AGU PUBLICATIONS

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Supporting Information for

Linking Southern Ocean mixed-layer dynamics to net community production on various timescales

Zuchuan Li[1,2*], M. Susan Lozier[3], and Nicolas Cassar[1*]

[1] Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina, USA

[2] Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA

[3] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, USA

[*] Corresponding authors: Zuchuan Li (zuchuanli@gmail.com) and Nicolas Cassar (Nicolas.Cassar@duke.edu)

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Caveats, limitations and future improvements

Our satellite estimates of annual NCP bear uncertainties associated with the algorithm parameterization [*Li and Cassar*, 2016]. Equation (3) explains 68% of variance in O_2/Ar-derived NCP. Because negative O_2/Ar values are not included in the training dataset, the algorithm can only predict positive NCP values. Furthermore, other factors may influence NCP [*Li and Cassar*, 2018]. Uncertainties in NCP predictions could result from predictors not being available, especially when these factors do not co-vary with other environmental variables in the algorithm. The algorithm should improve through further vicarious calibration and validation of the satellite optical properties and with the availability of hyperspectral sensors on future satellite missions.

Our estimates of NCP are calculated assuming a constant MLD over the residence time of O_2 at the ocean surface (~1-2 weeks). This assumption has a negligible impact on the NCP estimates because it is only used to estimate the time-weighted gas exchange velocity (see Reuer et al. [2007]). However, on intra-seasonal timescales, we use POC change from biogeochemical Argo floats for productivity, in which case no assumptions about MLD history are needed.

Uncertainties in annual NCP can also stem from errors in the input data and the training data sets. For example, the NCP-predictor NPP carries uncertainties associated with the satellite dataproducts (e.g., [Chl] and SST) and with assumptions and simplifications in the VGPM model. The parameterization of the maximum daily photosynthetic rate of the VGPM algorithm explains about 20% of observations [*Behrenfeld and Falkowski*, 1997; *Behrenfeld et al.*, 2002]. Some of these uncertainties may have a limited impact the intraseasonal variability analysis based on chlorophyll a concentration. However, they may influence results on seasonal timescales due to the potential for seasonal variations in the relationship between NCP and the environmental variables. More details on the performance of equation (3) can be found in *Li and Cassar* [2016].

Satellites cannot detect phytoplankton blooms under sea ice or cloud cover, nor can they detect deep chlorophyll below the first optical depth. They may also miss short phytoplankton blooms persisting for just a couple of days. If such blooms account for an appreciable proportion of NCP, our estimates represent a lower bound on the true NCP in these regions. Finally, MLD estimates based on the density-threshold method carry uncertainties in the

Southern Ocean particularly in the austral winter [*Holte et al.*, 2017]. This can impact the correlation between MLD and NCP on seasonal and interannual timescales.

In most regions, the signal to noise ratio is low in trends of annual NCP. The annual NCP trends are less than 10% of the changes in annual NCP over a decade. These changes are likely within the uncertainties of our satellite-NCP estimates [*Li and Cassar*, 2016]. Longer time series and more accurate satellite products are required to further investigate the multi-year NCP variability.

