Community Earth System Model CESM

The impact of climate engineering on temperatures and precipitation using an idealized solar dimming experiment

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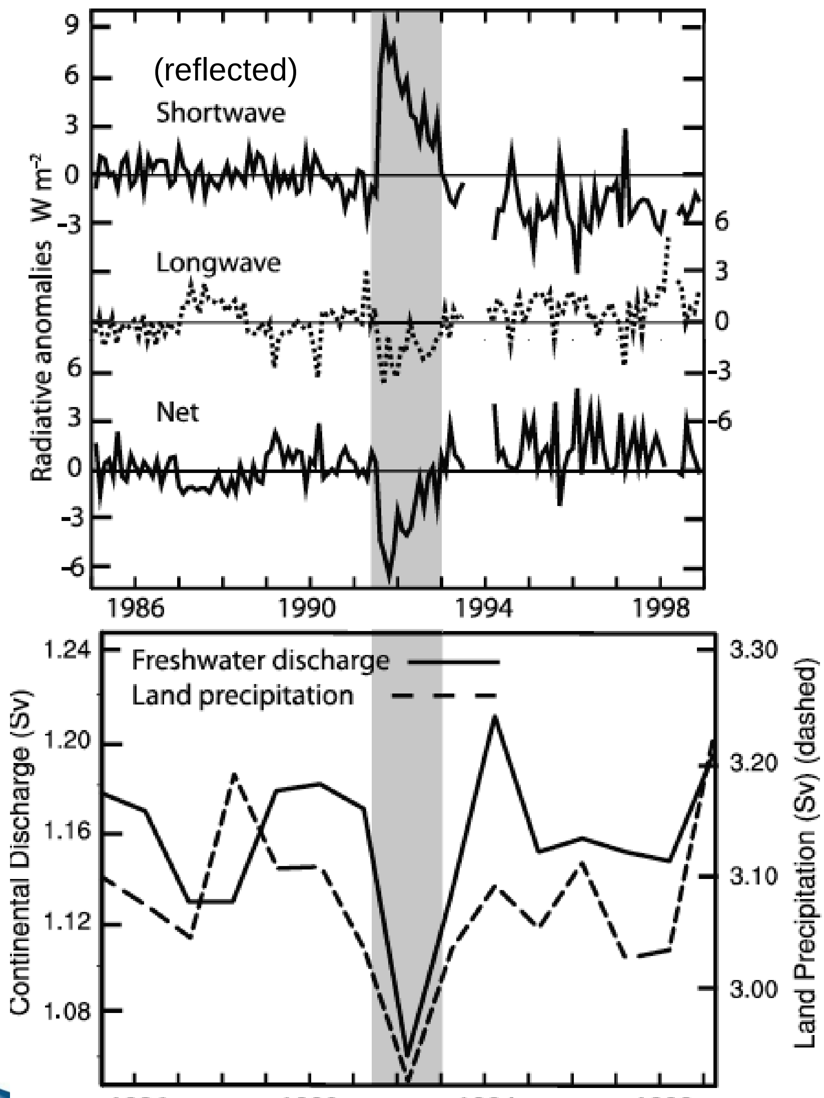
- Motivation
- Experimental Setup
- Impact on Surface Temperatures
- Impact on Precipitation

NESL

NSF

Motivation

20ºS-20ºN



Trenberth and Dai 2007

Decrease of Precipitation after major volcanic eruption as a result of:

Reduction of solar radiation:

- Cooling of the surface
- Reduction of evaporation and latent heat release
- Reduction of precipitation
- Droughts and reduced fresh water resources

Increased greenhouse gases:

- Increased temperature -> more RH in the air (Clausius-Clapeyron) 7%RH per 1K
- More intense precipitation, while reduction of frequency and duration
- Droughts

What is the impact of Solar Dimming in a future climate?

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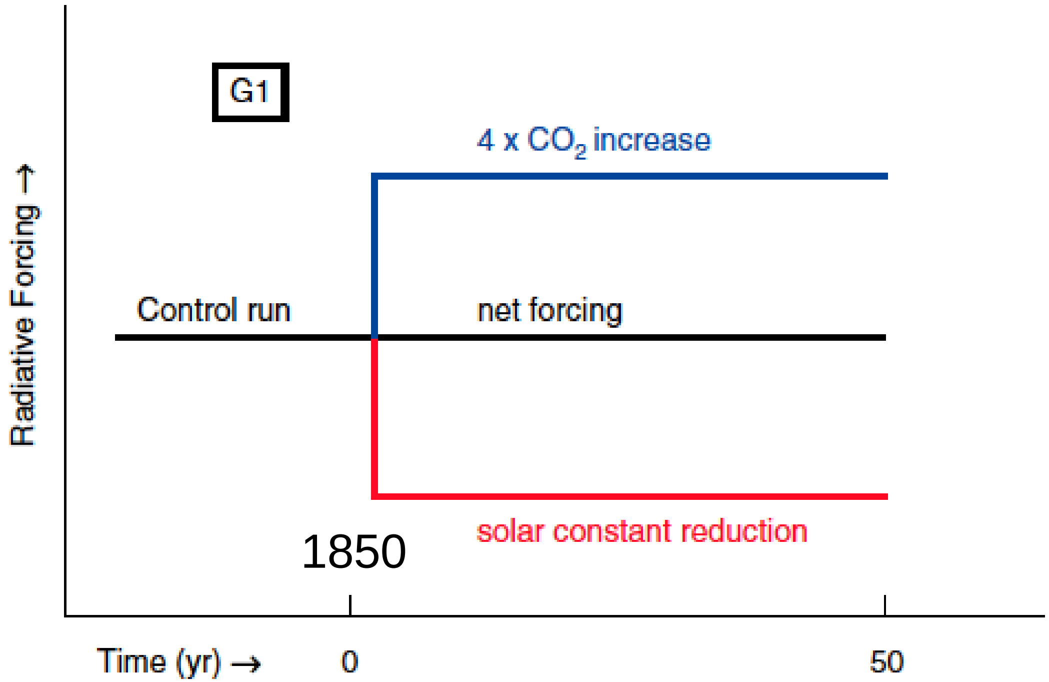
GEOMIP Simulations

