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Supplementary Materials for

Future climate response to Antarctic Ice Sheet melt caused by anthropogenic warming

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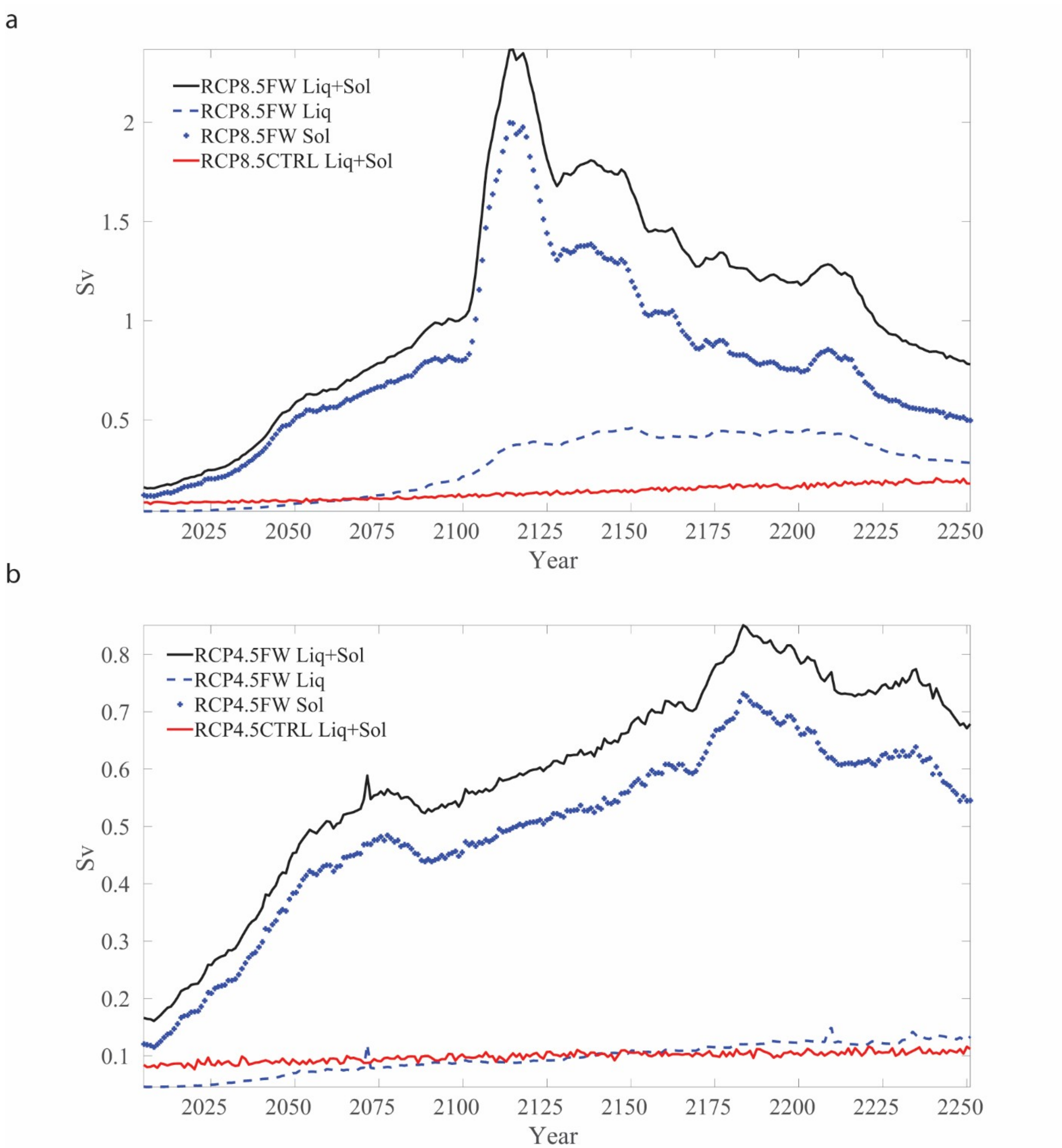

Fig. S1. Freshwater forcing quantities. (**A**) The forcing used in RCP8.5FW is shown with liquid and solid components separate, as well as combined, alongside the forcing computed by CESM in RCP8.5CTRL. (**B**) The same is (A), but for RCP4.5.

