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# SeaRISE: Modelling the present-day state and future evolution of the Greenland Ice Sheet with the models SICOPOLIS and IcIES



Courtesy NASA (STS-45, 1992-03-29)

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3 Atmosphere and Ocean Research Institute, University of Tokyo, Japan

# SeaRISE

## = Sea-level Response to Ice Sheet Evolution

- Multi-ice-sheet model community effort (> 10 models).

- 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.

- Possible ice-dynamic acceleration or destabilisation mechanisms will be investigated.

*Greve, Saito and Abe-Ouchi*

# Japanese contribution to SeaRISE

## Model SICOPOLIS

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

(Greve for GrIS, Sato for AIS → yesterday's poster C21C-0548)

## Model IcIES

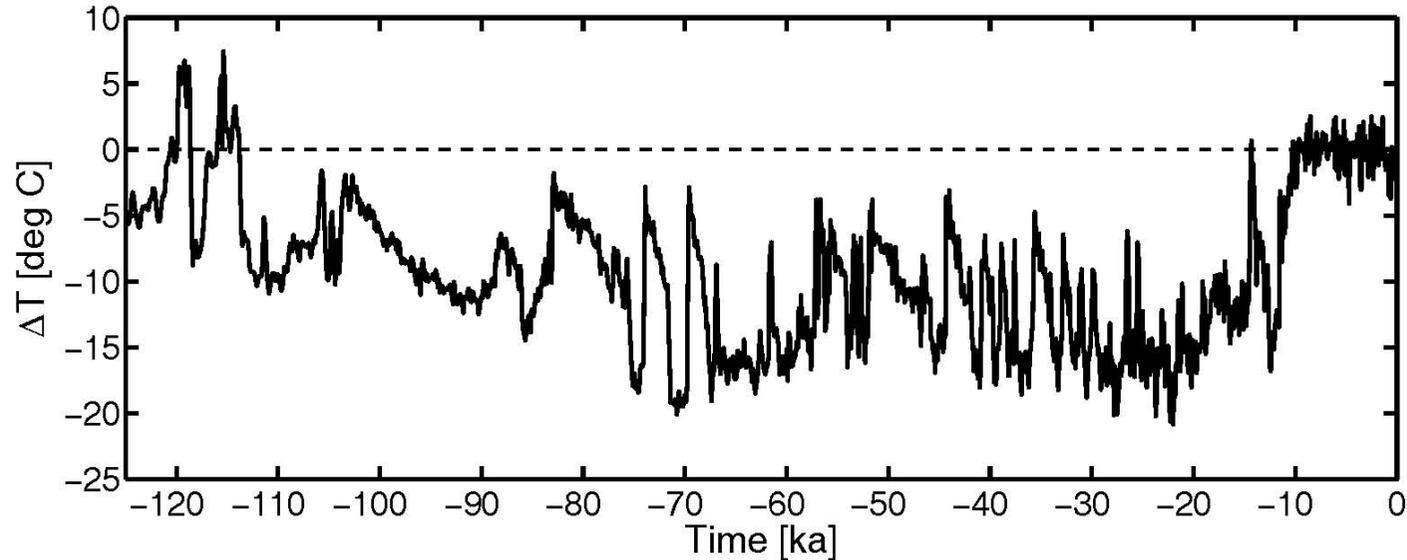= **Ic**e sheet model for **I**ntegrated **E**arth system **S**tudies

(Saito, Abe-Ouchi)

## Model Elmer/Ice

→ Yesterday's poster C21C-0552 by Seddik et al.

*Greve, Saito and Abe-Ouchi*

# Paleoclimatic spin-up

- Grid spacing: $\Delta x$ = 10 km (SICOPOLIS, IcIES).
- Model time: $t$ = −125 ka ... 0 ka (one glacial cycle).

- Climate forcing based on surface temperature anomaly (from GRIP δ$^{18}$O record):



