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Supplement of

Impact of Southern Ocean surface conditions on deep ocean circulation during the LGM: a model analysis

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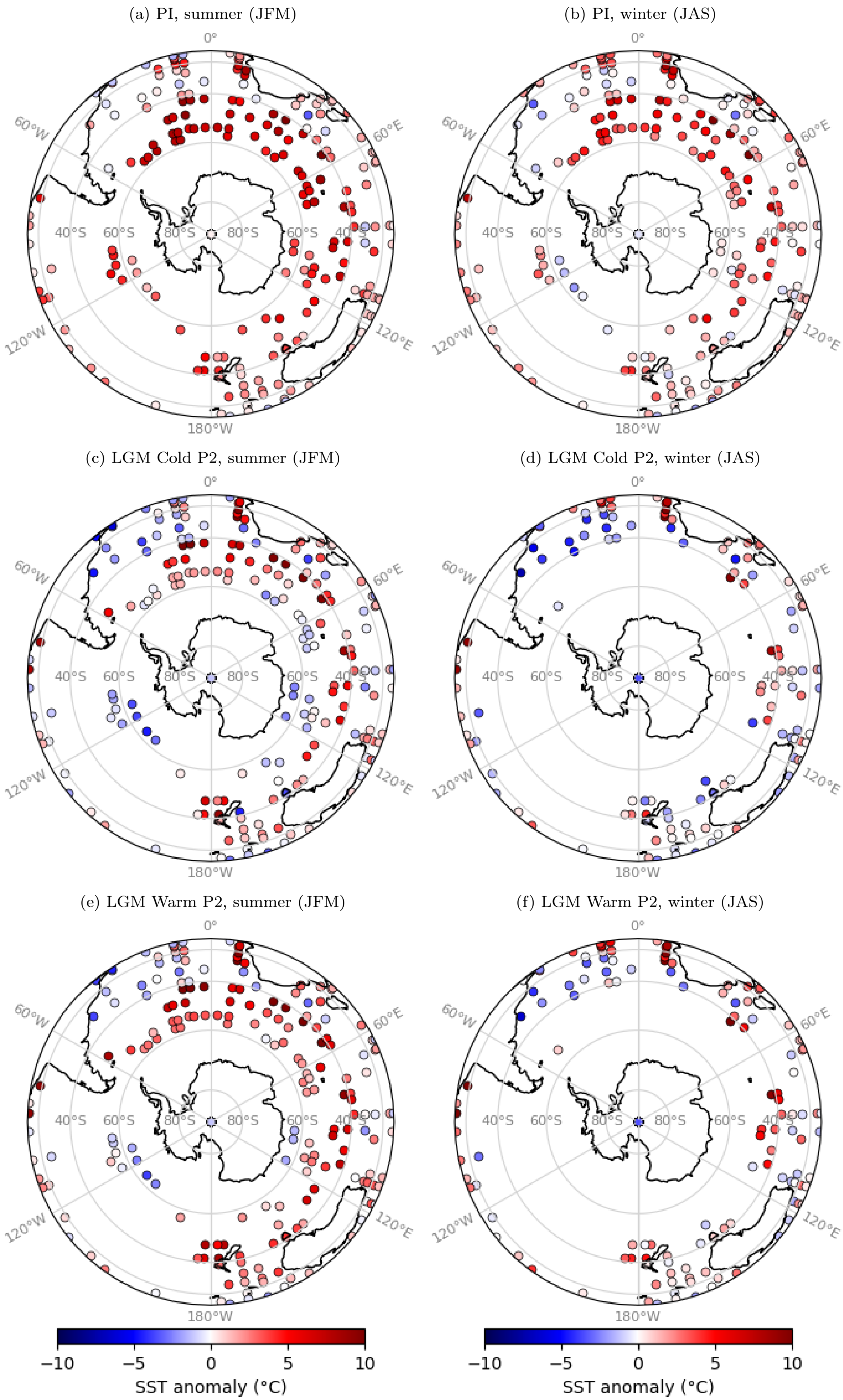
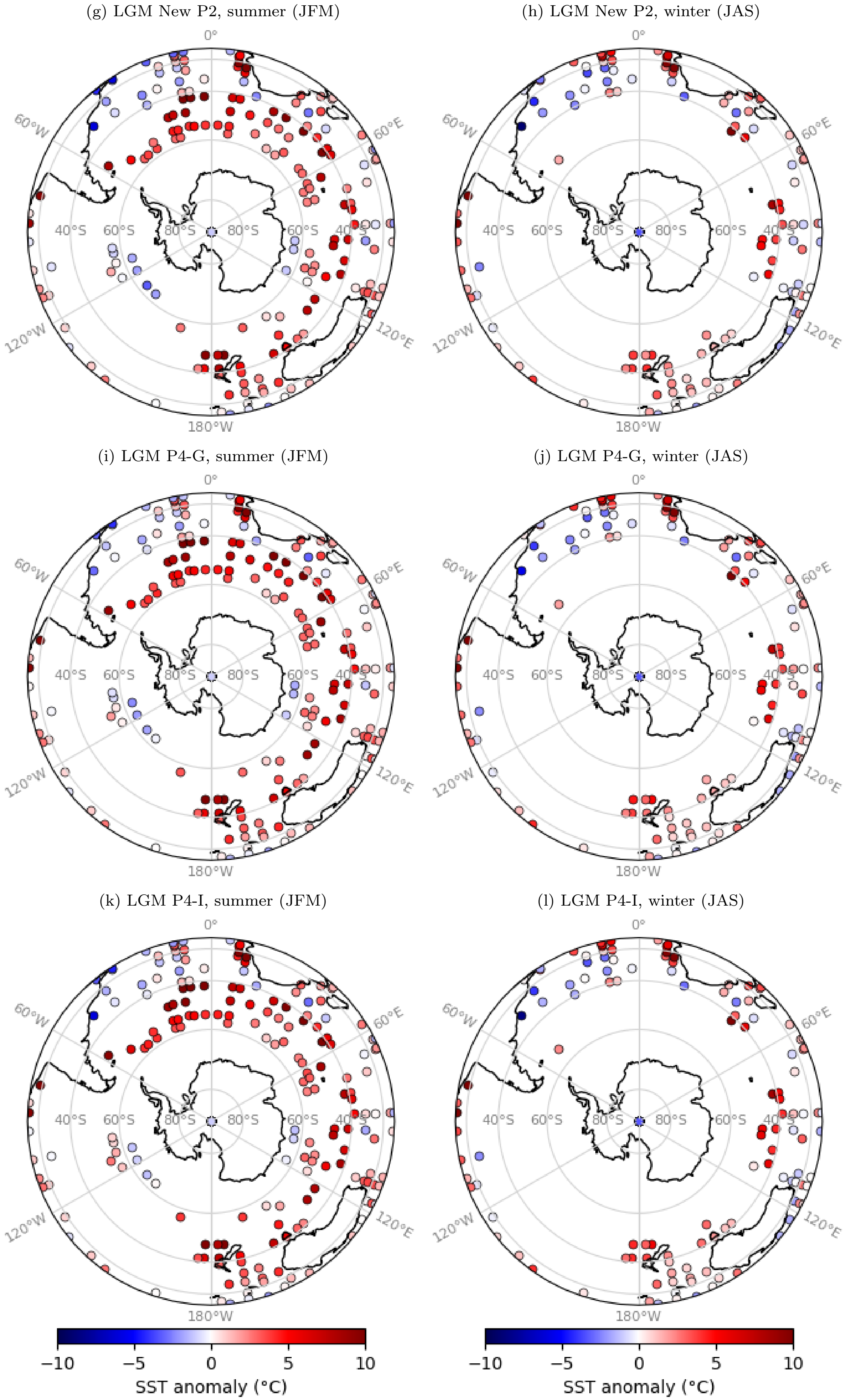


