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# Modelling the response of ice sheets to environmental forcing and projecting future sea level rise

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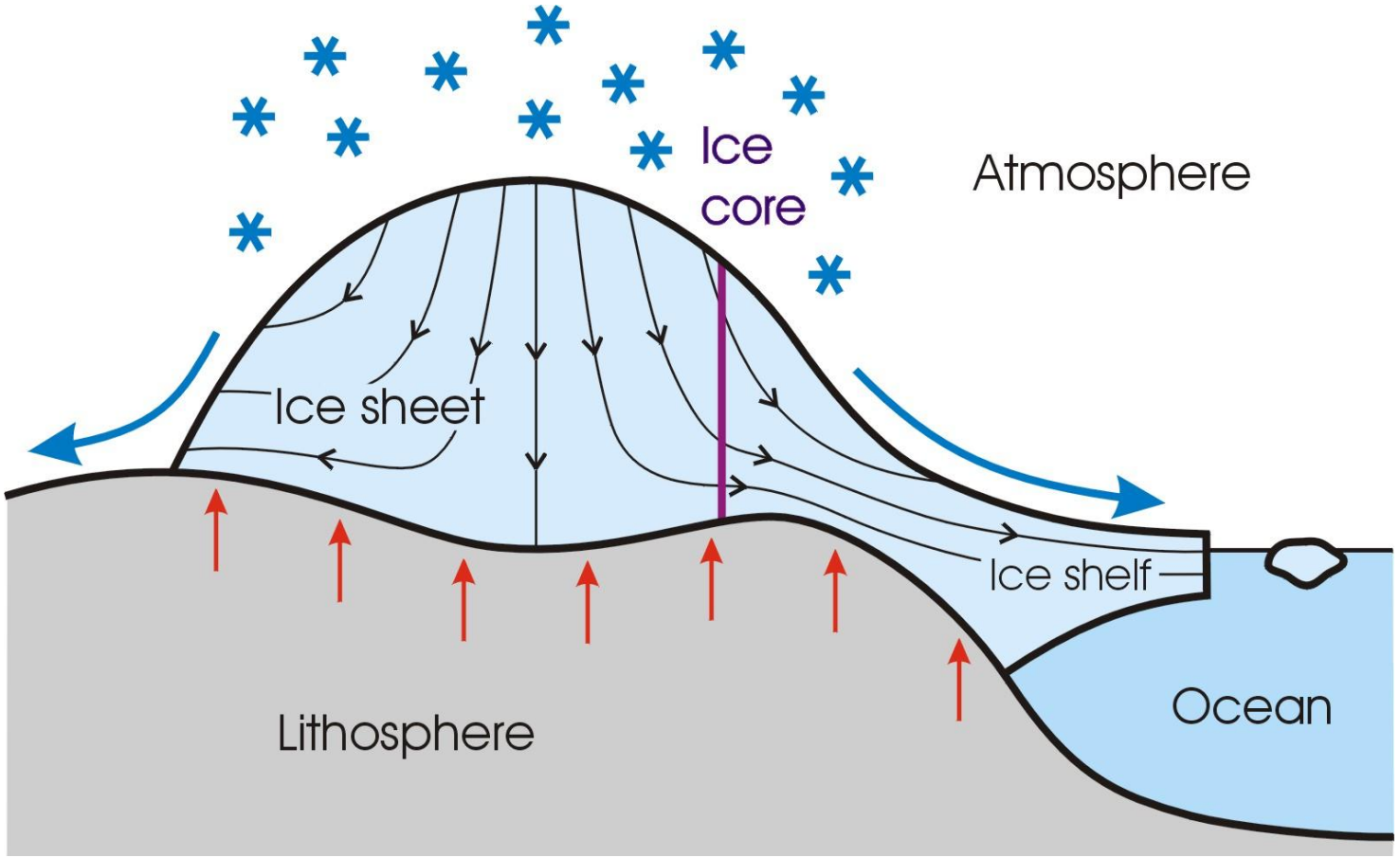
# Ice sheets on Earth (schematically)

