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Climate-driven chemistry and aerosol feedbacks in CMIP6 Earth system models

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S1 Model information

Earth System Model	Species	Description of emission parameterisation (Dependence on wind, temperature, vegetation, soil moisture …)	References
CNRM-ESM2-1	Sea Salt	Three particle size bins (boundaries of 0.03–0.5, 0.5–5, 5–20 μm)	(Michou et al 2020)
	Dust	Three particle size bins (boundaries of 0.01–1, 1–2.5, 2.5–20 μm	(Nabat et al, 2015)
	DMS	DMS flux is monthly climatology derived from DMS ocean concentration of Kettle et al (1999)	(Kettle et al., 1999, Michou et al, 2020)
	Vegetation VOC and OC	Climatology of biogenic secondary organic aerosol is taken from (Dentener et al., 2006)	(Michou et al., 2020)
	Marine VOC and OC	None	
UKESM1	Sea Salt	Primary emissions of sea-salt aerosols are calculated using the bin-resolved, windspeed-dependent flux parameterization.	(Gong, 2003)
	Dust	Mineral dust is described by a sectional/bin approach with 6 bins from size 0.0316 um to 31.6 um. Dependent on the interactively simulated bare soil fraction and soil moisture. UKESM1 uses the JULES land-surface scheme with TRIFFID vegetation dynamics	(Clark et al., 2011; Woodward, 2001)
	DMS	DMS are simulated interactively by the ocean biogeochemistry component, MEDUSA. The air-sea flux of DMS to the atmosphere uses the scheme of Liss and Merlivat (1986).	(Anderson et al., 2001; Liss and Merlivat, 1986)

	Vegetation VOC and OC	Emissions of monoterpenes and isoprene are generated by the interactive vegetation scheme. Monoterpene emissions are dependent on PAR and temperature whilst isoprene emissions are linked to photosynthesis rates. Monoterpenes are oxidised to generate condensable secondary organic material with a 26% molar yield.	(Guenther, 1995a; Pacifico et al., 2011)
	Marine VOC and OC	The organic mass fraction of the emitted sea spray aerosol is calculated as a function of the biological productivity (based on surface chlorophyll-a), the 10 m windspeed and the sea-salt dry diameter. Surface chlorophyll is interactively simulated by the ocean biogeochemistry scheme (MEDUSA).	(Gantt et al., 2011, 2012; Yool et al., 2013)
MIROC6	Sea Salt	Wind speed	(Monahan, 1986)
	Dust	6 radii from 0.1 to 10 μm	
	DMS	Dependence on downward solar flux	(Takemura et al., 2000)
	Vegetation VOC and OC	Global Emissions Inventory Activity (GEIA)	(Guenther, 1995b)
	Marine VOC and OC	Dependence on chlorophyll	(Gantt et al., 2011, 2012)
NorESM2	Sea Salt	Modal description of sea-salt with 3 modes (number median dry radii of 0.048, 0.30 and 0.75 um). Emissions depend on wind speed and sea-surface temperature.	(Kirkevåg et al., 2018; Salter et al., 2015)
	Dust	Modal description of mineral dust with 2 modes: accumulation and coarse (number mean dry radii of 1.59 and 2.0 um). Refractive index of dust: 1.53+2.4e-3i. Emissions based on DEAD model. Fixed map of soil erodibility and clay content, interactive vegetation state: LAI and canopy height; soil moisture and wind speed.	(Kirkevåg et al., 2018; Zender et al., 2003)

	DMS	DMS ocean concentration calculated by the ocean biogeochemistry module iHAMOCC interactively, dependent on wind speed and temperature.	(Nightingale et al., 2000; Tjiputra et al., 2020)
	Vegetation VOC and OC	Emissions of monoterpenes and isoprene are generated interactively by the MEGAN algorithm within the Community Land Model (CLM5). Dependence on plant functional type, light, temperature, leaf age, LAI, soil moisture (only for isoprene), and CO2 concentration (only for isoprene). LAI is calculated online in the model.	(Guenther et al., 2012; Kirkevåg et al., 2018)
	Marine VOC and OC	Primary organic upper ocean concentrations are based on a monthly chlorofyl-a climatology.	(O'Dowd et al., 2008)
GFDL-ESM4	Sea Salt	Sea salt is described in 5 bins with the following radii (0.1-0.5, 0.5-1,1-2,2-5,5-10 um). Emissions depend on wind speed and are modulated by sea surface temperature.	(Jaeglé et al., 2011; Monahan et al. 1986)
	Dust	Bin/modal scheme. Dust optical properties are calculated for each size bin using a Mie scattering code, with refractive indices from Balkanski et al. (2007), assuming a 2.7% content of hematite.	(Evans et al., 2016; Ginoux et al., 2001)
	DMS	DMS emissions depend on wind speed, using a prescribed monthly climatology of DMS concentrations in surface sea water, using parameterization of Liss and Merlivat (1986).	(Chin et al., 2002; Lana et al., 2011)
	Vegetation VOC and OC	Emissions of isoprene and monoterpenes are calculated online in GFDL-ESM4 using the Model of Emissions of Gases and Aerosols from Nature (MEGAN; as a function of simulated air temperature and shortwave radiative fluxes.	(Guenther et al., 2006, 2012)
	Marine VOC and OC	Oceanic source of OA - dependence on wind speed.	(O'Dowd et al., 2004)
GISS-E2-1	Sea Salt	Temperature and wind speed	

