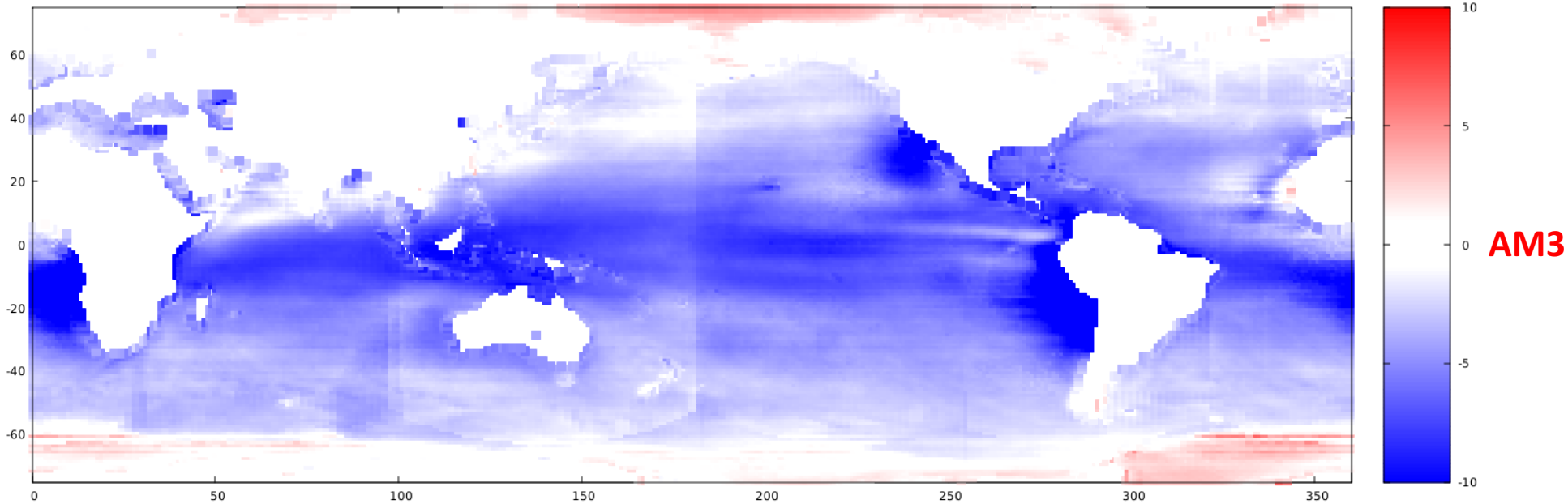
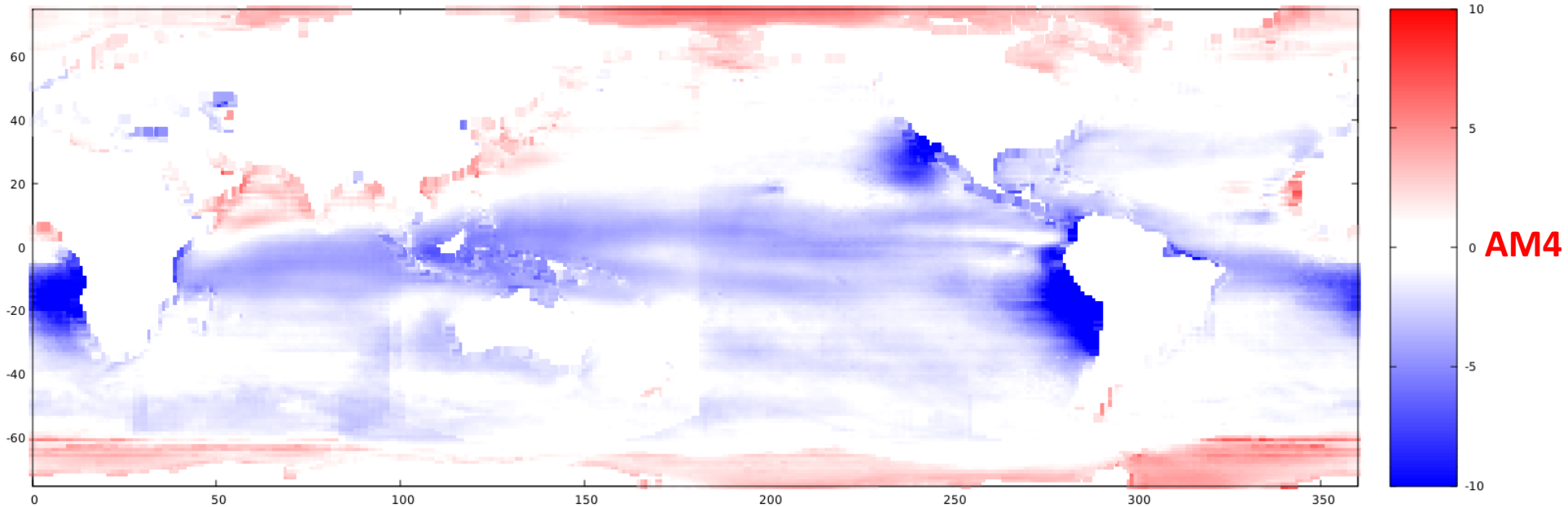
Changes to GCM Shortwave Radiation Code

