Land Ice Working Group Summary

William Lipscomb, Jan Lenaerts and LIWG members

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Outline

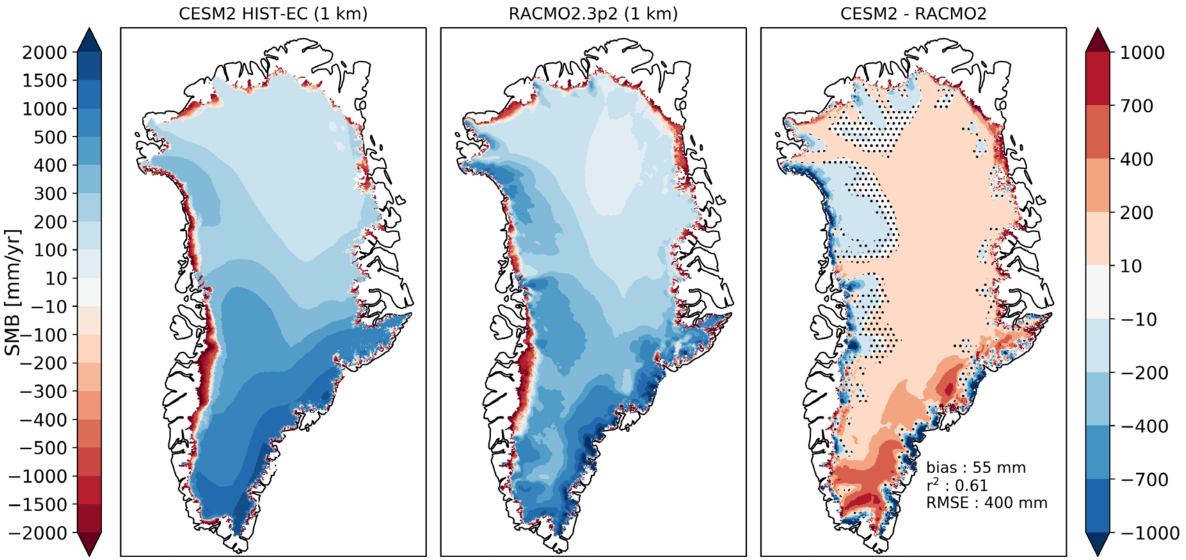
- LIWG research highlights
  - Improved ice-sheet climate in CESM2
  - Contributions to the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)
- Current and future work

Present-day Greenland surface mass balance in CESM2

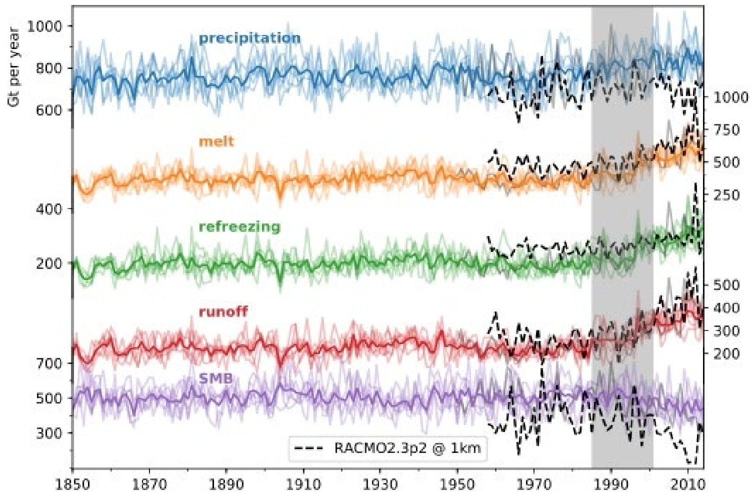
Van Kampenhout et al. (JGR-Earth Surface, 2019)

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.



Impact of cloud properties on Greenland Ice Sheet climate

Lenaerts et al. (JGR-Atmospheres, 2020)

