



# GEOMIP using CESM1-CAM4

*Simone Tilmes, Jean-Francois Lamarque, Dan Marsh, Mike Mills*

- **Understand the impact of Solar Radiation Management (SRM) on the Earth's system**
- **Four proposed experiments uniformly defined based on CIMP5 simulations: G1-G4 (Kravitz et al., 2011)**
- **Some model results**



# Understand the impact of Solar Radiation Management (SRM) on the Earth's System

## Uniformly performed experiments to study:

- **Climate and local response:** Temperature and Precipitation/Hydrology
- **Atmosphere:** Circulation pattern, Chemistry, Aerosol Microphysics
- **Ocean:** acidification, Ocean circulation, Cryosphere
- **Biosphere,** Biogeochemistry, Agricultural and other vegetation
- **Feedbacks** on Temperature, Dynamics, TS
- **Volcanic responses** of different models (CIMP5) in comparison to observations



# Understand the impact of Solar Radiation Management (SRM) on the Earth's System

## Participating Models:

- right now about 15 plan to participate
- including at least 2 models that simulate microphysics (WACCM CARMA)
- only a few have chemistry

## GeoMIP in CCMVal3

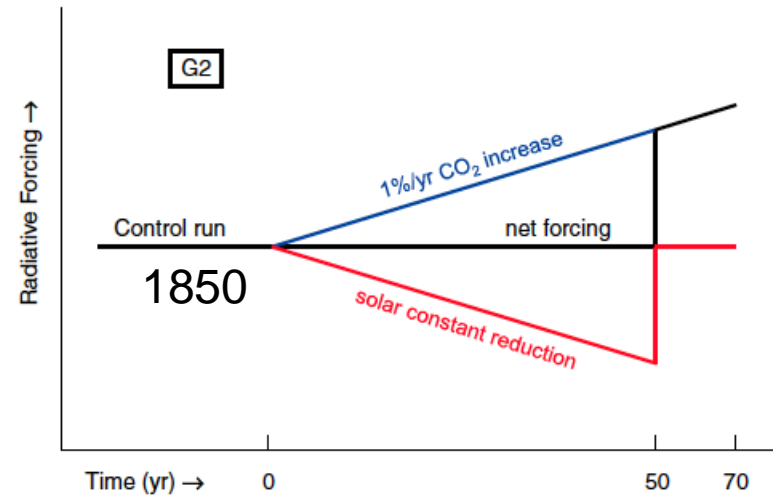
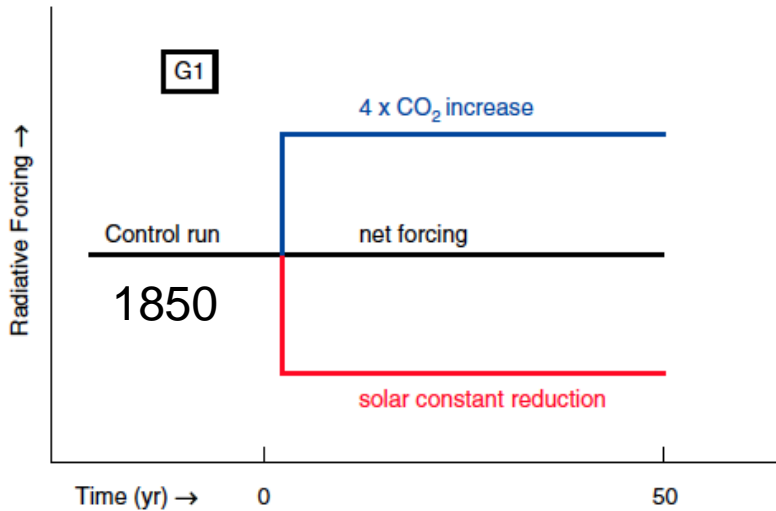
- possibly defined prescribed SAD from microphysical models



# GEOMIP Simulations

Four proposed experiments: **G1-G4**

**G1, G2:** balancing incoming LW forcing with reduced SW forcing (reduction of solar constant)



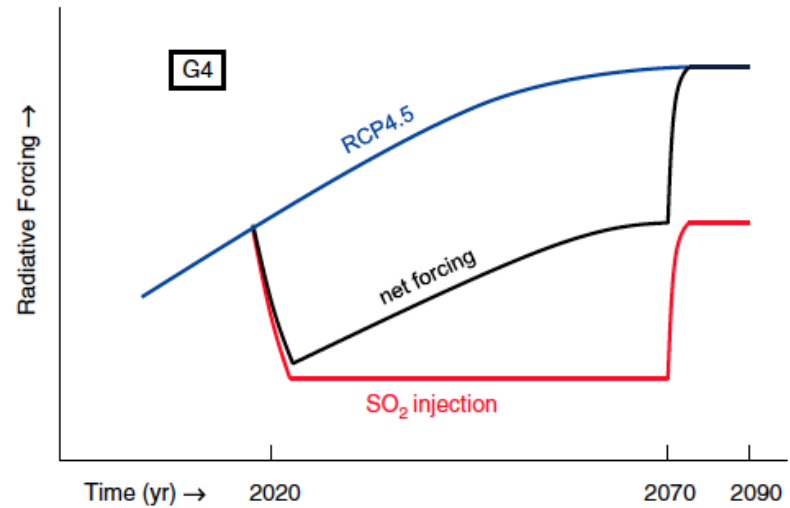
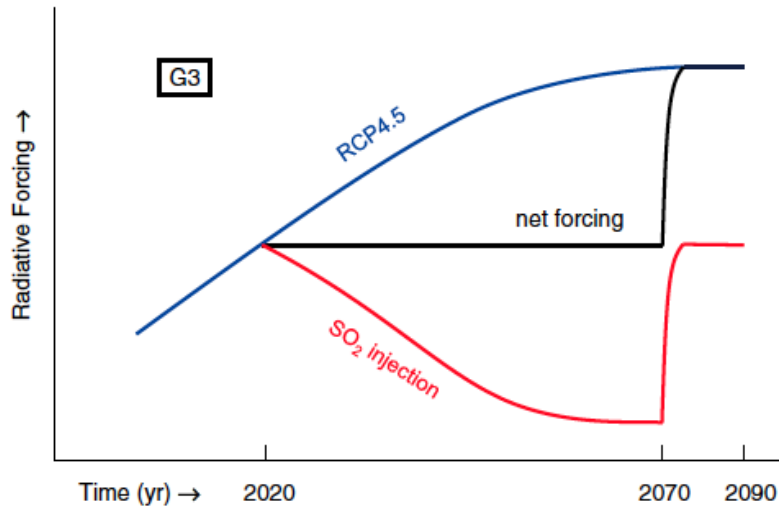
**G1: Baseline:** CMIP5 4xCO<sub>2</sub>, **Geoeng.:** radiative forcing will be balanced (model specific based on the planetary albedo)

**G2: Baseline:** CMIP 1% /yr CO<sub>2</sub> increase, **Geoeng.:** derived from G1 experiment



# GEOMIP Simulations

**G3, G4:** balancing incoming LW forcing with stratospheric aerosol injection



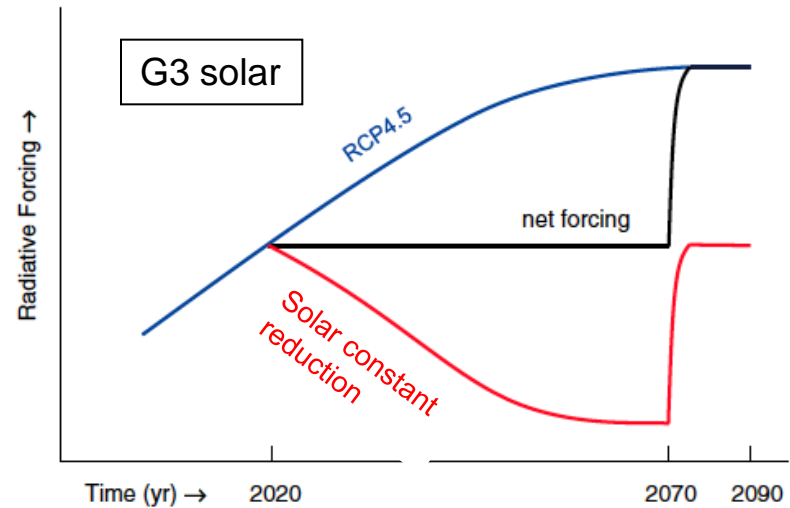
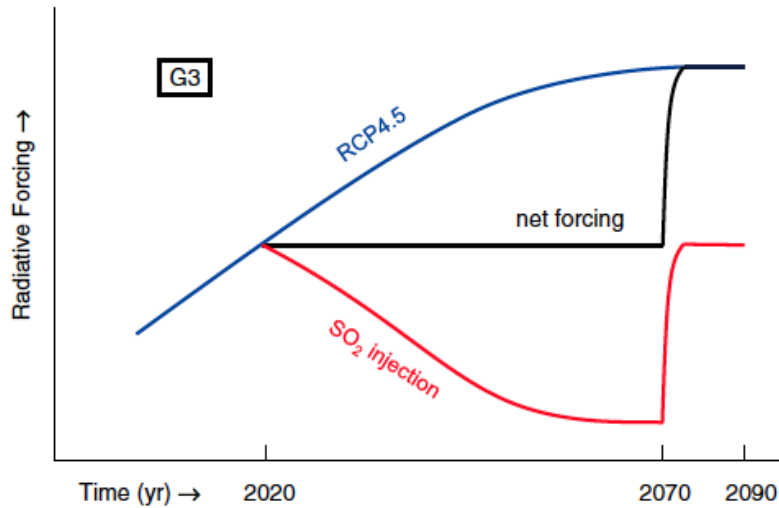
**G3: Baseline:** RCP4.5, **Geoeng.:** stratospheric aerosols in 2020 to balance are to be increased gradually, equatorial injection)