(a) PI, summer (JFM)
(b) PI, winter (JAS)
(c) LGM Cold P2, summer (JFM)
(d) LGM Cold P2, winter (JAS)
(e) LGM Warm P2, summer (JFM)
(f) LGM Warm P2, winter (JAS)
0°
60°E
120°E
180°W
120°W
60°W
40°S
60°S
80°S
−10
−5
0
5
10
SST anomaly (°C)



(g) LGM New P2, summer (JFM)
(h) LGM New P2, winter (JAS)
(i) LGM P4-G, summer (JFM)
(j) LGM P4-G, winter (JAS)
(k) LGM P4-I, summer (JFM)
(l) LGM P4-I, winter (JAS)
0°
60°W
60°E
40°S
60°S
80°S
120°W
120°E
180°W
−10
−5
0
5
10
SST anomaly (°C)

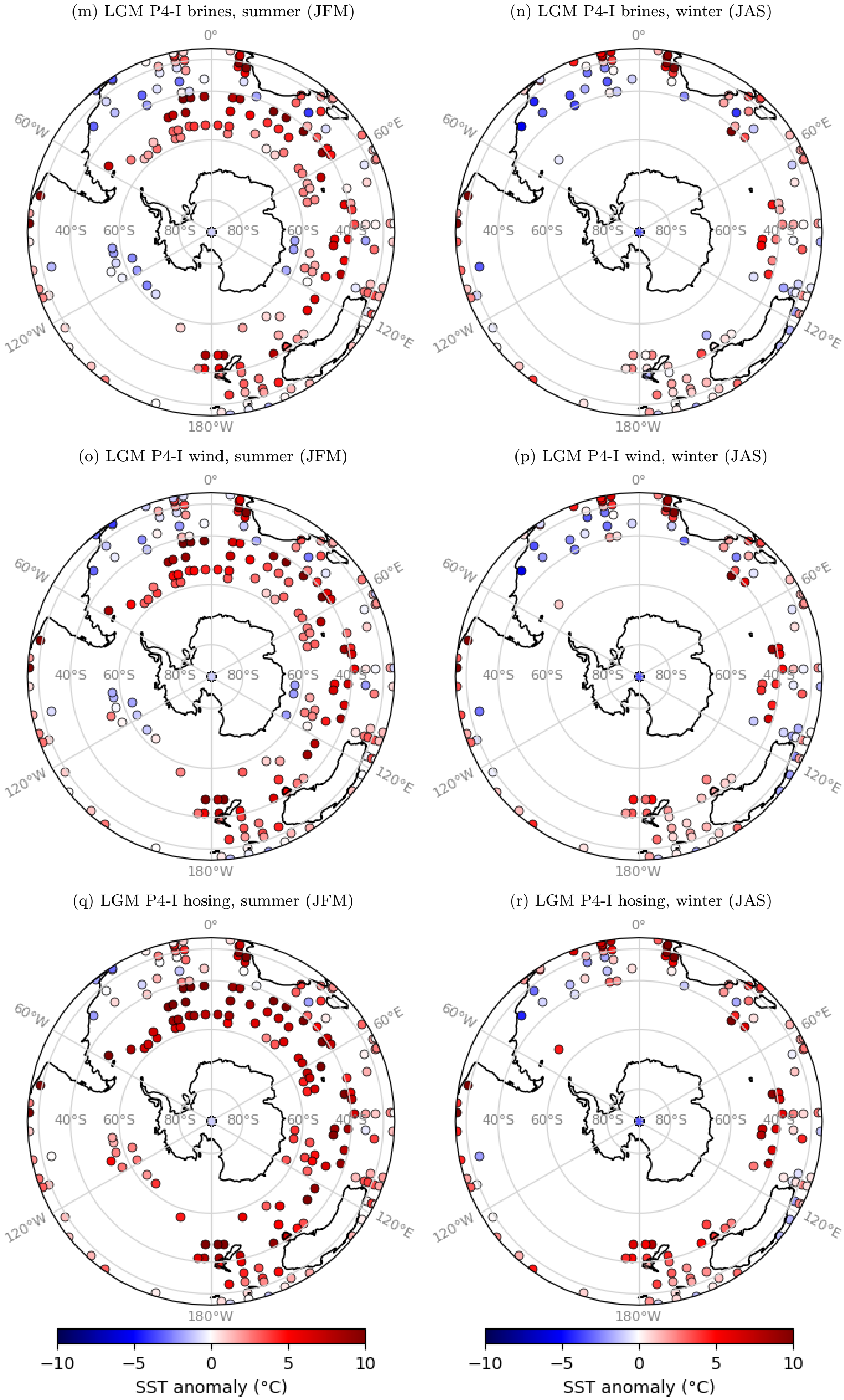
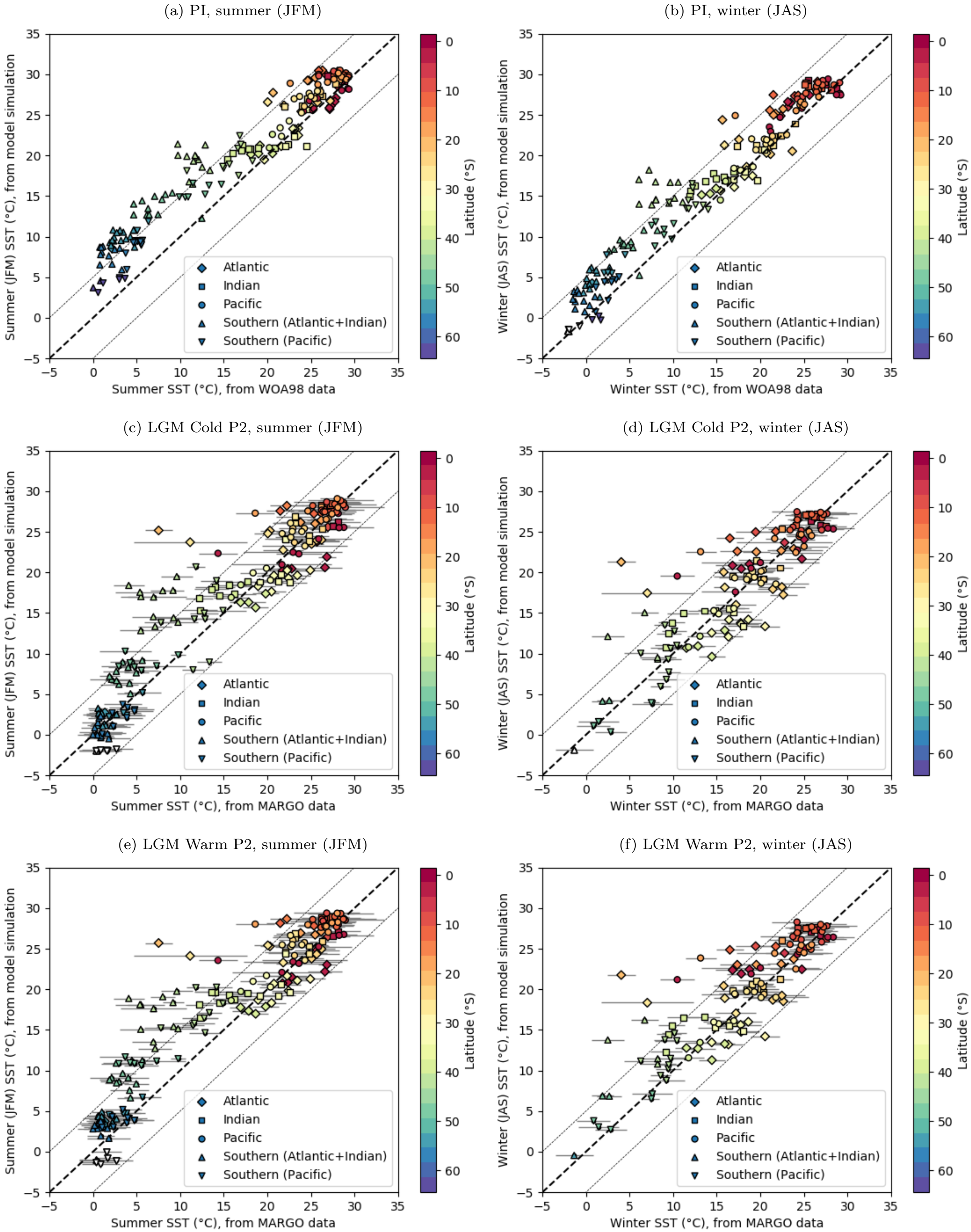
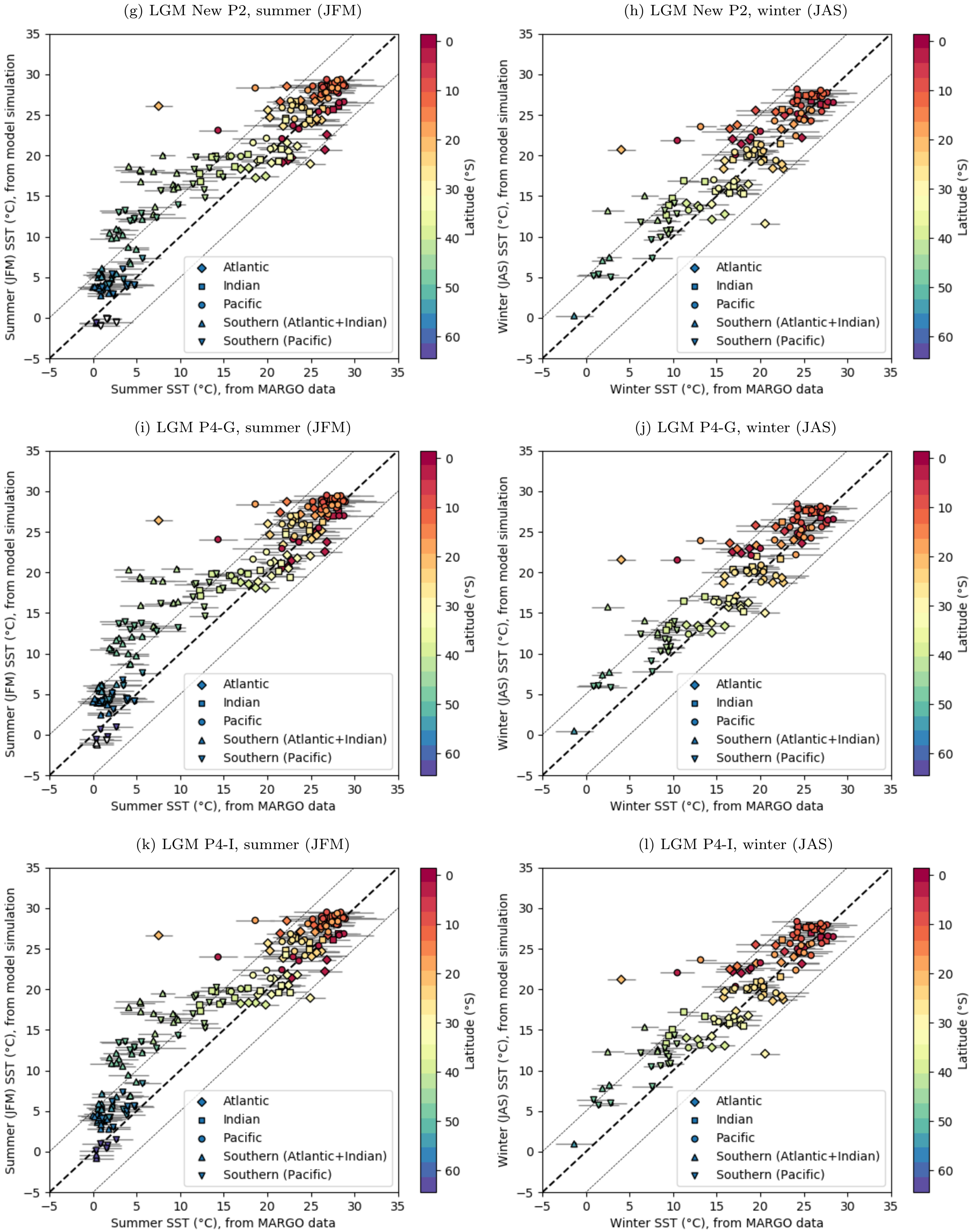


FIGURE S1 – Austral summer (JFM) and winter (JAS) SST anomalies relative to proxy data from the regridded product of MARGO Project Members (2009) (or World Ocean Atlas (1998) for the PI simulation).


