Counteracting global warming by using a locally optimized solar radiation management

D. Marchegiani[1], D. Dommenget[1]

[1]School of Earth, Atmosphere and Environment, ARC Centre of Excellence for Climate Extremes, Monash University, Clayton, Victoria, Australia.

Corresponding author: Davide Marchegiani (davide.marchegiani@monash.edu)

Supporting information content
1.Supplementary methods
2.Supplementary figures

1.Supplementary methods

Within our localized SRM approach, we built up an iterative optimization scheme in order to minimize local surface temperature anomalies (see Methods). The total number of iterations carried out for the FP optimization was 20. As a diagnostic to assess the degree of optimization, we used the root mean square error (rms) estimated for every grid point, between the annual mean of the i-th iteration and the control run, for both surface temperature and precipitation, respectively. In general, the scheme started converging around the 4th-5th iteration. However, minor variations were still present after convergence so, for the analyses shown, we chose the iteration with the minimum rms value among all 20 iterations. These turned out to be the 5th iteration for the SRM_{SW} approach and the 16th iteration for the SRM_{CLD} approach.

One of the core steps of our optimized procedure has been that of creating a kernel which could enable us to quantify, within our model, the sensitivity of surface temperature to changes in the FP. In order to obtain this sensitivity matrix S, we developed a series of perturbation experiments with the following setup: we carried out a 30-years $2xCO_2$ run, in which we scaled the FP along a ($15° x 15°$) moving square, and estimated S* at this location by the change in surface temperature:

$$S^*(x,y,t_S) = \frac{\Delta T(x,y,t_S)}{\Delta FP(x,y,t_S)} = \frac{T(x,y,t_S)_\delta - T(x,y,t_S)_{ctrl}}{FP(x,y,t_S)_\delta - FP(x,y,t_S)_{ctrl}} \tag{3}$$

with the surface temperature of the perturbation experiments, T_δ, the control, T_{ctrl}, the FP of the perturbation experiments, FP_δ, and the control, FP_{ctrl}. We repeated this for all locations and for each season (t_S) separately, for a total of 800 experiments. The final S is obtained by first joining all the S* together, smoothing them with a gaussian filter applied along the spatial coordinates, and ultimately by performing a linear interpolation over time.
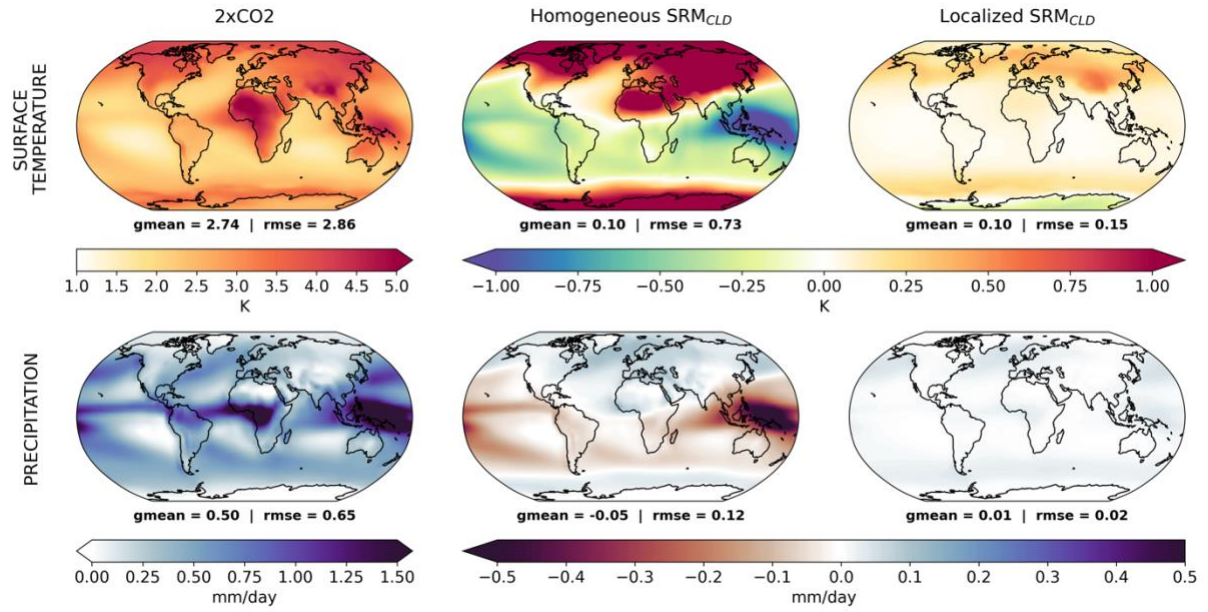
2.Supplementary Figures

