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Supporting Information for

Quantifying changes in the Arctic shortwave cloud radiative effects

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The ERA5 and CAM5 radiative kernels employed in Fig. S4 can be obtained from Huang et al. (2017) and Pendergrass et al. (2018), respectively.

Model Type	Model Number	Model name	Institution	PiControl abrupt-4xCO2	PiControl RCP4.5
cmip5	1	ACCESS1-0	CSIRO and BOM, Australia	Yes	Yes
	2	ACCESS1-3	CSIRO and BOM, Australia	Yes	Yes
	3	bcc-csm1-1	BCC, CMA, China	Yes	Yes
	4	bcc-csm1-1-m	BCC, CMA, China	Yes	Yes
	5	BNU-ESM	BNU, China	Yes	Yes
	6	CanESM2	CCCma, Canada	Yes	Yes
	7	CCSM4	NCAR, USA	Yes	Yes
	8	CESM1-BGC	DOE NCAR, USA	No	Yes
	9	CESM1-CAM5	DOE NCAR, USA	No	Yes
	10	CESM1-FASTCHEM	DOE NCAR, USA	No	Yes
	11	CNRM-CM5	CNRM and CERFACS, France	Yes	Yes
	12	CNRM-CM5-2	CNRM and CERFACS, France	Yes	Yes
	13	CSIRO-Mk3-6-0	CSIRO in collaboration with the QCCCE, Austrailia	Yes	Yes
	14	FIO-ESM	FIO,China	No	Yes
	15	GFDL-CM3	NOAA GFDL, USA	Yes	Yes
	16	GFDL-ESM2G	NOAA GFDL, USA	Yes	Yes
	17	GFDL-ESM2M	NOAA GFDL, USA	Yes	Yes
	18	GISS-E2-H	NASA/GISS, USA	No	Yes
	19	GISS-E2-H-CC	NASA/GISS, USA	No	Yes
	20	GISS-E2-R	NASA/GISS, USA	No	Yes
	21	GISS-E2-R-CC	NASA/GISS, USA	No	Yes
	22	HadGEM2-CC	MOHC, UK	No	Yes
	23	HadGEM2-ES	MOHC, UK	No	Yes
	24	IPSL-CM5A-LR	IPSL, France	Yes	Yes
	25	IPSL-CM5A-MR	IPSL, France	Yes	Yes
	26	IPSL-CM5B-LR	IPSL, France	Yes	Yes
	27	MIROC5	AORI, NIES, and JAMSTEC, Japan	Yes	Yes
	28	MIROC-ESM	AORI, NIES, and JAMSTEC, Japan	Yes	Yes
	29	MIROC-ESM-CHEM	AORI, NIES, and JAMSTEC, Japan	No	Yes
	30	MPI-ESM-LR	MPI-M, Germany	Yes	Yes
	31	MPI-ESM-MR	MPI-M, Germany	Yes	Yes
	32	MPI-ESM-P	MPI-M, Germany	No	Yes
	33	MRI-CGCM3	MRI, Japan	Yes	Yes
	34	NorESM1-M	NCC, Norway	Yes	Yes
	35	NorESM1-ME	NCC, Norway	No	Yes
	36	icnm4	INM, Russia	Yes	Yes

