Biogeochemistry of climate driven shifts in Southern Ocean primary producers

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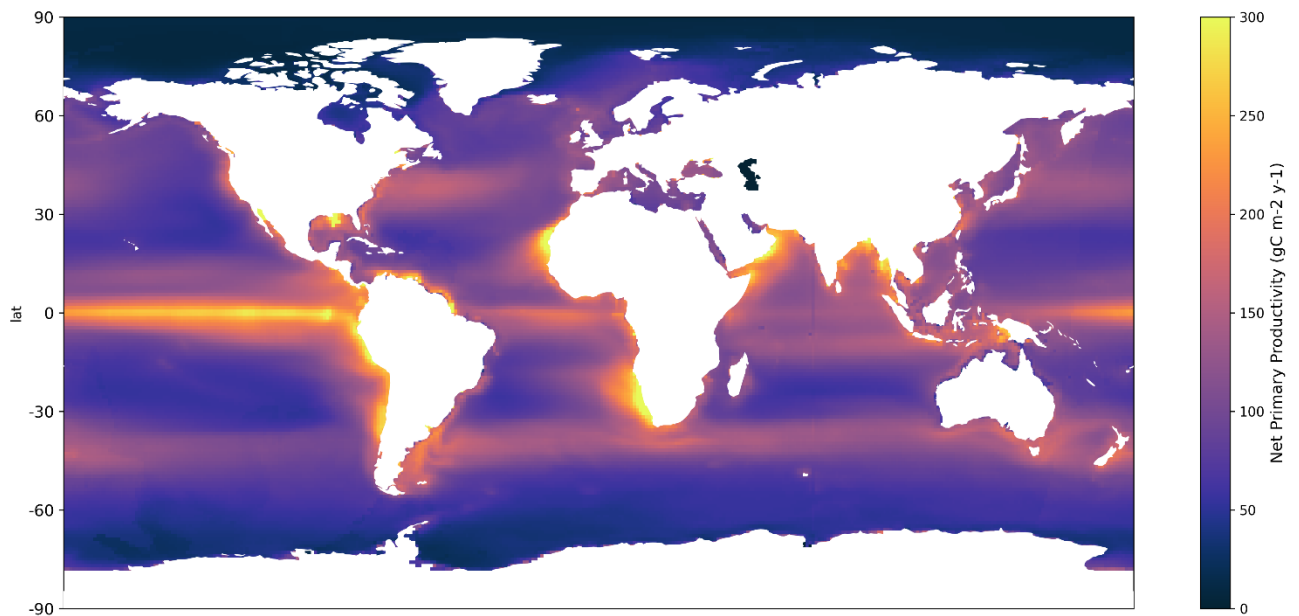
Figure S1: Global Net Primary Productivity (2015-2023) under a middle of the road, SSP2-4.5 pathway, from a multi-model CMIP6 ensemble. Models included are listed in Table 1. For the purpose of determining Southern Ocean productivity, the ocean area is defined as that south of 30°S, per Gregg et al. (2003).