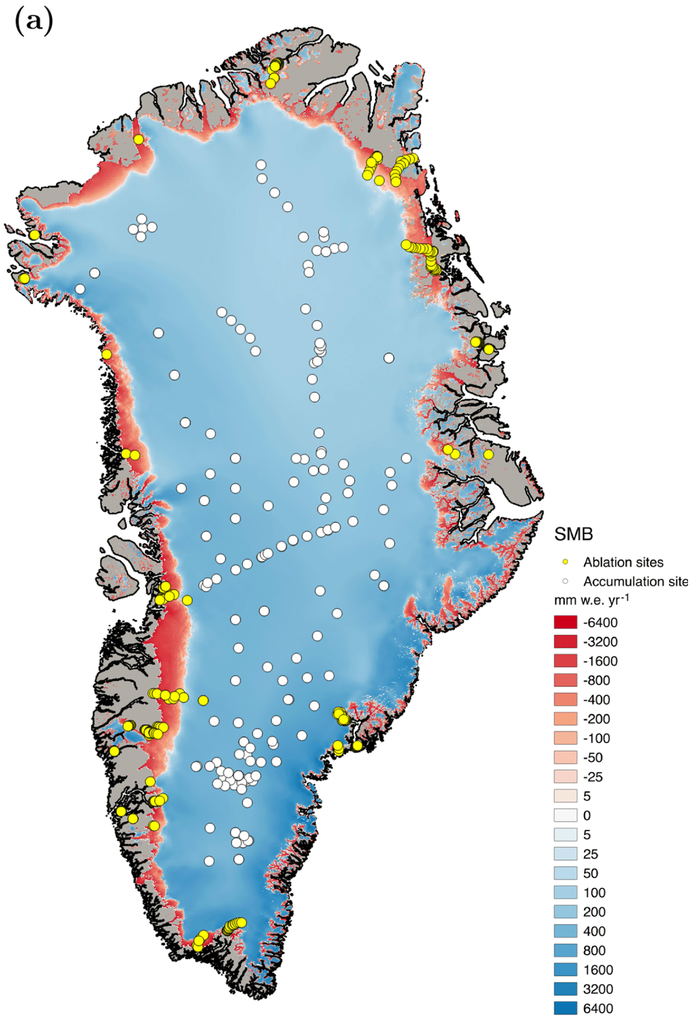
- The transition from CAM5 to CAM6 has a substantial impact on Greenland surface climate. CAM6 performs better compared to observations.

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

Below: Summer 2m temperature in CAM5, CAM6

CAM5 **CAM6**

CESM2 for dynamical downscaling on Greenland



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°).

LIWG contributions to ISMIP6

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)

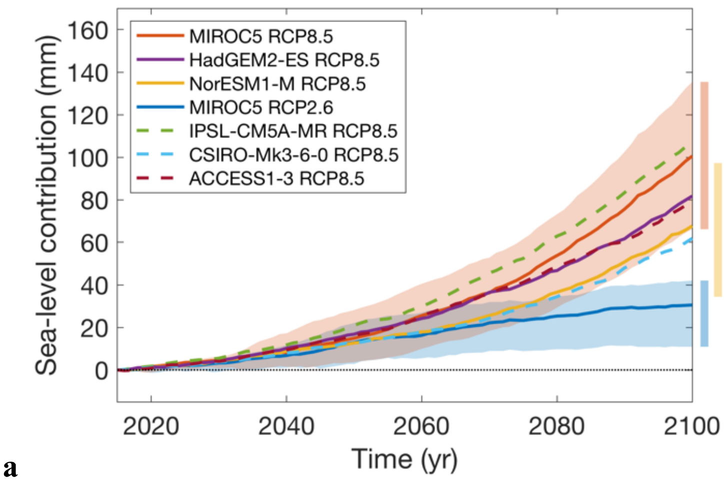
ISMIP6 Greenland and Antarctic projections, 2015–2100

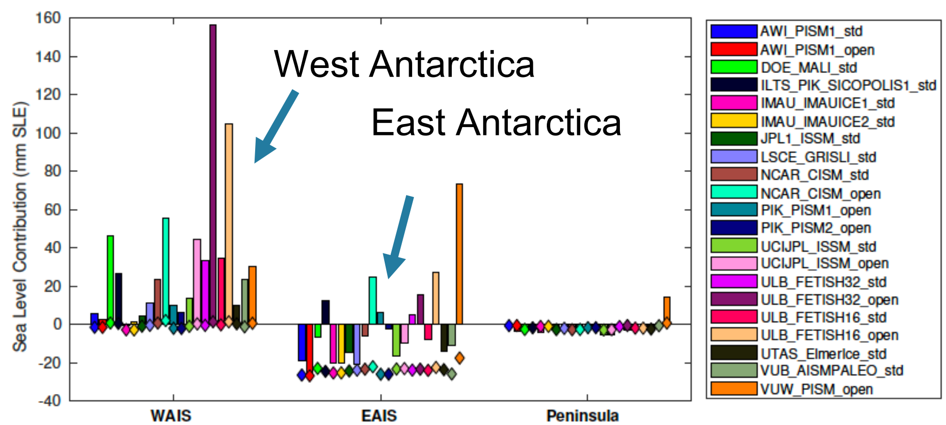
Greenland (Goelzer et al., TC, 2020)