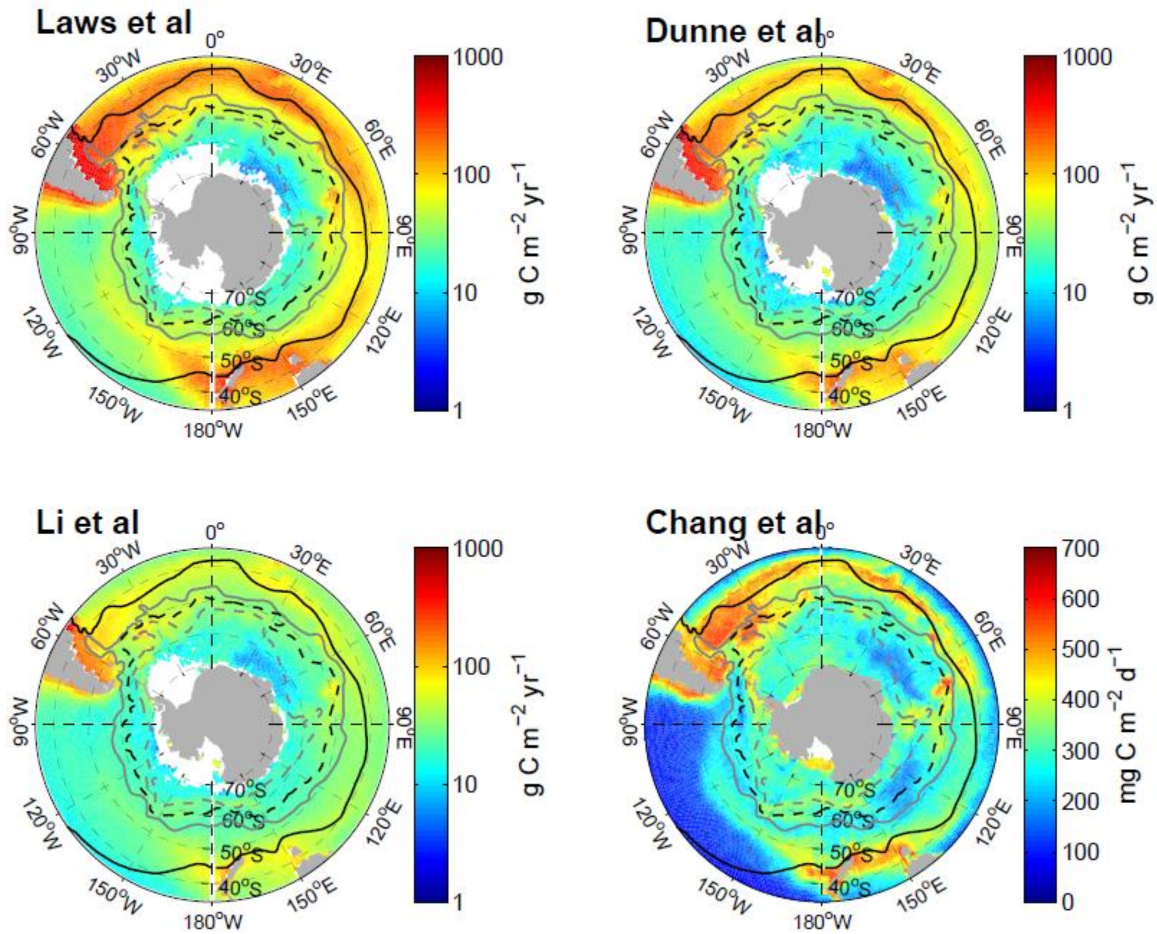

Figure S1. Climatologies of net community production (NCP) and export production according to: Laws *et al.* [2000], Dunne *et al.* [2005], Li *et al.* [2016], and Chang *et al.* [2014]. NCP estimates derived by Chang *et al.* [2014] are monthly climatology during the growing season (November-March), while estimates derived by other algorithms represent the climatology of annual NCP or export production. Solid, gray, black-dashed, and gray-dashed lines represent the climatological position of the Subtropical Front, Subantarctic Front, Polar Front, and Southern Antarctic Circumpolar Current Front, respectively (according to Orsi *et al.* [1995]).

