

Supplementary Material for “Climate drivers of Southern Ocean phytoplankton community composition and potential impacts on higher trophic levels” by Krumhardt et al.

1 SUPPLEMENTARY FIGURES

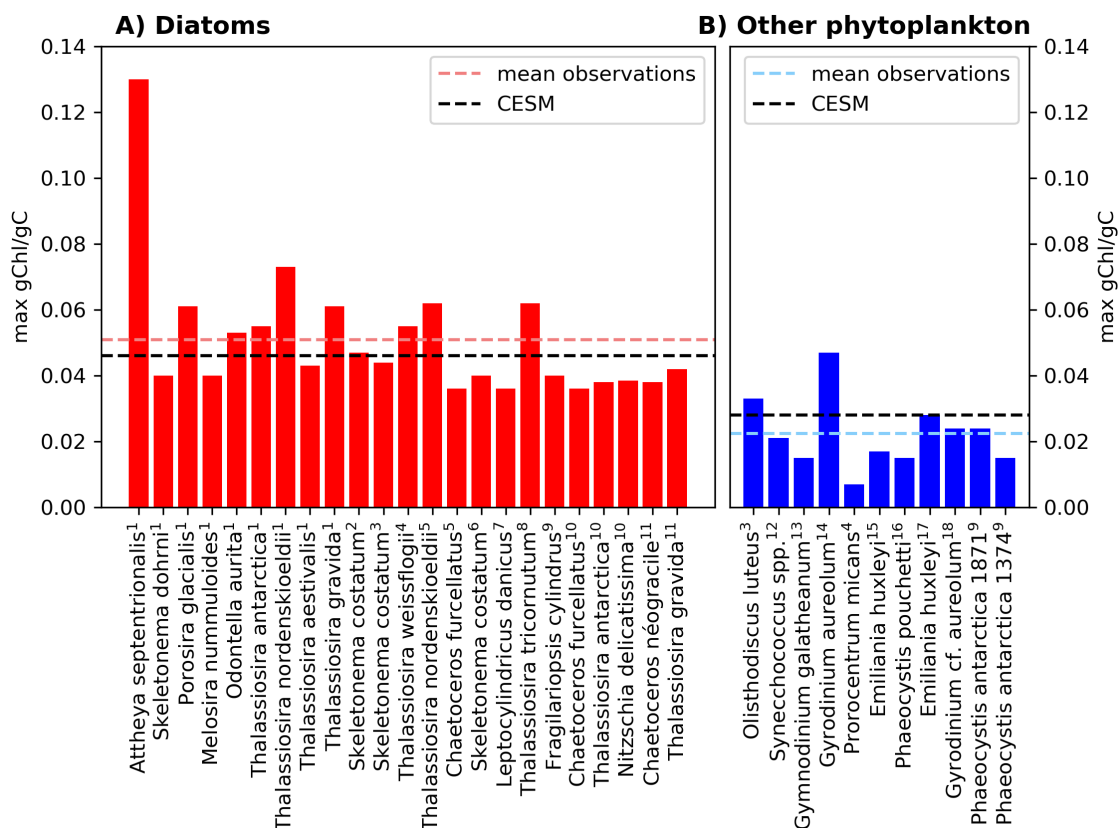


Figure S1. Maximum chlorophyll (Chl) to carbon ratios (g Chl (g C)^{-1}) for subpolar and polar marine phytoplankton collected from the literature, grouped as either diatoms (A) or other phytoplankton (B). All species were isolated from $>40^\circ$ latitude (from Northern or Southern hemispheres), except for *Synechococcus* spp., which was isolated from the Sargasso Sea. *Synechococcus* can be an important part of the subpolar Southern Ocean (Flombaum et al., 2013; Fourquez et al., 2020), so we opted to include it here. Means across all observed ratios are indicated by colored dashed lines and maximum Chl to C ratio, as parameterized in CESM are shown by black dashed lines (the small phytoplankton PFT value is shown for panel B). We used the maximum Chl to C ratio reported in each study. References for each species, indicated by superscripts, are as follows: ¹Lomas et al. (2019), ²Yoder (1979), ³Langdon (1987), ⁴Falkowski et al. (1985), ⁵Sakshaug et al. (1991), ⁶Verity (1982), ⁷MacIntyre et al. (2002), ⁸Arrigo et al. (2010), ⁹Hegseth (1989), ¹⁰Lacour et al. (2017), ¹¹Kana and Gilbert (1987), ¹²Nielsen (1996), ¹³Nielsen (1992), ¹⁴Muggli and Harrison (1997), ¹⁵Verity et al. (1991), ¹⁶Nielsen (1997), ¹⁷Garcia and Purdie (1992).

