Behrenfeld et al. (2005)

Carbon-based Productivity Model (CbPM)

Satellite (“Original”) CbPM

Westberry et al. (2009)



Argo CbPM

Arteaga et al. (2022)

- Floats provide Chl and C (no need to model it)
- Simplified implementation of the “original” CbPM
- Need surface light (remote sensing), which is attenuated at depth by biomass

Results

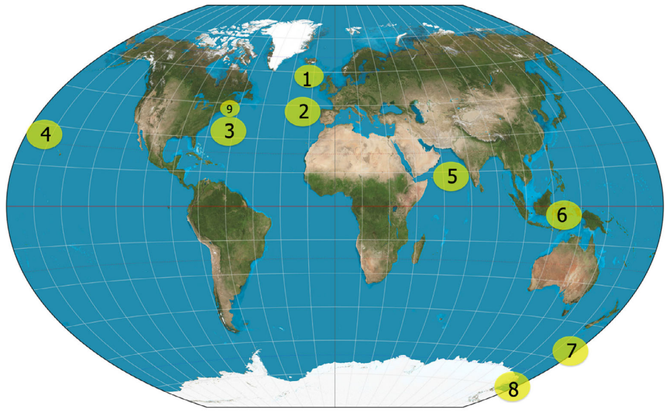
Argo-CbPM

Depth-resolved NPP from floats

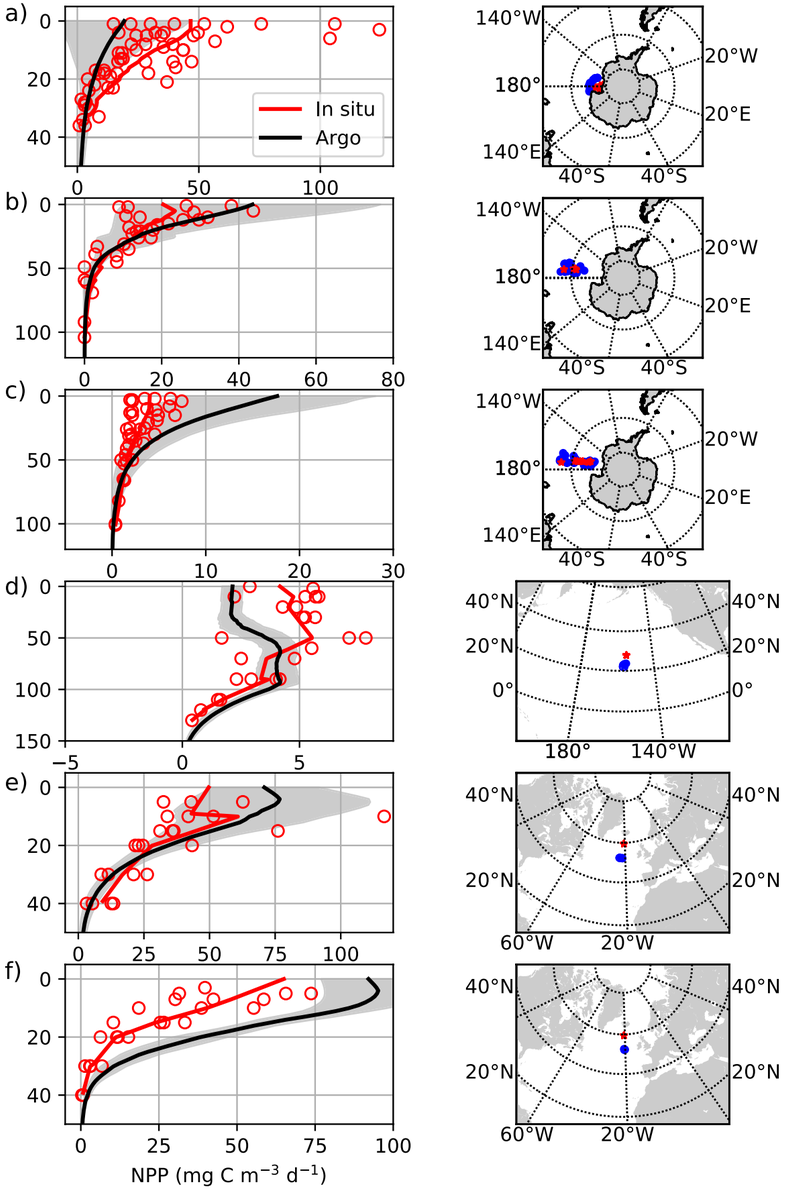
Arteaga et al. (2022)

Database of ocean primary productivity from ^{14}C

Marra et al. (2020)



1 (MLML 1991), **2** (NABE 1989), **3** (Biowatt-I 1985, Biowatt-II 1987, ONDEQUE 2008), **4** (PRPOOS 1985), **5** (Arabian Sea Exp. 1995), **6** (ARLINDO 1993,1994), **7** (AESOPS 1998), **8** (AESOPS 1997), **9** (MLML 1990)



CbPM$_{Argo}$ Code

CbPM: Original vs. Floats

Arteaga et al. (2022)

Table 1
Implementation of the Carbon-Based Productivity Model Used in This Study

	$CbPM_{Argo}$	$CbPM_{Orig}$
Above MLD	Depth-resolved or averaged, based on float obs.	Averaged based on float obs.
Below MLD	Depth resolved based on float obs.	Depth resolved reconstructed (as in satellite applications)
Nutrient stress north of 30°S	Based on local Chl:C (z)	Nitracline depth (>0.5 μ mol kg^{-1})
Nutrient stress south of 30°S.	Based on local Chl:C (z).	Nitracline depth (>0.5 μ mol kg^{-1})

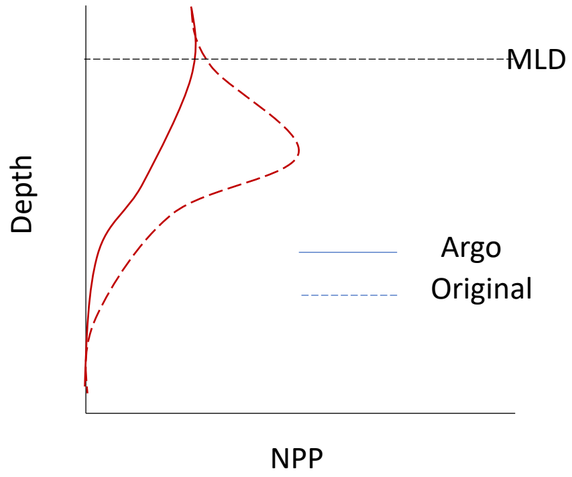
CbPM: Original vs. Floats

Arteaga et al. (2022)

