

Supporting Information for “Potential link between ice nucleation and climate model spread in Arctic amplification”

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1. Additional details of methodology

The cloud radiative kernels (CRKs) were used to directly compute the cloud feedback by multiplying the CRKs by joint histograms of τ and cloud-top pressure (CTP) gen-

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erated by version 1 of the International Satellite Cloud Climatology Project (ISCCP) simulator implemented in the GEOS-5 model. This calculation was performed on both the simulations with SSTs and sea-ice fraction prescribed to the 1979-2019 climatology obtained from MERRA-2 and the simulations with a uniform 4K increase in SSTs using the last 30 years of the simulations. Decomposed cloud feedbacks were then calculated by differencing the contribution of each of the three cloud properties to the TOA radiation in both simulations and normalizing by the change in the mean Arctic summertime SST.

When calculating the climate feedbacks and the cloud feedback by adjusting the cloud radiative effect by the masking of non-cloud feedbacks, the tropopause was defined at 100 hPa at the equator and linearly interpolated to 300 hPa at both the north and south poles. The contribution of the climate feedbacks to high Arctic and tropical (30°S to 30°N) surface warming were calculated by multiplying the respective local zonal mean radiation anomalies of the last 50 years of the simulation by the local mean change in surface air temperature and normalizing the product by the global mean Planck feedback parameter. Thus, the influence of rapid adjustments to CO₂ are not separated from the feedback calculations.

Table S1. Cloud properties and cloud radiative effects simulated by the four Type I immersion freezing experiments. Cloud properties were simulated by the MODIS satellite simulator and were averaged from 60°N to 80°N over the last 30 years of each simulation during polar day (March to September) when satellite observations were available. Observed values of LWP, IWP, mean droplet effective radius (REFFL) and mean ice effective radius (REFFI) were obtained from NASA’s MODIS instrument. The observed LWP from the Multisensor Advanced Climatology of Liquid Water Path (MAC-LWP) product is also shown for comparison. Observed SW and LW TOA cloud radiative effects ($\text{SWCRE}_{\text{TOA}}$ and $\text{LWCRE}_{\text{TOA}}$, respectively) and observed SW and LW surface cloud radiative effects ($\text{LWCRE}_{\text{surface}}$ and $\text{SWCRE}_{\text{surface}}$) were obtained from NASA’s Clouds and the Earth’s Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Level 3b Edition 4.1 satellite dataset.

Variable	BN09	M92	U17	D10	MODIS	MAC-LWP	CERES
LWP (gm^{-2})	81.0	82.0	75.1	77.8	183.6	78.3	—
IWP (gm^{-2})	154.0	158.3	140.0	141.6	182.1	—	—
REFFL (μm)	11.7	11.7	13.0	12.9	13.1	—	—
REFFI (μm)	37.1	36.7	36.3	33.7	35.3	—	—
$\text{SWCRE}_{\text{TOA}}$ (Wm^{-2})	−54.7	−54.9	−49.7	−51.2	—	—	−44.4
$\text{LWCRE}_{\text{TOA}}$ (Wm^{-2})	19.0	19.2	19.3	20.9	—	—	18.2
$\text{SWCRE}_{\text{surface}}$ (Wm^{-2})	−59.9	−60.1	−54.4	−56.1	—	—	−46.6
$\text{LWCRE}_{\text{surface}}$ (Wm^{-2})	41.7	42.0	40.5	43.7	—	—	41.3
Low cloud fraction (%)	29.2	29.1	26.6	27.2	22.9	—	—
Middle cloud fraction (%)	14.4	14.6	16.9	19.1	14.2	—	—
High cloud fraction (%)	20.7	20.7	20.5	21.2	14.2	—	—

