Impact World 2017, October 13, 2017, Potsdam, Germany
S-11: Evaluating the climate impacts of solar geoengineering

Solar radiation management and ecosystem functional responses

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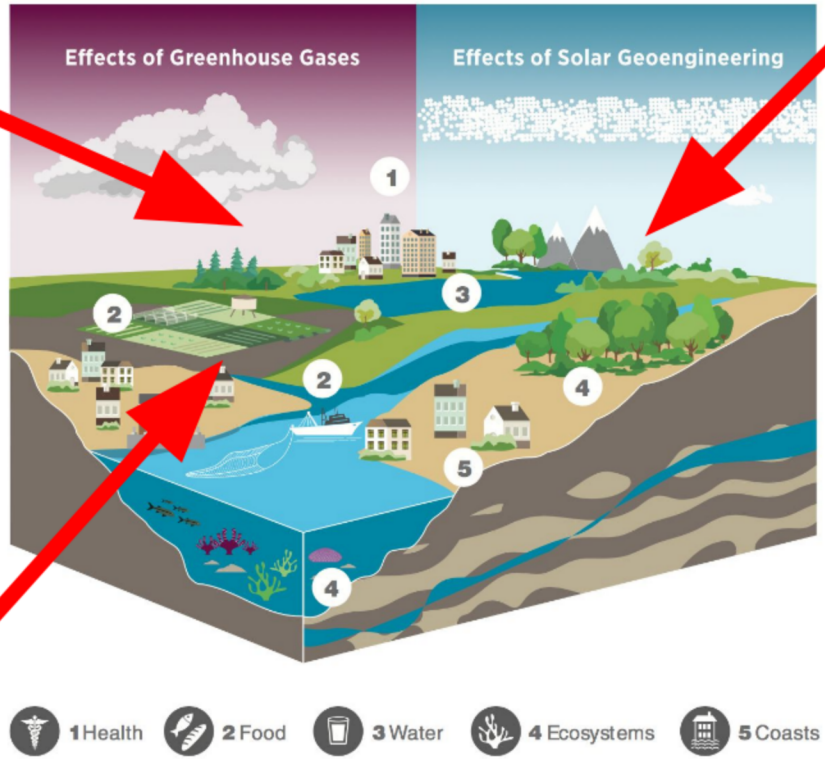
Acknowledgements
ICA-RUS (Integrated Climate Assessment: Risks, Uncertainties, and Society) funded by the Ministry of the Environment, Japan

Motivation

Climatic impacts
=> Adaptation

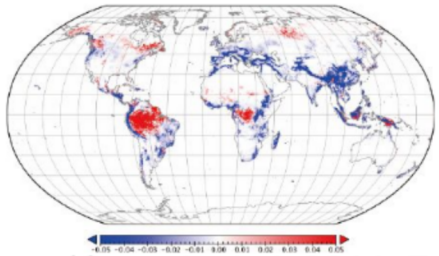


Climatic engineering
<SRM: solar radiation management>

=> ?