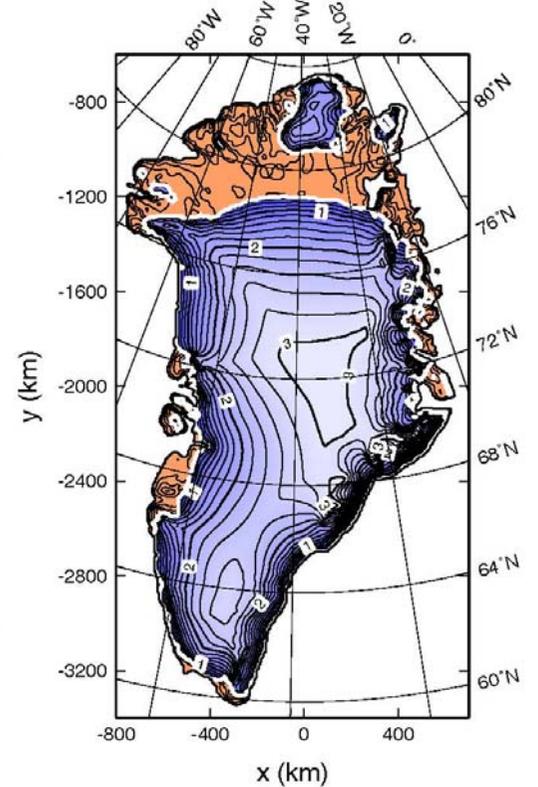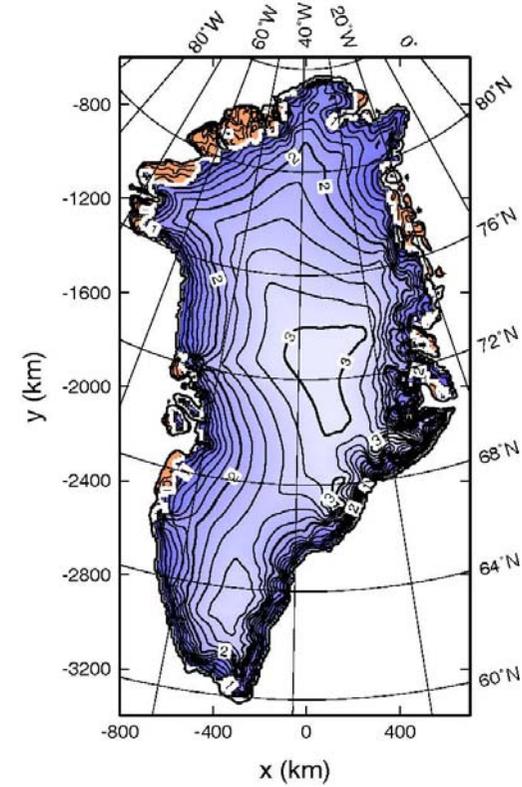*Greve, Saito and Abe-Ouchi*

# Spin-ups presented @ IGS Sapporo

Observed
present-day ice sheet
(Bamber et al. 2001)
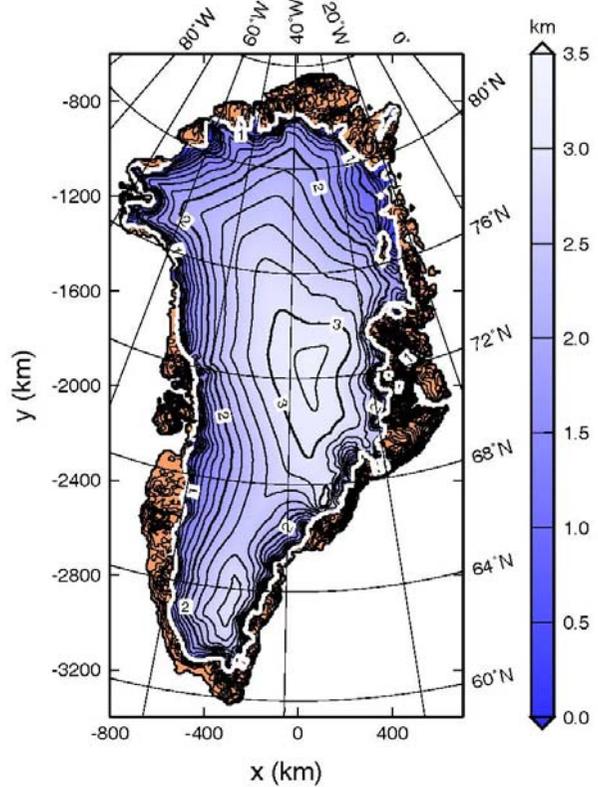
SICOPOLIS "off the shelf"
(PDD by
Tarasov and Peltier 2002)
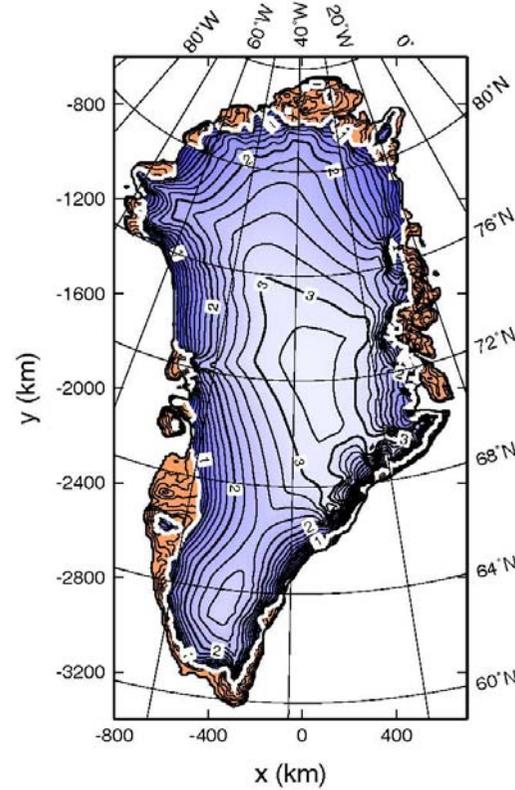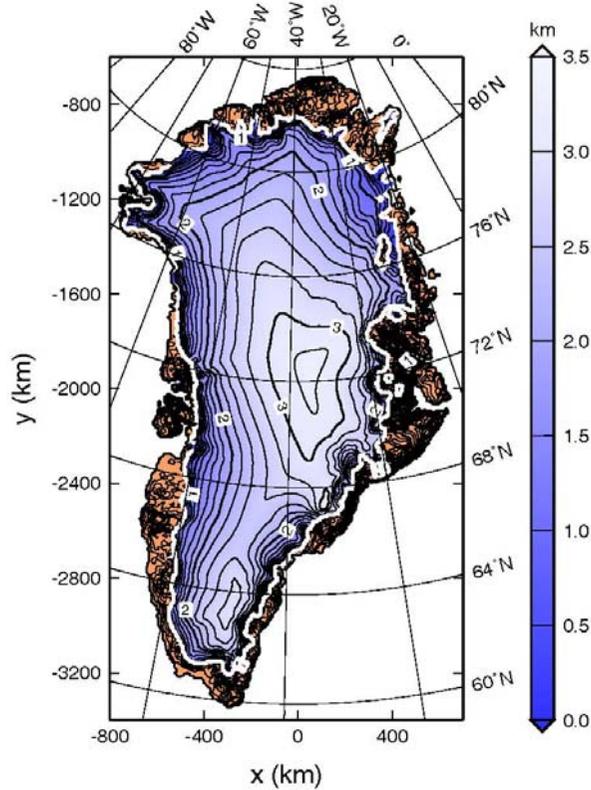
IcIES
"off the shelf"
(PDD by Reeh 1991)