G1 Simulations completed with CESM4 (0.9x1.25x26L), coupled ocean



Krawitz et al, 2010

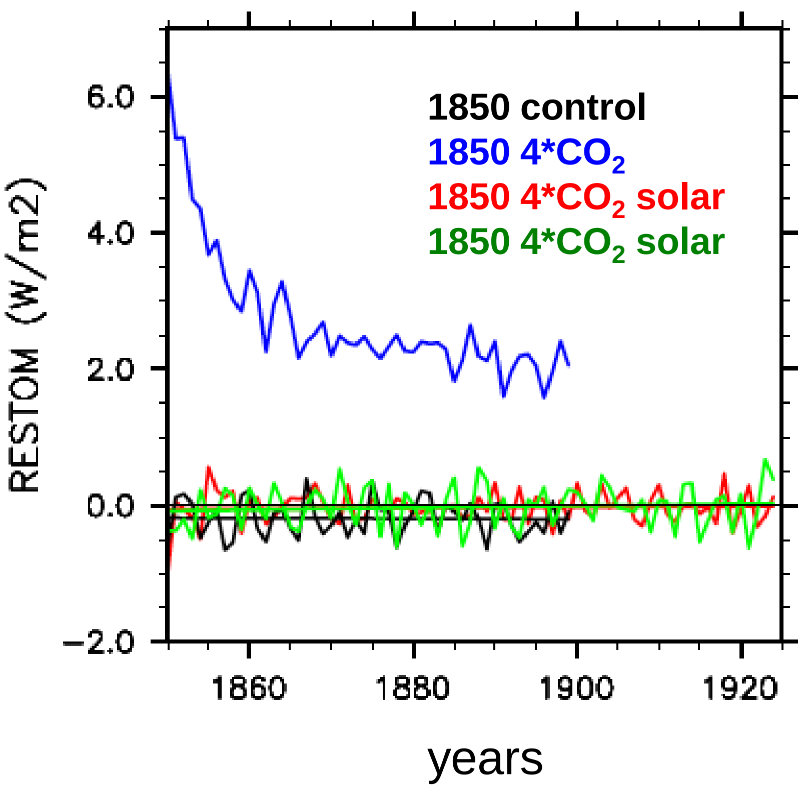
Solar constant reduction: radiative forcing will be balanced (model specific based on the planetary albedo)

Idealized Experiment:

- No impact of aerosols
- No changes in chemistry
- No changes in BGC

Balancing Radiative Forcing

SW+ LW: Residual on Top of the Atmosphere



4 x CO_2:
solar constant: 1360.89 W/m^2
CO_2: 1138.8e-06
RESTOM 1st year: 7.2 W/m^2

4 x CO_2 solar:
radiative forcing (RF) balanced:
RF= S/4 * (1-albedo)
S: solar constant reduction
-> S = 41.3 W/m^2 ,albedo = 0.3
not sufficient!

Balance:
Solar Constant = 55.8 W/m^2
CMIP5 4xCO_2, solar constant: 1305.09 (reduction of 4.1%)

