Present Day Forcing by Methane (CH_4)

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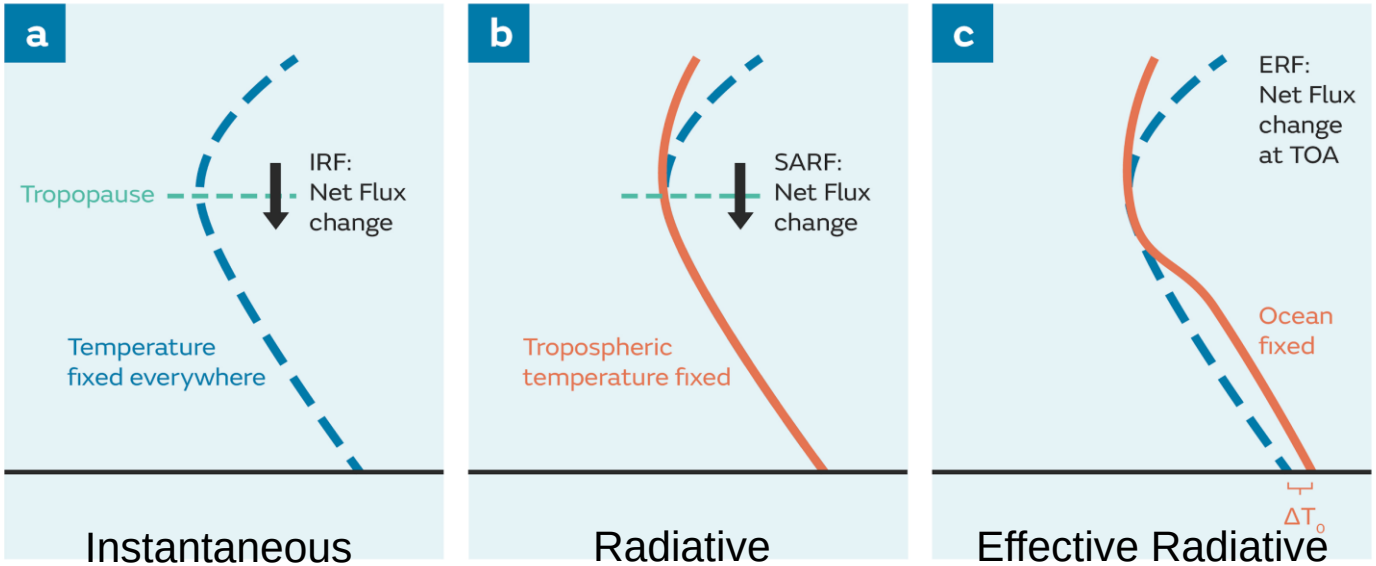
Motivation (1)

- Better characterization of changes to the Earth's radiative budget since the pre-industrial through co-ordinated experiments within RFMIP and AerChemMIP