**G4: Baseline:** RCP4.5, **Geoeng.:** fixed aerosol injection of 5 Tg SO<sub>2</sub> per year, after 50 years, stop of injection



# GEOMIP Simulations

**G3, G4:** balancing incoming LW forcing with stratospheric aerosol injection



**G4: Baseline:** RCP4.5, **Geoeng.:** fixed aerosol injection of 5 Tg SO<sub>2</sub> per year, after 50 years, stop of injection

**G3: Baseline:** RCP4.5, **Geoeng.:** stratospheric aerosols in 2020 to balance are to be increased gradually, equatorial injection)



# GEOMIP Simulations with CESM1-CAM4

**G1, G2, G3 solar:** reduced SW forcing (reduction of solar constant), 1850 conditions

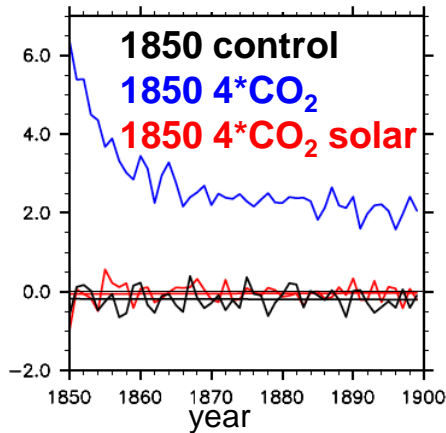
**G3, G4:** balancing incoming LW forcing with stratospheric aerosol injection, 2020

- Simulations completed with CESM4 (0.9x1.25x26L)  
**G1, G2, G3 solar**
- Simulations planned with CESM4-BGC (0.9x1.25x26L)  
**G3 solar**
- Simulations planned with CESM4 CAMChem (1.9x2.5x26L):  
**G3 solar, G3, G4**
- WACCM, WACCM-CARMA simulations (Mike Milles)
- CESM1-CAM5 (Phil Rasch)

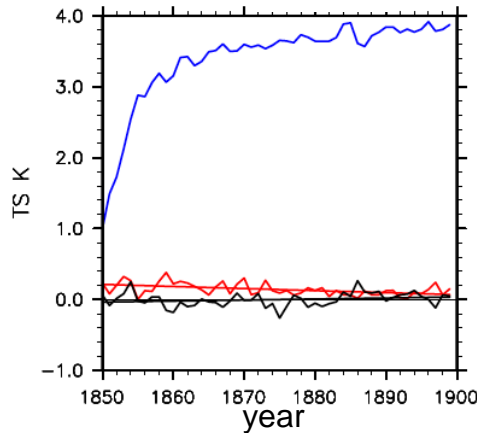


# Results: G1 Simulation

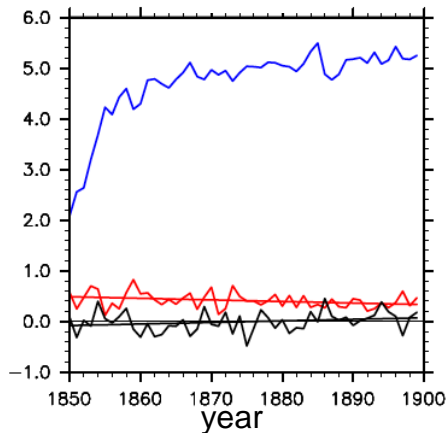
SW+ LW



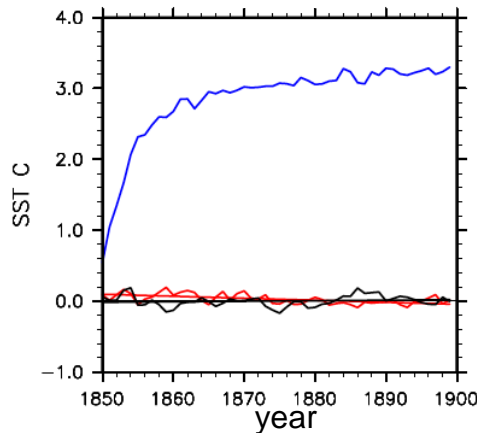
TS



TS Land



SST



**G1: Baseline:** CMIP5 4xCO<sub>2</sub>,  
solar constant: 1360.89,  
CO<sub>2</sub>: 1138.8e-06  
RESTOM 1<sup>st</sup> year: 7.2 W/m<sup>2</sup>

**Geoeng.:** radiative forcing RF  
balanced:

$$RF = S/4 * (1 - \text{albedo})$$

S: solar constant reduction

$$\rightarrow S = 41.3 \text{ W/m}^2, \text{albedo} = 0.3$$

**not sufficient!**

**Balance:**

Solar Constant = 55.8 W/m<sup>2</sup>

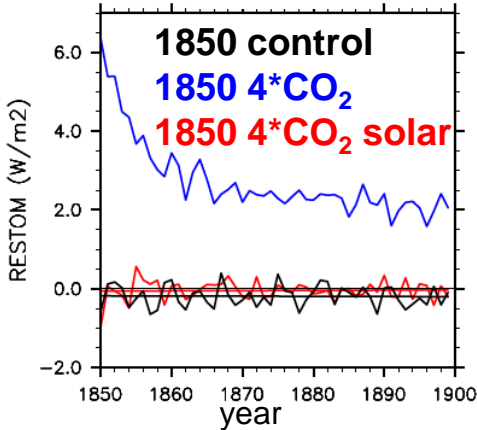
CMIP5 4xCO<sub>2</sub>, solar constant:  
1305.09 (reduction of 4.1%)



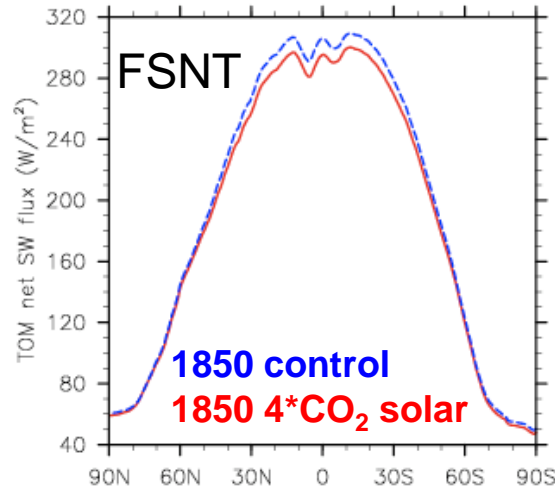


# Results: G1 Simulation

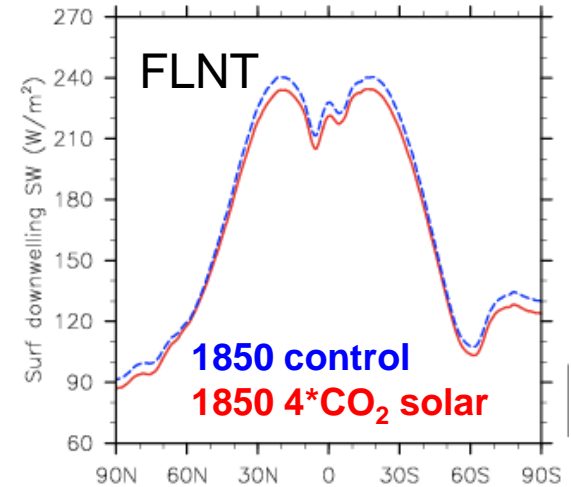
SW+ LW



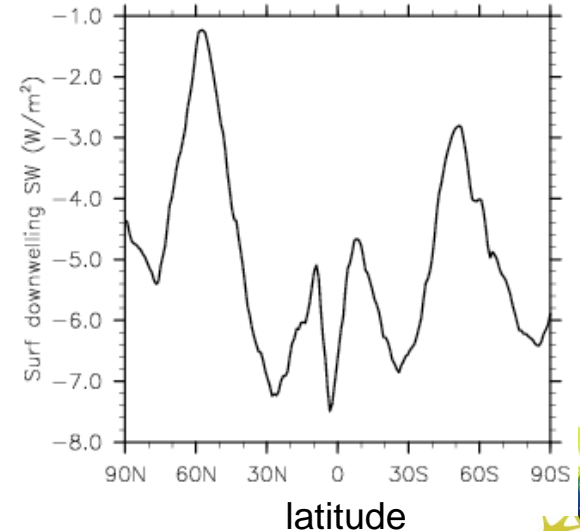
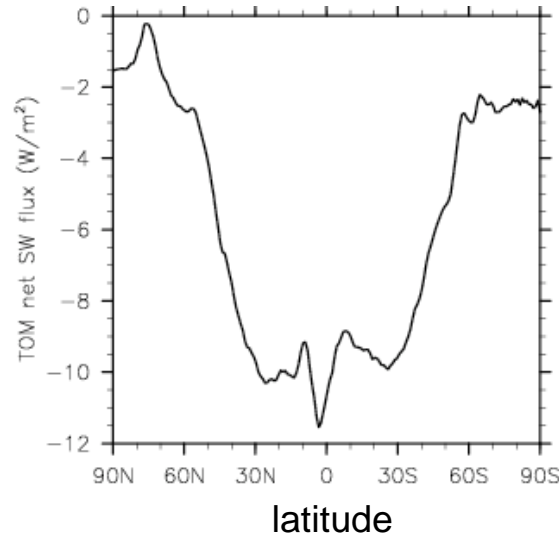
ANN



