

Supplementary Material

North Atlantic Basin	Annual Mean	Winter Mean	Spring Mean	Summer Mean	Winter Mean
a) MPI-GE RCP 4.5	-0.33 ± 0.02	-0.17 ± 0.01	-0.20 ± 0.01	0.03 ± 0.01	0.02 ± 0.01
b) MPI-GE RCP 8.5	-0.34 ± 0.02	-0.18 ± 0.01	-0.21 ± 0.01	0.03 ± 0.01	0.02 ± 0.01
c) (a-b)	0.01	0.01	0.01	0	0
d) Obs-based Ensemble	-0.38 ± 0.08	-0.14 ± 0.03	-0.14 ± 0.03	-0.04 ± 0.01	-0.06 ± 0.01

Supplementary Table 1: Sensitivity to the choice of RCP in the North Atlantic. Comparison of integrated air-sea carbon fluxes (Pg C year^{-1}) for the North Atlantic basin ($10\text{-}90^\circ\text{W}$, $15\text{-}65^\circ\text{N}$) over 2006-2020 for the MPI-ESM GE for RCP 4.5 (a, $n=100$), and RCP 8.5 (b, $n=89$) where net carbon uptake values are in blue, and net outgassing values are in red. The absolute difference between RCP 4.5 and 8.5 (c) and the observation-based ensemble (d) values are also provided. The MPI-ESM GE data was accessed from <https://esgf-data.dkrz.de/projects/mpi-ge/>.

Southern Ocean	Annual Mean	Summer Mean	Autumn Mean	Winter Mean	Spring Mean
a) MPI-GE RCP 4.5	-1.20 ± 0.05	-0.94 ± 0.07	0.21 ± 0.03	0.43 ± 0.05	-0.89 ± 0.05
b) MPI-GE RCP 8.5	-1.22 ± 0.06	-0.94 ± 0.06	0.21 ± 0.02	0.42 ± 0.06	-0.91 ± 0.04
c) (a-b)	0.02 ± 0.01	0 ± 0.01	0 ± 0.01	0.01 ± 0.01	0.02 ± 0.01
d) Obs-based Ensemble	-1.11 ± 0.10	-0.33 ± 0.05	-0.28 ± 0.03	-0.23 ± 0.02	-0.27 ± 0.04

Supplementary Table 2: Sensitivity to the choice of RCP in the Southern Ocean. Comparison of integrated air-sea carbon fluxes (Pg C year^{-1}) for the Southern Ocean ($0\text{-}360^\circ$, $35\text{-}65^\circ\text{S}$) over 2006-2020 for the MPI-ESM GE for RCP 4.5 (a, $n=100$), and RCP 8.5 (b, $n=89$) where net carbon uptake values are in blue, and net outgassing values are in red. The absolute difference between RCP 4.5 and 8.5 (c) and the observation-based ensemble (d) values are also provided. The MPI-ESM GE data was accessed from <https://esgf-data.dkrz.de/projects/mpi-ge/>.

North Atlantic Obs-based Ensemble	Annual Mean	Summer Mean	Autumn Mean	Winter Mean	Spring Mean
a) Historical Period (1990-2005)	-0.29 ± 0.10	-0.11 ± 0.04	-0.11 ± 0.04	-0.03 ± 0.01	-0.04 ± 0.02
b) RCP 4.5 Period (2006-2020)	-0.38 ± 0.08	-0.14 ± 0.03	-0.14 ± 0.03	-0.04 ± 0.01	-0.06 ± 0.01
c) b-a	-0.09	-0.03	-0.03	-0.01	-0.02

Supplementary Table 3: Contrasting historical period and RCP4.5 for the North Atlantic in observations. Integrated air-sea carbon fluxes (Pg C year⁻¹) in the North Atlantic basin (10-90 °W, 15-65 °N) over the historical period (a, 1990-2005) and RCP 4.5 period (b, 2006-2020) for the observation-based ensemble with the difference over the two periods (c, b-a). Net carbon uptake values are in blue, and net outgassing values are in red.