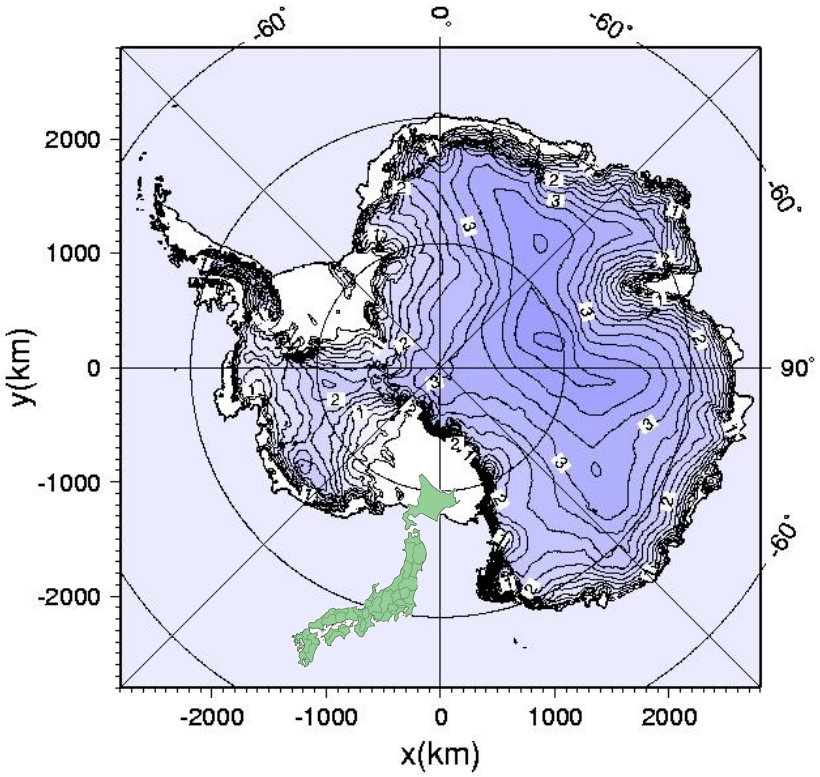


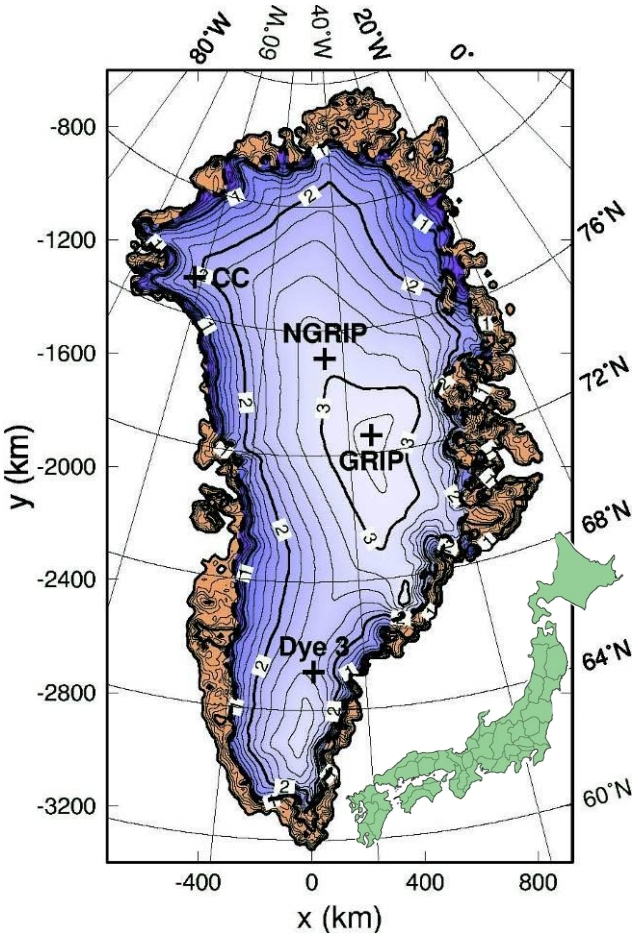

Vertical exaggeration factor ~200-500

# Today's ice sheets on Earth

Greenland ice sheet

Antarctic ice sheet
(with ice shelves)



# Ice inventory

| | | Greenland ice sheet | Antarctic ice sheet (+ shelves) |
|---|---|---|---|
| Area ($10^6$ km$^2$) | | 1.7 | 12.3 (+ 1.5) |
| Volume ($10^6$ km$^3$) | | 2.9 | 24.7 (+ 0.7) |
| Sea level equivalent (m) | | 7.3 | 56.6 (+ 0) |
| Turnover time (vol/accum, years) | | ~ 5,000 | ~ 12,000 |

Source: Lemke et al. (2007) [IPCC AR4 Ch. 4].