Supplementary Figure 1. Annual mean temperature (upper) and precipitation (lower) anomalies for the $2xCO_2$ (left), Homogeneous SRM_{CLD} (middle) and Localized SRM_{CLD} experiments (right). The Homogeneous SRM_{CLD} experiment is designed to have the same global mean (gmean) as the control. The area-weighted root mean square (rms) values based on all grid points are shown for each response pattern.
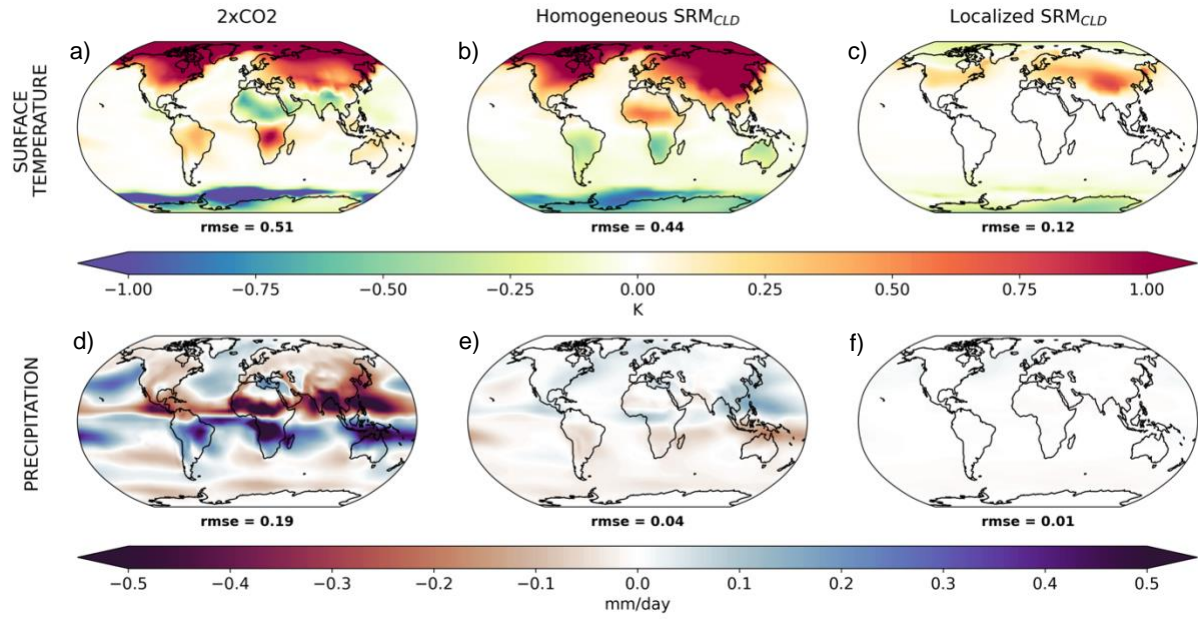
Supplementary Figure 2. Seasonal cycle, computed as $(DJF - JJA)/2$, of temperature (upper) and precipitation (lower) anomalies for the $2xCO_2$ (left), Homogeneous SRM_{CLD} (middle) and Localized SRM_{CLD} experiments (right). The area- weighted root mean squared (rms) values based on all grid points are shown for each response pattern.