- Use of the effective radiative forcing as the forcing metric of choice



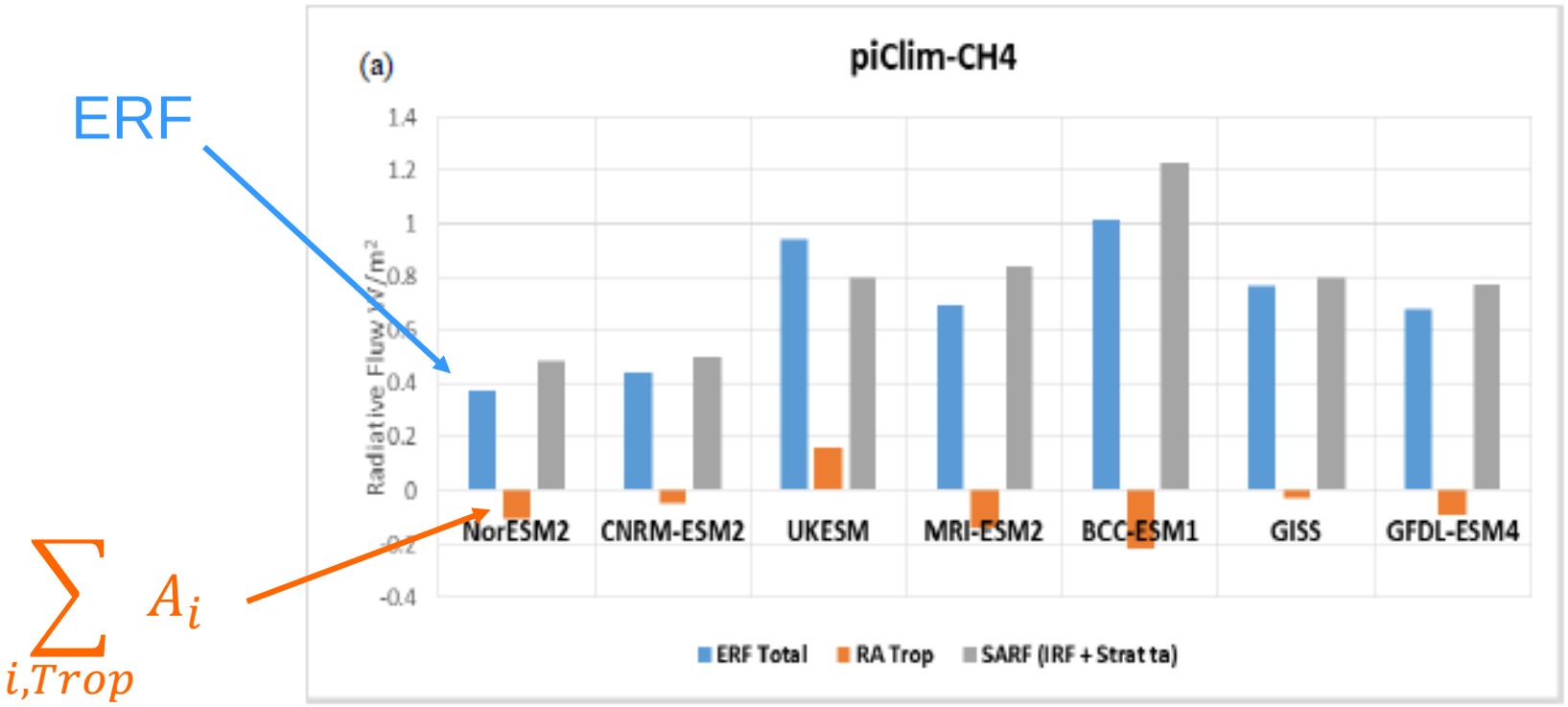
Instantaneous Radiative Forcing | Radiative Forcing | Effective Radiative Forcing

ERF is easier to diagnose in global climate models and is more representative of the eventual temperature response

$$ERF = IRF + \sum_i A_i$$

Chung and Soden, Environ. Res. Lett., 2016.

Motivation (2)



Thornhill et al., Atmos. Chem. Phys. (2021)

- Sum of the tropospheric adjustments in all models are negative except UKESM1 – most likely due to the positive cloud adjustment in UKESM1

- To provide a process-based understanding of the positive cloud adjustment in UKESM1