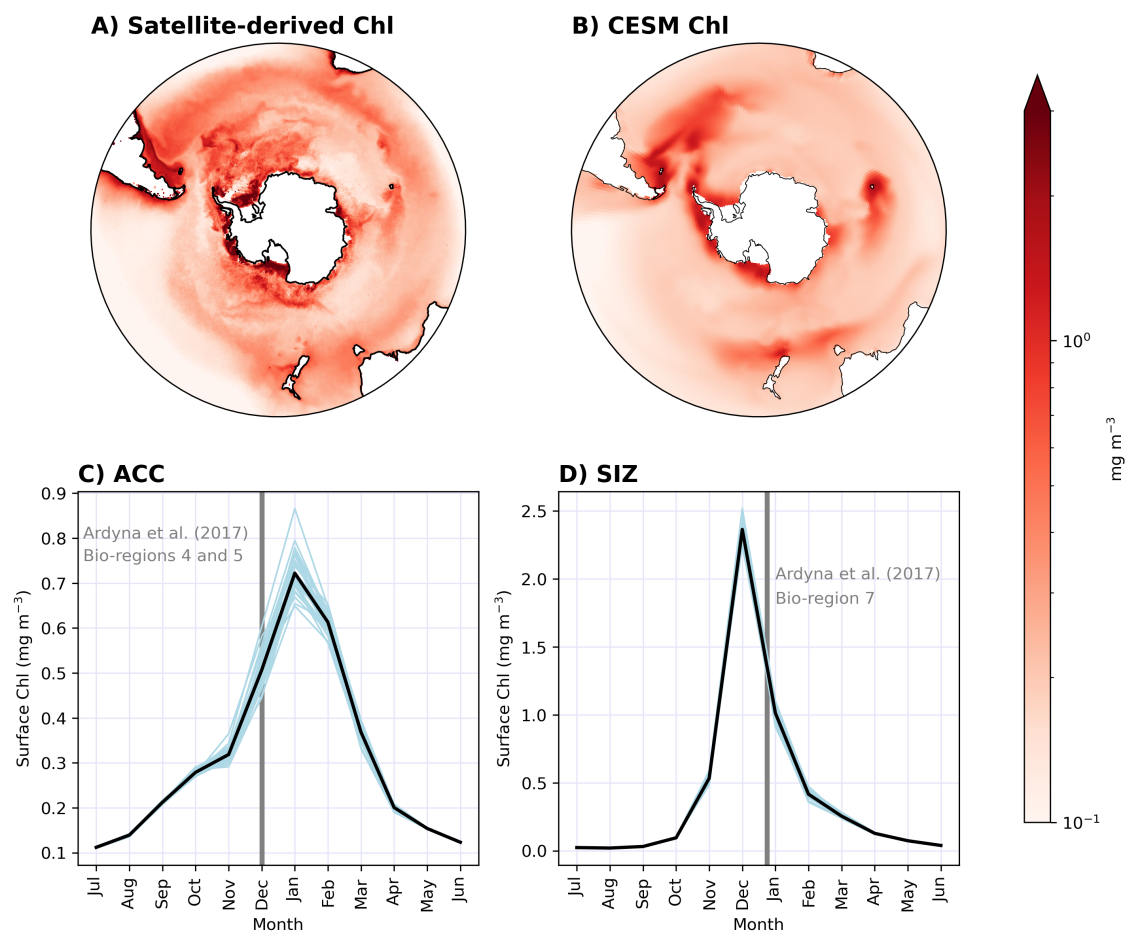


Figure S2. A spatial and phenological comparison between CESM1-LE surface chlorophyll (Chl) and satellite-derived Chl. Panel A shows a map of the mean GlobColour merged Chl product (Garnesson et al., 2019) over the period 1998 to 2005. Panel B shows the ensemble mean of the Chl in the top layer of the ocean model (top 10m) over the same period: 1998 to 2005. Panels B and C show the modeled climatology in surface Chl (mean over the 1998-2005 period) for the ACC and SIZ, respectively. Each ensemble member is shown in light blue with the ensemble mean in black. Gray lines show the bloom timing from Ardyna et al. (2017) for