Ecological risks
- functions & services
- spatial locality
- time-lag

Biofuel (BECCS) for
negative emission
=> Mitigation

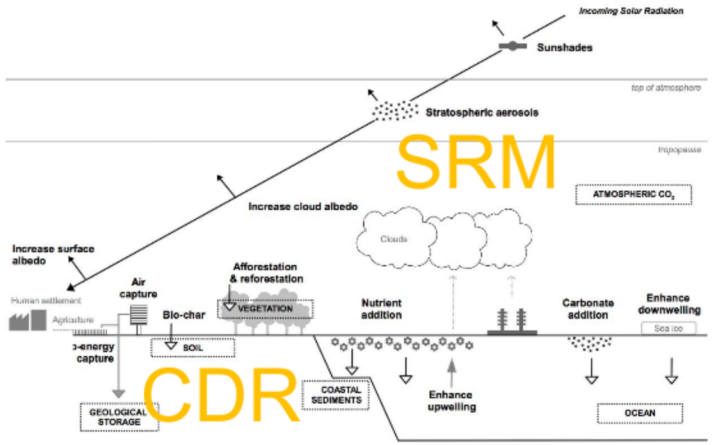


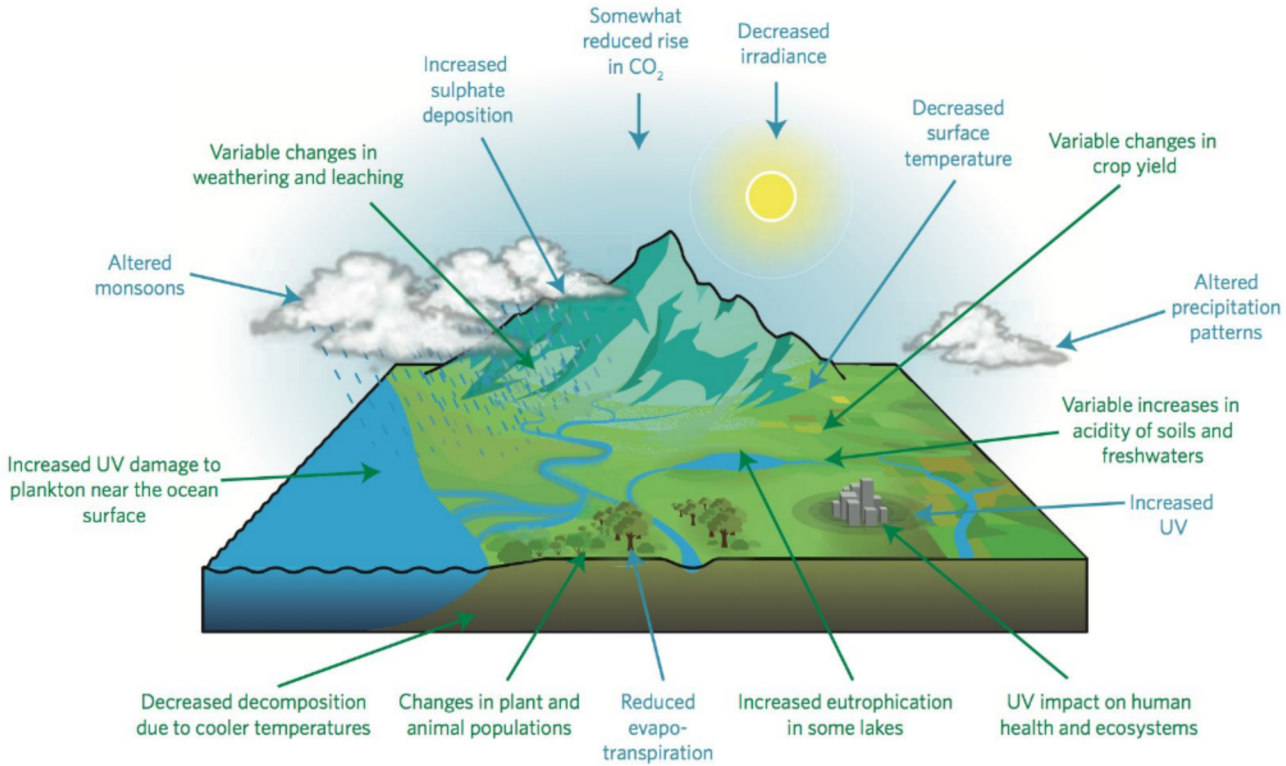
- soil loss by erosion
- biomass and biodiversity loss

(Cusack et al. 2014; Friend et al. 2014; Irvine et al. 2017; Yamagata et al. in revision)

Ecology of GE (SRM & CDR)

- Higher atmospheric CO_2 rise?
- More or less temperature change
- Altered hydrological regime
- More diffuse solar radiation?





Well-known analogue:
aftermath of Mt. Pinatubo eruption

(Lenton & Vaughan 2009; Barrett et al. 2014)

Precedent Studies

AGU PUBLICATIONS
Geophysical Research Letters

Tropical rainforest response to marine sky brightening climate engineering

Helene Muri[1], Ulrike Niemeier[2], and Jón Egill Kristjánsson[1]

Climate Dynamics

Modeling of solar radiation management: a comparison of simulations using reduced solar constant and stratospheric sulphate aerosols

Sirisha Kalidindi · Govindasamy Bala · Angshuman Modak · Ken Caldeira

Atmospheric Chemistry and Physics Open Access EGU

Stratospheric sulfate geoengineering could enhance the terrestrial photosynthesis rate

L. Xia[1], A. Robock[1], S. Tilmes[2], and R. R. Neely III[2,3]

cf. Russel et al. (2012), Govidasamy et al. (2002), Naik et al. (2003), Eliseev (2012)

Additional assessment with multiple ESM-based scenarios and process-based (ecophysiological) terrestrial ecosystem model

Experiments

Geo-MIP (output files from PCMDI)

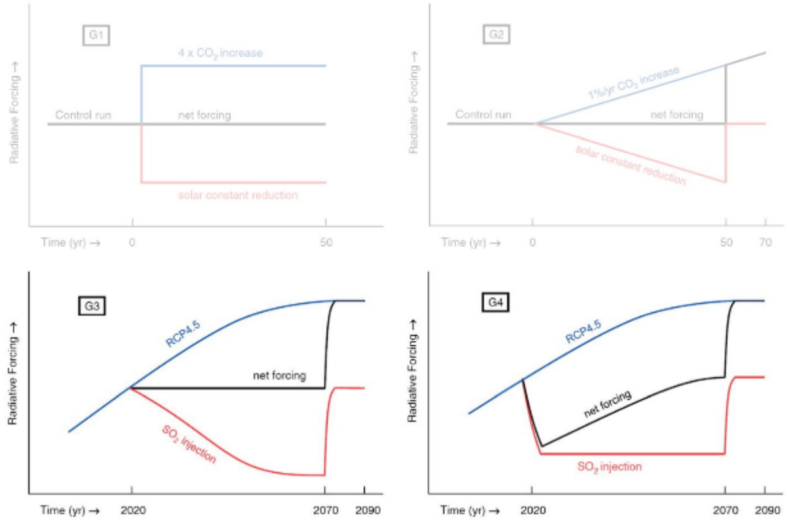


Table. Summary of GeoMIP models and experiments used in this study.