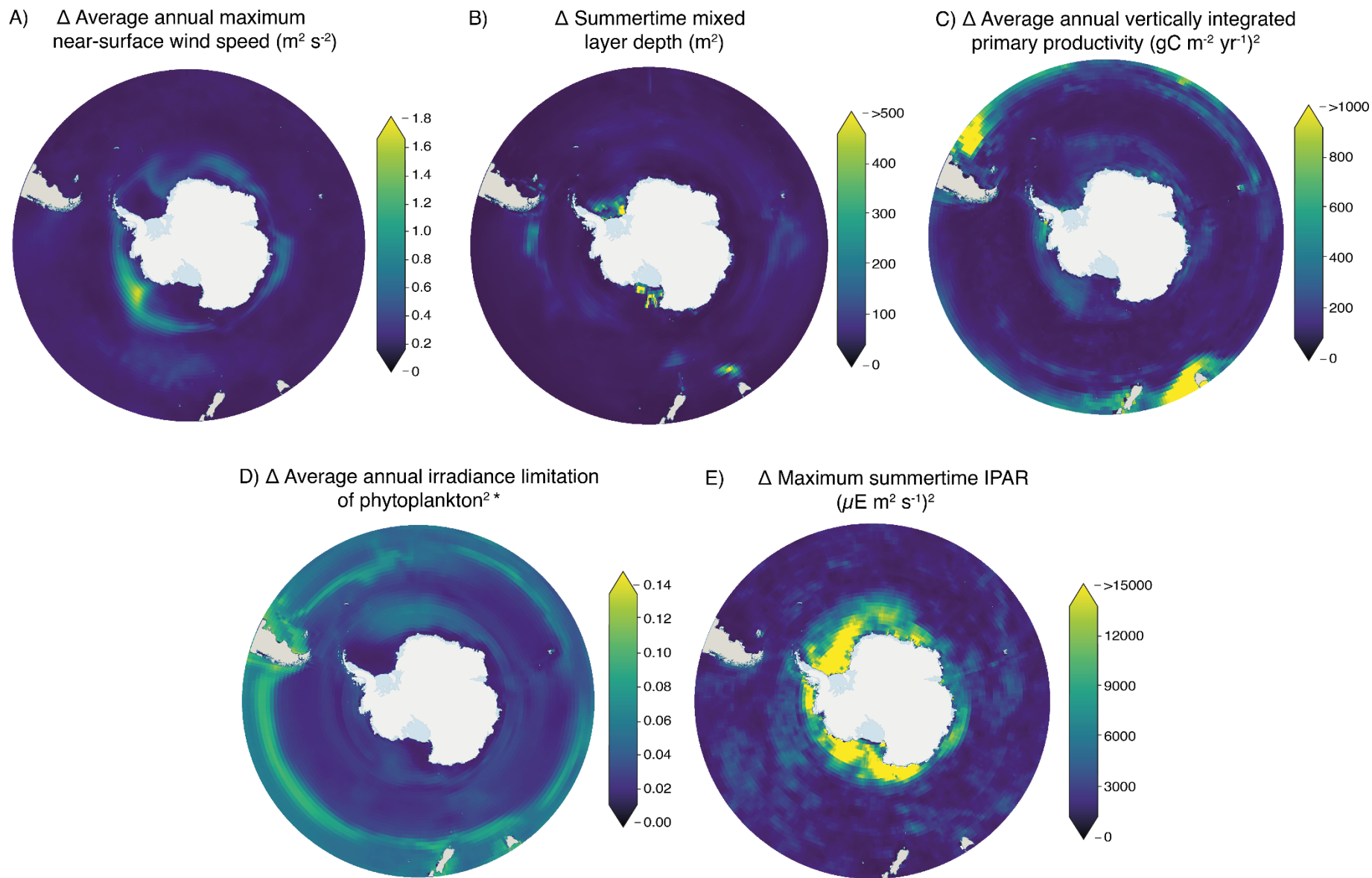
Figure S2: Variance in CMIP6 anomalies of the historical (1985-2015) vs end century time period (2090-2100) under the SSP5-85 scenario. Panels represent A) near-surface wind speed, B) mixed layer depth, C) net primary productivity, D) irradiance limitation of phytoplankton and E) incidental photosynthetically active radiation (IPAR). Outputs represent multi-model means, with model members listed in Table 1. No variance is given for iron limitation (Figure 2F) as only 1 model in our dataset includes the necessary parameters.