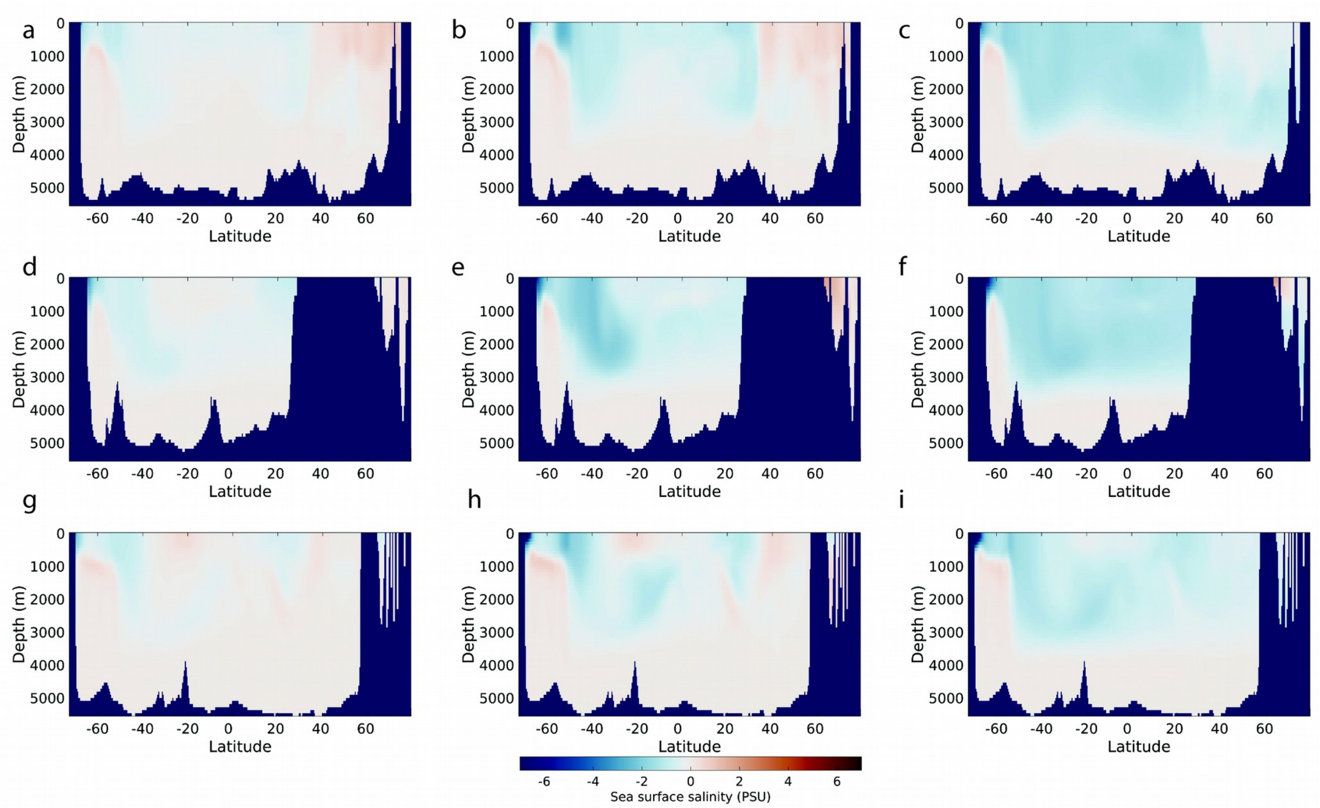

Fig. S2. Salinity distribution at depth in RCP8.5FW. (**A** to **C**) Salinity difference (RCP8.5FW minus RCP8.5CTRL) at depth, at longitude 342 in the Atlantic basin and decadally averaged for the time periods 2091-2100 (**A**), 2121-2130 (**B**), and 2191-2200 (**D**). (**D** to **F)**, The same but for the Indian Ocean at longitude 72. (**G** to **I**) The same for the Pacific Ocean at longitude 213.

