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Improving the Southern Ocean cloud albedo biases in a general circulation model

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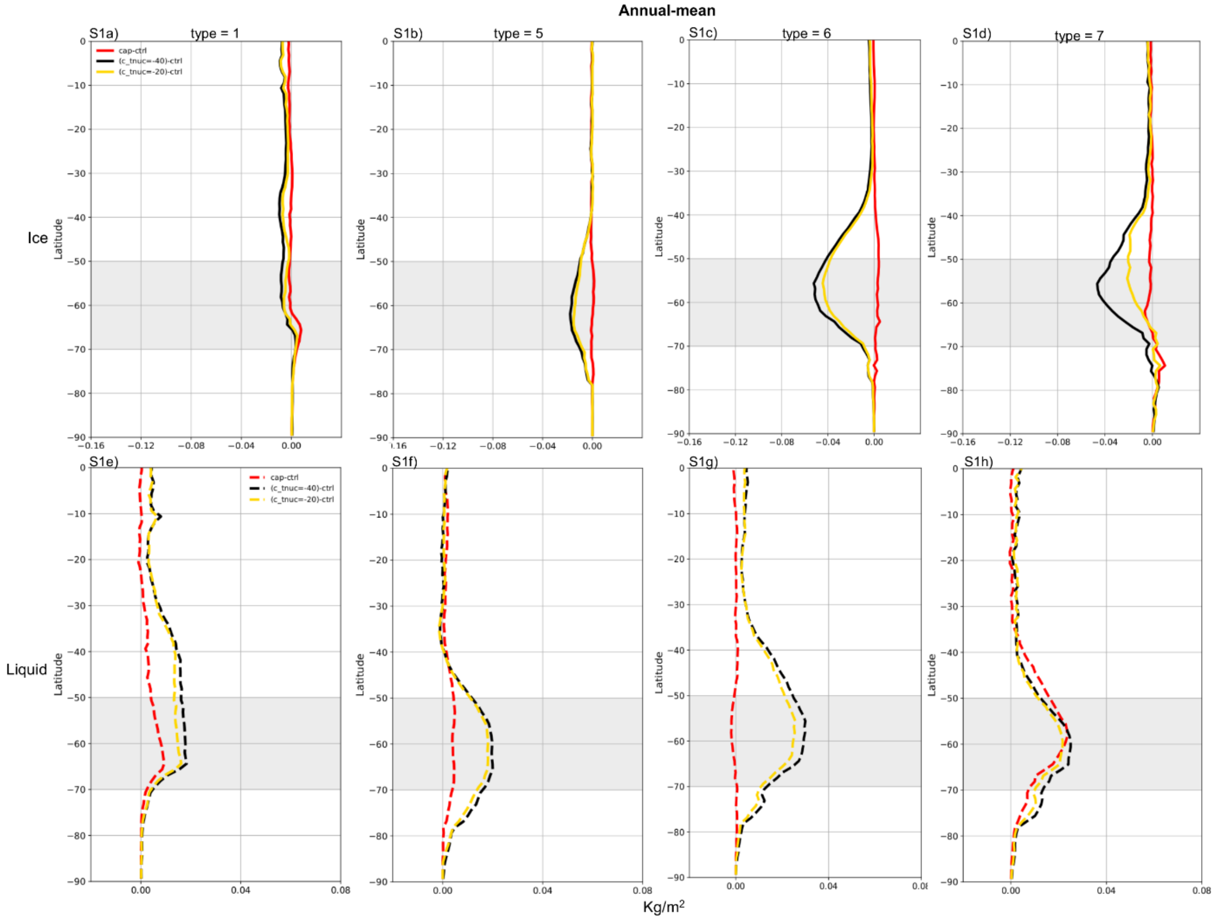

Figure S1. Global distribution of zonally averaged annual-mean anomalies in IWP (solid lines in S1a to S1d) and LWP (dashed lines in S1e to S1h) over the stratocumulus boundary layer type clouds in the model. The cloud types considered in the model are: **type 1 = stable boundary layer (with or without cloud), type 5 = boundary layer with de-coupled stratocumulus layer over cumulus, type 6 = cumuluscapped boundary layer and type 7 = shear-dominated unstable layer.** The colour codes are as follows: red = *cap* - control, black = *(tnuc=-40)* - control, yellow = *(tnuc=-20)* - control. Values are calculated from 12 hourly instantaneous model output over 22 years. The SO region identified in this study is highlighted in gray.

Similar to the stratocumulus boundary layer types (as shown in the main text), the *cap* experiment shows the least reduction in ice water path (IWP) compared to *(tnuc=-40)* and *(tnuc=-20).* For liquid water path (LWP) changes, the *cap* experiment shows mostly no response except for type 7 (shear-dominated unstable layer). The nucleation temperature experiments (*tnuc=-40* and *tnuc=-20*) show very similar response for both IWP and LWP changes in all cloud types except in type 7 (where *tnuc=-40* shows larger reduction in IWP). It could be noted that the shear dominated unstable boundary layer (type = 7) is defined to be like that of the well mixed layer. The idea is that the shear above a certain threshold disrupts the typical convection formation and leads to a more mechanically well mixed layer. Hence, type = 7 type cloud has a similar impact on LWP like that of the stratocumulus boundary layer types (in terms of *cap* experiment).