ANN



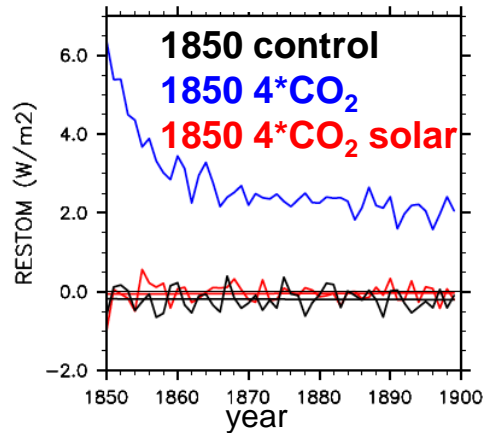
1850 4\*CO<sub>2</sub> solar - 1850 control



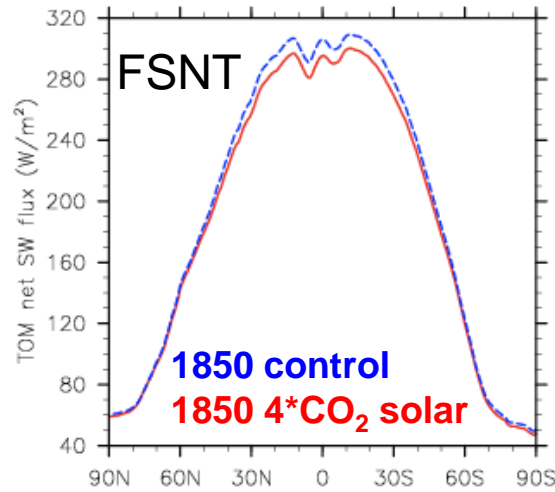


# Results: G1 Simulation

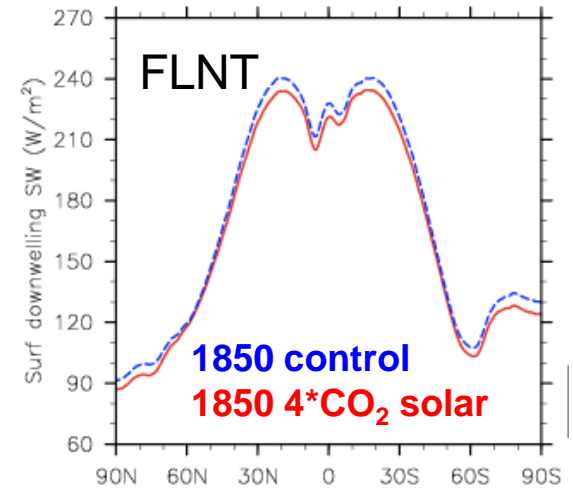
SW+ LW



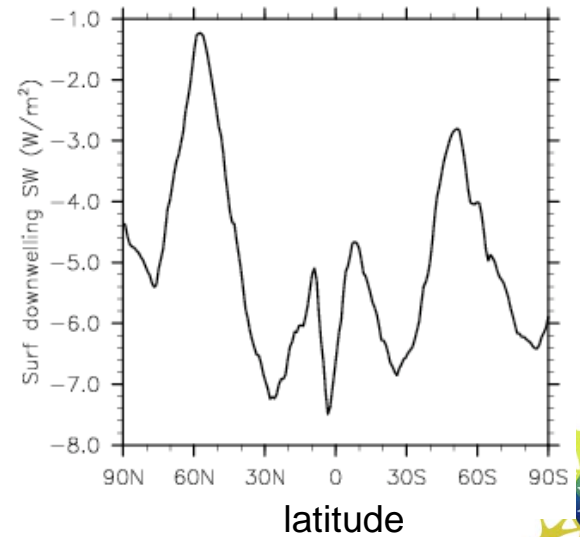
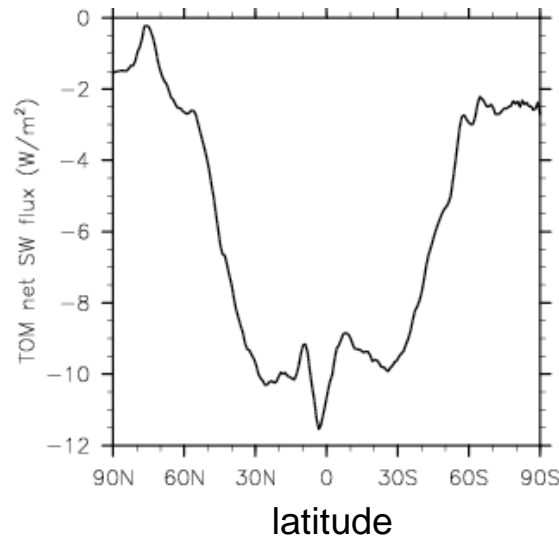
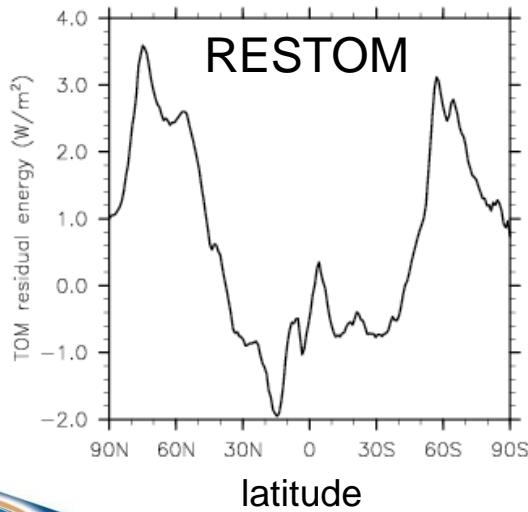
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ANN

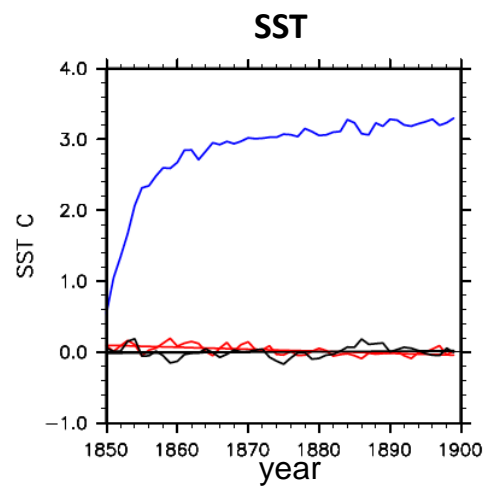
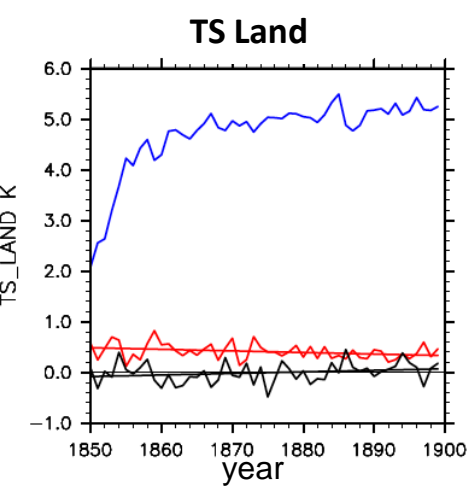
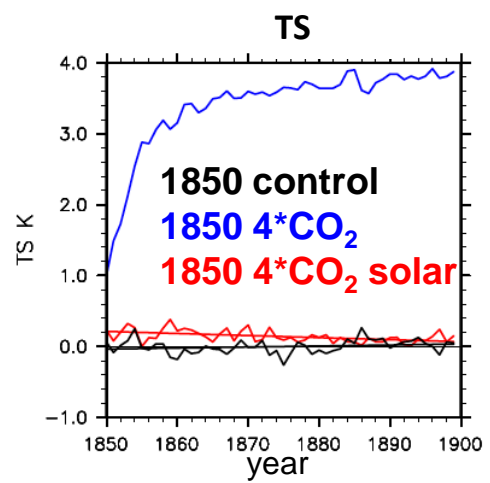
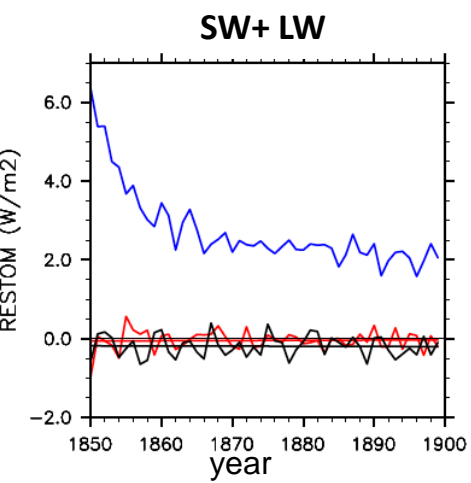