Methane ERF Breakdown

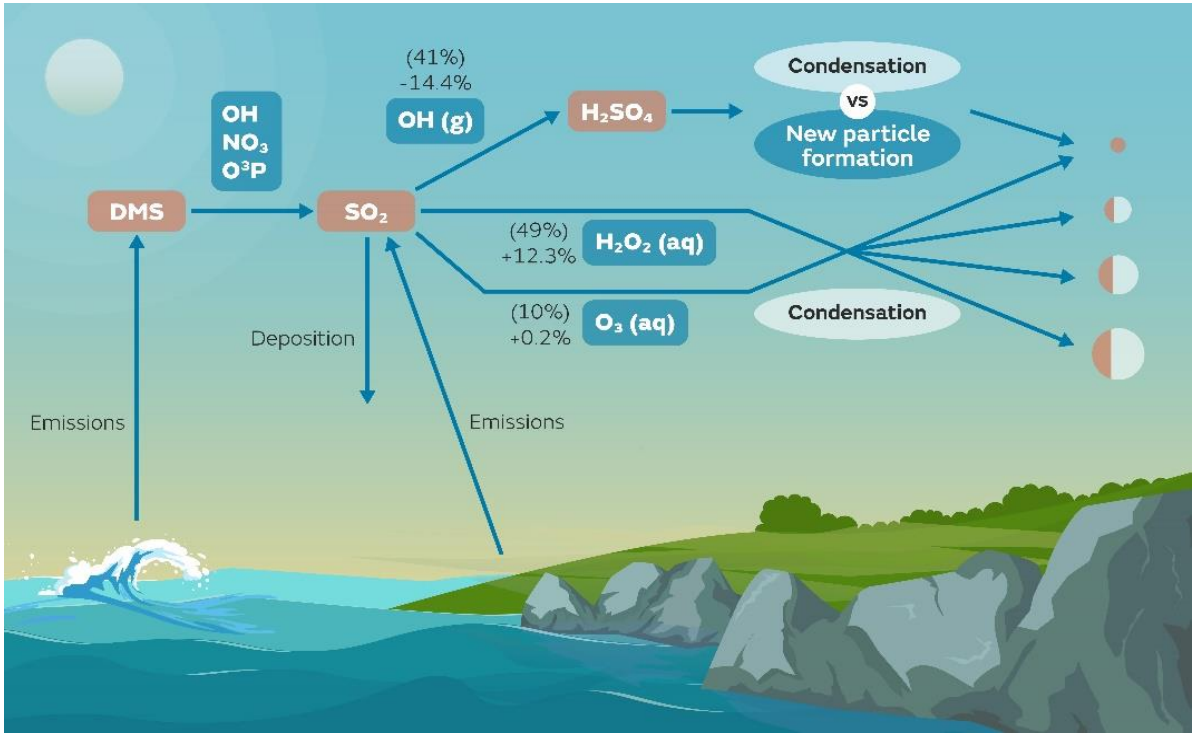
Perturbation	NET	LW'_{cs}	SW'_{cs}	LW CRE'	SW CRE'	NET'_{cs}	NET CRE'
ΔCH_4	0.97 ± 0.04	0.74 ± 0.02	0.11 ± 0.02	-0.39 ± 0.02	0.50 ± 0.02	0.85 ± 0.03	0.12 ± 0.02

Change in CRE diagnosed as recommended in Ghan (2013) Units: W m^{-2}

Active Forcing Agents and/or Interactions	LW'_{cs}	SW'_{cs}	LW CRE'	SW CRE'	NET CRE'
CH4, O3, H2O, ARI, **ACI**	0.74 ± 0.02	0.11 ± 0.02	-0.39 ± 0.02	0.50 ± 0.02	0.12 ± 0.02
CH4, O3, H2O, ARI	0.72 ± 0.03	0.11 ± 0.02	-0.38 ± 0.02	0.25 ± 0.03	-0.14 ± 0.03

- Using additional paired simulations, the **change in the CRE in UKESM1 is only positive when aerosol-cloud interactions are active**

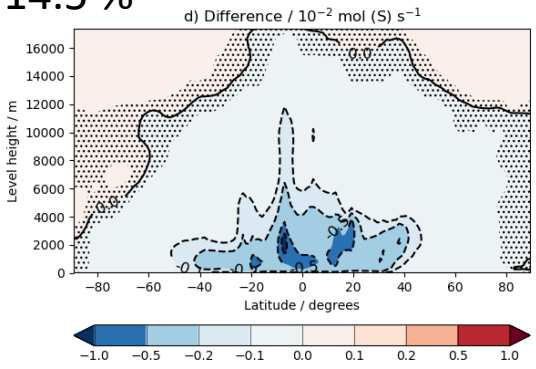
Sulphate Aerosol Formation



Schematic of sulphate aerosol formation in pre-industrial atmosphere

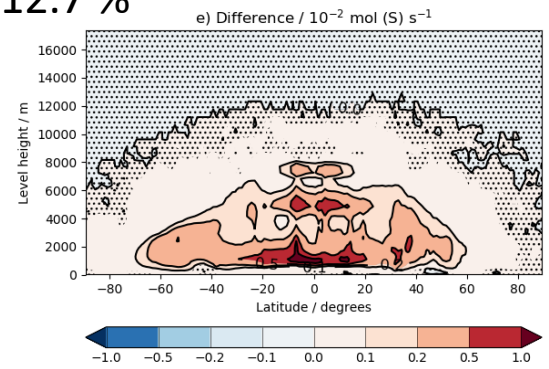
Stippling here indicates changes that are ***not*** significant at the 95% confidence level