(a) PI, summer (JFM)
(b) PI, winter (JAS)
(c) LGM Cold P2, summer (JFM)
(d) LGM Cold P2, winter (JAS)
(e) LGM Warm P2, summer (JFM)
(f) LGM Warm P2, winter (JAS)
Summer (JFM) SST (°C), from model simulation
Winter (JAS) SST (°C), from model simulation
Summer SST (°C), from WOA98 data
Winter SST (°C), from WOA98 data
Summer SST (°C), from MARGO data
Winter SST (°C), from MARGO data
Latitude (°S)
Atlantic
Indian
Pacific
Southern (Atlantic+Indian)
Southern (Pacific)


(g) LGM New P2, summer (JFM)
(h) LGM New P2, winter (JAS)
(i) LGM P4-G, summer (JFM)
(j) LGM P4-G, winter (JAS)
(k) LGM P4-I, summer (JFM)
(l) LGM P4-I, winter (JAS)
Summer (JFM) SST (°C), from model simulation
Summer SST (°C), from MARGO data
Winter (JAS) SST (°C), from model simulation
Winter SST (°C), from MARGO data
Latitude (°S)
Atlantic
Indian
Pacific
Southern (Atlantic+Indian)
Southern (Pacific)

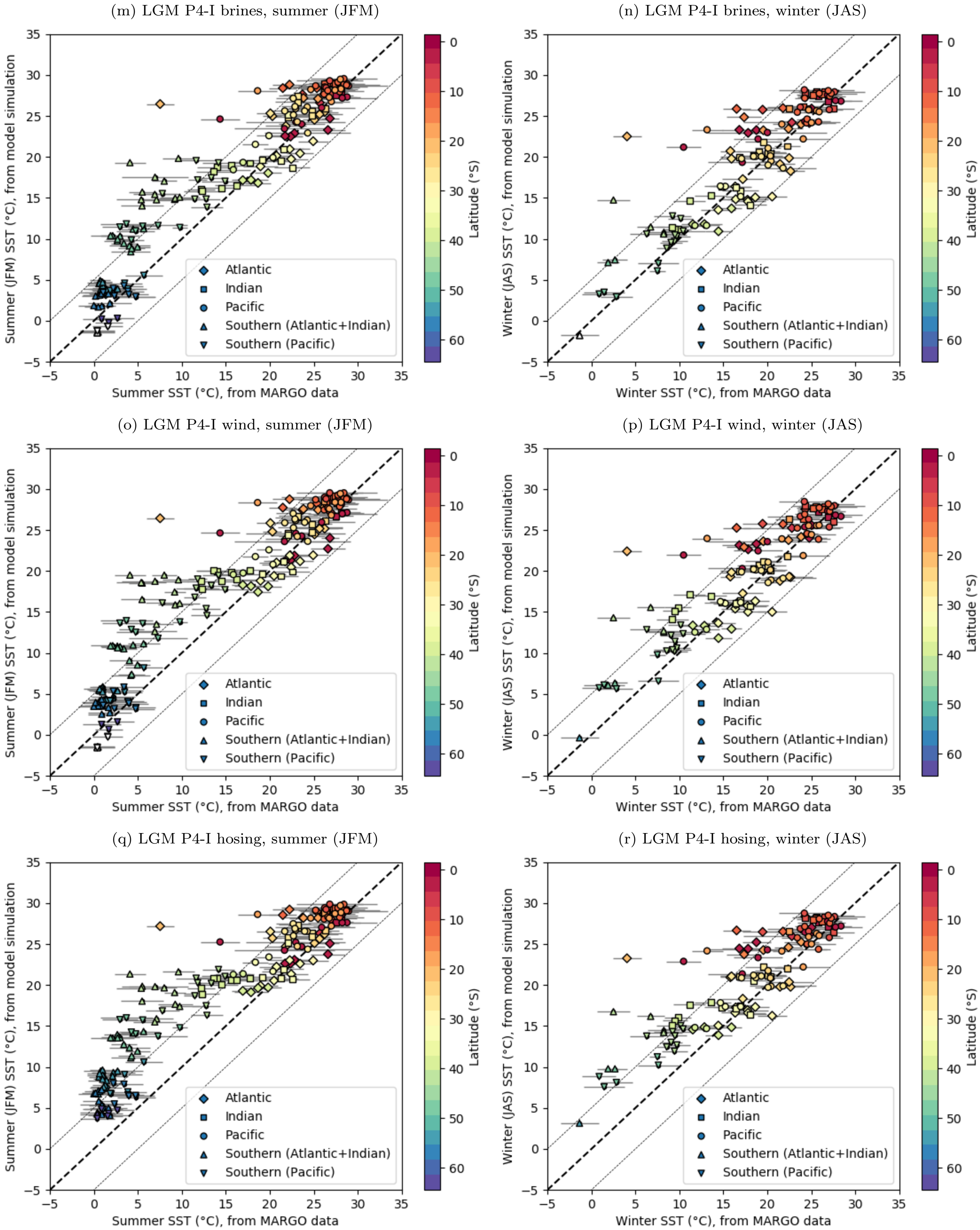


Figure S2 – Austral summer (JFM) and winter (JAS) sea-surface temperatures of the Southern Hemisphere in a model versus data diagram, for all simulations. The simulated SSTs are plotted against the SST data from the regridded product (MARGO Project Members (2009) or World Ocean Atlas (1998)) thanks to the aggregation of the coordinates on the nearest ocean grid cell. The 1 :1 line features a perfect model-data agreement (black dashed line), while the grey dotted lines features a 5°C departure from it. The marker style indicates the ocean basin of each core. The marker color shows the latitude of the core, except it is white where the model simulates sea ice in the Southern Ocean. The uncertainties associated with the SST data are plotted by the grey horizontal bars.

