GUIRR
13 Oct 2010

WHAT IS GEOENGINEERING?
A survey of the proposed options

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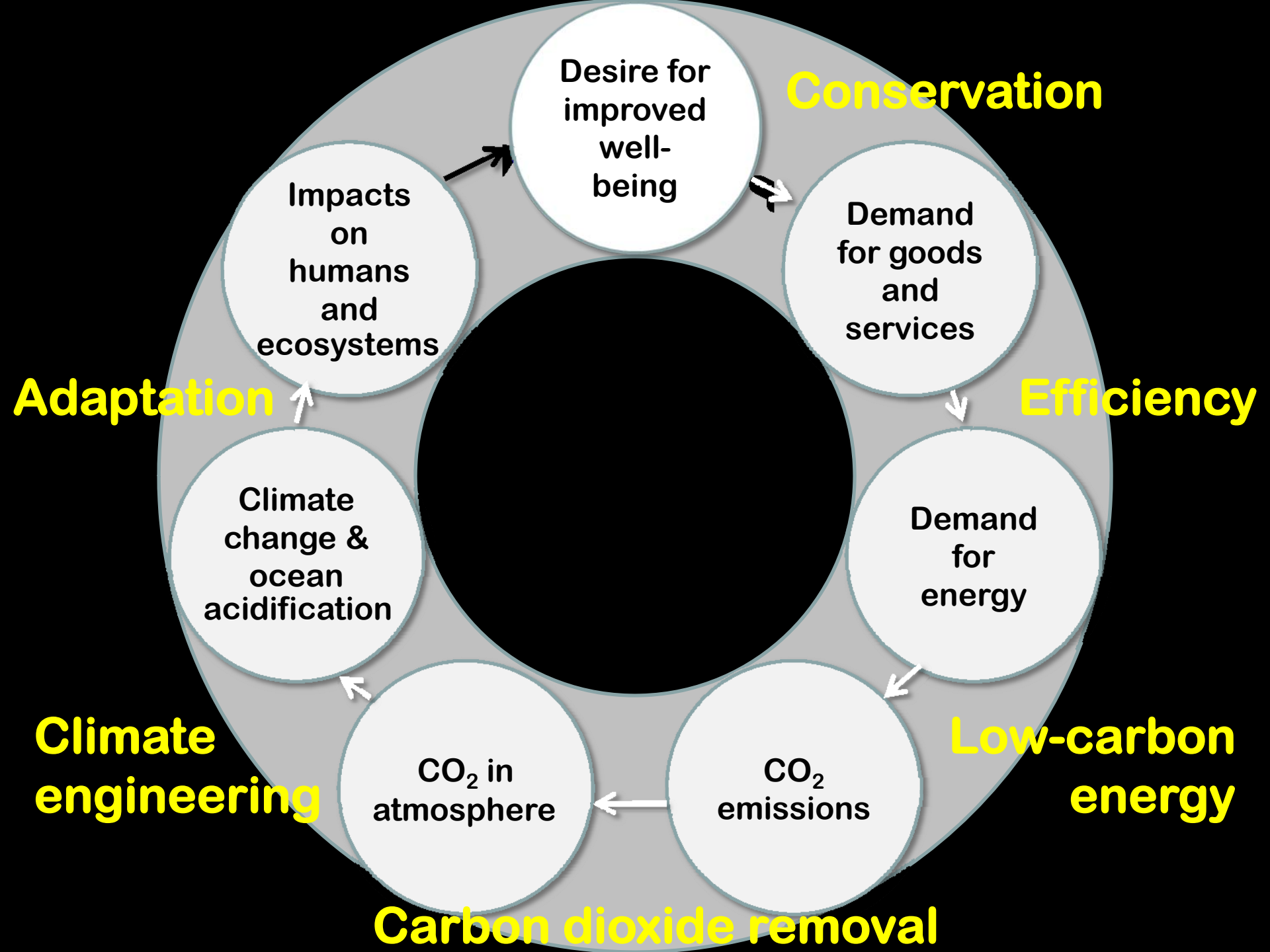
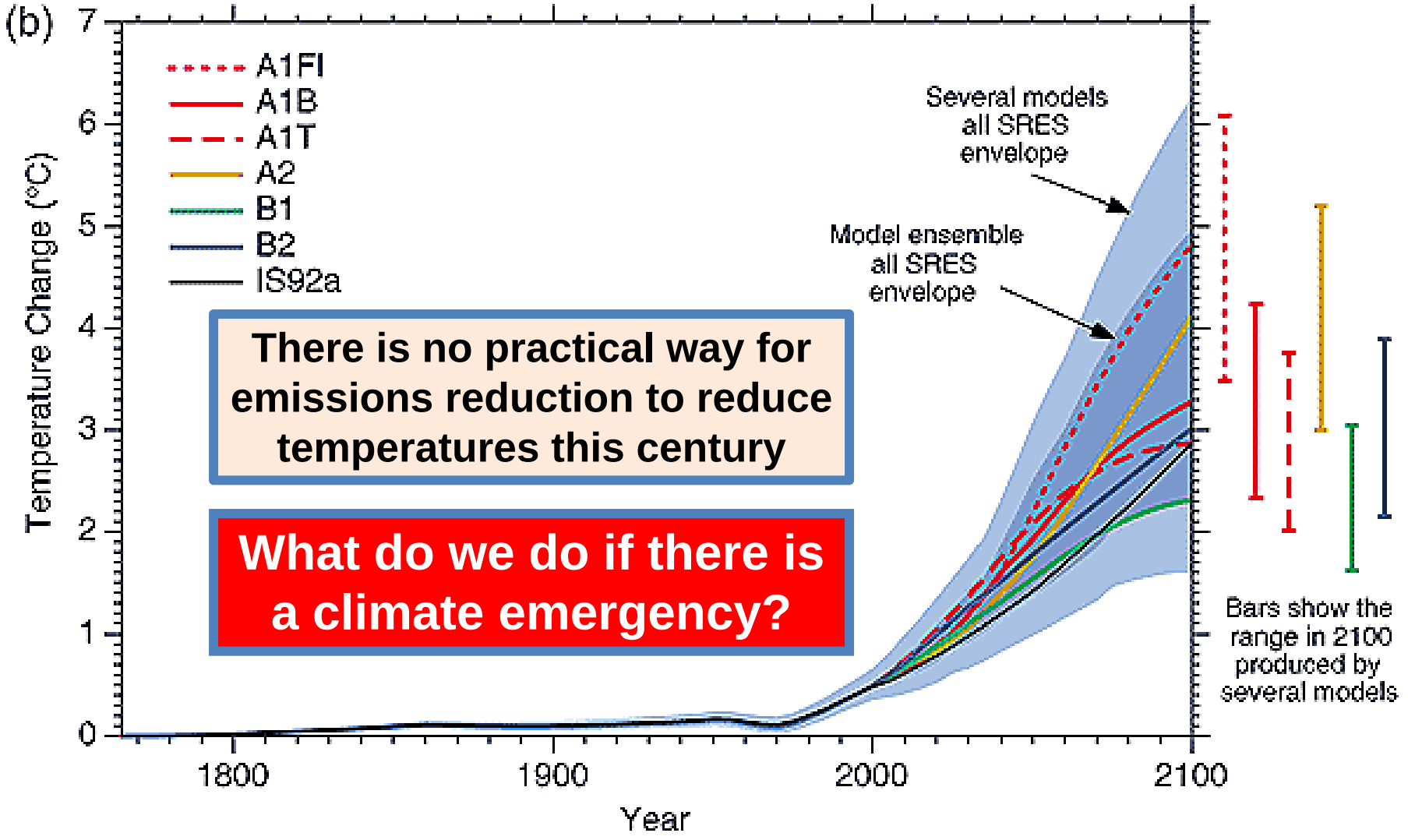
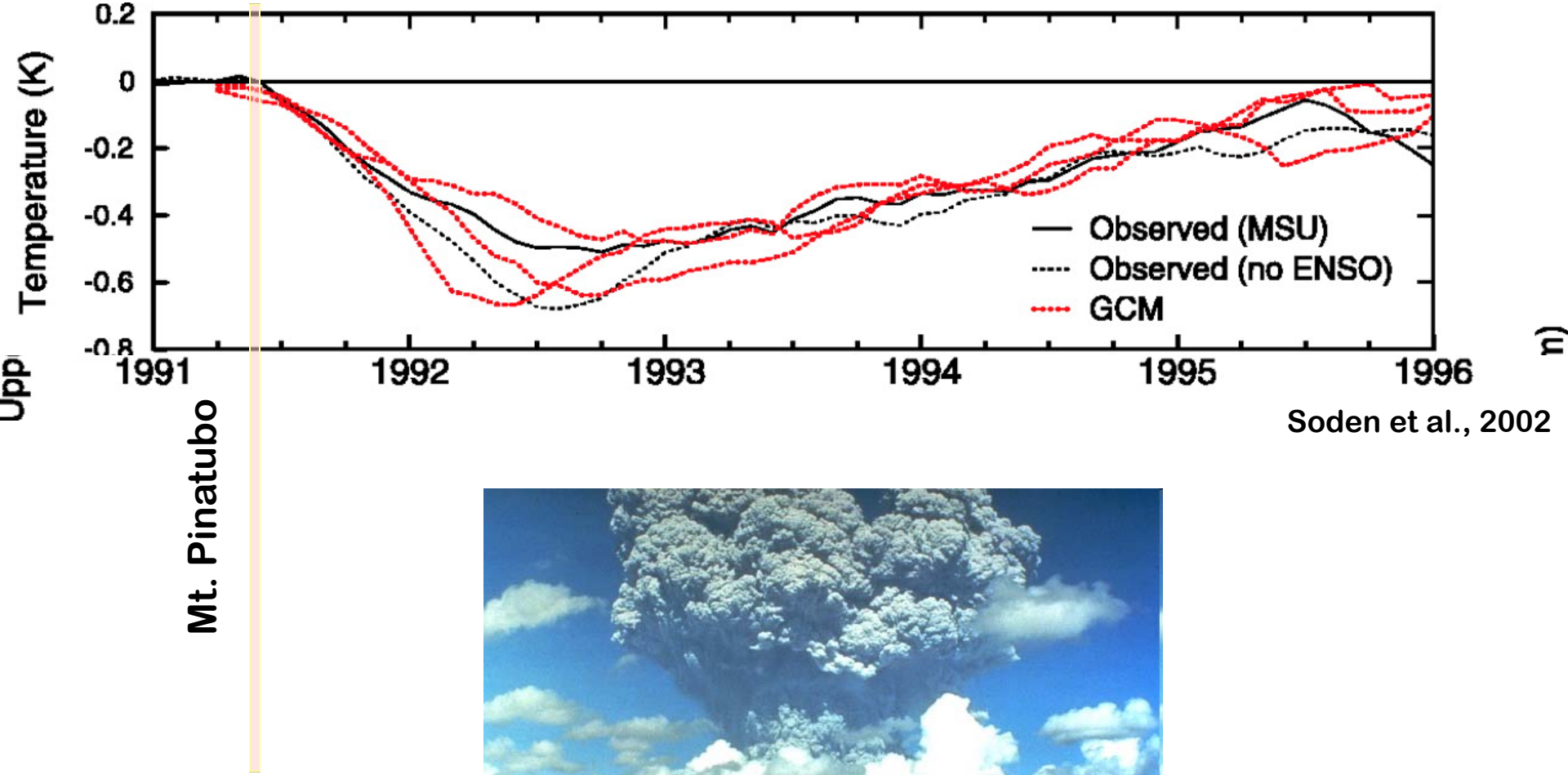