*Greve, Saito and Abe-Ouchi*

# Spin-ups presented @ IGS Sapporo

$V_{sim}$ = 8.26 m SLE

vs.

$V_{obs}$ = 7.2 m SLE

Observed
present-day ice sheet
(Bamber et al. 2001)

SICOPOLIS with PDD tuning
(latitude-dependent PDD factors)

Thickness misfit (sim. – obs.)
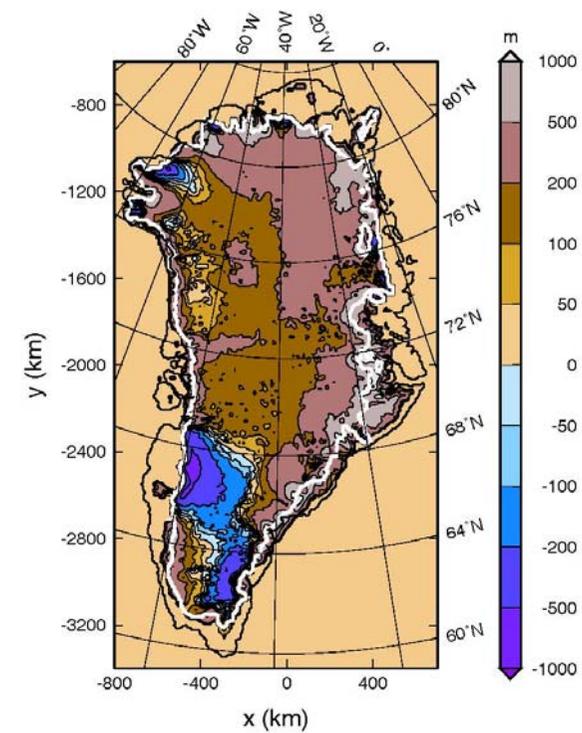


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# Changed enhancement factor improves the fit

SICOPOLIS, $E$ = 3 (like IcIES) instead of $E_{interglac}$ = 1 / $E_{glac}$ = 3.
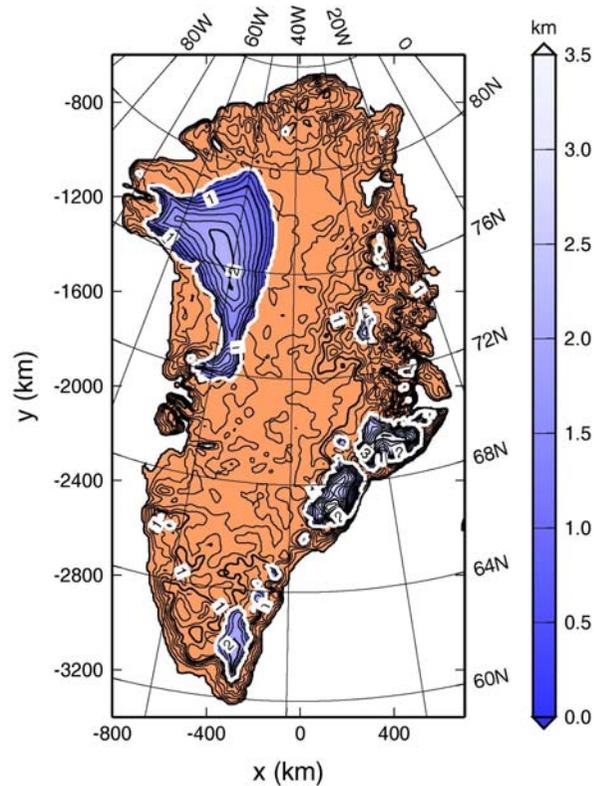
Thickness misfit (sim. – obs.)
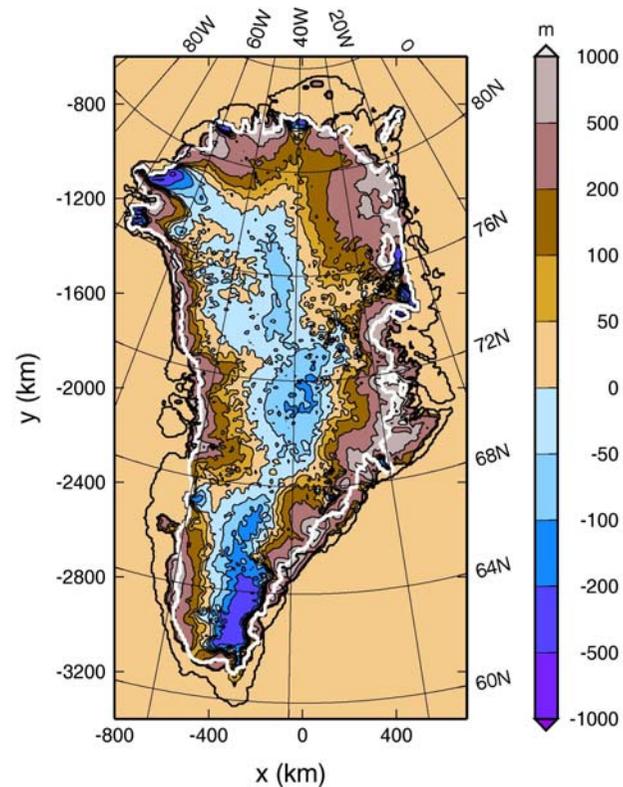