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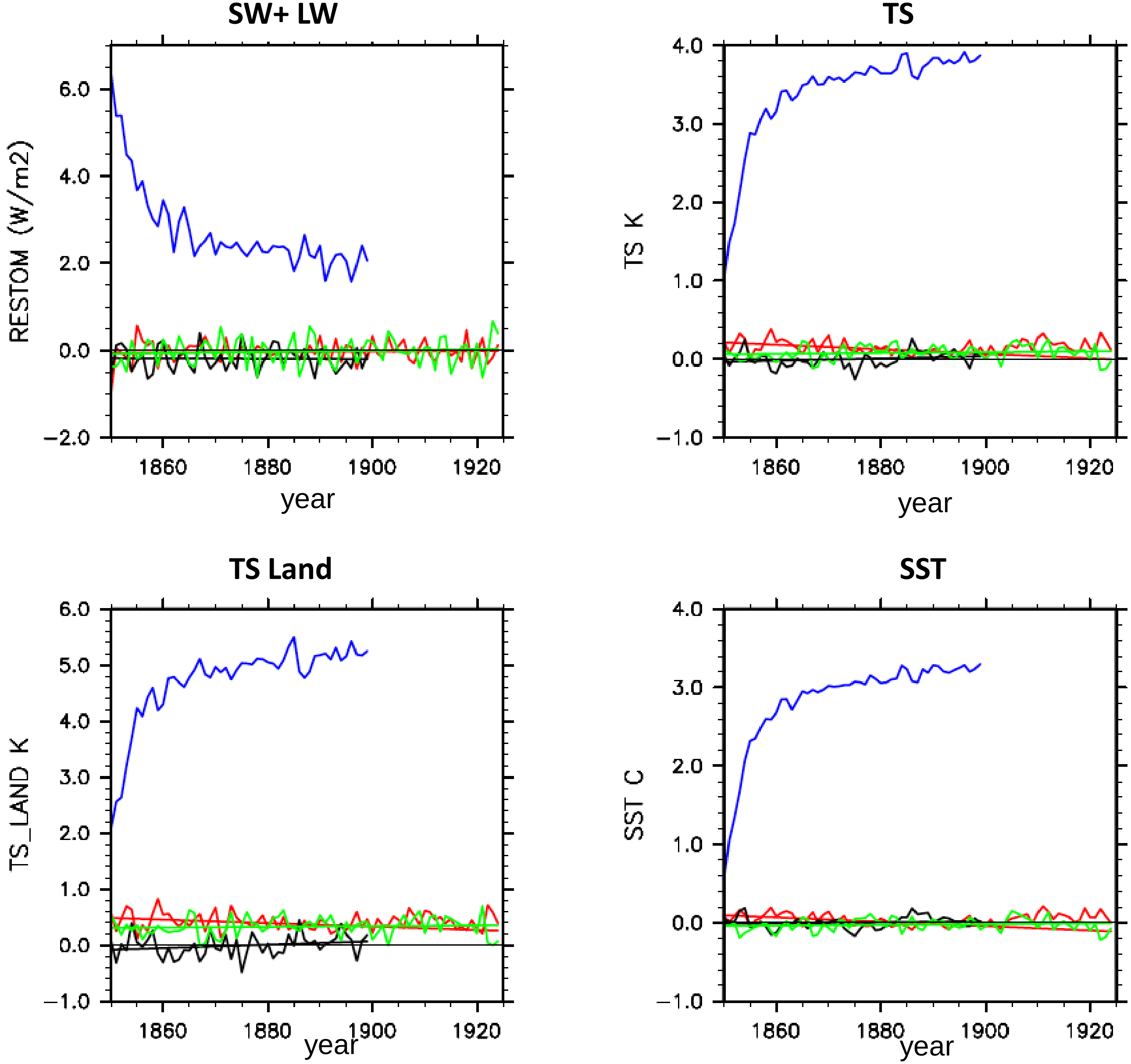
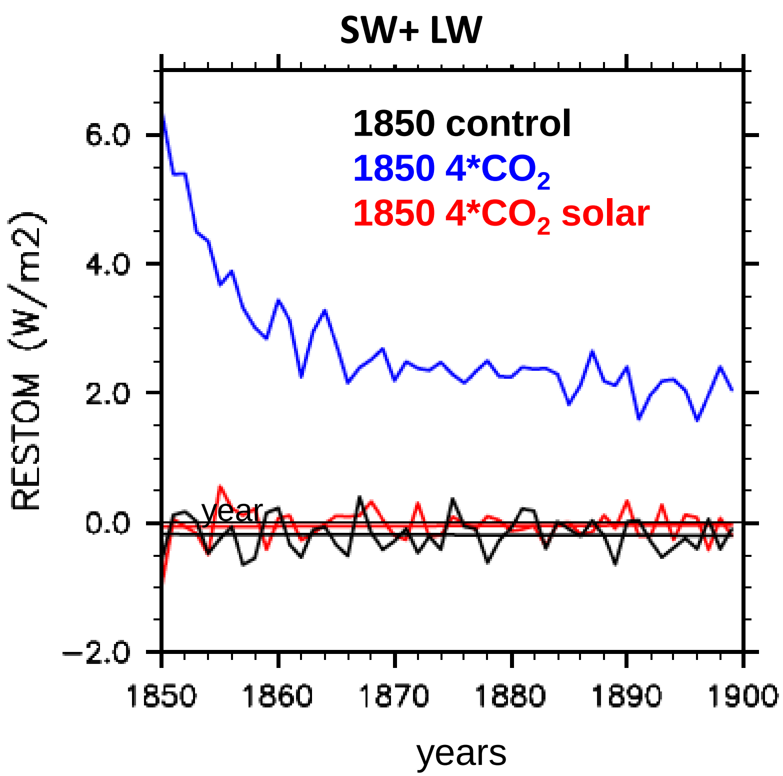
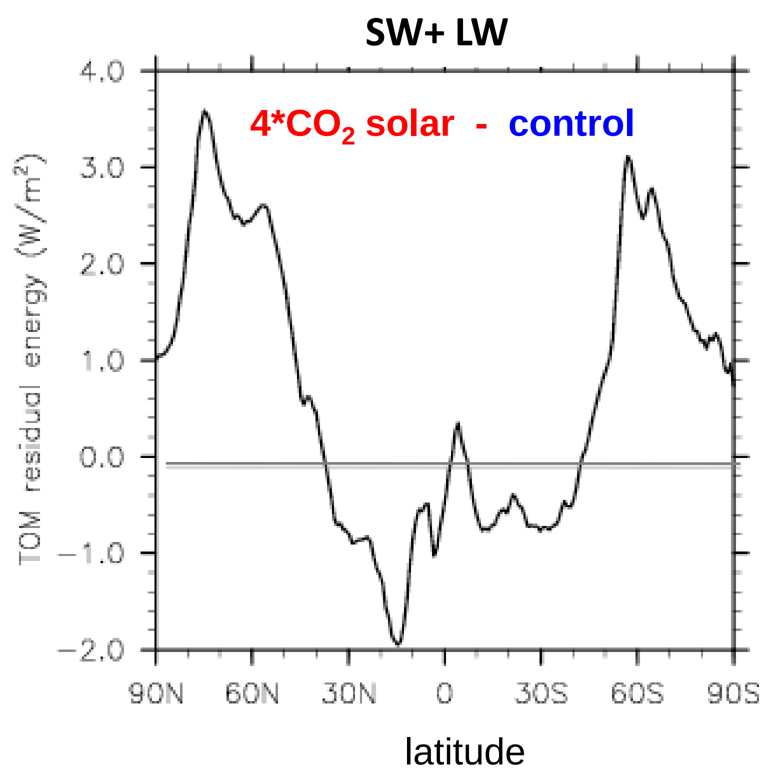
Balancing Radiative Forcing