-14.5 %



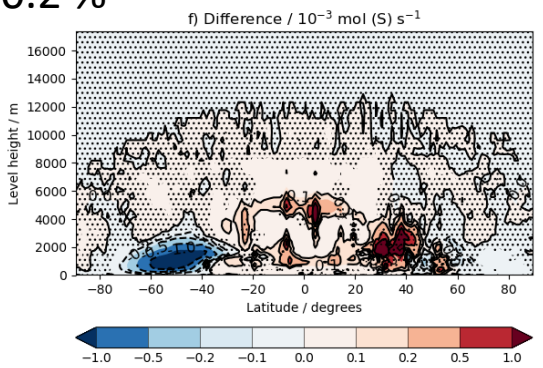
SO2+OH (g)

+12.7 %



SO2+H2O2 (aq)

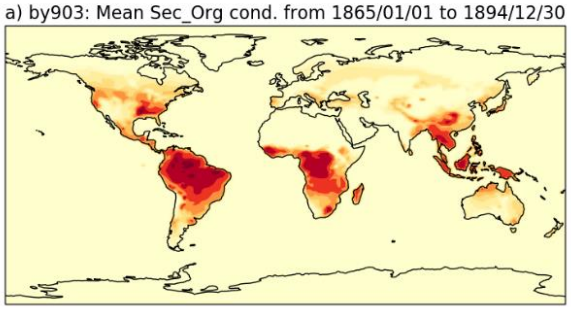
+0.2 %

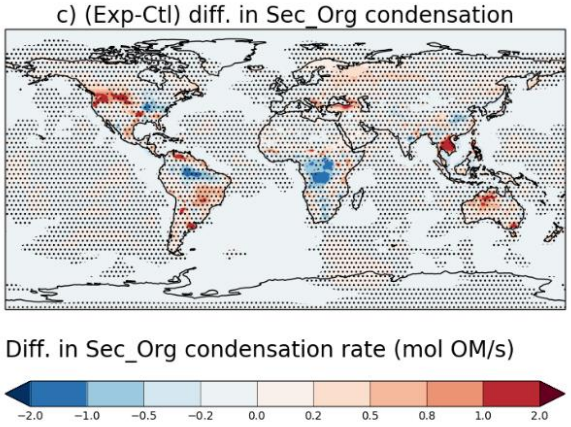


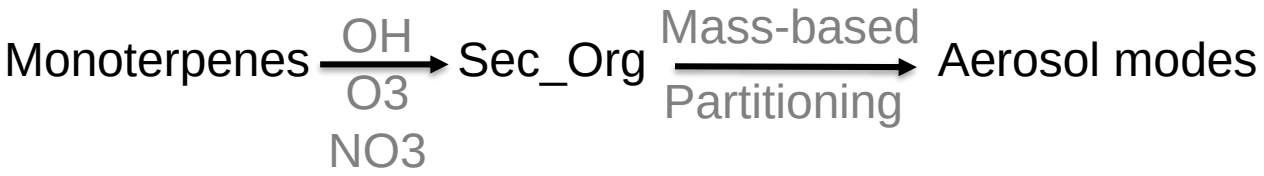
SO2+O3 (aq)

Biogenic SOA Formation

Species	Simulation	Production (Tg/yr)		Loss (Tg/yr)		Burden (Tg)
		Primary	Secondary	Dry	Wet	
OM	*piClim-control*	49.25 ± 0.01	38.24 ± 0.37	17.79 ± 0.14	69.35 ± 0.32	1.28 ± 0.02
	piClim-CH4	49.25 ± 0.01	38.35 ± 0.30	17.78 ± 0.12	69.46 ± 0.24	1.28 ± 0.02