$V_{sim}$ = 7.89 m SLE

vs.

$V_{obs}$ = 7.2 m SLE

So far, so good, but…

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# Brute-force PDD tuning kills too much ice in the Eemian

114 ka BP,
$V_{sim}$ = 0.68 m SLE



GRIP, GISP2, Dye 3 and NGRIP ice-free

→ apparently not realistic!

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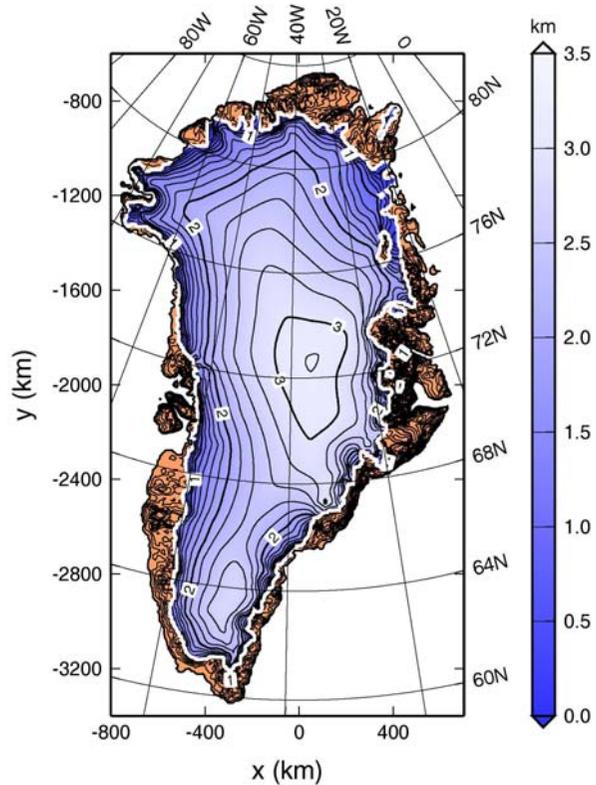# Alternative strategy:
# Spin-up with fixed topography

Initial relaxation over 100 years (with evolving topography), then topography kept fixed.

Some changes in order to account for the recommendations by Cuffey and Paterson, "The Physics of Glaciers" (4th ed. 2010):
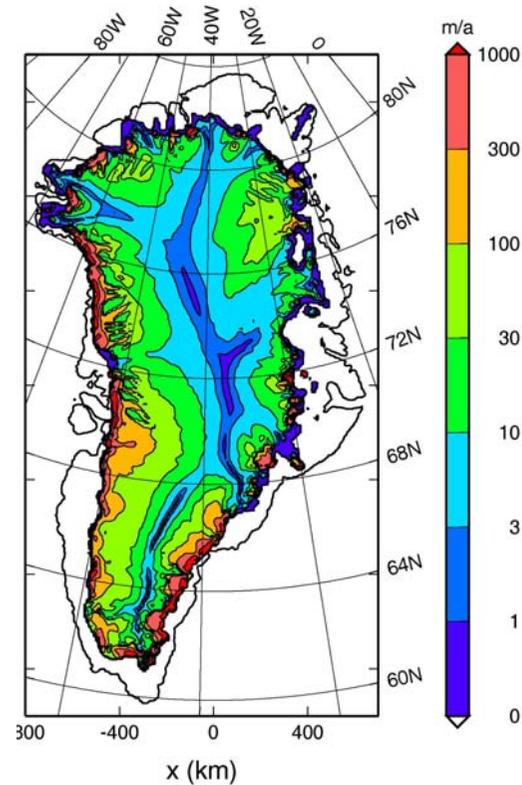
- Rate factor: $A(-10°C) = 3.5 \times 10^{-25}$ s$^{-1}$ Pa$^{-3}$.