1850 4\*CO<sub>2</sub> solar - 1850 control





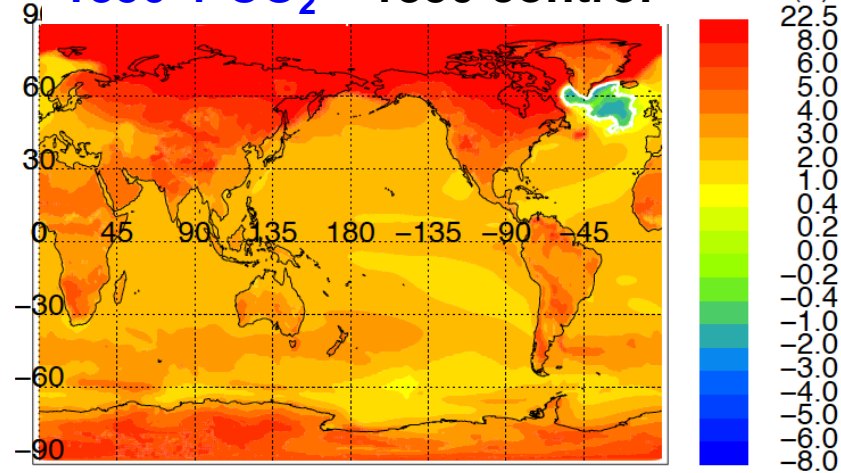
## Results: G1 Simulation



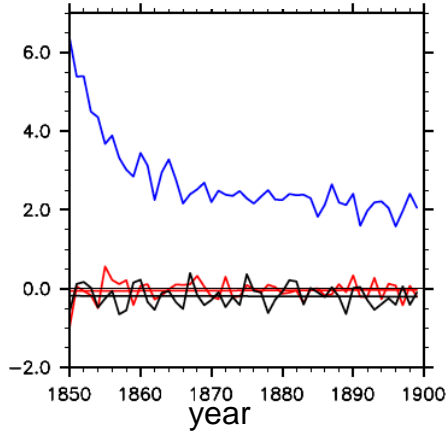


### 1850-1898 DJF

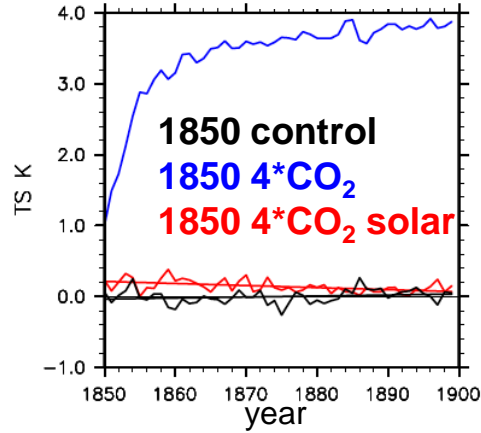
### 1850 4\*CO<sub>2</sub> – 1850 control



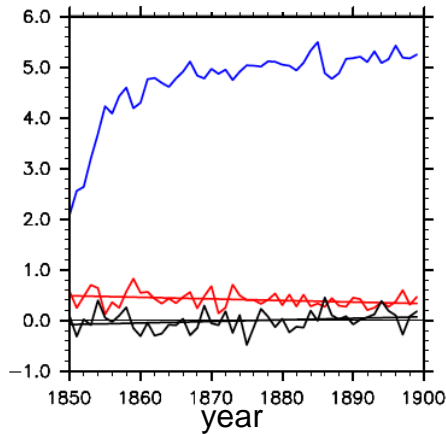
### SW+ LW



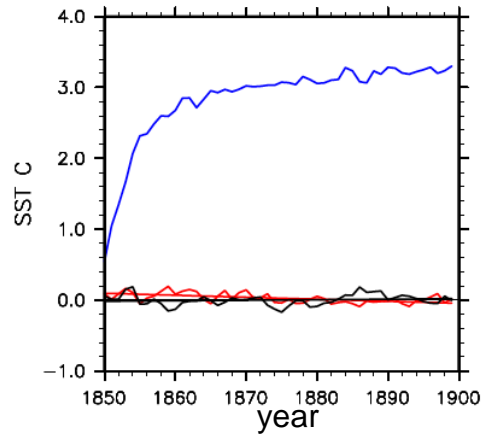
### TS



### TS Land



### SST

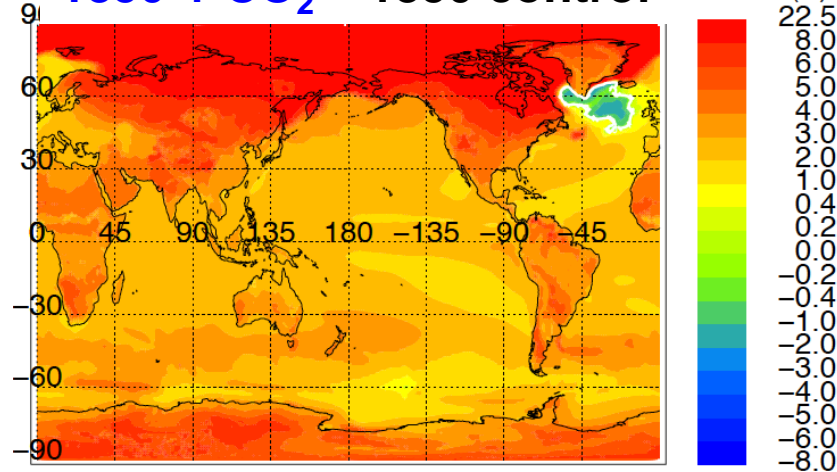


Hatched areas are not significant at 95% level based on Student's t test.

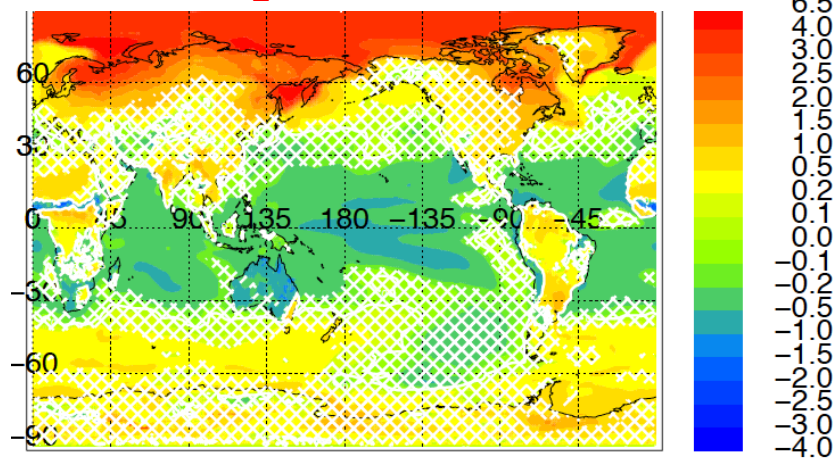


### 1850-1898 DJF

#### 1850 4\*CO<sub>2</sub> – 1850 control



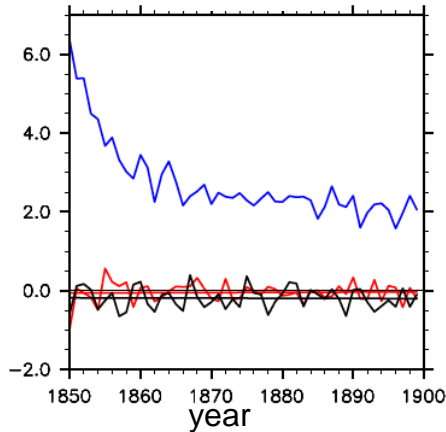
#### 1850 4\*CO<sub>2</sub> solar - 1850 control



