Understanding how light controls the timing of the Southern Ocean spring bloom

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Introduction

- Timing and intensity of the spring bloom is controlled by light, mixed layer depth, nutrients, and grazing, which all vary seasonally
- Our current understanding is based on satellite observations extrapolated to depth
- Biogeochemical (BGC) Argo and other long term water-column observations allow us to question these findings, and further to understand the air-sea-biology connections in the upper ocean
- We specifically aim to understand the variability in photosynthetically available radiation (PAR) a phytoplankton cell experiences in the mixed layer when the spring bloom onset occurs

Dataset

- For now, we focus on one BGC-Argo profiler with 2 m vertical resolution and one night- and day-time sample every ~5 days
- We use ERA5 reanalysis and satellite data to estimate the atmospheric forcing

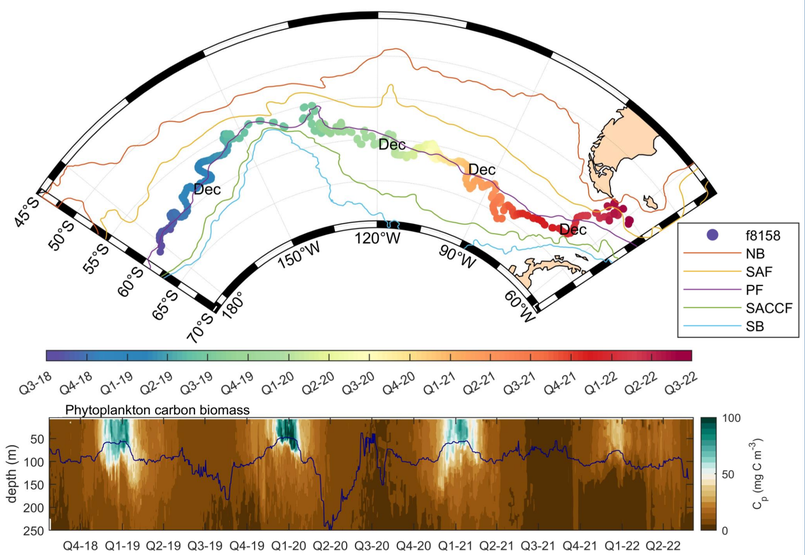

Figure 1: (Top) BGC-Argo float trajectory from July 2018 to June 2022 with approximate Antarctic Circumpolar Current (ACC) front locations (Park et al. JGR 2019). (Bottom) Observed biomass and '**spring' bloom** in the austral summer.

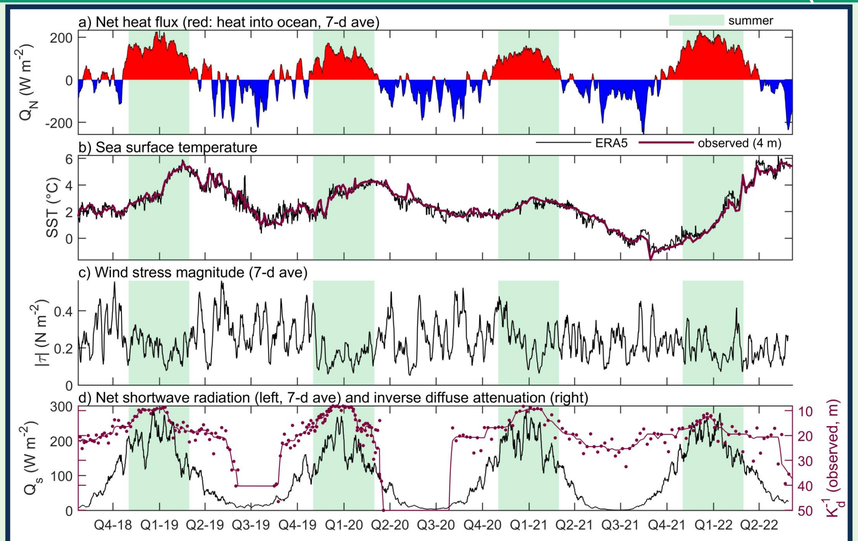

Figure 2: ERA5 atmospheric forcing along the BGC-Argo track with the high biomass summer months shaded. The seasonal trend in shortwave radiation (~47% PAR) is impacted by the opposing trend in diffuse attenuation as light penetrates the water-column. **Light absorption is larger in summer** due to self-shading of phytoplankton cells, so although surface light is larger in summer, light more rapidly exponentially decays with depth.