# SeaRISE

## = **Sea**-level **R**esponse to **I**ce **S**heet **E**volution

- Multi-ice-sheet model community effort.
- Objective:
  To predict the likely range of contributions of the Greenland and Antarctic ice sheets to sea level rise over the next 100's of years under global warming conditions.
- As at 2012.07.31 (paper submission deadline for IPCC AR5):
  8 models for Greenland
  (AIF, CISM-2, Elmer/Ice, IcIES, ISSM, PISM, SICOPOLIS, UMISM),
  6 models for Antarctica
  (AIF, UMISM w/o shelves, ISSM, PennState3D, Potsdam-PISM, SICOPOLIS w/shelves).

# SeaRISE @ ILTS

## Model SICOPOLIS

= **SI**mulation **CO**de for **POL**ythermal **I**ce **S**heets

(Greenland: Ralf Greve, Antarctica: Tatsuru Sato)

## Model Elmer/Ice

= **Elmer Ice Sheet Model**

(Greenland: Hakime Seddik)

# SeaRISE future climate experiments

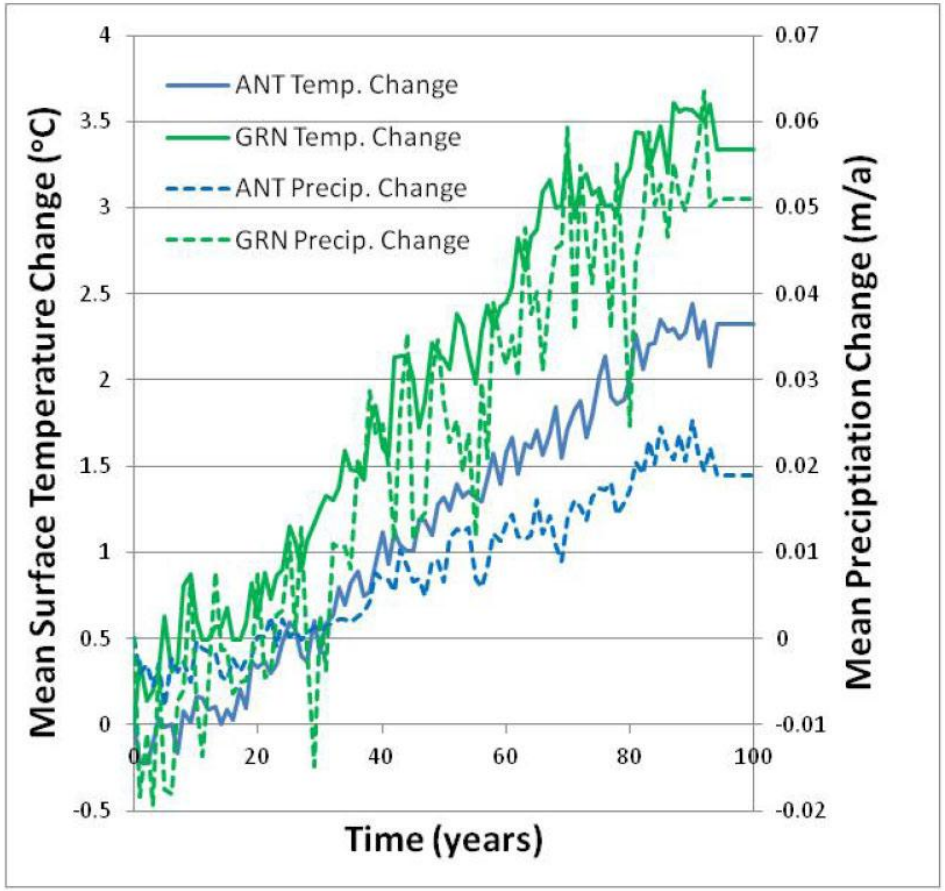
(for Antarctica and Greenland, over 500 years)

## Sensitivity experiments

- CTL – constant climate control run.
- C1, 2, 3 – 1 x / 1.5 x / 2 x A1B climate forcing over 100 a, then constant.
- S1, 2, 3 – 2 x / 2.5 x / 3 x basal sliding.
- M1, 2, 3 – ocean-induced sub-ice-shelf and marginal melting of 2 / 20 / 200 m/a.