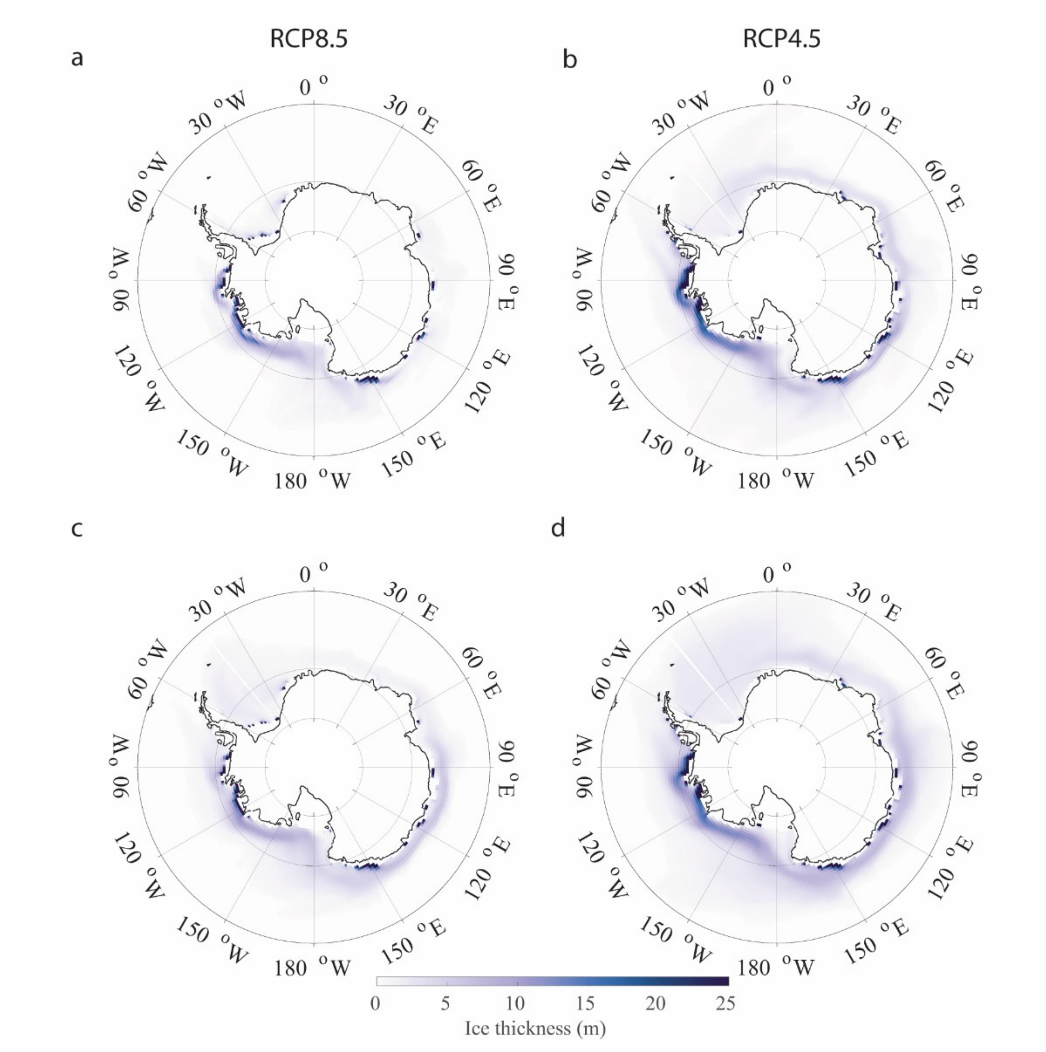

Fig. S3. Southern Ocean sea ice in the 2190s. (**A**) Southern Ocean sea ice in RCP8.5FW at the end of the 21st century decadally averaged from 2191-2200 for February. Grid cells where ice area is <10% and ice thickness is <0.005 m have been removed. (**B**) The same period is shown for RCP4.5FW. Note the more extensive sea ice development for this time period compared to RCP8.5FW. (**C**) RCP8.5FW in September for the same time span as (A) and (B). (**D**) RCP4.5FW in September for the same time span as (A to C). RCP8.5CTRL RCP4.5CTRL are not included as there is virtually no ice in those runs for this time period (Fig. 2a).