Table 1
Implementation of the Carbon-Based Productivity Model Used in This Study

	$CbPM_{Argo}$	$CbPM_{Orig}$
Above MLD	Depth-resolved or averaged, based on float obs.	Averaged based on float obs.
Below MLD	Depth resolved based on float obs.	Depth resolved reconstructed (as in satellite applications)
Nutrient stress north of 30°S	Based on local Chl:C (z)	Nitracline depth (>0.5 μ mol kg^{-1})
Nutrient stress south of 30°S.	Based on local Chl:C (z).	Nitracline depth (>0.5 μ mol kg^{-1})

Southern Ocean example



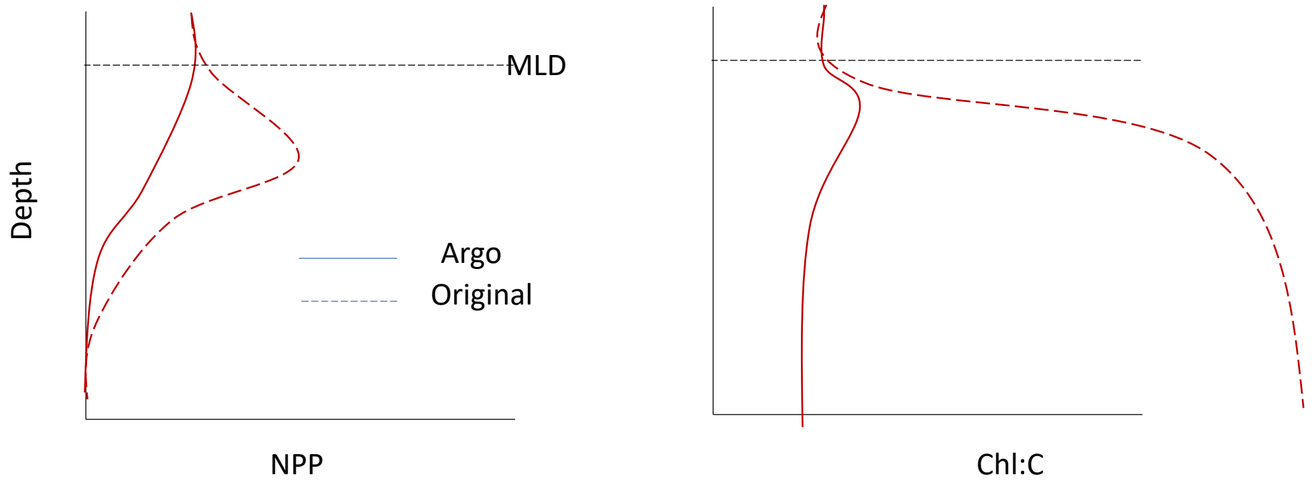
CbPM: Original vs. Floats

Arteaga et al. (2022)

Table 1
Implementation of the Carbon-Based Productivity Model Used in This Study

	$CbPM_{Argo}$	$CbPM_{Orig}$
Above MLD	Depth-resolved or averaged, based on float obs.	Averaged based on float obs.
Below MLD	Depth resolved based on float obs.	Depth resolved reconstructed (as in satellite applications)
Nutrient stress north of 30°S	Based on local Chl:C (z)	Nitracline depth (>0.5 μ mol kg^{-1})
Nutrient stress south of 30°S.	Based on local Chl:C (z).	Nitracline depth (>0.5 μ mol kg^{-1})

Southern Ocean example



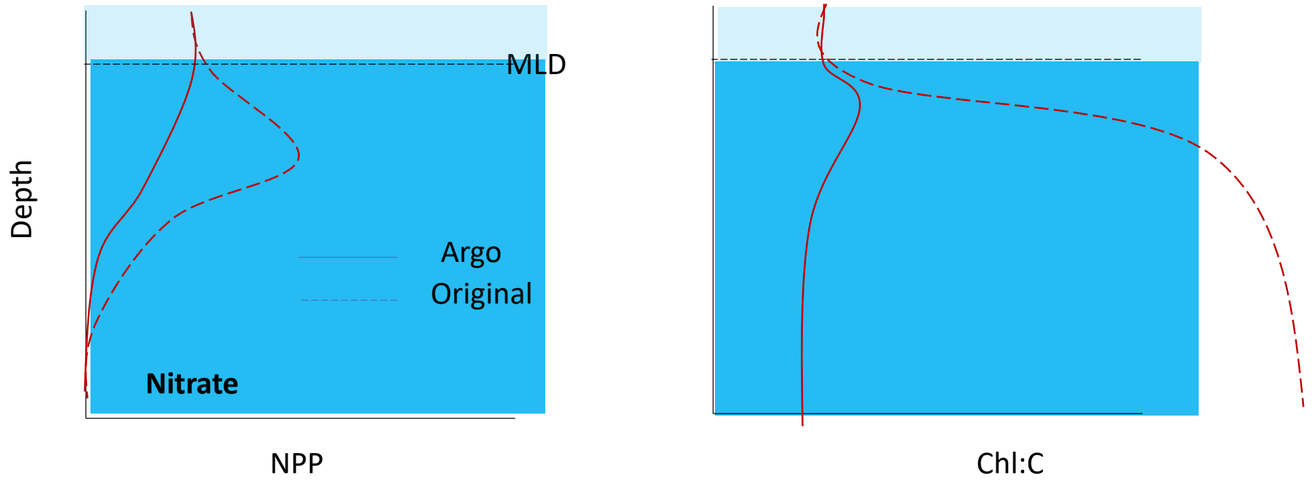
CbPM: Original vs. Floats

Arteaga et al. (2022)

Table 1
Implementation of the Carbon-Based Productivity Model Used in This Study

	$CbPM_{Argo}$	$CbPM_{Orig}$
Above MLD	Depth-resolved or averaged, based on float obs.	Averaged based on float obs.
Below MLD	Depth resolved based on float obs.	Depth resolved reconstructed (as in satellite applications)
Nutrient stress north of 30°S	Based on local Chl:C (z)	Nitracline depth (>0.5 μ mol kg^{-1})
Nutrient stress south of 30°S.	Based on local Chl:C (z).	Nitracline depth (>0.5 μ mol kg^{-1})