Climate models	Experiments
BNU-ESM	RCP4.5, G3, G4
CanESM2	RCP4.5, G4, G4cdcn
CCSM4	RCP4.5, G3S
CSIRO-mk3L-1-2	RCP4.5, G3S, G4
GISS-EL-R	RCP4.5, G3, G4
HadGEM2-ES	RCP4.5, G3, G3S, G4, G4cdcn, G4seasalt
IPSL-CM54-LR	RCP4.5, G3, G5
MIROC-ESM	RCP4.5, G4, G4cdcn
MIROC-ESM-CHEM	RCP4.5, G4
MPI-ESM-LR	RCP4.5, G3
NorESM	RCP4.5, G4cdcn

Offline simulations

- 2006–2090 (SRM: 2020–2069)
- Geo-MIP G3 (5)
- Geo-MIP G4 (7)
- Control: RCP4.5
- Atmospheric CO_2: RCP4.5
- Δtas, Δpr, Δrsds, Δhuss
- PAR (beam/diffuse) estimated

Terrestrial functional variables

- GPP (photosynthesis)
- NEP (net CO_2 budget)
- RO (runoff discharge)

(Yu et al. 2015, GPC)

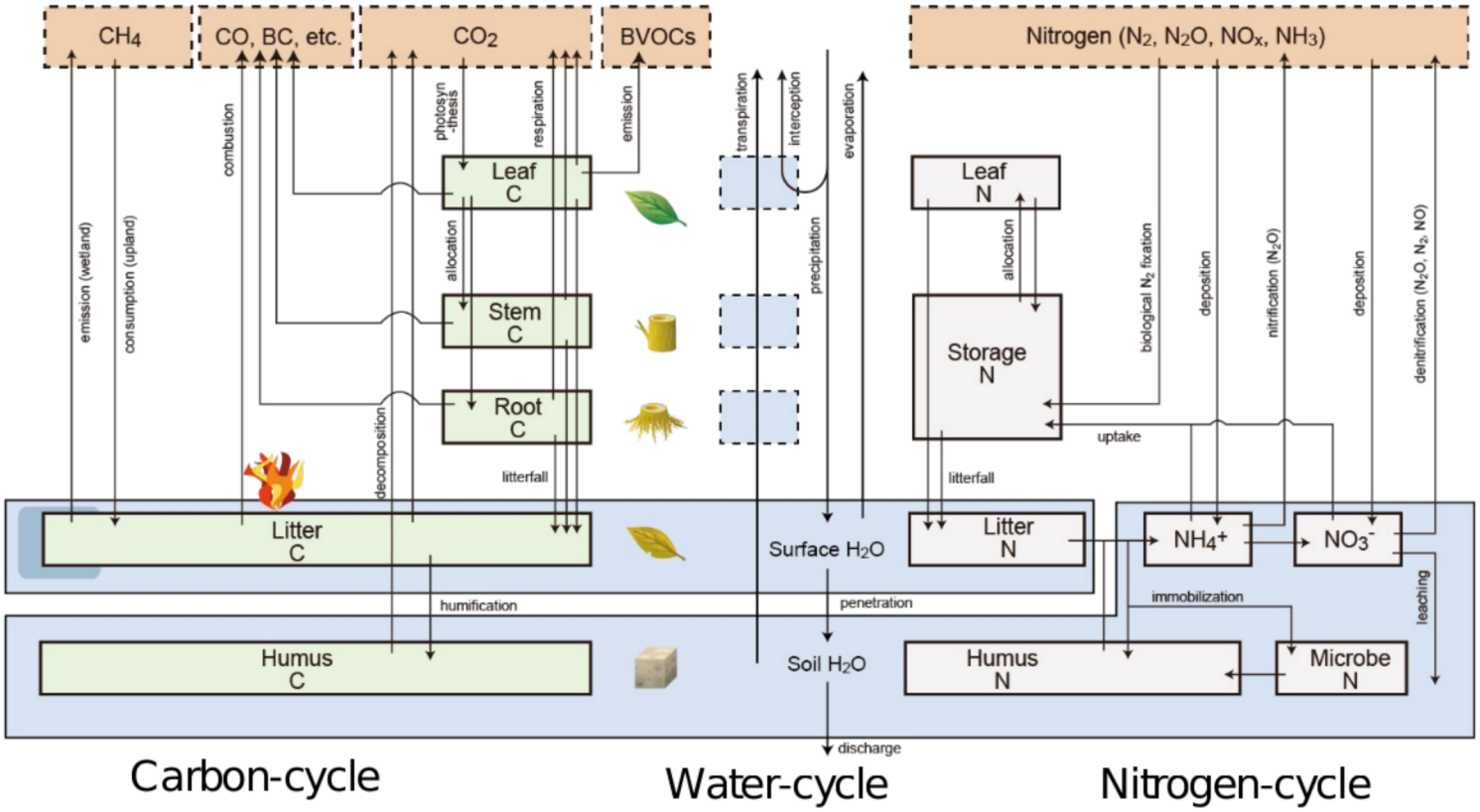
Model Description

VISIT — Vegetation Integrated SImulator for Trace gases

(Developed by NIES & JAMSTEC)