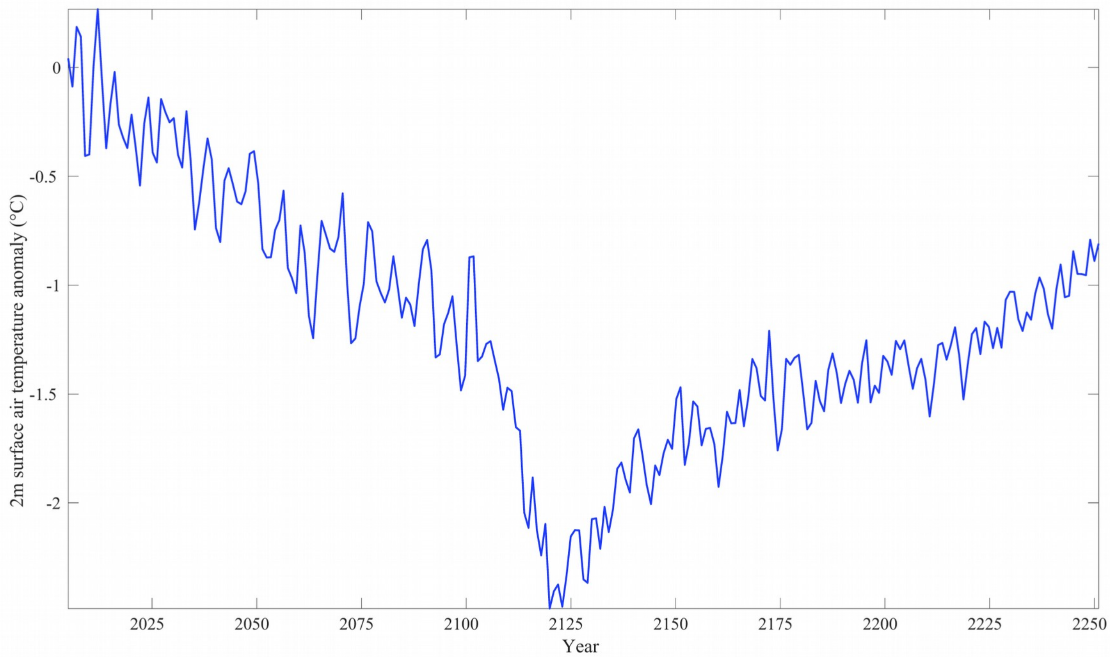

Fig. S4. Globally averaged 2 meter air temperature anomaly. The difference in 2 m air temperature between RCP8.5FW and RCP8.5CTRL is maximized during peak Antarctic ice loss, peaking at around 2.5°C between years 2120-2125. The AIS discharge perturbation delays the warming, but once the AIS is exhausted of ice the temperatures between the two runs begin to converge.

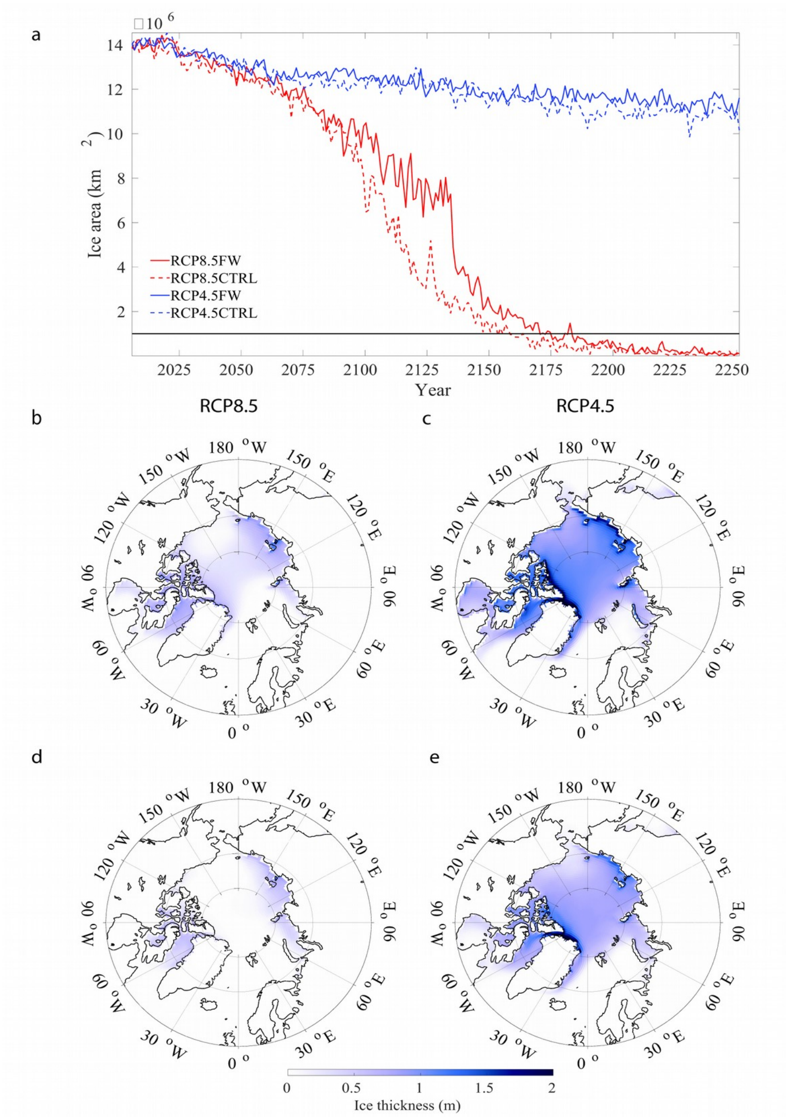

Fig. S5. Winter Arctic sea ice. (**A**) Arctic ice loss is delayed during the 21st century in RCP8.5FW due to delayed surface air temperature increases as a result of the AIS discharge forcing. The black line represents ice free conditions defined as 1 million square kilometers. (**B**) RCP8.5FW, (**C**) RCP4.5FW, (**D**) RCP8.5CTRL, (**E**) RCP4.5CTRL show sea ice thickness for February, decadally averaged from 2121-2130. Grid cells where ice area is less then 10% and ice thickness is less then 0.005 m have been removed.