Desire for improved well-being
Conservation
Demand for goods and services
Efficiency
Demand for energy
Low-carbon energy
CO_2 emissions
Carbon dioxide removal
CO_2 in atmosphere
Climate engineering
Climate change & ocean acidification
Adaptation
Impacts on humans and ecosystems

Temperatures continue to increase throughout this century in every plausible emissions scenario



IPCC TAR

Volcanoes caused global cooling by putting dust in the stratosphere



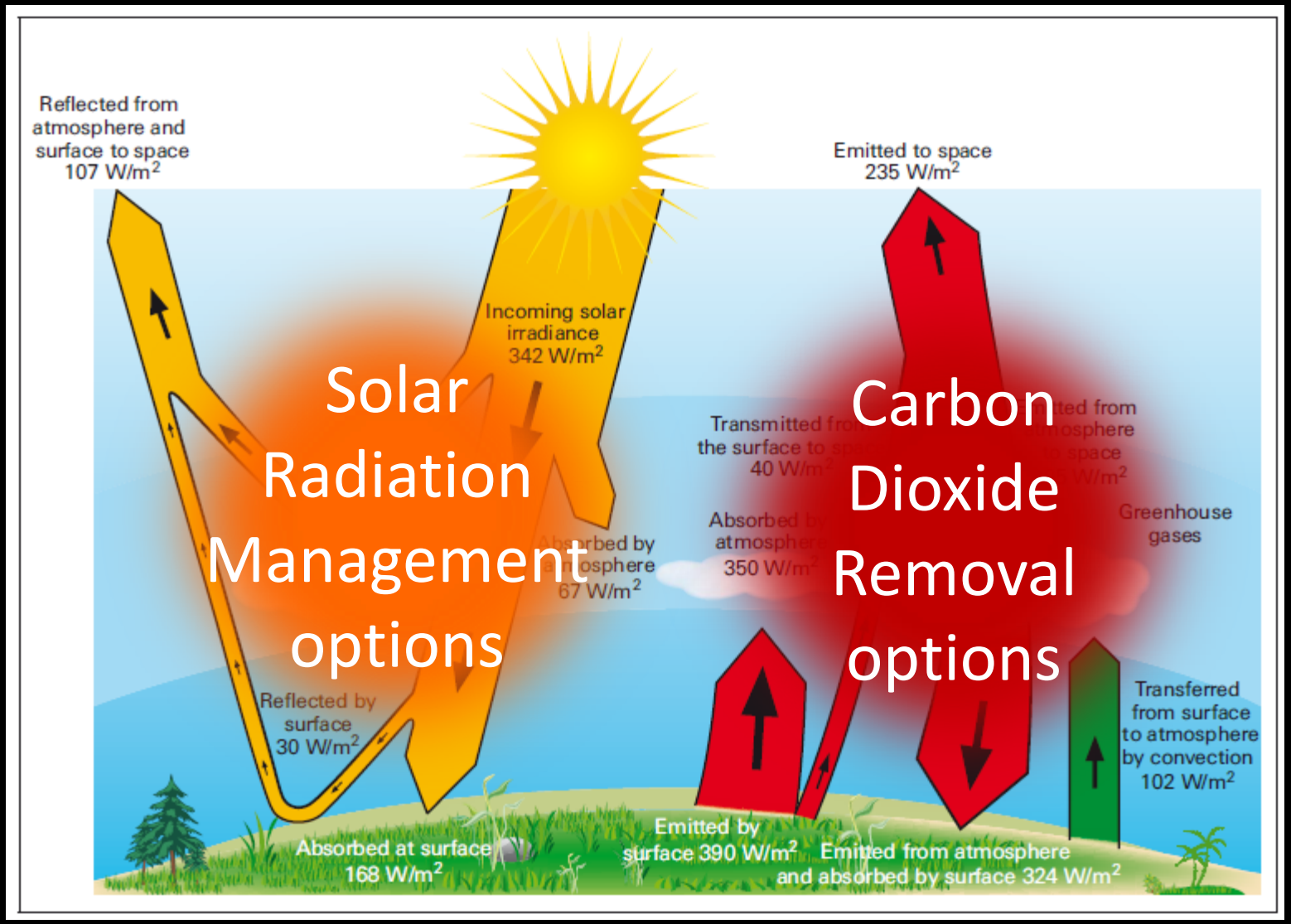
Soden et al., 2002

Definition of “Geoengineering”

- No commonly accepted definition

- Typical elements in definitions
  - Intentional
  - Large scale
  - Involves alteration of natural systems
  - Novel or unfamiliar
  - Attempts to diminish climate change impacts