bio-regions that are closely aligned with the ACC and SIZ regions in this study; Bio-regions 4 and 5 were used for the ACC and bio-region 7 is shown for the SIZ.

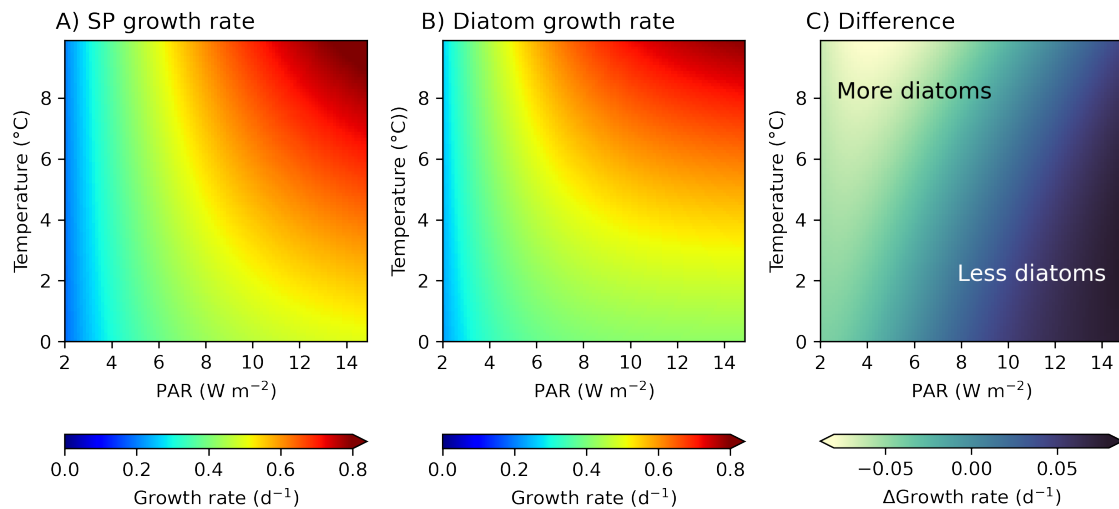


Figure S3. Resource competition plots. Panels A and B show growth rates for small phytoplankton (SP) and diatoms, respectively, under varying temperature and irradiance (as photosynthetically active radiation, PAR) levels. The “Difference” matrix shown in panel C is panel A minus panel B, where lighter areas indicate conditions in which diatoms have faster growth rates and darker areas show combinations where small phytoplankton would have faster growth rates.