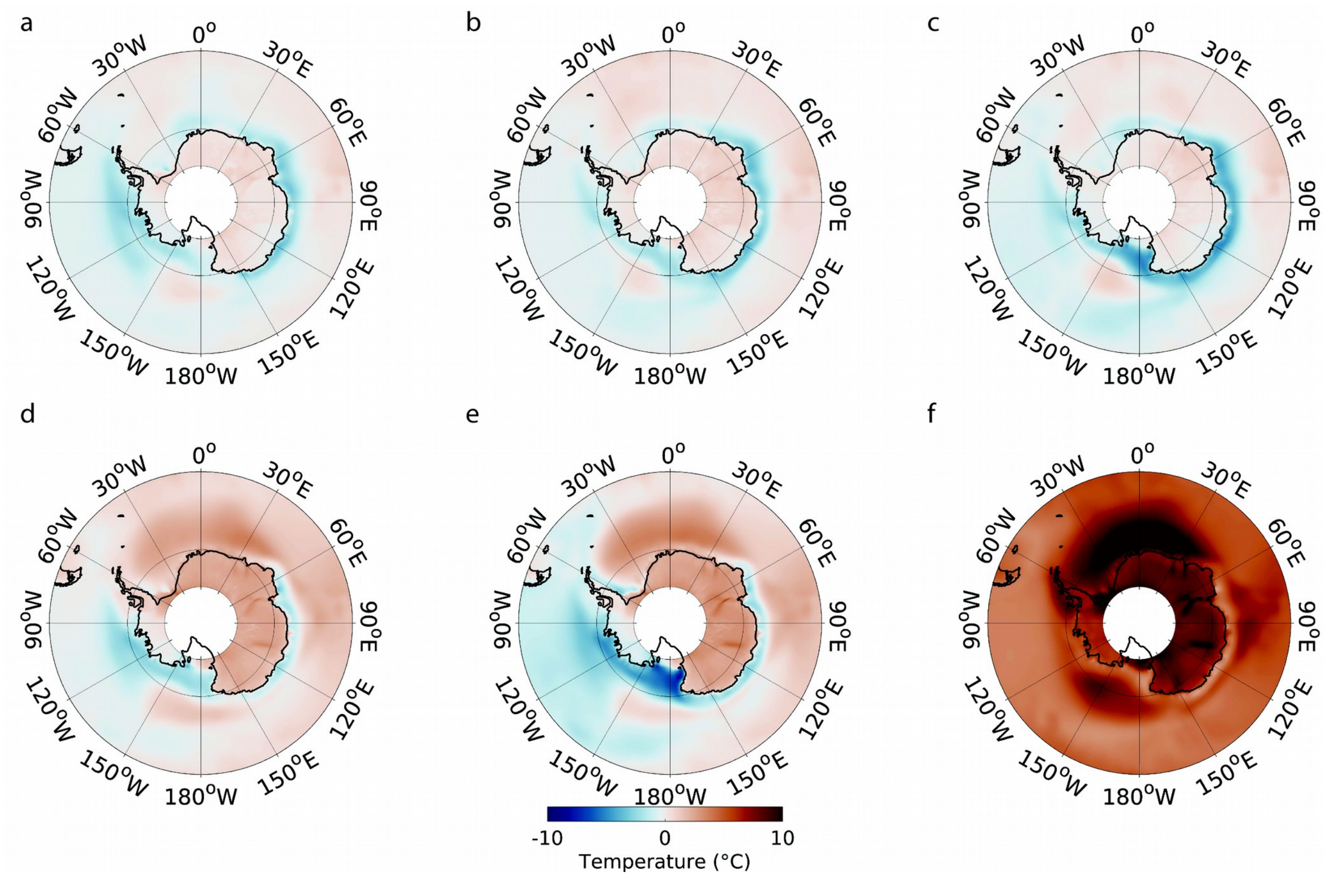

Fig. S6. Southern Ocean 2m air temperature evolution. (**A**) Surface air temperature for RCP4.5FW averaged from 2091-2100 minus the 2005-2014 average. The same is shown for (**B**) 2121-2130 and (**C**) 2191-2200. The expansion of sea ice where the freshwater perturbation was applied has lower SAT values than at the start of the run, due to the sustained freshwater forcing in this experiment. (**D** to **F**) The same time periods for RCP8.5FW shows that this effect is sustained only through the peak AIS discharge period; after that temperatures rise rapidly due to anthropogenic greenhouse gas forcing.