Earth's energy balance



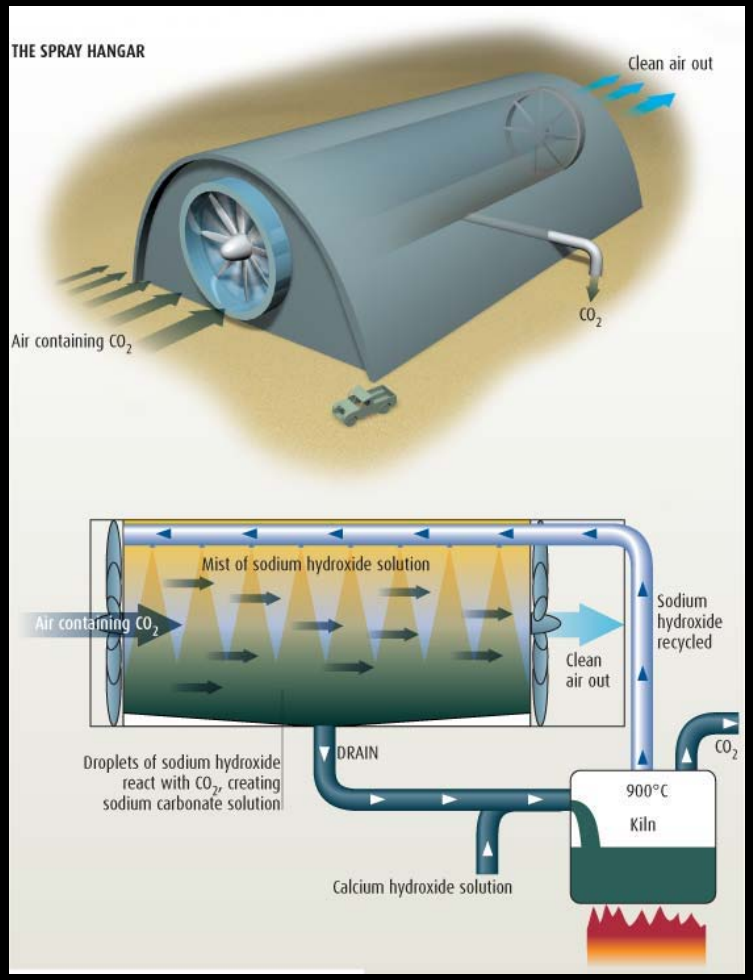
The best Carbon Dioxide Removal options –

- Are slow
- Are either expensive or not scalable
- Do not introduce new kinds of environmental risk
- Do not introduce new governance issues
- **Address the root causes of the problem (excess CO_2 in the environment)**

The best Solar Radiation Management options –

- Act quickly
- Are inexpensive and scalable
- Introduce new kinds of environmental risk
- Introduce new governance issues
- Do not address the root causes of the problem (excess CO_2 in the environment)

Carbon Dioxide Removal: Industrial CO_2 removal from air



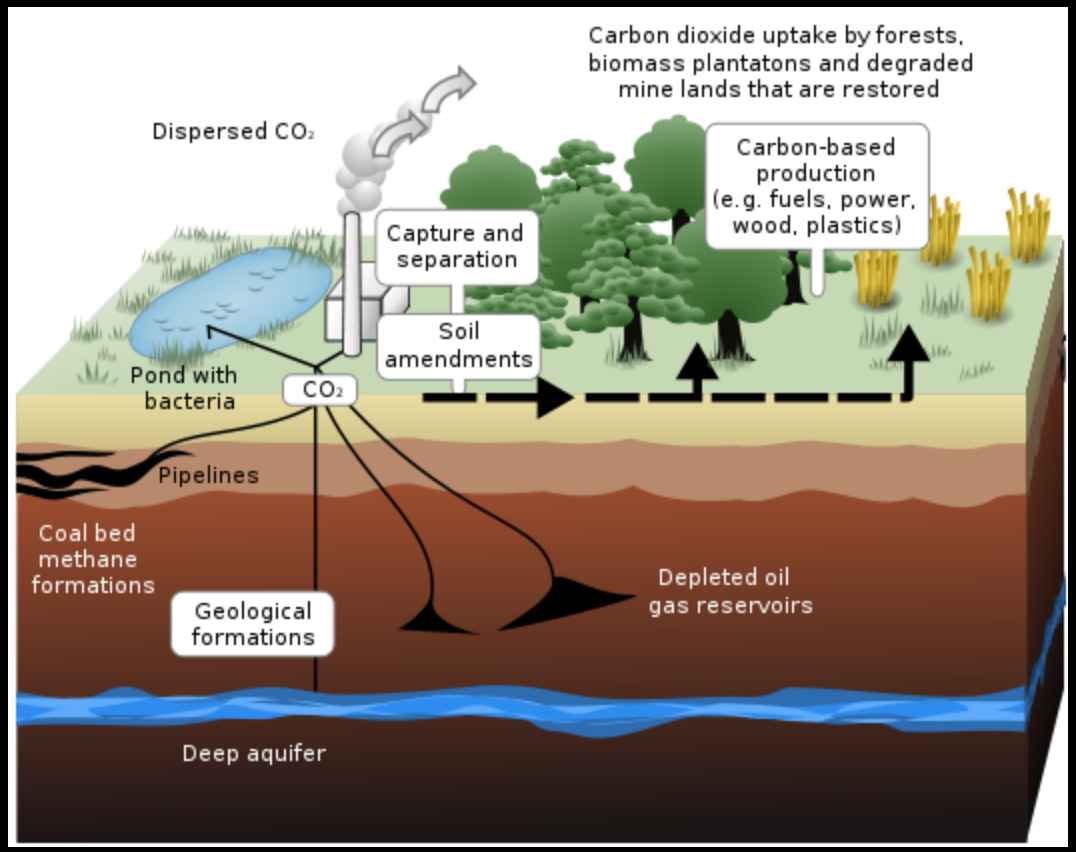
New Scientist

Carbon Dioxide Removal:
Land use and afforestation

www.antipixel.com/blog/archives/2006/08/15/yakushima_forest.html

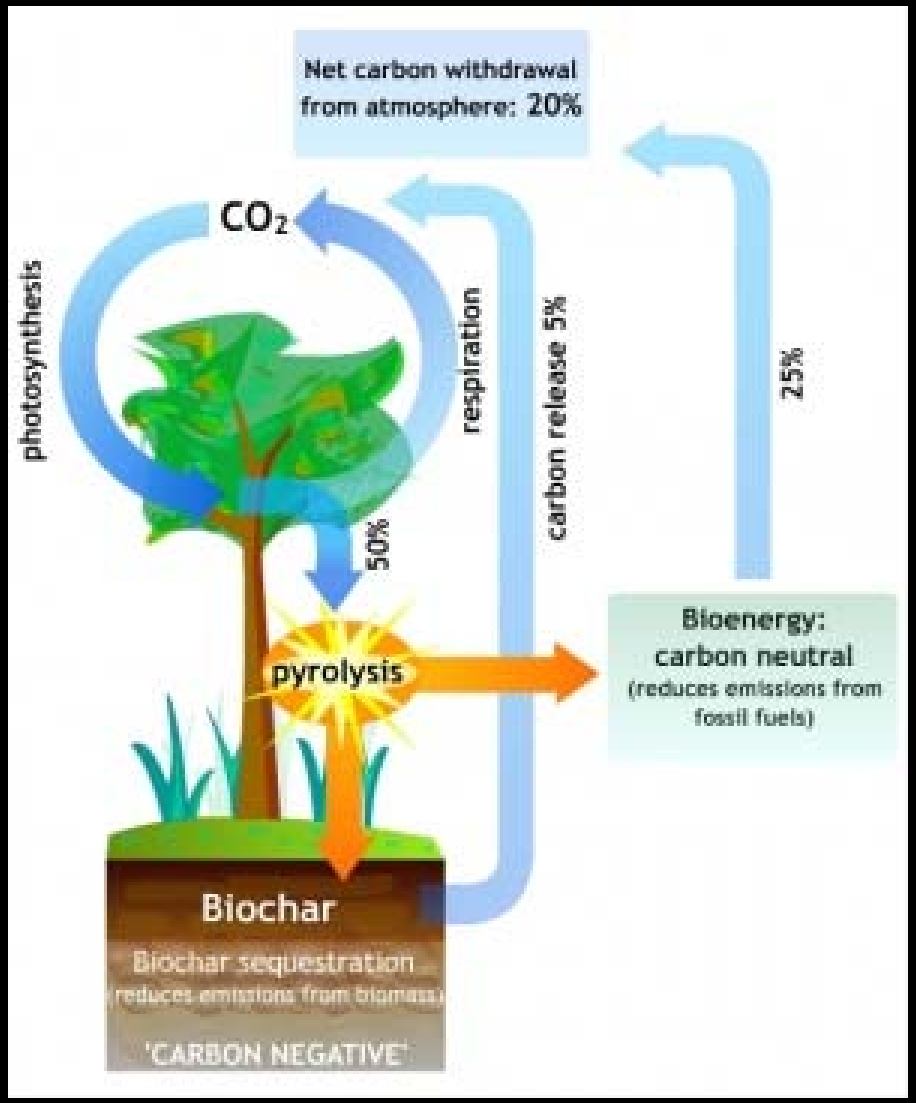
Carbon Dioxide Removal:

Biomass energy with carbon sequestration



LeJean Hardin and Jamie Payne

Carbon Dioxide Removal: Biochar



Ken Webster and Craig Johnson

Carbon Dioxide Removal:
Enhanced weathering – terrestrial

$CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2$

A Parkinson, FRGS

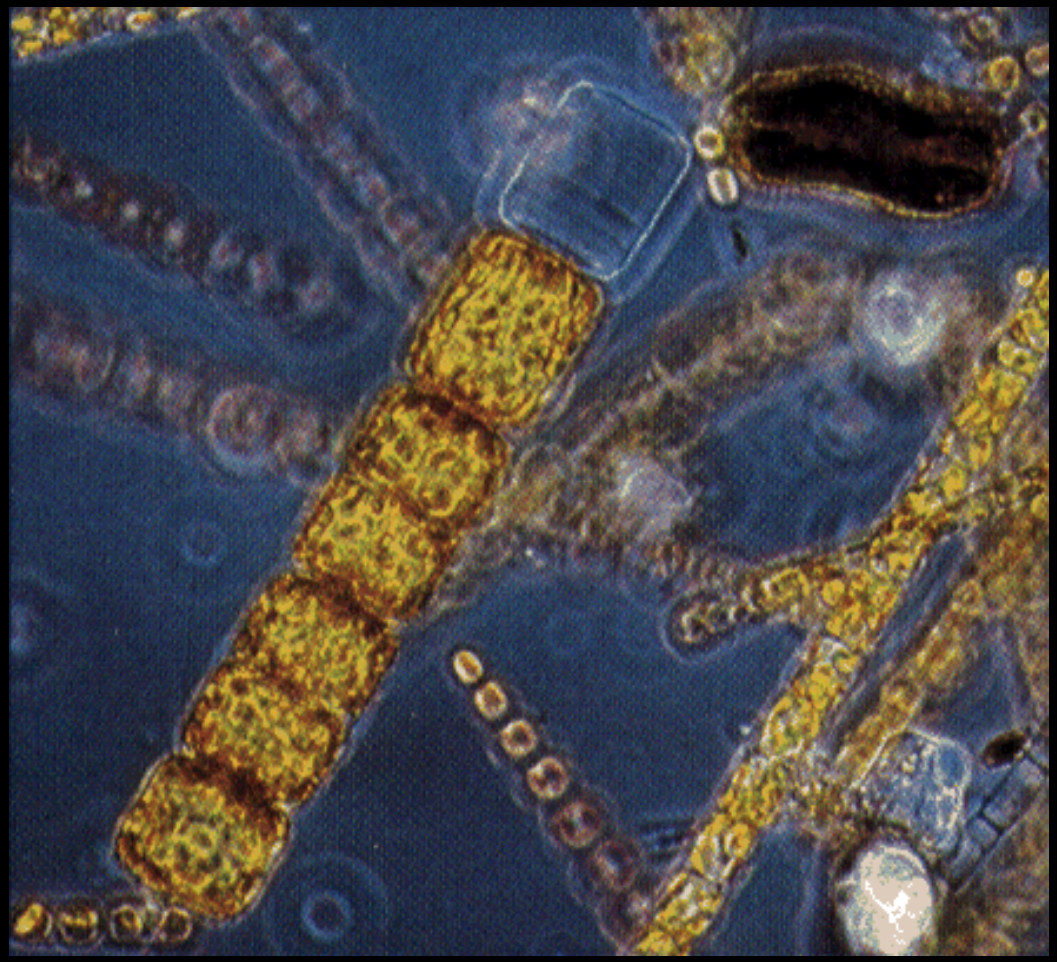
Carbon Dioxide Removal:
Enhanced weathering – oceans

$$CaSiO_3 + 2CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^- + SiO_2$$

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3$$

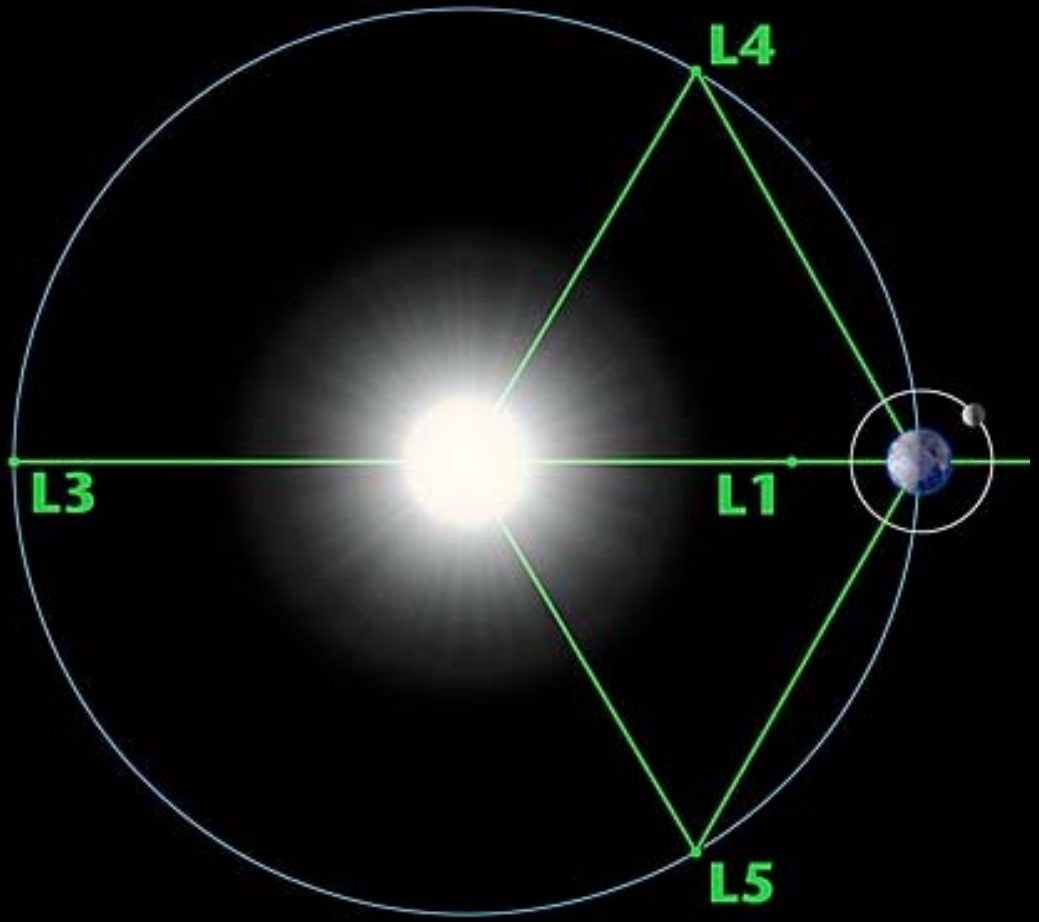
/commons.wikimedia.org/wiki/File:White_cliffs_of_dover_09_2004.jpg

Carbon Dioxide Removal:
Ocean fertilization



http://disc.sci.gsfc.nasa.gov/oceancolor/additional/science-focus/images/diatom.gif

SRM: Space-based methods



Solar Radiation Management: Surface albedo (human settlement)