Supplementary Figure 3. Annual mean anomalies over SREX regions [Seneviratne et al., 2012] of temperature (upper) and precipitation (lower), for the $2xCO_2$ (black circle), Homogeneous SRM_{SW} (red square), Homogeneous SRM_{CLD} (blue square), Localized SRM_{SW} (red cross) and Localized SRM_{CLD} (blue cross) experiments, respectively.
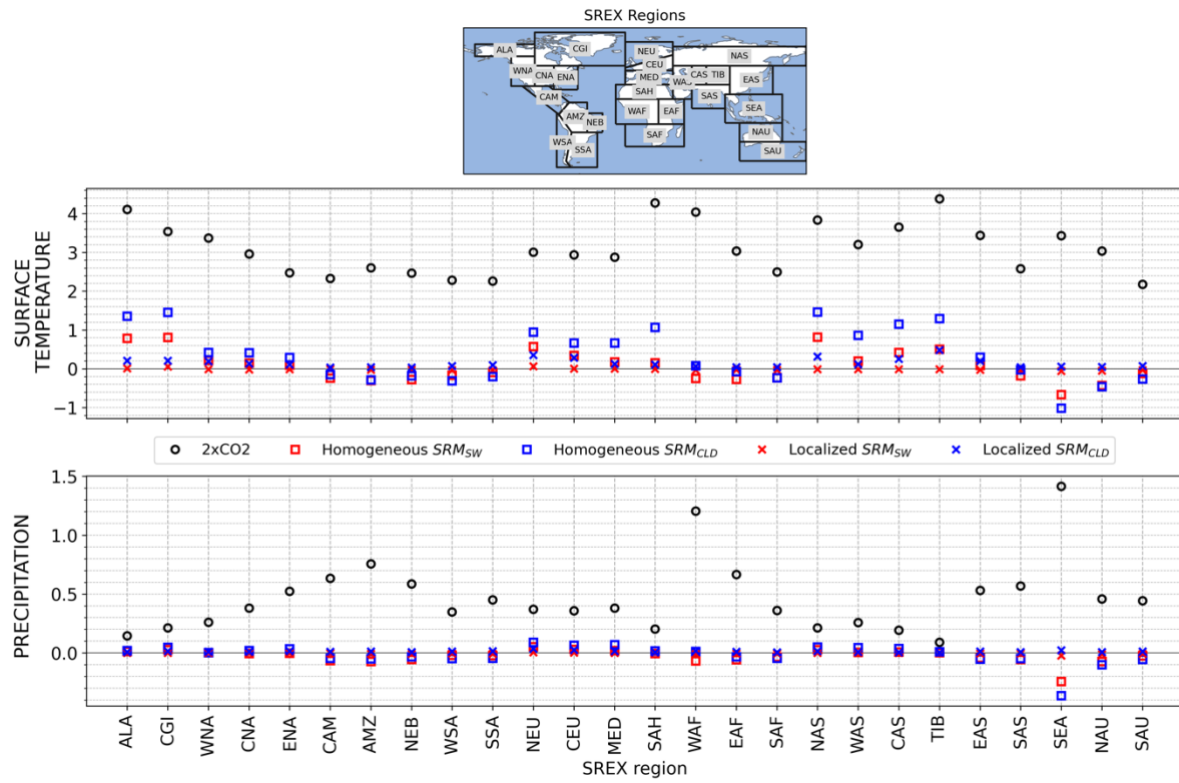
Supplementary Figure 4. Seasonal cycle, computed as $(DJF - JJA)/2$, over SREX regions [Seneviratne et al., 2012], of temperature (upper) and precipitation (lower), for the $2xCO_2$ (black circle), Homogeneous SRM_{SW} (red square), Homogeneous SRM_{CLD} (blue square), Localized SRM_{SW} (red cross) and Localized SRM_{CLD} (blue cross) experiments, respectively.
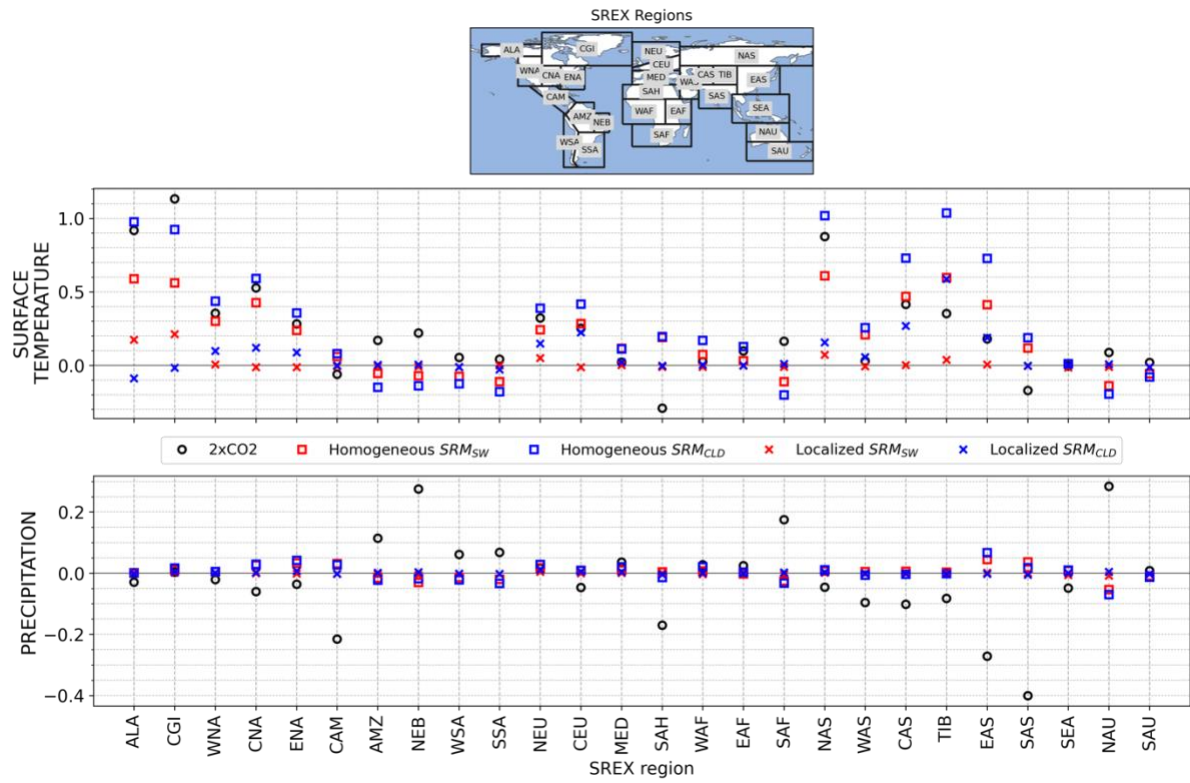
Supplementary Figure 1. Annual mean temperature (upper) and precipitation (lower) anomalies for the 2xCO$_2$ (left), Homogeneous SRM$_{CLD}$ (middle) and Localized SRM$_{CLD}$ experiments (right). The Homogeneous SRM$_{CLD}$ experiment is designed to have the same global mean (gmean) as the control. The area-weighted root mean square (rms) values based on all grid points are shown for each response pattern.

Supplementary Figure 2. Seasonal cycle, computed as $(DJF - JJA)/2$, of temperature (upper) and precipitation (lower) anomalies for the $2xCO_2$ (left), Homogeneous SRM$_{CLD}$ (middle) and Localized SRM$_{CLD}$ experiments (right). The area- weighted root mean squared (rms) values based on all grid points are shown for each response pattern.

Supplementary Figure 3. Annual mean anomalies over SREX regions [Seneviratne et al., 2012] of temperature (upper) and precipitation (lower), for the 2xCO$_2$ (black circle), Homogeneous SRM$_{SW}$ (red square), Homogeneous SRM$_{CLD}$ (blue square), Localized SRM$_{SW}$ (red cross) and Localized SRM$_{CLD}$ (blue cross) experiments, respectively.

Supplementary Figure 4. Seasonal cycle, computed as $(DJF - JJA)/2$, over SREX regions [Seneviratne et al., 2012], of temperature (upper) and precipitation (lower), for the 2xCO₂ (black circle), Homogeneous SRM$_{SW}$ (red square), Homogeneous SRM$_{CLD}$ (blue square), Localized SRM$_{SW}$ (red cross) and Localized SRM$_{CLD}$ (blue cross) experiments, respectively.