EGU General Assembly 2022, Presentation EGU22-3279, 2022.05.26

Reduced mass loss from the Greenland ice sheet under stratospheric aerosol injection

Ralf Greve[1,2], John C. Moore[3,4,5], Thomas Zwinger[6], Fabien Gillet-Chaulet[7], Chao Yue[3], Liyun Zhao[3], Heiko Goelzer[8]

(1) Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan
(2) Arctic Research Center, Hokkaido University, Sapporo, Japan
(3) College of Global Change and Earth System Science, Beijing Normal University, Beijing, China
(4) Arctic Centre, University of Lapland, Rovaniemi, Finland
(5) CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing, China
(6) CSC – IT Center for Science, Espoo, Finland
(7) Grenoble Alpes University, Grenoble, France
(8) NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway

Introduction

Mass loss from ice sheets is a major contributor to sea-level rise.

Stratospheric aerosol injection (SAI) has been proposed as a potential method of meeting the IPCC 1.5°C (well below 2°C) global temperature rise targets.

(e.g., Jones+ 2018, MacMartin & Kravitz 2019)

This study:

Modelling the impact of an SAI scenario ("GeoMIP G4") on the mass loss of the Greenland ice sheet, compared to RCP8.5 and RCP4.5.

(Kravitz+ 2011)

Two ice-sheet models

SICOPOLIS (www.sicopolis.net)

Finite difference method.

Shallow-ice–shelfy-stream hybrid dynamics.

Regular grid, 5 km resolution.

(elmerice.elmerfem.org)

Finite element method.

“Elmer/Ice-sheet” set-up with shelfy-stream dynamics.

Unstructured mesh, 195k nodes forming 372k triangular elements.

ISMIP6-like climate forcing

(Goelzer+ 2020, Nowicki+ 2020)

Model time 2015–2090.

Three scenarios:

RCP8.5 (worst-case scenario),

RCP4.5 (intermediate scenario),

GeoMIP G4

(RCP4.5 + 5 Tg/a sulfate aerosol insertion to the equatorial lower stratosphere).

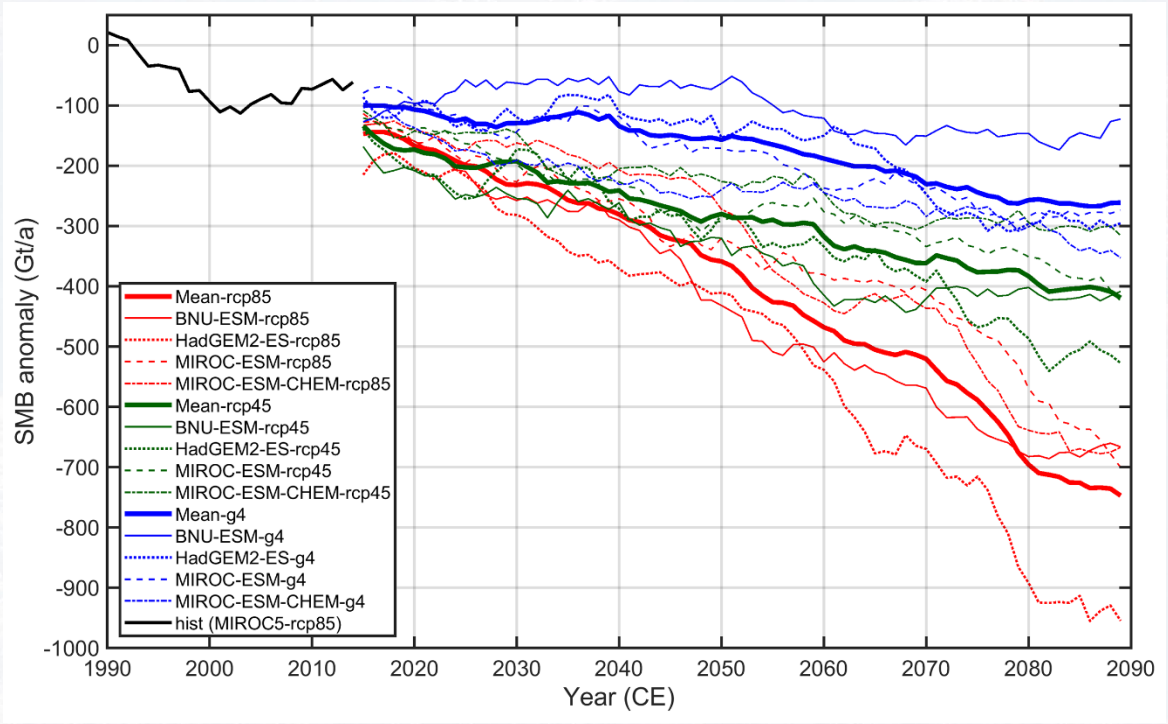
Four Earth system models (ESMs):

