Improving Seasonality of Glacier Runoff in CESM

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How to Stop Glaciers from Sucking Water Out of the Ocean

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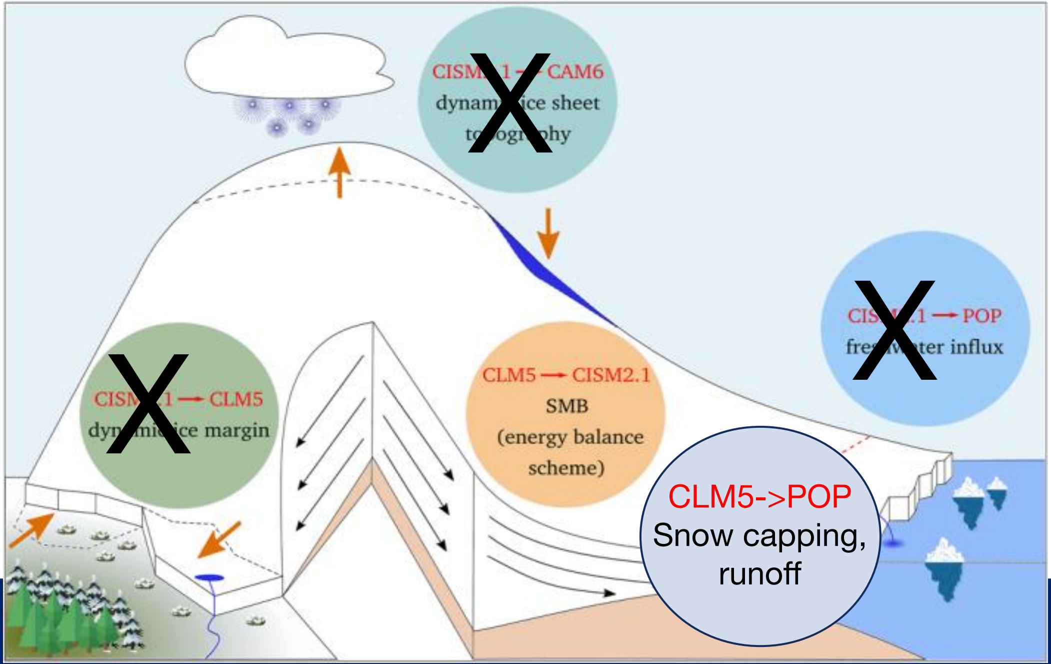
Overview

- ➔ Why does the Greenland Ice Sheet (GrIS) suck water out fo the ocean in CESM2?
- ➔ What is the plan to stop this?
- ➔ Where are we at in the implementation of the plan?

Why does the Greenland Ice Sheet (GrIS) suck water out of the ocean in CESM2?

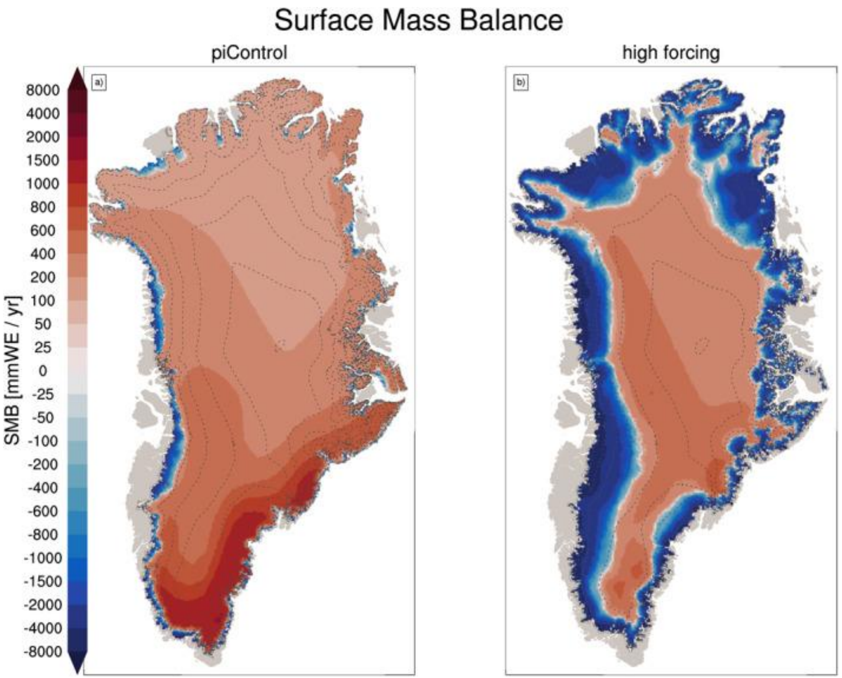
- ➔ In CESM2 currently, the default fully coupled configuration runs with CISM in a one-way coupled (No-Evolve) configuration in Greenland and Antarctica.



(1) *Muntjewerf et al. 2021*

Why does the Greenland Ice Sheet (GrIS) suck water out of the ocean in CESM2?

- ➔ Because the ice sheet is not evolving, its mass cannot change over the course of the simulation.
- ➔ But the land model still calculates and downscales surface mass balance for CISM, including melt fluxes in the summer and snow fluxes in the winter.



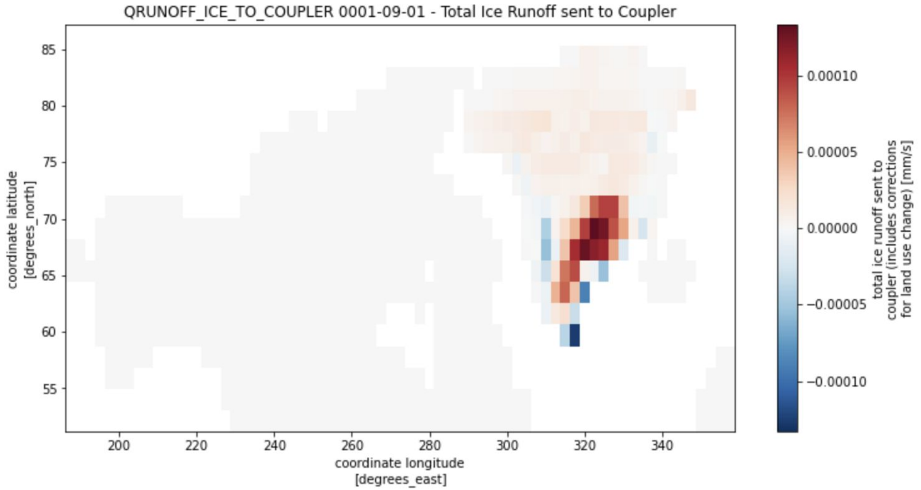
(1) *Muntjewerf et al. 2021*

Why does the Greenland Ice Sheet (GrIS) suck water out of the ocean in CESM2?

- Snow Capping:
  - If CISM is Evolving, then once the snow depth over the ice sheet exceeds 10m (water equivalent), it is converted to ice as a positive SMB for CISM, and mass is added.
  - If CISM is Not Evolving, then it cannot increase or decrease mass, and excess snow is “capped” and sent to the ocean from CLM as runoff.

Why does the Greenland Ice Sheet (GrIS) suck water out of the ocean in CESM2?

- Melt:
  - If CISM is Evolving, then once gridcells with positive smb melt all of their snow then ice is melted and sent to the ocean as a freshwater flux.
  - If CISM is Not Evolving, then it cannot increase or decrease mass, and after ice is melted, CLM pulls water from the ocean to maintain the ice sheet mass balance (a negative freshwater flux).



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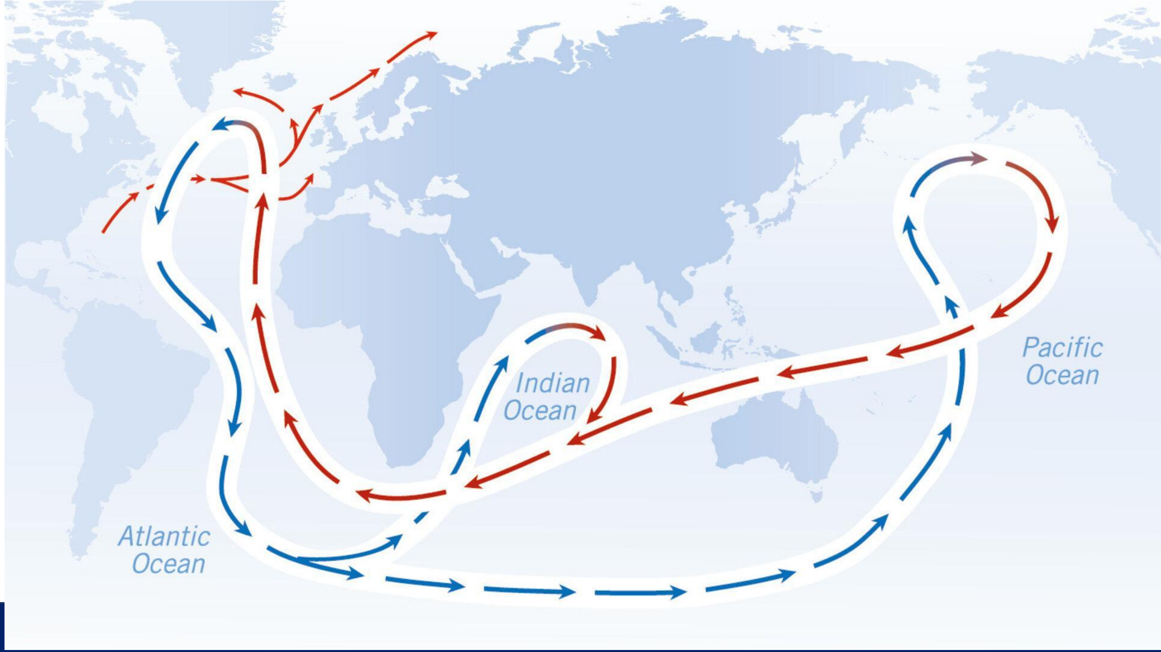
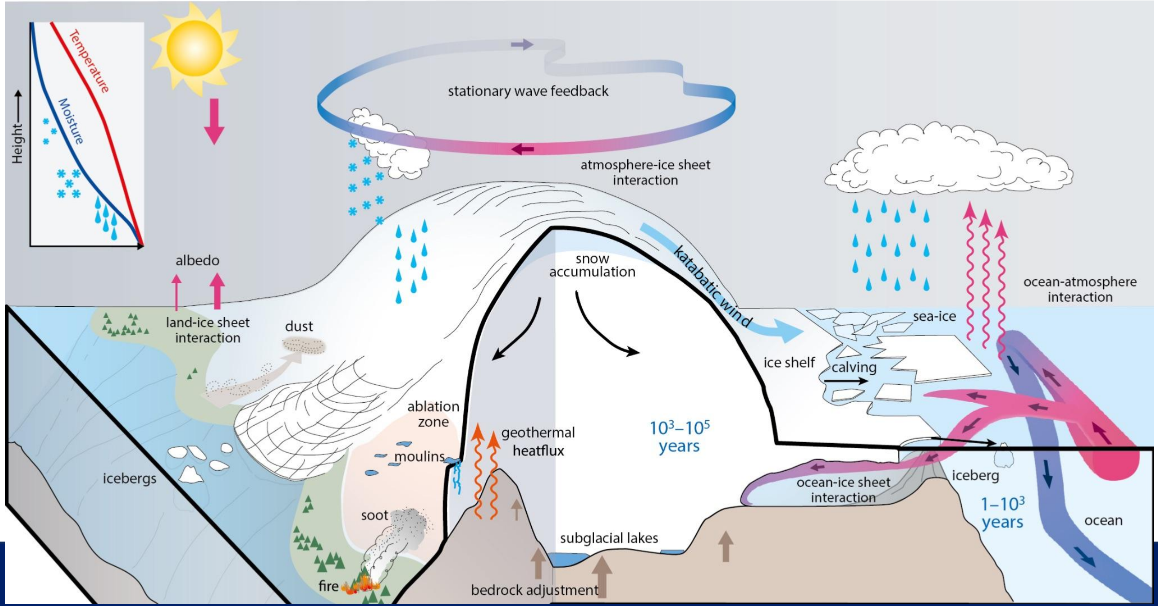
Problems with this method…

➔ Treating the ocean as a giant glacial water reservoir works great from a land perspective, but causes some problems with sea ice and salinity budgets



What is the plan to stop this?

➔ In real life, excess snow on top of the ice sheet pushes more ice slowly towards the melt zones, so there is more ice available to melt each spring, and the ice sheet can exist in (somewhat) balance.



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What is the plan to stop this?

- ➔ Basically, we need to move the snow capping reservoir from the ocean into the land model.
- ➔ We can implement a storage reservoir for excess snow mass in CLM that replenishes the melted grid cells each summer.
- ➔ Since snow capping is spread out somewhat evenly during the year, but melt is concentrated in the summer months, we need to build up snow in the reservoir that contains enough ice to balance summer melt.

What is the plan to stop this?

- ➔ For Each timestep, until 1 year plus accumulates
  - ◆ For Each land gridcell
    - Accumulate all Melt = ΣM
    - Accumulate SnowC = ΣSc
    - Add SnowC to Reservoir $Res += Accum\, Sc$

➔ Total Melt = $\int_{GrIS} AccumM$

➔ Total SnowC = $\int_{GrIS} AccumSc$

What is the plan to stop this?

- Frac Melt = Total Melt / Total SnowC
  - Percent of total reservoir required to cover total melt
- Local replenish = Res * Frac Melt to each gridcell
  - Each local reservoir replenishes with the same fractional amount of water
- Replenish timescale = 1 / (Days Accumulation * Ts per Day)
- Ocean runoff = Res * (1 - Frac Melt) * Replenish Scale
  - Send a proportional amount of melt reservoir to the ocean as before

What is the plan to stop this?

- ➔ So, say the total melt at the coupling timestep is 5 Gt. And the total reservoir or capped snow is 500 Gt.
- ➔ Frac Melt = 5 / 500 = 0.01 = 1%
- ➔ Each local reservoir gives 1% of its ice as a “melt tax” (1% is removed from every local reservoir, as long as some amount of water is in the reservoir)
- ➔ To add an appropriate amount of water back to the ocean, for a reservoir with 1 year of stored melt and a half hour time step…
  - ◆ Ocean runoff = 500 Gt * (1 - 0.01) * (1/(365*48)) = 0.0183 Gt

Where are we at in implementation?

- ➔ My first CTSM project! Bill Sacks helping.
- ➔ For Each timestep, until 1 year plus accumulates
  - ◆ For Each land gridcell
    - Accumulate all Melt = ΣM ✓
    - Accumulate SnowC = ΣSc ✓
    - Add SnowC to Reservoir $Res += Accum\ Sc$ ✓
- ➔ Next up, global sums over the ice sheet. More difficult as CLM does not currently support this.

Where are we at in implementation?

- ➔ Took about 2 time steps for CLM balance checker to stop the run.
- ➔ Issues with the column to grid average.
- ➔ Turned off the Balance checker and it ran for about 5 months, diverting ice from snow capping to the reservoir!

Where are we at in implementation?

- Possible (Probable?) future issues…
  - Questions about including this in the water conservation equations of CLM.
  - Implementing the time delay (how long to accumulate) will need some custom time functionality.
  - Need more inter-process communication than CTSM currently has.
  - After all of this work, it's possible that there will still be negative ice fluxes occasionally (hopefully less often).

Thanks!

- ➔ Thoughts, comments, issues ….?
- ➔ References…

1. Muntjewerf L, et al. Description and Demonstration of the Coupled Community Earth System Model v2 - Community Ice Sheet Model v2 (CESM2-CISM2). J Adv Model Earth Syst. 2021 Jun;13(6):e2020MS002356. doi: 10.1029/2020MS002356.