1850 control
1850 4*CO_2
1850 4*CO_2 solar
1850 4*CO_2 solar

Balancing Radiative Forcing





Zonal response: RESTOM is not balanced.
-> Cooling in the Tropics and a heating in the middle and high latitudes

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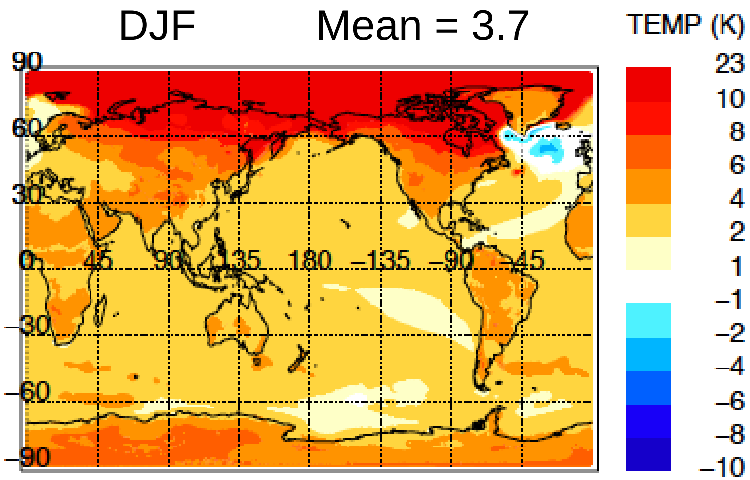
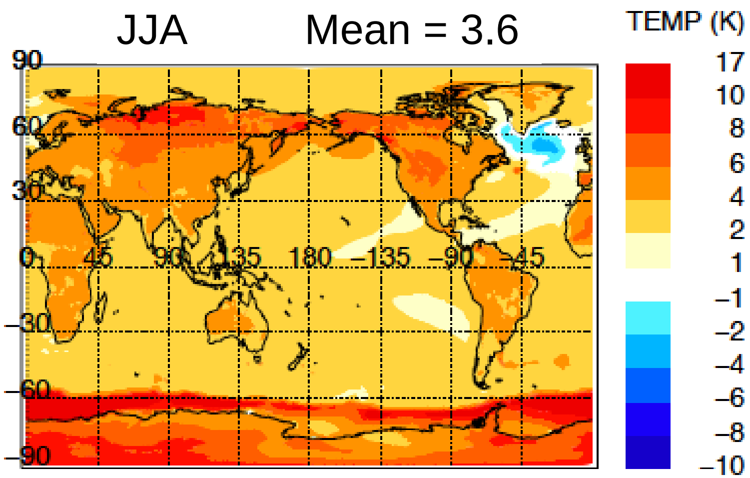
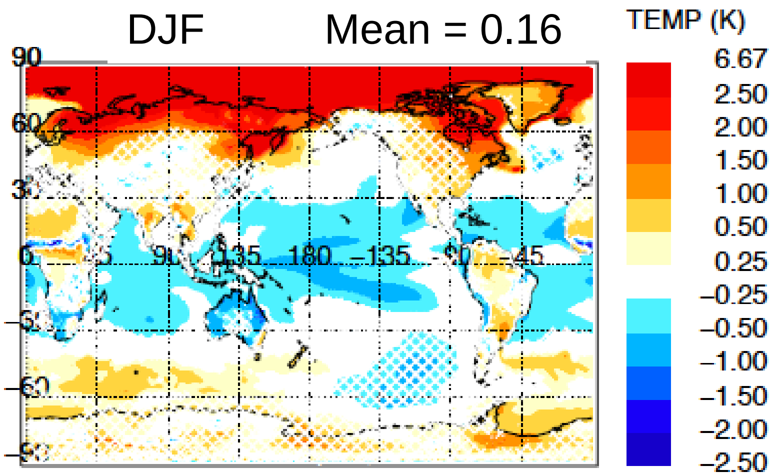
Temperature Response

