“Solar” Geoengineering:

What is it?

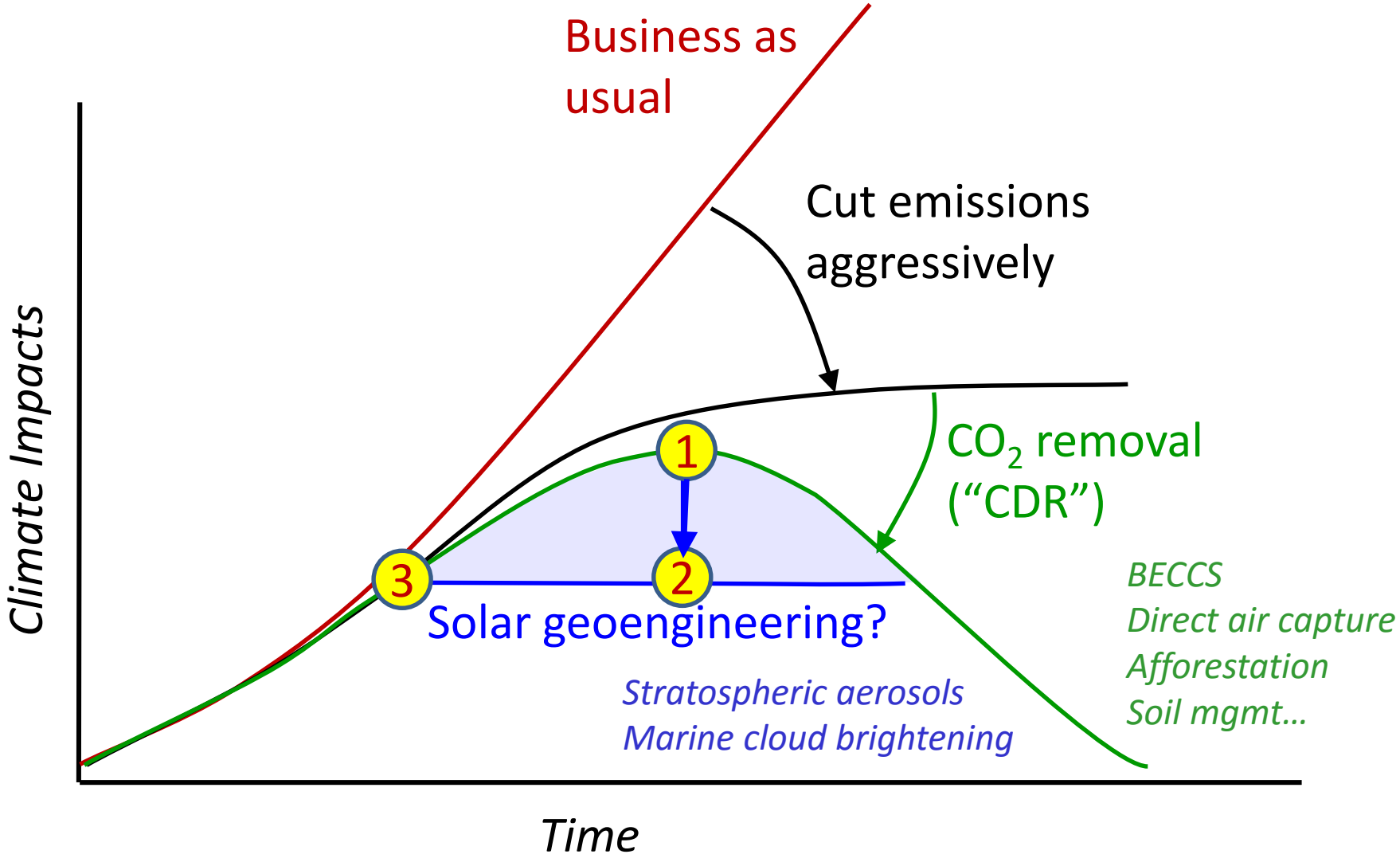
What role might it play in an overall climate strategy?