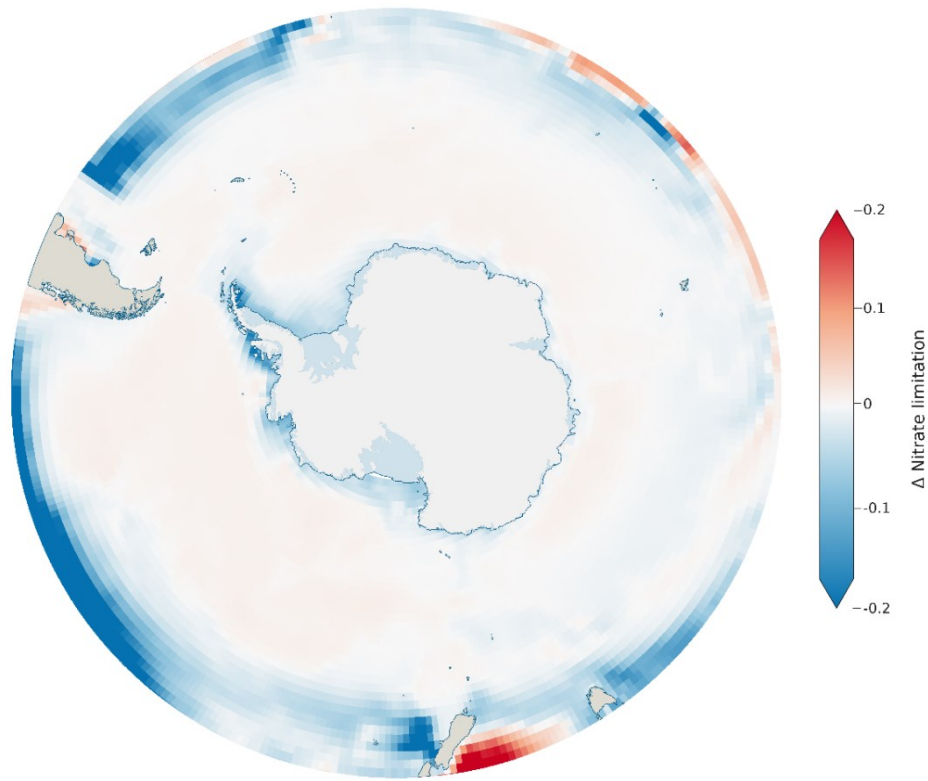
Figure S3: Anomaly in nitrate limitation of all groups of phytoplankton across the Southern Ocean for 2090-2100 under SSP5-8.5 compared to a historical mean (1985-2015). Data shown for GFDL-ESM4, being the only CMIP model to include nitrate limitation. Limitation of all groups is derived as the sum of "limndiat","limnpico" and "limnmisc". Units are the anomaly value between a ratio of growth under environmental nitrate concentrations and theoretical growth under unlimited nitrate.