	Dust	Clay particles with radii less than 1 µm, while the three silt classes have radii between 1–2, 2–4, and 4–8 µm, respectively.	(Ginoux et al., 2001; Miller et al., 2006)
	DMS	Dependent on wind speed and DMS concentration	(Koch et al., 1999; Liss and Merlivat, 1986)
	Vegetation VOC and OC	Isoprene parameterized using light availability, underlying vegetation and temperature. Terpenes do not change interannually, seasonality based on the ORCHIDEE model.	(Guenther, 1995b; Tsigaridis et al., 2005)
	Marine VOC and OC	None	
CESM2-WACCM	Sea Salt	Modal description of sea-salt with 3 modes (aitken, accumulation and coarse model). Emissions depend on wind speed and sea-surface temperature	(Liu et al., 2012)
	Dust	Modal description of mineral dust with 3 modes (aitken, accumulation and coarse model). Emissions depend on wind friction velocity, soil moisture, and vegetation/snow cover	(Albani et al., 2015)
	DMS	Prescribed emissions	(Kettle and Andreae, 2000)
	Vegetation VOC and OC	No direct emissions of OC Vegetation VOC using MEGANv2.1 implementation in CLM as described in Guenther et al., 2012	(Guenther et al., 2012)
	Marine VOC and OC	No direct emissions of OC	(Emmons et al., 2020)

		Marine VOC are climatological emissions from ocean of CO, C2H6, C2H4, C3H8, C3H6 (see Fig. S1 of Emmons et al., 2020)	

Table S1: Descriptions of model components

Model	**piControl, abrupt-4xCO2**	**piClim-xx**
CNRM-ESM2-1	r1i1p1f2	r1i1p1f2
UKESM1	r1i1p1f2	r1i1p1f4
MIROC6	r1i1p1f1	r11i1p1f1 (piClim-control) r1i1p1f1(piClim-2x)
NorESM2	r1i1p1f1	r1i1p1f1
GFDL-ESM4	r1i1p1f1	r1i1p1f1
GISS-E2-1	r1i1p3f1	
CESM2-WACCM	r1i1p1f1	r1i2p1f1 (piClim-control) r1i1p1f1 (piClim-2x)

Table S2: List of CMIP6 simulation variant numbers used in the analysis

S2 Figures in support of analysis in section 4 of the main text.

