Observation-based validation of ice sheet model initial conditions using realistic atmospheric forcing for Greenland

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AGU Fall Meeting, December 2011

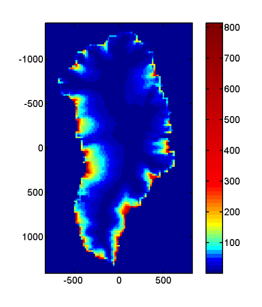
Sea-level rise is all the rage. . .

"...but recent changes in ice sheet margins and ice streams cannot be simulated accurately with these models.(*IPCC, 2007, Box 4.1: Ice Sheet Dynamics and Stability*)"

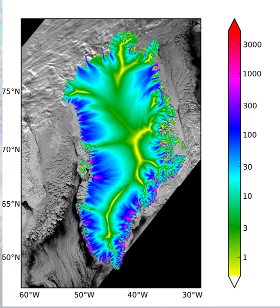
Progress report 2011

- ice sheet models are a big step closer to simulate the recent past

EISMINT



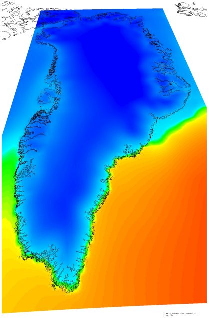
today



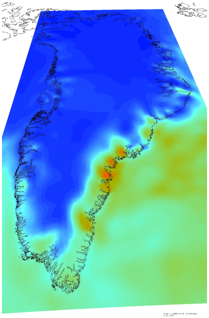
Boundary Conditions: Realistic Climate Forcing

- output from a regional climate model HIRHAM
- timeseries from the ERA-interim period 1989-2009 with monthly values of

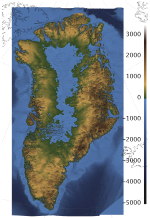
2m air temperature

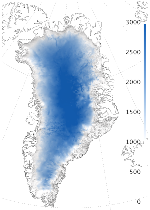


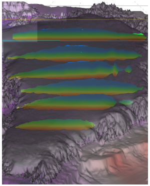
mass balance (precipitation)



Initial conditions







- basal topography
- ice thickness
- enthalpy (temperature)
- and other stuff such as basal slipperiness, depending on model physics

Problem

- we can't get initial conditions from observations alone

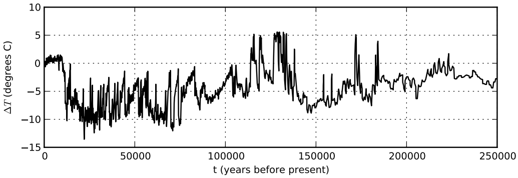
Solution

- use of assimilation techniques
  - inverse modeling
  - "spin-up"

Initial conditions

As an example we test 3 initial conditions (ways to initialize a model)

- constant-climate
- paleo-climate
- paleo-climate with flux correction (compensatory mass balance)



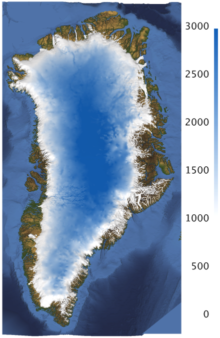
Initialization “constant climate”

HHSMB

- use 1989–2009 monthly-mean climate, run for 50 ka
- ice sheet is in equilibrium with its climate (no shocking)
- ice sheet geometry is not in agreement with observations

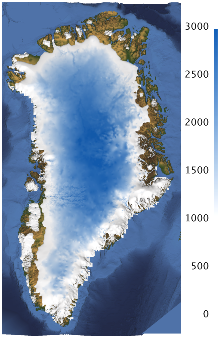
observed ice thickness

$V = 2.93 \times 10^6 \text{km}^3$



modeled ice thickness

$V = 2.75 \times 10^6 \text{km}^3$



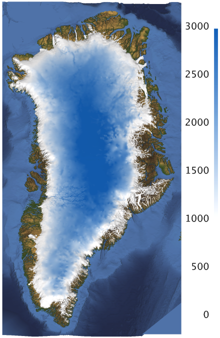
Initialization "paleo-climate"