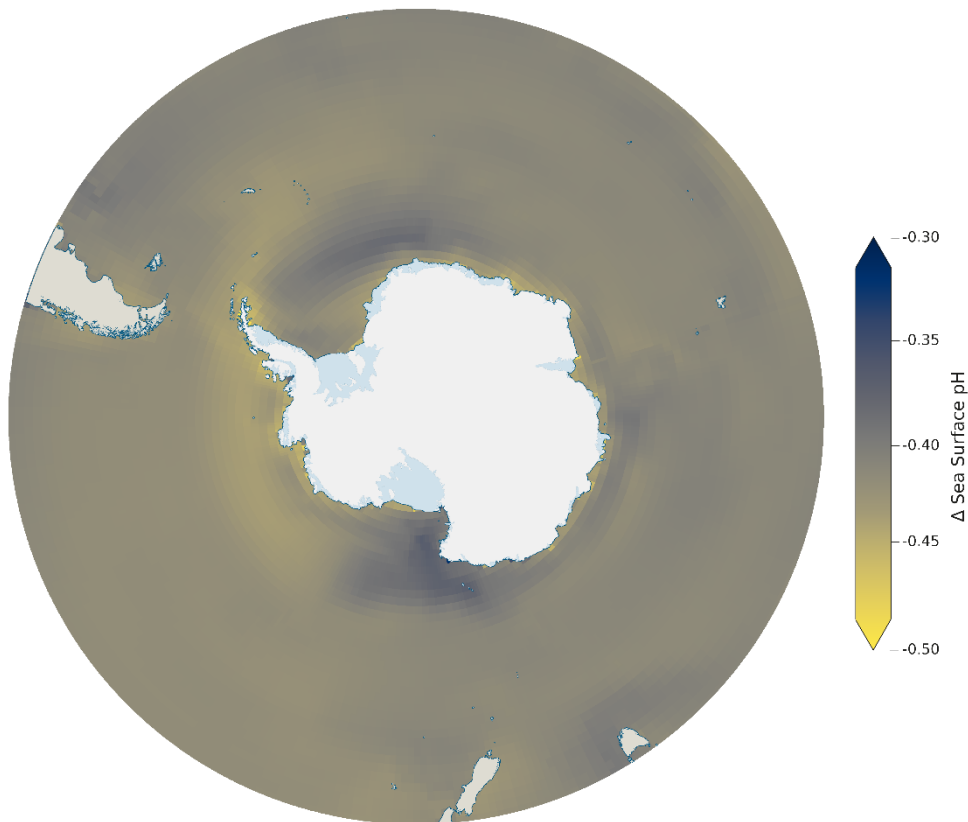
Figure S4: Anomaly in sea surface pH between 2100 (SSP5-8.5) and a historical average (1985-2015). Representative of a multi-model ensemble of CMIP6 models; models included are detailed in Table 1
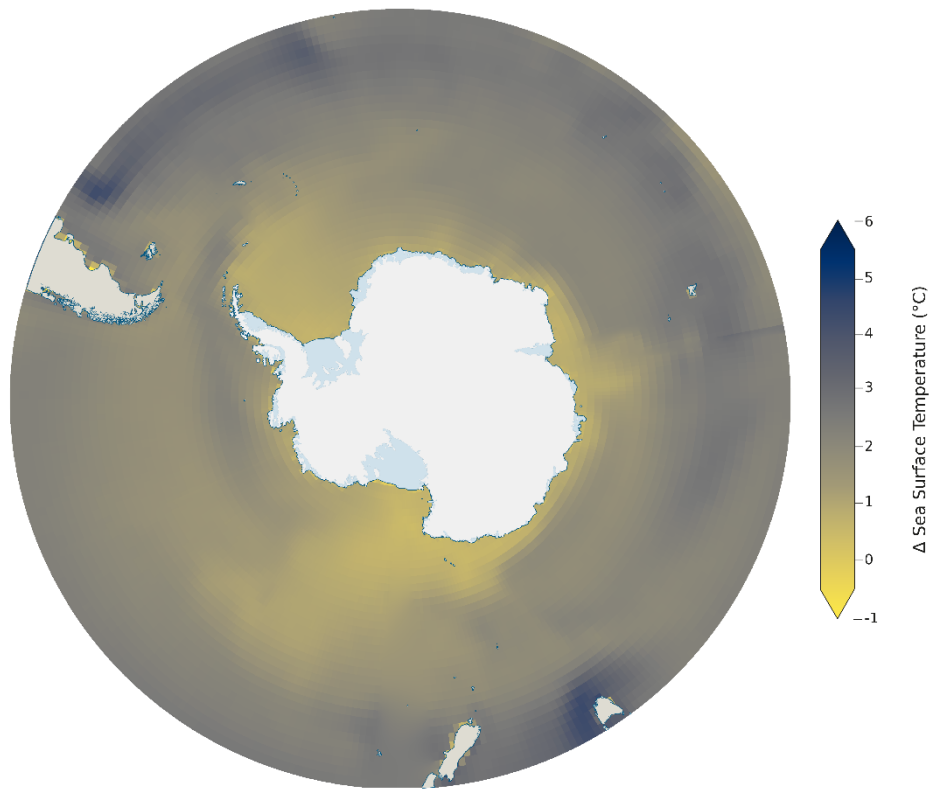
Figure S5: Anomaly in sea surface temperature (°C) between 2100 (SSP5-8.5) and a historical average (1985-2015). Representative of a multi-model ensemble of CMIP6 models; models included are detailed in Table 1.