Douglas MacMartin

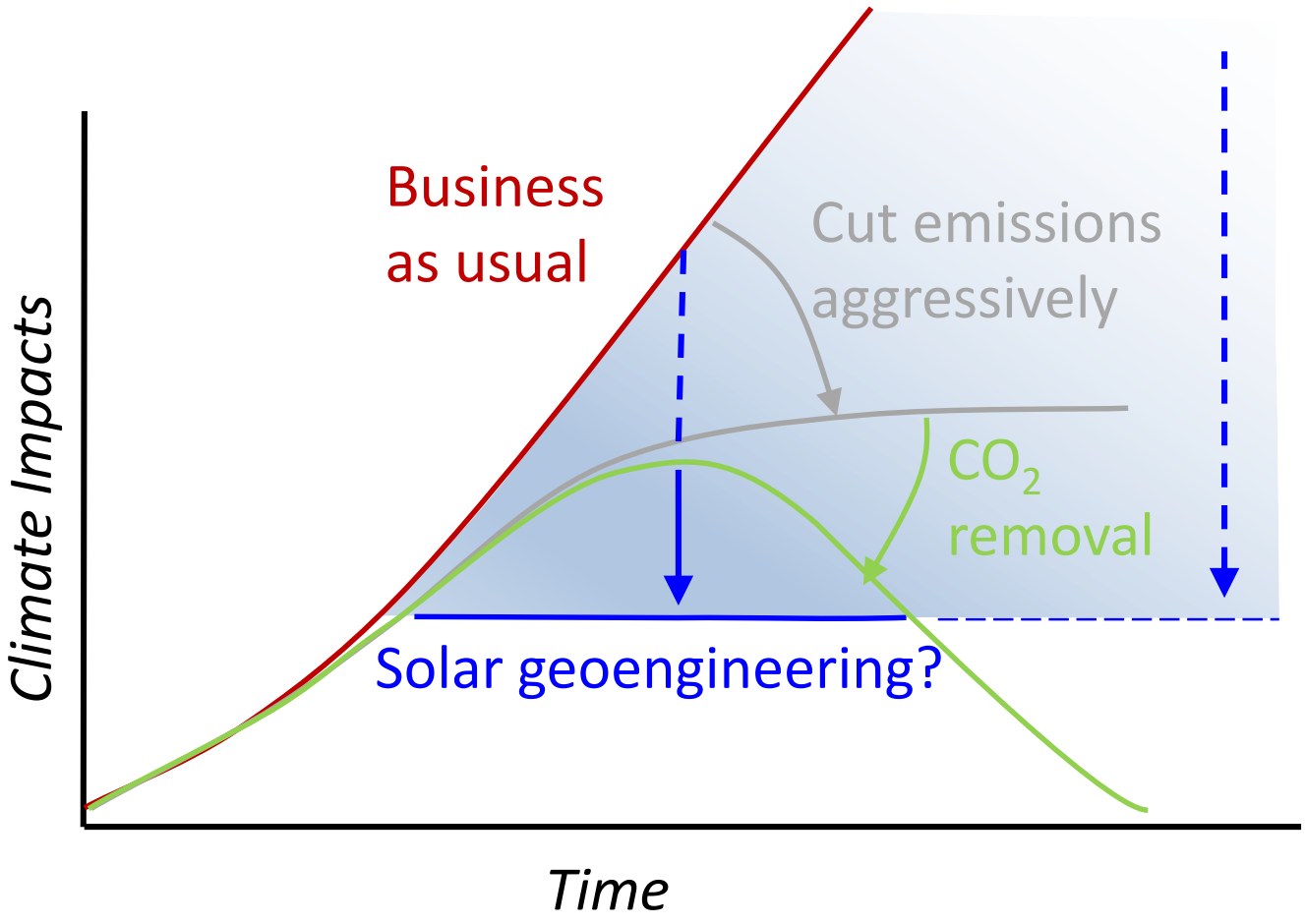
Mechanical and Aerospace Engineering, Cornell University

Computing + Mathematical Sciences, California Institute of Technology

What is the role for geoengineering?