	AM3	AM4
H2O Lines	HITRAN 2000 38 Int Points	HITRAN 2012 74 Int Points stratospheric absorption self broadening*
O2 Lines	HITRAN 2000	HITRAN 2012
CO2	HITRAN 2000	HITRAN 2012 With ESF FIT
O3	WMO 1987	WMO 1987
N2O	NON-EXISTENT	HITRAN 2012
CH4	NON-EXISTENT	HITRAN 2012
H2O Continuum	NON-EXISTENT	BPS 2.1
O2 Continuum	NON-EXISTENT	MTCKD 2.5
Liquid Drop	Slingo 4 → 16 µm	Hu 2.5 → 60 µm*
Solver:	2 Stream DE	2 Stream DE or 4 Stream DE (Li and Ramaswamy 1995)

All-Sky Shortwave Absorption by Atmosphere
CERES EBAF 2.8 minus GCM over ocean, Wm^{-2}





All differences due to physics updates shown in previous table

CERES EBAF:
81.3 Wm^{-2}
AM3:
76.8 Wm^{-2}
AM4:
79.7 Wm^{-2}

Impact of Improved Longwave CO_2 Formulation in AM4

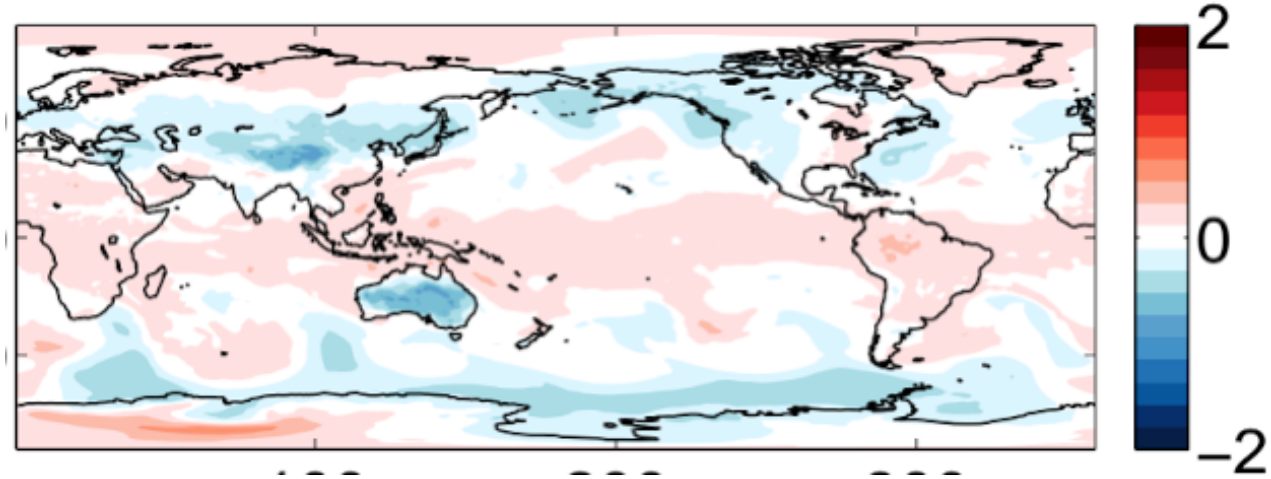
TROPOPAUSE

PPMV CO_2	LBL Wm^{-2}	GFDL (AM3) Wm^{-2}	GFDL (AM4) Wm^{-2}
280 → 560	5.63	5.16	5.59
560 → 1120	5.78	5.09	5.69
1120 → 2240	6.02	5.12	5.91
2240 → 4480	6.39	4.99	6.09
4480 → 8920	7.07	4.99	6.49

