Lessons learned from coupling ice sheet models to Earth system models

Sophie Nowicki, NASA GSFC
and many conversations with
R. Cullather, B. Zhao, E. Fischer and ISMIP6 participants

The Future of Earth System Modeling: Polar Climates, 11/28/2018
A lot of the action occurs at the margins of the ice sheets...

Csatho et al., 2014
What would a typical CMIP5 model give you...
Surface Mass Balance from CMIP5 AMIP (1980-2008)

Slide courtesy of R. Cullather
Climate models are improving over the polar regions: SMB as simulated by the Community Earth System Model...
As ice sheets are being coupled to climate models, one of the first steps is to improve the SMB models...

GOES5/MERRA → GEOS5/MERRA-2

- No snow hydrology: Solid precipitation becomes runoff
- Fixed albedo (0.775)
- 2m Ice Depth
- Sub-surface fixed temperature (230K)

Fractional snow cover on ice surface permitted

Variable Snow Depth Capped at 15m

- Melt, runoff may occur on bare ice surface
- Snow depth capped at 15m
- 15m Fixed Ice Layers

Zero heat flux condition at lowest level

Cullather et al. 2014
More fancy snowpack models include the Crocus snowpack model...

Vionnet et al. 2012
In GEOS-5 albedo is now a function of snow density (it used to be fixed)...

Other models also consider albedo change due to: snow age, grain size, aerosol deposition, etc.
In GEOS-5, improvements in the SMB model (and albedo) results in a better treatment of the shortwave flux...

Cullather et al. 2014
Elevation classes are being implemented in ESM to allow for more refined SMB at ice sheet margins...

Elevation classes also used in CESM, MPI, ModelE...

In GEOS5, we compute SMB on surface tiles that correspond to the ISSM mesh.

Plot courtesy of R. Smith
Other tricks implemented in CESM that improve the SMB: variable resolution...

van Kampenhout et al., in preparation
Most models simply “dump” surface runoff to the closest ocean cell, but there are development in...

- Routing of surface water (aka river flow)
- Firn models and firn aquifers (following development in RCMs)

Discovery of firn aquifer in region of high melt and high accumulation
An issue is that ESM and ISM see different ice sheets, and that many ocean models cannot do partial grid cells...

Plot courtesy of E. Fischer
Ice sheet-ocean interaction remains super tricky, as most ESM do not allow for ocean to flow within the ice shelf cavities...

... but this is changing with MITgcm, MOM6...

However capturing "moving boundaries" also remains non trivial...
As ice sheets are being coupled to climate models, we see that albedo and ice-elevation feedback matters for SMB...

On the importance of the albedo parameterization for the mass balance of the Greenland ice sheet in EC-Earth

Michiel M. Helsen¹, Roderik S. W. van de Wal¹, Thomas J. Reerink¹, Richard Shuting Yang³, Qiang Li⁴, and Qiong Zhang⁴

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As ice sheets are being coupled to climate models, we see that dynamic ice sheets matter...

“Both UKESM and CESM have seen significant impacts on North Atlantic when interactive ice sheet runoff/calving (changing freshwater balance) and snow/ice building up in the north of Greenland”
ISMIP6 participants, AOGCM-ISM break out group, Sassenheim workshop (September 2018)
Could ice sheets influence climate and Earth energy budget in ways that we have not yet thought of?
Ice sheets and their coupling to Earth system models: a little improvement goes a long way...

- Ice sheet, SMB & ESM models are rapidly becoming more fancy, and feedbacks are important
- However many processes are still poorly known, and being discovered

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<th>Climate model</th>
<th>Ice-sheet model</th>
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Thank you!