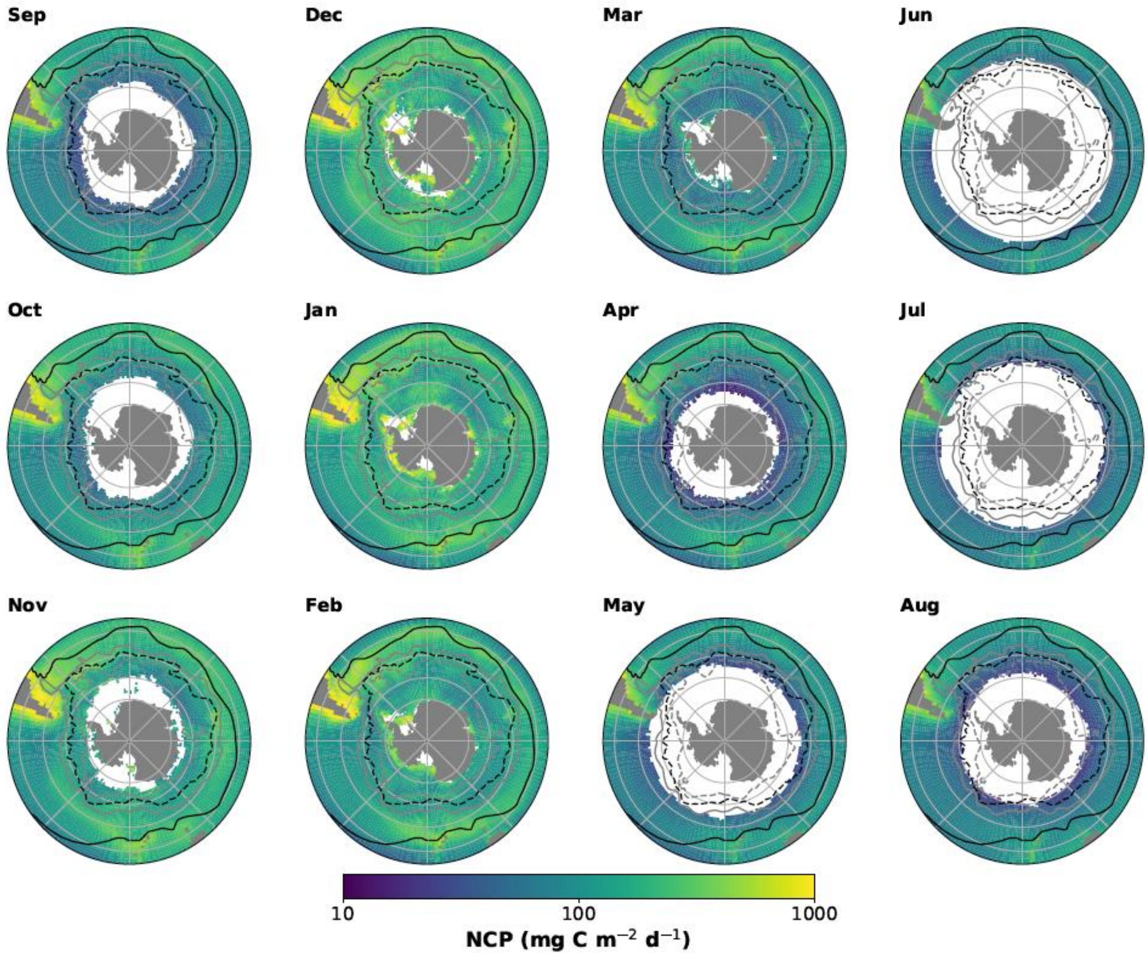

Figure S2. Climatologies of monthly net community production. Solid, gray, black-dashed, and gray-dashed lines represent the Southern Ocean fronts, as described in Figure S1.