- Enhancement factor: $E_{interglac} = 2$, $E_{glac} = 5$.

- Creep function: $f(\sigma_e) = \sigma_e^{n-1} + \sigma_0^{n-1}$
  with $n = 3$ and $\sigma_0 = 10$ kPa
  (finite-viscosity flow law; Greve and Blatter 2009).

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# Alternative strategy:
# Spin-up with fixed topography

Surface topography

Surface velocity

Basal temperature
(relative to PMP)



*Greve, Saito and Abe-Ouchi*
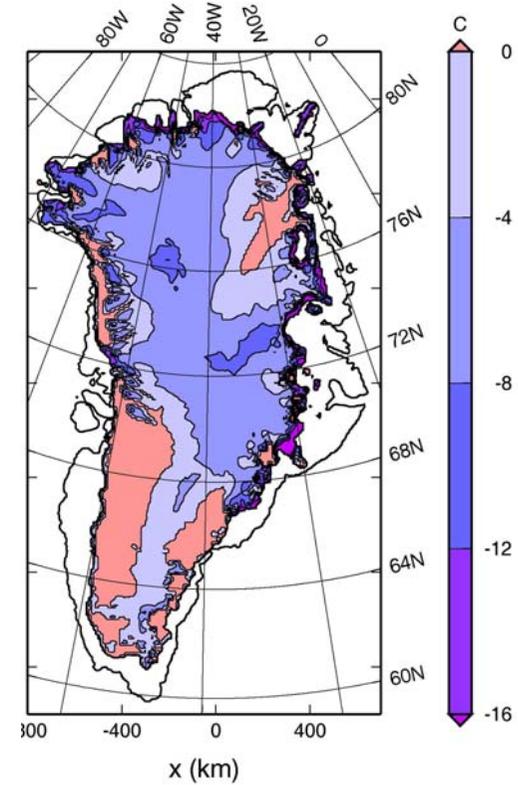
# Alternative strategy:
# Spin-up with fixed topography

Basal temperature of ice core locations:

|  | GRIP | NGRIP | CC | Dye 3 |
|---|---|---|---|---|
| Sim. $T_b$ [°C] | −10.76 | −9.91 | −9.94 | −2.73 |
| Obs. $T_b$ [°C] | −8.56 | −2.4* | −13.0 | −13.22 |

*: pressure melting point

Quite bad → geothermal heat flux?