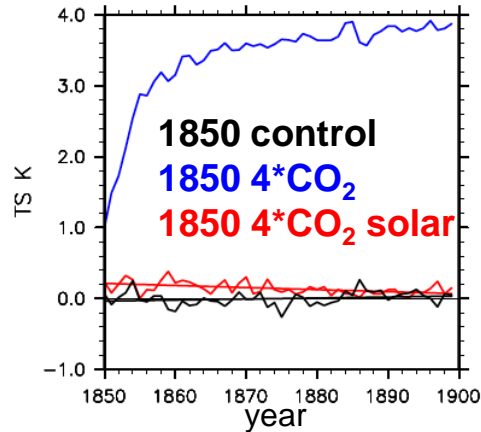
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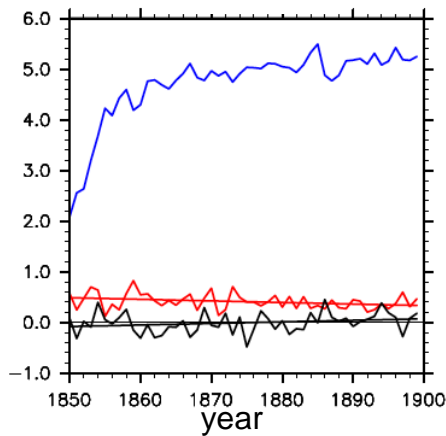
#### SW+ LW



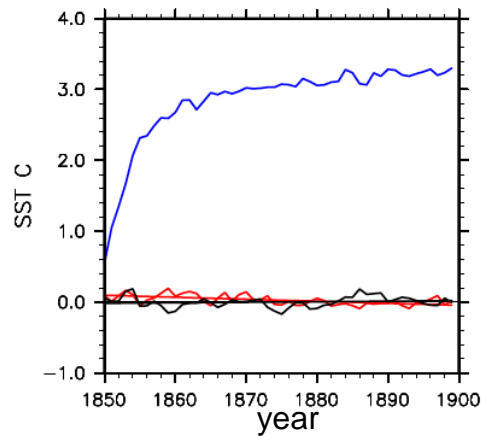
#### TS



#### TS Land



#### SST

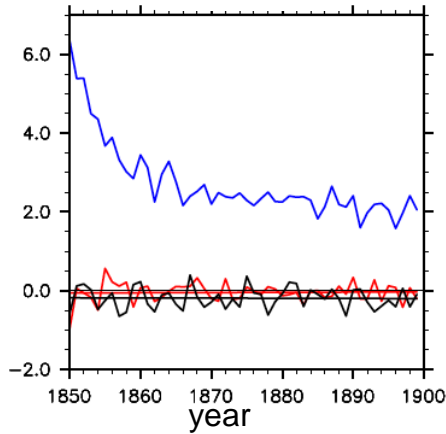




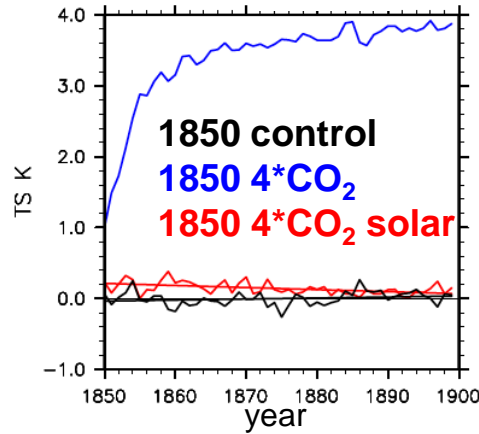


### 1850-1898 JJA

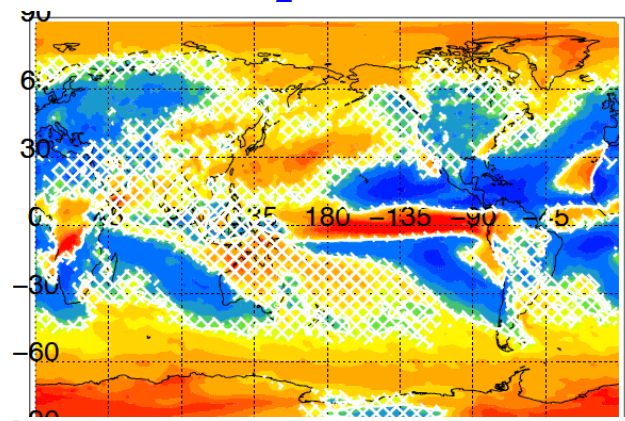
SW+ LW



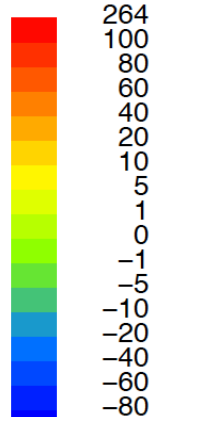
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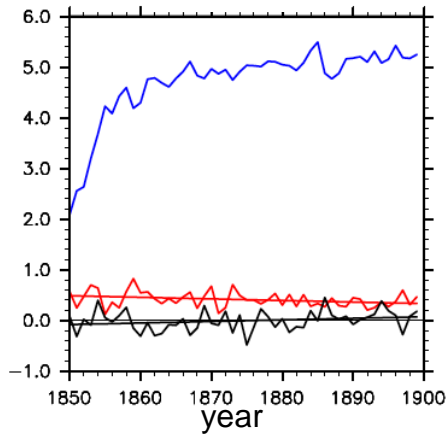
1850 4\*CO<sub>2</sub> - 1850 control



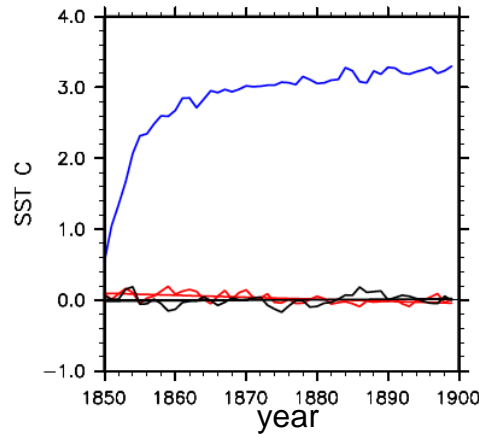
%PREC mm/day



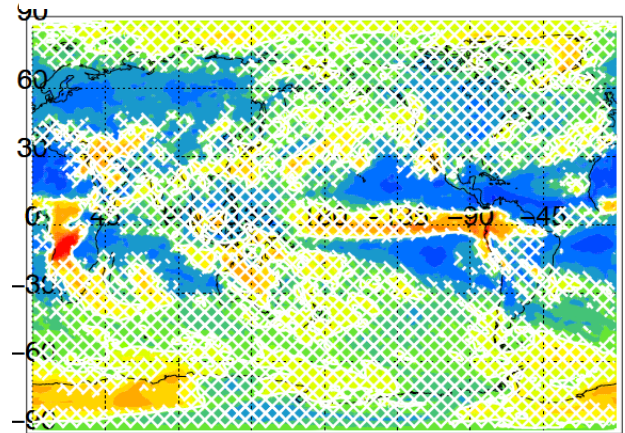
TS Land



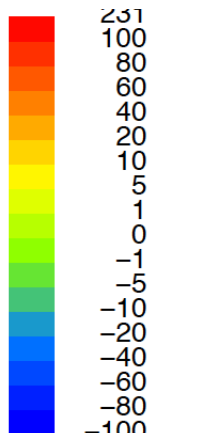
SST



1850 4\*CO<sub>2</sub> solar - 1850 control



n/day



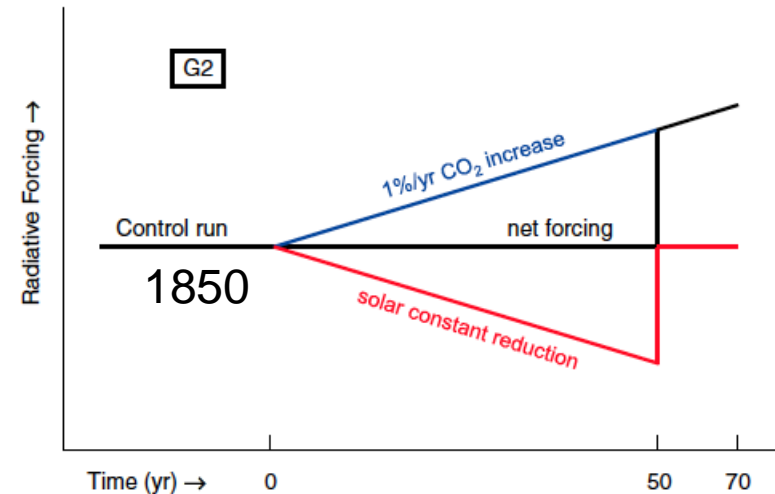
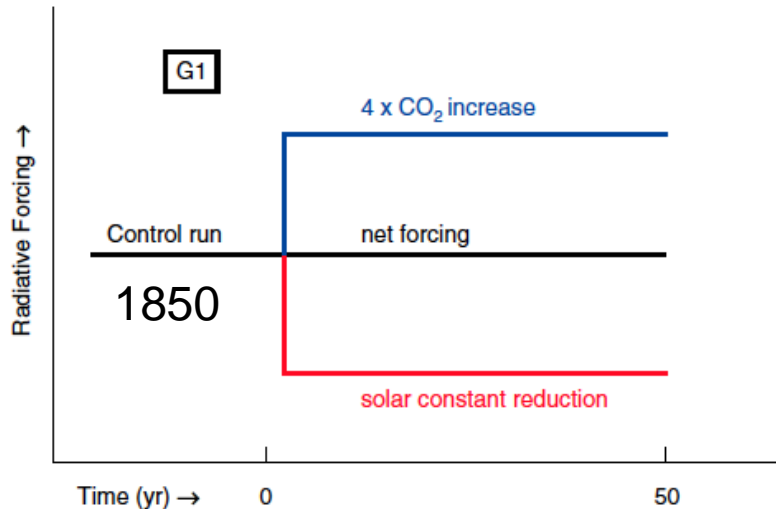
Hatched areas are not significant at 90% level based on Student's t test.