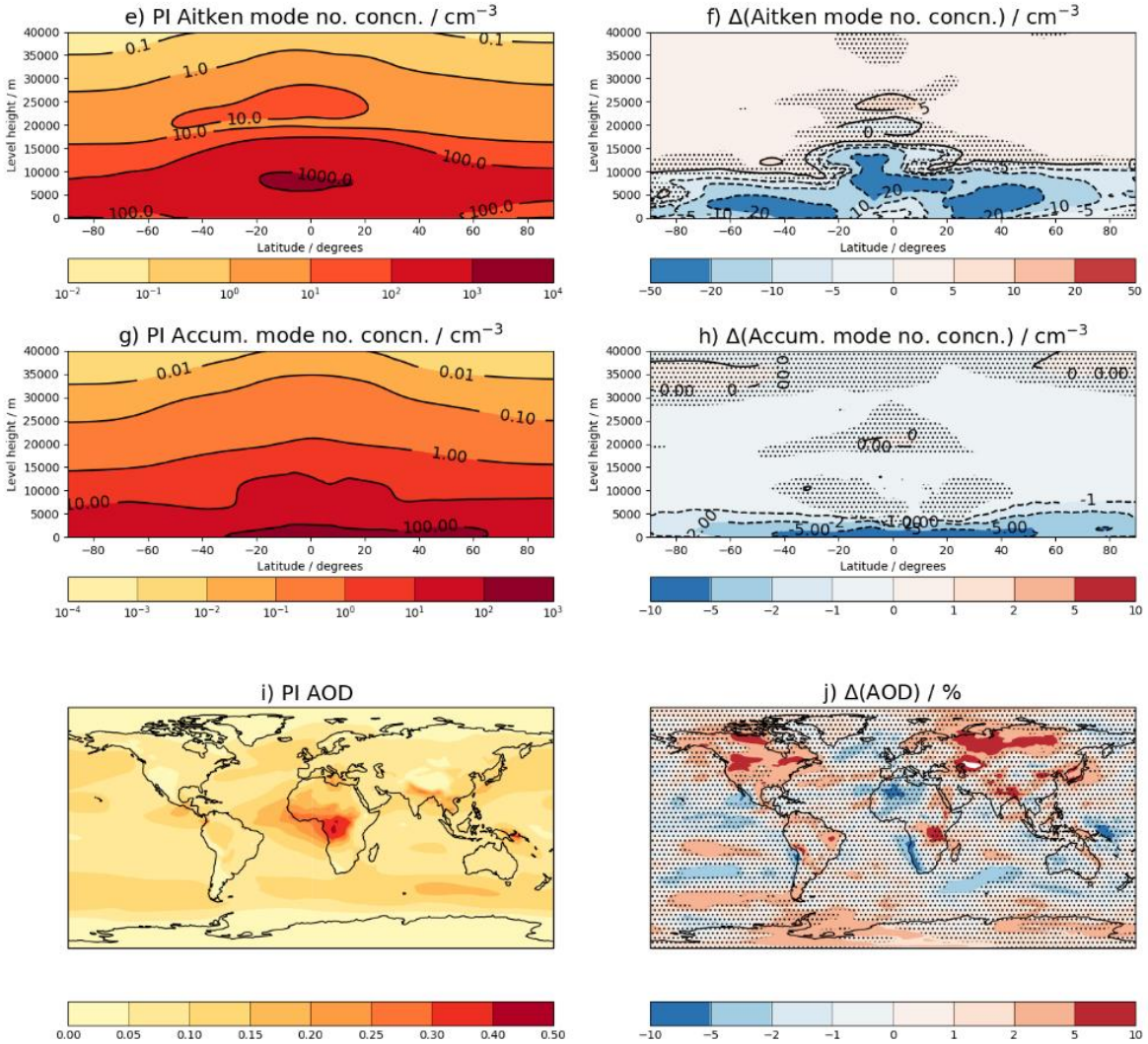






Global mean SOA production unchanged despite less condensation onto nucleation & Aitken modes

Aerosol Response



Aitken mode no. concn.