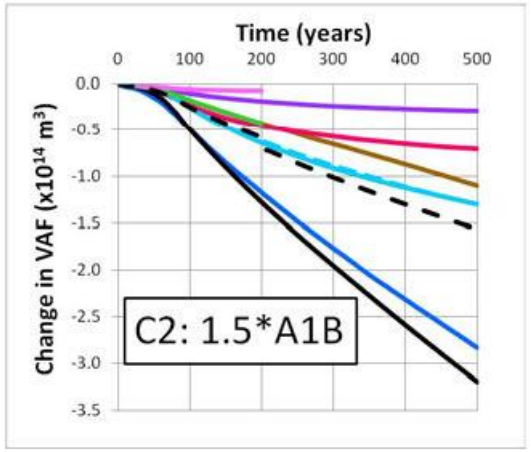
# SeaRISE future climate experiments

## 1 x A1B climate forcing used for run C1



# Simulated ice volume changes – Greenland, forcing by climate



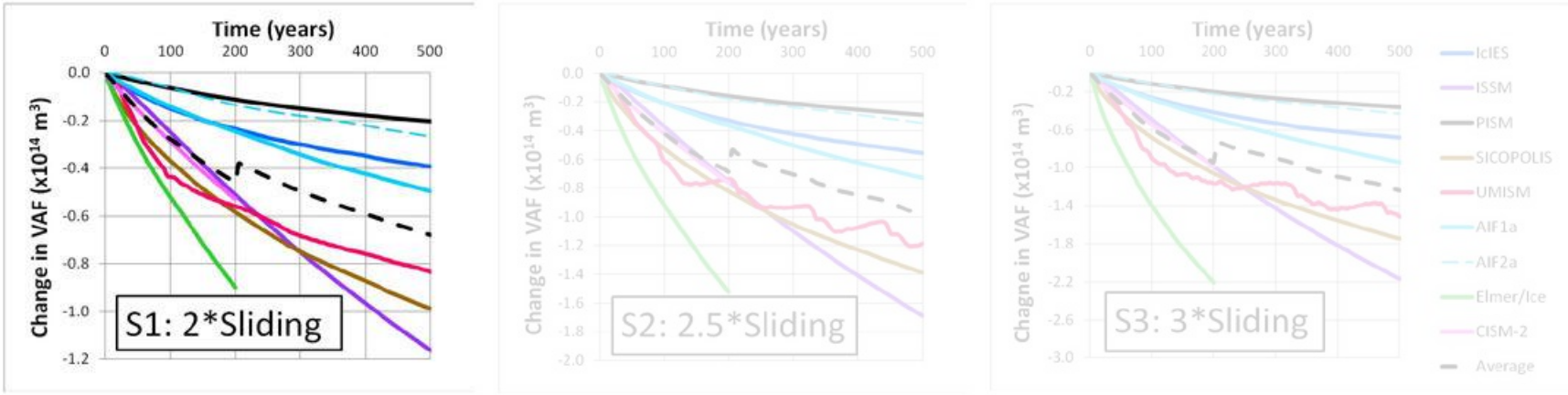







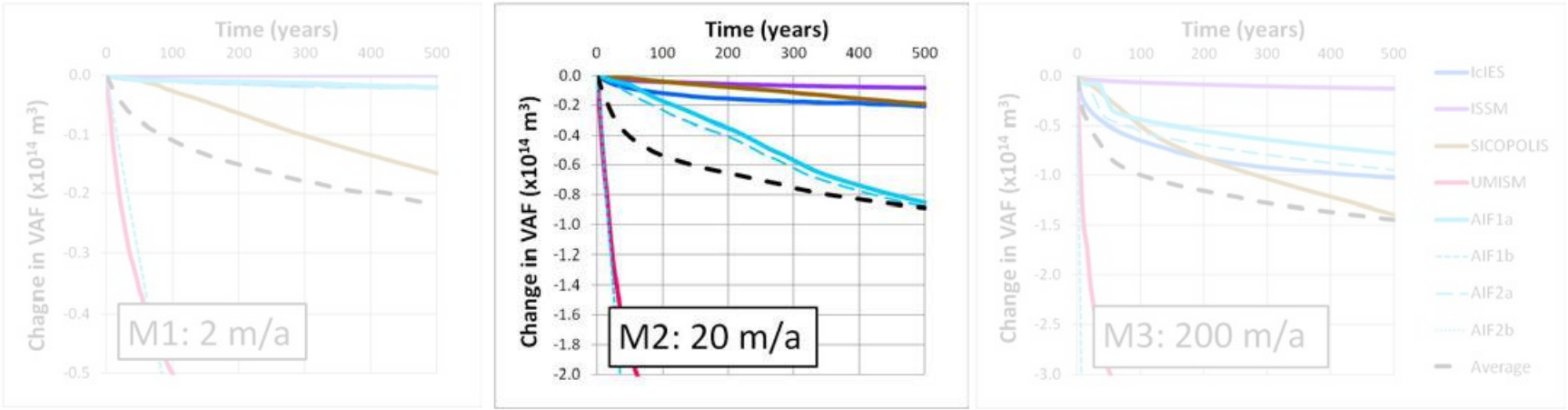