NOT a substitute for mitigation



- Would require high forcing
  - Risks scale with amount
- Would require practically indefinite commitment
- Doesn't address all impacts of climate change
  - E.g. ocean acidification

Key Observations

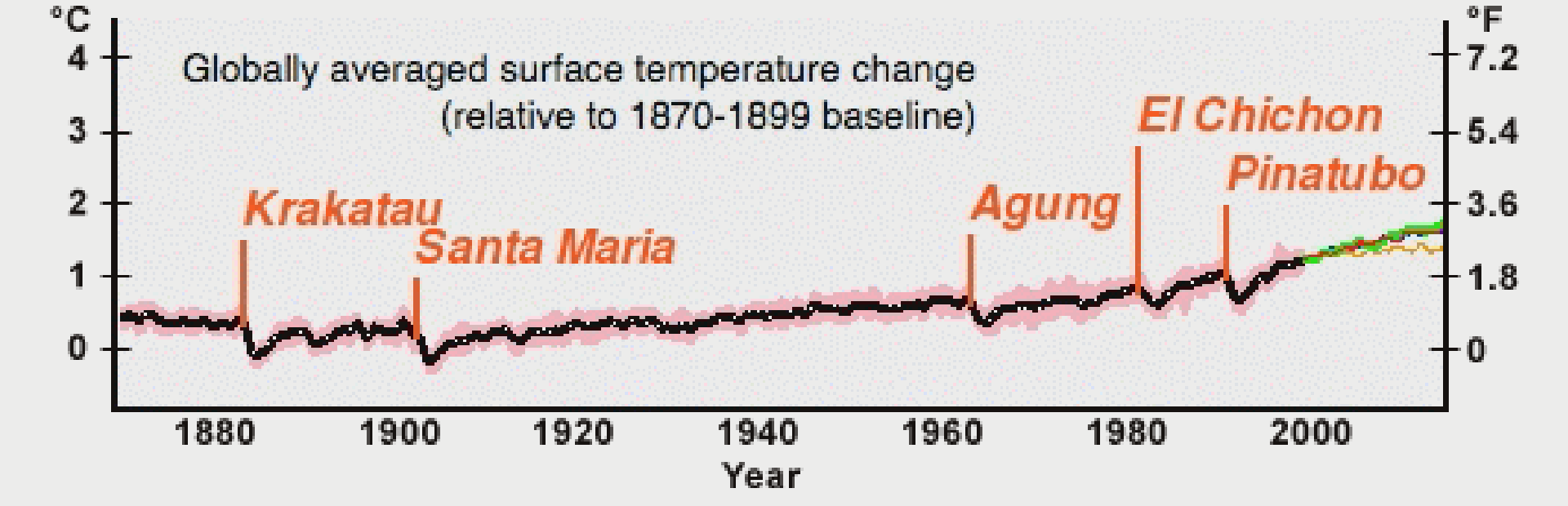
- A limited deployment of solar geoengineering in addition to mitigation might reduce many climate risks and avoid tipping points

- We don't know enough today to make an informed decision
  - My guess is we need ~20 years
  - There will always be uncertainty; this will always be a risk/risk tradeoff

- There are both physical climate risks and societal risks associated with solar geoengineering

