Land Ice Working Group Summary

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25th Annual CESM Workshop

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Outline

- LIWG research highlights
  - Improved ice-sheet climate in CESM2
  - Contributions to the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)
- Current and future work
Van Kampenhout et al. (JGR-Earth Surface, 2019)

Right: Greenland Ice Sheet surface mass balance (SMB) in historical period from CESM2 and the RACMO2 regional model.

Below right: GrIS-integrated surface fluxes, 1850–2014.

- Simulation of Greenland Ice Sheet climate and SMB in CESM2 compares well to reanalyses and RACMO2.
- GrIS-integrated melt, runoff and refreezing in CESM2 are bracketed by RACMO2 values at 11 and 1 km.
- There is a break point in SMB at 1993 ± 8, driven by increased melt and runoff.
Lenaerts et al. (JGR-Atmospheres, 2020)

- The transition from CAM5 to CAM6 has a substantial impact on Greenland surface climate. CAM6 performs better compared to observations.

*Right:* Liquid cloud frequency at 72.5°N in observations, CAM5 and CAM6

*Below:* Summer 2m temperature in CAM5, CAM6
Noël et al. (The Cryosphere, 2020)

- The RACMO2 regional climate model, with boundary forcing from CESM2, provides a realistic mean state of the Greenland Ice Sheet climate and captures the recent increase in meltwater runoff.
- First use of climate forcing from a global ESM, without corrections, to reconstruct historical Greenland surface mass balance.

*Left:* Greenland SMB, 1950–2014, from RACMO2 (11-km) with lateral forcing from CESM2 (1°).
The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) is the first CMIP component focused on ice sheets.

- **Estimate past and future sea level contributions** from the Greenland and Antarctic ice sheets, with associated uncertainty.
  - Standalone ice sheet experiments with forcing from CMIP global models

- **Investigate feedbacks due to dynamic coupling** between ice sheet and climate models, and impacts of ice sheets on the Earth system.
  - Coupled ESMs with evolving ice sheets

**Community Ice Sheet Model (CISM):**
- 57 Greenland Ice Sheet simulations and 75 Antarctic simulations for many CMIP5/CMIP6 forcing scenarios

**CESM–CISM with an interactive Greenland Ice Sheet:**
- **Spin-up**, 9000 ice sheet years (Lofverstrom et al., JAMES, in review)
- **Pre-industrial**
- **Transient CO2**, 1%/yr to quadrupling (Muntjewerf et al., JAMES, in review)
- **ssp5-85**, 2015–2100 (Muntjewerf et al., GRL, 2020)
Greenland (Goelzer et al., TC, 2020)

- Submissions from 13 modeling groups
- RCP8.5: Sea level rise of $89 \pm 51$ mm by 2100 from Greenland mass loss, mainly from increased melting and runoff

Antarctica (Seroussi et al., TC, 2020)

- Submissions from 15 modeling groups
- Mass gain in E. Antarctica from increased snowfall
- Mass loss in W. Antarctica from retreat of marine-based ice; large differences among models
Lipscomb et al. (TC, in review):
CISM Antarctic experiments to test sensitivity to ocean forcing and melt schemes

- Ocean warming by 2100 is sufficient to drive long-term retreat in the Ross, Filchner-Ronne and Amundsen Sea basins of the West Antarctic Ice Sheet.
- The Antarctic sea level contribution over 500 years varies from ~10 cm to 2 m depending on the sub-ice-shelf melt scheme and the ESM ocean forcing.

**Left:** Surface ice speed from a 20,000-yr CISM Antarctic spin-up with climatological ocean forcing.

**Right:** Ice thickness difference at the end of a 500-year projection with 21st century NorESM ocean forcing and a high-sensitivity sub-ice-shelf melt scheme.
Muntjewerf et al. (GRL, 2020):

- 5.4 K global mean temperature increase and strong NAMOC weakening (similar to CESM-only simulations) by 2100 in SSP5-8.5 w.r.t. preindustrial.

- Mass loss from the Greenland Ice Sheet accelerates after mid-century. The total sea level rise contribution is 23 mm by 2050, **109 mm by 2100**.

- The relative sea-level contribution of northern basins increases after mid-century.
Ongoing and future work

Model development

- Support an interactive Antarctic ice sheet in coupled CESM-CISM simulations
  - For now, POP geometry is fixed
  - Later, MOM6 geometry would evolve
- CISM physics improvements
  - Transient subglacial hydrology (SHAKTI, Sommers et al. 2018)
  - Reduced-order ocean model to represent sub-ice-shelf circulation and melting
  - Improved calving model

Coupled simulations

- Additional ISMIP6 runs (ssp5-85 extension, ssp2-45)
- Work with the Paleoclimate WG on new simulations of the Last Interglacial (including Antarctica), glacial inception, Last Glacier Maximum, and last deglaciation.
- Run the first CESM-CISM simulations with a dynamic Antarctic ice sheet.
- Explore variable-resolution grids to reduce precip and melting biases.
**Lofverstrom et al. (in prep):**

Simulations of Northern Hemisphere glacial inception in CESM-CISM

- Orbital and greenhouse-gas forcing for 116 ka (low NH summer insolation)
- After 650 model years, there is glacial ice in the regions where inception actually occurred.
- Total ice volume = 12 m sea level equivalent (consistent with proxy data)
- Inception in Scandinavia only after Canadian gateways closed
- Probably too much ice in E. Siberia (common ESM bias)

Surface topography on the 4-km extended CISM grid, CESM-CISM simulation with 116 ka forcing.

*Gray* = initial Greenland Ice Sheet
*Red* = areas covered by glacial ice after 650 years
Goal: Conduct a fully coupled CESM-CISM simulation of Northern Hemisphere climate and ice sheets at 21 ka BP

1) Generate paleo-vegetation data set and spun-up snowpack.
2) First results from CESM: climatology.
3) Response of N. Hemisphere ice sheets to the LGM SMB

Climatological mean surface temperature, 21 ka BP

Northern Hemisphere ice sheets at the Last Glacial Maximum on the 4-km extended CISM grid

Courtesy of Sarah Bradley and Michele Petrini
Variable-resolution grids

Historical runs completed with new Arctic grids in CESM2.2 (CAM-SE)

Testing the ability of VR-CESM to simulate cryospheric-hydrological variables in High Mountain Asia

1/8° grid (**ARCTICGRIS**) captures narrow ablation zones AND orographic precipitation associated with steep ice sheet margins.

**Collaborators:** Herrington & Gettelman (AMWG), Lipscomb & Leguy (LIWG), Lofverstrom (U. Arizona), Noël (Utrecht)


**Collaborators:** Wijngaard (Yonsei), Herrington (AMWG), Lipscomb & Leguy (LIWG)

Contact aherring@ucar.edu for data availability
Thank you!

For more information:

**Web page:** [http://www.cesm.ucar.edu/working_groups/Land+Ice/](http://www.cesm.ucar.edu/working_groups/Land+Ice/)

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