Model Type	Model Number	Model name	Institution	PiControl abrupt-4xCO2	PiControl SSP245
cmip6	1	ACCESS-CM2	CSIRO and ARCCSS, Australia	No	Yes
	2	ACCESS-ESM1-5	CSIRO and ARCCSS, Australia	No	Yes
	3	AWI-CM-1-1-MR	AWI, Germany	Yes	Yes
	4	AWI-ESM-1-1-LR	AWI, Germany	No	Yes
	5	BCC-CSM2-MR	BCC, China	Yes	Yes
	6	BCC-ESM1	BCC, China	Yes	Yes
	7	CESM2	NCAR, USA	Yes	Yes
	8	CESM2-FV2	NCAR, USA	Yes	Yes
	9	CESM2-WACCM	NCAR, USA	Yes	Yes
	10	CESM2-WACCM-FV2	NCAR, USA	Yes	Yes
	11	CIESM	THU,China	No	Yes
	12	CMCC-CM2-HR4	CMCC,Italy	No	Yes
	13	CMCC-CM2-SR5	CMCC,Italy	Yes	Yes
	14	CNRM-CM6-1	CNRM and CERFACS, France	No	Yes
	15	CNRM-CM6-1-HR	CNRM and CERFACS, France	Yes	Yes
	16	CNRM-CM6-1	CNRM and CERFACS, France	Yes	Yes
	17	CanESM5	CCCma, Canada	Yes	Yes
	18	E3SM-1-0	DOE E3SM-Project, USA	Yes	Yes
	19	E3SM-1-1	DOE E3SM-Project, USA	No	Yes
	20	E3SM-1-1-ECA	DOE E3SM-Project, USA	No	Yes
	21	EC-Earth3	EC-Earth consortium	No	Yes
	22	EC-Earth3-Veg	EC-Earth consortium	No	Yes
	23	FGOALS-f3-L	CAS, China	Yes	Yes
	24	FGOALS-g3	CAS, China	Yes	Yes
	25	GFDL-CM4	NOAA GFDL, USA	Yes	Yes
	26	GFDL-ESM4	NOAA GFDL, USA	No	Yes
	27	GISS-E2-1-G	NASA/GISS, USA	Yes	Yes
	28	GISS-E2-1-G-CC	NASA/GISS, USA	No	Yes
	29	GISS-E2-1-1-H	NASA/GISS, USA	Yes	Yes
	30	GISS-E2-2-G	NASA/GISS, USA	Yes	Yes
	31	HadGEM3-GC31-LL	MOHC, UK	No	Yes
	32	HadGEM3-GC31-MM	MOHC, UK	No	Yes
	33	IITM-ESM	CCCR-IITM, India	No	Yes
	34	INM-CM4-8	INM, Russia	Yes	Yes
	35	INM-CM5-0	INM, Russia	Yes	Yes
	36	IPSL-CM6A-LR	IPSL, France	Yes	Yes
	37	KACE-1-0-G	NIMS-KMA, Korea	No	Yes
	38	KIOST-ESM	KIOST, Rebuplic of korea	Yes	Yes
	39	MIROC-ES2L	AORI, NIES, and JAMSTEC, Japan	No	Yes
	40	MIROC6	AORI, NIES, and JAMSTEC, Japan	Yes	Yes
	41	MPI-ESM-1-2-HAM	MPI-M, Germany	Yes	Yes
	42	MPI-ESM1-2-HR	MPI-M, Germany	Yes	Yes
	43	MPI-ESM1-2-LR	MPI-M, Germany	Yes	Yes
	44	MRI-ESM2-0	MRI, Japan	Yes	Yes
	45	NESM3	NUIST, China	Yes	Yes
	46	NorCPM1	NCC, Norway	No	Yes
	47	NorESM2-LM	NCC, Norway	Yes	Yes
	48	NorESM2-MM	NCC, Norway	No	Yes
	49	SAM0-UNICON	SNU, Republic of korea	Yes	Yes
	50	TaiESM1	RCEC, Taiwan	Yes	Yes
	51	UKESM1-0-LL	MOHC, UK	No	Yes

Table S1. Descriptions of CMIP5/6 models used in this study.