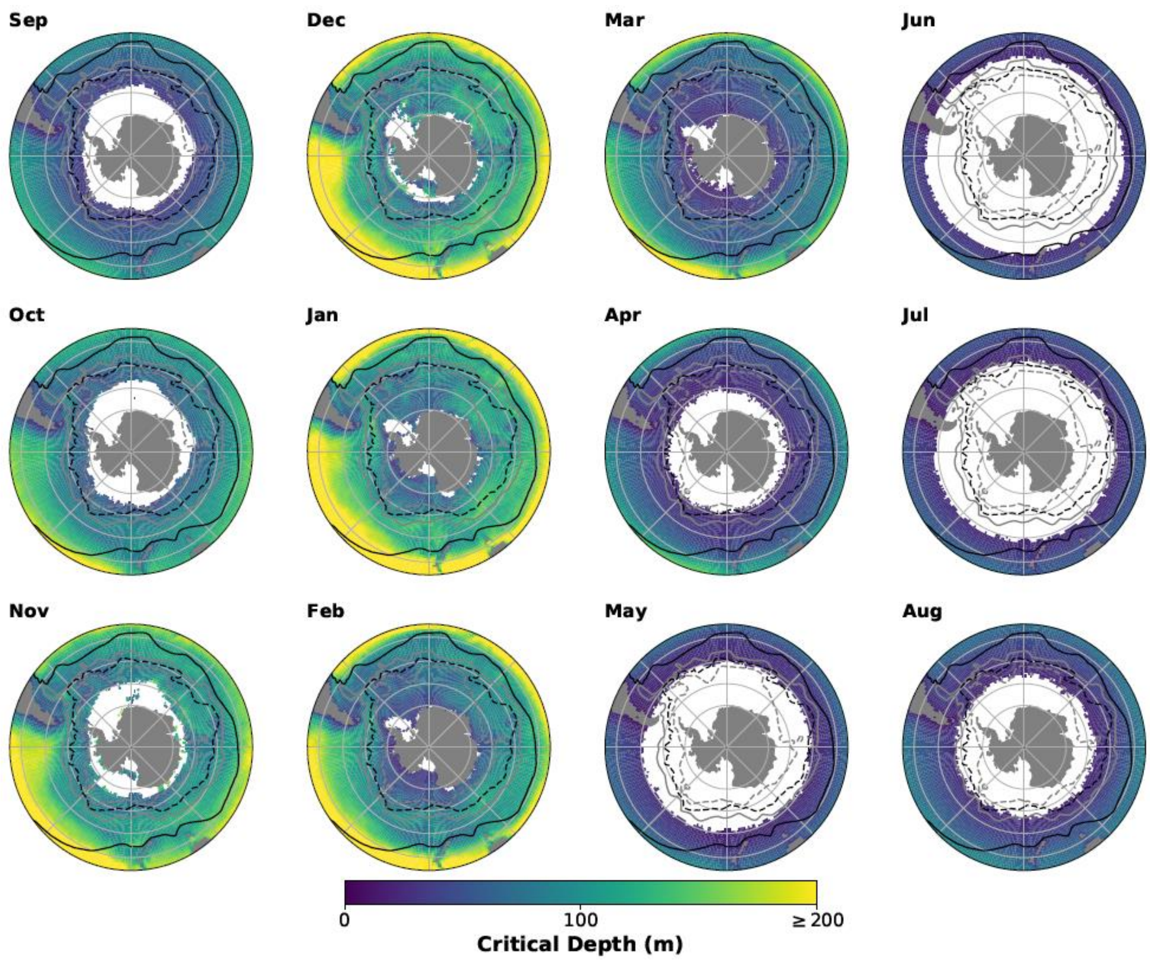

Figure S3. Climatologies of critical depth. Solid, gray, black-dashed, and gray-dashed lines represent the Southern Ocean fronts, as described in Figure S1.

