Global Biogeochemical Cycles

Supporting Information for

Variability in the mechanisms controlling Southern Ocean phytoplankton bloom phenology in an ocean model and satellite observations

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Contents of this file

Text S1
Figures S1 to S3
Tables S1
Introduction

Due to computational storage capacity limitations certain variables were only saved as monthly averages. Supplementary Material S1 details the diagnostic model used to approximate surface phytoplankton carbon concentrations for calculations at daily resolution.

Text S1. CESM Surface Concentration Correction Factor

Due to computational storage capacity limitations surface phytoplankton carbon concentrations were only saved at the monthly resolution and thus must be approximated for calculations at daily resolution.

Our first approximation assumes a homogeneously distributed vertical profile in which all biomass is stored evenly within the greater of the mixed layer or euphotic depth (referred to as the Profile Depth, \( Z_{\text{profile}} = \max(\text{MLD}, Z_{\text{eu}}) \)). Under this assumption the surface concentration (also equivalent to the mean concentration) is calculated by dividing the vertical inventory (\( \Sigma C_{\text{phyto}} \)) by \( Z_{\text{profile}} \) (see Section 2.3.1).

This assumption holds well for deep, well mixed, mixed layers that exceed the euphotic depth [Boss et al. 2008; Boss & Behrenfeld, 2010; Behrenfeld et al., 2013]. However the surface concentrations of shallower profiles, where phytoplankton growth can persist in stratified water below the mixed layer, are not approximated as well. In order to improve our approximations, we weight the surface concentration of shallow profiles (\( Z_{\text{profile}} < 100\text{m} \)) by a spatially and depth dependent correction factor.

S1.1 Correction Factor Model

We use explicitly resolved monthly surface concentrations to create a model to approximate the true correction factor as a function of grid cell and \( Z_{\text{profile}} \).

To do so, we first approximate the monthly surface concentration using the first order approximation defined above and \( \Sigma C_{\text{phyto}} \) and \( Z_{\text{profile}} \) values calculated as described in Section 2.3.1 but from monthly means,

\[
[C_{\text{phyto}}]_{\text{surf\_approx}} = \frac{\Sigma C_{\text{phyto}}}{Z_{\text{profile}}}. \quad \text{EQ. S1.1}
\]

We then divide the true surface concentration by the approximated to calculate the correction factor, \( C_{\text{fact}} \)

\[
C_{\text{fact}} = \frac{[C_{\text{phyto}}]_{\text{surf\_true}}}{[C_{\text{phyto}}]_{\text{surf\_approx}}}. \quad \text{EQ. S1.2}
\]

Distributions of \( C_{\text{fact}} \) as a function of \( Z_{\text{profile}} \) at each model grid point are then fit to a simple model, such that we can model the requisite \( C_{\text{fact}} \) of the daily data given a grid cell and \( Z_{\text{profile}} \).

Figure S1 shows a typical distribution in which \( C_{\text{fact}} \) approaches 1.0 as the \( Z_{\text{profile}} \) reaches 100m (See Fig S1). Our simple model fits a linear regression to all points.
where $Z_{\text{profile}}<100\text{m}$ and assigns a $Cor_{\text{factor}}$ of 1.0 where $Z_{\text{profile}}>100\text{m}$ where our uniform distribution assumption is acceptable.

An independent function is modeled at each grid point and compiled. With this model, we can now assign a reasonably well-estimated $Cor_{\text{factor}}$ for any particular spatial coordinate and $Z_{\text{profile}}$ at the daily resolution.

**S1.2 Test of Model Skill**

We use monthly mean values of $\Sigma C_{\text{phyto}}$ and $Z_{\text{profile}}$ and our correction factor model to compute corrected approximate surface concentrations that can be directly compared to the true surface concentrations stored at the monthly resolution to test model skill.

In Figure S2, plotting time series from one year at the same grid point modeled in Figure S1, it is clear the corrected values match the true values much better than our initial approximation (Eq. S.1.1).

We test the skill of the approximated values at each grid cell. Figure S3a projects the mean absolute value percent deviation of the corrected approximation from the true surface values. Error ranges from 5-15%. More importantly, figure S3b shows consistently high ($r>.95$) correlations between the two time series across the Southern Ocean. Thus despite minor discrepancies in the absolute magnitude, seasonal trends (our primary concern) remain tightly coupled. Table S1 outlines the percent deviation and correlation coefficient values spatially averaged over each swath considered in Section 3.2 and 3.3 in addition to the entire Southern Hemisphere.

Figure S1. The $Cor_{\text{factor}}$ needed to convert the approximated surface concentration to the true surface concentration plotted as a function of $Z_{\text{profile}}$ for the timeseries at a single grid point (Lat = 50S, Lon = 91W) and monthly resolution. The modeled fit is plotted in black.
Figure S2. A single year, monthly resolution time series plotted for the true surface phytoplankton biomass concentration (black trace) along a first approximation (red trace) and the corrected approximation (blue trace). Time series are from the same gridcell as Fig. A1 (Lat = 50S, Lon = 91W).

Figure S3. The mean absolute value percent deviation of the corrected approximation from the true surface values for each grid cell is plotted on the left (a) with correlation coefficient between the two time series plotted on the right (b).

Table S1. The percent deviation and correlation coefficient values spatially averaged over each swath considered in Section 3.2 and 3.3 in addition to the entire Southern Hemisphere (SH).