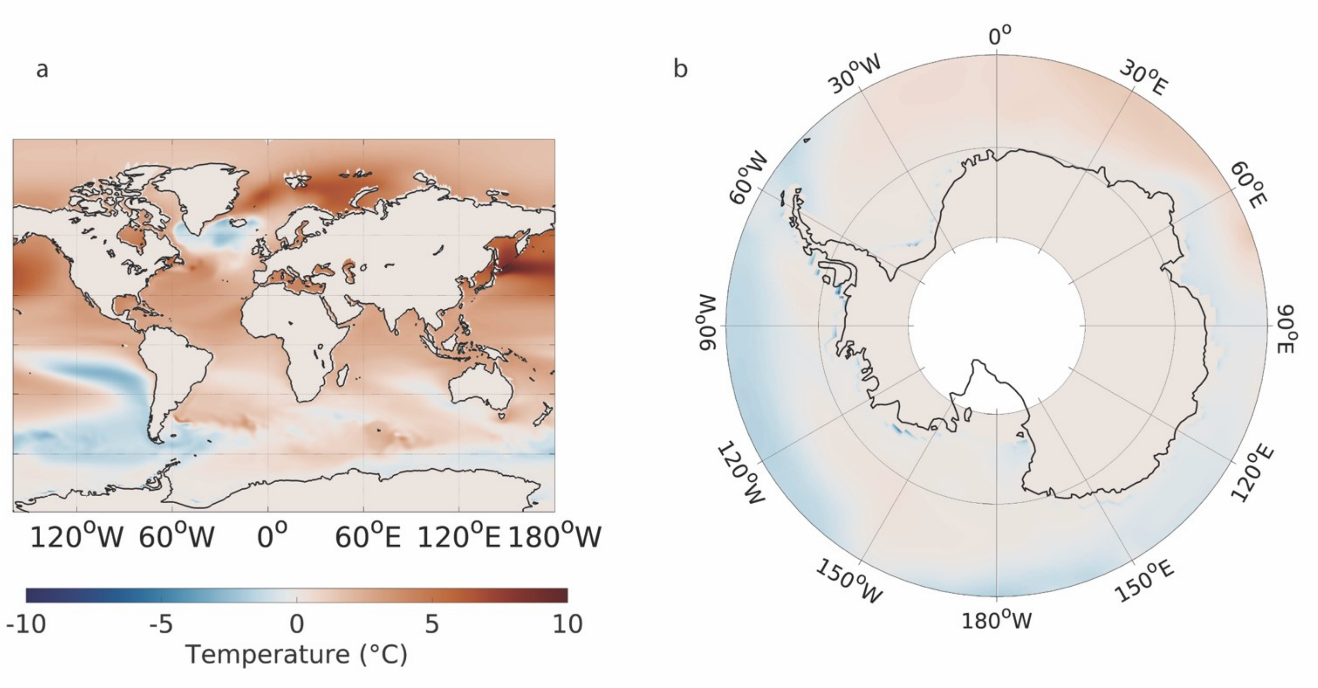

Fig. S7. Sea surface temperature (SST) evolution. (**A**) The SST values for RCP8.5FW decadally averaged from 2121-2130, compared to the decadal averages from 2005-2014 (first decade of the run) show that during peak AIS discharge the SST values in the Southern Ocean are lower than at the start of the simulation. (**B**) The same data shown in a polar stereographic projection.