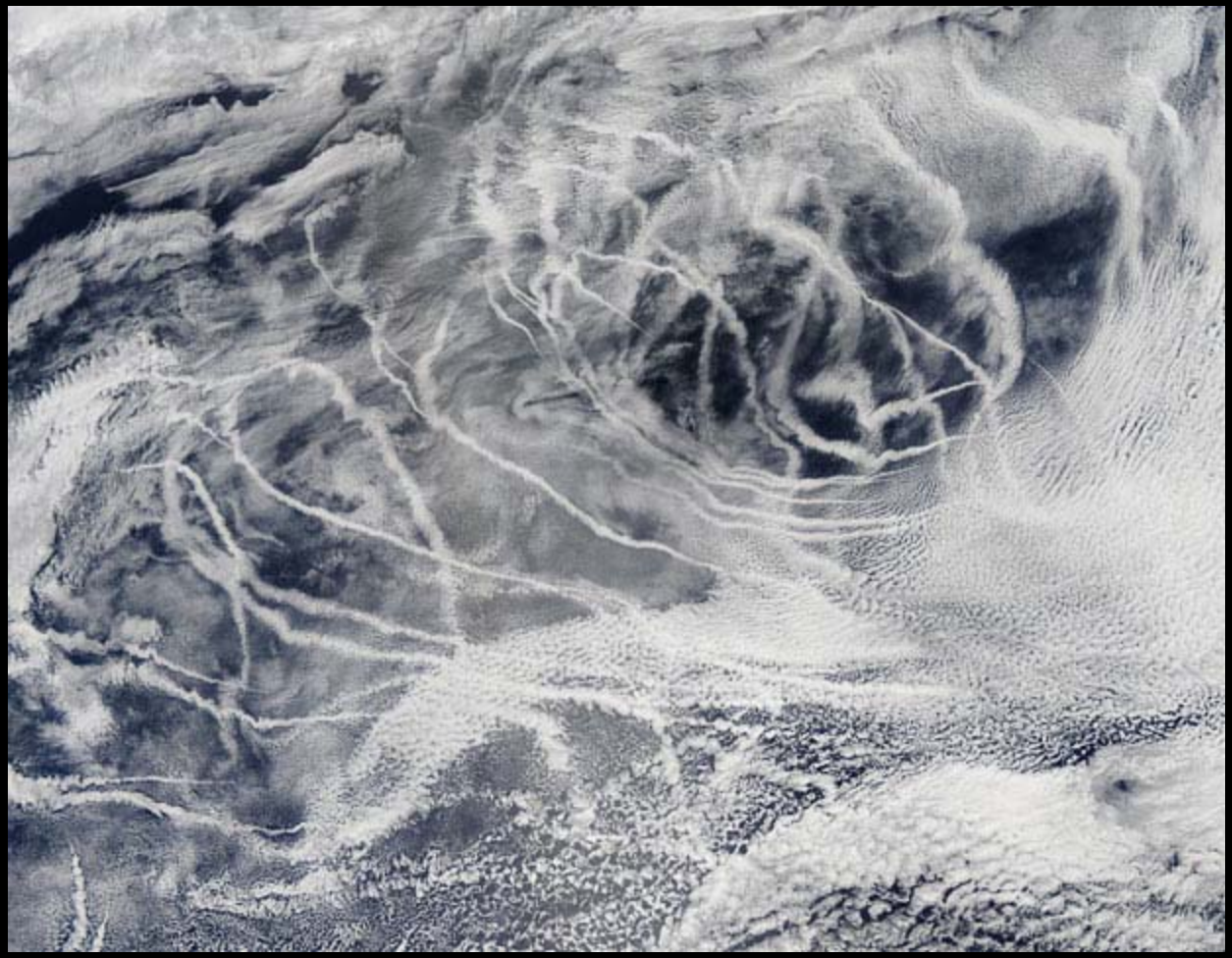
Santorini - Telegraph

Montepulciano – ItalianVisits.com

Solar Radiation Management: Surface albedo (desert)

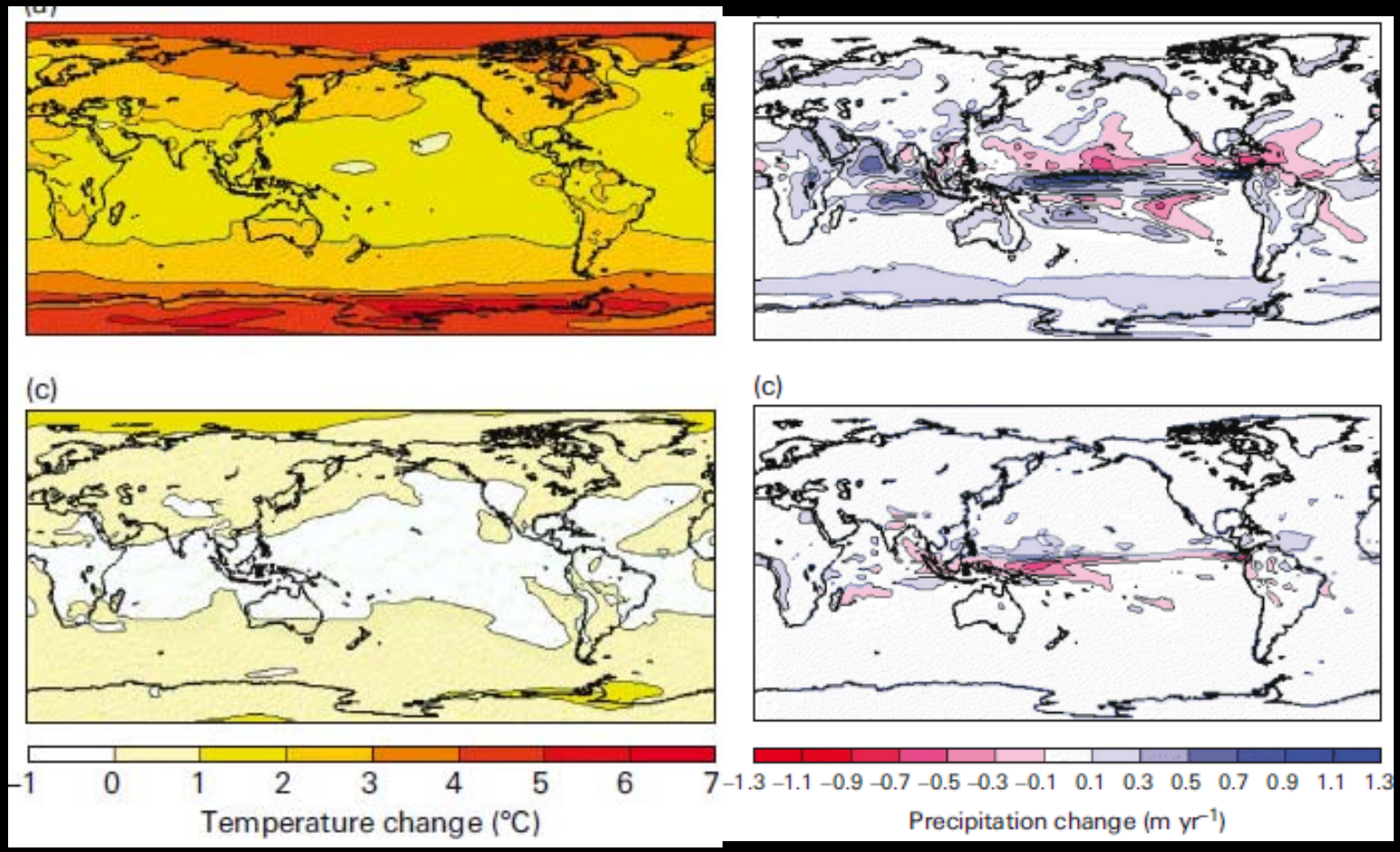
Mark Brodie, KJZZ

Solar Radiation Management: Marine cloud whitening



NASA

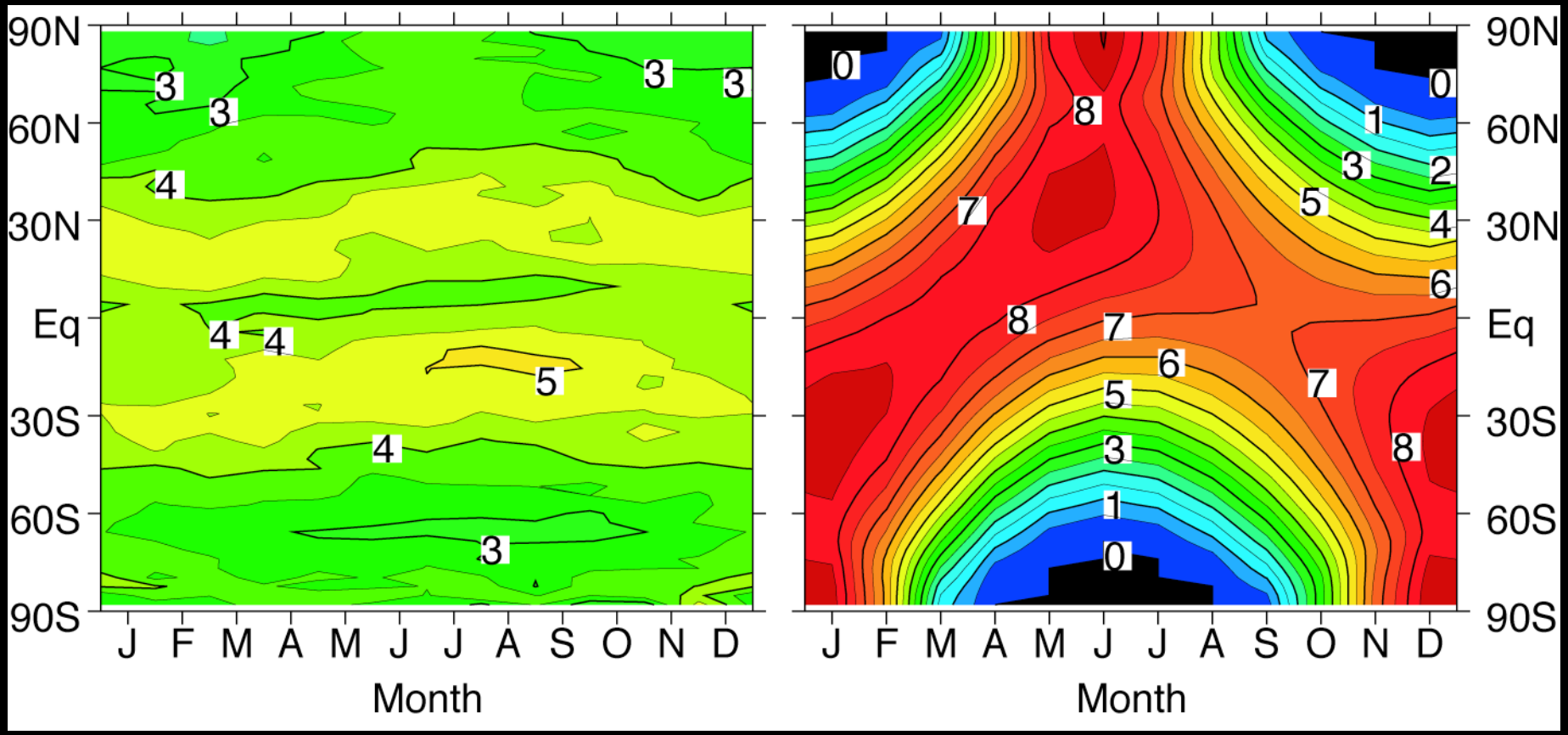
Solar Radiation Management: Stratospheric aerosols