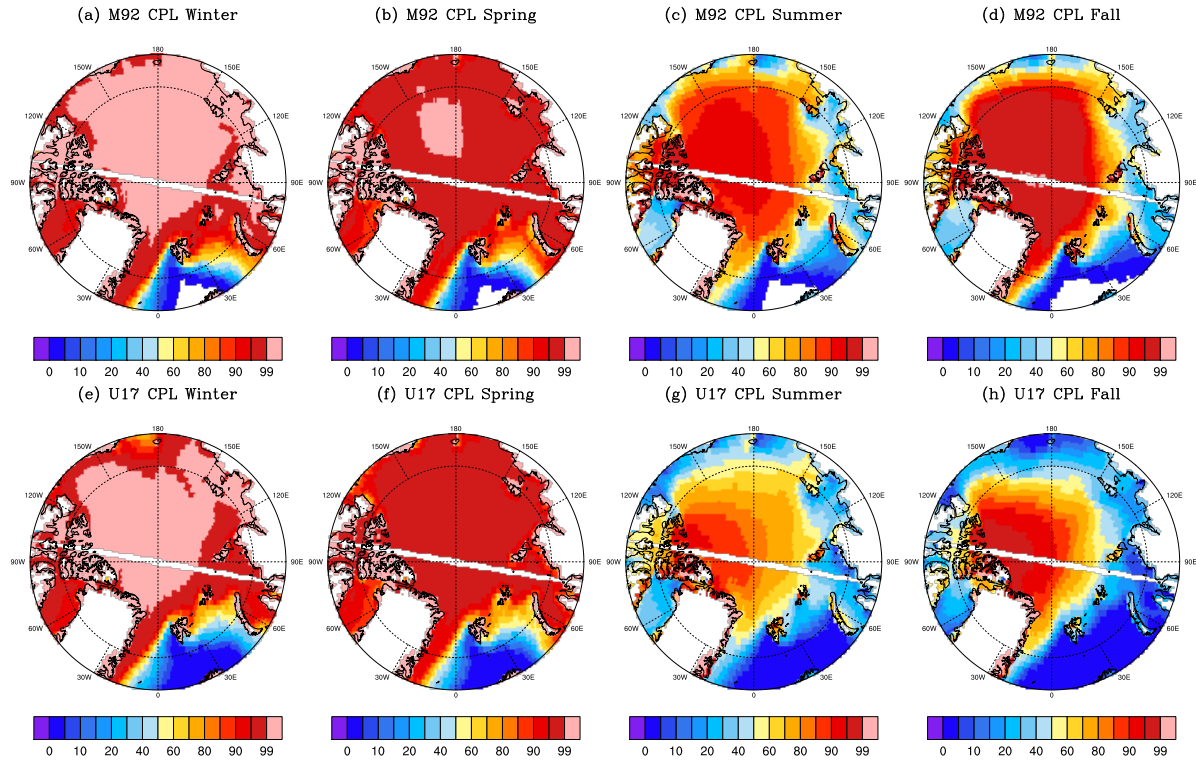


Figure S1. Arctic projections of mean sea ice concentration simulated by the two fully-coupled piControl experiments over the last 50 years of the simulations: M92_CPL averaged over (a) winter, (b) spring, (c) summer and (d) autumn and U17_CPL averaged over (e) winter, (f) spring, (g) summer and (h) autumn.

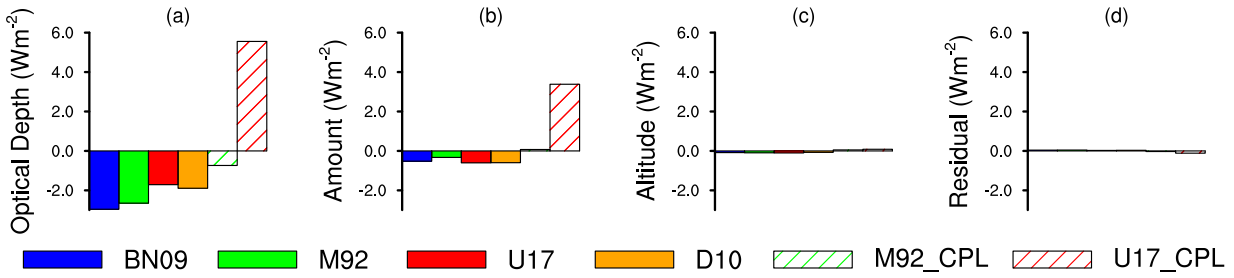


Figure S2. High Arctic summertime shortwave cloud (a) optical depth (b) amount and (c) altitude feedbacks and (d) residual term for the four parameterizations run in standalone atmosphere configuration and two fully-coupled configurations.