Objectives

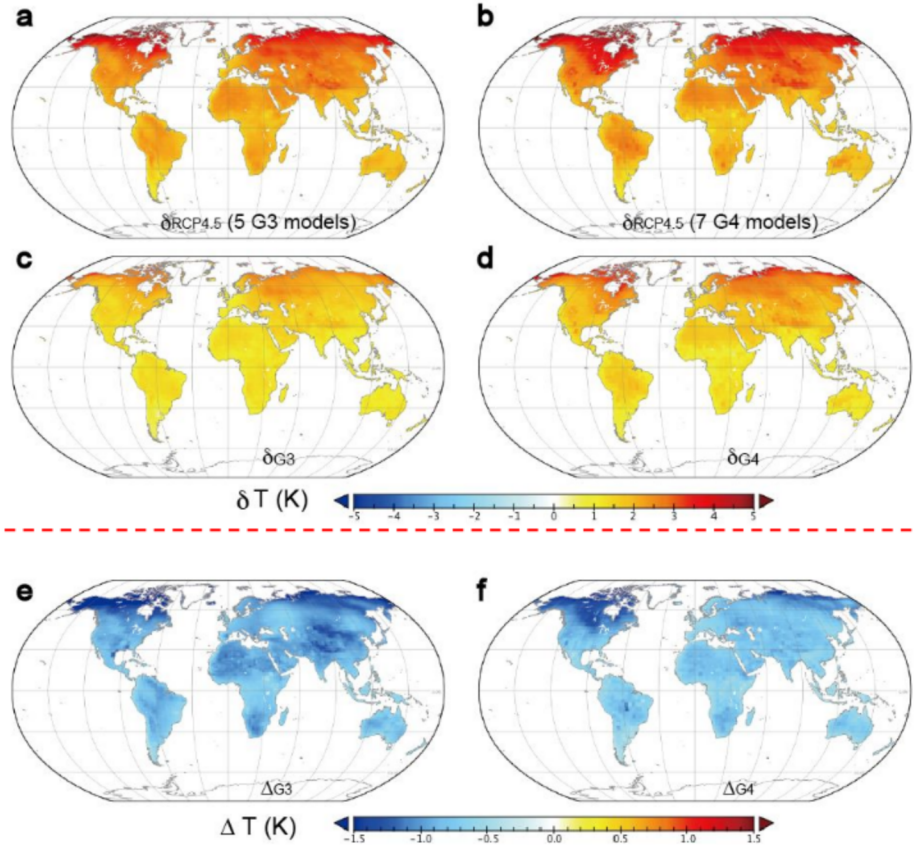
- Atmosphere-ecosystem biogeochemical interactions
- Assessment of climatic impacts and biotic feedbacks
- Ecosystem functions related to ecosystem services



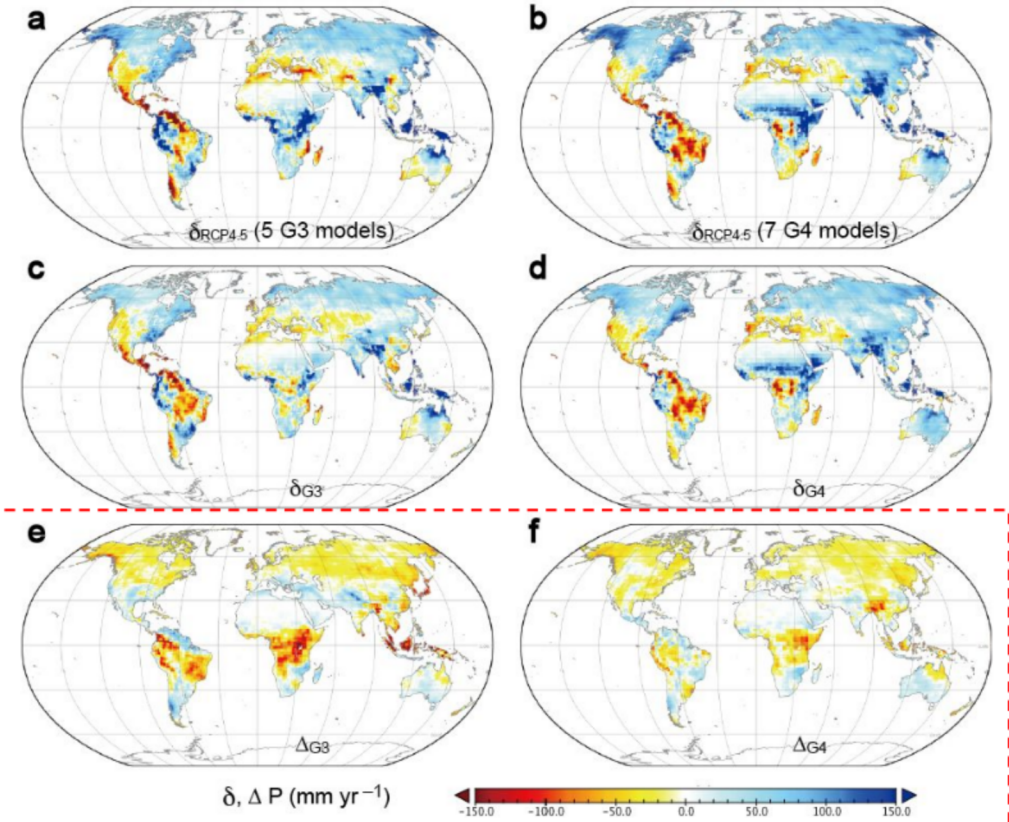
Results

(2060s – 2000s)