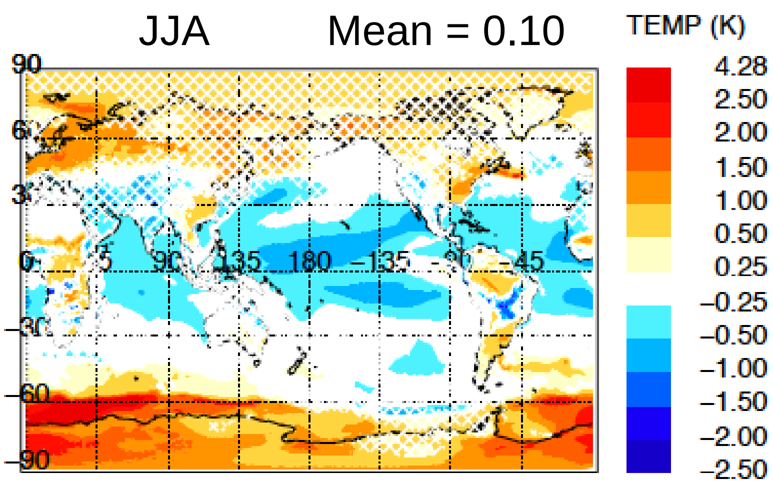
4*CO_2 – 1850 control





4*CO_2 solar - 1850 control





Hatched areas are not significant at 95% level based on Student’s t test.

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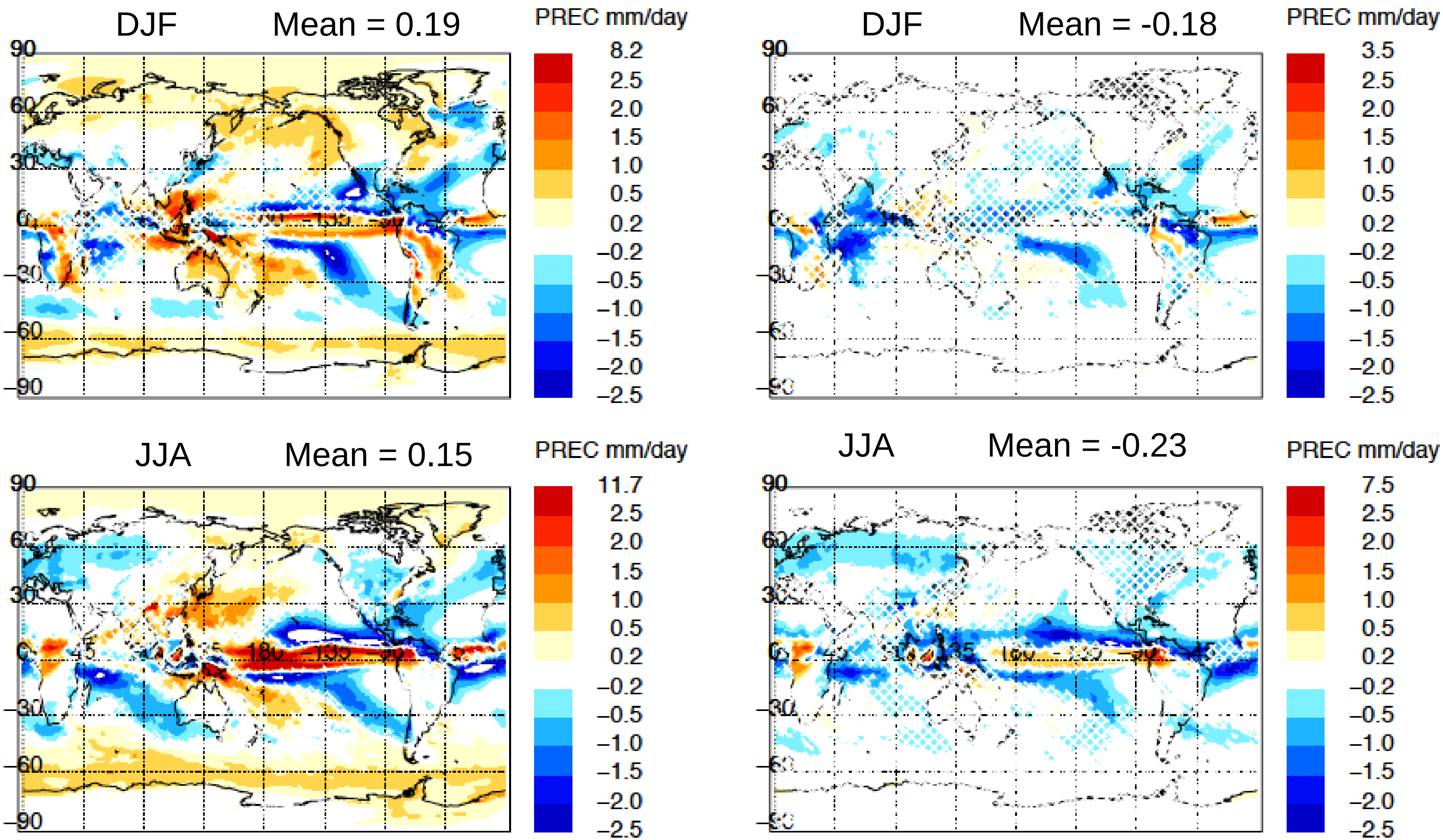
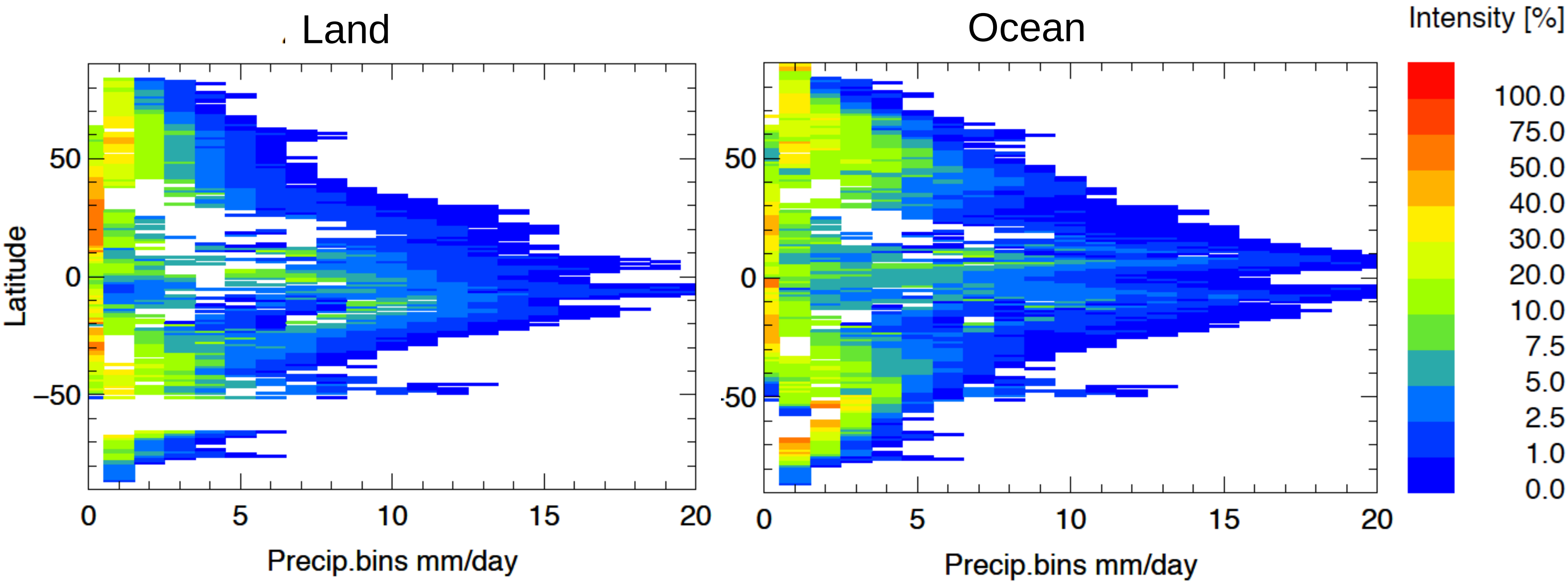
Precipitation Response