Southern Ocean example



CbPM: Iron limitation effect

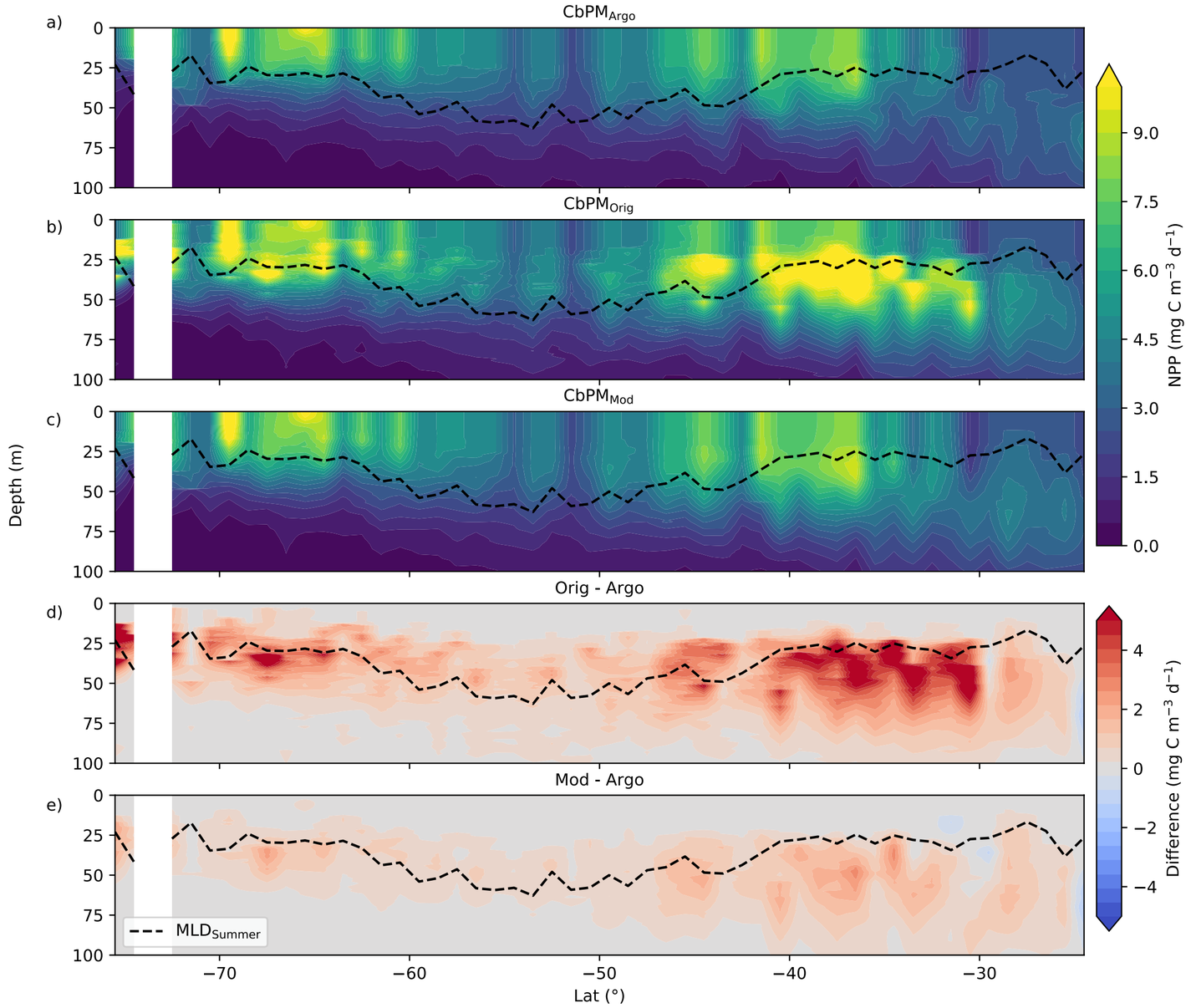
Modified CbPM to account for iron limitation

Table 1
Implementation of the Carbon-Based Productivity Model Used in This Study

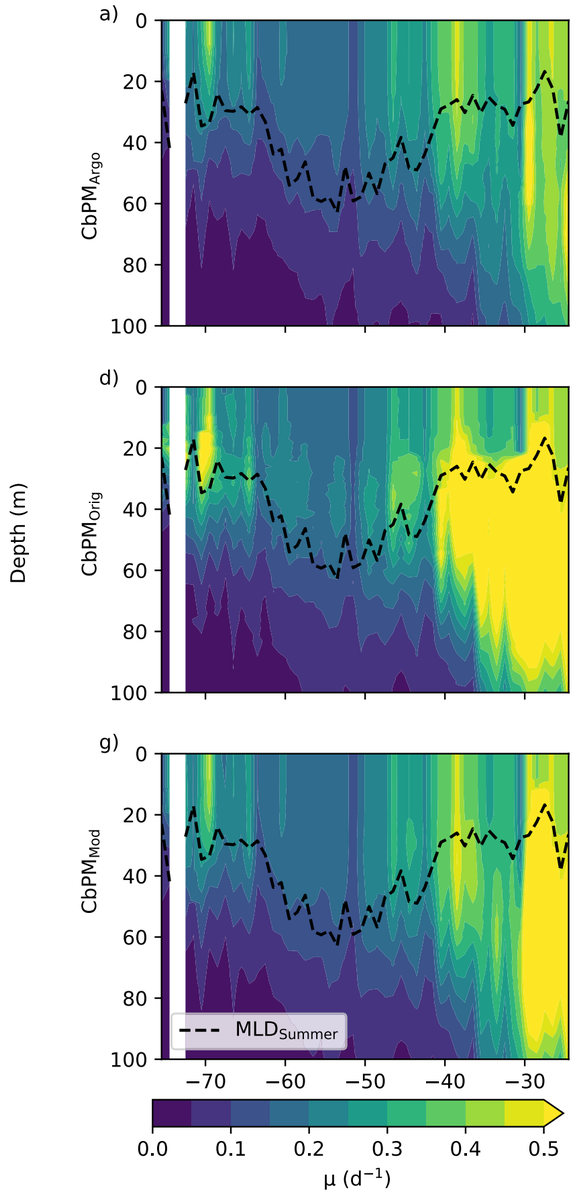
	$CbPM_{Argo}$	$CbPM_{Orig}$	$CbPM_{Mod}$
Above MLD	Depth-resolved or averaged, based on float obs.	Averaged based on float obs.	Averaged based on float obs.
Below MLD	Depth resolved based on float obs.	Depth resolved reconstructed (as in satellite applications)	Depth resolved reconstructed (as in satellite applications)
Nutrient stress north of 30°S	Based on local Chl:C (z)	Nitracline depth (>0.5 μ mol kg^{-1})	Nitracline depth (>0.5 μ mol kg^{-1}) or depth of maximum nitrate gradient when nitracline depth < MLD.
Nutrient stress south of 30°S.	Based on local Chl:C (z).	Nitracline depth (>0.5 μ mol kg^{-1})	Ferricline depth (333 m)

Arteaga et al. (2022)