Air temperature



Precipitation

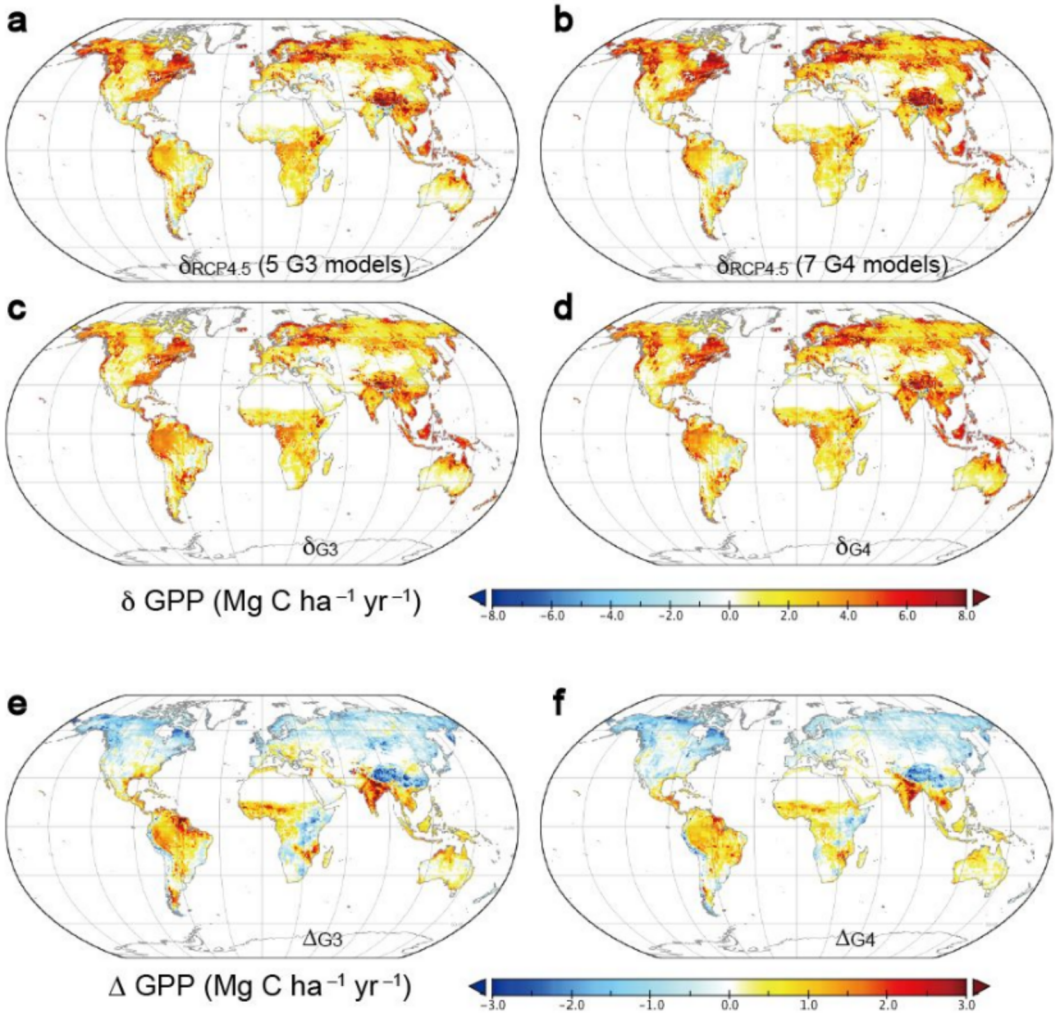


Net effect of SRM

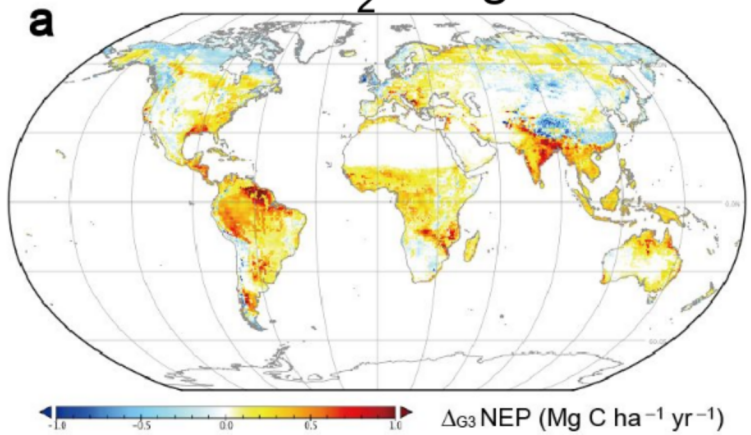
Results

(2060s – 2000s)