# GEOMIP Simulations

Four proposed experiments: G1-G4

**G1, G2:** balancing incoming LW forcing with reduced SW forcing  
(reduction of solar constant)



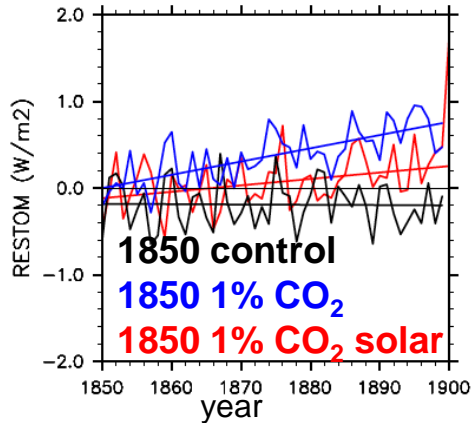
**G1: Baseline:** CMIP5 4xCO<sub>2</sub>, **Geoeng.:** radiative forcing will be balanced (model specific based on the planetary albedo)

**G2: Baseline:** CMIP 1% /yr CO<sub>2</sub> increase, **Geoeng.:** derived from G1 experiment

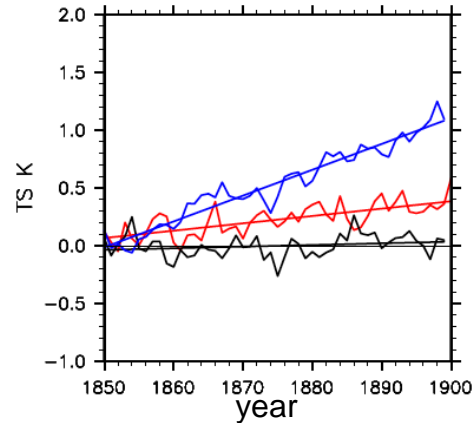


# Results: G2 Simulation

SW+ LW



TS



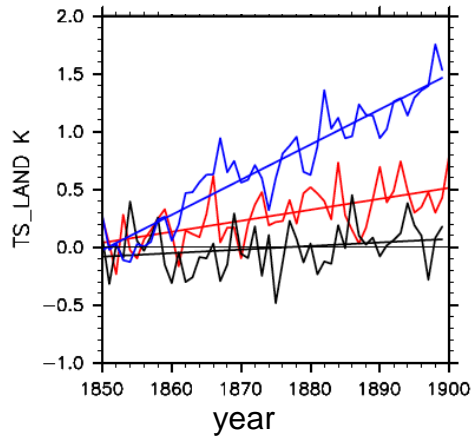
**G2: Baseline:** CMIP5 1% ramp-up CO<sub>2</sub>, solar constant: 1360.89, RESTOM increasing

**Geoeng.:**

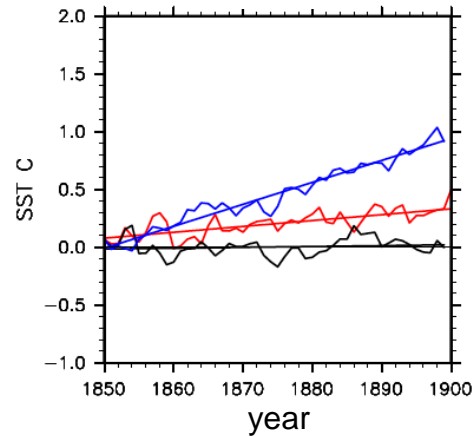
Solar constant scaled down from G1 experiment, assuming linear increase in the solar constant for a the 1% CO<sub>2</sub> simulation.

Linear increase of solar constant not sufficient after 30 year.

TS Land



SST







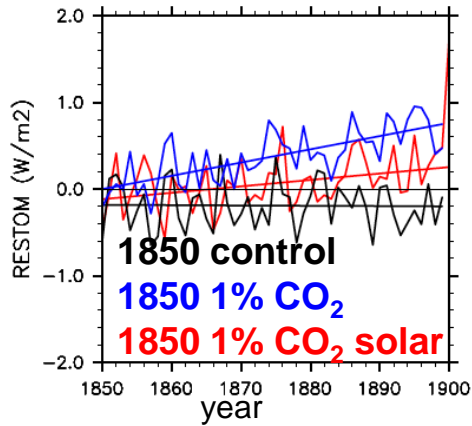
# Results: G2 Simulation

1875-1898

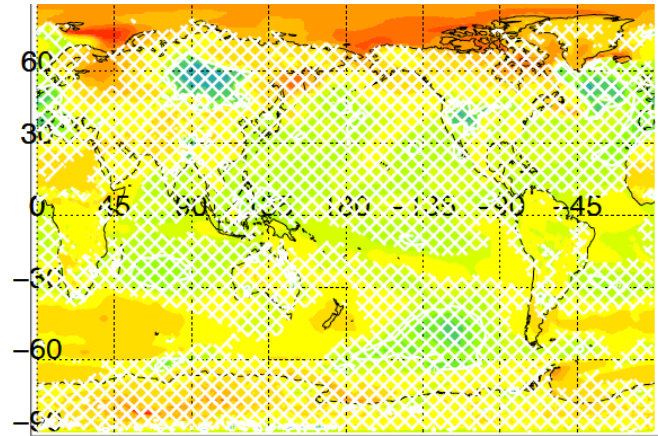
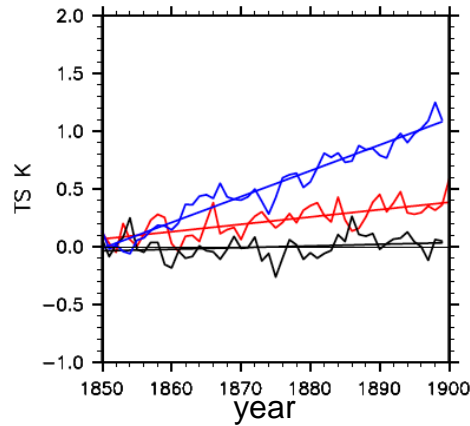
DJF

