Supplemental Material

Drivers of precipitation change: An energetic understanding: Supplementary Materials

Table S1: PDRMIP model details.

Model	**Version**	**Ocean Setup**	**Aerosol Setup**	**Baseline**
CanESM2	2010	Coupled Ocean	Emissions	Present-day
CESM1-CAM4	1.0.3	Slab Ocean	Fixed Concentrations	Present-day
CESM1-CAM5	1.1.2	Coupled Ocean	Emissions	Present-day
GISS-E2-R	E2-R	Coupled Ocean	Fixed Concentrations	Present-day
HadGEM2	6.6.3	Coupled Ocean	Emissions	Pre-industrial
HadGEM3	GA 4.0	Coupled Ocean	Fixed Concentrations	Present-day
IPSL-CM5A	CMIP5	Coupled Ocean	Fixed Concentrations	Present-day
MPI-ESM	1.1.00p2	Coupled Ocean	N/A	Present-day
NorESM1	M (intermediate resolution)	Coupled Ocean	Fixed Concentrations	Present-day
MIROC-SPRINTARS	5.9.0	Coupled Ocean	Emissions	Present-day

Table S2: CMIP5 models used for historical and future analysis. Crosses indicate model data was available and dashes indicate data was not available.

Model	Historical	RCP4.5	RCP8.5
CNRM-CM5	X	X	X
CNRM-CM5.2	X	-	-
FGOALs-g2	X	X	X
GFDL-CM2.1	X	-	-
GFDL-CM3	X	X	X
GFDL-ESM2G	X	X	X
GFDL-ESM2M	X	X	X
GISS-E2-H	X	X	X
GISS-E2-H-CC	X	-	X
GISS-E2-R	X	X	X
GISS-E2-R-CC	X	X	X
HadCM3	X	-	-
HadGEM2-AO	X	X	X
HadGEM2-CC	X	X	X
HadGEM2-ES	X	X	X
INM-CM4	X	X	X
IPSL-CM5A-LR	X	X	X
IPSL-CM5A-MR	X	X	X
IPSL-CM5B-LR	X	X	X
MIROC5	X	X	X
MIROC-ESM	X	X	X
MIROC-ESM-CHEM	X	X	X
MPI-ESM-LR	X	X	X
MPI-ESM-MR	X	X	X
MPI-ESM-P	X	-	-
MRI-CGCM3	X	X	X
NorESM1-ME	X	X	X

Table S3: PDRMIP multi-model mean *R* factors (fast precipitation response per unit global mean TOA forcing), and hydrological sensitivities calculated with respect to global-mean surface air temperature change (*HS*) and sea-mean surface air temperature change (*HS_SST*). Values are given for the global, land and sea mean.

Forcing Scenario	***R* Factor (P_{fast}/F_{TOA}) (mm yr^{-1}/W m^{-2})**		
	Global	**Land**	**Sea**
2xCO2	-7.53 ± 1.5	0.17 ± 4.4	-10.7 ± 1.2
3xCH4	-5.52 ± 2.9	4.46 ± 3.4	-9.62 ± 3.8
5xSO4	0.57 ± 2.0	10.8 ± 3.8	-3.62 ± 1.9
10xBC	-28.7 ± 6.8	-5.24 ± 10.3	-38.3 ± 7.7
2%Sol	-1.93 ± 0.5	8.17 ± 1.3	-6.06 ± 0.6
	***HS* (mm yr^{-1} K^{-1})**		
	Global	**Land**	**Sea**
2xCO2	31.2 ± 4.3	14.3 ± 5.4	38.1 ± 5.9
3xCH4	34.9 ± 7.1	15.1 ± 10.5	43.1 ± 10.2
5xSO4	32.0 ± 4.9	12.1 ± 6.3	40.1 ± 7.3
10xBC	32.3 ± 10.6	-11.6 ± 20.0	50.2 ± 18.7
2%Sol	32.6 ± 5.2	8.04 ± 7.0	42.6 ± 8.1
	***HS_SST* (mm yr^{-1} K^{-1})**		
	Global	**Land**	**Sea**
2xCO2	33.6 ± 4.4	15.3 ± 5.5	41.0 ± 6.3
3xCH4	37.2 ± 7.7	15.9 ± 10.9	46.0 ± 11.2
5xSO4	36.2 ± 5.7	13.6 ± 6.9	45.4 ± 8.7
10xBC	36.9 ± 14.9	-14.2 ± 22.5	57.8 ± 26.3
2%Sol	35.4 ± 5.5	8.63 ± 7.5	46.3 ± 8.8
Simple Model		12.5 ± 4.9	44.2 ± 7.5