Very sensitive.

# Simulated ice volume changes – Greenland, forcing by basal sliding



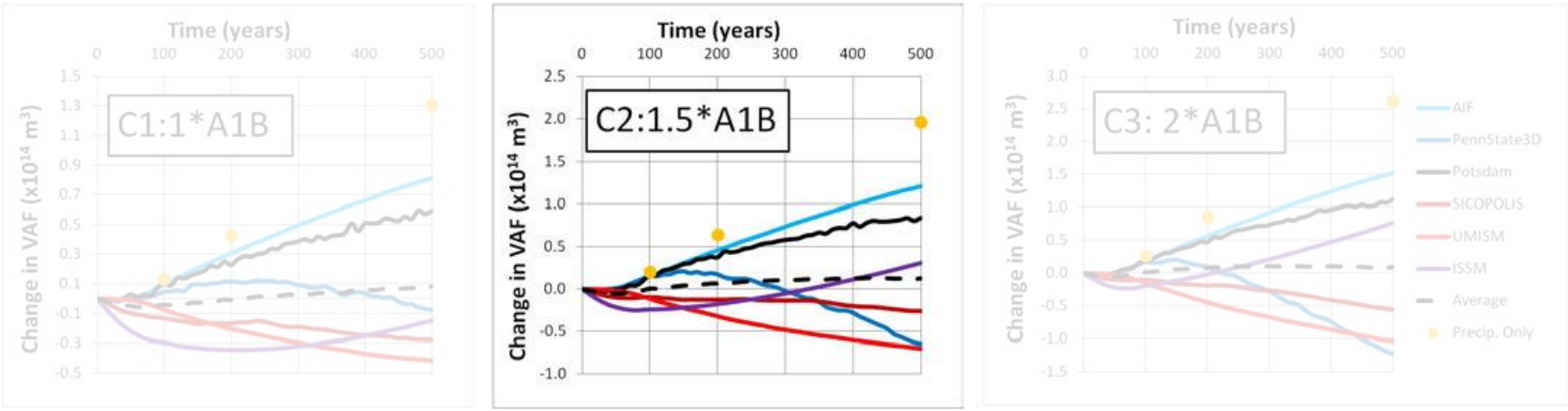

Moderately sensitive.

# Simulated ice volume changes – Greenland, forcing by marginal melting




Moderately sensitive.