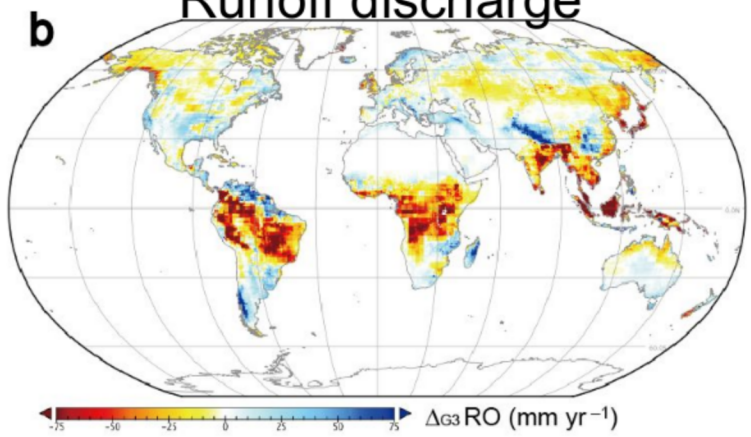
Gross photosynthetic production



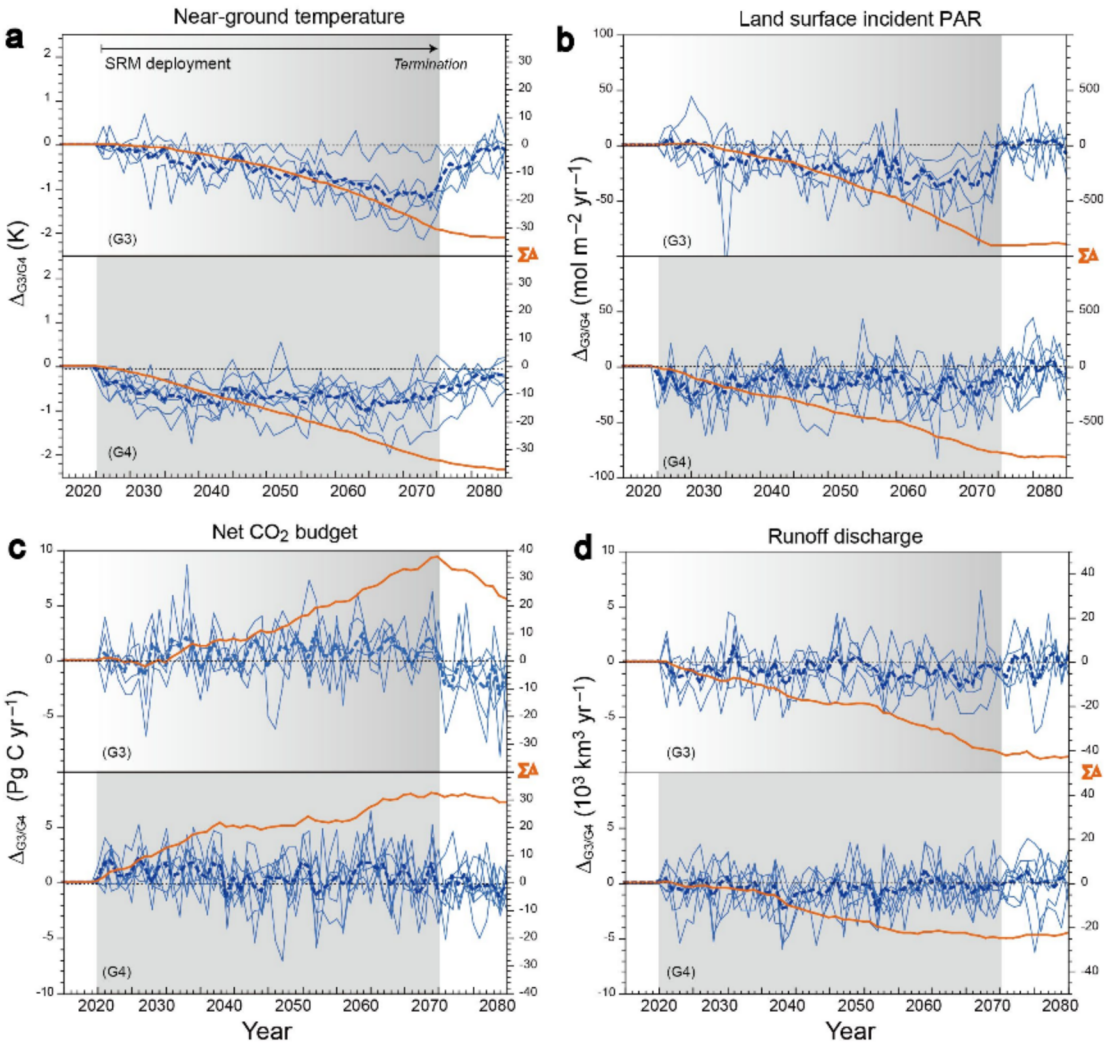
Net CO_2 budget



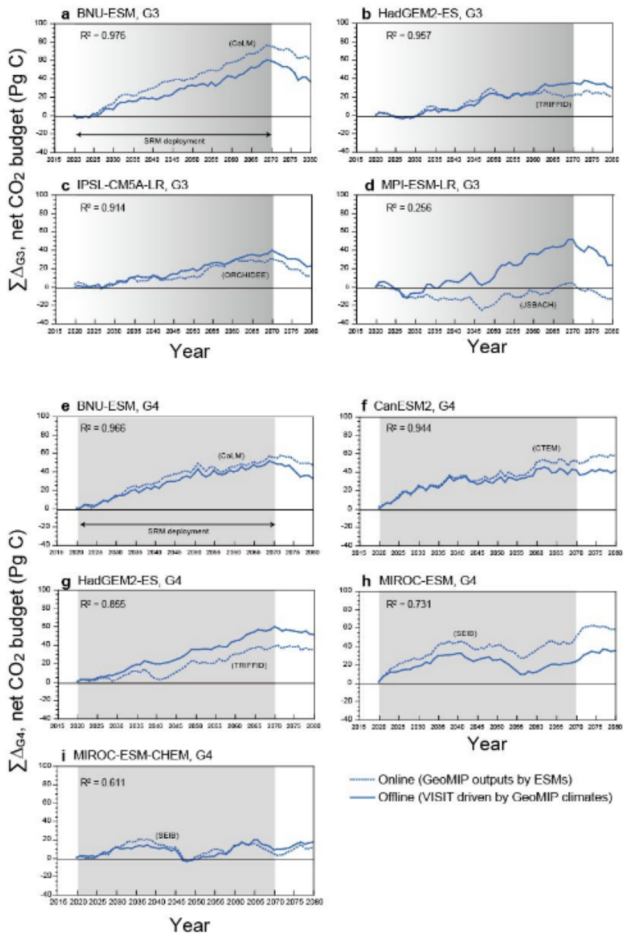
Runoff discharge



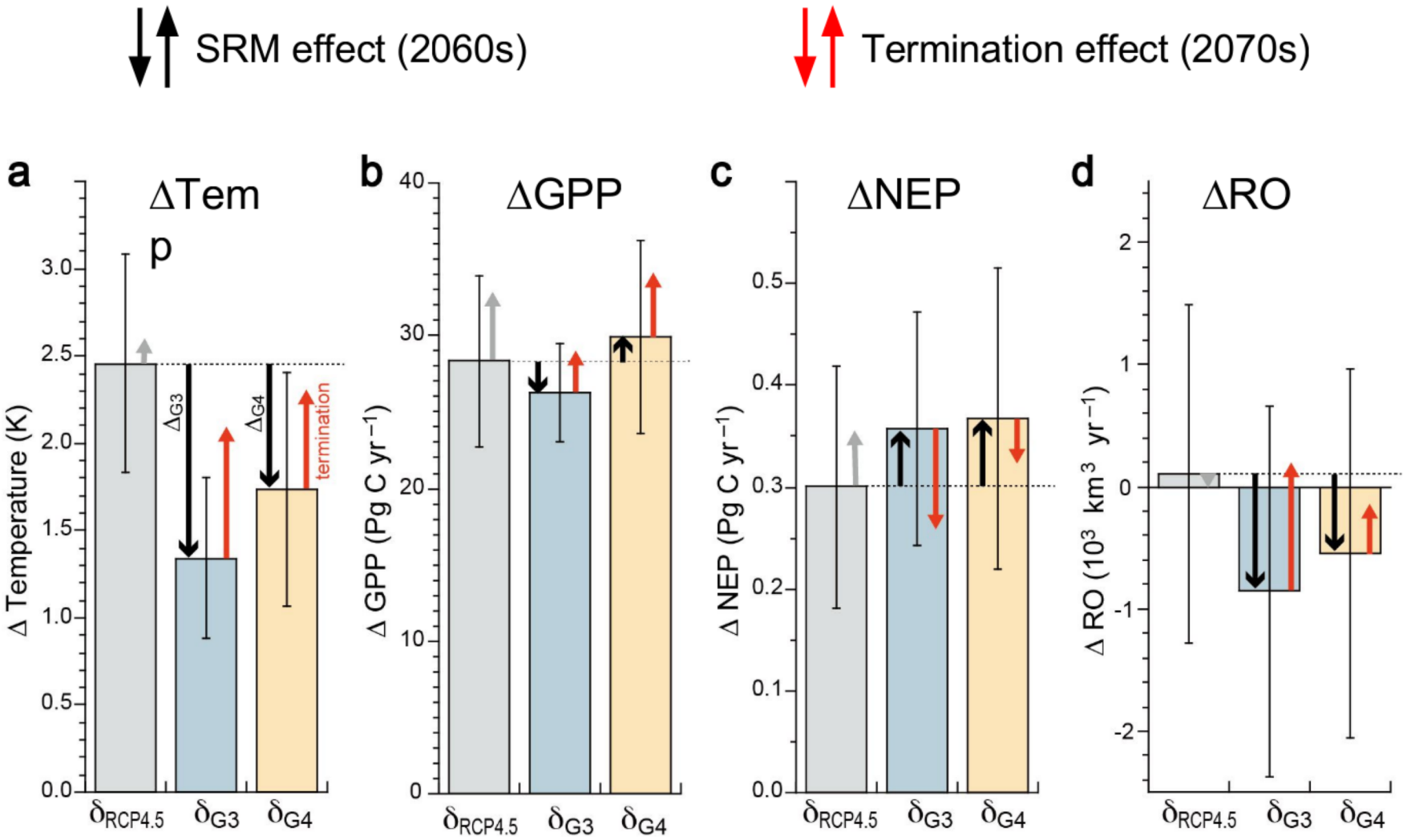
Results



Comparison with ESMs



Results


SRM effect (2060s)
Termination effect (2070s)
a
ΔTemp
Δ Temperature (K)
ΔG3
ΔG4
termination
δRCP4.5
δG3
δG4
b
ΔGPP
Δ GPP (Pg C yr−1)
c
ΔNEP
Δ NEP (Pg C yr−1)
d
ΔRO
Δ RO (10³ km³ yr−1)

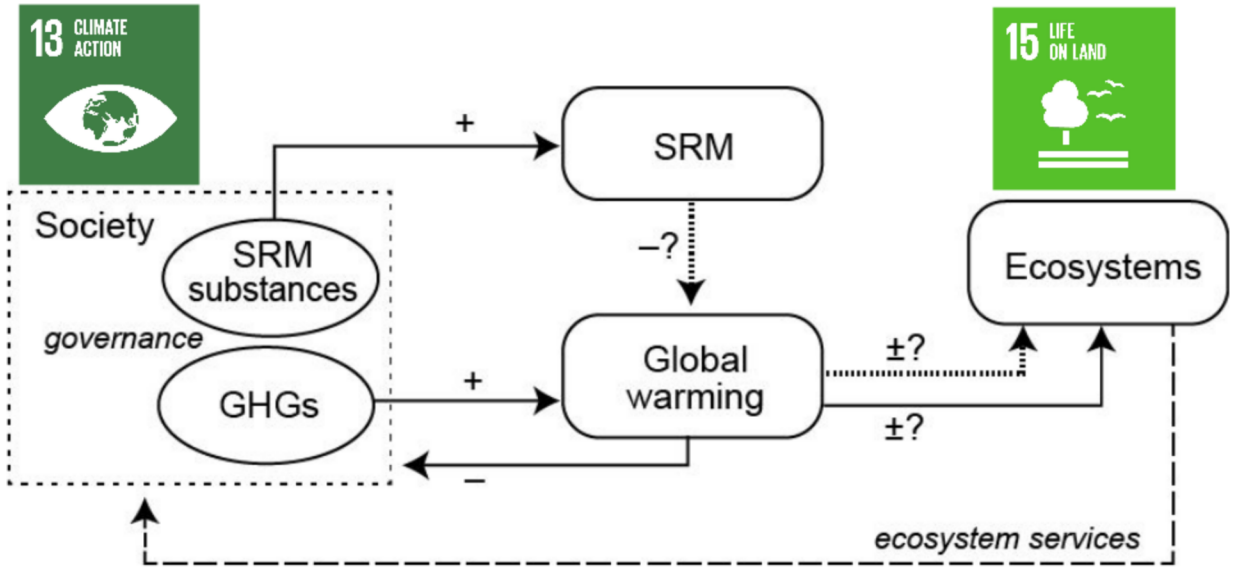
Summary

Climatic Change (2017) 142:53–66
DOI 10.1007/s10584-017-1930-3

Solar radiation management and ecosystem functional responses

Akihiko Ito[1,2]

- PAR beam / diffuse
- Canopy-absorbed PAR
- Light use efficiency
- Evapotranspiration
- Other scenarios: G3S, G4cdcn, G4seasalt