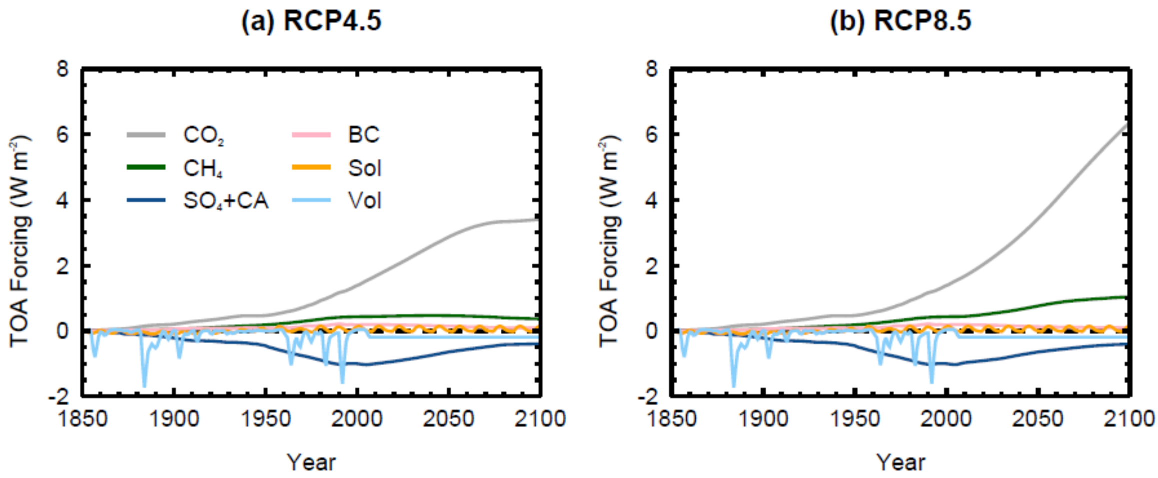

Figure S1: Global mean top of the atmosphere radiative forcing from 1850 to 2100 taken from Meinshausen et al. (2011) for each of the forcing agents included in the simple model.

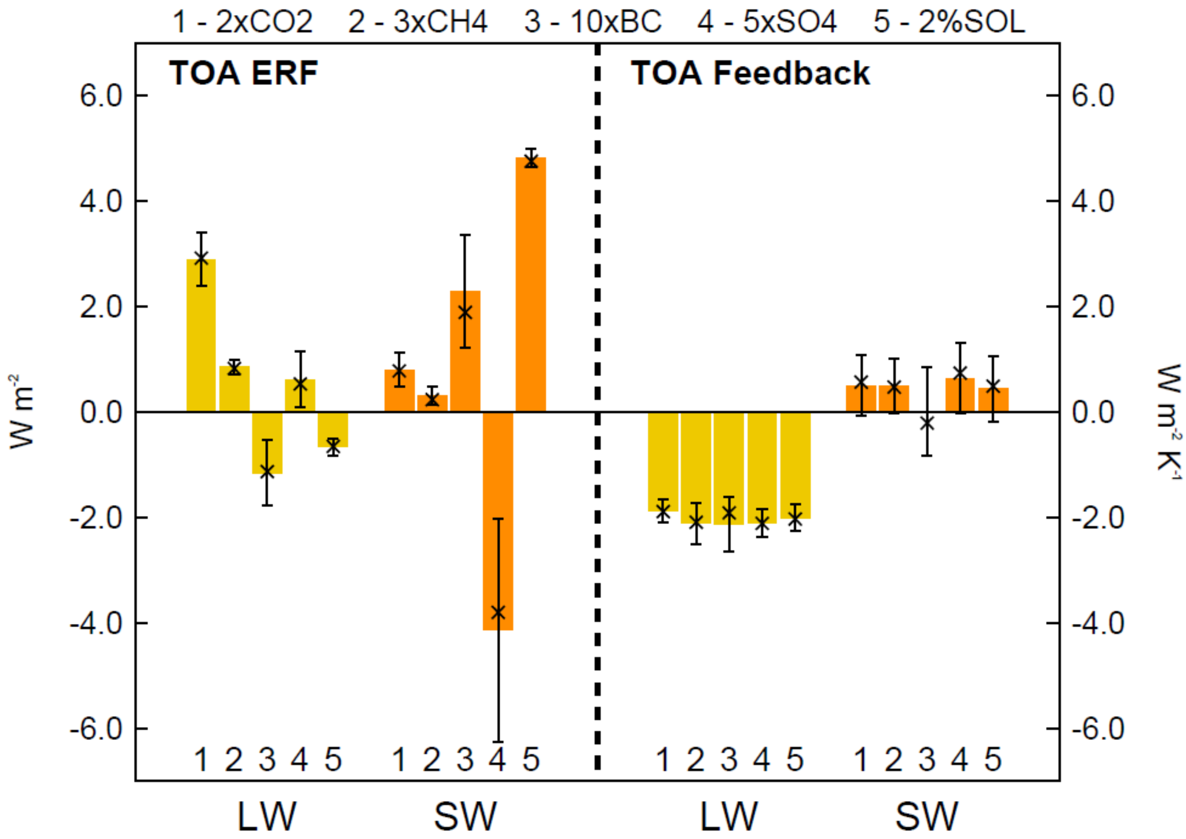

Figure S2: Multi-model global mean effective radiative forcing (left) and feedbacks (right) for top of the atmosphere (*TOA*) longwave (*LW*) and shortwave (*SW*) fluxes in response to the five PDRMIP forcing scenarios. Values are positive downward. Forcings are given in W m^{-2}, and feedbacks in W m^{-2} K^{-1}. Error bars denote the standard deviation of model spread, and crosses show the median value.