Geoengineering

CO_2 radiative forcing from a CO_2 doubling (W / m^2)

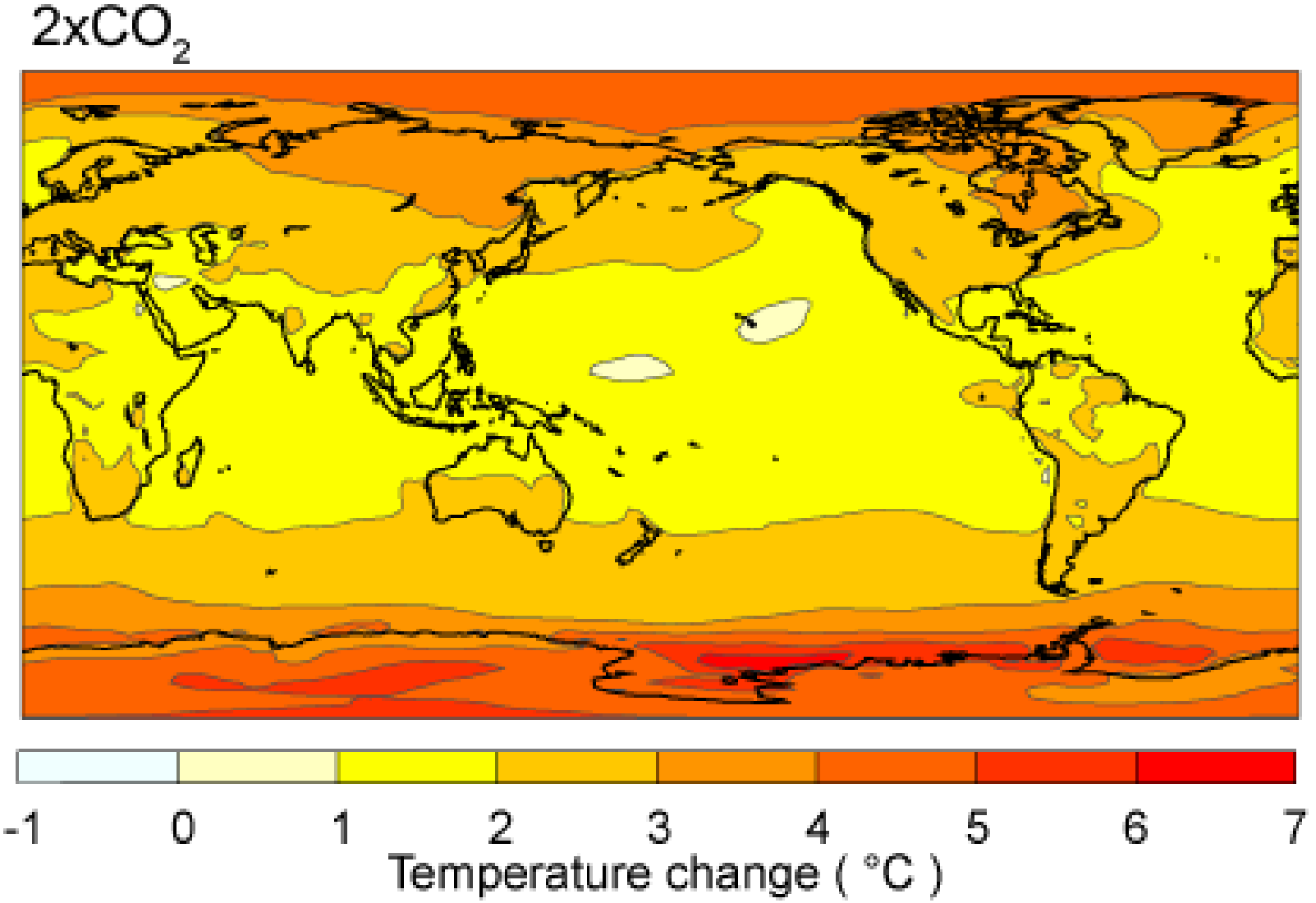
Radiative forcing from 1.8% reduction in solar intensity (W / m^2)



Can these cancel ???