PALEO

- use paleo-climate information to run ice sheet model through glacial/intraglacial cycles
- ice sheet geometry is not in agreement with observations

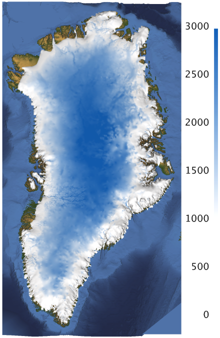
observed ice thickness

$V = 2.93 \times 10^6 \text{km}^3$



modeled ice thickness

$V = 3.32 \times 10^6 \text{km}^3$

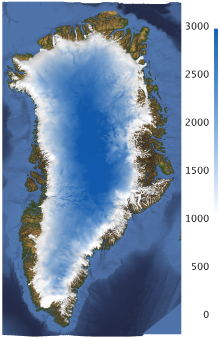


Initialization “flux-corrected paleo-climate”

PFLUX

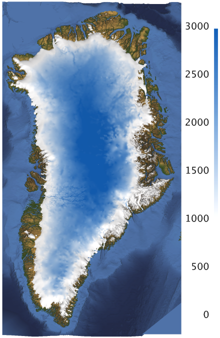
- as PALEO, alter mass balance such that modeled geometry is close to observed geometry at the end of the initialization period
- apply compensatory mass balance to prevent drifting

observed ice thickness



$V = 2.93 \times 10^6 \text{km}^3$

modeled ice thickness



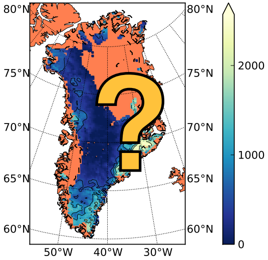
$V = 2.96 \times 10^6 \text{km}^3$

Model setup

- “un-tuned” model with default (but carefully chosen) parameters,
- same parameters for all simulations
- structured grid with horizontal resolution of 2.5 km
- simulations performed on ARSC’s supercomputer “PACMAN” in parallel on up to 256 cores

Arctic Region Supercomputing Center

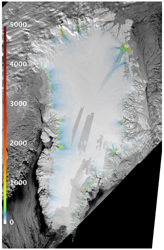
Ice sheet model validation



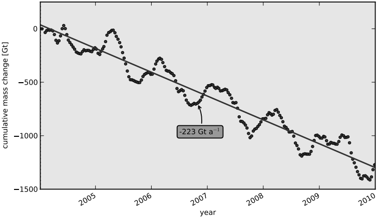
Working hypotheses

1. we understand rates of changes better than absolute values
2. getting the rate of changes right is at least as important as getting absolute values right
3. comparing modeled rates of changes to observations provides a tool for validating initial conditions

Ice sheet model validation using

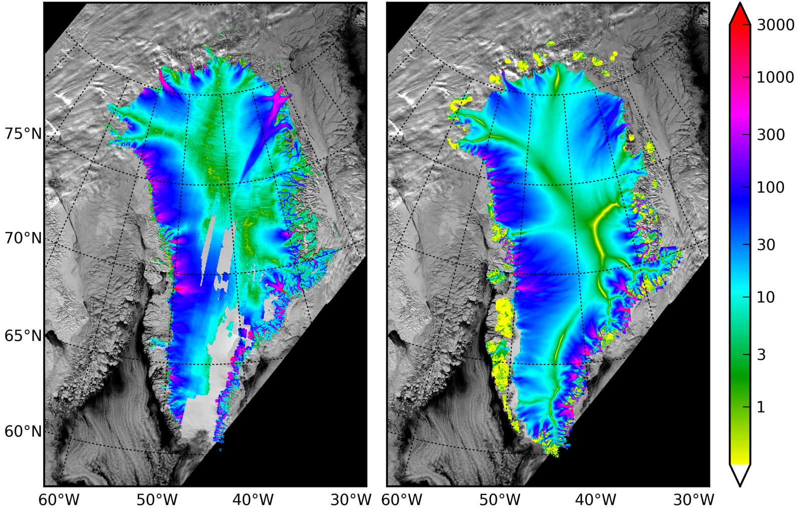


- mean flow speed from 2000,2006–2008 (InSAR) from *Joughin et al.* (2010)