North Atlantic MPI-GE Ensemble	Annual Mean	Summer Mean	Autumn Mean	Winter Mean	Spring Mean
a) Historical Period (1990-2005)	-0.29 ± 0.02	-0.15 ± 0.07	-0.18 ± 0.01	0.02 ± 0.0	0.02 ± 0.01
b) RCP 4.5 Period (2006-2020)	-0.33 ± 0.02	-0.17 ± 0.01	-0.20 ± 0.01	0.03 ± 0.01	0.02 ± 0.01
c) b-a	-0.04	-0.02	-0.02	0.01	0

Supplementary Table 4: Contrasting historical period and RCP4.5 for the North Atlantic in MPI-GE Ensemble. Integrated air-sea carbon fluxes (Pg C year⁻¹) in the North Atlantic basin (10-90 °W, 15-65 °N) over the historical period (a, 1990-2005) and RCP 4.5 period (b, 2006-2020) for the MPI-GE with the difference over the two periods (c, b-a). Net carbon uptake values are in blue, and net outgassing values are in red.

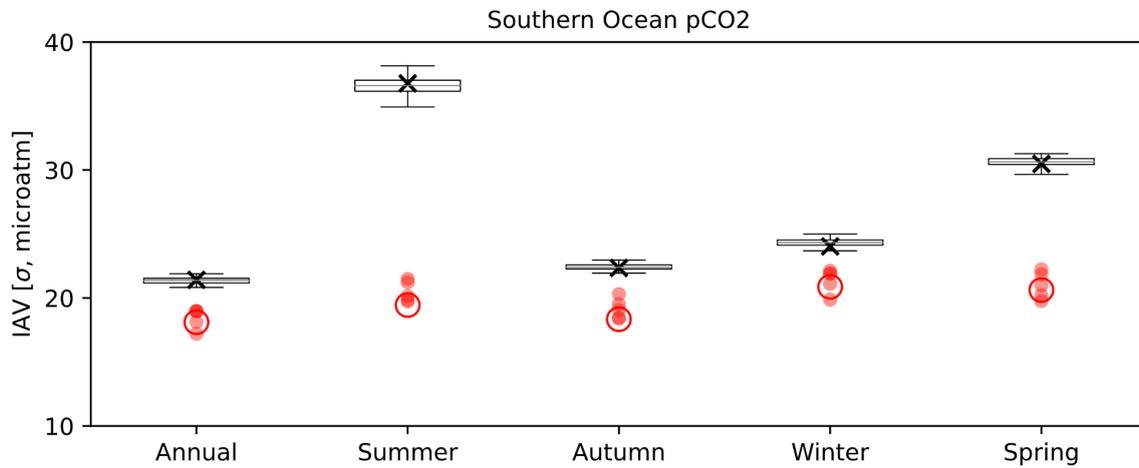
Southern Ocean Obs-based Ensemble	Annual Mean	Summer Mean	Autumn Mean	Winter Mean	Spring Mean
a) Historical Period (1990-2005)	-0.79 ± 0.18	-0.25 ± 0.06	-0.20 ± 0.03	-0.16 ± 0.04	-0.18 ± 0.06
b) RCP 4.5 Period (2006-2020)	-1.11 ± 0.10	-0.33 ± 0.05	-0.28 ± 0.03	-0.23 ± 0.02	-0.27 ± 0.04
c) b-a	-0.32	-0.07	-0.08	-0.07	-0.09

Supplementary Table 5: Contrasting historical period and RCP4.5 for the Southern Ocean in observations. Integrated air-sea carbon fluxes (Pg C year^{-1}) in the Southern Ocean ($0-360^\circ$, $35-65^\circ\text{S}$) over the historical period (a, 1990-2005) and RCP 4.5 period (b, 2006-2020) for the observation-based ensemble with the difference over the two periods (c, b-a). Net carbon uptake values are in blue, and net outgassing values are in red.

