Land Ice Working Group Update

• First Science
• Progress/Upcoming Work
• Future Science & Prospects for Collaboration

Jeremy Fyke, Miren Vizcaíno, William Lipscomb, Bill Sacks and the LIWG
First Science

• First model surface mass balance evaluations and sea level rise projections for Greenland Ice Sheet under review for *Journal of Climate* Special Issue:
  – Miren Vizcaino et al. (x2)
  – Bill Lipscomb et al. (x1)

• Contributors and contributions from:
1960-2005 SMB: comparison with RCMs & future SMB trends

### Table

<table>
<thead>
<tr>
<th></th>
<th>CESM</th>
<th>RACMO2</th>
<th>Other RCMs (MAR/PMM5/ERA40-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net SMB</td>
<td>359</td>
<td>376</td>
<td>288/356/287</td>
</tr>
<tr>
<td>PREC</td>
<td>866</td>
<td>723</td>
<td>600/696/610</td>
</tr>
<tr>
<td>Rain/PREC</td>
<td>0.15</td>
<td>0.04/0.03/0.05</td>
<td></td>
</tr>
<tr>
<td>MELT</td>
<td>568</td>
<td>504</td>
<td></td>
</tr>
<tr>
<td>Refreezing</td>
<td>242</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>RUN-OFF</td>
<td>457</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>SU</td>
<td>54</td>
<td>40</td>
<td>5/108/38</td>
</tr>
</tbody>
</table>

Units: Gt yr⁻¹

**RACMO2, 5 km**

**CESM, 5 km**

---

$r = 0.79$
1850-2005 GIS SMB evolution

+0.14 Gt yr\(^{-2}\)
+0.87 Gt yr\(^{-2}\)
-0.75 Gt yr\(^{-2}\)
+0.0086 K yr\(^{-2}\)
GIS projections (RCP8.5)

Change in SMB distribution

1980-99!

2080-99!

Units: kg m\(^{-2}\) yr\(^{-1}\)

SMB\(<0\)

SMB\(>0\)
Preindustrial CISM Greenland steady-state perturbed-physics ensemble
CESM-driven CISM Greenland sea level contribution

- GIS sealevel prediction (RCP8.5)
Non-GIS SMB evaluation

- SMB generated anywhere in CESM where mountain glaciers occur in comprehensive Randolph Glacier Inventory
Ice sheet initialization

- CESM-and-climate-consistent 122,000 year spin up completed through last glacial cycle
- Forced with GRIP $\delta^{18}O$-interpolated SMB, end-members from CCSM4 LGM/mid-Holocene/preindustrial IG simulations
Ice sheet initialization
Progress/upcoming work

• Ongoing/upcoming work broadly falls under:
  – Ice sheet-climate coupling development
  – Climate model surface mass balance validation
  – Ice sheet model development

• Collaborators come from:

Coupling to-dos:

• **Dynamic landunits** (Bill Sacks, Jon Wolfe):
  – Necessary to grow tundra, etc., as Greenland Ice Sheet retreats
  – Complementary to other CESM requirements for dynamic land units
  – Summer 2013 completion?

• **Runoff routing to ocean**:
  – Necessary for linking ice volume changes to ocean freshwater forcing, isolating ocean-sea ice/ice sheet feedbacks
  – Summer 2013 completion?
Coupling to-dos, *continued*:

- **Dynamic atmosphere coupling** (Fyke, Lauritzen):
  - Necessary to allow dynamic atmospheric adjustment to ice sheet geometry changes
  - First coupling to be bash-scripted, based on DART
  - Fall 2013 completion?

- **Conservative downscaling to ice grid, multiple ice sheet instances** (Wolfe, Sacks, Lipscomb):
  - Current downscaling scheme non-conservative
  - Multiple ice instances needed to support simultaneous Antarctic, Laurentide, Fennoscandian (etc.) ice sheets
  - Fall 2013 completion?

- **Ice shelf-ocean coupling**: more to follow
CLM-RASM coupling (Fyke)

- Regional Arctic System Model requires a land ice component
- Development of SMB in VIC land model ongoing
- Alternate approach: couple regional SMB-enabled CLM to RASM
Upcoming CESM-side evaluations

- **CAM5-forced BG simulation** (Fyke, Vizcaino):
  - Can we improve marginal Greenland + SMB bias?

- **SMB evaluation Antarctic Ice Sheet** (CAM4/5) (Vizcaino):
  - What does CESM AIS SMB look like?

- **SMB evaluation in CLM4.5** (Fyke, Vizcaino):
  - How will SMB change with migration to CLM4.5?

- **Diagnosis tools for evaluating land ice performance in CESM** (Kate Evans, Jenn Kay)
Land ice model development: “tactical”

- **CISM1.0:**
  - ‘software coupled’ and tested, current operational, computationally cheap shallow-ice-approximation model

- **CISM2.0:**
  - ‘software coupled’, will undergo testing within CESM with higher-order ice dynamics
  - parallel, expensive, untested in CESM: available for ‘alpha’ CESM use late 2013

- **Bicicles***:
  - block-structured AMR model potentially operational within a year over Antarctic domain, but integration into CESM TBD.

- **Ice-ocean coupling with POP2***:
  - ability to couple dynamic ice shelves to upper boundary of ocean model, at high resolution, critical for Antarctic simulations
  - Integration into CESM TBD
BISICLES: Antarctic ice sheet velocities using L1L1 with block-struct. AMR

Figure courtesy of D. Martin (LBL) & S. Cornford (UOB)
POP2 sub-ice-shelf circulation: regional Southern Ocean model

Water temperature

No Ice Shelves

Idealized Ice Shelves
Land ice model development: “strategic”

• **MPAS-based dycore development:**
  – Variable resolution grids
  – FE-based (more robust, improved treatment of BCs, etc.)
  – Formal optimization capabilities

• **MPAS ocean-ice shelf coupling***:
  – Common high-res mesh in ice shelf cavity/grounding line, but decreased elsewhere
  – MPAS-ocean upper boundary depression can handle evolving ice shelf drafts (100s of meters) stably – very difficult with POP
MPAS ice shelf-ocean coupling
Near-term potential science applications

- Long-term stability of Greenland Ice Sheet
- Quantification of albedo and height feedbacks
- Future changes in radiative forcing for GIS and AIS
- 21st century projections of AIS SMB
- Impact of realistic and coupled glacial runoff on ocean circulation
- SMB variability & trends: connection with atmospheric patterns & sea-ice state
- Attribution of SMB changes to anthropogenic forcing
- Explaining recent observed GIS SMB extremes & trends using CESM
- Ideas from the PCWG welcome! Greenland is in the polar climate!
- PCWG wishes and technical criticisms will be valuable in:
  - guiding remaining coupling
  - figuring out biases
  - informing ice sheet model development priorities