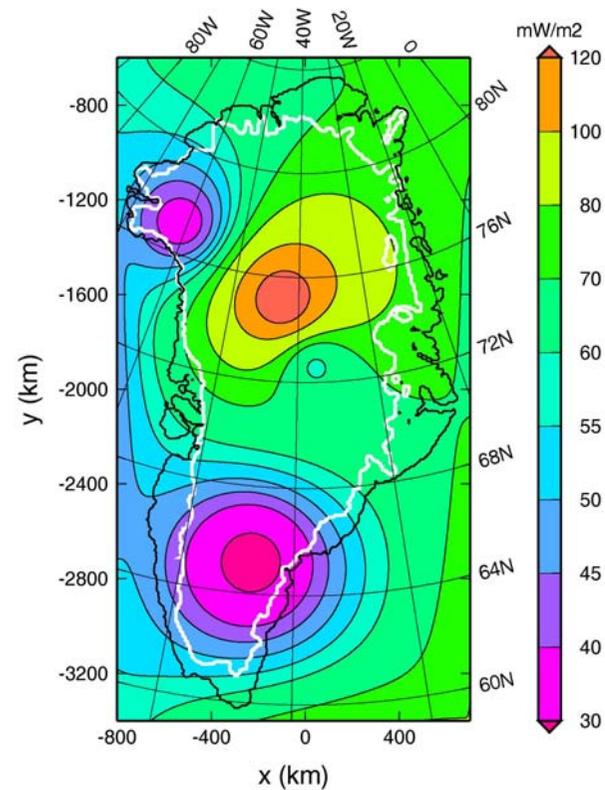*Greve, Saito and Abe-Ouchi*

# Geothermal heat flux

SeaRISE
(Shapiro and Ritzwoller 2004)
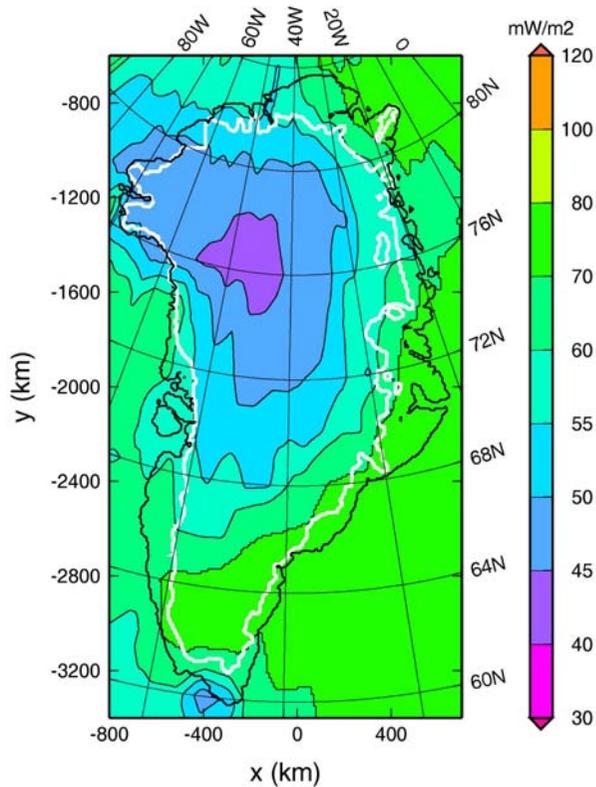
Greve (2005):
Pollack et al. (1993) plus
ice core temperatures
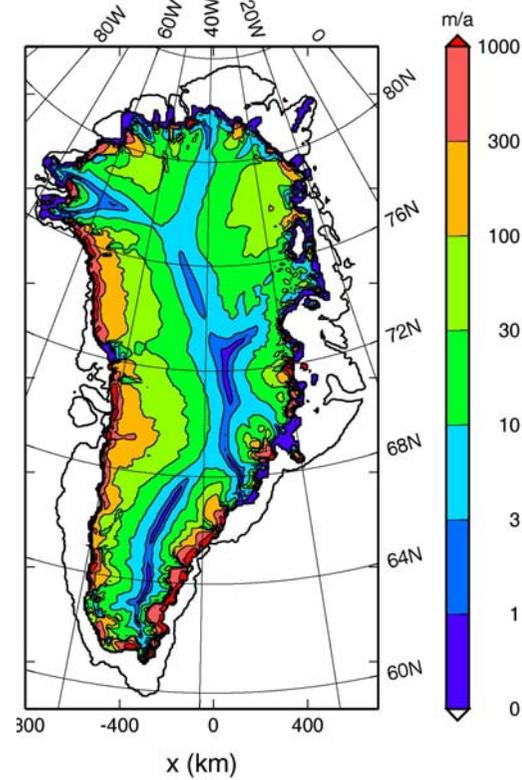
*Greve, Saito and Abe-Ouchi*

# Fixed-topography spin-up with the geothermal heat flux based on Greve (2005)



Surface topography
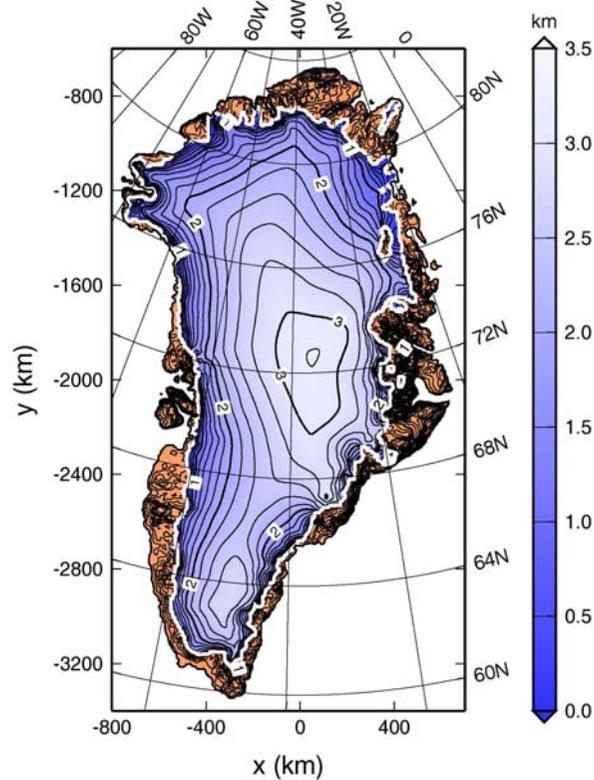
Surface velocity

Basal temperature (relative to PMP)

*Greve, Saito and Abe-Ouchi*
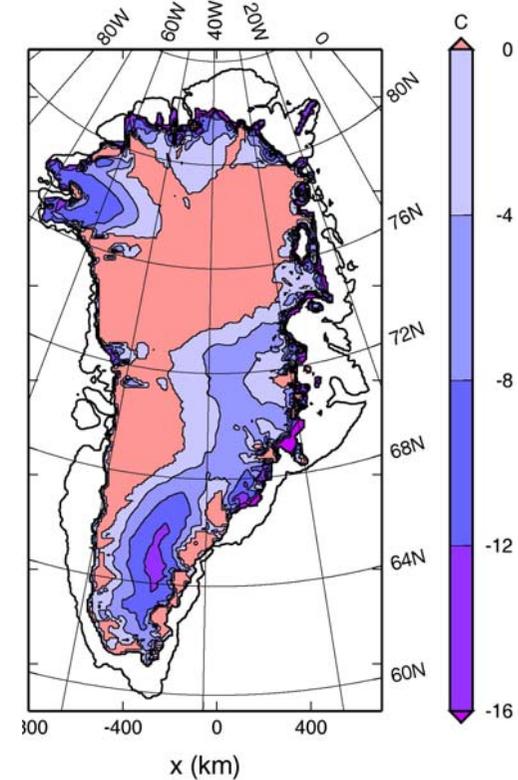
# Fixed-topography spin-up with the geothermal heat flux based on Greve (2005)