BNU-ESM, HadGEM2-ES, MIROC-ESM, MIROC-ESM-CHEM.

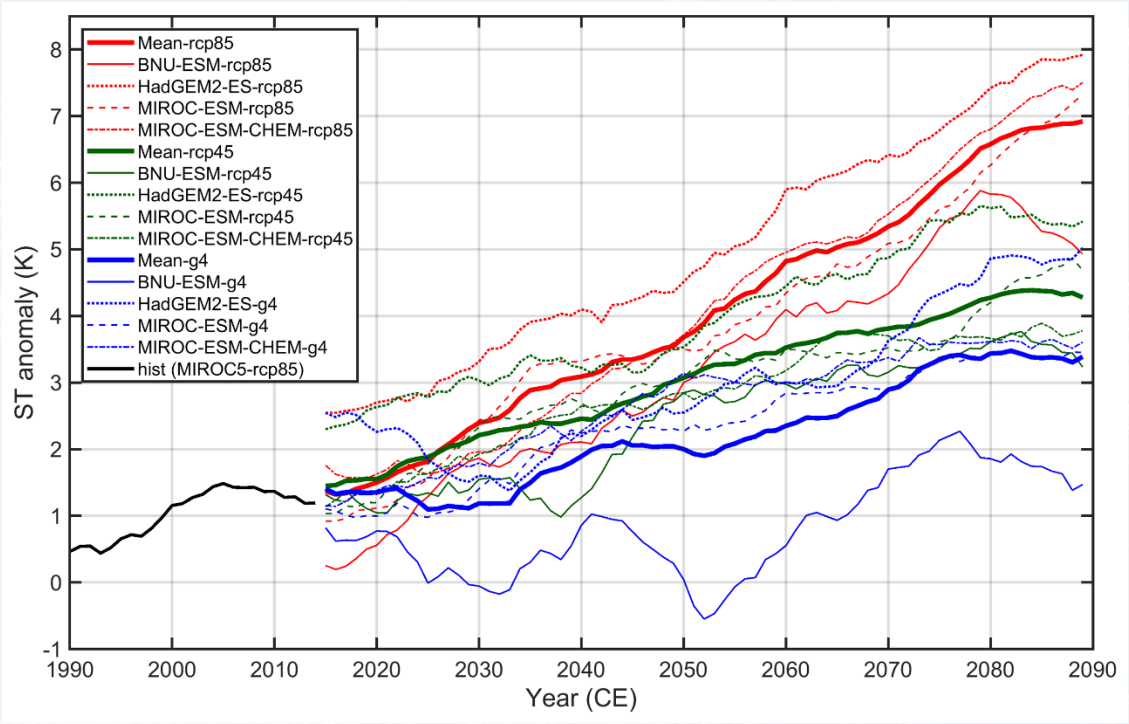
No oceanic forcing yet.