S2.1 Dust

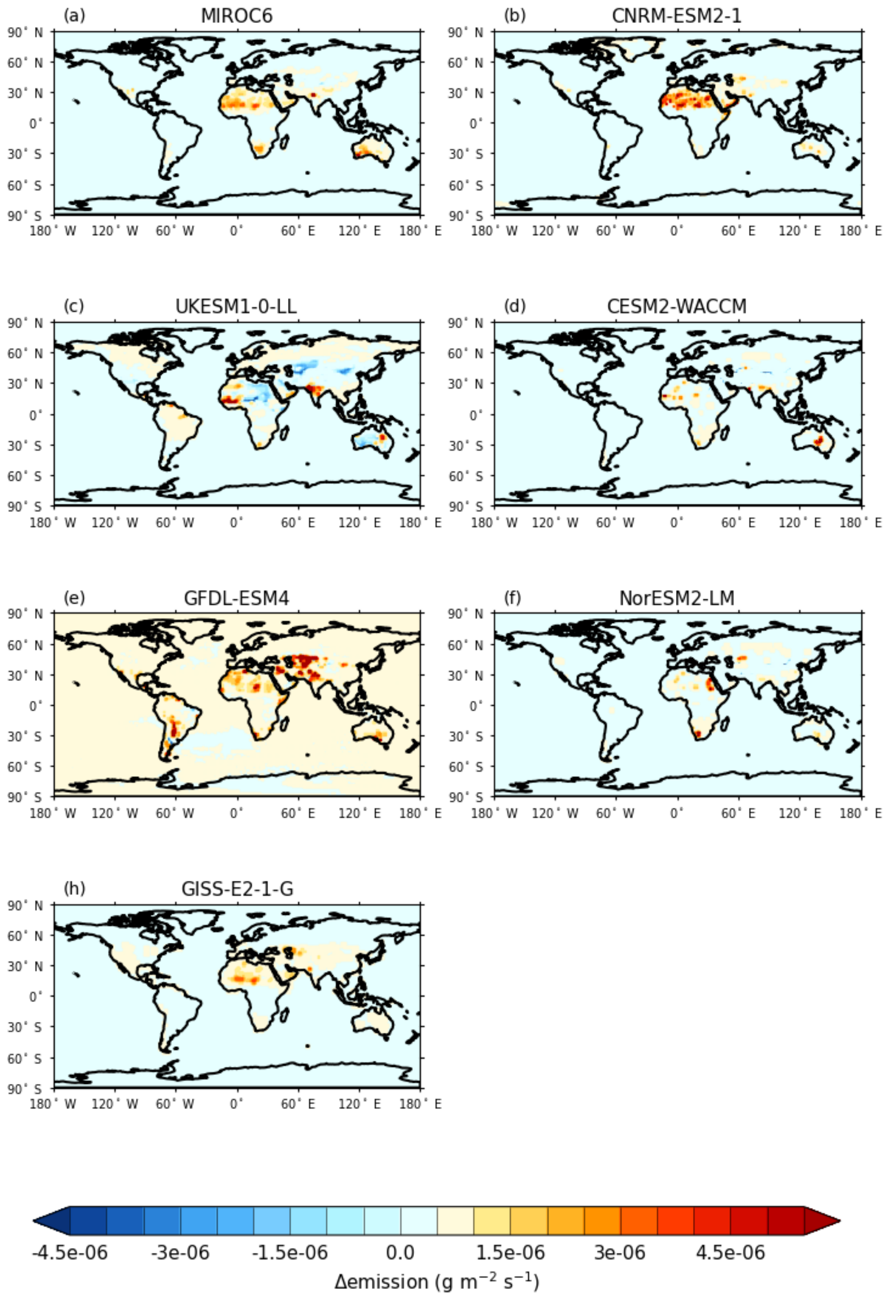

Figure S1: Change in dust emission abrupt-4xCO2 vs piControl .

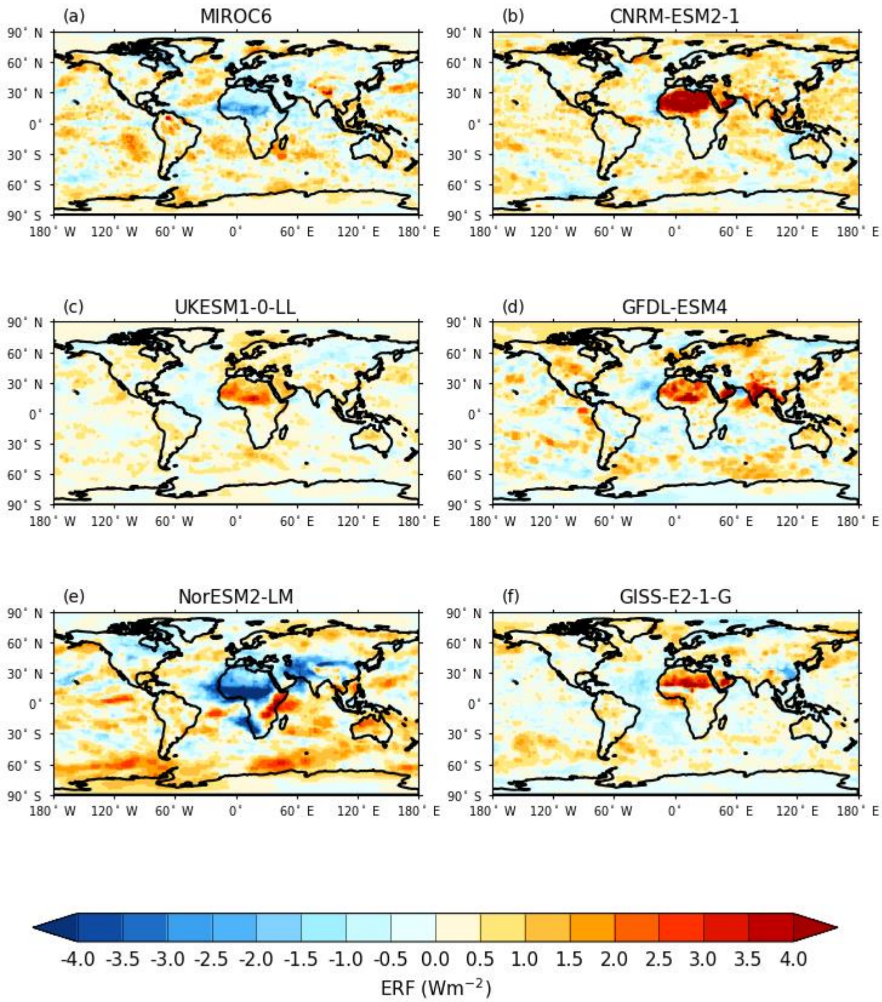

Figure S2: Effective radiative forcing from *2xdust* experiments.