Basal temperature of ice core locations:

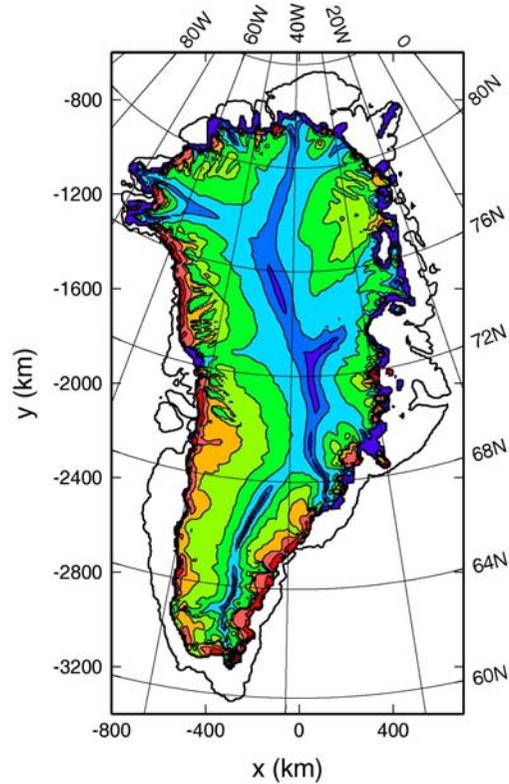| | GRIP | NGRIP | CC | Dye 3 | |
|---|---|---|---|---|---|
| Sim. $T_b$ [°C] | −10.76 −8.47 | −9.91 −2.65* | −9.94 −13.01 | −2.73 −13.22 | (S&R04) (Gr05) |
| Obs. $T_b$ [°C] | −8.56 | −2.4* | −13.0 | −13.22 | |

*: pressure melting point

Excellent agreement was achieved!

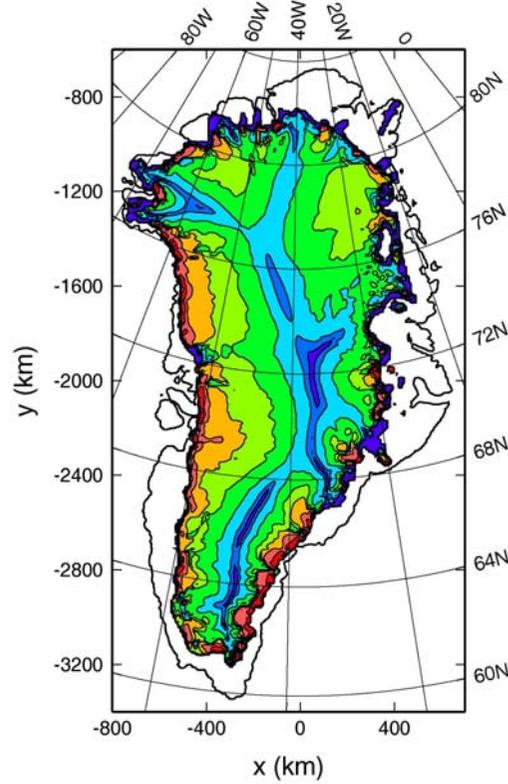*Greve, Saito and Abe-Ouchi*

# Comparison of surface velocities

Fixed-topography
spin-up, S&R04

Fixed-topography
spin-up, Gr05

Obs. (Joughin et al.,
        SeaRISE website)