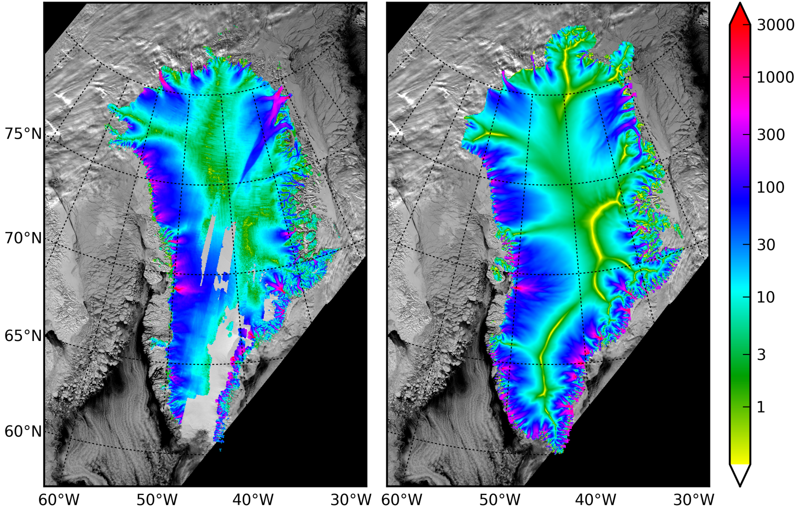
- cumulative mass change from 2004–2010 (GRACE) from *S. Luthcke* (see talk Thursday, 10:42am, Rm. 2006)

Surface velocities



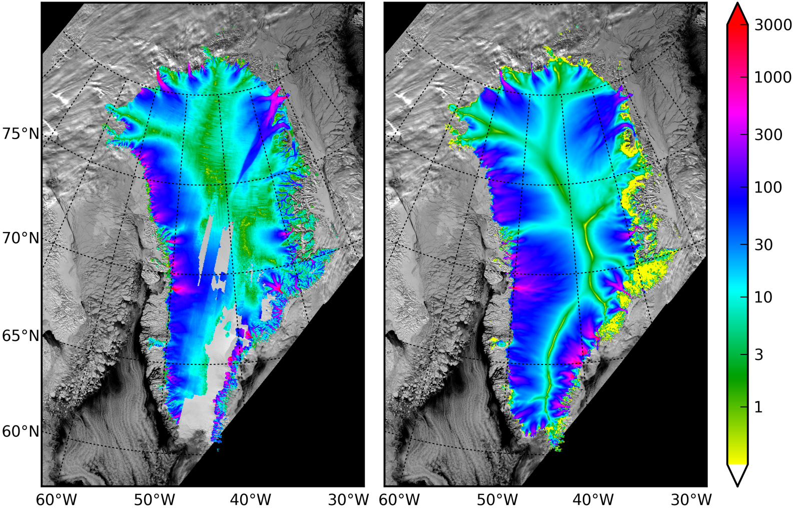
left: InSAR (Joughin et al., 2010), right: HHSMB. Values in m/a.

Surface velocities



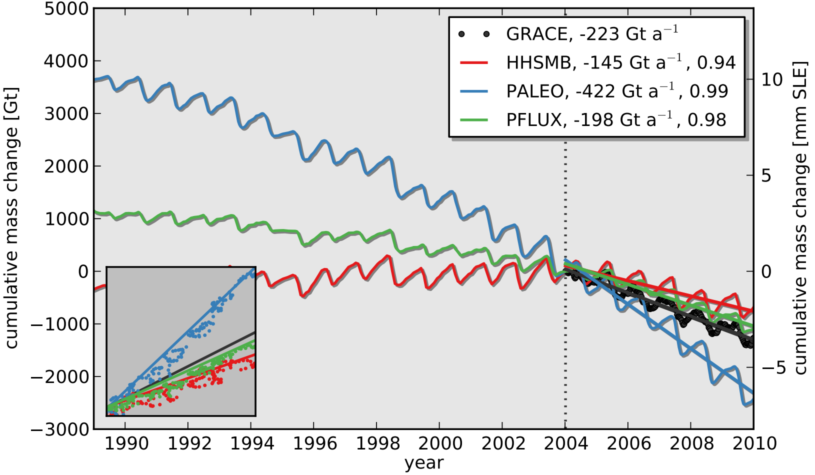
left: InSAR (Joughin et al., 2010), right: PALEO. Values in m/a.