1850 1% CO<sub>2</sub> solar – 1850 control

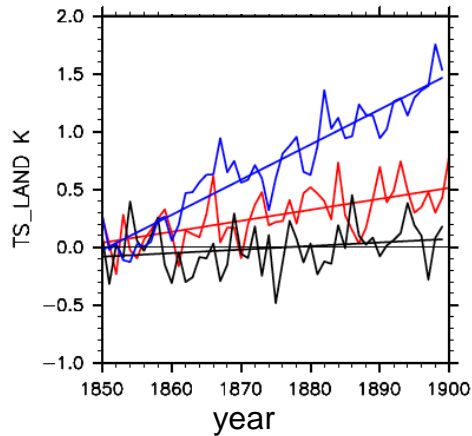
SW+ LW



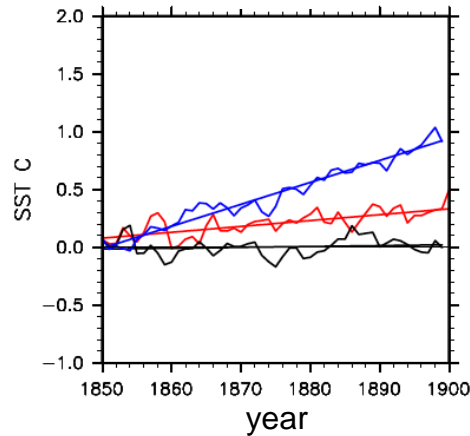
TS



TS Land

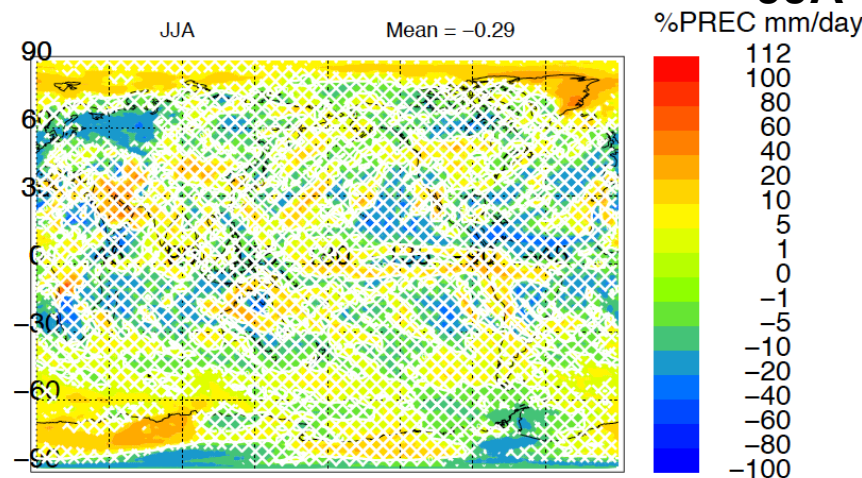


SST



Hatched areas are not significant at 95%

JJA



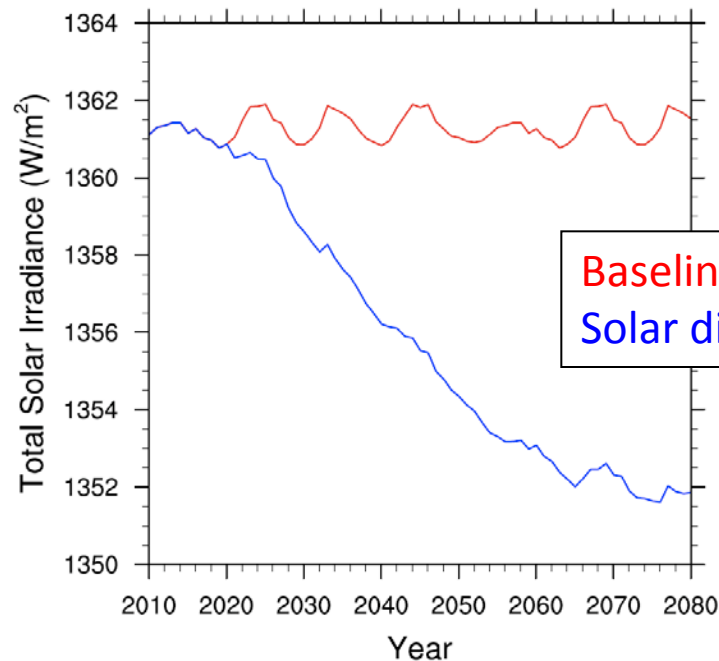
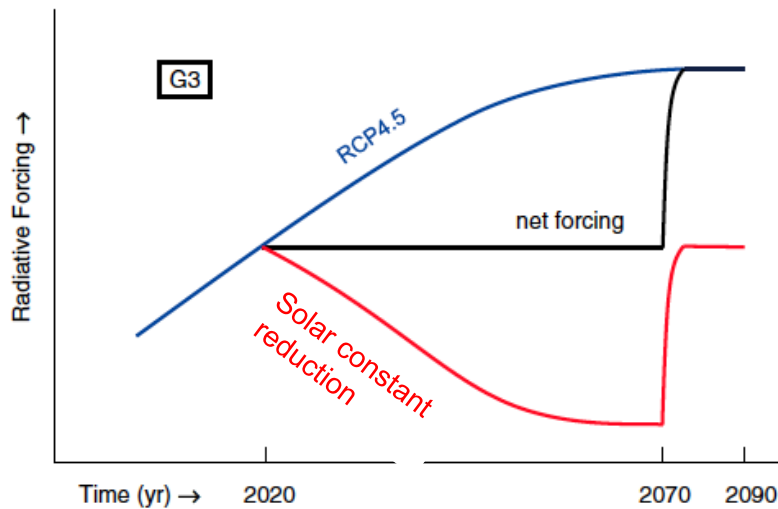


# GEOMIP Simulations

**G3 solar:** balancing incoming LW forcing with solar dimming

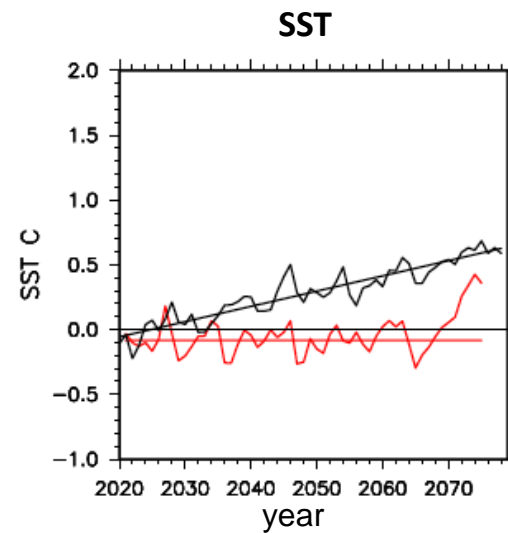
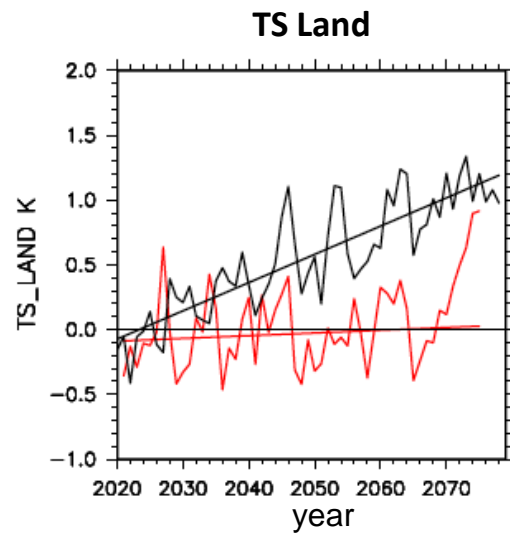
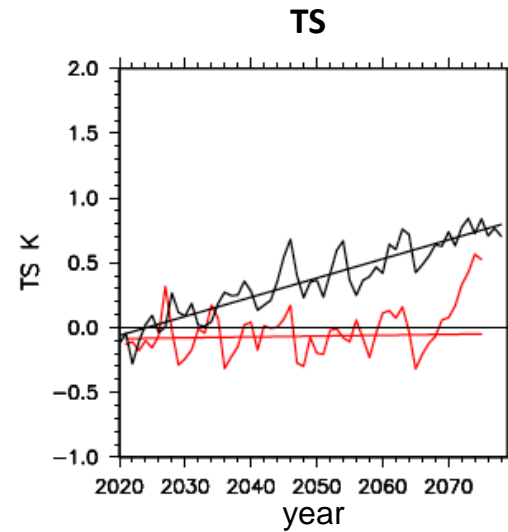
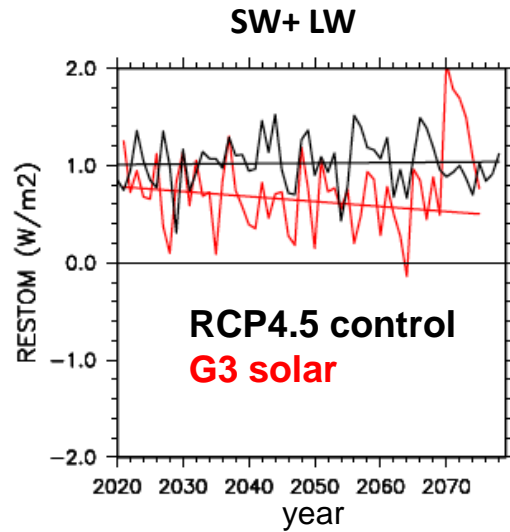
$\Delta RF$ : Annual change of total anthropogenic forcing from RCP4.5 simulation

$$\Delta RF = (\Delta S/4.) * (1-\alpha)$$





# Results: G3solar Simulation (2deg)





# Conclusions

- G1: Annual balanced global TOA flux includes strong in-balance in different latitudes
- G1: 4xCO<sub>2</sub> solar simulations show significant temperature changes in high latitudes in summer in comparison to 1850 conditions
- G1: Precipitation patterns changes are similar to those from a 4\*CO<sub>2</sub> model run.
- G2: Temperature and precipitation changes less significant but go in the same direction as the G1 model run
- G2: Assuming linear change in RF is not sufficient to achieve a balance at the TOA more that 30 year.
- Further simulations with BGC and atmospheric chemistry planned using CESM
- Further simulations planned with WACCM/CARMA (sulfur injection)