4*CO_2 – 1850 control | **4*CO_2 solar - 1850 control**



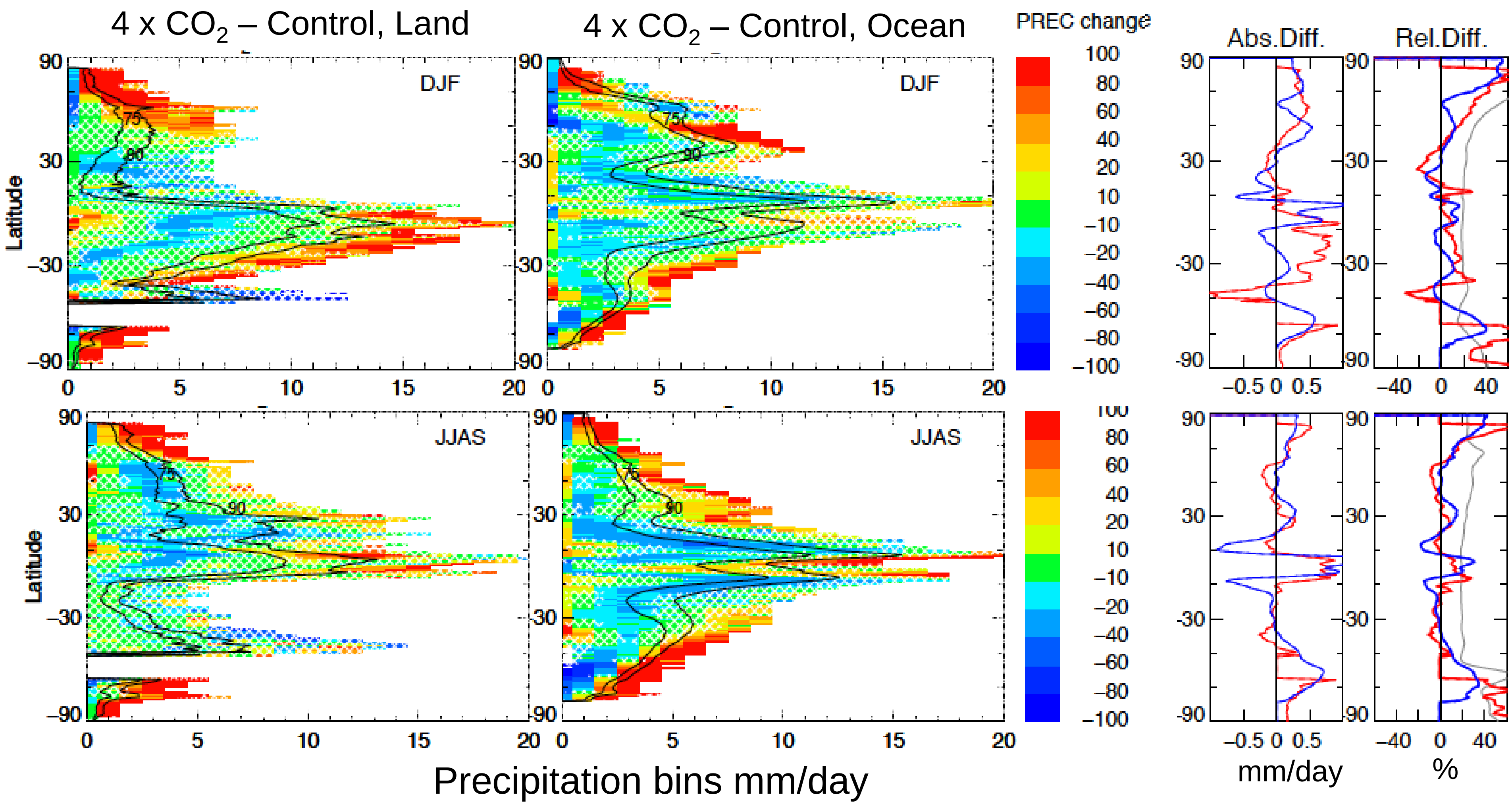
Hatched areas are not significant at 95% level based on Student's t test.