Govindasamy and Caldeira, GRL, 2000

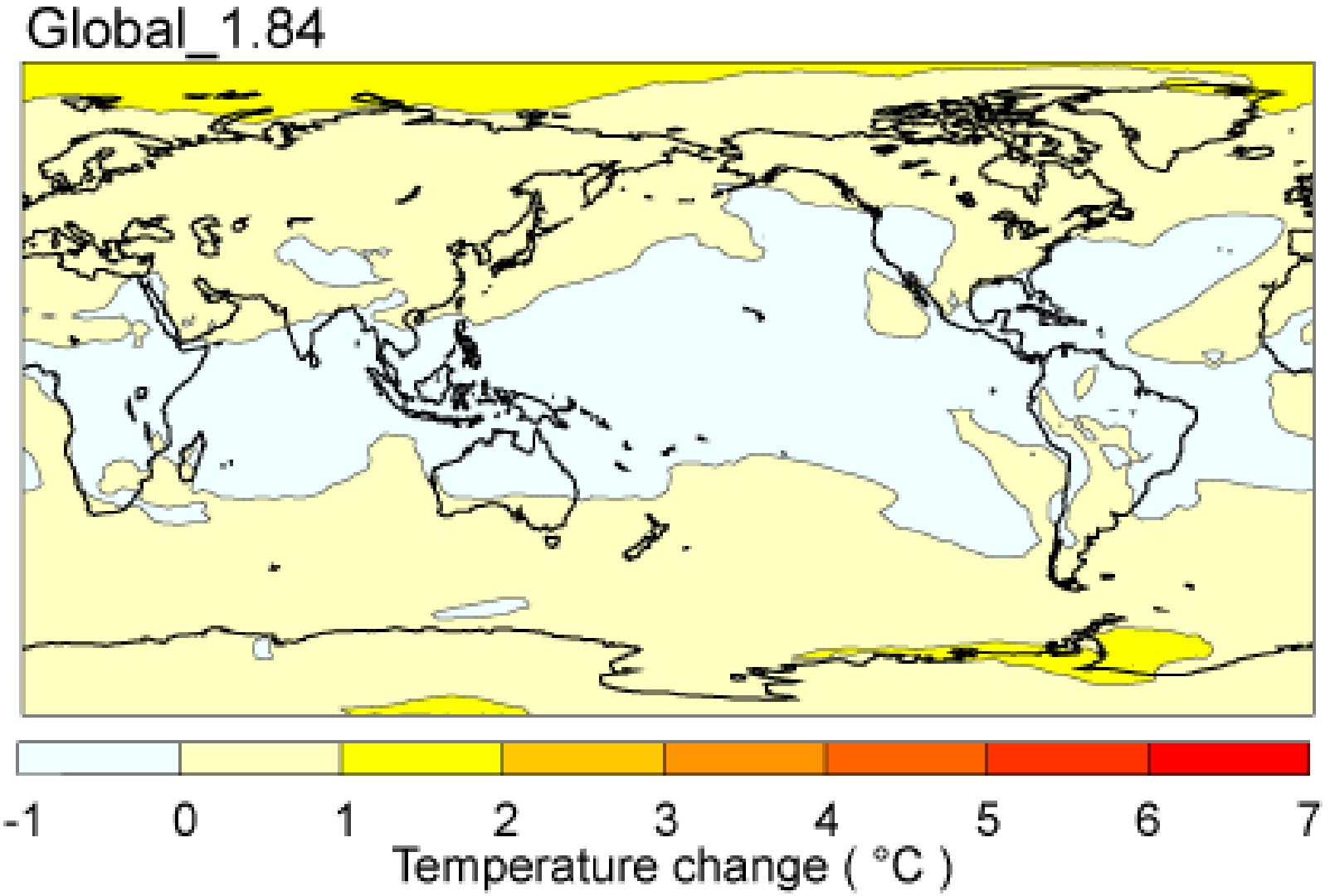
Temperature effects of doubled CO_2



Caldeira and Wood, 2008

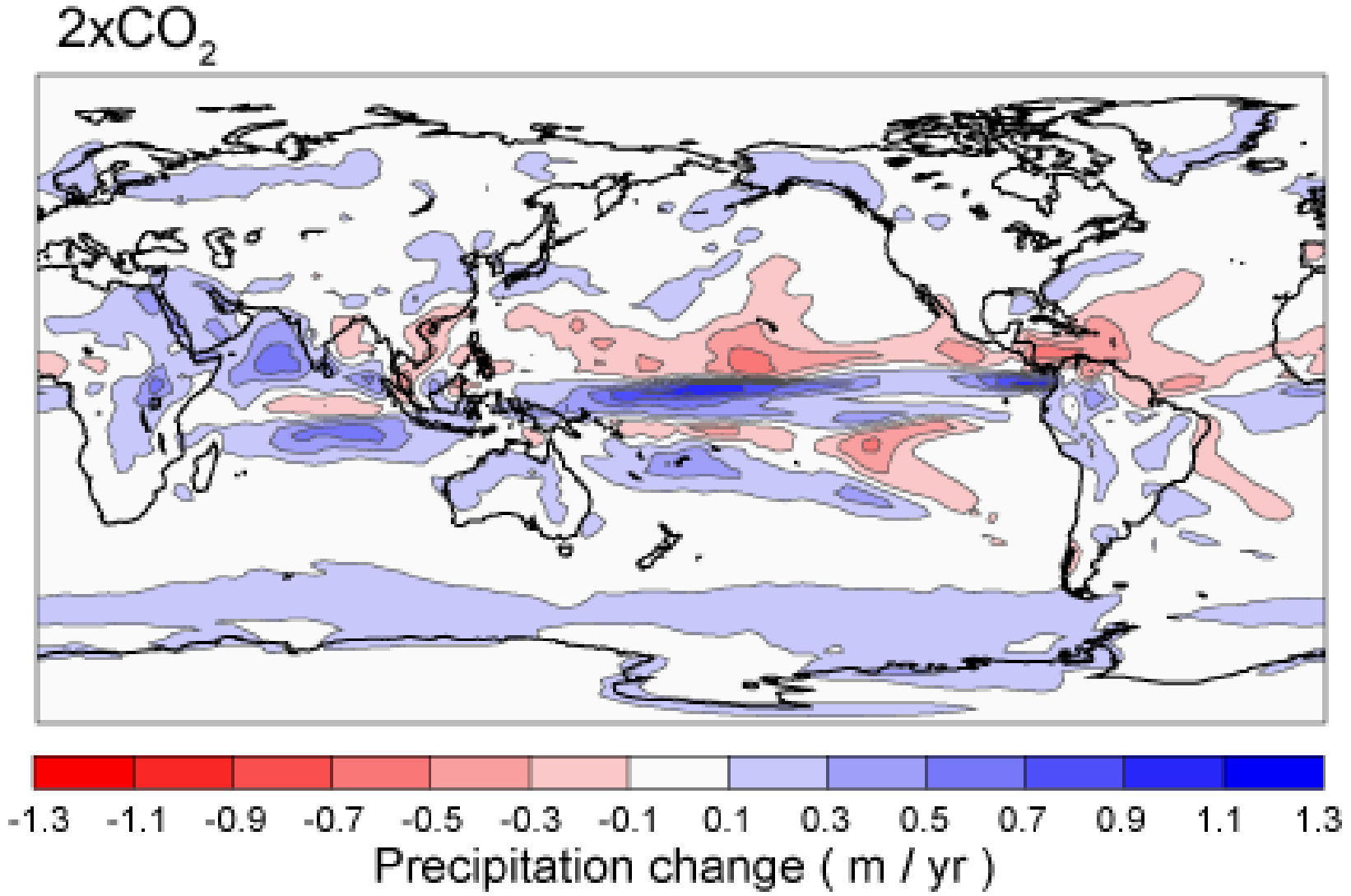
Temperature effects of doubled CO_2

with a uniform deflection of 1.84% of sunlight



Caldeira and Wood, 2008

Precipitation effects of doubled CO_2



Caldeira and Wood, 2008

Temperature effects of doubled CO_2

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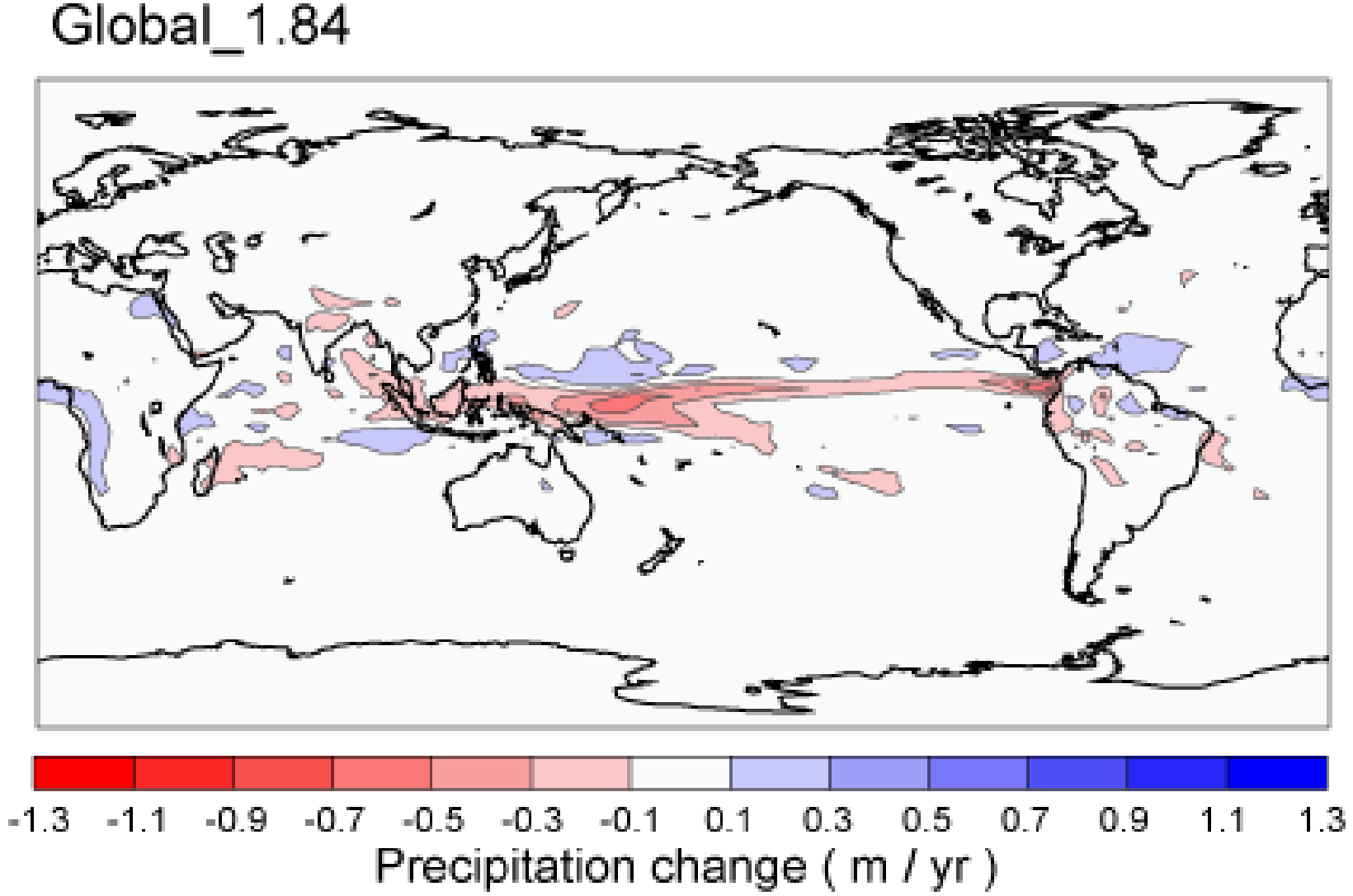
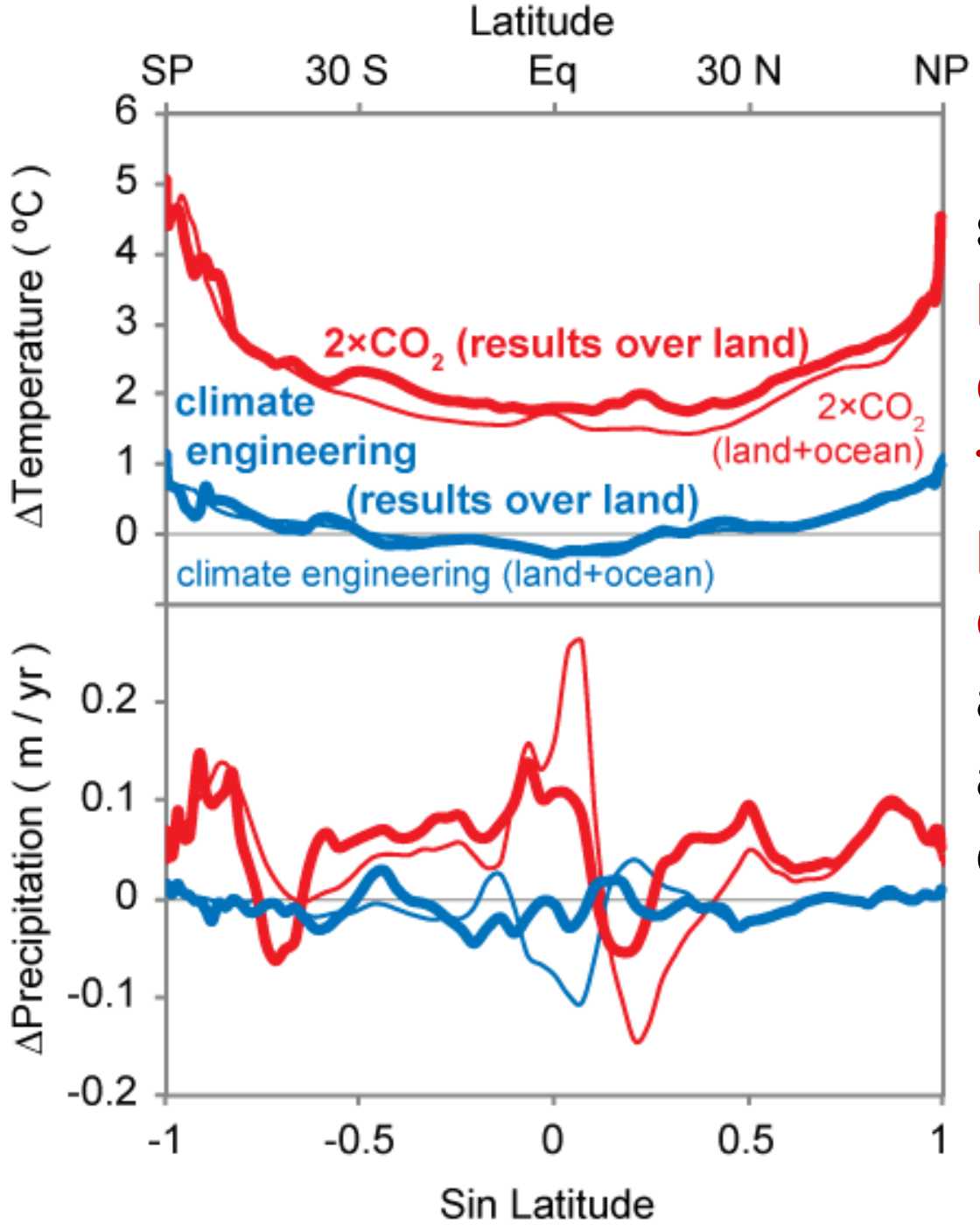


Caldeira and Wood, 2008



Deflecting 1.8% of sunlight reduces but does not eliminate simulated temperature and precipitation change caused by a doubling of atmospheric CO_2 content