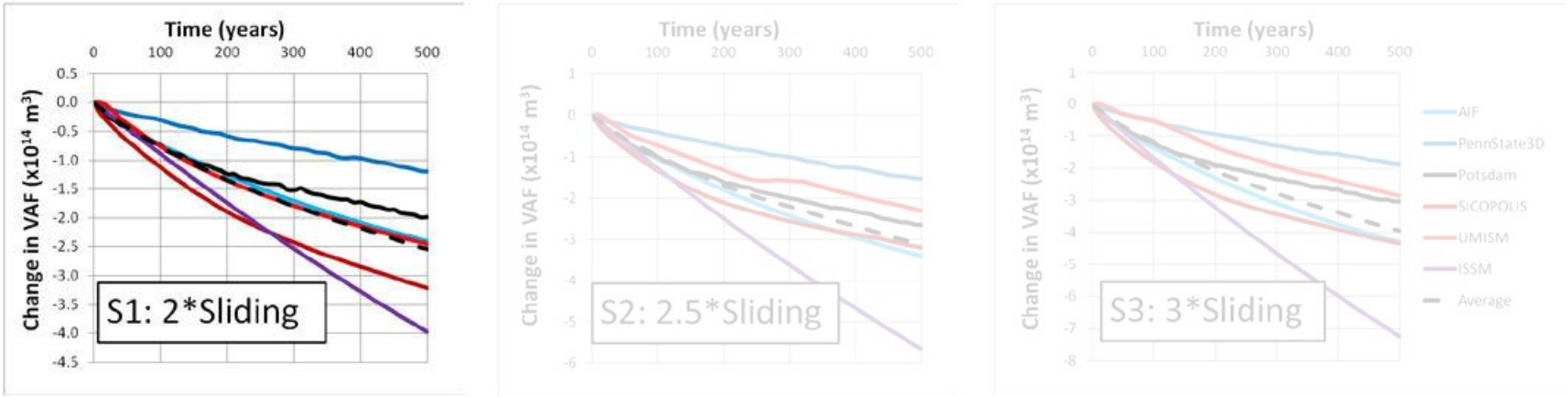
# Simulated ice volume changes – Antarctica, forcing by climate




Little sensitive.

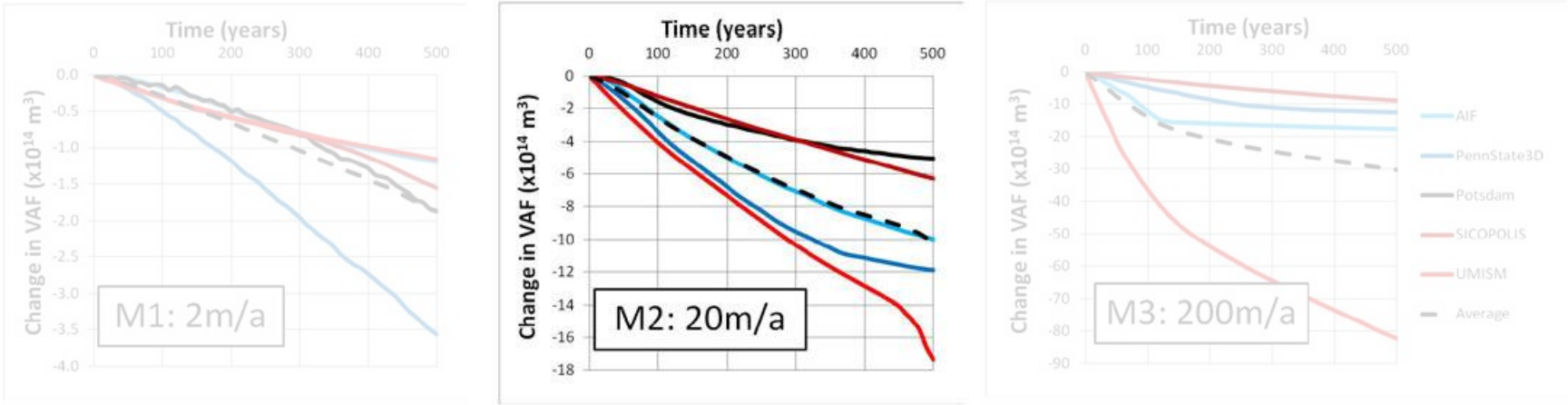
Even the sign is unclear!