CbPM: Iron limitation effect



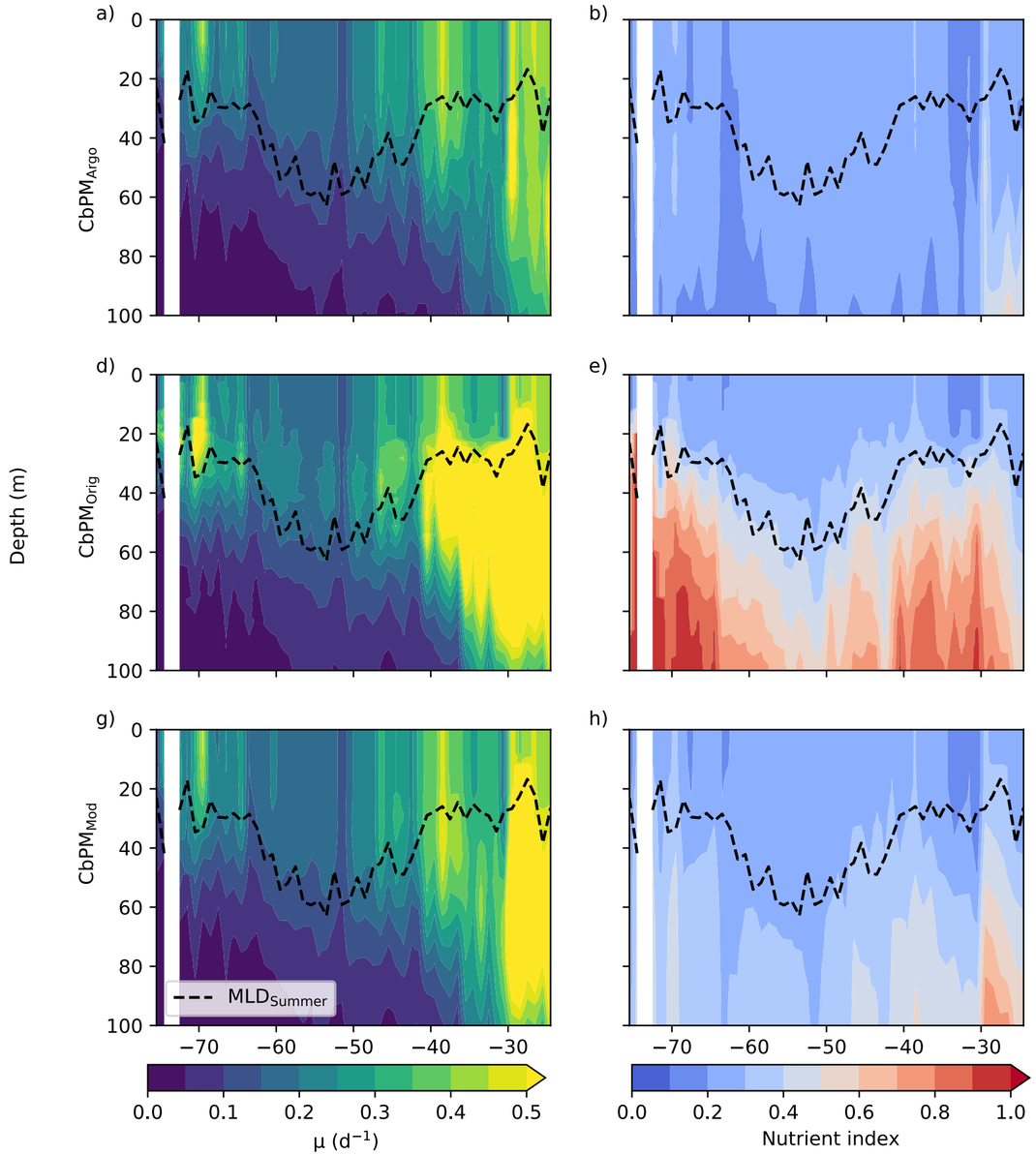
Under the hood: Growth controls



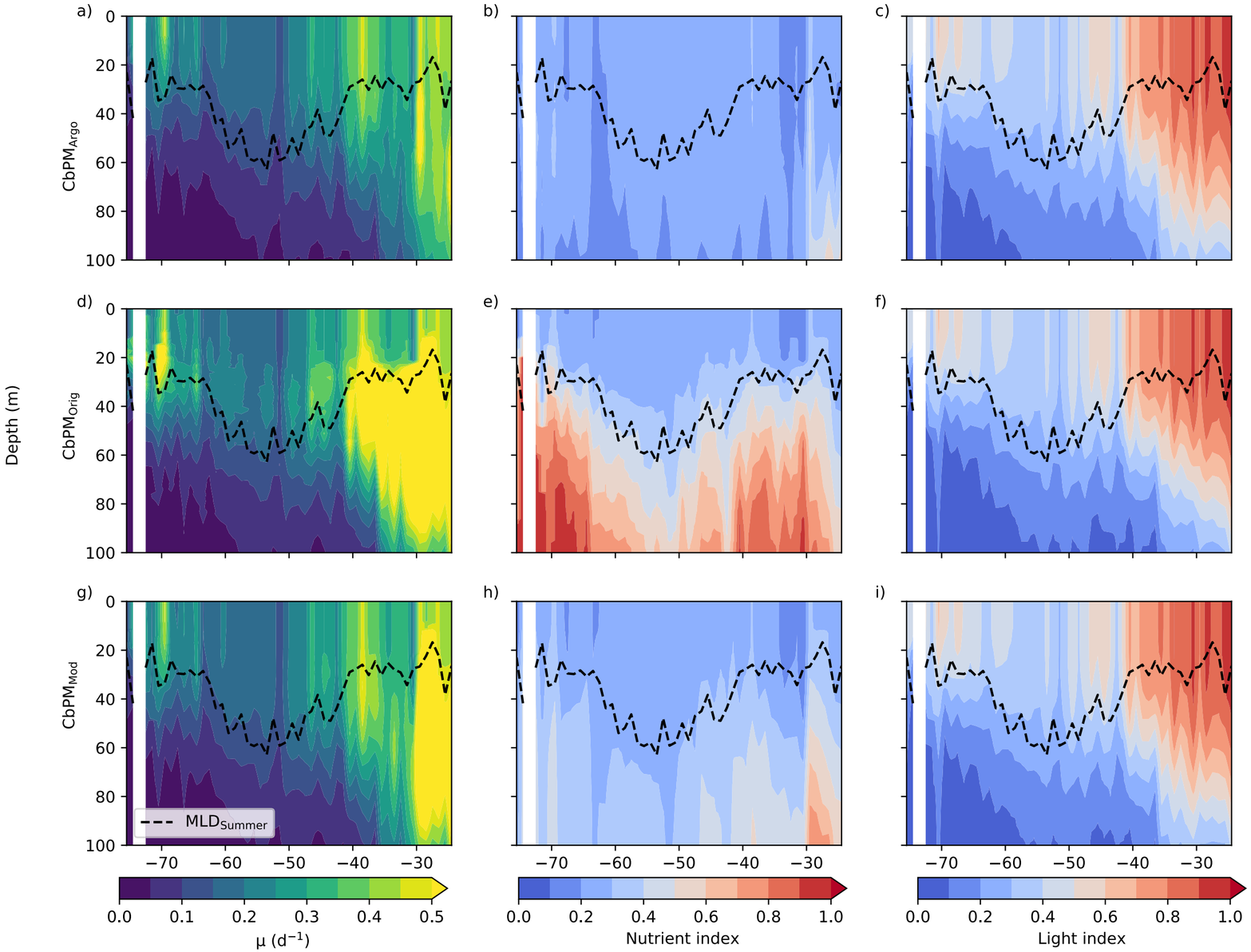
Nutrient index

Light index