*Greve, Saito and Abe-Ouchi*
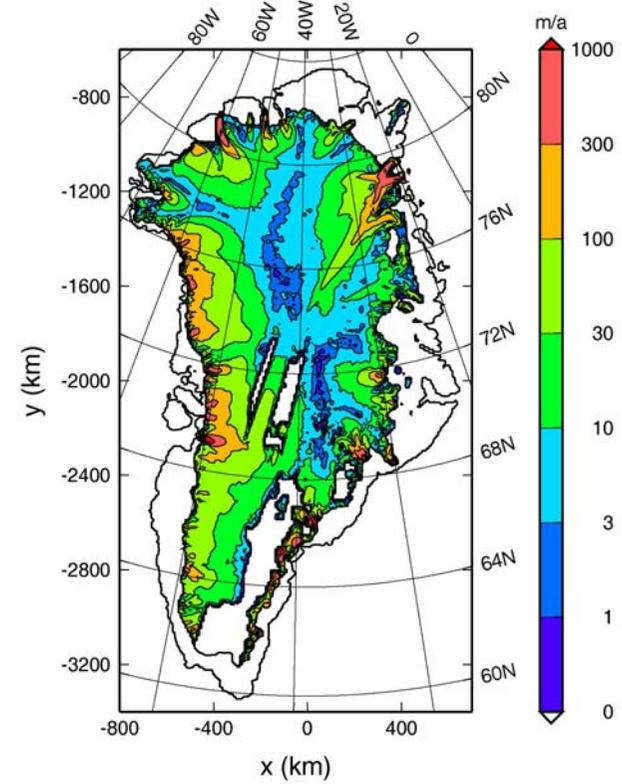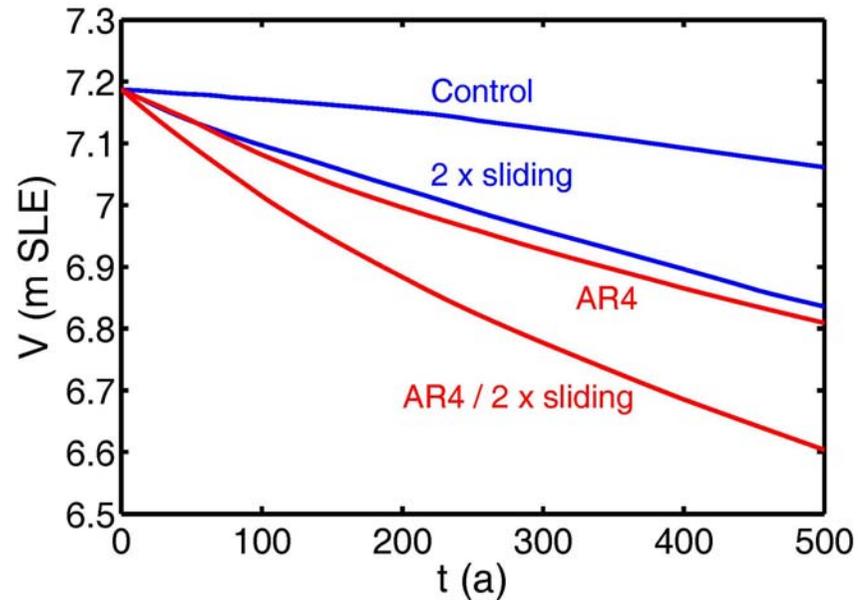
# Future climate experiments

- Grid spacing: $\Delta x$ = 10 km (SICOPOLIS, IcIES).
- Model time: $t$ = 0 a ... 500 a.

- C1_E0: Constant climate control run.

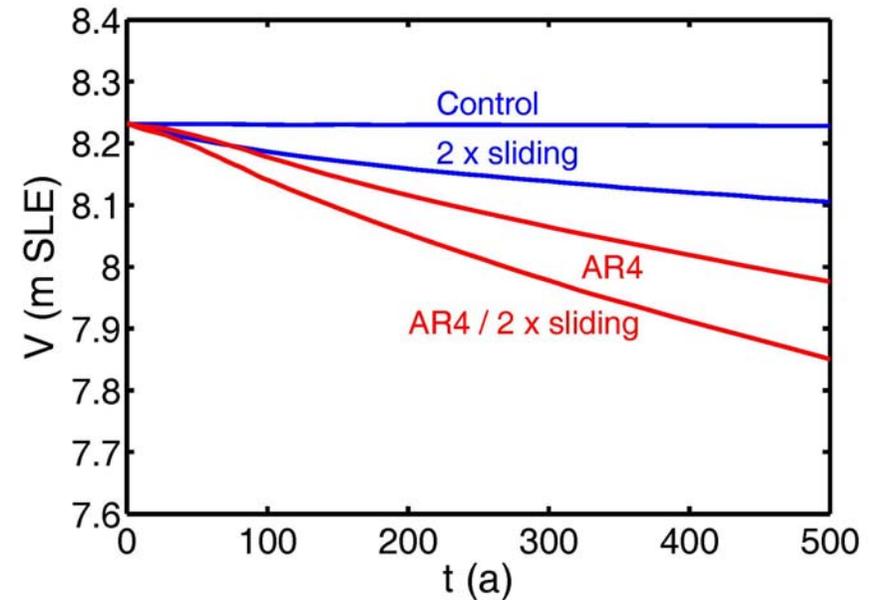- C1_E1: Constant climate forcing + doubled basal sliding.

- C2_E0: AR4 climate control run (A1B scenario).

- C2_E1: AR4 climate forcing + doubled basal sliding.

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# Future climate experiments

SICOPOLIS                                                          IcIES



Sensitivities are very similar for (AR4 – Control)  [climatic forcing],

but

significantly different for (2 x sliding – Control)  [ice dynamics].

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# Lessons to learn

- Quite difficult to get a reasonable spin-up without strong constraints.

- Ice-dynamic effects are of concern, but let's not forget about surface mass balance issues.

- Sensitivity between models can vary significantly
  $\rightarrow$ model ensemble reasonable for predictions.

*Greve, Saito and Abe-Ouchi*

# Thanks to…

- Bob Bindschadler, Sophie Nowicki, Jesse Johnson, …
  for getting and keeping SeaRISE up and running;

- Kunio Takahashi for running the SeaRISE experiments with
  IcIES at JAMSTEC;

- JSPS for providing funding
  (Grant-in-Aid for Scientific Research A, No. 22244058);

- **YOU** **for listening…** 🙂