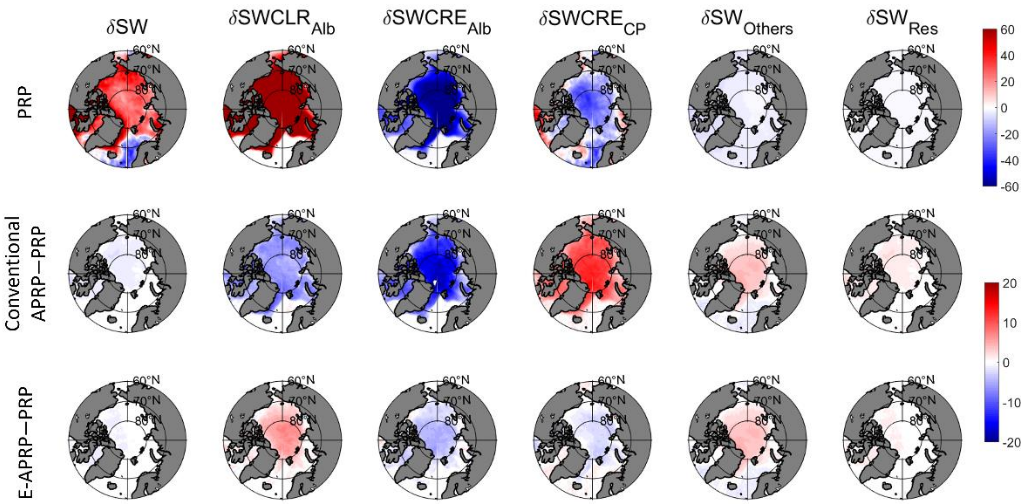

Figure S1. Changes in surface SW fluxes (W/m^2) averaged over the sunlit season (i.e., March through September) in response to a quadrupling of CO_2 from the CESM2 model simulations: PRP methods (first row), the difference between the conventional APRP and the PRP methods (second row), and the difference between the E-APRP and the PRP methods as in Figure 3 (third row).

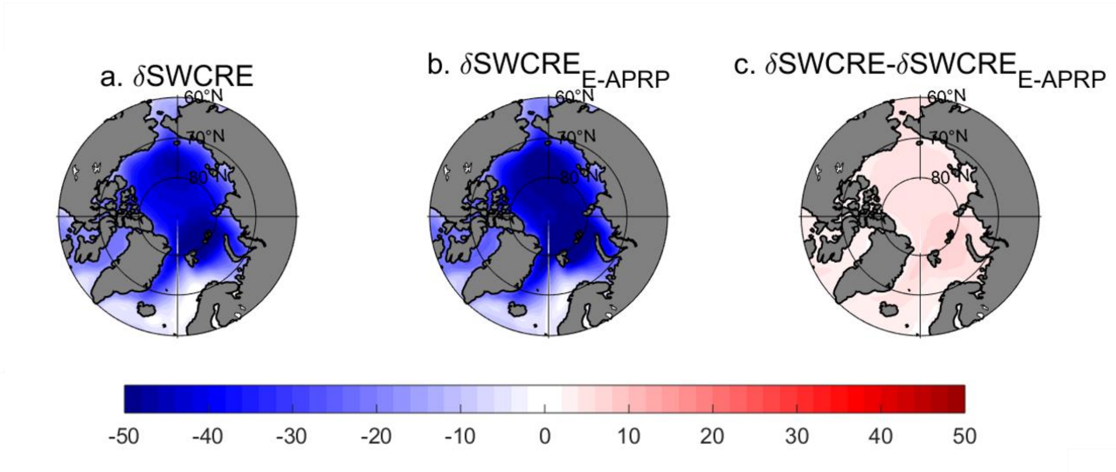

Figure S2. Average monthly maps of changes in SWCRE (W/m^2) in response to increases in CO_2 from **a.** CMIP multi-model mean outputs, **b.** the E-APRP method, and **c.** residual by subtracting the sum of E-APRP method from the model outputs. The months are averaged over the sunlit season after an abruptly quadrupling of CO_2 concentrations from the corresponding pre-industrial control climatology.