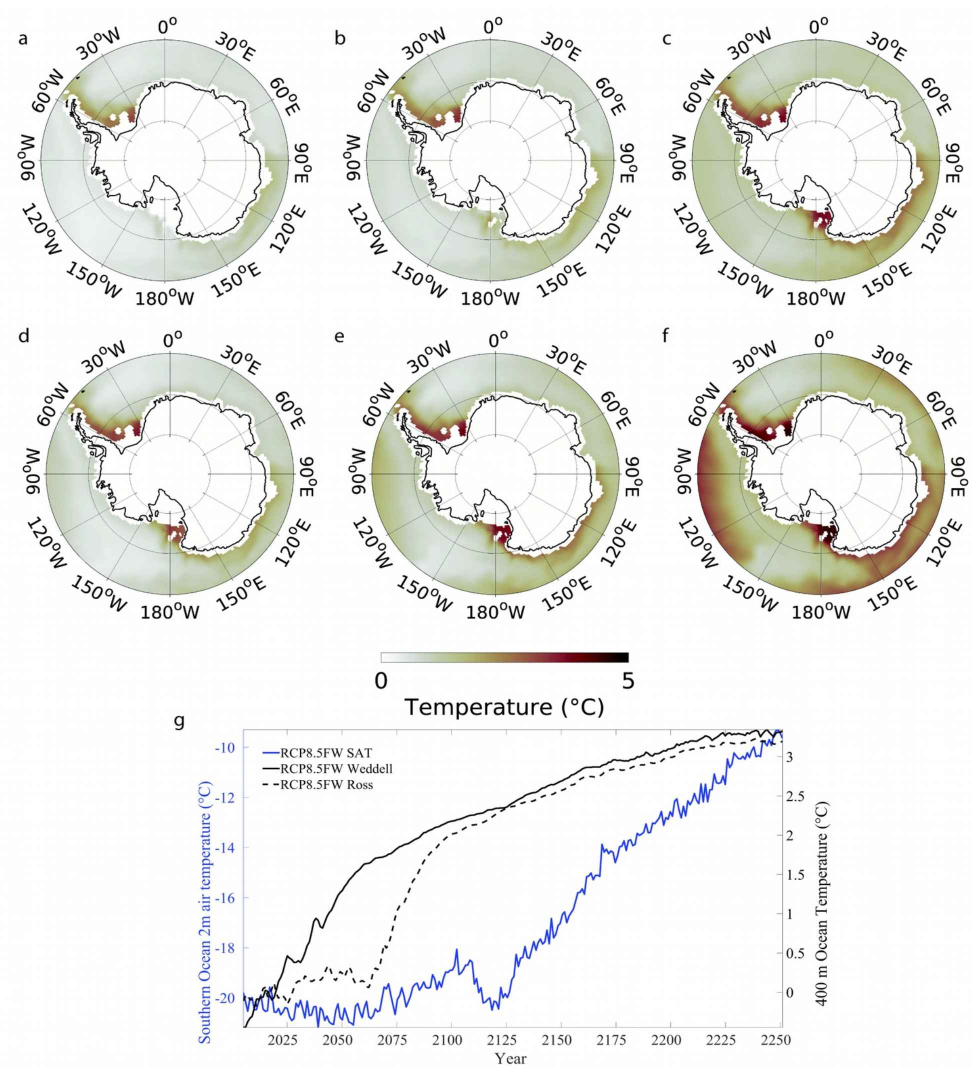

Fig. S8. Ocean temperature evolution at 400 m in FW simulations. (**A**) 400 m water temperature in RCP4.5FW with the 2005-2014 (first decade of the integration) average subtracted from the 2091-2100 average. (**B**) RCP4.5FW 2005-2014 average subtracted from the 2121-2130 average. (**C**) RCP4.5FW 2005-2014 average subtracted from the 2191-2200 average. (**D** to **F**) The same time periods as above but for RCP8.5FW. (**G**) The temperature evolution in the Ross and Weddell Seas at 400 m as compared to the surface air temperature over the Southern Ocean in RCP8.5FW.