Calculated for CIRC1 atmosphere, so magnitude does not represent Global Mean

Global Mean ERF Radiative forcing to 4xCO2: AM3: 7.74 Wm-2
AM4: 8.46 Wm-2

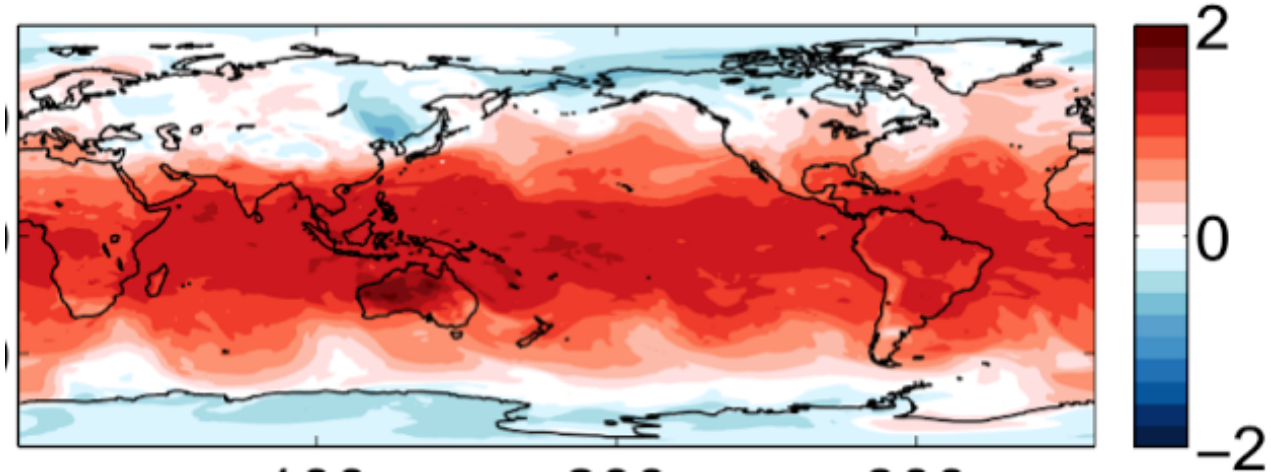
Benchmark of New AM4 CO_2 Longwave Radiation Code Against Line-by-Line Code
$1xCO_2$ -> $4xCO_2$ Radiative Forcing