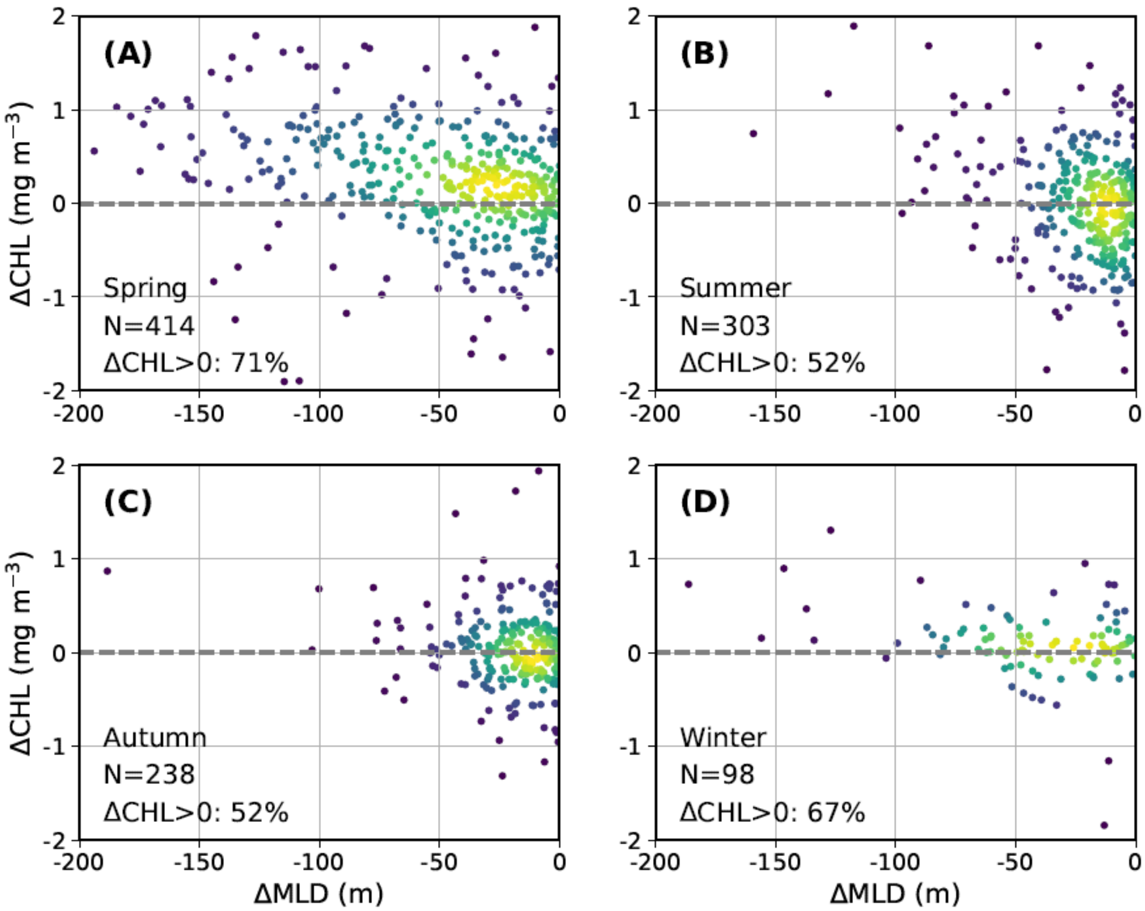

Figure S4. Changes in chlorophyll *a* concentration (Δ[Chl]) as a function of shoaling mixed layer (ΔMLD) in austral (A) spring, (B) summer, (C) autumn, and (D) winter. N and Δ[Chl]>0 represent the number of points and the percentage of points showing increases in chlorophyll *a* concentration, respectively. Points above the dashed lines (Δ[Chl]=0) show increases in chlorophyll *a* concentration. Chlorophyll *a* concentration is log-transformed before calculating the difference. Points are color coded for the density of observations.