Mt. Pinatubo 1991

Resulted in 30Mt of sulfate aerosols in stratosphere



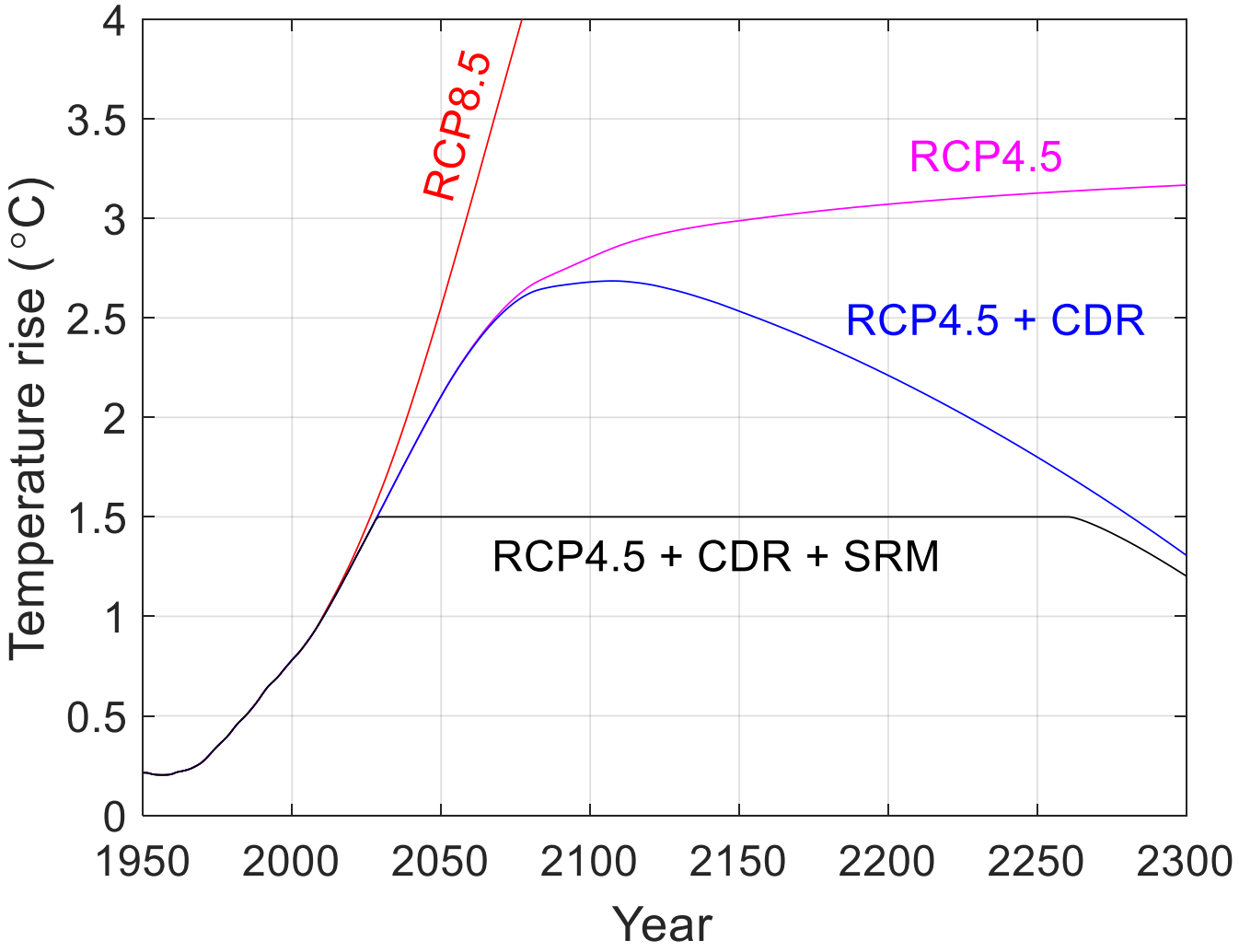
Marine Cloud Brightening

Ship tracks due to aerosols

- A fleet of wind-powered ships spraying salt-water into low clouds might cool the planet
- Cloud-aerosol interactions are poorly understood!
- Doesn't work everywhere: spatially heterogeneous radiative forcing