Difference GFDL minus LBL at Tropopause, Wm^{-2}

RMSE=0.2 Wm^{-2}

Global Mean Error = 0.1 Wm^{-2}



Difference RRTMG minus LBL at Tropopause, Wm^{-2}

RMSE = 0.9 Wm^{-2}

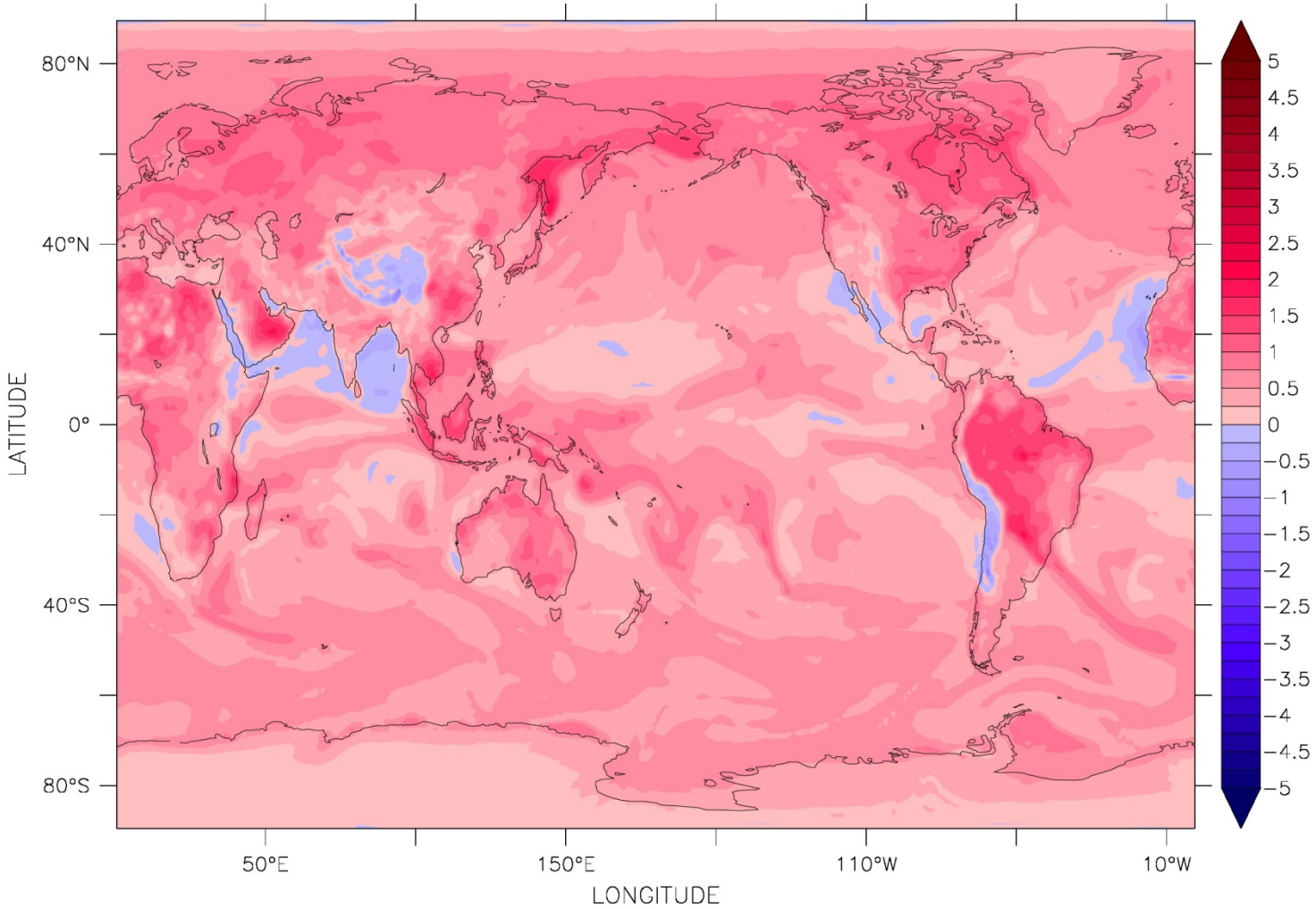
Global Mean Error = 0.9 Wm^{-2}

New GFDL code outperforms RRTMG for 4xCO2 Forcing in most regions.

Credit: Alexandra Jones

Clean-Sky Absorption Error GFDL

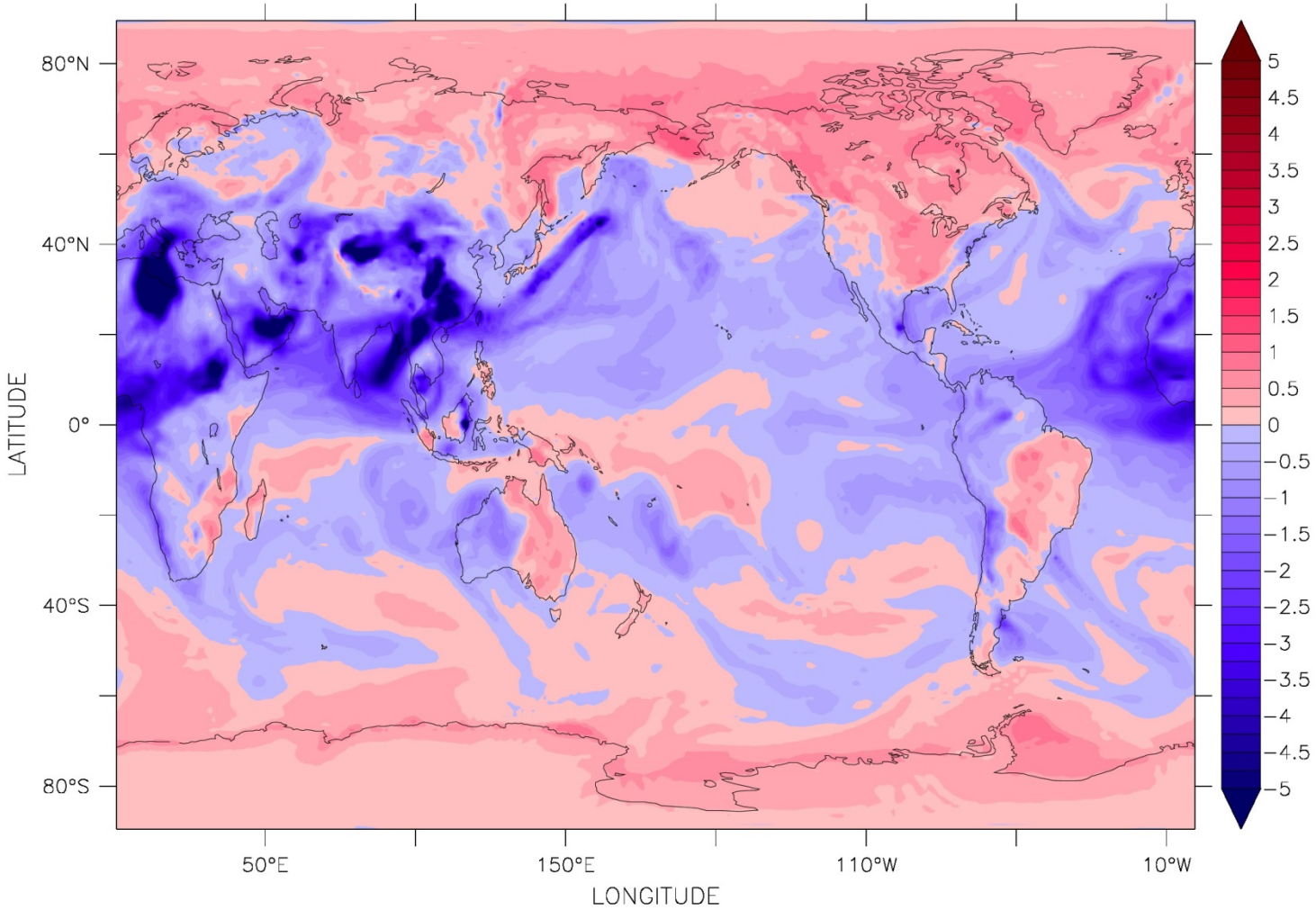
RED = GCM has too much absorption in atmosphere



