Evaluation of present-day surface energy and mass balances of the Greenland ice sheet with CESM (CAM5)

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Comparison of 3 products

<table>
<thead>
<tr>
<th></th>
<th>CESM (CAM5)</th>
<th>RACMO2.3</th>
<th>2B-FLXHR-LIDAR (R05)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>type</strong></td>
<td>ESM</td>
<td>RCM</td>
<td>satellite data (CloudSat, CALIPSO, MODIS)</td>
</tr>
<tr>
<td><strong>resolution</strong></td>
<td>100km</td>
<td>11km</td>
<td>200 km (resampled)</td>
</tr>
</tbody>
</table>

- RACMO does state-of-the-art modeling of ice sheet climate [Van Angelen 2012, Lenaerts 2012]
- 2B-FLXHR-LIDAR Rev05 has improved detection of supercooled liquid clouds
Large-scale atmospheric circulation is captured well.
General pattern is well resolved.

But CESM has cold bias of ~ 2K.
General pattern is well resolved.

But CESM has cold bias of ~ 2K.
Better match with observations than RACMO

Does NOT explain missing energy
LW deficit
- CESM ~ 15 Wm^-2
- RACMO ~ 5 Wm^-2

→ could explain missing energy!
Underestimation of LWP reduces capacity of clouds to absorb and re-emit LW radiation

→ Explains negative LW bias
Total water path also too low: too few / thin clouds?
Mean surface energy fluxes in period 1960-2005

(absorbed shortwave radiation)

Albedo

(incoming longwave radiation)

Surface sensible heat flux

(surface latent heat flux)

Surface melt heat flux
Effects on the surface mass balance (SMB)
Snowfall is near perfect

Only NW has slight underestimation
Rainfall pattern looks also great

CAM4 rainfall problem at low temperatures has been solved!
Melt is underestimated due to bias in the energy budget.
Runoff is underestimated directly through the melt bias.
RACMO has increased sublimation rates due to drifting snow scheme.
RACMO has increased sublimation rates due to drifting snow scheme.
Ablation areas in CESM are much smaller and fewer in CESM due to negative melt bias.
Mean surface mass fluxes in period 1960-2005

(a) Melt
(b) Precipitation
(c) Refreezing
(d) Sublimation
(e) Runoff
(f) SMB
Conclusions

the **Good:**

✓ Many improvements over CAM4 (shortwave, albedo)
✓ Rainfall problem in the interior is resolved
✓ Spatial patterns are all good

the **Bad:**

✗ Cold bias due to insufficient downwelling LW
   ✓ Unrealistically low melt and
     √ subsequently high SMB
✗ Clouds are too thin?
Outlook

• We are very interested in evaluating new cloud schemes as they are continually improved

• How we can help?
  – IMAU has been operating automatic weather stations (AWS’s) at Greenland for over 20 years;
  – Long history in regional climate modeling, ice core data
  – Remote sensing data made suitable for ice sheets (Kristof van Tricht, paper in preparation)
Thanks

- Brice Noël for providing his RACMO2 data
- Kristof van Tricht for providing the 2B-FLXHR-LIDAR data
- Michiel van den Broeke
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  Jan Lenaerts for their advice