ISMIP6-like climate forcing

Surface mass balance (SMB) anomaly

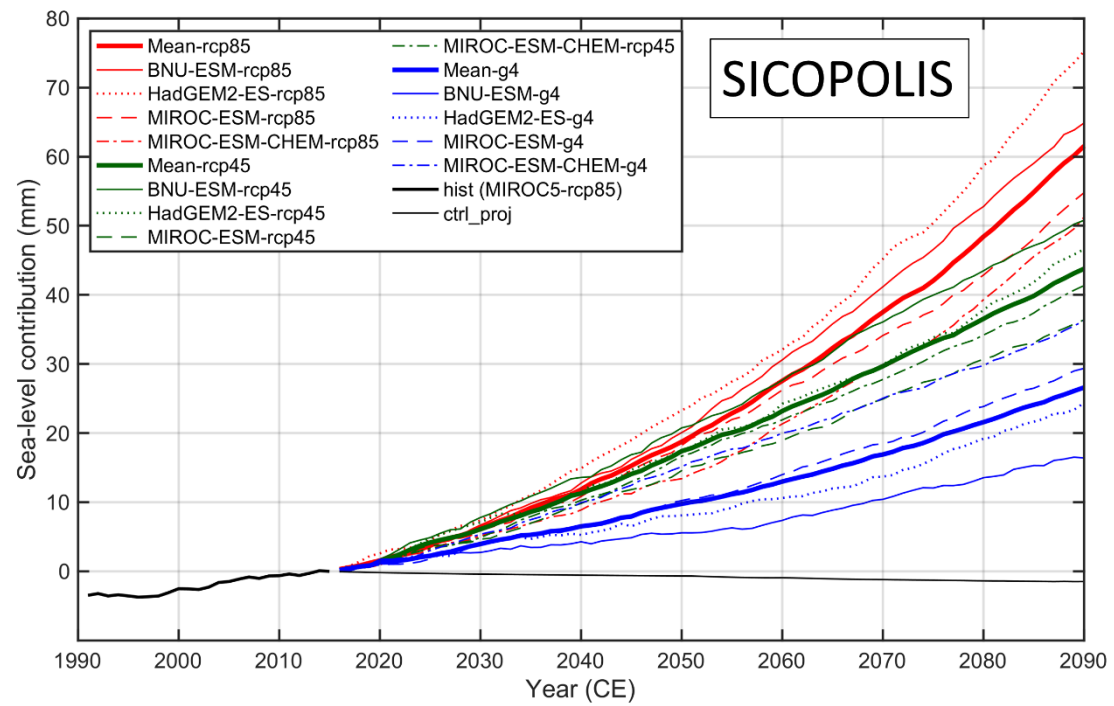


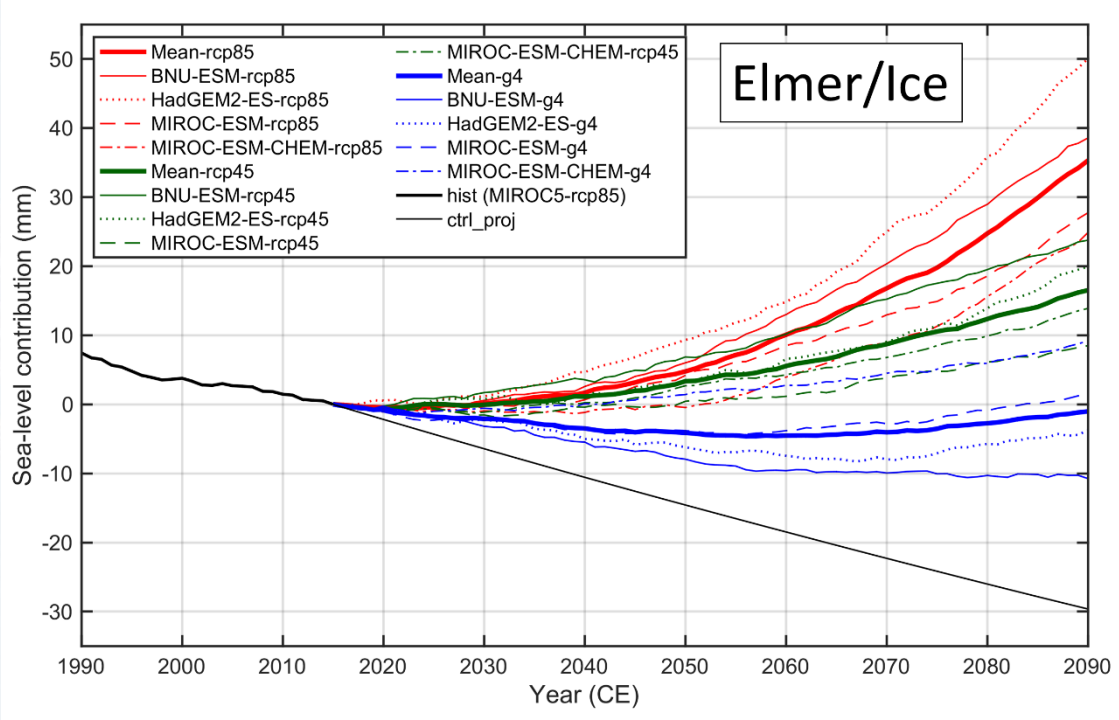
Surface temperature (ST) anomaly



As expected, RCP8.5 > RCP4.5 > G4.