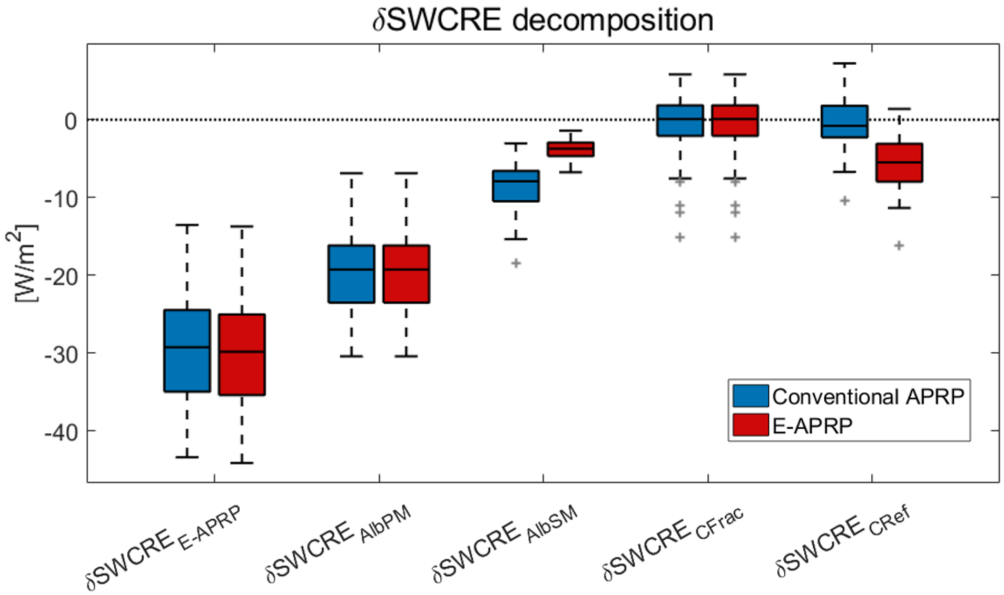

Figure S3. The box-and-whisker plot showing the inter-model spread of changes in SWCRE (W/m^2) from 54 CMIP models (Table S1) after an abrupt quadrupling of CO_2 concentrations from the pre-industrial level. The inter-model spread of changes in the SWCRE components as in Fig. 5 is calculated by conventional APRP (blue) and E-APRP (red). The definition of the boxplots is as in Fig. 4.

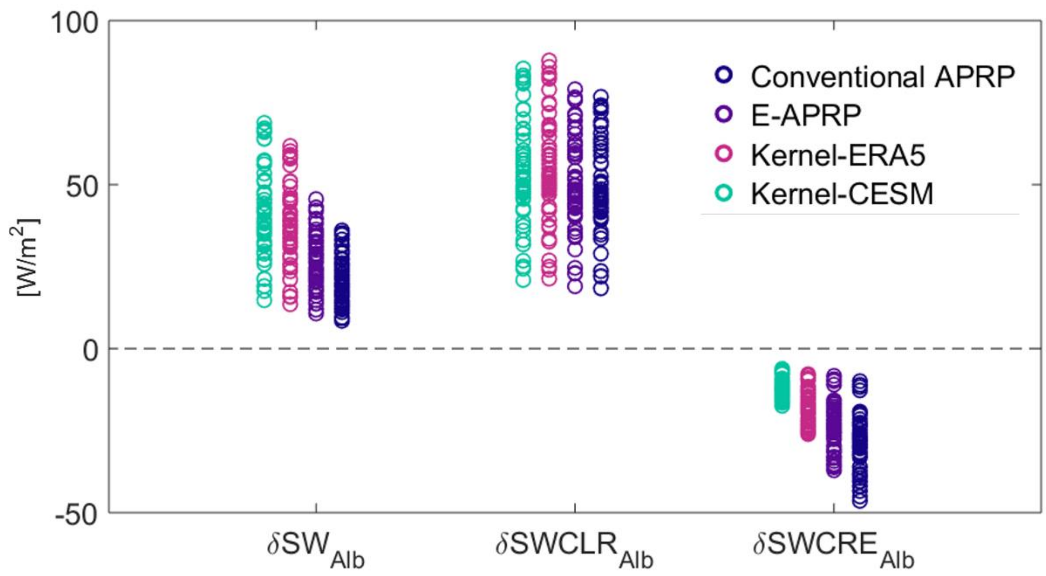

Figure S4. The scatter plot showing the inter-model spread of changes in SW, SWCLR and SWCRE due changes in surface albedo from 54 CMIP models (Table S1) after an abrupt quadrupling of CO_2 concentrations from the pre-industrial level. The conventional APRP and E-APRP methods calculate $\delta SWCRE_{Alb}$by summing the primary and secondary albedo cloud masking effect. Using the kernel-ERA5 (Huang et al. 2017) and kernel-CESM (Pendergrass et al. 2018) methods, $\delta SWCRE_{Alb}$ term is derived by subtracting the $\delta SWCRE_{Alb}$ and the $\delta SWCLR_{Alb}$ terms.