Precipitation Intensity



Base state: Land/Ocean precipitation intensity different.
Land-Sea contrast of precipitation trends in climate models more robust than mean changes.

Precipitation Response



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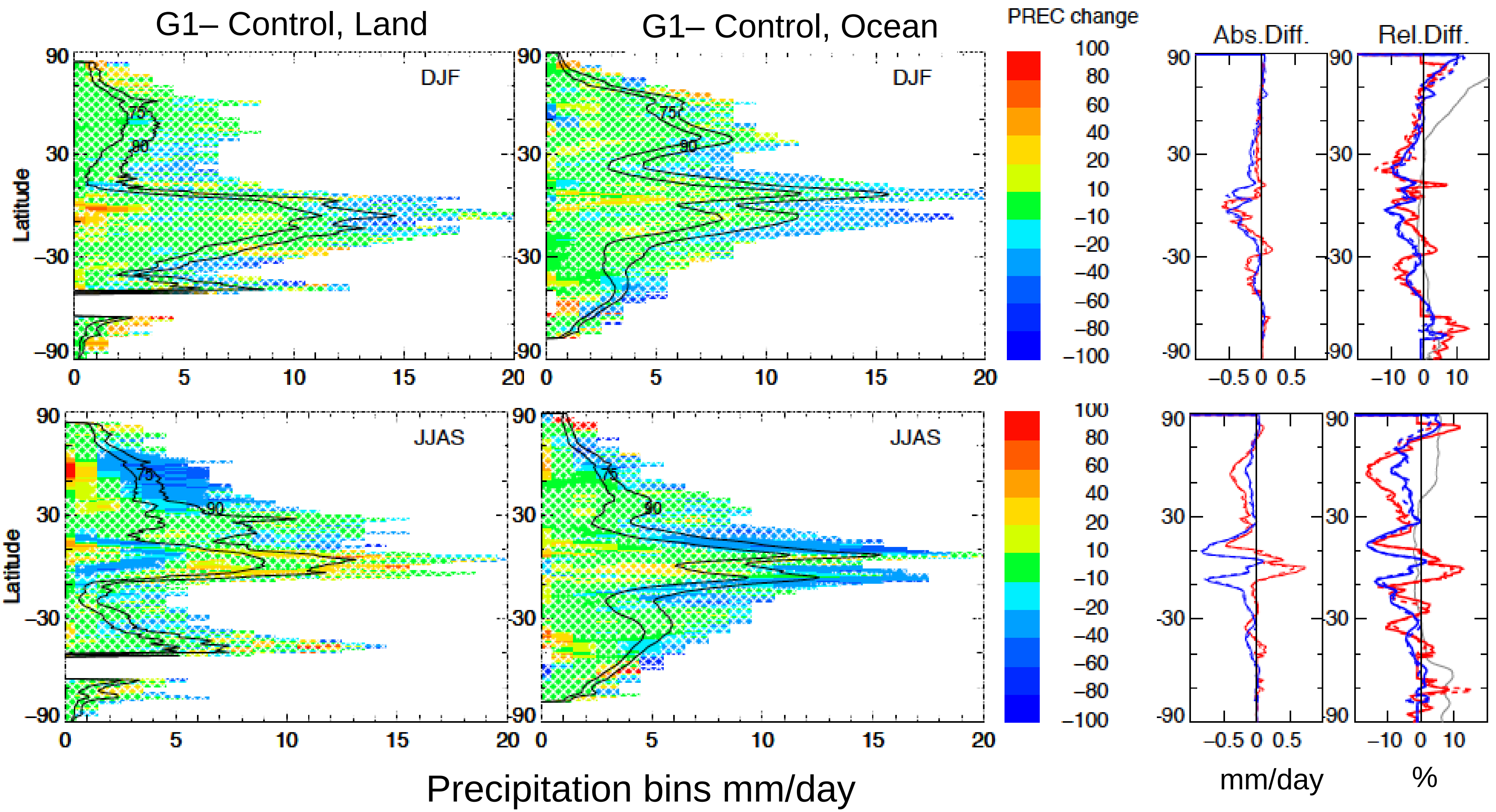
Precipitation Response