# Simulated ice volume changes – Antarctica, forcing by basal sliding




Moderately sensitive.

# Simulated ice volume changes – Antarctica, forcing by sub-ice-shelf melting

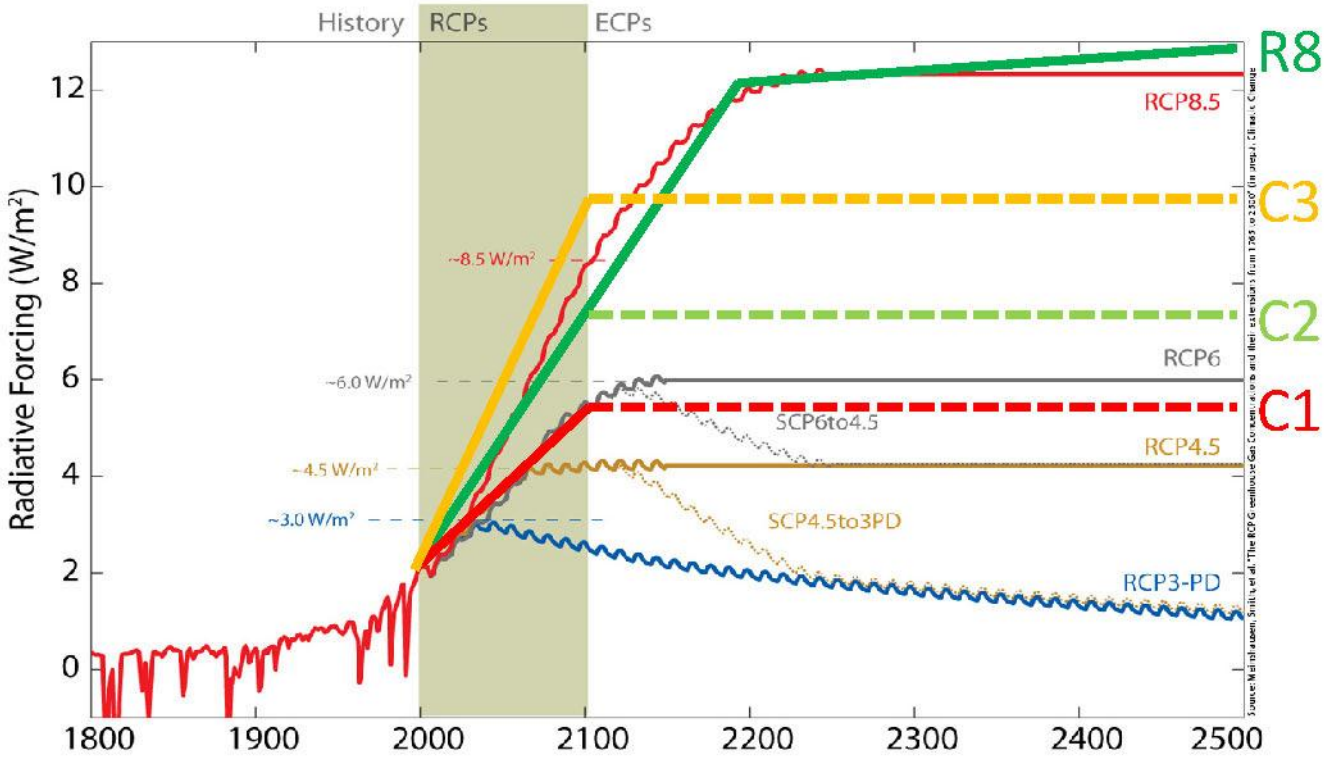



Very sensitive.