- Submissions from 13 modeling groups
- RCP8.5: Sea level rise of 89 ± 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



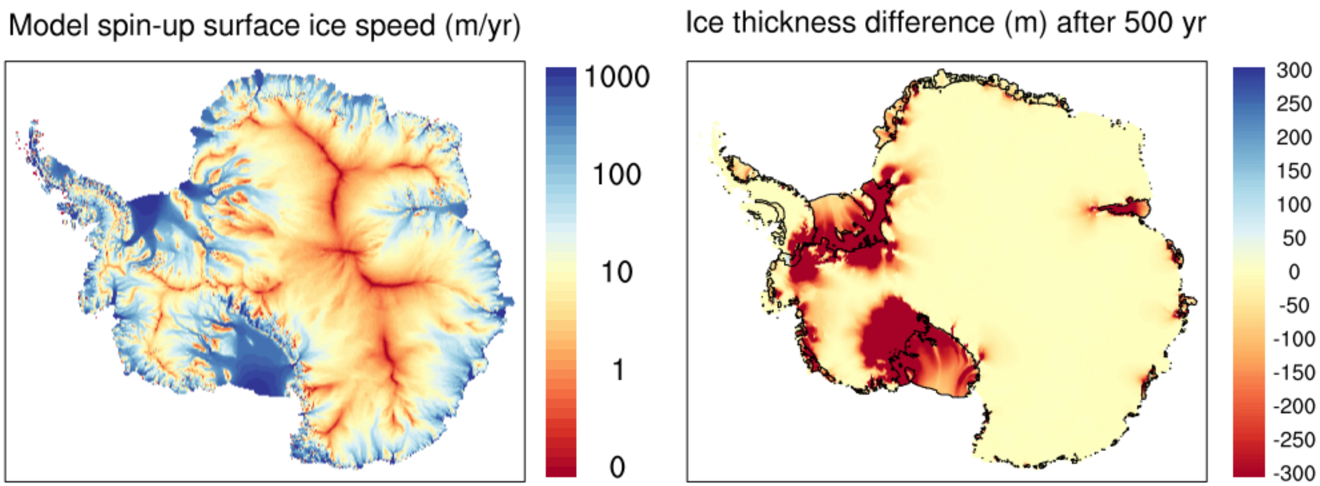


CISM Antarctic simulations with ISMIP6 ocean forcing

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.



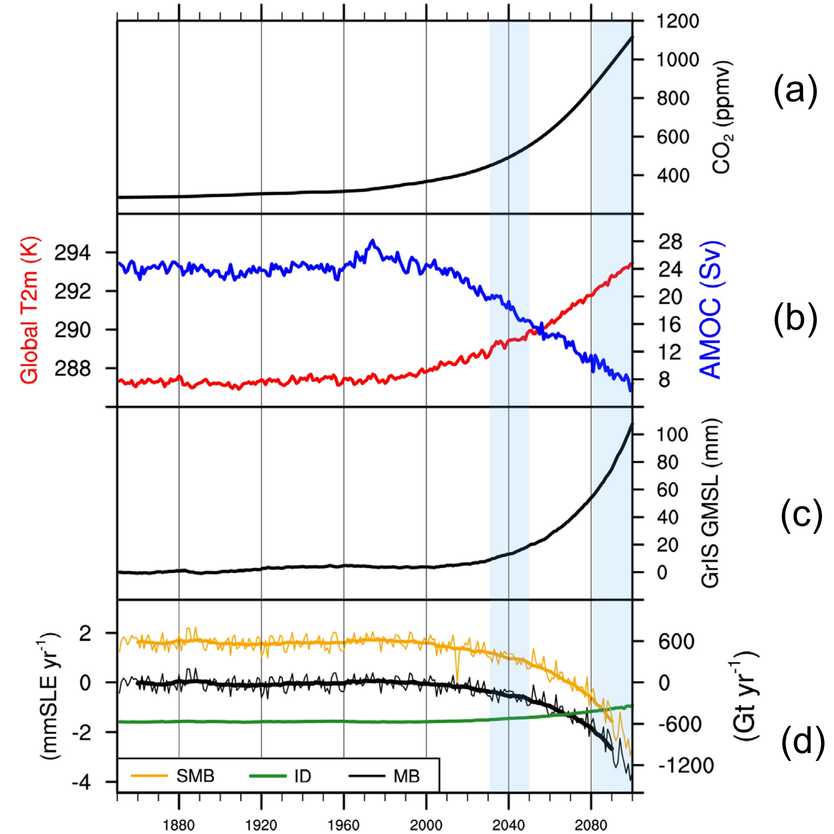
Left: Surface ice speed from a 20,000-yr CISM Antarctic spin-up with climatological ocean forcing.