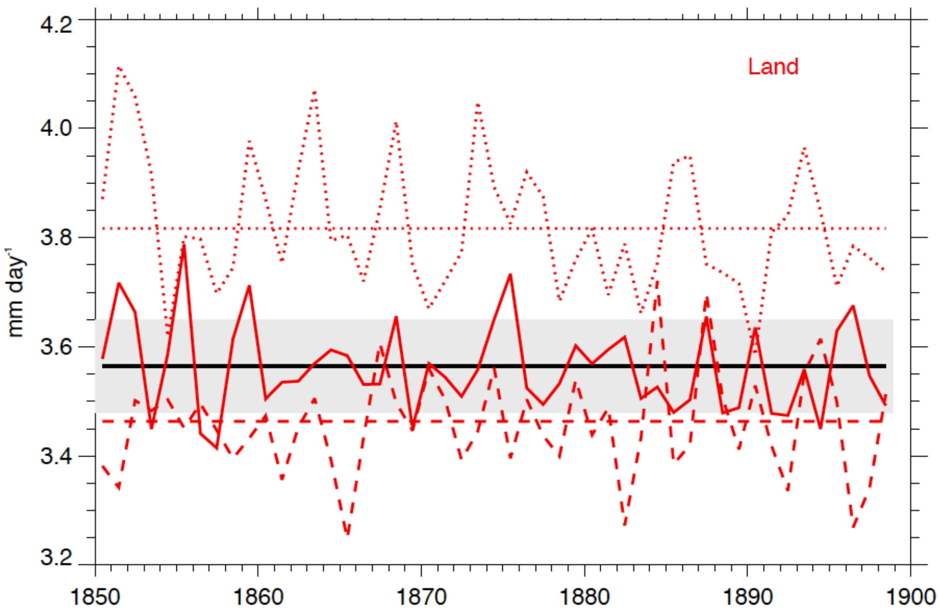


Hatched areas are not significant at 95% level based on Student's t test.

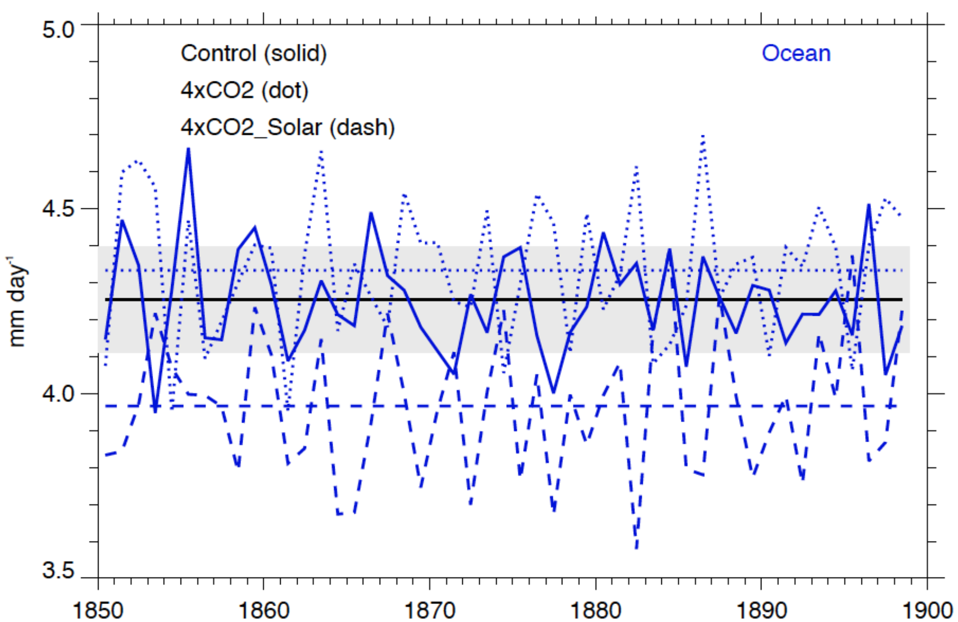
Global Monsoon Rainfall

Control: solid
4xCO2: dot
G1: dashed

Land



Ocean



$4xCO_2$: pronounced increase of precipitation over land and not significant increase over the ocean
G1: pronounced decrease over the ocean, smaller but significant decrease over land

Conclusions

Global solar dimming does not result in a homogeneous cooling of the Earth's surface, but a cooling of the Tropics and a heating in high latitudes.

4*CO^2 simulations show an intensification of convective precipitation, but a reduction moderate precipitation (90%). Most significant impact in the tropics and high latitudes.

Solar dimming results in a global decrease of precipitation, with a significant decrease of convective precipitation. This is most pronounced over the tropical ocean in JJAS.

A strong decrease of 20-40% of more than 25% of the intensive precipitation is reduced in high northern latitudes in summer over land.

Significant land/ocean contrast for both 4*CO^2 and G1 simulations in comparison to 1850 conditions.

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Precipitation Response

4*CO_2 – 1850 control | **4*CO_2 solar - 1850 control**