Greenland Ice Sheet model optimization in CESM: generating a ‘good’ preindustrial ice sheet

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Overview

• Ice sheet surface mass balance (SMB) can now be generated by CLM over Greenland Ice Sheet (GIS) (Bill Lipscomb, LANL)

• **Question 1**: what sort of equilibrium preindustrial Greenland Ice Sheet does this CESM-derived SMB produce?

• **Question 2**: how to optimize CISM using ensemble of ‘perturbed physics’ simulations to get reasonable preindustrial Greenland for future simulations, given climate forcing?
Modelling approach

• CAM output from CCSM4 MOAR simulation used to force 300 year CLM simulation to generate SMB fields (Gail Gutowski, Texas)
• CISM initialized with present-day ice geometry, linear surface-to-bed internal temperature profile
• 100 years of post-spinup CLM SMB looped for 9000 years to provide SMB forcing for SIA CISM to evolve to ‘quasi-equilibrium’ under control forcing
Optimization approach
(Stone et al., 2010; Applegate et al., 2011)

• Generate 100 GIS realizations with LHS-determined random combinations of:
  – Ice sheet enhancement factor
  – Basal sliding coefficient
  – Geothermal heat flux

• Compare final states (after 9 kyr simulation) to observed GIS state for relative:
  – Ice volume errors
  – Ice area errors
  – RMSEs of ice surface elevation
  – Maximum ice elevation errors
  – Summit horizontal offset errors

• Rank models by ‘worst diagnostic ranking’ to get best all-around GIS realization
Optimization approach

9000 years

today

future simulations

future

9000 years
Optimization results: volume evolution
Optimization results: example GIS model-observed elevation differences
Optimization results: rankings for all diagnostics
Optimization results: dependence of diagnostics on LHS parameters
Optimization results: top-performing ice sheet model realizations
Ice sheet spinup/optimization issues

• Spinup/optimization issues to work on:
  – Thermal timescale of ice sheet (thus, ice viscosity) is $10^5$ years – analogous to spinning up the deep ocean (but worse!)
  – How to spin up a GIS model, using climate model energy-balance-derived SMB forcing that is continuous between past and future, that captures transient thermal and geometric state of ice sheet?
  – LHS ensemble limited to sampling internal ice sheet parameters
  – Optimization likely compensates for CCSM-derived ice growth bias in it’s choice of ice sheet parameters
  – Optimization limited to existing runs: can we make a statistical emulator to fill in unsampled parameter space?
Conclusions

• LHS sampling provides a fast way to determine optimal initial state for GIS models within CESM framework
• Flow factor parameter exerts major control on ice sheet optimization in CISM
• CESM climate-derived surface mass balance field has large role in determining long-term GIS spin up geometry
  – Spin up GIS geometry is a sensitive indicator of Arctic climate model performance
  – Spin up GIS geometry and future Arctic climate trends will influence CESM sea level rise (SLR) predictions
  ➢ SLR(climate) means CESM SLR predictions will soon become a group-integrating coupled-model task