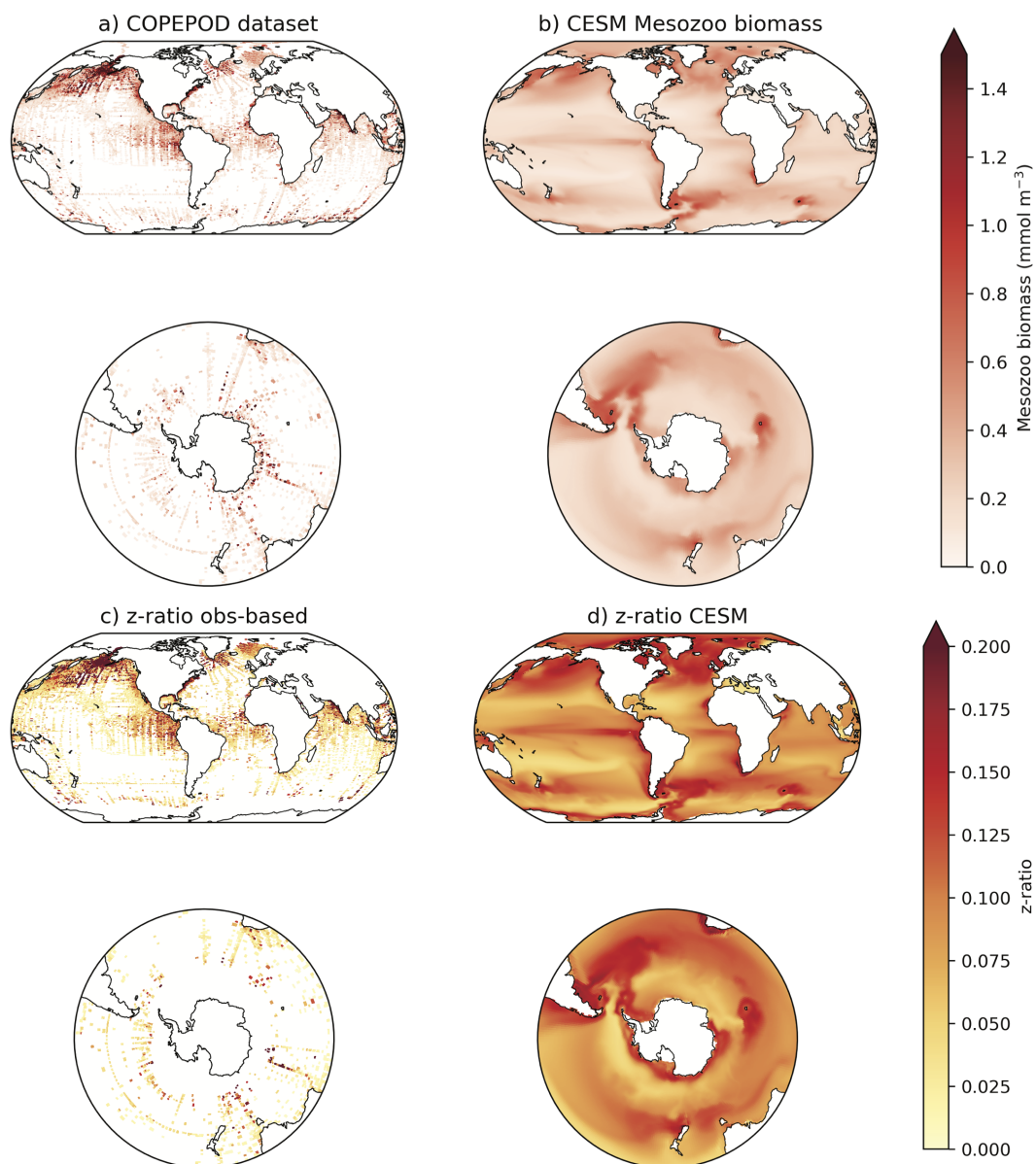


Figure S4. Model-observation comparisons for mesozooplankton biomass and the z-ratio. CESM1-LE ensemble mean mesozooplankton biomass (panel b) during the 1920s is compared to the COPEPOD dataset (panel a) (Moriarty and O'Brien, 2013). The CESM1-LE ensemble mean (1920s) z-ratio (mesozooplankton production/NPP) is compared to the observational based z-ratio, which is calculated as in Stock and Dunne (2010). We include both global and South Pole stereographic maps for the comparisons.