Simulated sea-level contribution



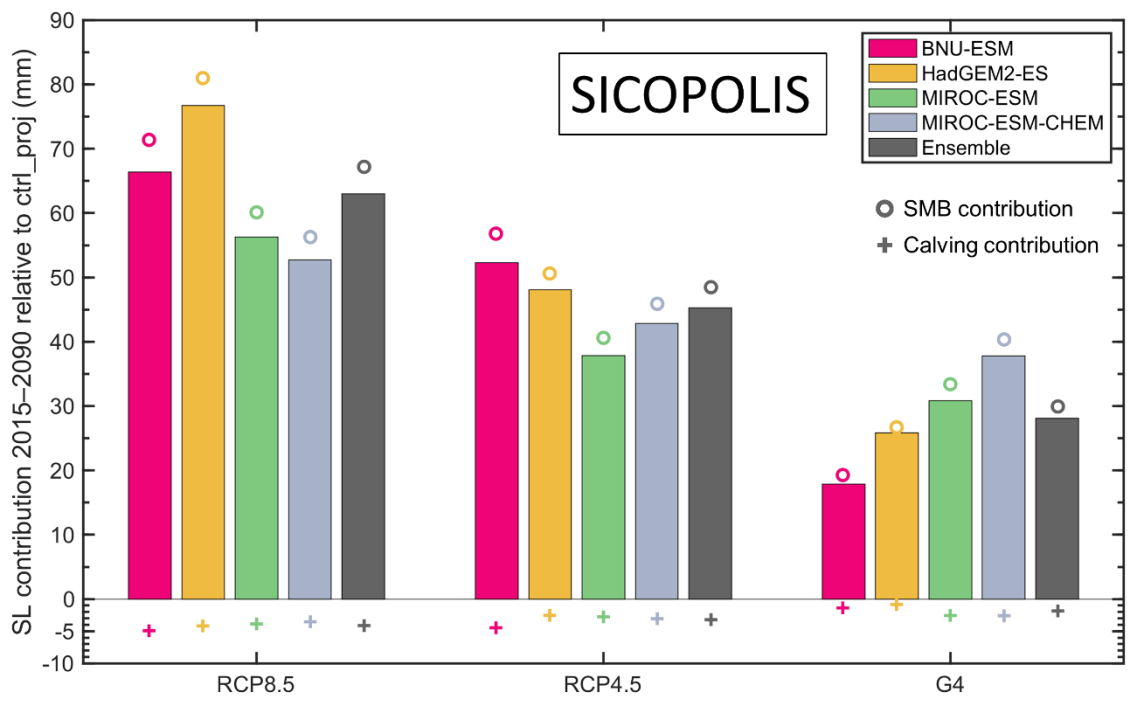


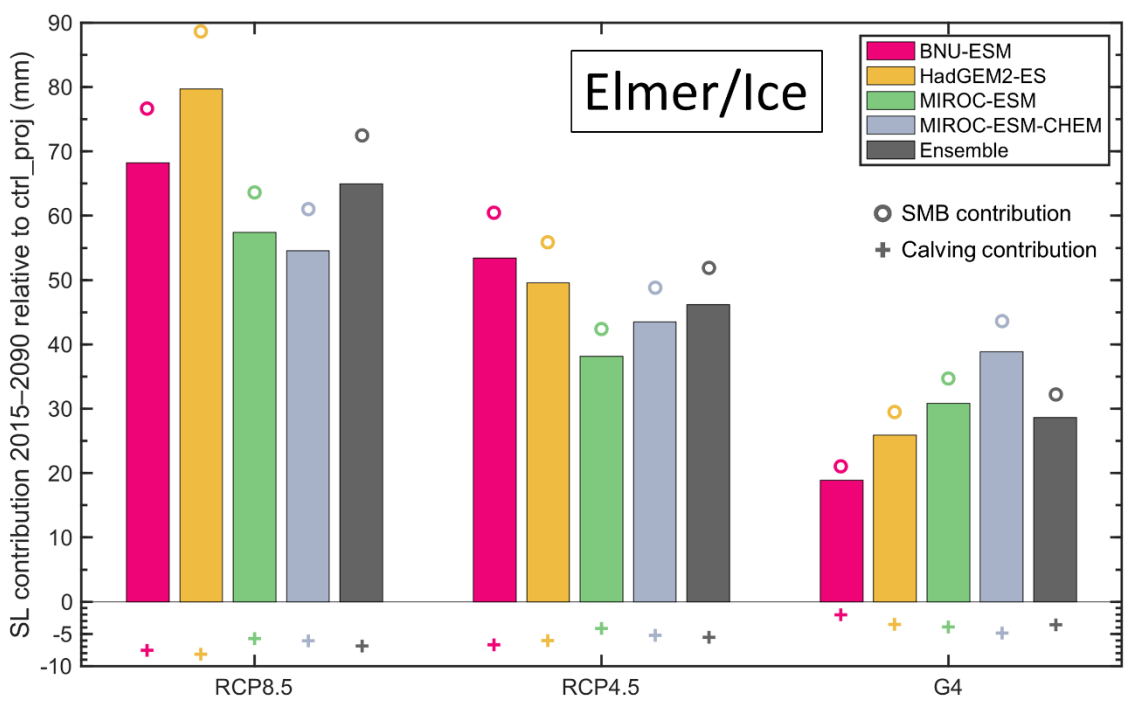
Elmer/Ice produces more drift than SICOPOLIS in the control run.

Reason: “off-the-shelf” set-up for Elmer/Ice vs. tuning by “implied SMB” for SICOPOLIS.

Relative to control, the results from the two ice-sheet models are very similar.