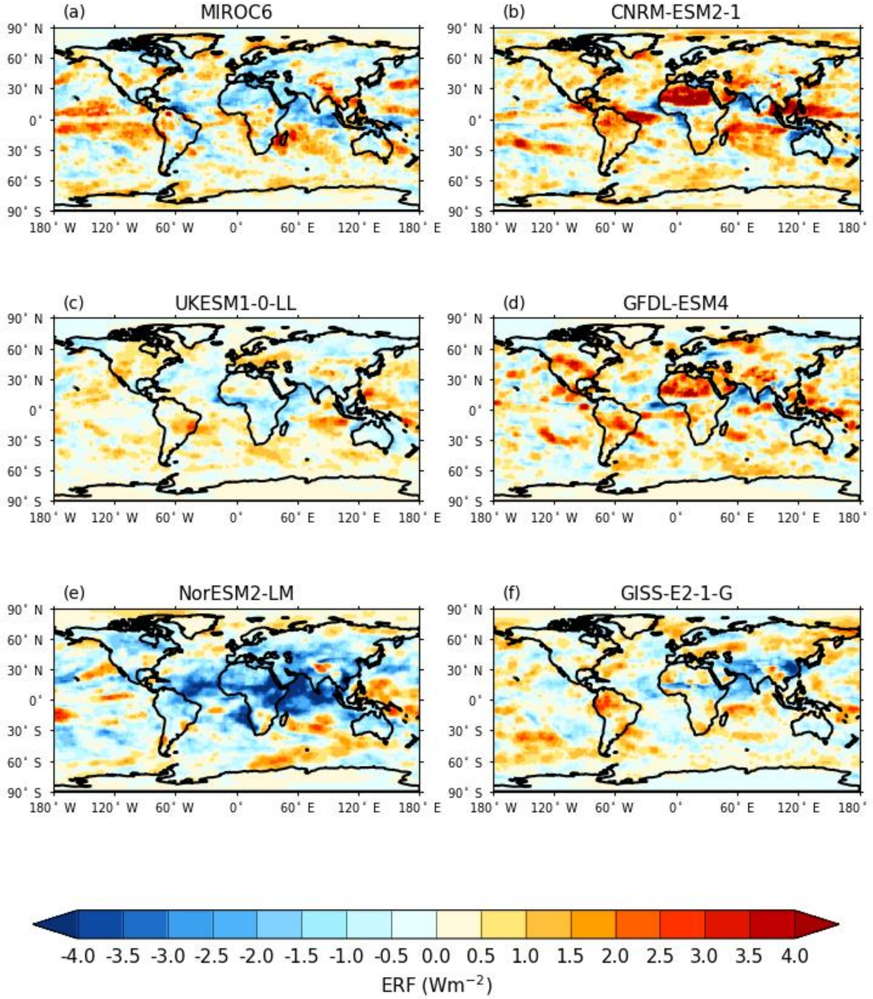

Figure S3: Shortwave effective radiative forcing from *2xdust* experiments.

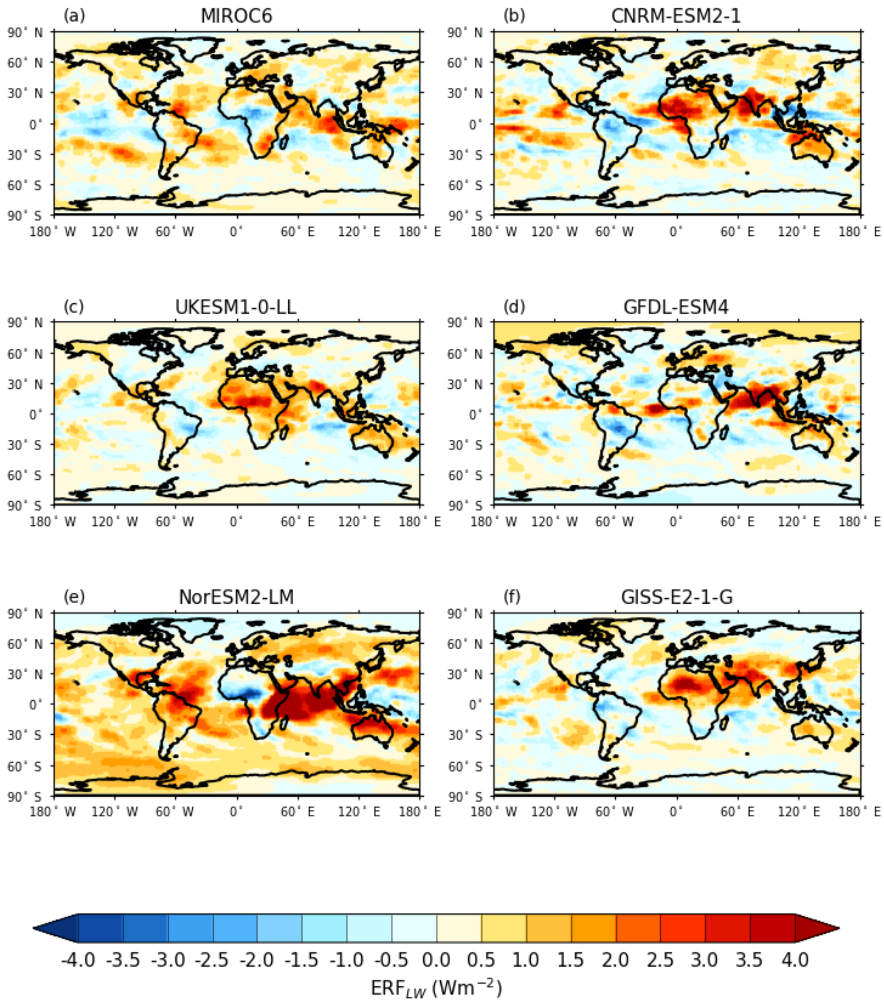

Figure S4: Longwave effective radiative forcing from *2xdust* experiments.