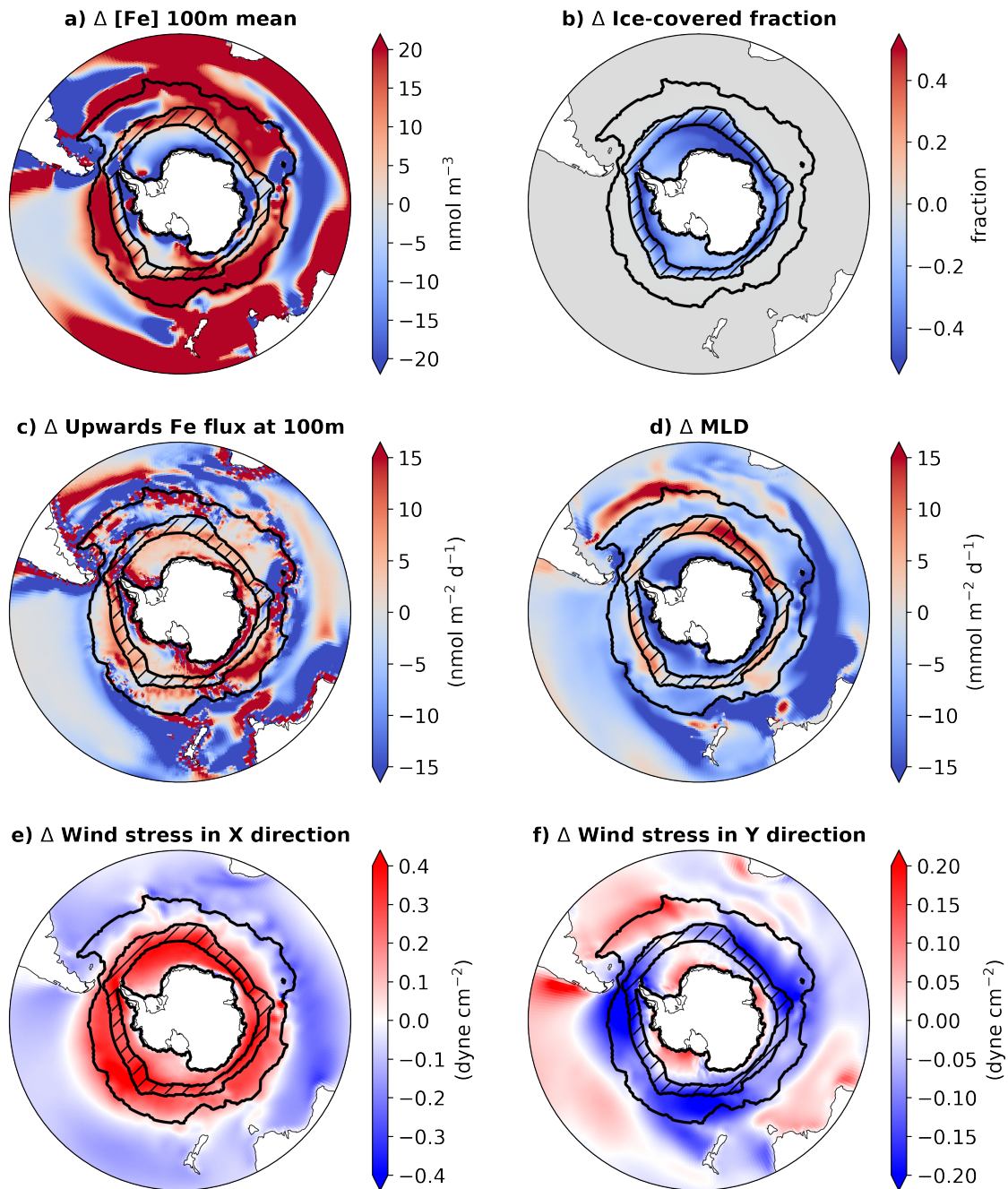


Figure S5. CESM1-LE ensemble mean change maps from the 1920s to the 2090s (2090s minus 1920s) showing the climate change-forced changes to the top 100m mean iron concentration ($[\text{Fe}]$; panel a), sea ice coverage fraction (panel b), upwards Fe flux (panel c; does not include horizontal advection which is included on Figure 1b in the main text), mixed layer depth (MLD; panel d), wind stress in X direction (panel e), and wind stress in the Y direction (panel f). ACC and SIZ regions are shown black contours, with the marginal SIZ hatched.