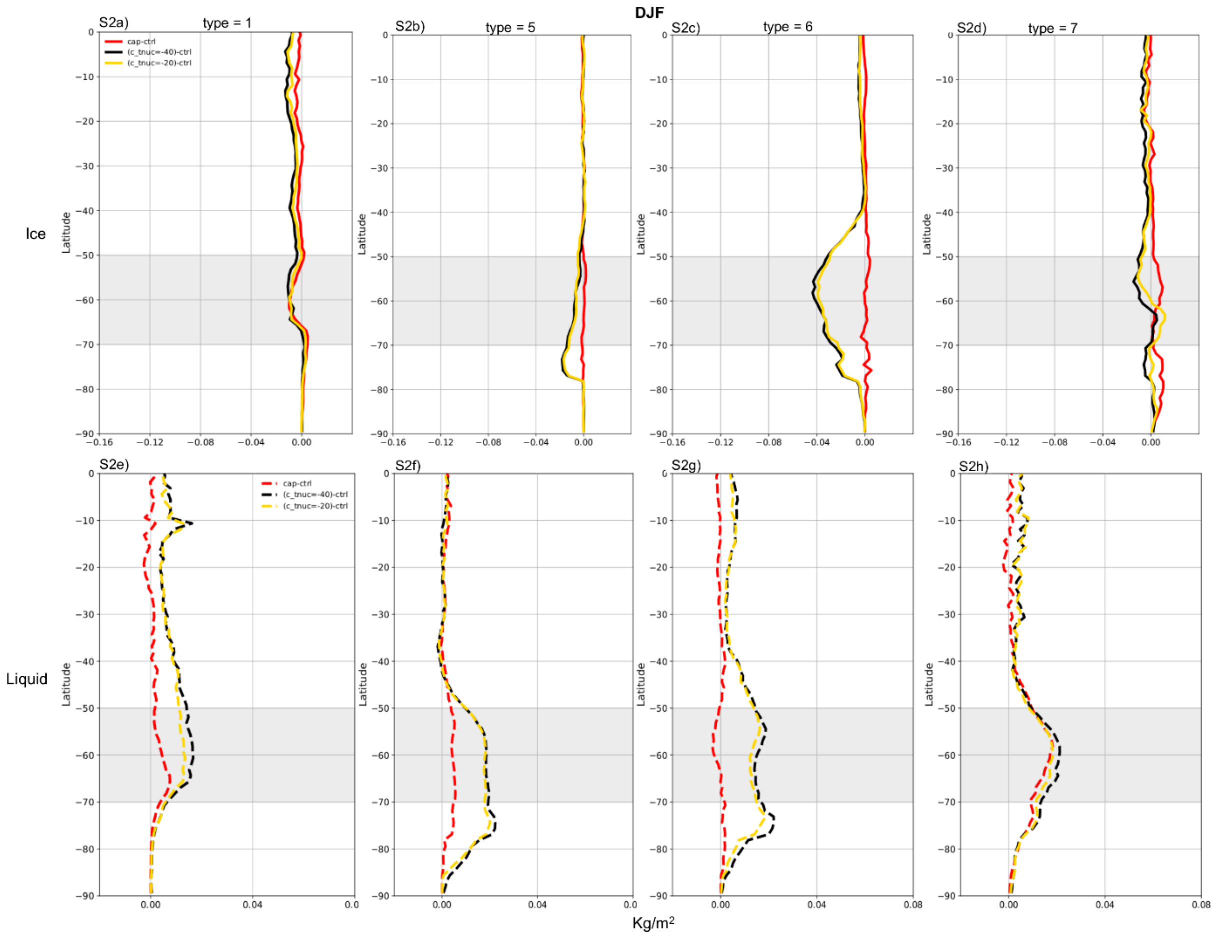

Figure S2. Similar to S1 but for DJF season.

Table S1. Anomalies in the annual - mean values for SW CRE averaged over 50°S – 70°S (Southern Ocean region defined in this study).

	SW CRE (W/m^2)
control - obs	3.02
cap - obs	-0.63
(c_tnuc=-40) - obs	0.83
(c_tnuc=-20) - obs	-0.01
cap - control	-3.66
(c_tnuc=-40) - control	-2.20
(c_tnuc=-20) - control	-3.11

Model simulations minus CERES EBAF TOA observational data (highlighted in blue text) and experiments minus control model (black text). The SW CRE shows the impact of cloud on TOA SW flux and is calculated by taking the anomaly of TOA SW flux between the clear-sky and all-sky conditions. Upward fluxes are used for all TOA values.

Table S2. Anomalies in the annual - mean values for LW and SW fluxes at TOA (upward fluxes) in model simulations with respect to the CERES EBAF observational data averaged for SO region defined in the study (bold text; outside bracket) and global mean values (inside bracket).

	LW	**SW**
control - obs	**-6.56** (-16.15)	**-1.03** (3.57)
cap - obs	**-9.41** (-17.52)	**2.27** (4.92)
(c_tnuc=-40) - obs	**-9.76** (-18.11)	**0.86** (4.88)
(c_tnuc=-20) - obs	**-10.76** (-18.53)	**1.83** (5.26)

Table S3. Area-weighted RMSE values for annual - mean LW and SW fluxes at TOA (upward fluxes) in model simulations with respect to the CERES EBAF observational data averaged for SO region defined in the study (bold text; outside bracket) and global mean values (inside bracket).

	LW	**SW**
control - obs	**5.931** (8.03)	**7.686** (8.35)
cap - obs	**8.620** (8.48)	**8.124** (8.67)
(c_tnuc=-40) - obs	**9.015** (8.44)	**6.902** (8.43)
(c_tnuc=-20) - obs	**10.20** (8.70)	**7.558** (8.59)