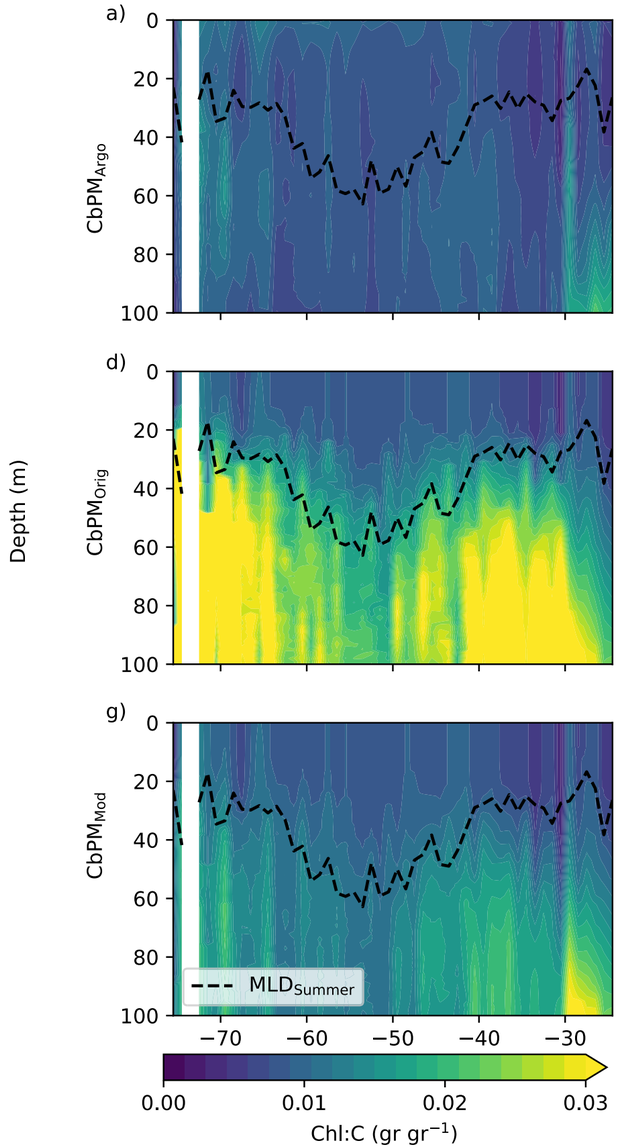
Under the hood: Growth controls



Under the hood: Growth controls



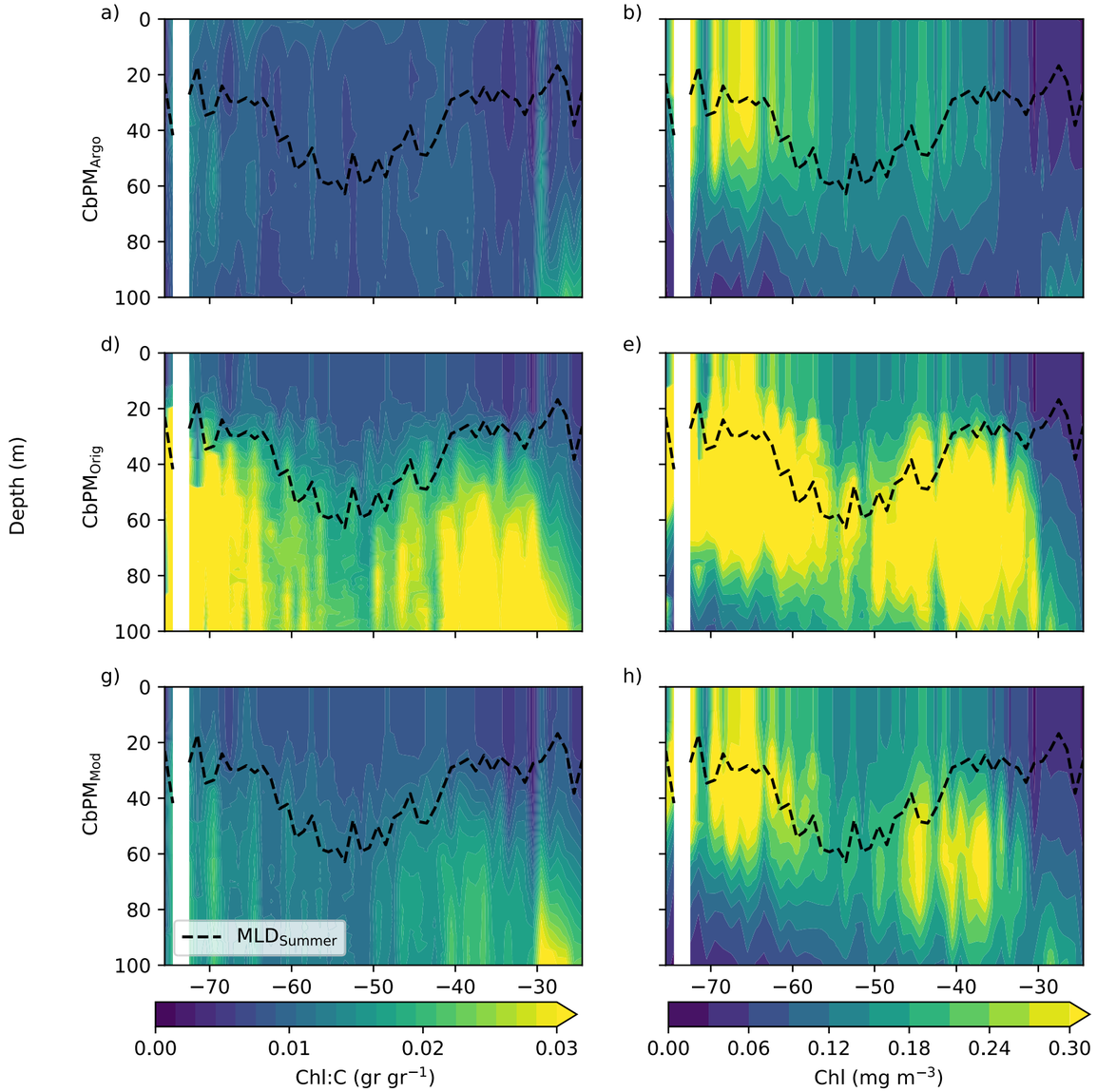
Under the hood: Biomass and acclimation



Chl (mg m^{-3})