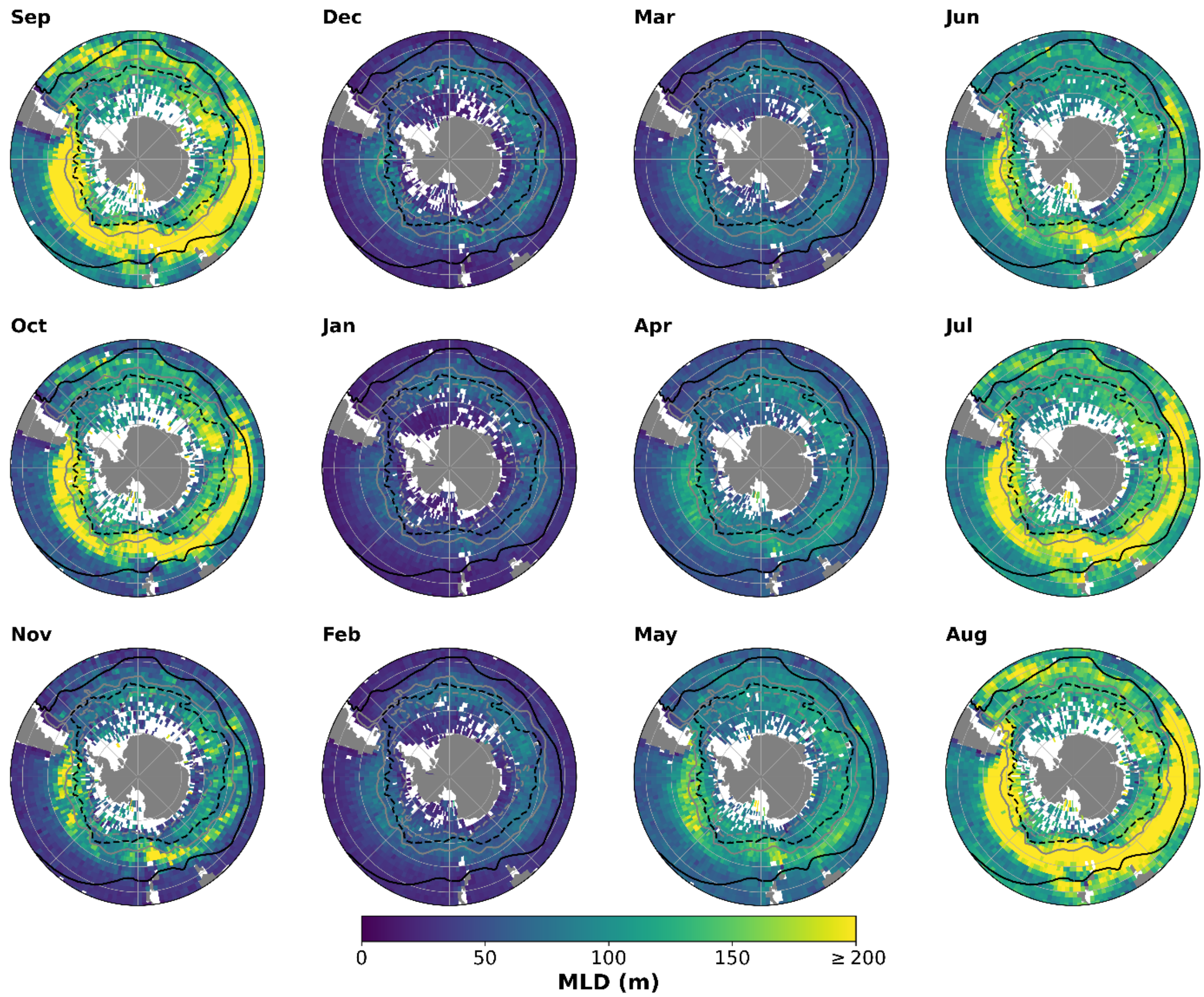

Figure S5. Climatologies of mixed layer depth. Solid, gray, black-dashed, and gray-dashed lines represent the Southern Ocean fronts, as described in Figure S1.