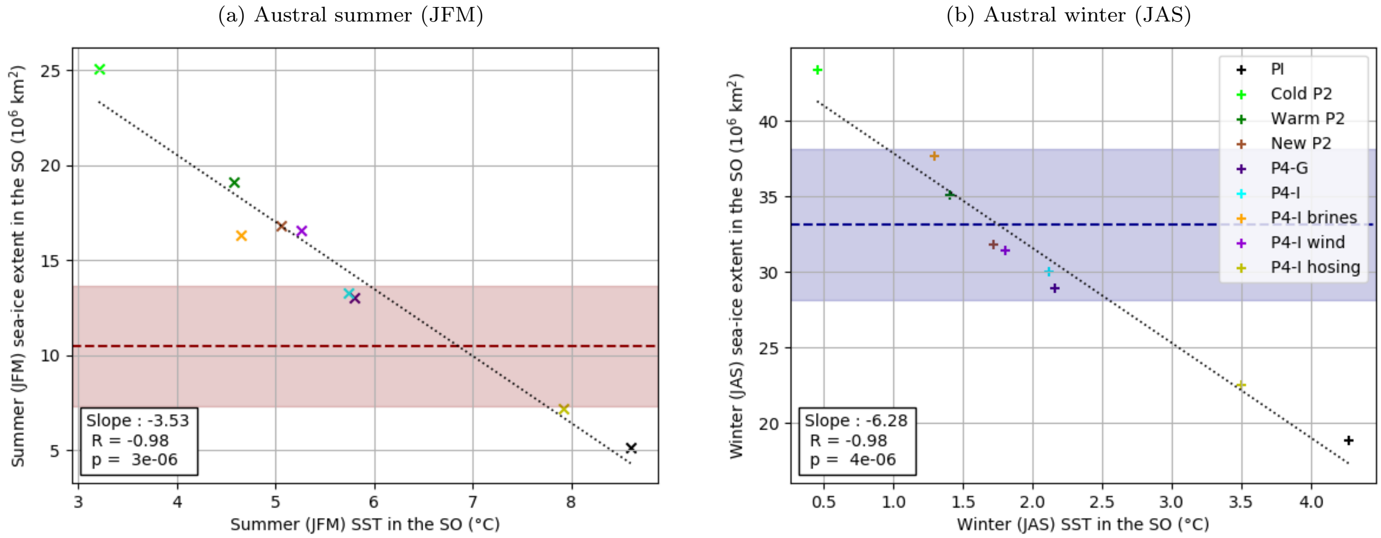
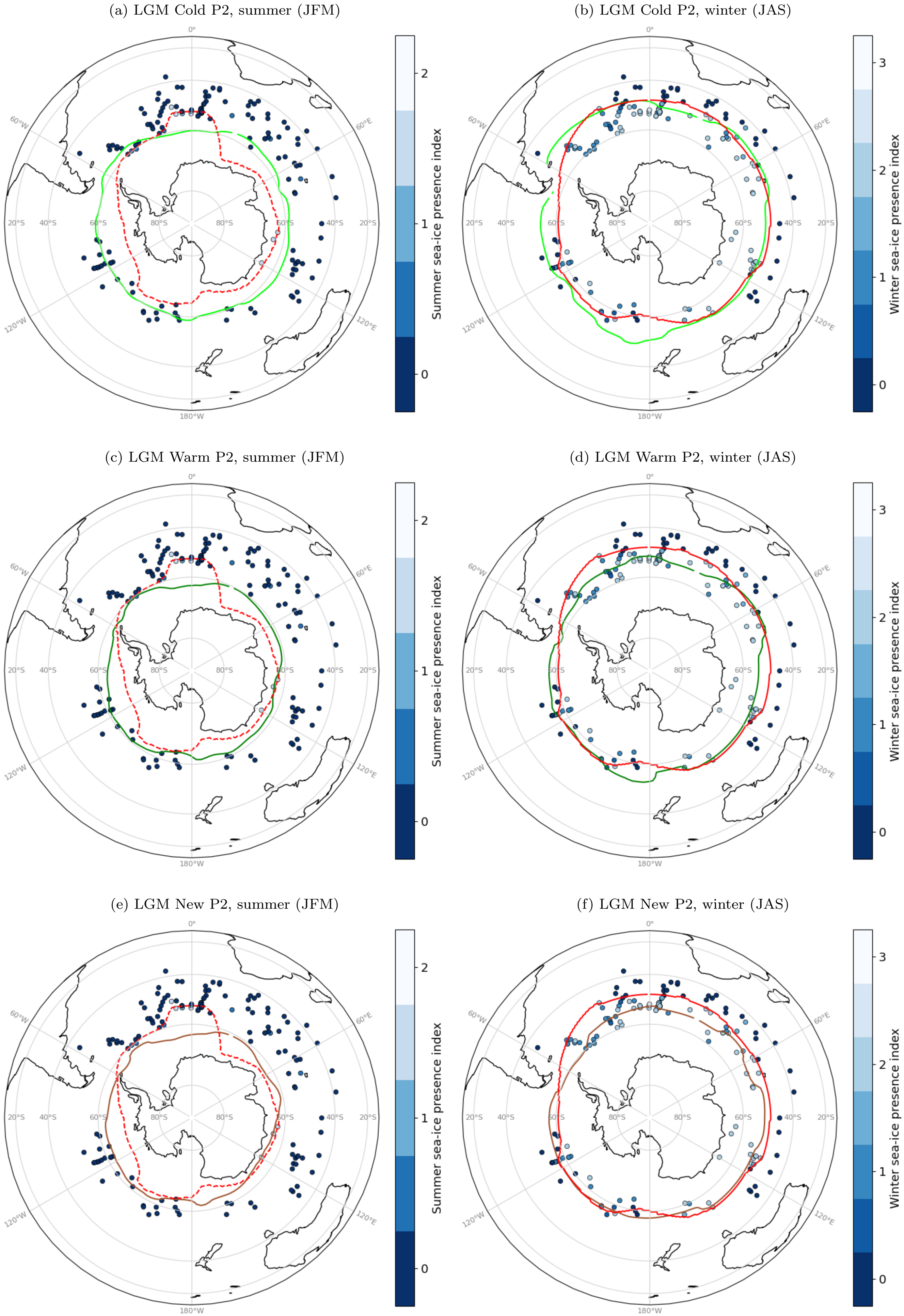
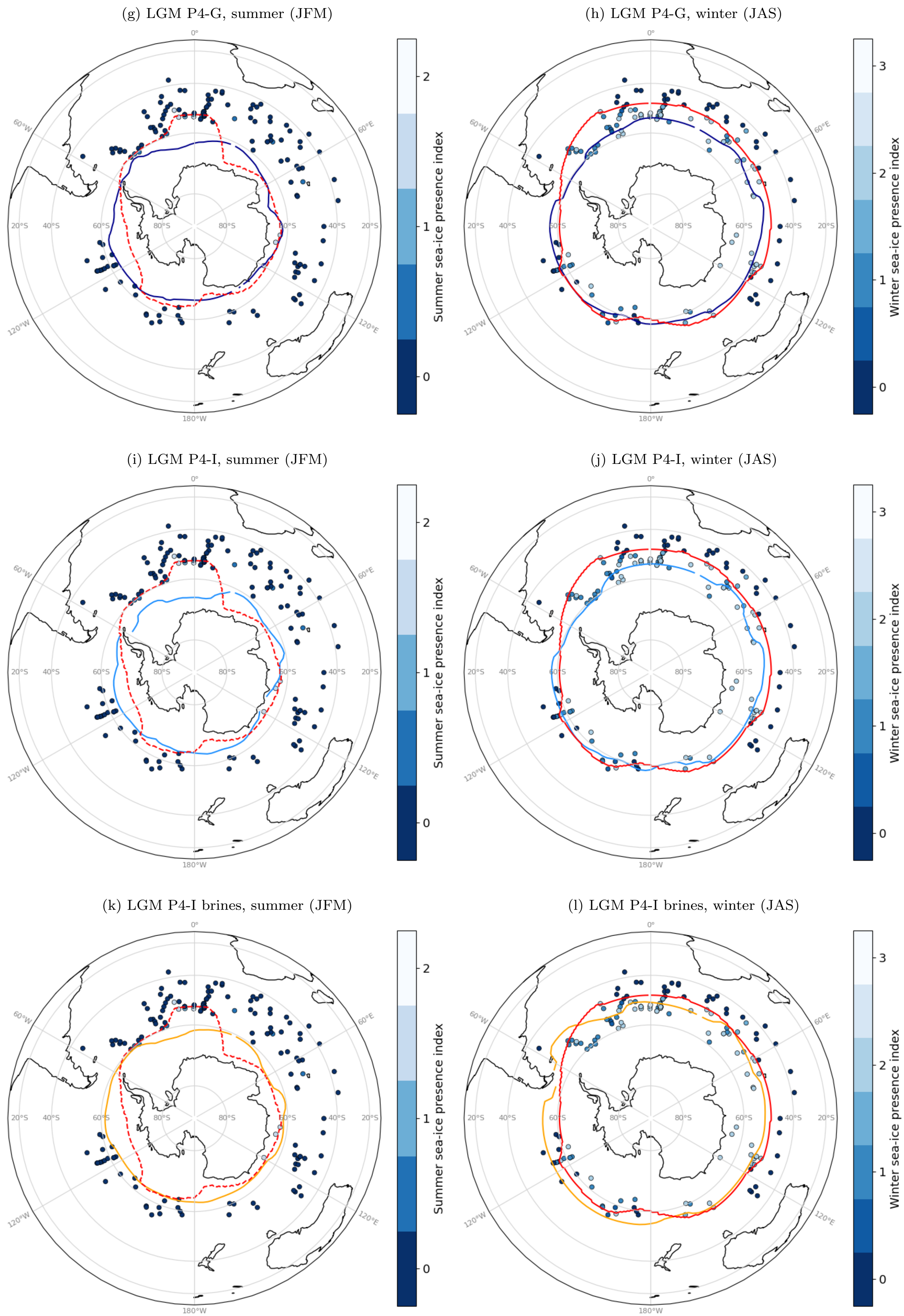