- (Effect on Amazon tropical forest dieback)



- Indirect pathways: e.g., acidification, nutrient cycling, etc.
- Complexity of biological processes and ecosystems (e.g., failure to capture Pinatubo carbon anomaly by current models)
  <= insufficient participation of ecological researchers

Ecological study by climatologists + Climatological study by ecologists

Four discussion topics

1. The state of understanding about the climate impacts of solar geoengineering, identifying critical research gaps.
   => Preliminary model-based assessments
2. The contribution that the impacts modelling community can make to this emerging discussion as a part of CMIP6 and in the run up to the IPCC's 6th assessment report.
   => Applications of ISI-MIP models and ESMs
3. The novel challenge for research that arises from the possibility to tailor solar geoengineering deployment to achieve different objectives.
   => Best mix of SRM, CDR/BECCS, and adaptation?
4. The potential for solar geoengineering to alter the impacts of climate change and so affect progress towards a number of sustainable development goals.
   => Goal 15 (land system)?

ISI-MIP (biomes)

Project coordination: PIK team
Sector coordinator: Philippe Ciais [LSCE, France]

Participating models: CARAIB, DLEM, LPJ-GUESS, LPJmL, ORCHIDEE, VEGAS, VISIT (JULES)

Foci: productivity, carbon budget, vegetation dynamics, etc.

Experiments: Fast Track (4RCPs x 5GCMs)

- ISI-MIP2a (historical, 4 forcing data)
- ISI-MIP2b (1.5/2.0K long-term impacts)

Geo-ISI-MIP?