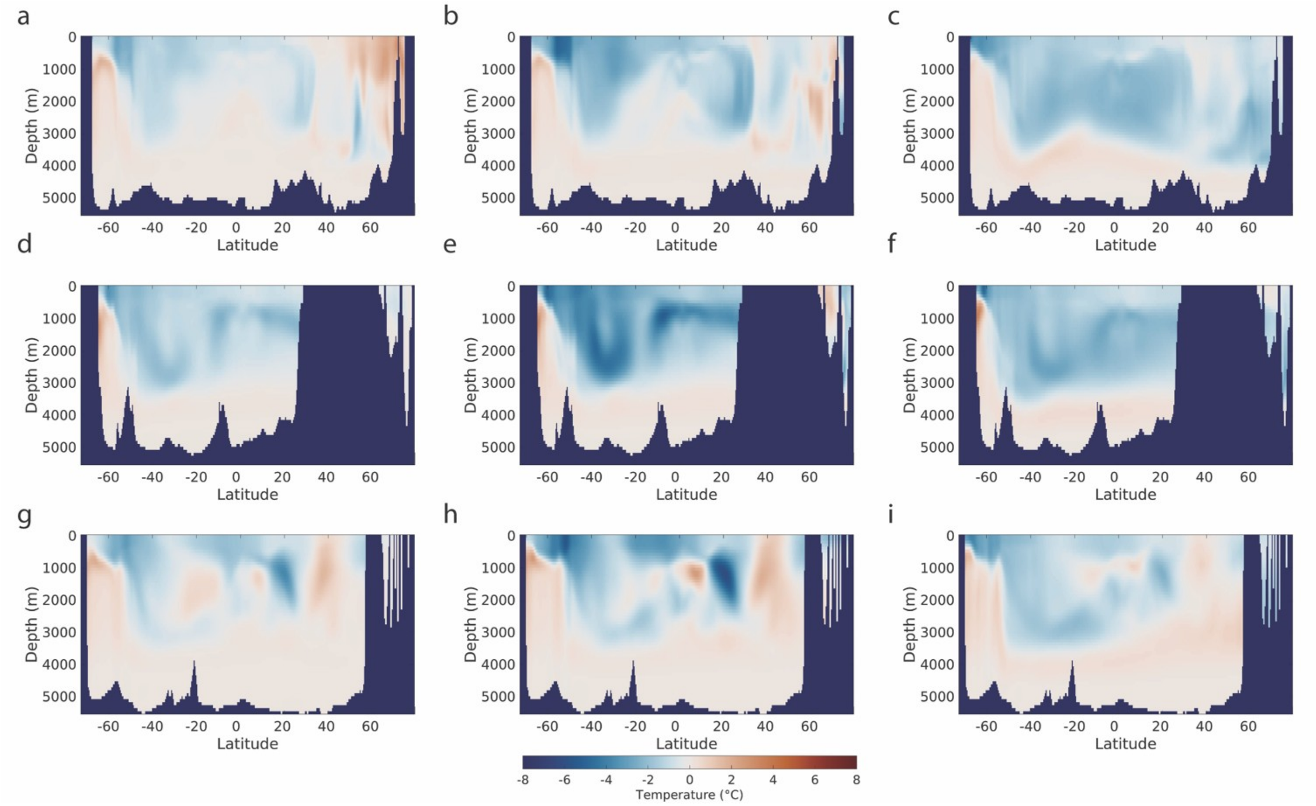

Fig. S9. Temperature anomaly at depth. (**A** to **C**) The temperature difference between RCP8.5FW and RCP8.5CTRL at depth for the Atlantic, decadally averaged for the time periods 2091-2100 (a), 2121-2130 (b), and 2191-2200 (c). (**D** to **F**) The same as (A to C) but for the Indian Ocean. (**G** to **I**) The same as (A to C) but for the Pacific Ocean. The cooler sub-surface ocean temperatures relative to the simulation without freshwater forcing from AIS discharge forcing are pervasive throughout much of the water column above 4000 m depth. Warmer relative temperatures in the perturbation run are evident at depths below 400 m in the Southern Ocean.

Table S1

	RCP8.5FW	RCP8.5CTRL	RCP4.5FW	RCP4.5CTRL
2006				
GMST (C)	14.0539	14.0120	14.1929	14.1226
GMST increase over 1979-2000 (C)	0.3950	0.3531	0.5340	0.4637
Southern Ocean air temperature	-19.7941	-19.7299	-19.7903	-19.8114
AMOC (Sv)	24.9189	24.2989	24.3412	24.3237
Southern Ocean ice area ($10^6 km$)	3.1276	3.2739	2.8595	2.4876
2050				
GMST	15.4120	15.7964	14.4843	15.3484
GMST increase over 1979-2000	1.7531	2.1375	0.8253	1.6895
Southern Ocean air temperature	-20.7809	-18.0770	-21.0767	-18.3307
AMOC	19.4244	20.6395	21.6083	20.9936
Southern Ocean ice area	5.4382	1.8630	5.4666	1.9562
2100				
GMST	17.0289	18.4440	15.4751	16.1700
GMST increase over 1979-2000	3.3700	4.7851	1.8161	2.5110
Southern Ocean air temperature	-18.8967	-14.1521	-19.7687	-17.5023
AMOC	15.2980	12.1330	19.9960	17.7662
Southern Ocean ice area	4.2109	0.0837	5.0735	1.3677
2200				
GMST	21.2402	22.5913	15.7283	16.9301
GMST increase over 1979-2000	7.5813	8.9324	2.0693	3.2712
Southern Ocean air temperature	-12.5720	-7.9139	-20.4821	-16.4034
AMOC	8.3380	9.4018	19.6999	21.2097
Southern Ocean ice area	1.3659	0.0000	5.7304	0.4388
2250				
GMST	22.8242	23.6334	15.8442	17.3196
GMST increase over 1979-2000	9.1653	9.9745	2.1852	3.6607
SO Temp	-9.4375	-6.3080	-19.4973	-15.6418
AMOC	7.7511	7.9471	19.2572	21.4680
Southern Ocean ice area	0.4567	0.0000	4.2865	0.4293

Table. S1. Select model values. Tabulated model quantities include globally averaged 2 m surface air temperatures, 2 m surface air temperature rise averaged over 1979-2000, relative to (13.66°C) from the CESM pre-industrial simulation. 2 m air temperature averaged over the Southern Ocean, maximum AMOC strength in the North Atlantic, and the area of the Southern Ocean covered by sea ice.