Simulated sea-level contribution by 2090





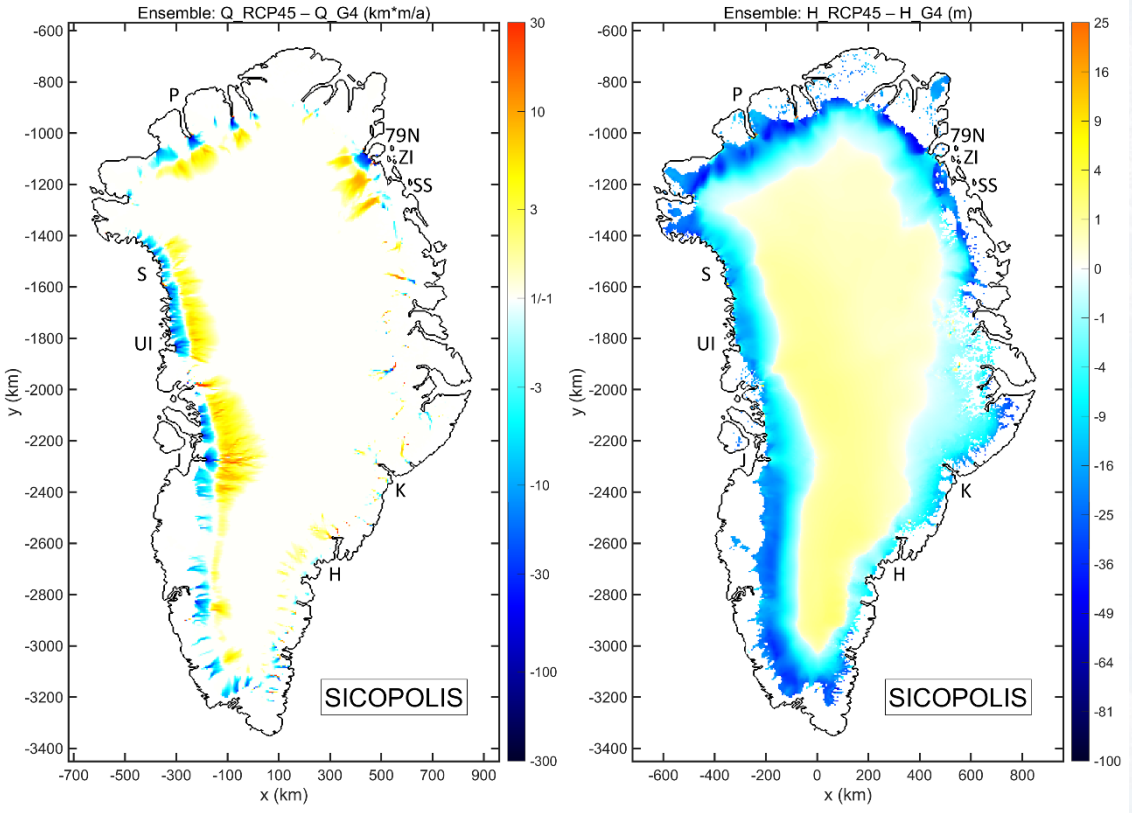
Mean mass loss for 2015–2090 under G4 ~38% smaller than under RCP4.5,
~55% smaller than under RCP8.5.

Slightly negative feedback from reduced mass loss due to calving in more extreme climate scenarios.

Simulated mass flux and thickness changes by 2090

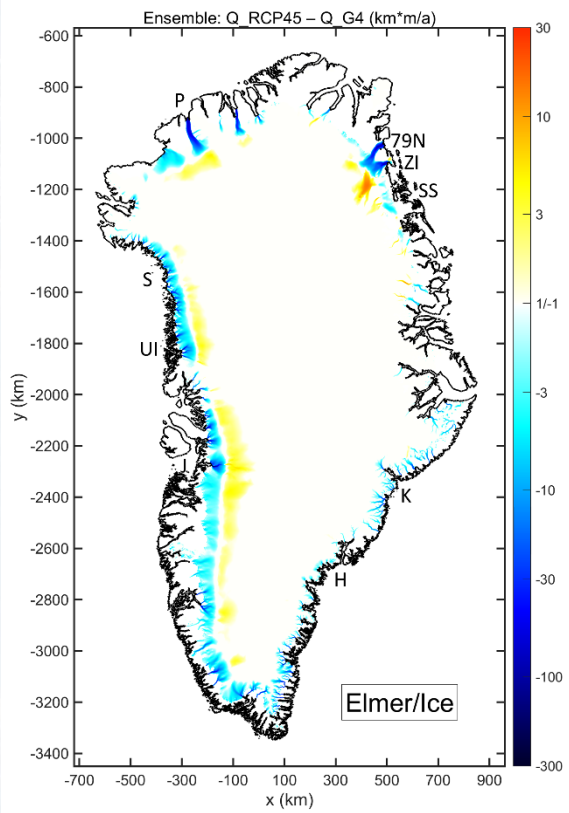
(ESM ensemble, RCP4.5 relative to G4)