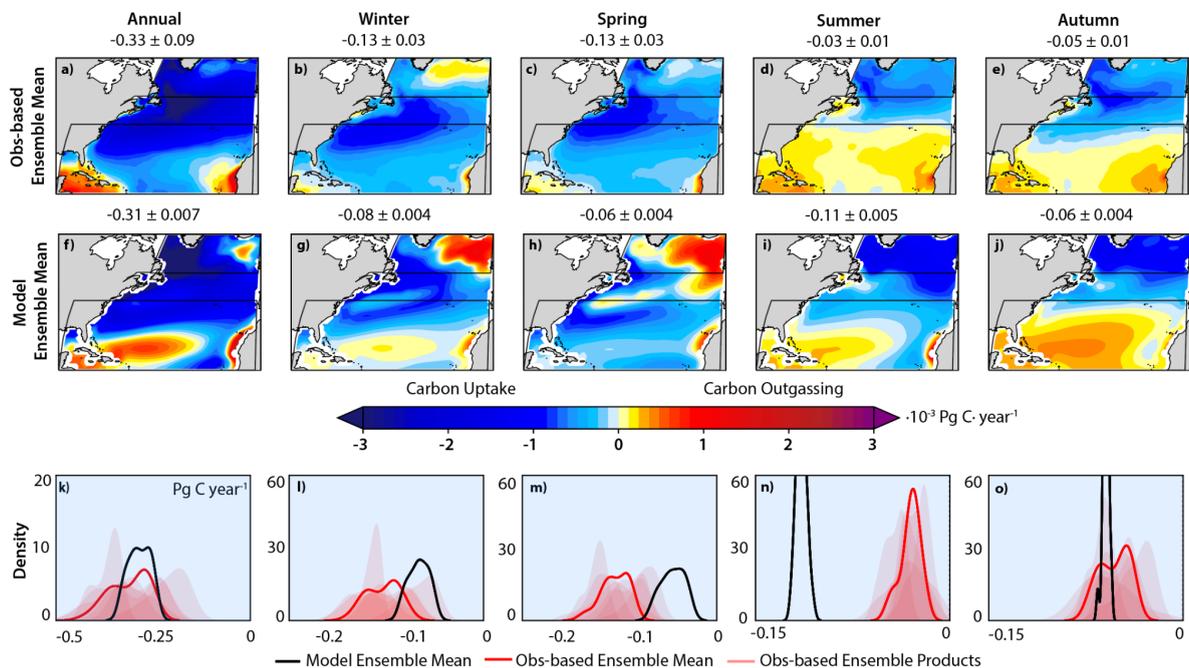
Southern Ocean MPI-GE Ensemble	Annual Mean	Summer Mean	Autumn Mean	Winter Mean	Spring Mean
a) Historical Period (1990-2005)	-1.01 ± 0.06	-0.87 ± 0.07	0.19 ± 0.02	0.44 ± 0.05	-0.76 ± 0.06
b) RCP 4.5 Period (2006-2020)	-1.20 ± 0.05	-0.94 ± 0.07	0.21 ± 0.03	0.43 ± 0.05	-0.89 ± 0.03
c) b-a	-0.19	-0.07	0.02	-0.01	-0.13

Supplementary Table 6: Contrasting historical period and RCP4.5 for the Southern Ocean in MPI-GE Ensemble. Integrated air-sea carbon fluxes (Pg C year^{-1}) in the Southern Ocean ($0-360^\circ$, $35-65^\circ\text{S}$) over the historical period (a, 1990-2005) and RCP 4.5 period (b, 2006-2020) for the MPI-GE with the difference over the two periods (c, b-a). Net carbon uptake values are in blue, and net outgassing values are in red.

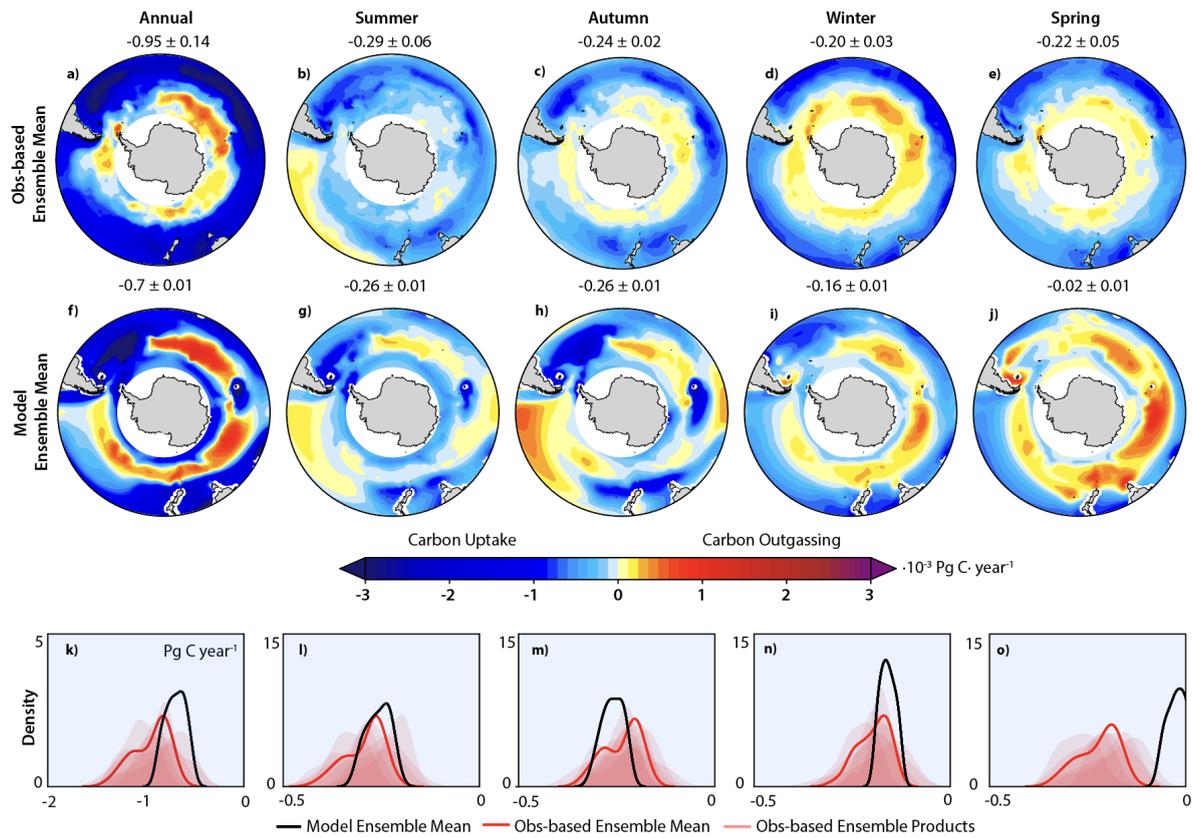
Supplementary Figures



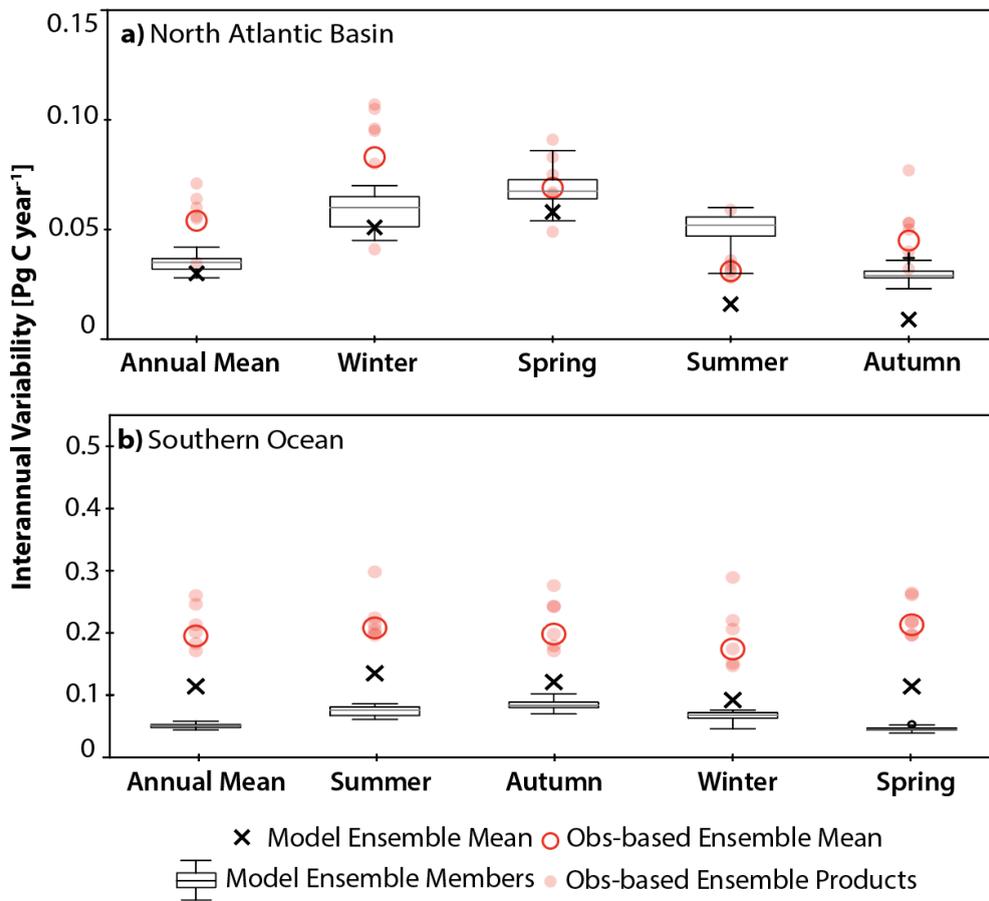
Supplementary Figure 1: Interannual variability of pCO₂ (micro atm) in the Southern Ocean. Partial pressure of carbon dioxide in the ocean for the observation-based products (red dots) overlaid on a box plot of variability in the model members for the Southern Ocean. The centre line, edges and whiskers of the box are the median, upper and lower quartiles, and the range of values in the model ensemble space. The black crosses represent the variability of the model ensemble mean, and the large red circle is the IAV of the observation-based ensemble mean. Note: the obs-based ensemble mean does not include the JMA-MLR product since pCO₂ data was unavailable for the study period.



Supplementary Figure 2: Air-sea carbon fluxes in the North Atlantic basin (10-90 °W, 15-65 °N) for the CESM-LE model mean. Annual (a, f) and seasonal (Pg C·year⁻¹) carbon fluxes averaged over 1990-2020 in the observation-based (b-e) and model (g-j) ensemble mean with corresponding probability density plots in the observation-based (red) and model-based (black) (k-o). The red shadings represent the probability density plots of the individual data products in the observation-based ensemble. Background colours indicate uptake (blue).



Supplementary Figure 3: Air-sea carbon fluxes in the Southern Ocean (0-360 °, 35-65 °S) for the CESM-LE model mean. Annual (a, f) and seasonal (Pg C·year⁻¹) carbon fluxes averaged over 1990-2020 in the observation-based (b-e) and model (g-j) ensemble mean with corresponding probability density plots in the observation-based (red) and model (black) ensembles (k-o). The red shadings represent the probability density plots of the individual data products in the observation-based ensemble. Background colours indicate uptake (blue).



Supplementary Figure 4: Interannual variability of air-sea carbon fluxes for the CESM-LE model. Interannual variability [IAV, Pg C·year⁻¹] of annual and seasonal carbon fluxes in observation-based products (red dots) overlaid on a box plot of variability in the model members for a) the North Atlantic basin and b) the Southern Ocean. The centre line, edges and whiskers of the box are the median, upper and lower quartiles, and the range of values in the model ensemble space. The black crosses represent the variability of the model ensemble mean, and the large red circle is the IAV of the observation-based ensemble mean.