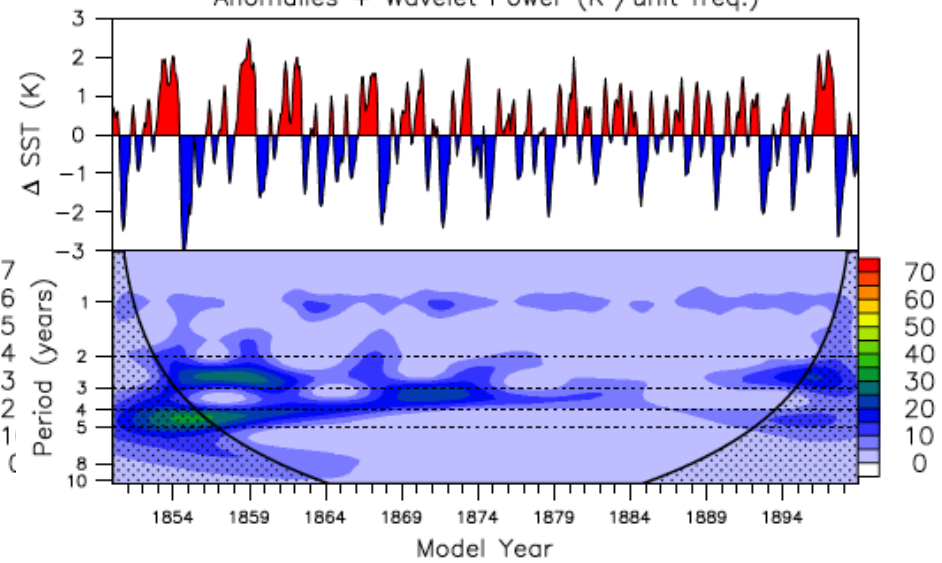
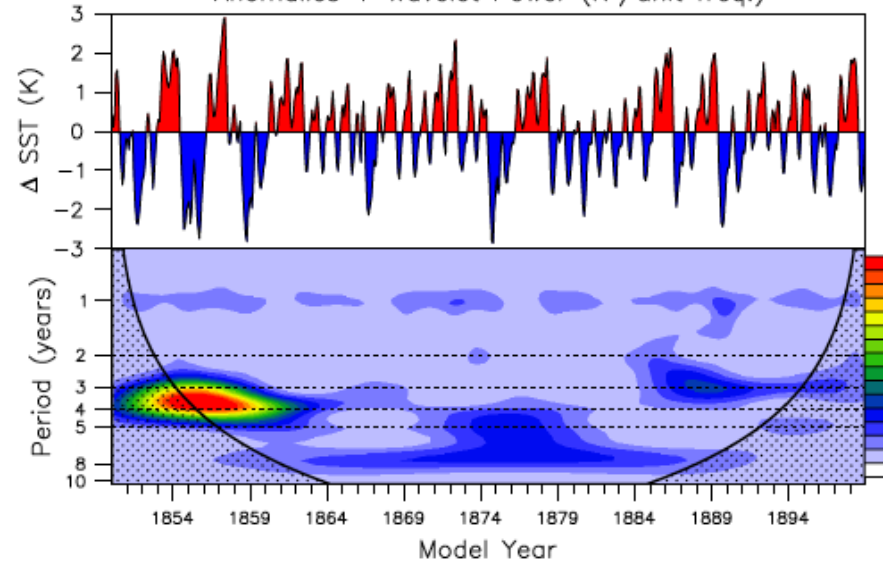
# Results: G1 Simulation

## 1850 Control

## 1850 Control, 4\*CO<sub>2</sub>, solar

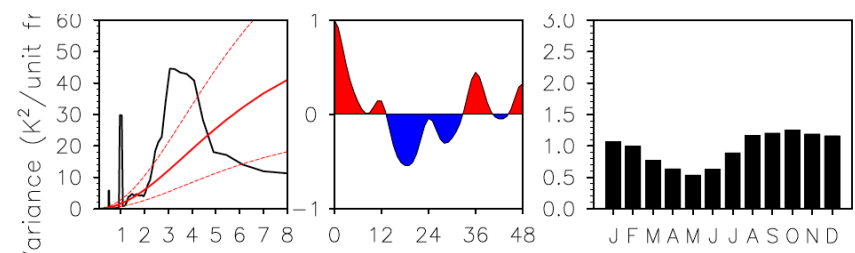
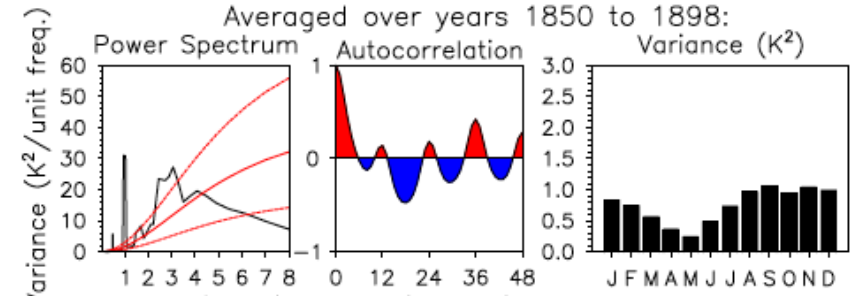
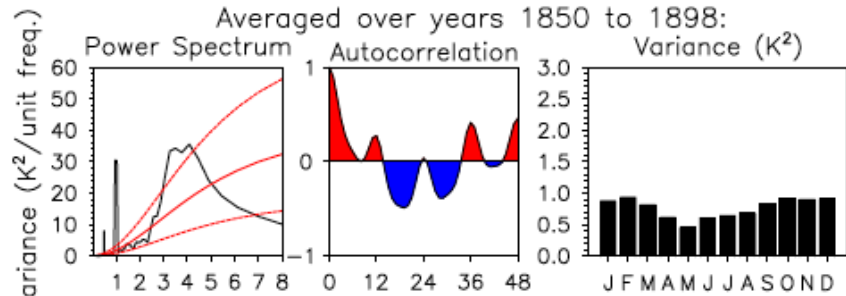
Anomalies + Wavelet Power (K<sup>2</sup>/unit freq.)

Anomalies + Wavelet Power (K<sup>2</sup>/unit freq.)



Averaged over years 1850 to 1898:

Averaged over years 1850 to 1898:





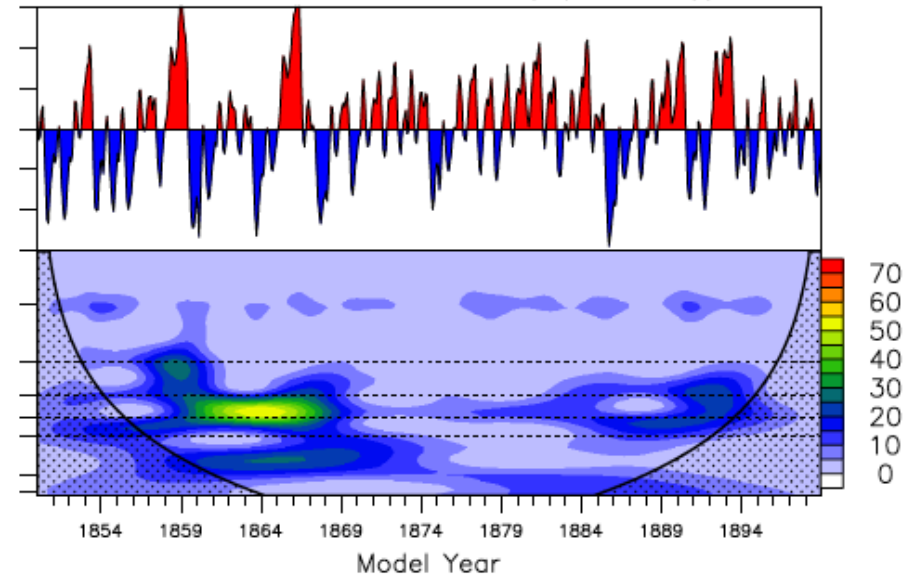
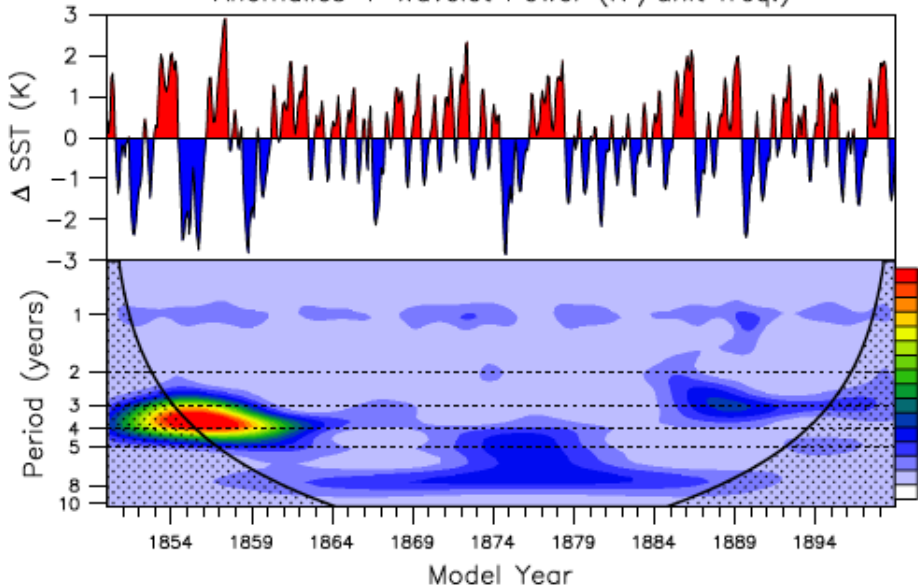
# Results: G2 Simulation

## 1850 Control

## 1850 Control, 1%rampCO<sub>2</sub>, solar

Anomalies + Wavelet Power (K<sup>2</sup>/unit freq.)

Anomalies + Wavelet Power (K<sup>2</sup>/unit freq.)



Averaged over years 1850 to 1898:

Averaged over years 1850 to 1898:

