Green light for Greenland?

Progress and challenges in improving CESM’s ice sheet climate

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Why care about ice sheets?

• Paleo-thermometers (*Paleo working group*)
• Impact on ocean circulation (*Ocean working group*)
• Impact on large-scale atmosphere circulation (*Atmosphere working groups*)
• Firn and snow, meltwater runoff (*Land working group*)
• It’s my daily job (*Land ice working group*)
• Sea ice – ice sheet interactions (*Polar climate Working group*)
• Polar amplified climate change (*all*)
• Sea level rise (*all*)

...
Why care about ice sheets in CESM2?

1. Two-way coupled CESM2-CISM2 in place: we can study ice sheet – climate interactions... providing realistic ice sheet climate forcing

2. All CESM2 simulations will have ice sheet surface mass balance downscaling active by default.
   
   SMB = precipitation – sublimation – meltwater runoff

   Forcing for ice sheet dynamics (CISM2)

   Dependent on ice sheet climate (atmosphere + snow)
Greenland SMB in CESM1
Greenland SMB in CESM1

*CAM5 too cold!*
Clouds over Greenland


Cloud LWP
Incoming longwave radiation
Surface energy balance

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Clouds over Greenland

Clouds over Greenland

Cloud LWP

Incoming longwave radiation

Surface energy balance


Incoming LW [W m\(^{-2}\)]
Clouds over Greenland


20 - 30 W m^{-2} more downward longwave
Better shortwave cloud forcing
In line with findings over sea ice

Incoming LW [W m^{-2}]
Cloud ice gone...

Auto-conversion will help
Antarctic SMB in CESM1

SMB [kg m$^{-2}$ yr$^{-1}$]
Antarctic SMB in CESM1

1. low snow density
   - heat conduction exaggerated
2. limited firn depth (1 m w.e.)

RACMO2

CESM

SMB [kg m\(^{-2}\) yr\(^{-1}\)]
Antarctic SMB in CESM1

1. Low snow density
   - Heat conduction exaggerated
2. Limited firn depth (1 m w.e.)

Resolved 1. and 2. in CLM

But...
Surface winds

Winds

Snow compaction
Surface winds

- Winds
- Snow compaction
- Turbulent fluxes
- Surface energy balance

10 m wind speed [m s$^{-1}$]

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New wave drag scheme
Julio Bacmeister (NCAR)

10m wind speed

2 m temperature

RACMO2
(evaluated with observations)
CAM 5.4 (AMIP)
Averages for Antarctica
New wave drag scheme
Julio Bacmeister (NCAR)

10m wind speed

RACMO2
(evaluated with observations)

CAM 5.4

Averages for Antarctica

2 m temperature
New bias: precipitation

1. Generally overestimated total precipitation (~30%) (general Arctic problem – ref. Dave L.)

2. High-elevation liquid precipitation is back!
Hot Antarctic summers

2 meter air temperature [K]

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Where does the ‘heat’ come from?

Surface energy balance does not look too bad.

Summer temperature too high below 800 hPa and bias increasing to the surface.

Promotes snow grain growth, lowering albedo, further increasing bias.

Reason? Solution? Tuning possible (clouds)?

**Note**: Albedo&melt look OK in forced CLM5 simulations – which means that with colder atmosphere things will probably get much better.
Antarctic melt

Obs: ~100 Gt per year

CESM1.5: ~700 Gt per year

Note: this does not directly impact Antarctic SMB because all meltwater refreezes in the firn.

Surface melt [mm w.e.]
Greenland SMB

![Map showing Greenland SMB comparison between RACMO2 and CESM models. The color bar indicates SMB in kg m$^{-2}$ yr$^{-1}$. RACMO2 model shows higher SMB in the north, while CESM model shows a different pattern.]
Greenland SMB

CESM1.5 (‘simulation 28’) 1980-2005

RACMO2

CESM

CESM(2)

SMB [kg m$^{-2}$ yr$^{-1}$]
Antarctic SMB

SMB [kg m$^{-2}$ yr$^{-1}$]
Antarctic SMB

CESM1.5 (‘simulation 28’) 1980-2005

RACMO2

CESM

CESM(2)

SMB [kg m\(^{-2}\) yr\(^{-1}\)]
Green light for ice sheets in CESM2?

- Firn processes
- Snow density
- Clouds
- Surface winds
- (Liquid) precip
- Antarctic melt