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.

Greenland Ice Sheet contribution to sea level rise, CESM-CISM

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.



Climate and ice sheet trends, 1850–2100.
(a) Atmospheric CO_2, (b) Global 2m temperature and Atlantic meridional overturning, (c) GrIS-sourced global mean sea-level rise, (d) GrIS SMB and mass balance.

Ongoing and future work

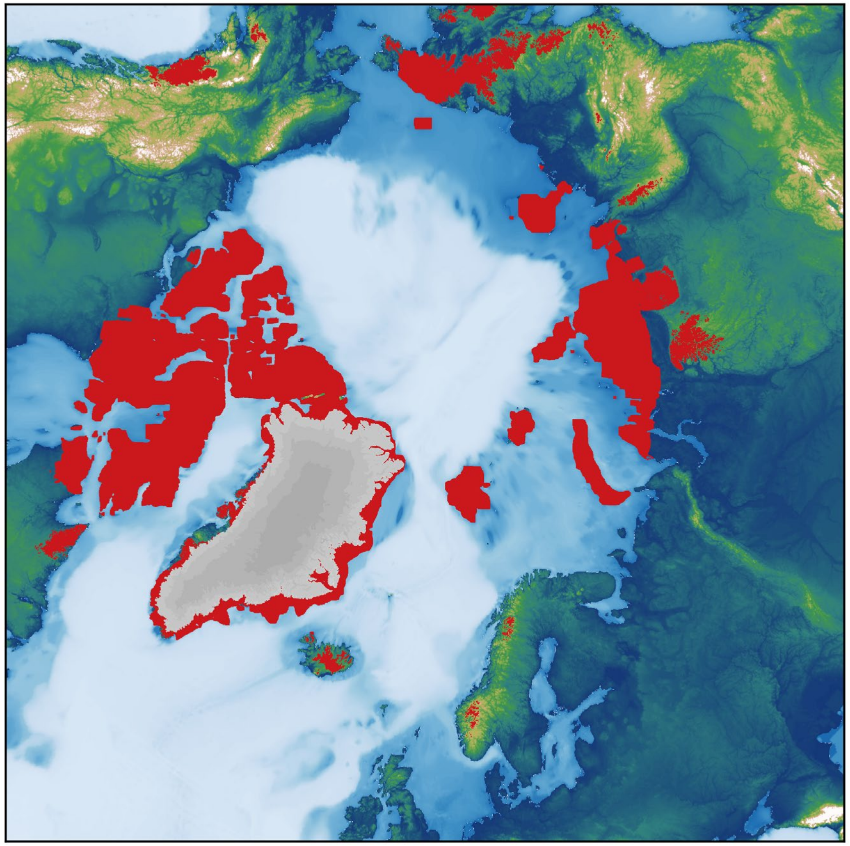
Model development

- 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.

Glacial inception



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

Lofverstrom et al. (in prep):

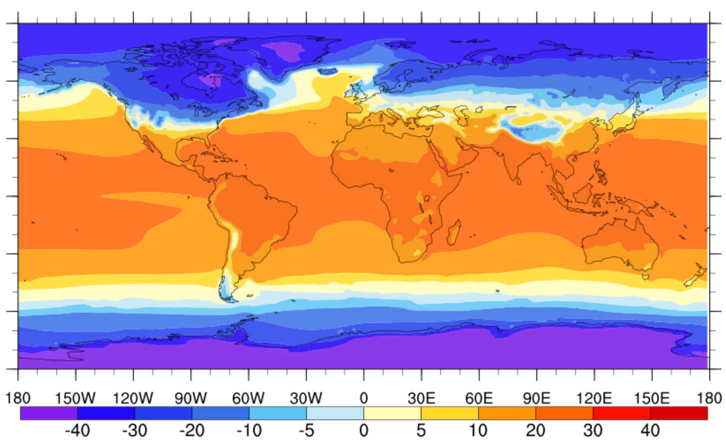
Simulations of Northern Hemisphere glacial inception in CESM-CISM

- 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)