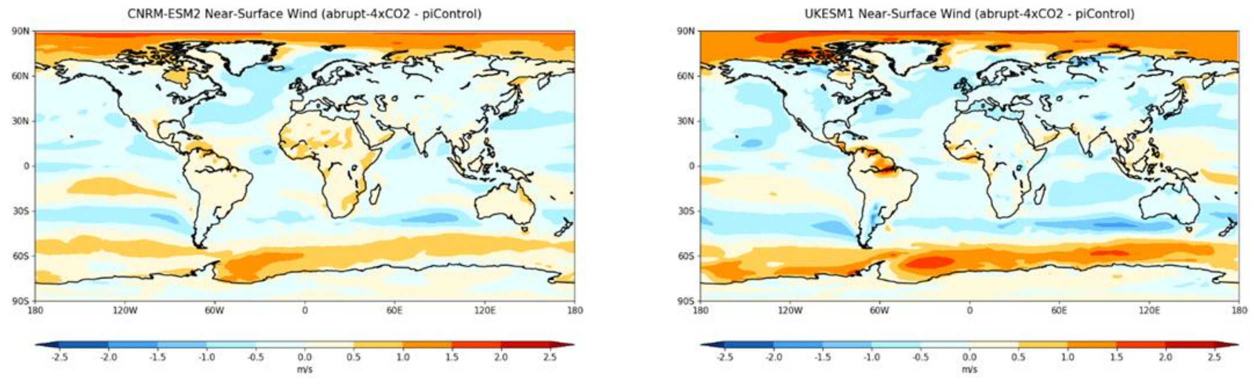

Fig S5: Difference in near-surface wind speeds for *4xCO2*. Shown are the difference for *4xCO2* against the pre-industrial climatology for (left) CNRM-ESM2-1 and (right) UKESM1 for the mean (over the last 30 years) of near-surface winds.

S2.2 Sea salt

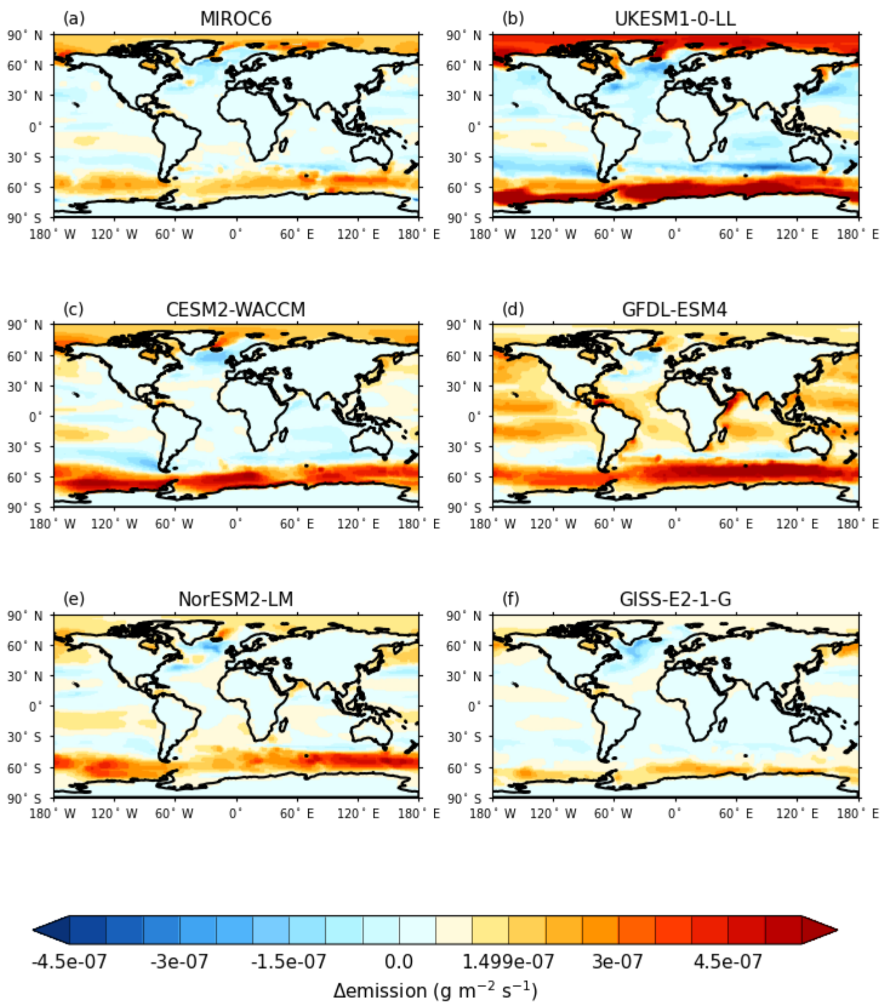

Figure S6: Change in sea salt emission abrupt-4xCO2 vs piControl .