Caldeira and Wood, 2008

Climate models indicate –

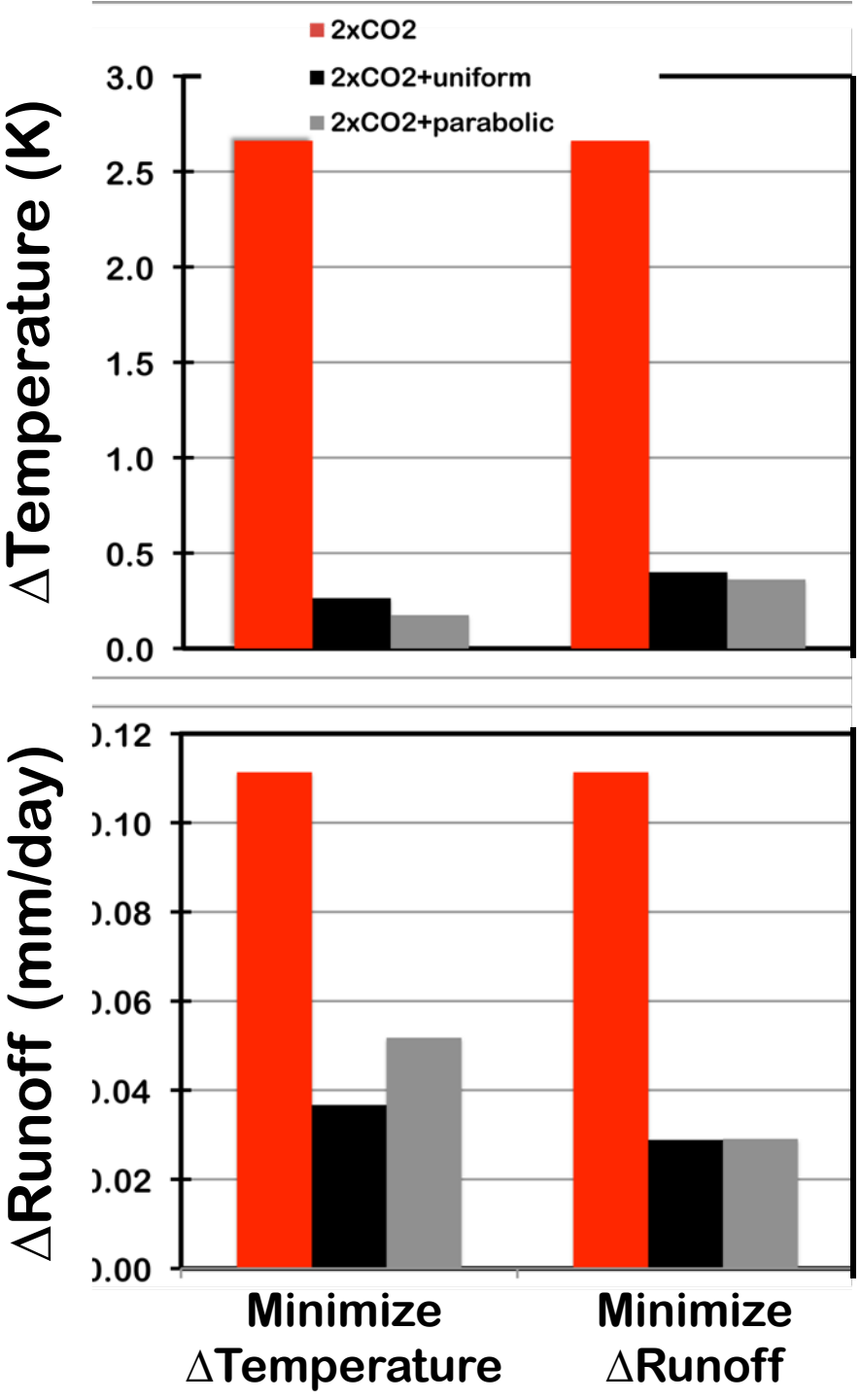
Deflection of sunlight can offset most climate change in most places most of the time

$2xCO_2$

with uniform aerosol distribution

with parabolic aerosol distribution

rms differences based on zonal mean analysis



Ban-Weiss and Caldeira, in prep.

Unanticipated outcomes

Additional points

Reducing absorbed solar is not same as reducing greenhouse gas. Thus, any offsetting of effects will at best be partial (e.g., ocean acidification).

Important issues:

governance, atmospheric chemistry, equity, unanticipated consequences, possible socio-political consequences.