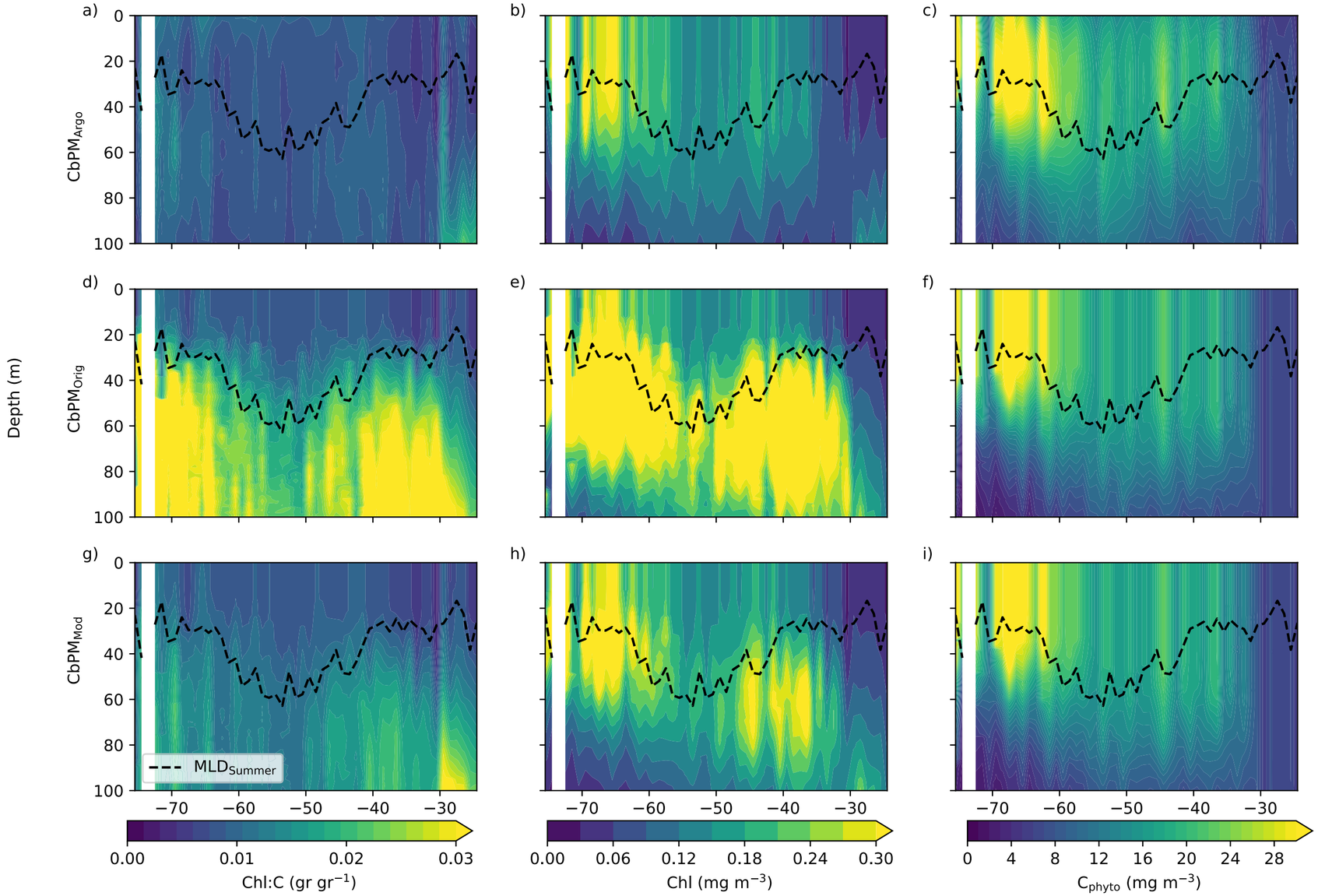
C$_{phyto}$ (mg m^{-3})

Under the hood: Biomass and acclimation



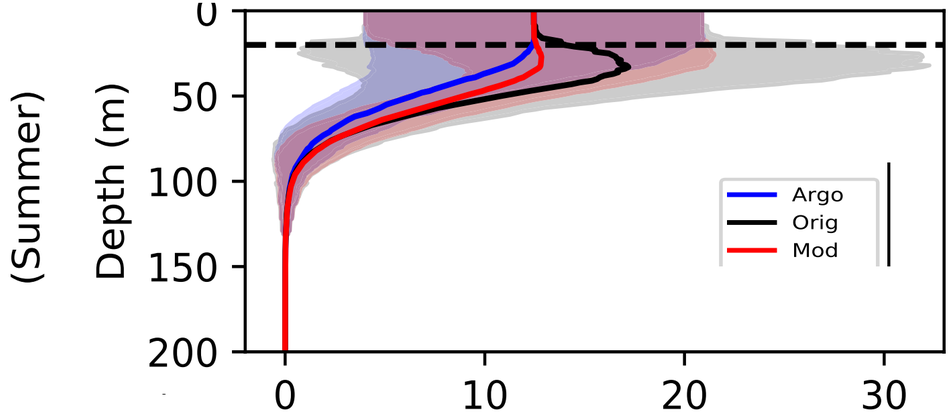
C$_{phyto}$ (mg m^{-3})