Error in Clean Sky Absorption: GCM− LBL

Clear-Sky Absorption Error GFDL

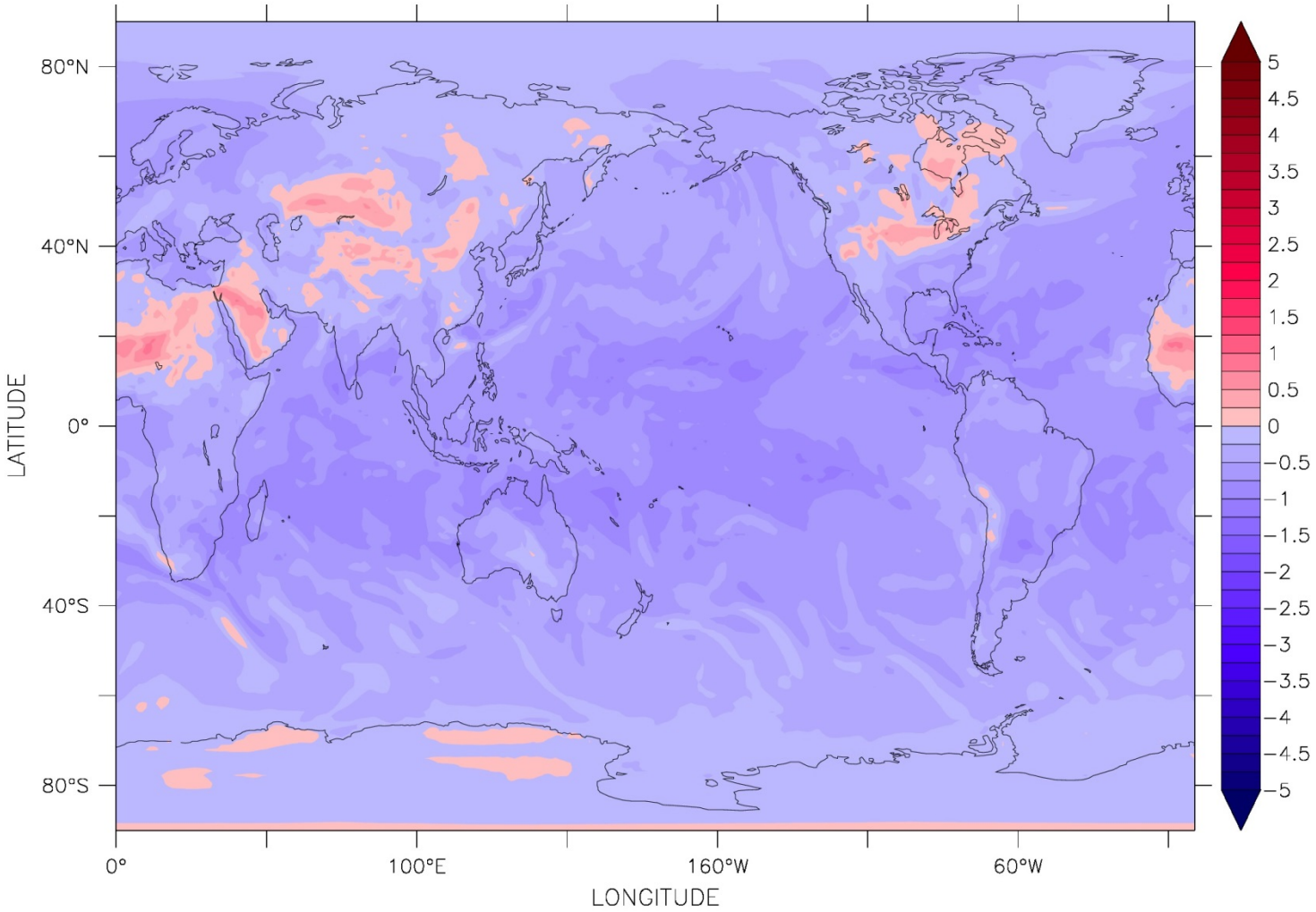
RED = GCM has too much absorption in atmosphere