A specific scenario…

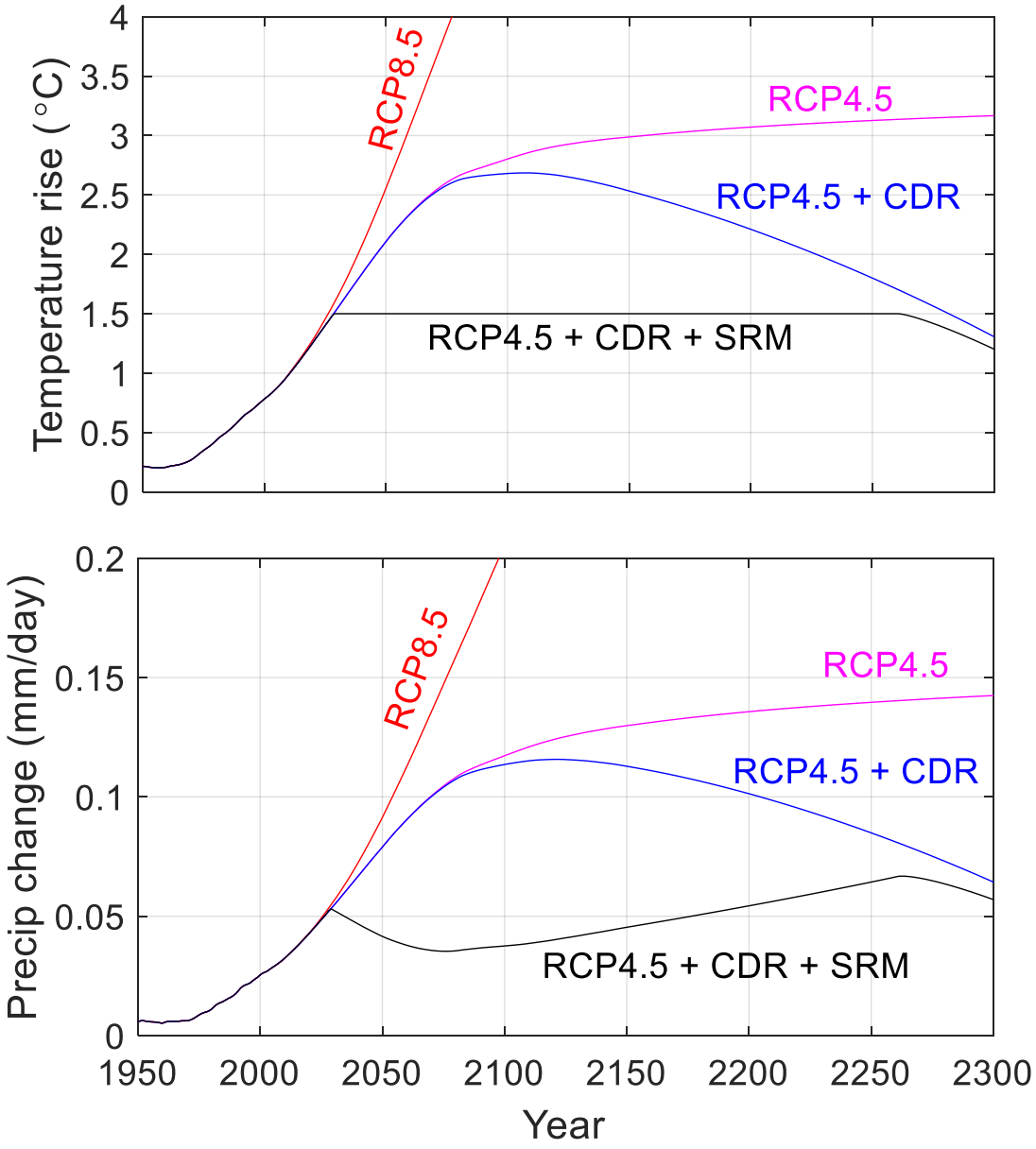
- "CDR" level is chosen to reduce CO_2 at 1ppm per year
  - Of order 15 Gt per year
- Temperature overshoots are measured in centuries