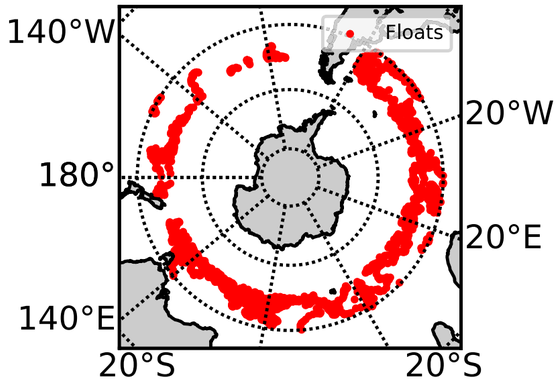
Under the hood: Biomass and acclimation



Observations at ALOHA

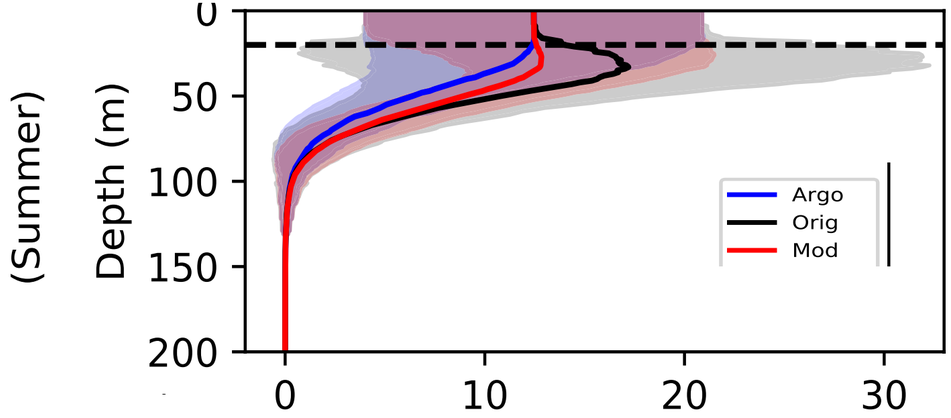
Southern Ocean

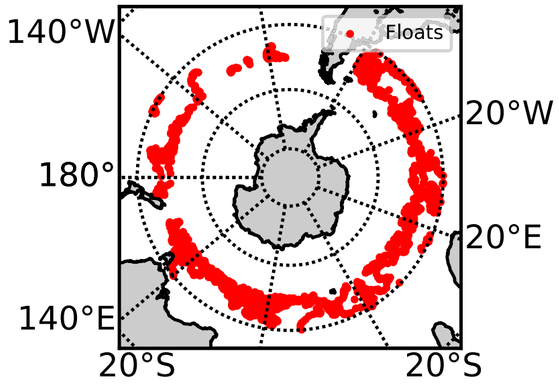




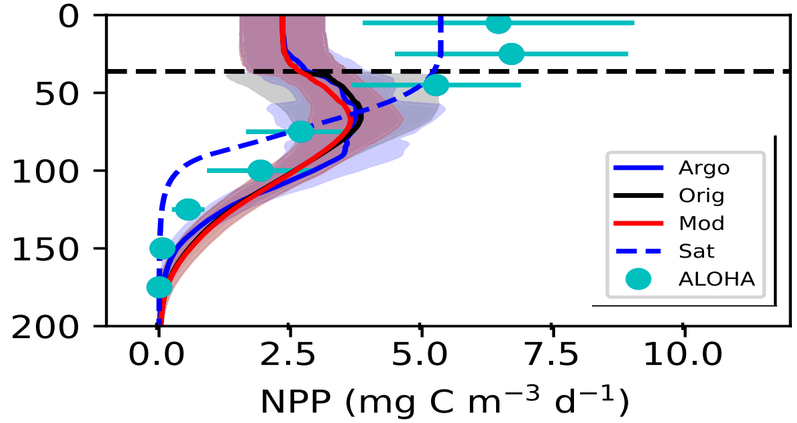
Observations at ALOHA

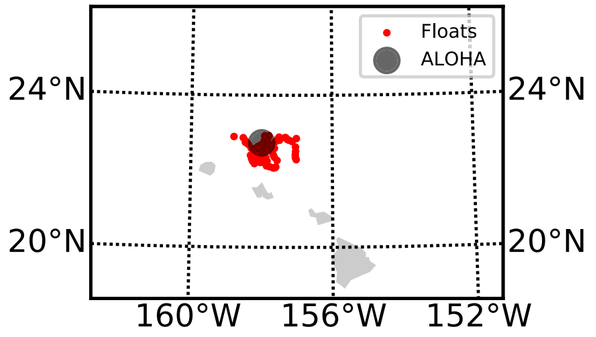
Southern Ocean





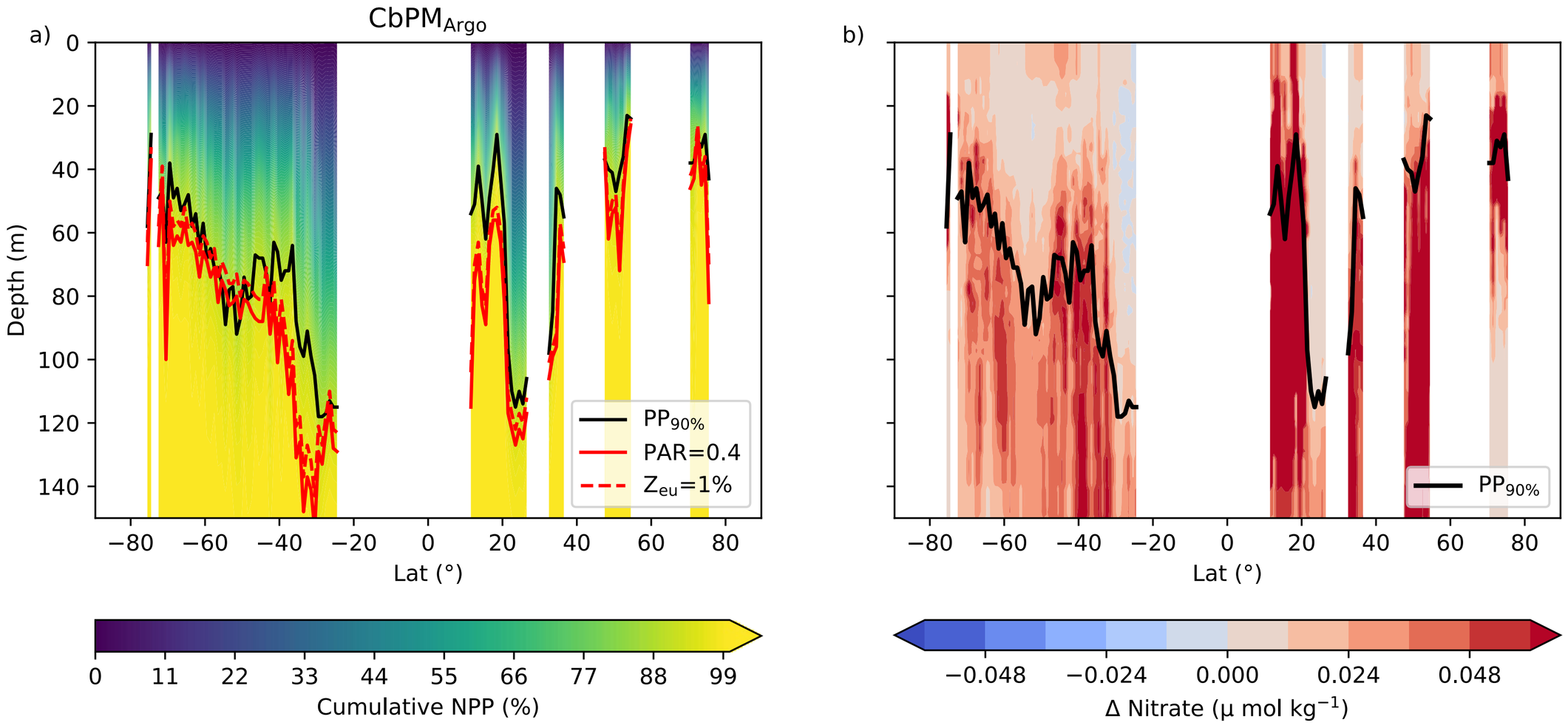
ALOHA (North Pacific)