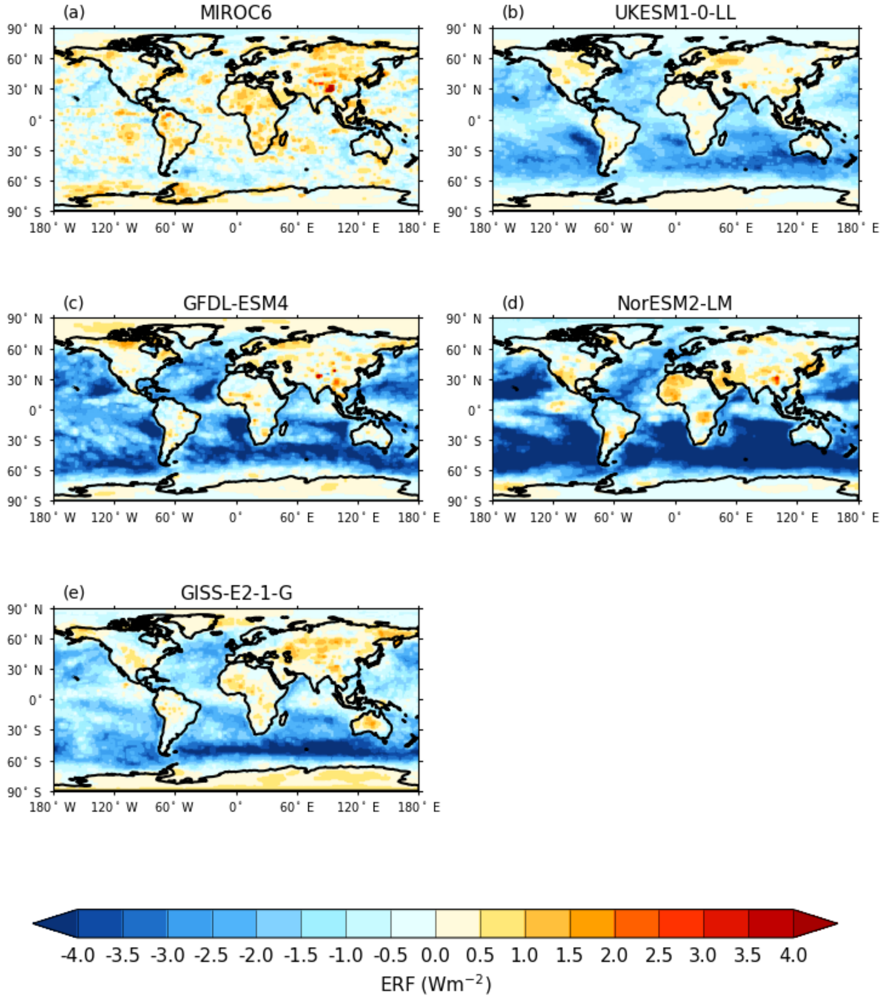

Figure S7: Effective radiative forcing from *2xss* experiments.

S2.3 DMS

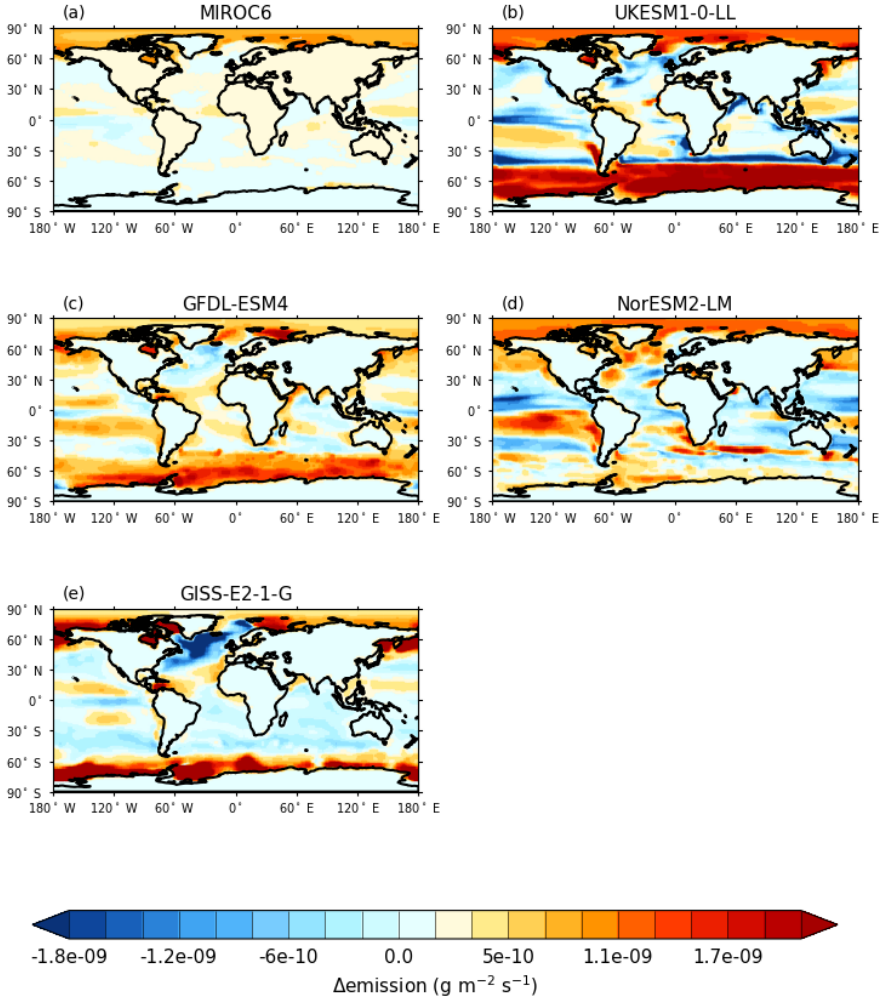

Figure S8: Change DMS emission (as g(S)) for abrupt-4xCO2 vs piControl .