# SeaRISE future climate experiments

## Combination experiment R8

(approximating IPCC's RCP8.5 scenario)



# SeaRISE future climate experiments

## Set-up of exp. R8 for Greenland

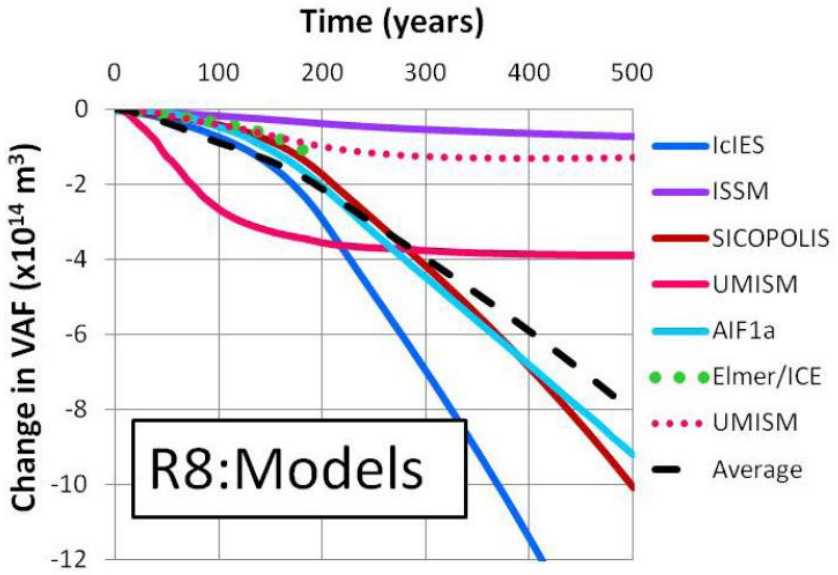
1.5 x A1B climate (continued over 500 a)
+ 1.5 x basal sliding
+ up to 70 m/a ocean-induced marginal melting.

## Set-up of exp. R8 for Antarctica

1.5 x A1B climate (continued over 500 a)
+ up to 1.8 x basal sliding (coastal regions only)
+ up to 70 m/a ocean-induced sub-ice-shelf melting
(Amundsen Sea and Amery Ice Shelf only).

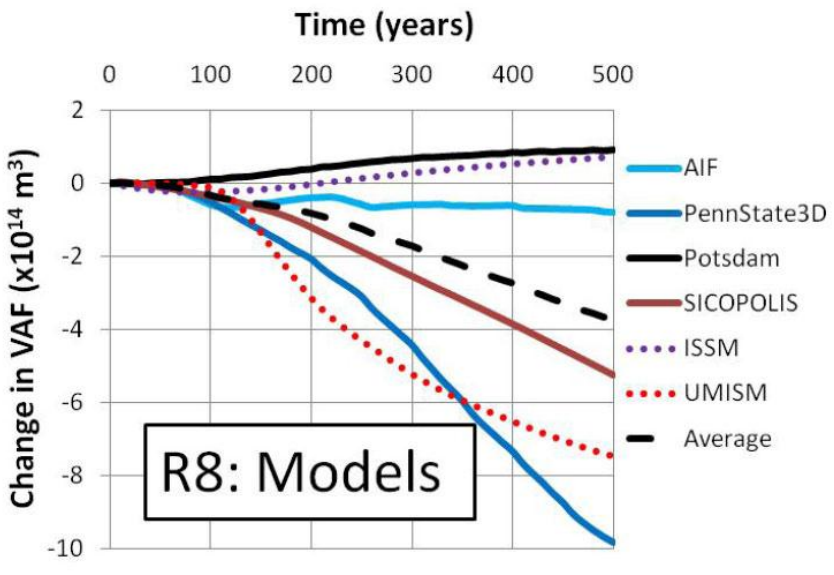
# Simulated ice volume changes of exp. R8

## Greenland:




Average after 100 a: 0.22 m SLE
200 a: 0.53 m SLE
500 a: 2.02 m SLE

## Antarctica:




Average after 100 a: 0.07 m SLE
200 a: 0.21 m SLE
500 a: 0.93 m SLE

# Concluding remarks

- Greenland is most sensitive to atmospheric changes in temperature and precipitation.
- Antarctica is most sensitive to sub-ice-shelf melting.
- Large spread of results between the different models.
- Average results for exp. R8 (~RCP8.5 scenario):
  After 500 years Greenland loses ~25% of its VAF,
  Antarctica loses ~1.6% (average results).

# Acknowledgements


- Bob Bindschadler, Sophie Nowicki, Jesse Johnson, … for launching, running and contributing to SeaRISE

(figures on slides 10-17 and 19 taken from Bindschadler and 27 others, *J. Glaciol.*, submitted).

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Thank you !

Ralf Greve