Error in Clear Sky Absorption: GCM− LBL

Clean-Sky Absorption Error CESM

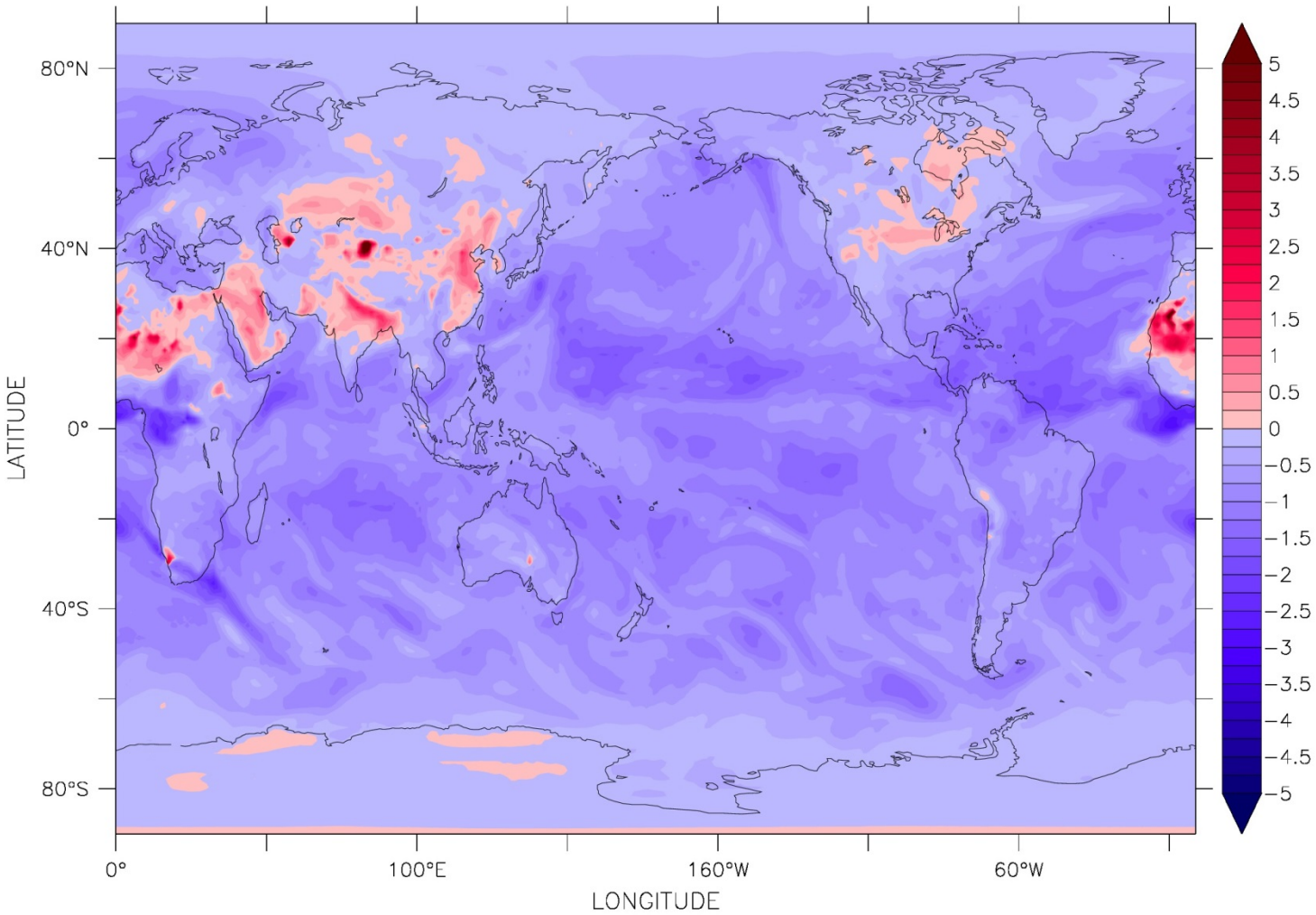
RED = GCM has too much absorption in atmosphere