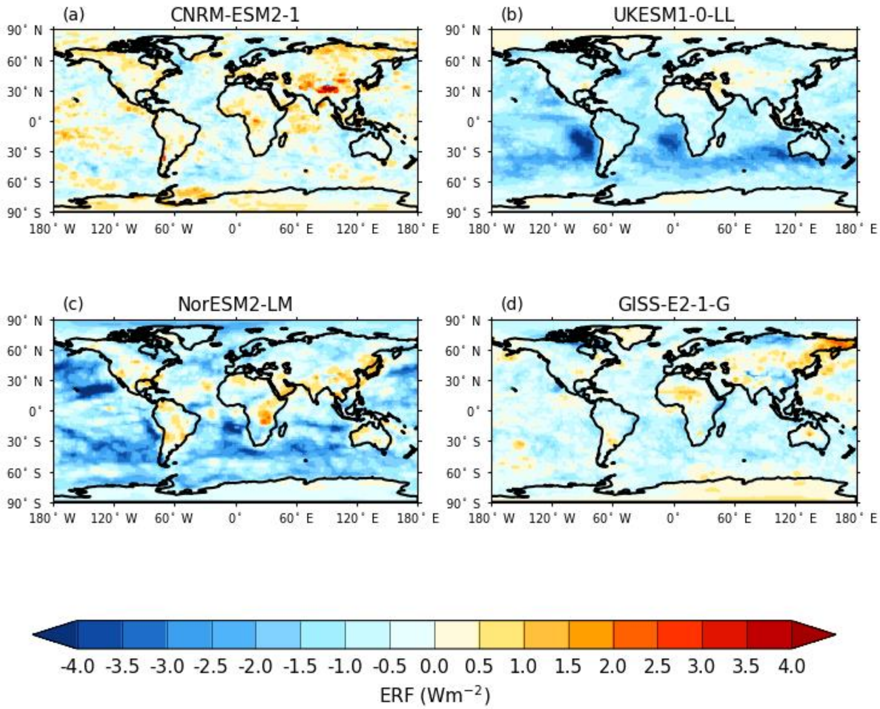

Figure S9: Effective radiative forcing from *2xDMS* experiments.

S2.4 Biogenic VOCs

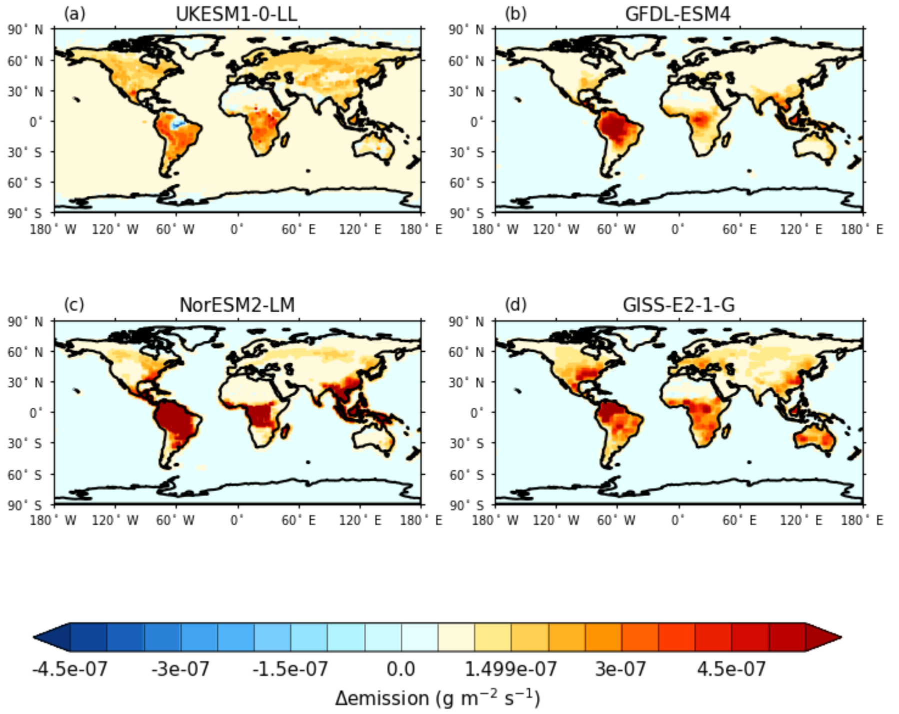

Figure S10: Change BVOC emission for abrupt-4xCO2 vs piControl .