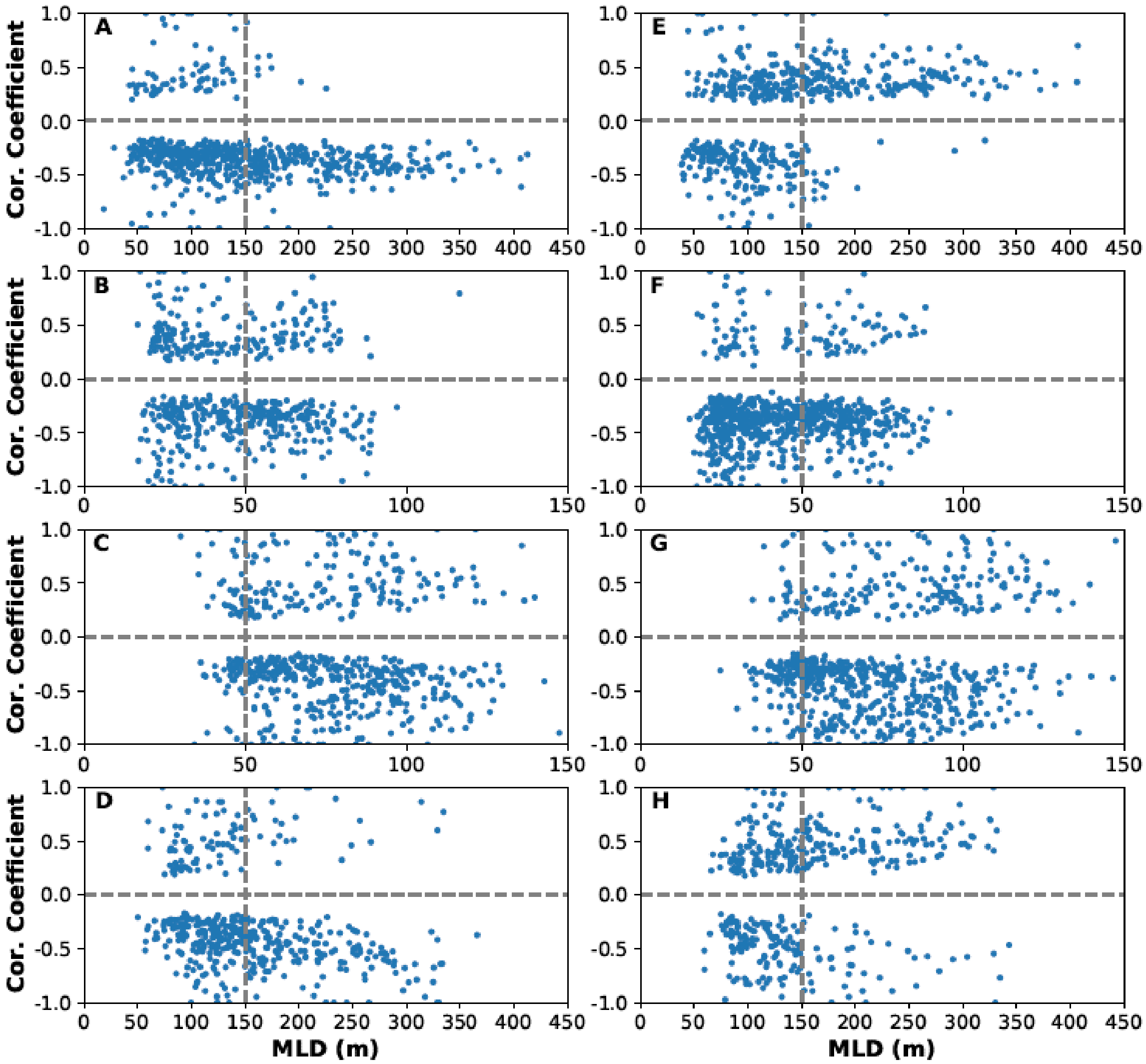

Figure S6. Seasonal mixed layer depth and Spearman correlation coefficients between monthly anomalies of net community production, (A-D) mixed layer depth, and (E-H) mixed-layer-averaged PAR in austral (A and E) spring, (B and F) summer, (C and G) autumn, and (D and H) winter.