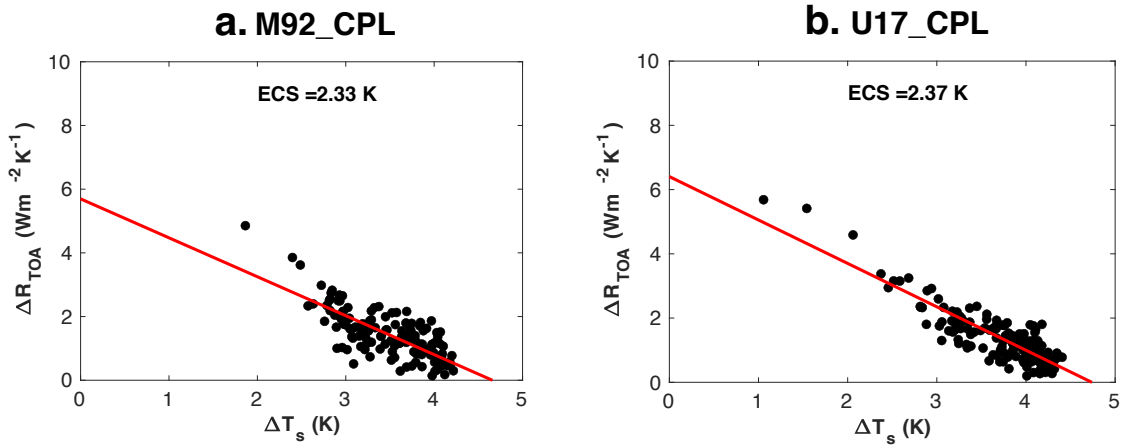


Figure S3. Annual global mean net TOA radiation anomaly linearly regressed against annual global mean 2-metre air temperature anomalies for (a) M92_CPL and (b) U17_CPL. The slope of the least squares linear regression is equal to the effective climate sensitivity (ECS) (24) and is displayed in the figure.

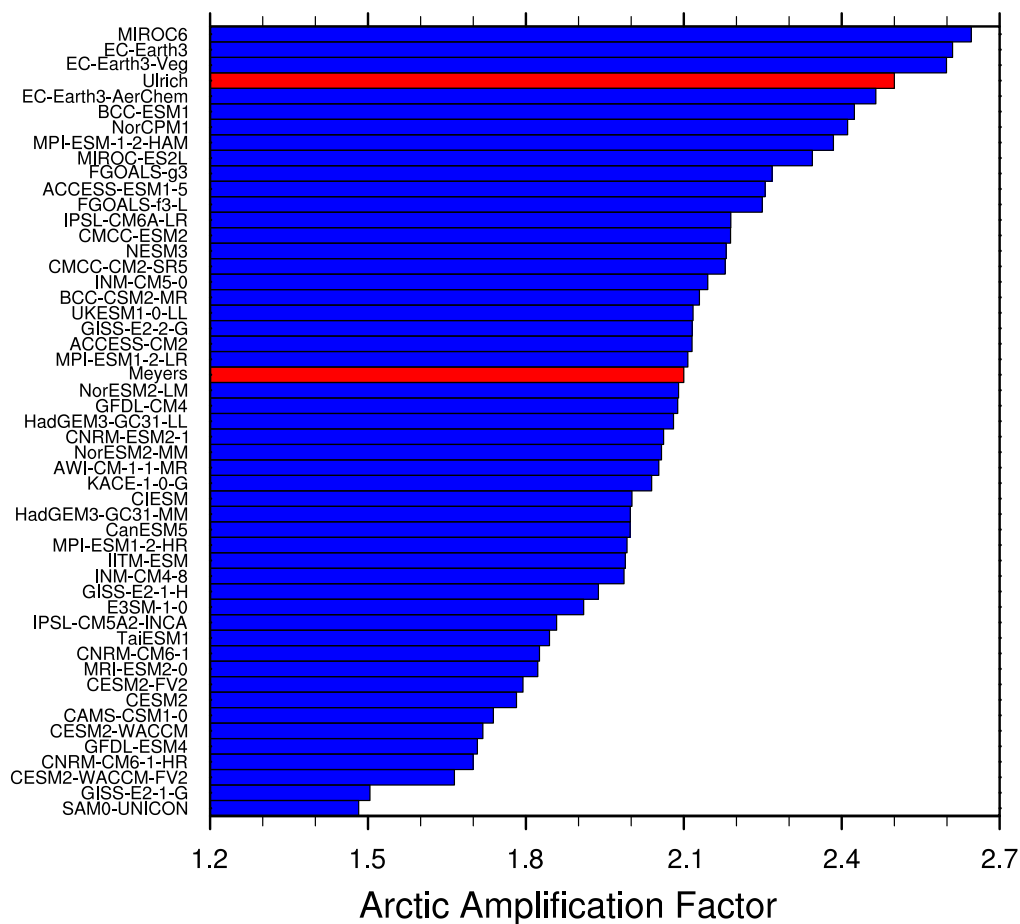


Figure S4. Arctic amplification factor for 49 CMIP6 models in blue and M92 and U17 highlighted in blue based on the last 50 years of the piControl and abrupt4xCO₂ simulations.