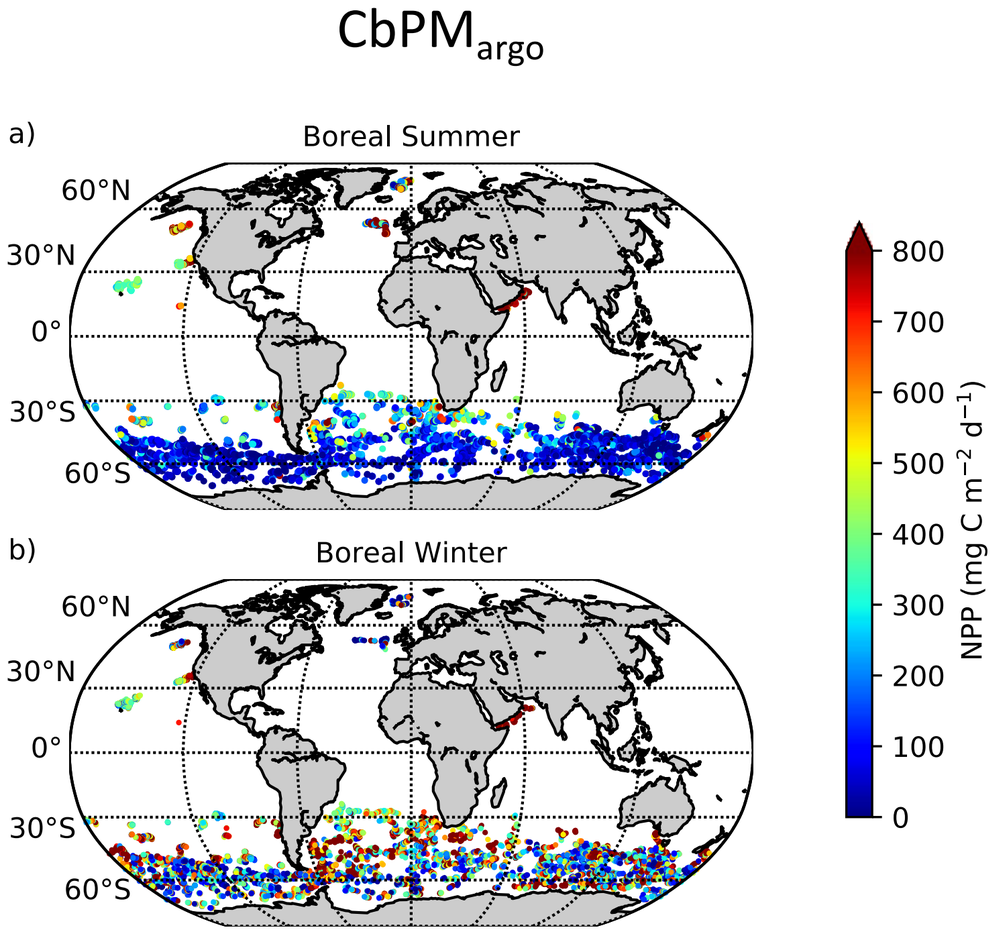


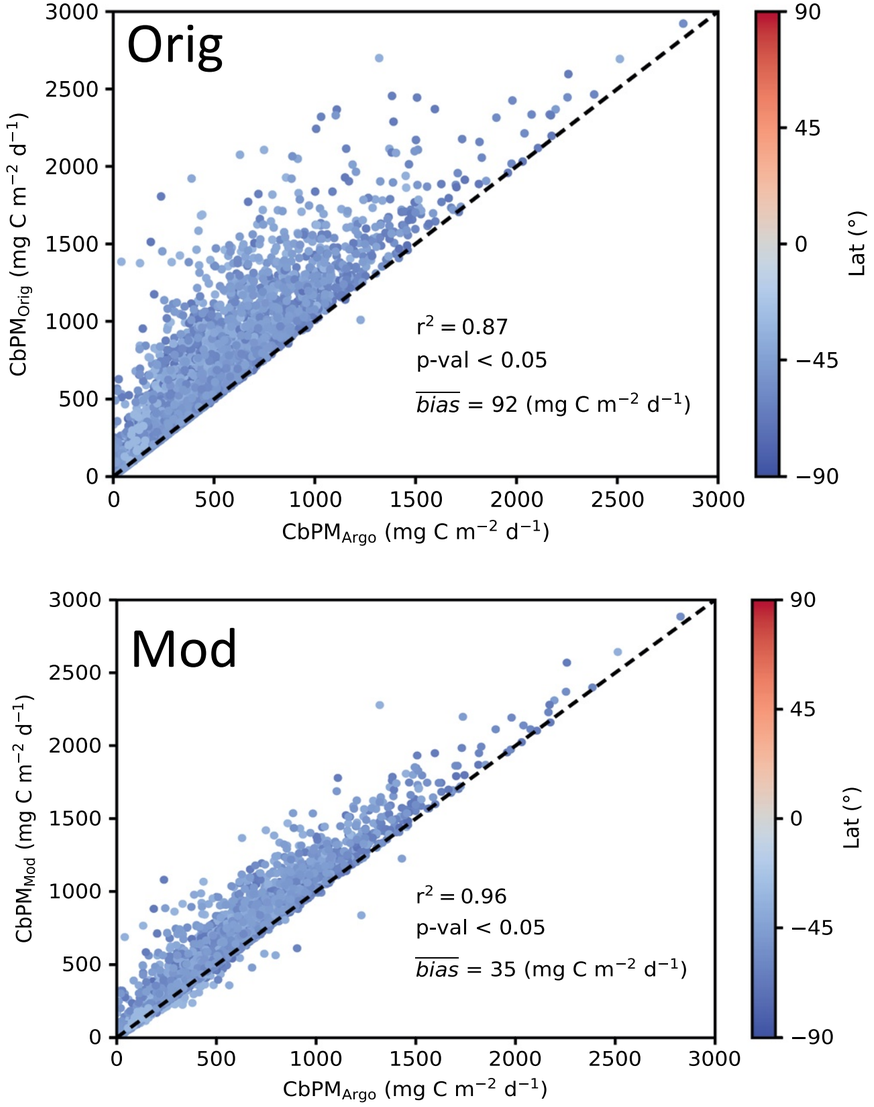
GODDARD EARTH SCIENCES

Inferring the upper productive layer



Impact on depth-integrated productivity





Conclusions

- Depth-resolved estimates of NPP from the $CbPM_{argo}$ agree reasonably well (in shape and magnitude) with historical ^{14}C observations.
- BGC-Argo data suggest that the original CbPM needs to be modified in iron-limited regions. This is an example of how BGC-Argo can help improve remote sensing productivity algorithms.
- For depth-integrated NPP, the inclusion of iron limitation reduces the bias in the original CbPM by 62 % (with respect to $CbPM_{argo}$)

$CbPM_{Argo}$ Code

https://zenodo.org/record/6599224#23.YqJZFC1h3uM

$CbPM_{Argo}$ Paper

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022GB007389