MacMartin, Ricke, Keith, *Phil. Trans. Royal Soc. A* 2018

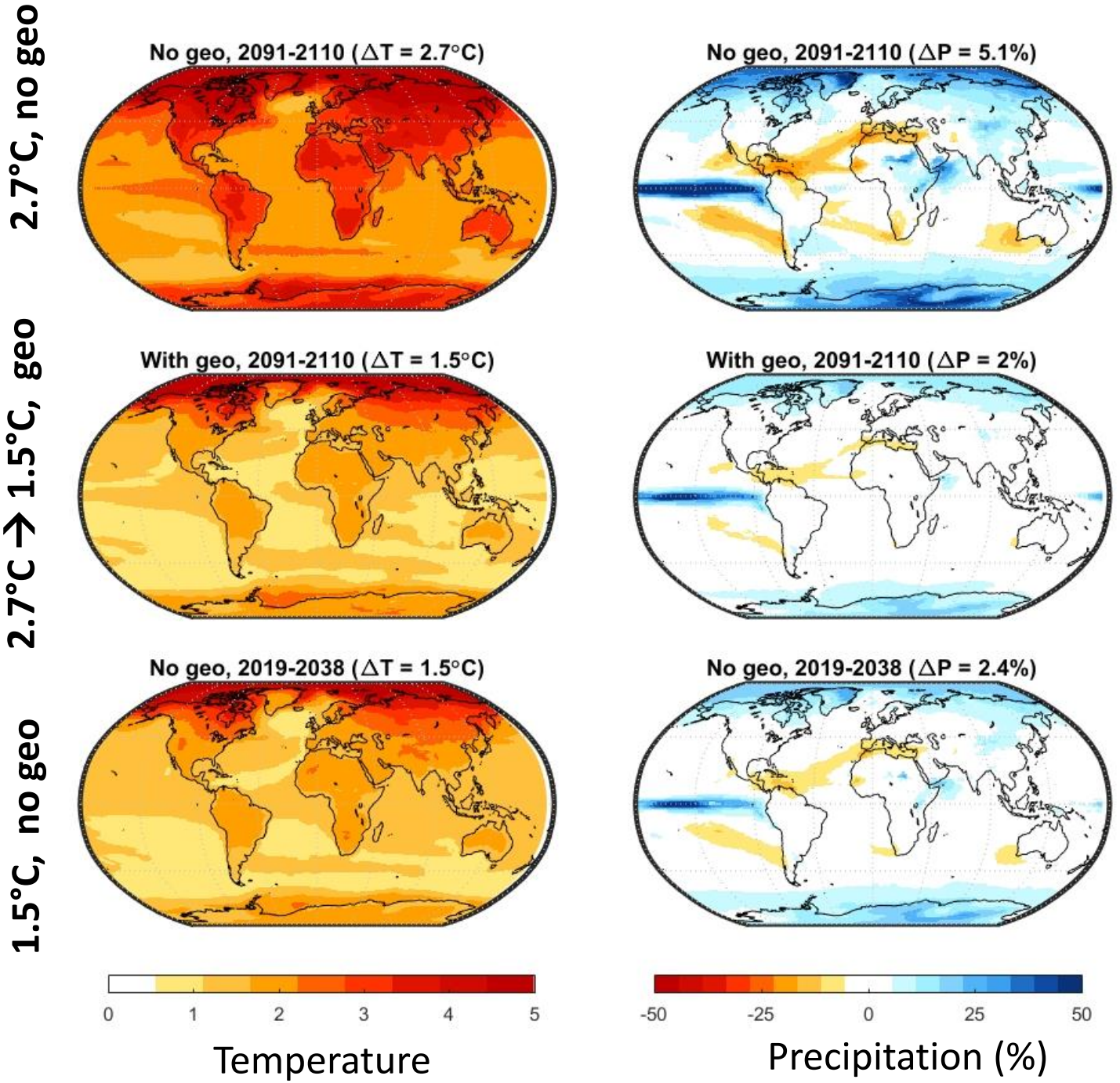
Not all variables respond the same way

- Solar geoengineering would overcompensate global mean precipitation
- Other variables like ocean pH would hardly be affected



Median over 12 models:

- Temperature is reduced everywhere
- Precipitation changes are reduced in most places
- Median hides model uncertainty!
- Solar reduction; not same as stratospheric aerosols



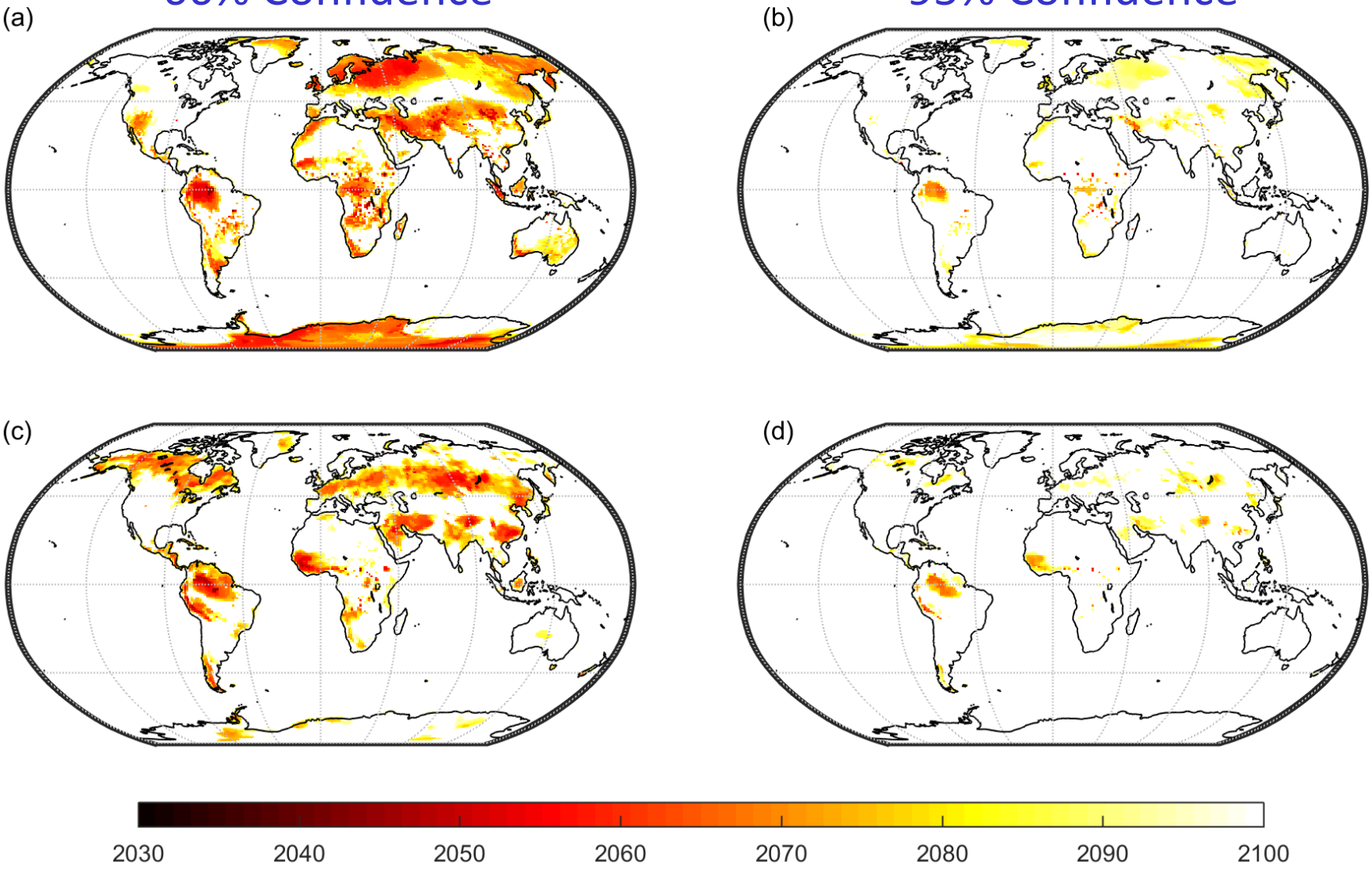
Detection: Moderate Scenario (1.5°C with RCP4.5)