FIGURE S3 – Relationship between the mean SST (averaged up to 36°S) and the sea-ice extent in the Southern Ocean. The LGM sea-ice extent estimated using the proxy data compilation is represented by the red (summer) and the blue (winter) dashed lines (with an indicative error bar of 30% and 15% respectively). The dotted line represents the linear fit to the model results plotted here.


(a) LGM Cold P2, summer (JFM)
(b) LGM Cold P2, winter (JAS)
(c) LGM Warm P2, summer (JFM)
(d) LGM Warm P2, winter (JAS)
(e) LGM New P2, summer (JFM)
(f) LGM New P2, winter (JAS)
Summer sea-ice presence index
Winter sea-ice presence index
0°
60°W
60°E
120°W
120°E
180°W
20°S
40°S
60°S
80°S
0
1
2
3



(g) LGM P4-G, summer (JFM)
(h) LGM P4-G, winter (JAS)
(i) LGM P4-I, summer (JFM)
(j) LGM P4-I, winter (JAS)
(k) LGM P4-I brines, summer (JFM)
(l) LGM P4-I brines, winter (JAS)
Summer sea-ice presence index
Winter sea-ice presence index
0
1
2
3
0°
60°E
120°E
180°W
120°W
60°W
20°S
40°S
60°S
80°S

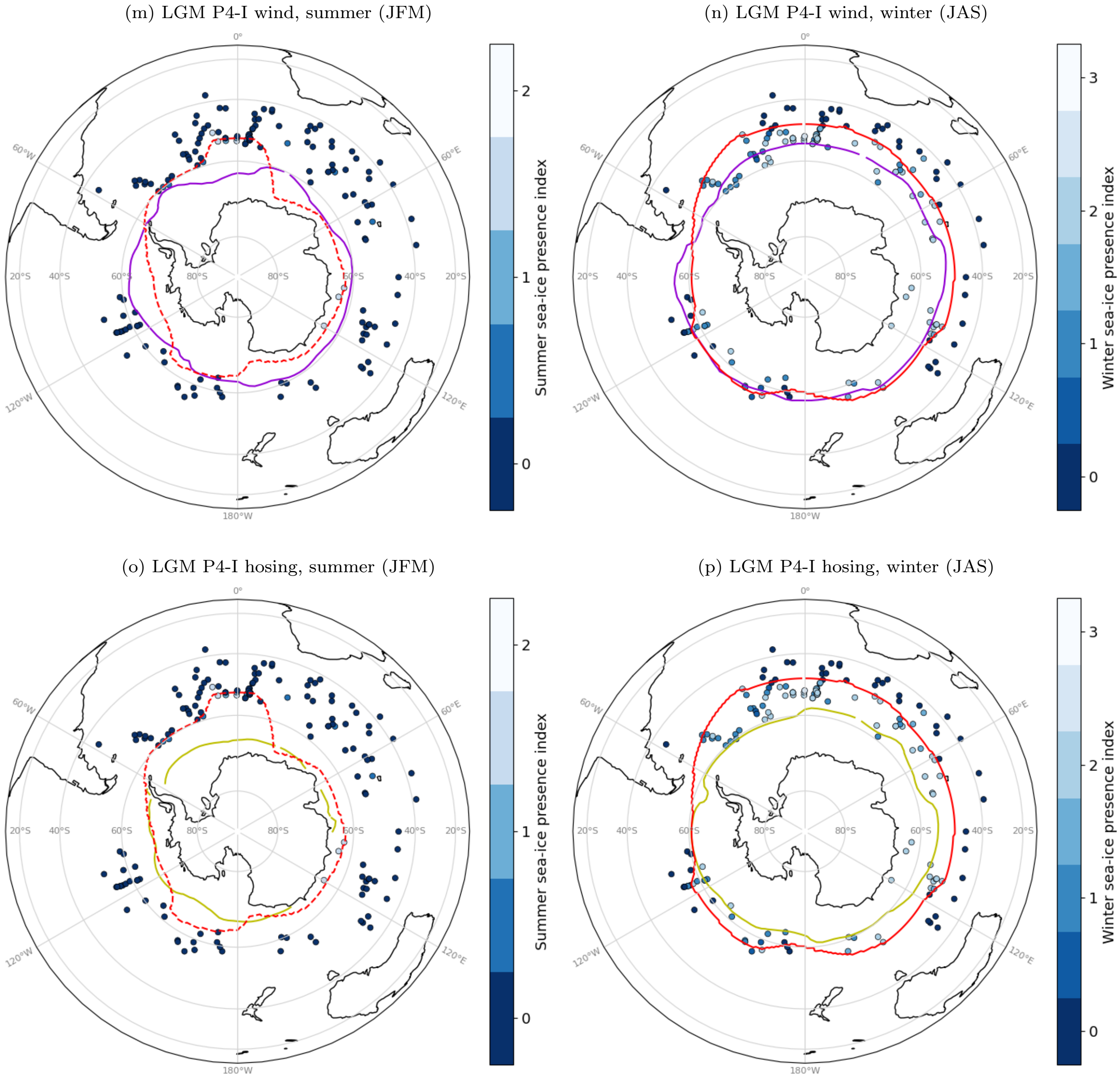


FIGURE S4 – Austral summer (JFM) and winter (JAS) sea-ice edges (at 15% of sea-ice concentration) in the Southern Ocean. The sea-ice presence suggested by marine cores data is represented as an arbitrary index on a blue to white scale, where blue denotes no indication of sea ice in proxies, and white denotes agreement of several proxies on the presence of sea ice. The red lines mark the likely delimitation of the sea-ice presence according to the proxy data (compilation of data from Gersonde et al. (2005), Allen et al. (2011), Ferry et al. (2015), Benz et al. (2016), Xiao et al. (2016), Nair et al. (2019), and Ghadi et al. (2020)). We used a solid red line for the winter months but a dashed line for the summer months as the summer contour is not well-constrained (see Sect. 2.4).