Surface velocities



left: InSAR (Joughin et al., 2010), right: PFLUX. Values in m/a.

Cumulative total mass changes



Conclusions & Outlook

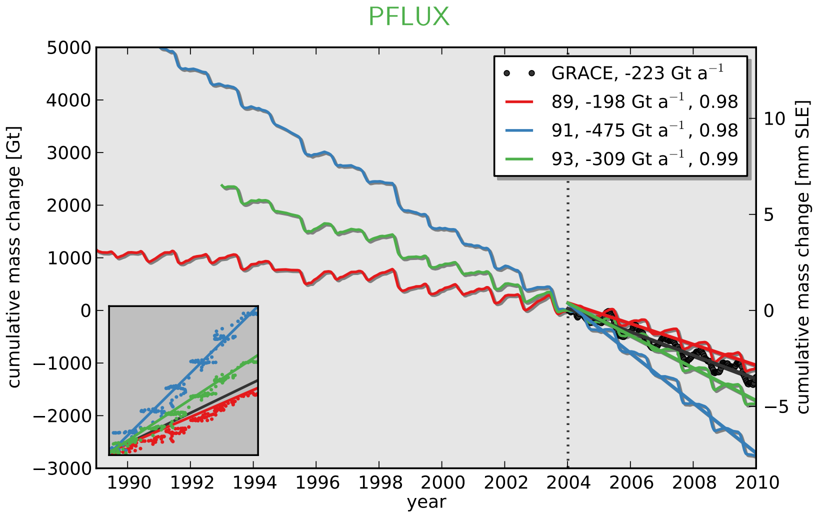
Conclusions

- able to simulate seasonal variability in ice mass
- excellent agreement between observed and simulated mass changes for some initial conditions
    - powerful tool for validation
- dynamical effects such as speed-ups due to loss of a floating tongue are not included here. Likely to underestimate mass loss trend

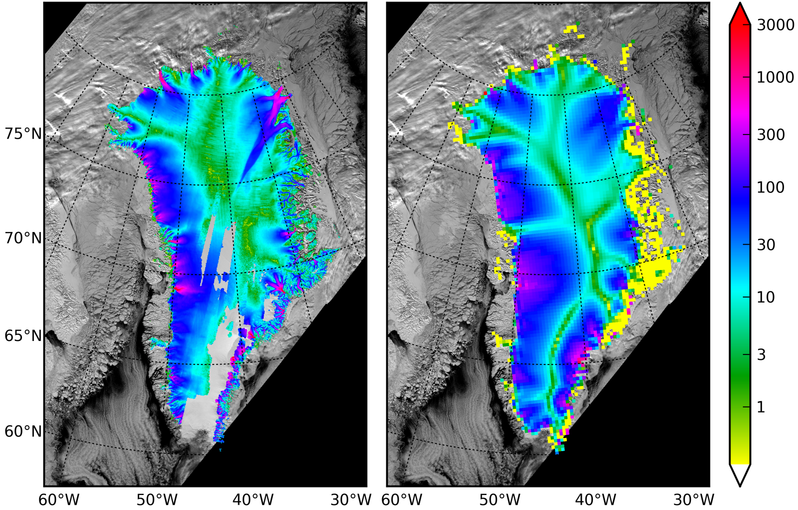
Outlook

- 1km grid resolution in 2012
- incorporate dynamic changes (oceanic forcing)
- dH/dt from ICESat, dated radar layers for validation