Error in Clean Sky Absorption: GCM− LBL

Clear-Sky Absorption Error CESM

RED = GCM has too much absorption in atmosphere



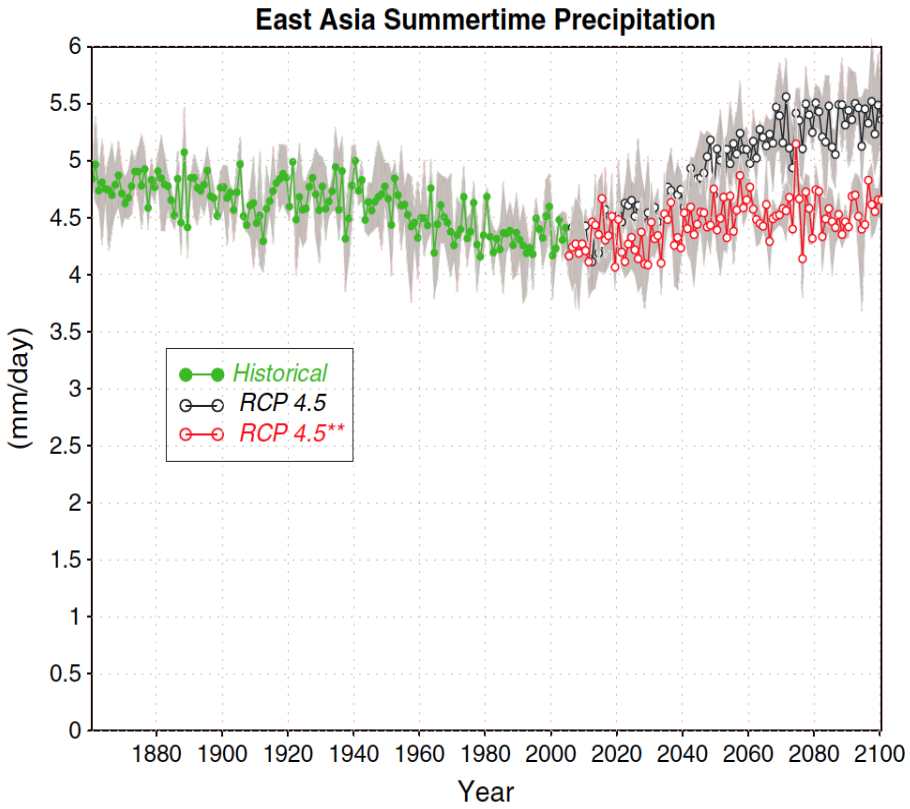
Error in Clear Sky Absorption: GCM− LBL

US-centric MIP

Jean-Francois Lamarque and Gavin Schmidt

Basic research question

- What have been the climate and air quality impacts of the Clean Air policies in the United States?

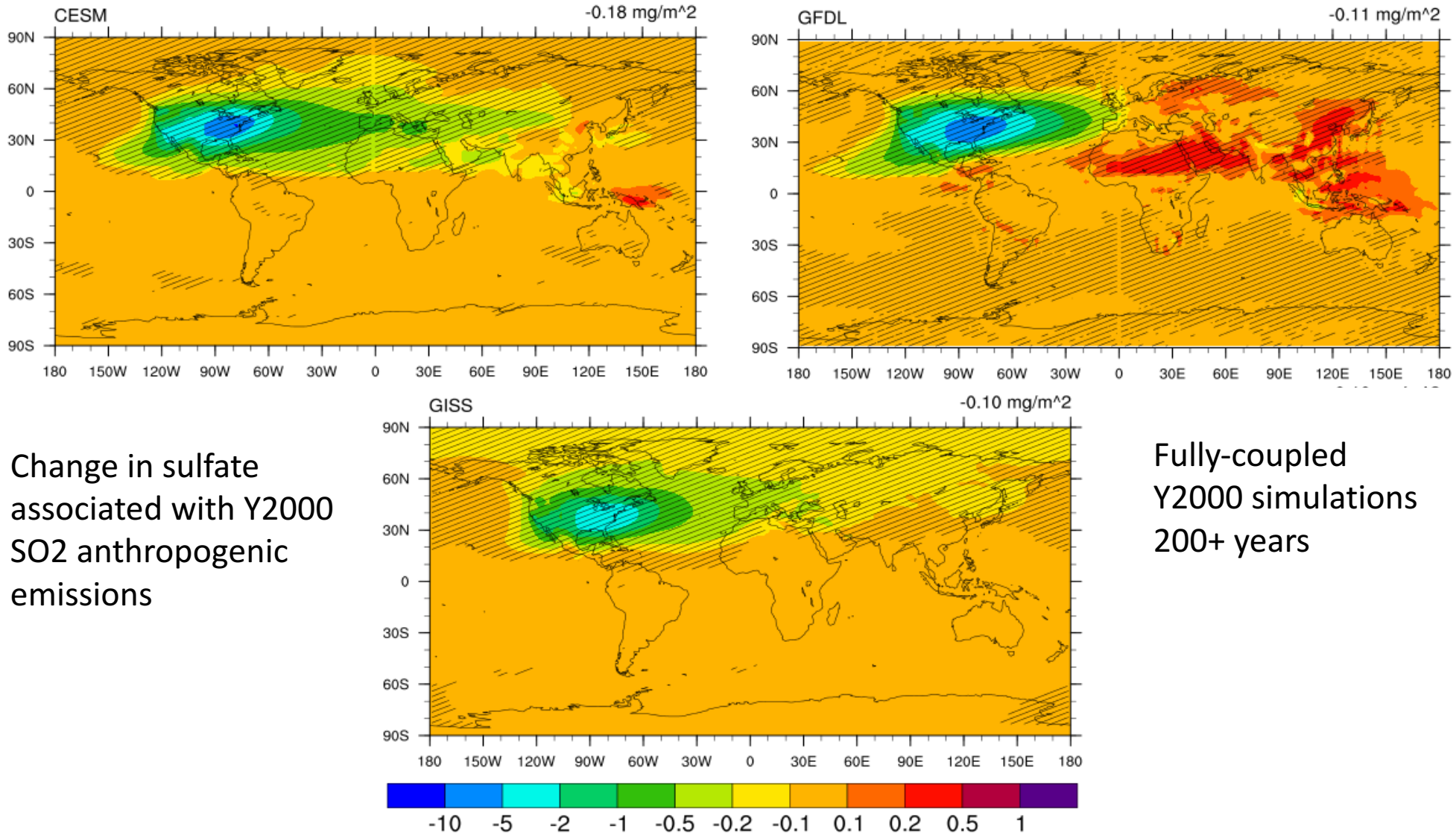


Summertime precipitation (mm.day^{-1}) as simulated by GFDL CM3, averaged over East Asia. The red dots indicate the simulation in which the RCP4.5 aerosol emissions are kept at their 2005 level throughout the 21st century, rather than the global reduction in SO_2 (black carbon) emissions by a factor of 5 (2) by 2100 in RCP4.5. Shading indicates the 3-member ensemble envelope. From Levy et al. (2013).