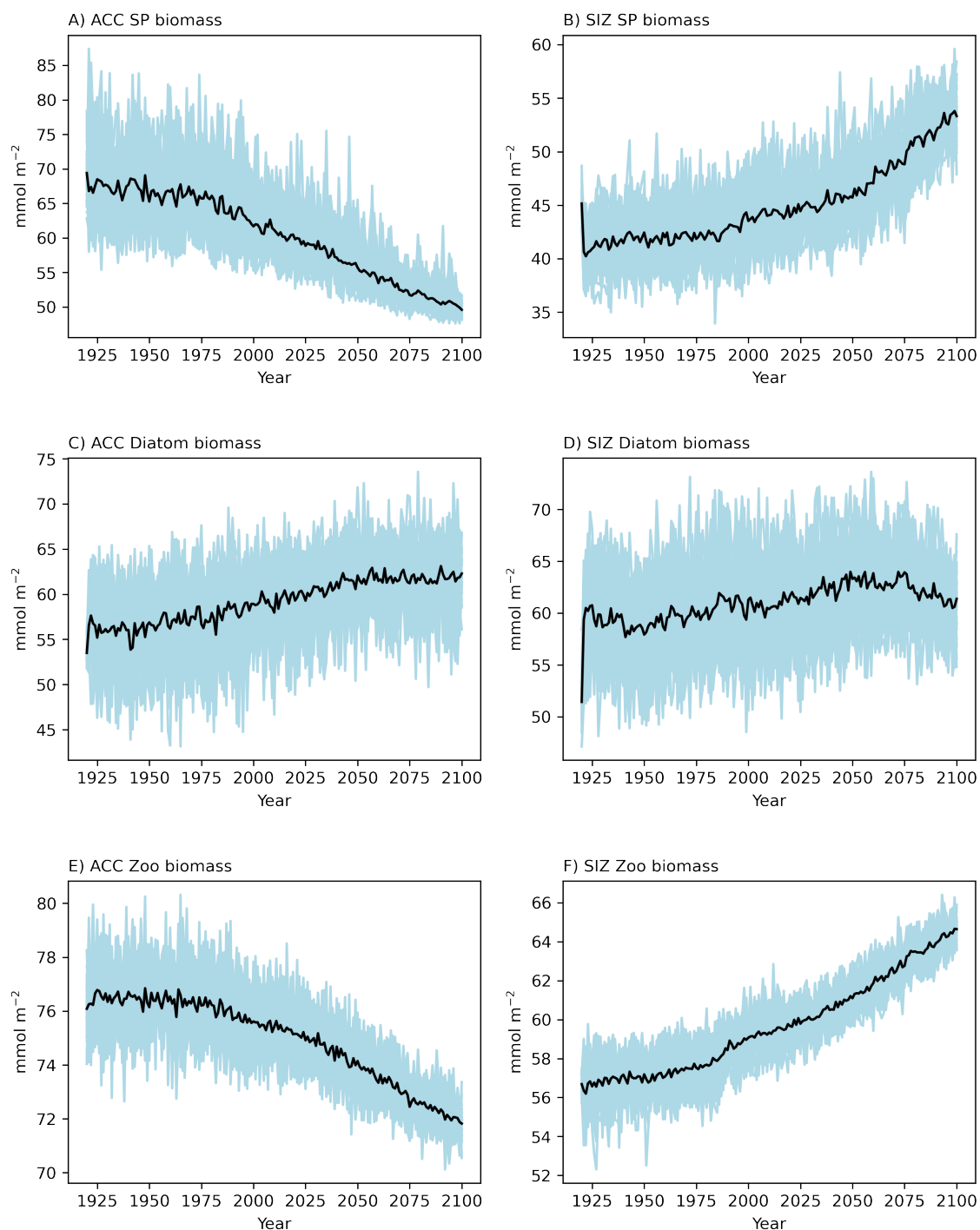


Figure S6. Time-series of plankton biomass fields from the CESM1-LE for the ACC (left panels) and SIZ (right panels). Panels A and B show small phytoplankton (SP) biomass; panels C and D show Diatom biomass; and panels E and F show total zooplankton (zoo) biomass. Individual ensemble members are shown in light blue lines and the ensemble mean is shown in black.