Supplement: Sensitivity to start year

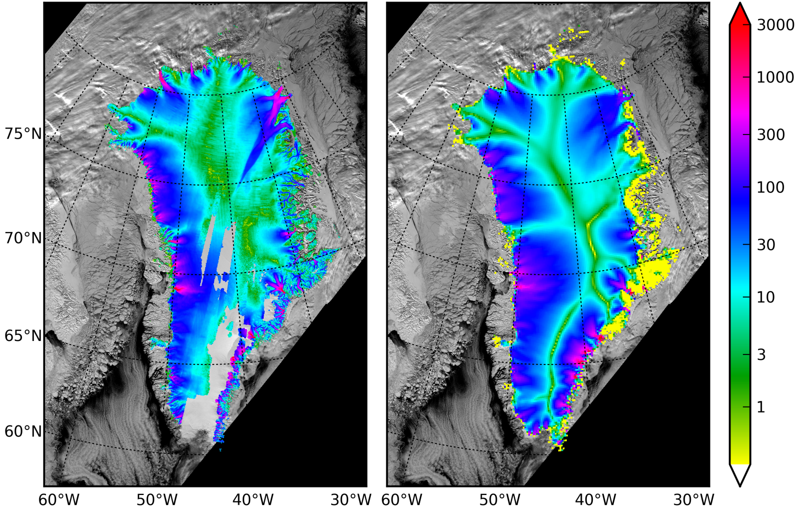


Supplement: grid resolution



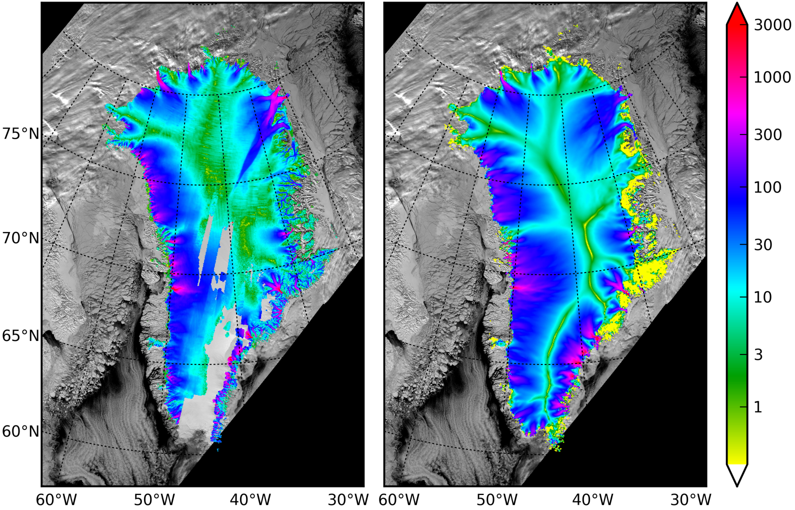
left: InSAR (Joughin et al., 2010), right: 20km. Values in m/a.

Supplement: grid resolution



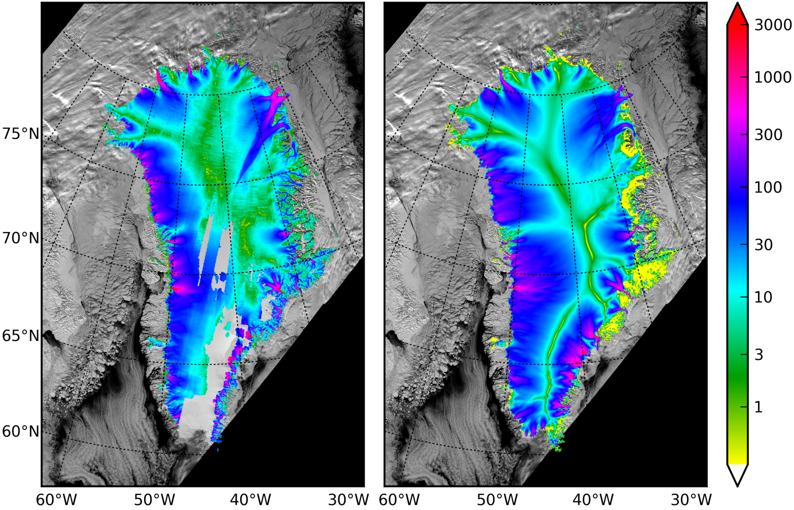
left: InSAR (Joughin et al., 2010), right: 10km. Values in m/a.

Supplement: grid resolution



left: InSAR (Joughin et al., 2010), right: 5km. Values in m/a.

Supplement: grid resolution



left: InSAR (Joughin et al., 2010), right: 2.5km. Values in m/a.