Mass flux

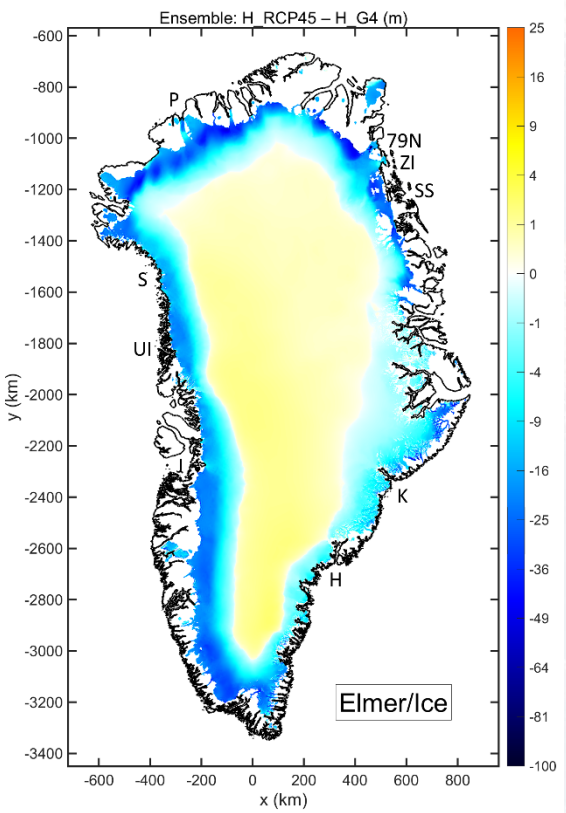


Thickness

Mass flux



Thickness



Slow-down & thinning near the coast, speed-up further inland.

Summary

Mass loss under G4 (RCP4.5 + SAI) significantly reduced compared to normal RCP4.5.

Geoengineering (e.g., SAI) remains a highly contentious topic:

Can be a tool to mitigate some of the worst aspects of global warming.

May serve as an excuse to delay tackling the root course of the problem (reducing greenhouse gas emissions) even further.

To do: Implementation of ISMIP6-like oceanic forcing.

Thank you!

Funding acknowledgements:

JSPS KAKENHI Grant Nos. JP16H02224 and JP17H06104;
Arctic Challenge for Sustainability project (ArCS II) of MEXT (program grant no. JPMXD1420318865);
Hokkaido University Foreign Visiting Professorship at the Institute of Low Temperature Science (ILTS);
Leadership Research Grant of ILTS;
National Key Research and Development Program of China (2018YFC1406104);
National Basic Research Program of China (2016YFA0602701);
Finnish Academy COLD consortium grant 322430.

Appendix

References

Goelzer, H. and 41 others. 2020. The future sea-level contribution of the Greenland ice sheet: a multi-model ensemble study of ISMIP6. *Cryosphere*, 14 (9), 3071-3096, doi: 10.5194/tc-14-3071-2020.

Jones, A. C., M. K. Hawcroft, J. M. Haywood, A. Jones, X. Guo and J. C. Moore. 2018. Regional climate impacts of stabilizing global warming at 1.5 K using solar geoengineering. *Earth's Future*, 6 (2), 230-251, doi: 10.1002/2017EF000720.

Kravitz, B., A. Robock, O. Boucher, H. Schmidt, K. E. Taylor, G. Stenchikov and M. Schulz. 2011. The geoengineering model intercomparison project (GeoMIP). *Atmos. Sci. Lett.*, 12(2), 162-167, doi: 10.1002/asl.316.

MacMartin, D. G. and B. Kravitz. 2019. Mission-driven research for stratospheric aerosol geoengineering. *Proc. Natl. Acad. Sci. U.S.A.*, 116 (4), 1089-1094, doi: 10.1073/pnas.1811022116.

Nowicki, S. and 29 others. 2020. Experimental protocol for sea level projections from ISMIP6 stand-alone ice sheet models. *Cryosphere*, 14 (7), 2331-2368, doi: 10.5194/tc-14-2331-2020.