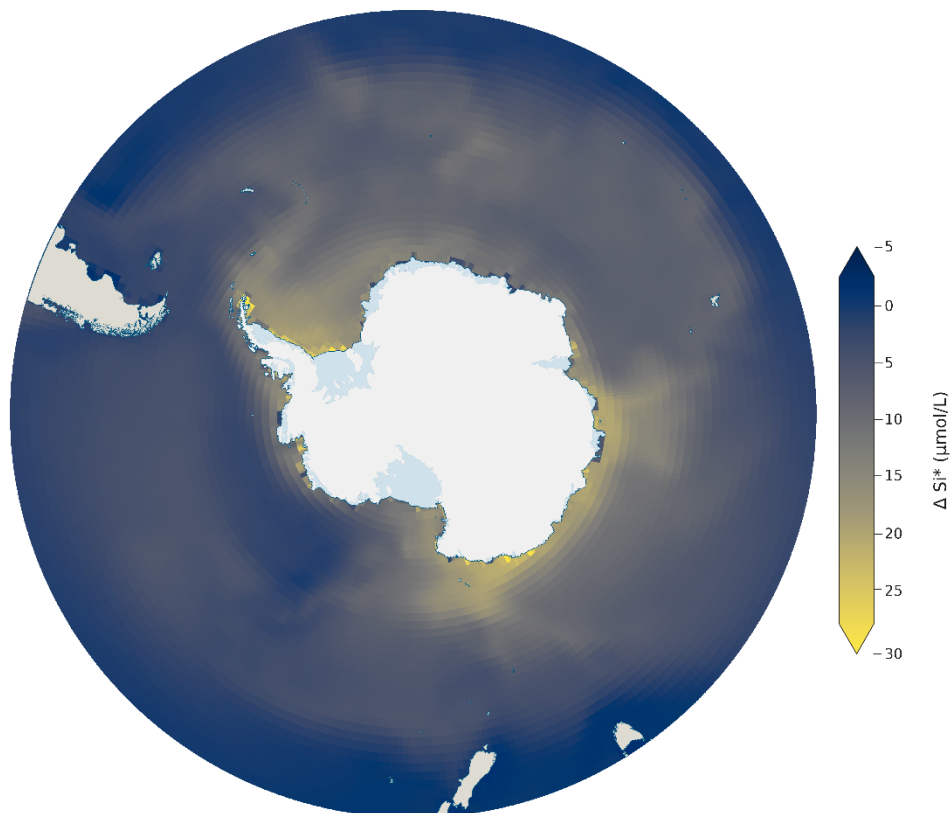
Figure S6: Anomaly in Si* ([Si(OH)$_4$]−[NO$_3^-$] (µmol/L)) between 2100 (SSP5-8.5) and a historical average (1985-2015). Representative of a multi-model ensemble of CMIP6 models; models included are detailed in Table 1.
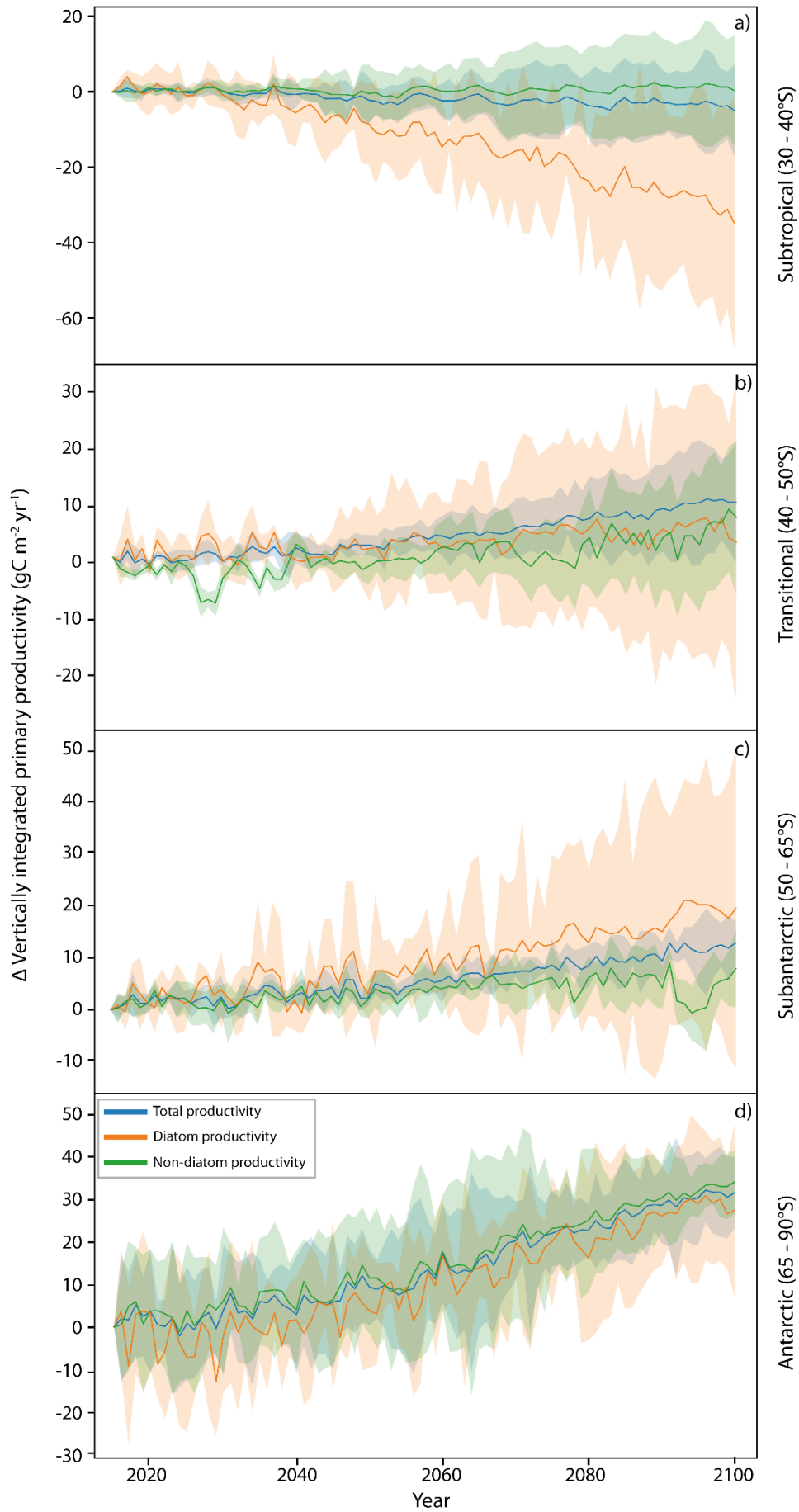
Figure S7: Changes in productivity (%) and the contribution of different phytoplankton classes to productivity 2015-2100 in CMIP6 Adapted version of main figure 3 showing the relative change in productivity and phytoplankton group contributions compared to annual productivity at the first time point (2015) in the SSP5-8.5 run. Representative of a multi-model ensemble of CMIP6 models; models included are detailed in Table 1.

Table S1: Data descriptors for Figure 1.

Variable	Value	Detail	Reference
Warming at depth	+0.62 °C	Expected warming of Antarctic shelf bottom waters by 2100 across SSP5-8.5 in a CMIP6 multi-ensemble mean. (Purich & England 2021).	Purich and England (2021)
Changes in stratification.	CMIP6: -1.9 m/ -7.8% Uncertain, sign change within standard deviation.	Changes in mixed layer depth are highly spatially variable. In the coastal Southern Ocean (south of 60°S) CMIP5 models disagree on the direction of MLD change due to the competing effects of freshwater input with increased upwelling and wind driven mixing (Hauck et al., 2015). CMIP6 models similarly disagree but give an overall mean of -1.9 m. Melting of the Antarctic ice sheet is not a process considered within CMIP models.	Hauck et al. (2015)
pCO_2	+200%	Increase from ~500 µatm (GLODAP) to ~1000 µatm under RCP8.5.	Kawaguchi et al. (2013)
pH	-0.3 pH units	Decrease in Southern Ocean pH from 8.09 to 7.79 calculated using the CSIRO ocean carbon model from CC IS92a atmospheric CO_2 scenario.	McNeil and Matear (2008)
Increased surface warming	+2.50°C	Spatial average taken from the temperature anomaly data shown in Figure S1. Representative of a CMIP6 multi-model ensemble anomaly between 2100 and (1985-2015) under SSP5-8.5.	This study

References:

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