Basic research question

- What have been the climate and air quality impacts of the Clean Air policies in the United States?
- Builds on CMIP6 historical emissions, with an additional “world-avoided” scenario for short-lived climate forcers
- ➢ Have contacted S. Smith (PNNL) and he agreed that he could generate such emission scenario
- Will take advantage of the CMIP historical simulation ensemble (3-10 members)
- Will complement AerChemMIP AQ topic (based on future conditions)

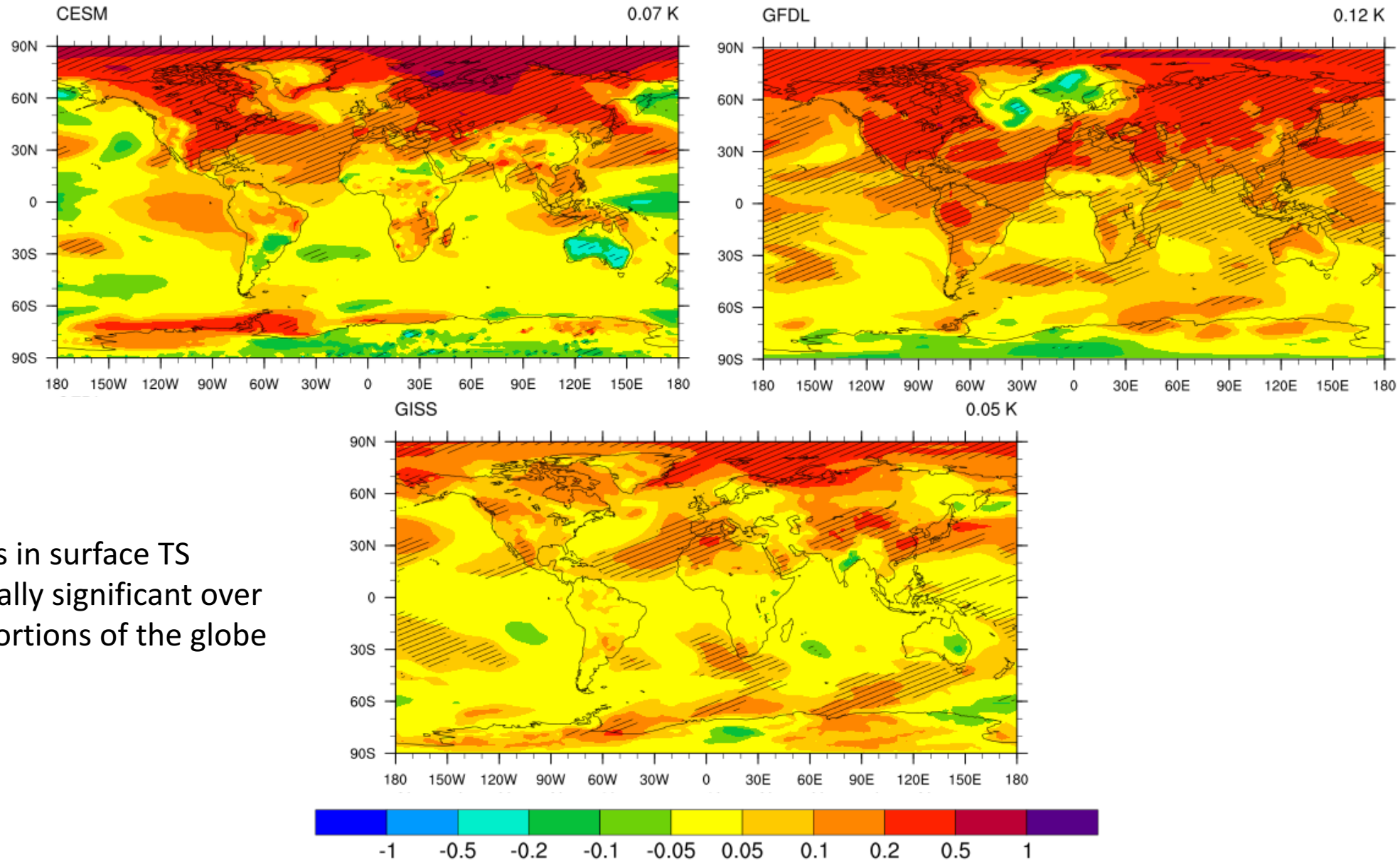
Proof of concept: US SO2 emissions



Change in sulfate associated with Y2000 SO2 anthropogenic emissions

Fully-coupled Y2000 simulations 200+ years

Change in surface T



Changes in surface TS statistically significant over many portions of the globe