PAR variability within the mixing layer

- First we find the **turbulent friction velocity** (w_*) from the wind stress,

$$\tau = \rho_a C_{10} U_{10}^2 = \rho_w w_*^2,$$

where ρ_a is the air density, C_{10} is the drag coefficient, U_{10} is the wind speed, and ρ_w is the water density (Denman & Gargett 1983).

- Then, we find the **turbulent Ekman layer thickness**,

$$L_e = 0.4 w_* / f,$$

where f is the Coriolis frequency. However, if $h < L_e$, then h is the mixing layer depth.

- A cell will complete one cycle around the mixed layer in time,

$$T = h / 2 w_*,$$

where if $h = L_e$, $T = 0.2/f \approx$26 min.

Next steps

- We compare mixed layer biomass and its rate of change to the PAR a phytoplankton cell experiences, given mixed layer depth and cell cycle time
- Spring and summer variations in wind stress, diffuse attenuation, and upper ocean stratification cause surface PAR and the PAR a phytoplankton cell experiences in the mixed layer to deviate
- Mixed layer depth will also be influenced by heat and moisture fluxes and surface waves, which we will resolve in future work
- We will run numerical simulations like PWP and GOTM with the ERA5 forcing to estimate mixed layer depth under realistic conditions and observed stratification
- We will expand our analysis to include **additional BGC-Argo floats** with PAR sensors and contrast these observations to **ACCESS 0.1° runs with biogeochemical component**

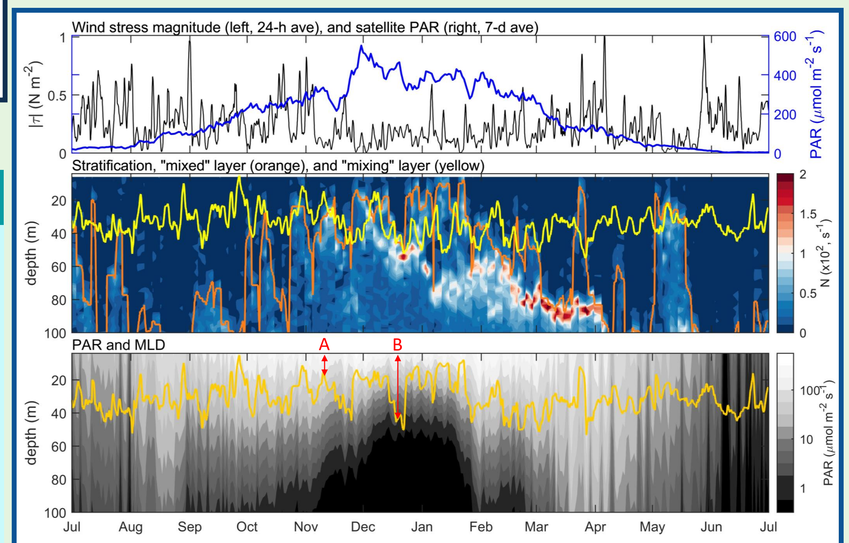

Figure 3: BGC-Argo observations alone suggest a much deeper mixed layer (orange) than what is expected from the wind stress (L_e, yellow). A phytoplankton cell is expected to completed a cycle up-and-down the mixed layer in less than 30 min. Depending on biomass, and the dependent diffuse attenuation, a **cell may experience PAR variability of multiple orders of magnitude** in a single cycle.