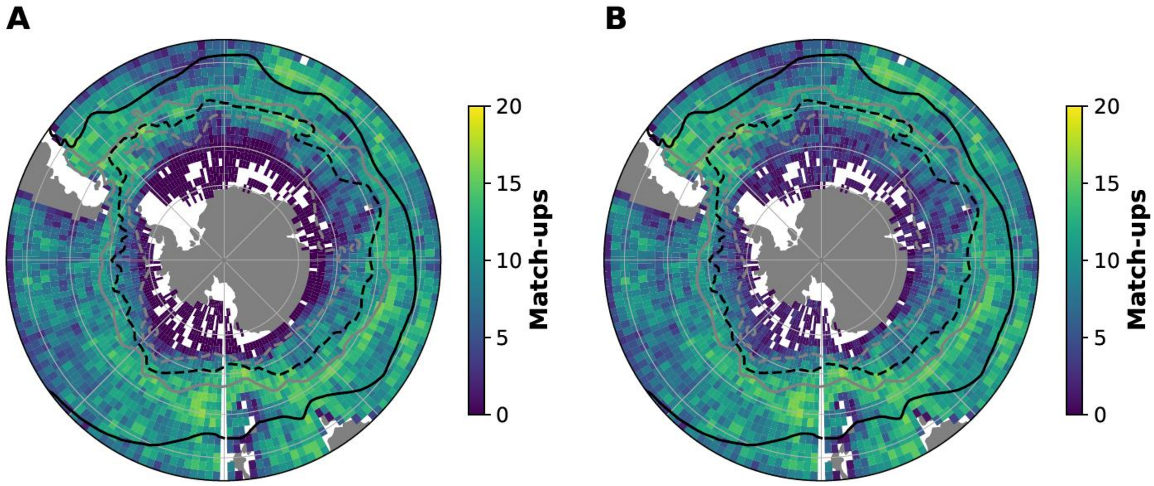

Figure S7. The number of mixed layer depth estimates in the austral winter that are matched to the net community production in austral (A) spring and (B) summer.

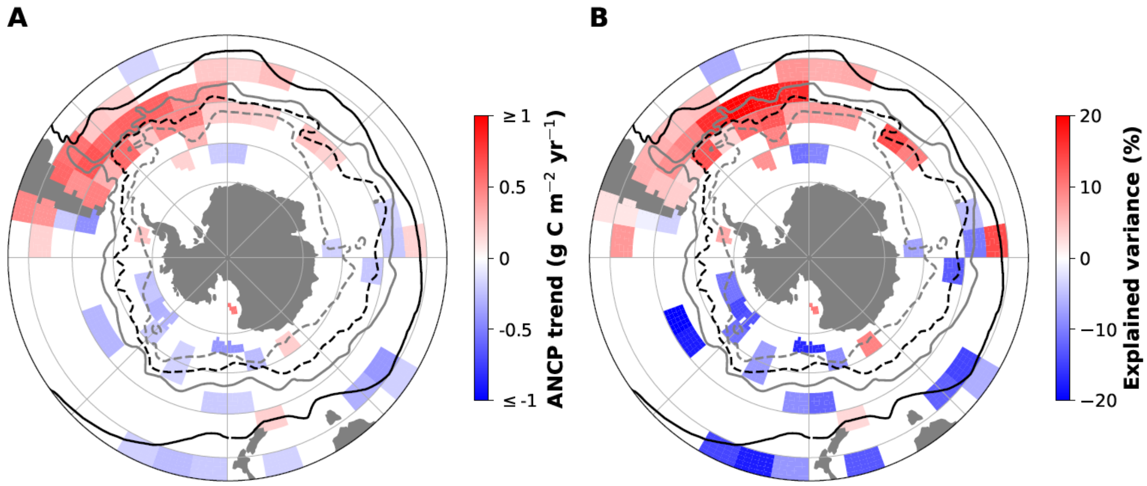

Figure S8. Annual net community production trends between 2002 and 2011. Solid, gray, black-dashed, and gray-dashed lines represent the Southern Ocean fronts, as described in Figure S1.

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