66% Confidence

95% Confidence

Temperature

Precipitation



MacMartin et al, submitted

Stratospheric Aerosol Geoengineering: What don't we know?

- What size distribution of aerosol particles are created?
- Effect on stratospheric dynamics and heating, atmospheric chemistry
- What is the effect on cirrus clouds? (A positive or negative feedback?)
- Regional precipitation response remains uncertain (ditto for CO_2)
- Effect on ecosystems? Impacts?
- The ap[illegible]
- [illegible] can we design the system given uncertainty, nonlinearity, and variability?
- What are the limits to how well we can know the system?
- Societal response:
  - Would people emit more CO_2?
  - Would people blame everything on the deployment?
  - How might this be governed, how would amount be adjusted over time?

This will take a LOT of research

"Forcing"

"Response" & impacts

Strategic

Societal Feedbacks

Physical-Science Research

- How would one (responsibly) deploy?

- What are the resulting impacts of a responsible and limited deployment strategy?
  - Including ecosystem, agriculture, etc.

- How confident are we?
  - What is the range of possible outcomes?
  - Reducing uncertainty is likely to require some *small-scale* outdoor experimentation

Summary

Context:

- Mitigation is necessary, it probably won't be sufficient to avoid serious risks
  - 2°C target requires
    - extremely aggressive reductions in emissions, combined with
    - negative emissions (or CO_2 removal)
  - 1.5°C is much harder than 2°C
  - Current INDC commitments are more likely to lead to ~3°C

A strategic approach for managing climate change

- Developing capability for CO_2 removal is essential
- It is plausible that an additional, limited deployment of solar geoengineering could reduce aggregate climate risks
  - Not enough is known today to make informed decisions
  - Raises challenging issues in ethics, governance, etc.

Options

CO_2-removal

- BECCS (bio-energy with carbon capture and sequestration)
- Direct air capture (DAC)
- Afforestation/reforestation
- Carbon-smart soil management
- Enhanced mineral weathering
- Ocean iron fertilization??

- Typically either expensive or hard to do at sufficient scale
- Low climate risk but potentially significant local issues if deployed at scale

Solar geoengineering

- Stratospheric aerosols
  - Guaranteed to "work", relatively straightforward to implement
- Marine cloud brightening
  - Cloud aerosol interactions
- Cirrus cloud thinning??
- Ocean albedo, land albedo,…

- Cools quickly
- Doesn't affect the climate the same way as increased CO_2
- Novel risks, both climate and socio-political