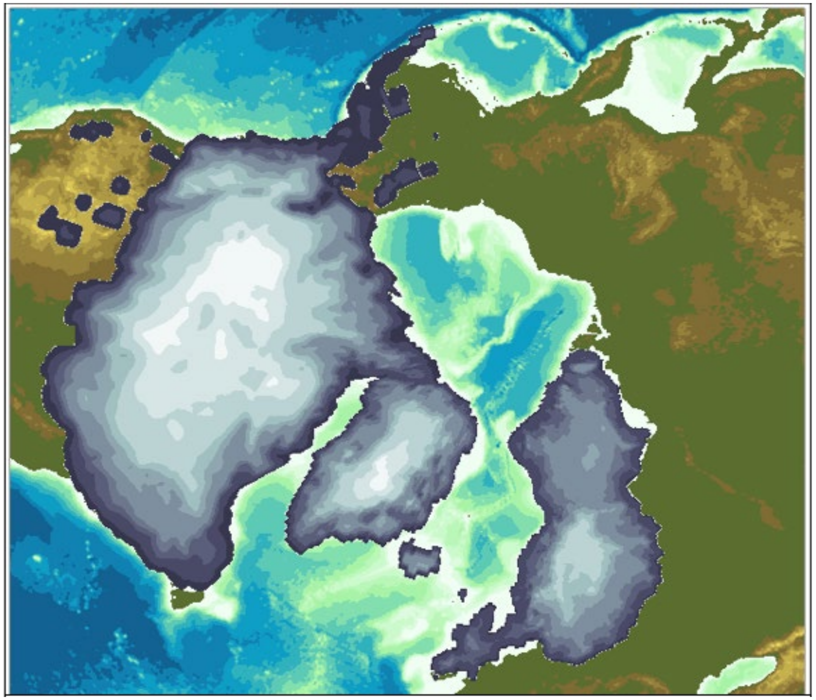
Last Glacial Maximum simulation of N. Hemisphere ice sheets

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

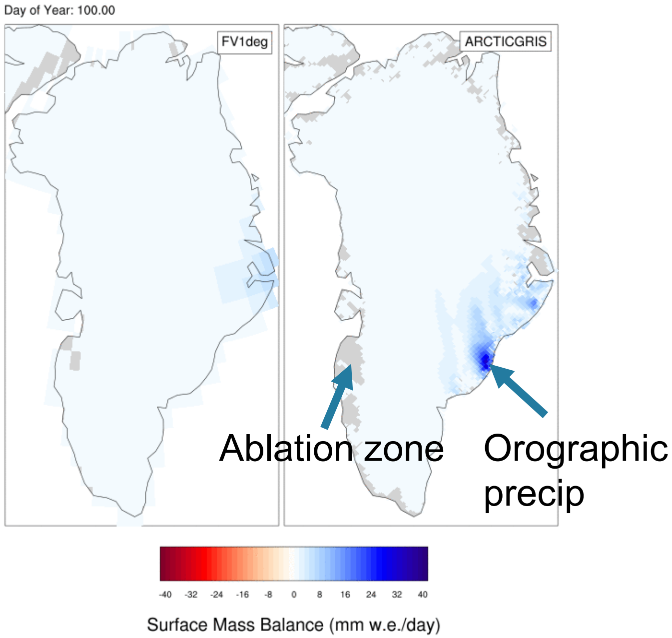


Northern Hemisphere ice sheets at the Last Glacial Maximum on the 4-km extended CISM grid

Courtesy of Sarah Bradley and Michele Petrini

Variable -resolution grids

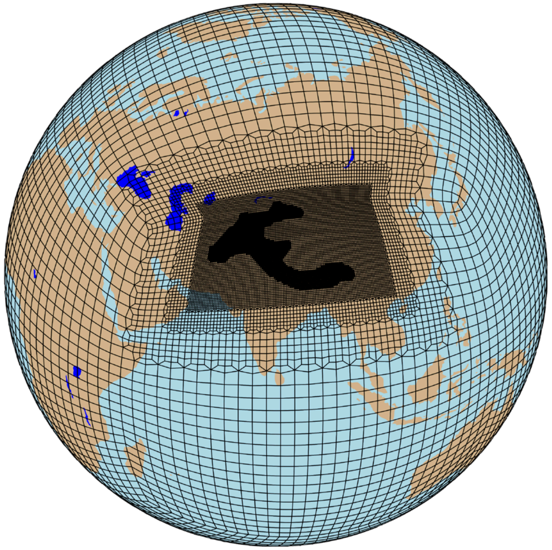
Historical runs completed with new Arctic grids in CESM2.2 (CAM-SE)



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)

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



Can 1/16° refinement simulate the surface mass balance of HMA glaciers? Testing 4 grids for stability and performance.

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/

Co-chairs:

Jan Lenaerts, CU Boulder, jan.lenaerts@colorado.edu

William Lipscomb, NCAR CGD, lipscomb@ucar.edu

Liaisons:

Gunter Leguy, NCAR CGD, gunterl@ucar.edu

Kate Thayer-Calder, NCAR CGD, katec@ucar.edu