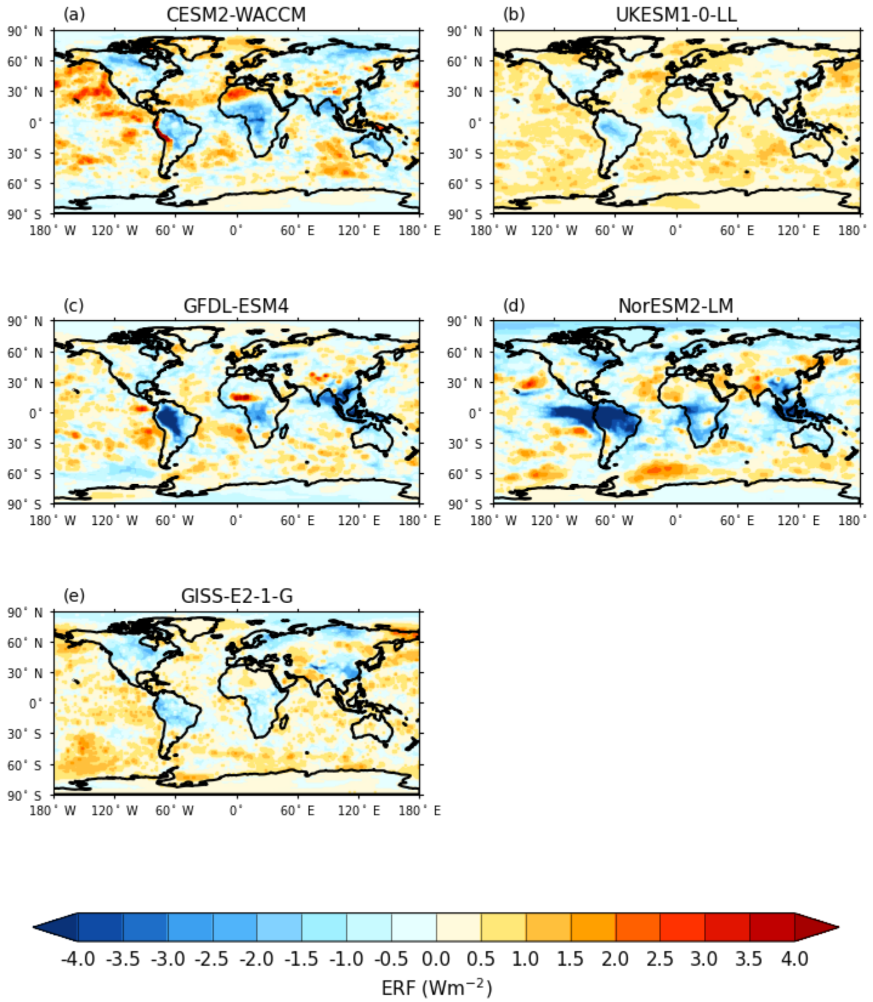

Figure S11: Effective radiative forcing from *2xVOC* experiments. For models other than NorESM2 this includes changes in ozone too.

S2.5 Ozone

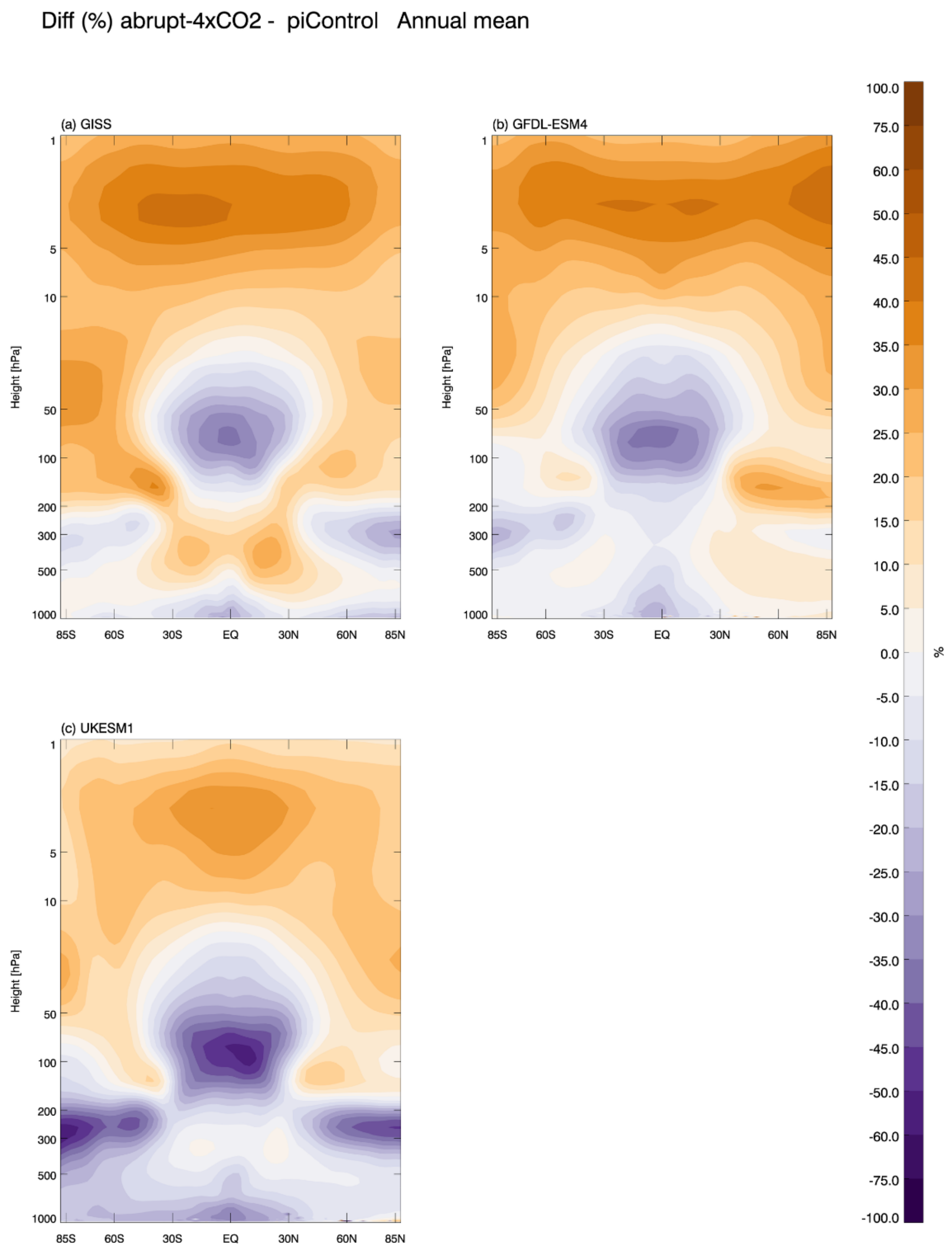

Figure S12: Change in ozone (%) for abrupt-4xCO2 vs piControl

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