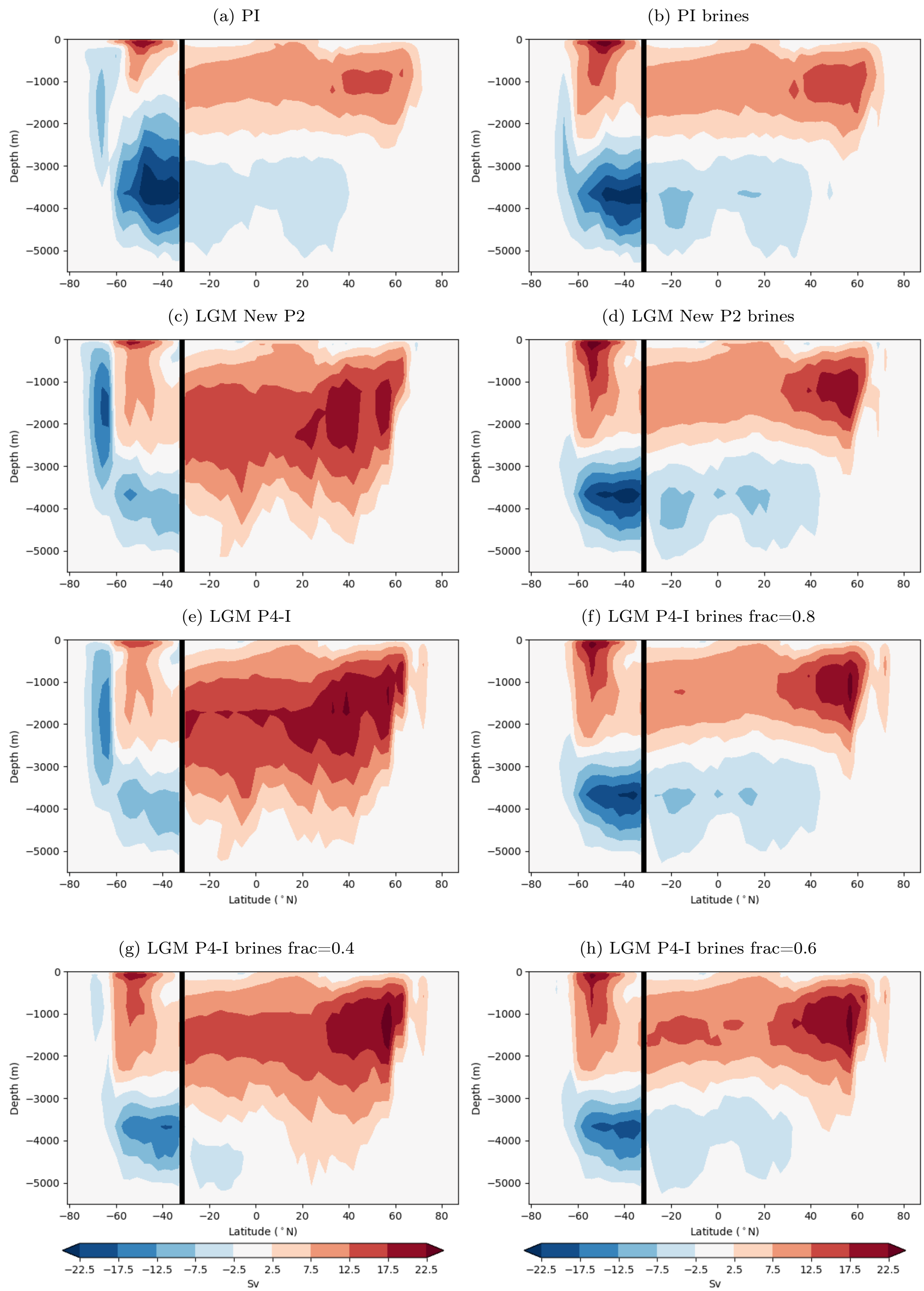


FIGURE S5 – Streamfunctions (Sv) in the Atlantic (North of 32°S) and Southern Ocean basins (South of 32°S). The black vertical line represents the limit between these two basins, chosen at 32°S. This figure shows similar plots as in Figure 7. The streamfunctions of additional simulations using the parameterization of the sinking of brines are displayed to show the effect of the chosen boundary conditions (those of 'PI', 'New P2', or 'P4-I') and of the parameter choice (fraction at 0.4, 0.6 or 0.8) on the streamfunction. For more information, note that the parameter choice and the brine parameterization in general has been discussed in the reviews of Bouttes et al. (2010), which can be found at : https ://cp.copernicus.org/articles/6/575/2010/cp-6-575-2010-discussion.html.