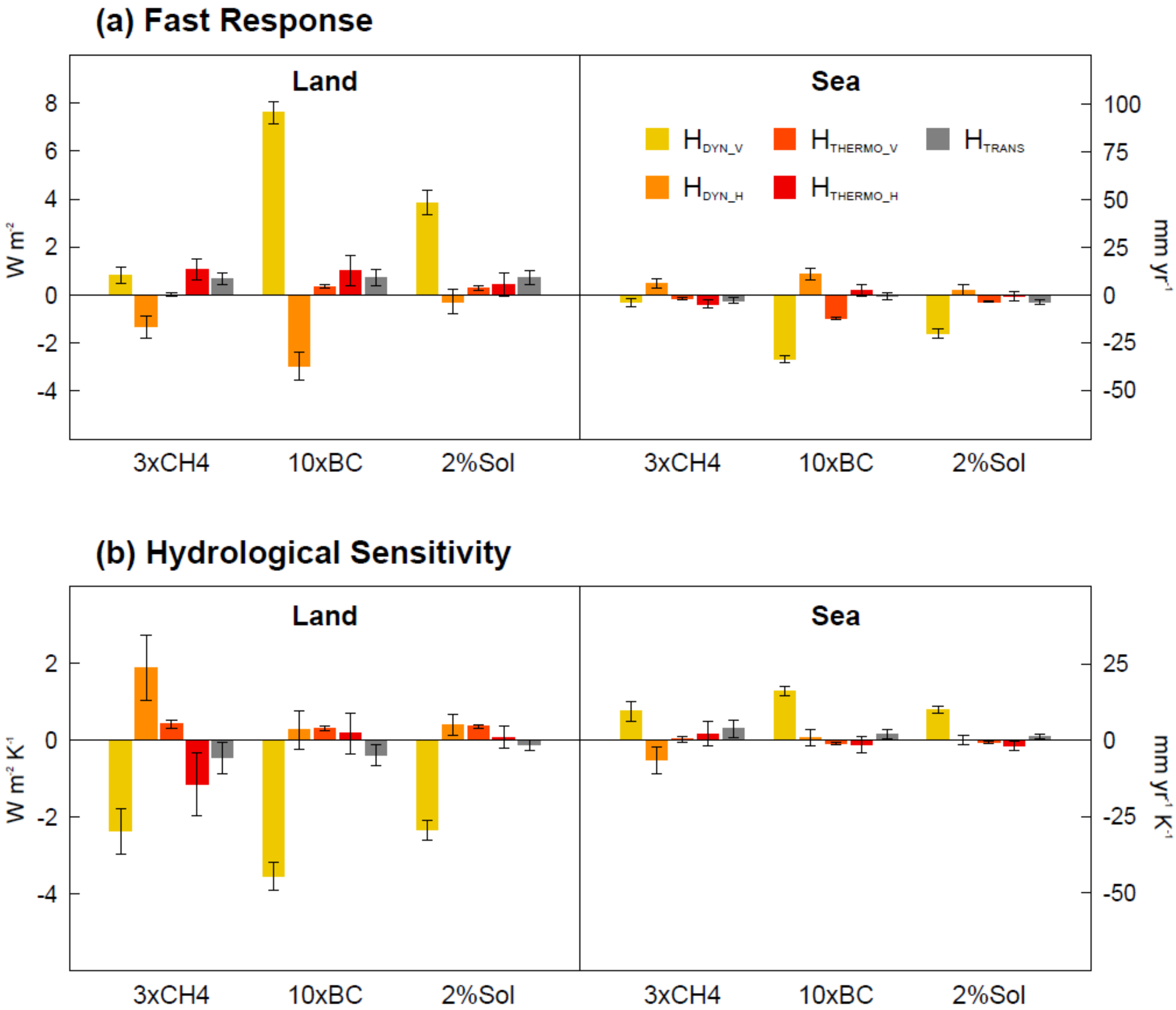

Figure S3: Contributions to changes in land and sea-mean dry static energy flux divergence due to changes in monthly mean vertical velocity (H_{DYN_V}), horizontal winds (H_{DYN_U}), vertical gradients in dry static energy (H_{THERMO_V}), horizontal gradients in dry static energy (H_{THERMO_U}) and transient eddy fluxes (H_{TRANS}) for HadGEM2. Results are shown for the (a) fast response and (b) the hydrological sensitivity for two forcing scenarios (3xCH4, 10xBC, 2%Sol). Error bars denote the standard error due to inter-annual variability.

References

Meinshausen, M., and Coauthors, 2011: The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Clim. Change*, **109**, 213–241, doi:10.1007/s10584-011-0156-z.