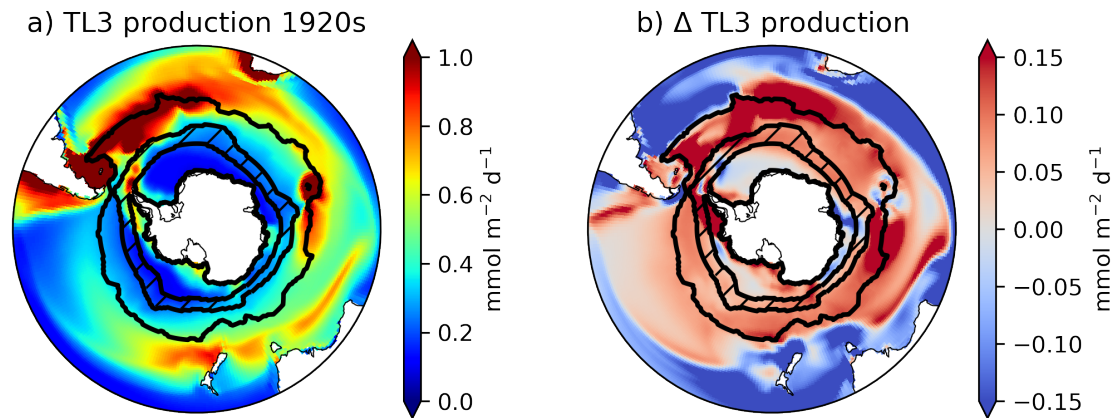


Figure S7. Southern Ocean trophic level 3 production (TL3) in the 1920s (panel a) and the change in TL3 production from the 1920s to the 2090s (panel b), where red areas indicate increases in TL3 production and blue areas indicate decreases.

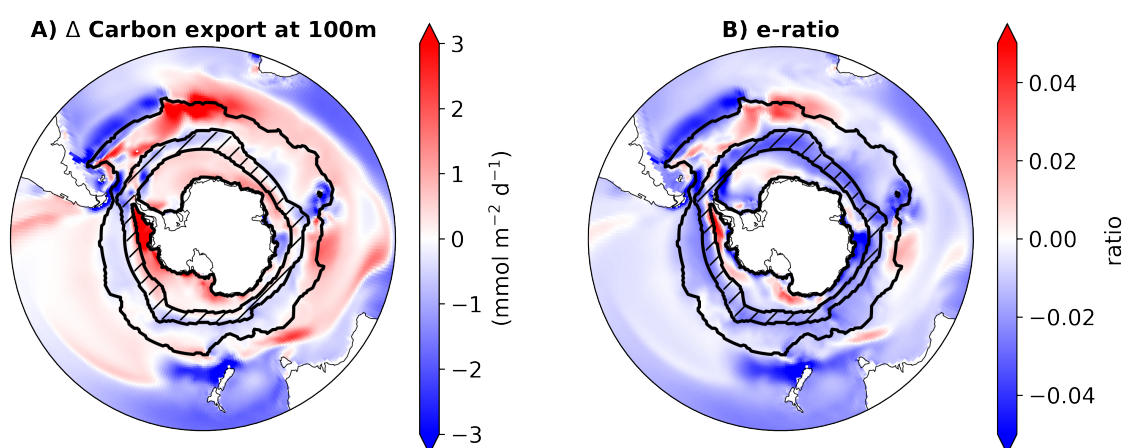


Figure S8. CEMS1-LE ensemble mean change maps from the 1920s to the 2090s (2090s minus 1920s) showing the climate change-forced changes to particulate organic carbon (POC) export at 100m (panel A) and the export ratio (POC export at 100m/NPP; e-ratio; panel B). ACC and SIZ regions are shown black contours, with the marginal SIZ hatched.

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