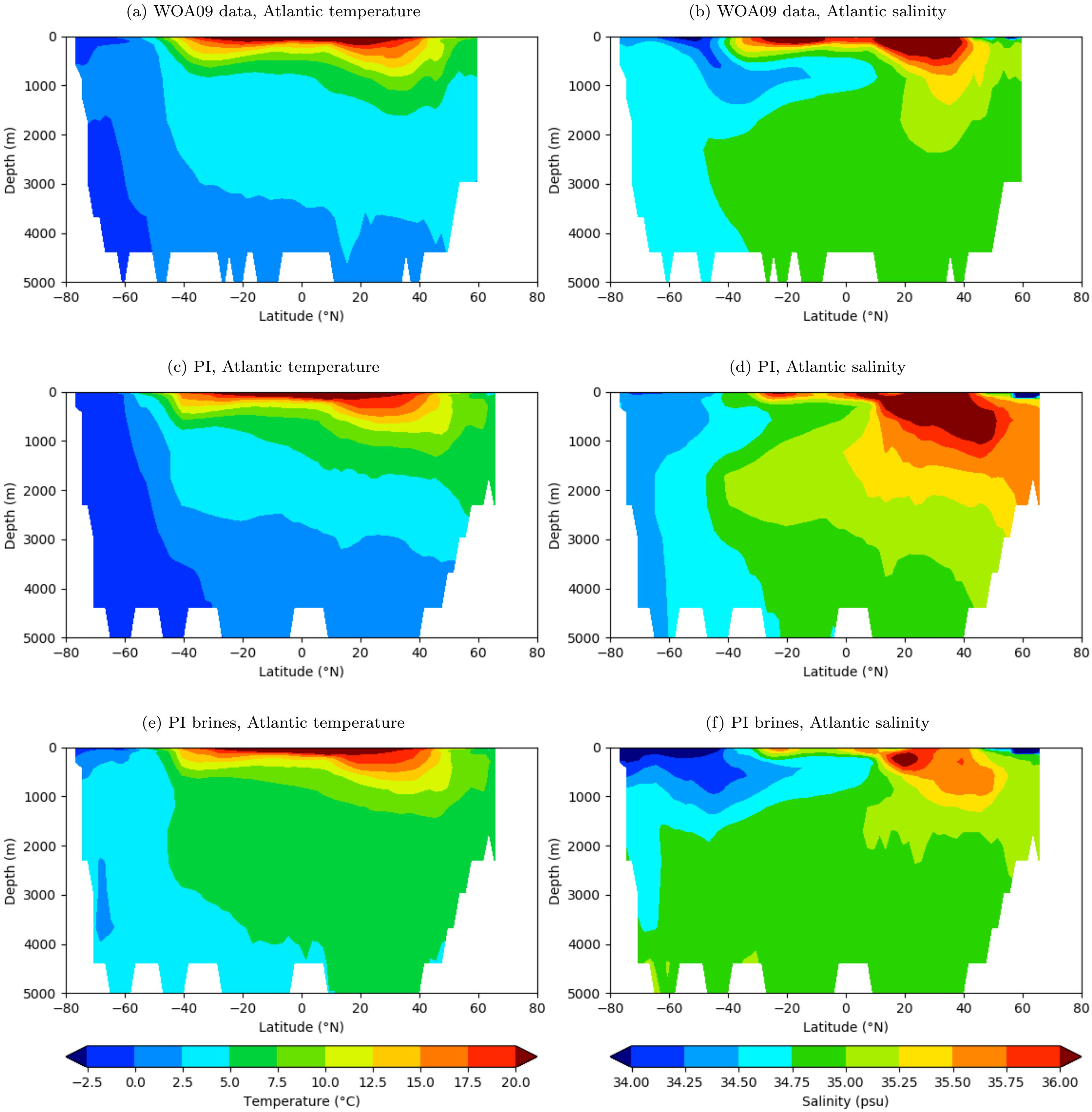


FIGURE S6 – Zonal average of the temperature (a, c, e) and salinity (b, d, f) distribution in the Atlantic ocean. The temperature and salinity distribution simulated at the PI with (e, f) or without (c, d) the parameterization of the sinking of brines is compared to data from the World Ocean Atlas 2009 (Locarnini et al., 2010 ; Antonov et al. 2010).

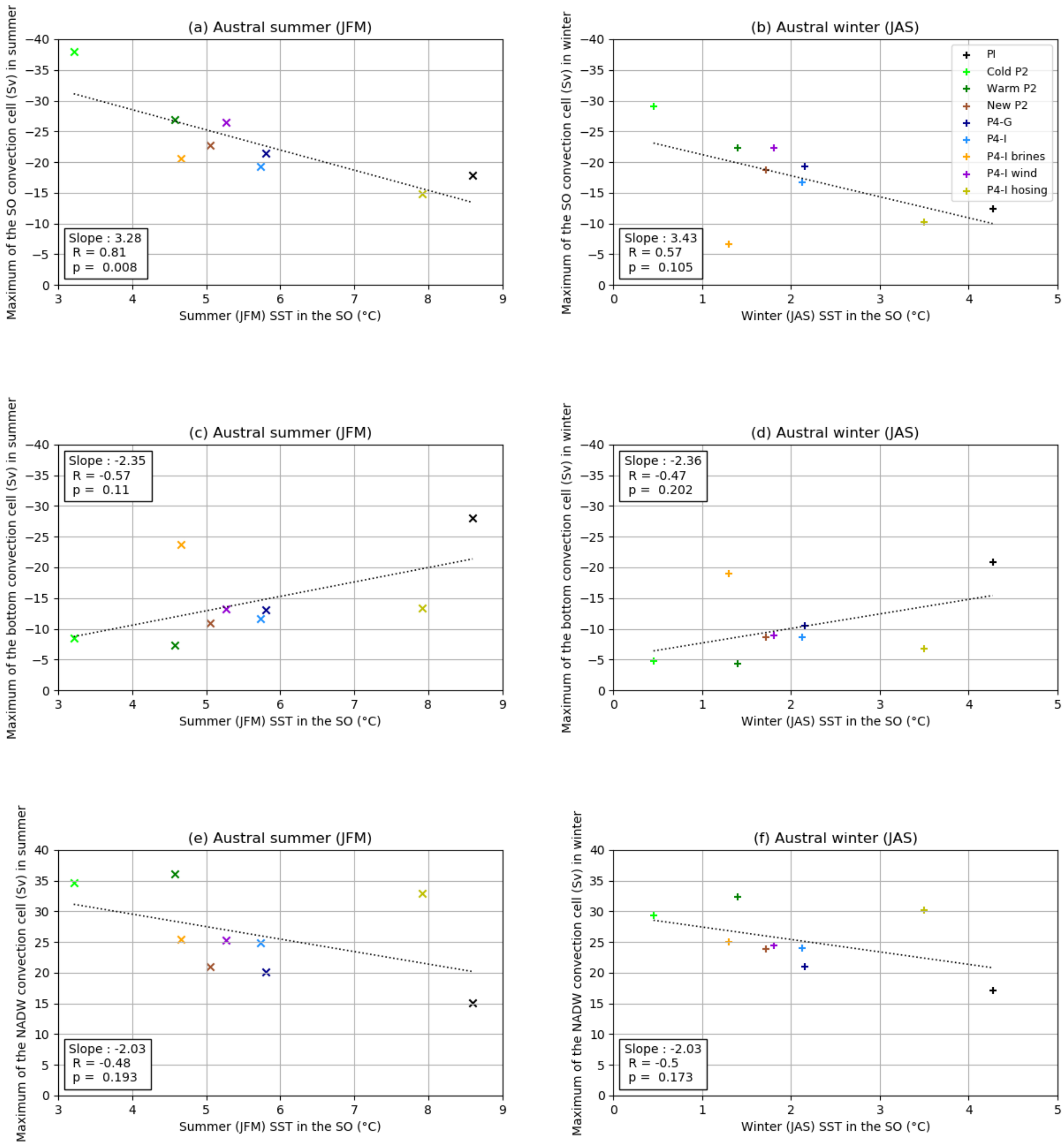


FIGURE S7 – Relationships between the mean SST in the Southern Ocean (averaged up to 36°S) and the Southern Ocean (a, b), bottom (c, d) or NADW (e, f) overturning cell maximum for all simulations. The y-axis is inverted for the two anticlockwise cells (a, b, c, d). The dotted line represents the linear fit to the model results plotted here.