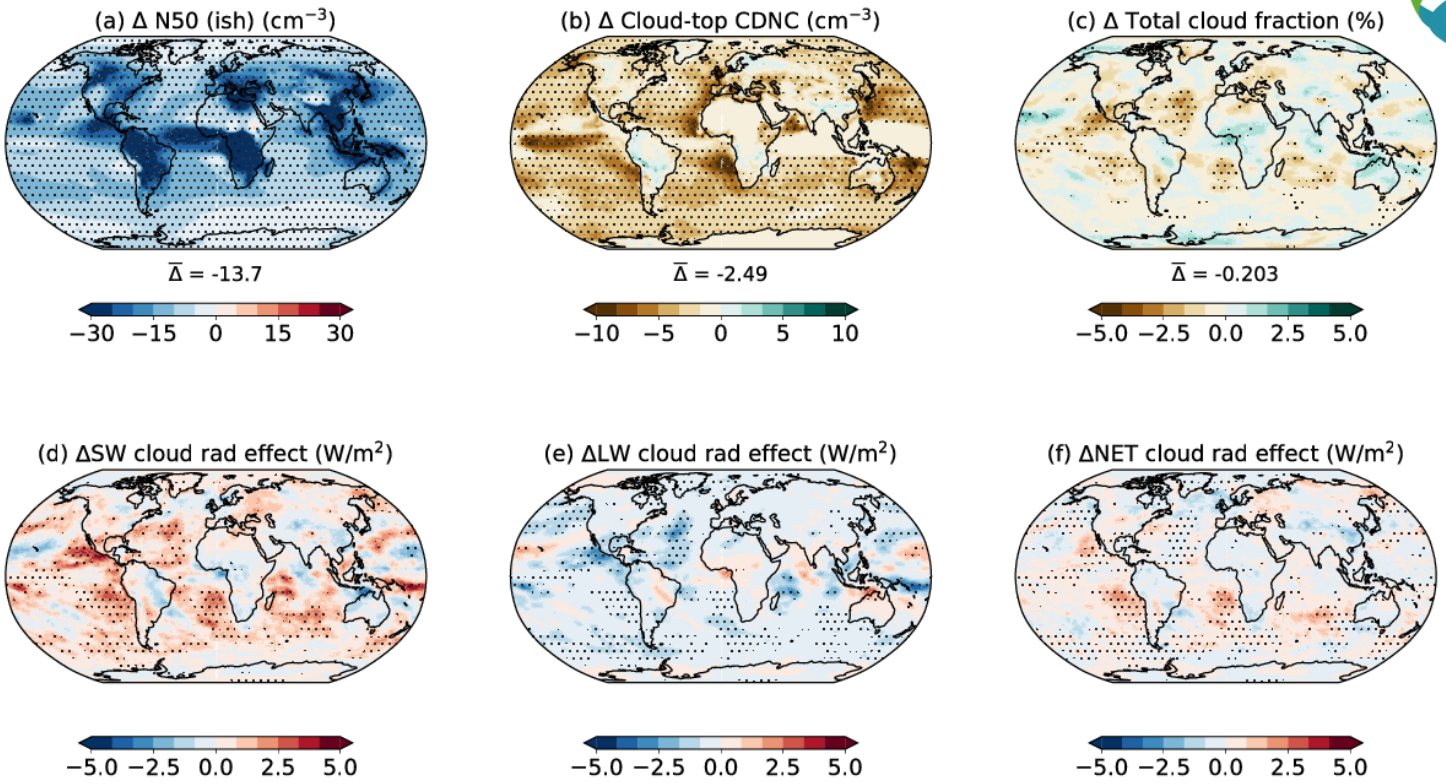
Accum. mode no. concn.

Aerosol optical depth (AOD)

Stippling here indicates changes that are ***not*** significant at the 95% confidence level

Global mean changes in aerosol mass & AOD are near-zero, but aerosol size distribution changes

Aerosol & Cloud Response



Stippling indicates changes that are significant at the 95% confidence level

- Little evidence that the positive cloud adjustment is dynamically-driven
- Local to regional changes in CRE correspond mainly with changes in cloud fraction
- The global mean CRE is ~0.12 Wm^{-2} more positive: +ve SW outweighs –ve LW
- Cloud Droplet Number Concentration (CDNC) decline is making the SW CRE generally more positive

Conclusions

- Methane ERF from UKESM1 is one of the highest of the AerChemMIP models
- Partly due to the inclusion of tropospheric chemistry (e.g., O_3)
- Partly due to the tropospheric adjustments being positive (Cloud adjustment)

We find:

- Little evidence that the cloud adjustment in UKESM1 is dynamically-driven
- Positive cloud adjustment is aerosol-mediated
- Overall reduction in cloud fraction & the positive LW CRE outweighs the negative SW CRE
- Changes in SO_2 oxidation pathways lead to a reduction in nucleation, a shift in aerosol size distribution and a reduction in CDNC

O'Connor et al., J. Adv. Earth Sys. Modeling, In revision (2021)