Impact of horizontal resolution on the meteorology and climate of Greenland

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Historical simulations with CESM2.2

- FV2deg (f19), FV1deg (f09), SE_pg3_1deg (ne30pg3) SE_pg2_1deg (ne30pg2)
- VR-CESM grids: ARCTIC & ARCTICGRIS
- 1979-1998 SSTs / GHGs / Aerosols (FHIST compset)
- CISM in NO_EVOLVE mode  
  (elevation classes used for downscaling SMB to CISM grid)
- CLM set to Satellite Phenology Mode  
  (no biogeochem cycling)
  
  - Spin-up snow-depths in ARCTIC grid from scratch  
    (zero out snow, run for 20 yrs, force CLM offline for 500 years)
  
  - CESM2.2 uses high resolution (ne120pg3) initial conditions  
    (interpolates to target grid at initialization)

Right: snow-depths averaged over first month of a hi-res simulation using low-res initial conditions leads to ugly aliasing
Topography & Ice-mask

- Consistent Variable-Resolution topography ([https://github.com/NCAR/Topo/tree/TopoCESM2](https://github.com/NCAR/Topo/tree/TopoCESM2))

- CLM ice-mask
Drainage Winds

- ARCTICGRIS resolves downslope katabatic winds at ice sheet margins
- Are winds & environ. consistent with obs? (KABEG’97 aircraft field campaign)
- Working with Tim Scheitlen & Matt Rehme (CISL) to develop VAPOR visualization

Figure from Dave Bromwich, Polar WRF

Streamlines at the lowest model level in a single winter
Resolution sensitivity in 3 plots*: aqua-planets

*not incl. additional mechanisms in deep tropics

1.) Resolved vertical velocities increase with increasing resolution

2.) Grid-scale condensation scales with vertical velocity at cloud base (e.g., Rauscher et al. 2016)

3.) Greater condensational heating warms / stabilizes free troposphere

Herrington and Reed, in review
**Changes to environment in low-res runs**

**f09 – f19:** greater condensational heating, and free troposphere warming

**ne30pg3 – f10:** modest increase in condensational heating and modest warming

**ne30pg3-ne30pg2:** tiny increase in clubb tendencies and high latitude / high altitude warming
**Changes to environment in var-res runs: JJA**

**ARCTIC-ne30pg3**: greater condensational heating and tropospheric warming in refined region.

Both the **4X smaller physics time-step** and the **4X increase in resolution** will increase resolved vertical velocities (Herrington and Reed 2018)

**ne30pg3** = ne30pg3 with 4X smaller physics timestep
Changes to environment in var-res runs: DJF

ARCTICGRIS-ARCTIC: warming west of Greenland throughout troposphere

*300 hPa eddy streamfunction with wave-activity flux overlain (eq. 5.7 in Plumb 1985). Courtesy of M. Lofverstrom

Weaker stationary low in lee of Rockies / west of Greenland creates anomalous northerly flow in eastern Canada & anomalous southerly flow east of Greenland.

*streamfunction and fluxes with 5X and 3X exaggeration, respectively
Changes to environment in var-res runs: DJF

**ARCTICGRIS-ARCTIC**: warming west of Greenland throughout troposphere

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*DJF meridional wind anomaly, from +3 m/s (red) to -3 m/s (blue)*
• Z500 anomaly blocking detection algorithm of Dole and Gordon (1983), with modifications described in Pinheiro et al. 2019, implemented in the TempestExtremes package (Ullrich and Zarzycki 2017)

• Blocking criterion: +5 day persistence of +100 m Z500 anomaly

• **ARCTICGRIS differences with respect to all grids** are shown to highlight that the increased blocking in west Greenland is not a feature of the other simulations

• Increase in DJF blocking west of Greenland is consistent with weakening of stationary low in this region
Greenland Surface Mass Balance

*a sneak peak*

- Plot after van Kampenhout et al. (2019)
- Split up into radar (IceBridge), in-situ (pits, cores and stakes) accumulation zone & ablation zone (LIVVkit 2.1; Evans et al. 2018)
- Find CLM grid cell nearest to observation, if on ice mask compute the difference
- "raw" violin plots: draw a polygon around the pdf of the point-wise differences, close the polygon through a mirror image (-1*probability), then rotate it so it's vertical.
Conclusions

• 20 year historical runs using new grids, incl. var-res grids in CESM2.2 completed
• Solutions in refined region consistent with mechanisms of resolution sensitivity
• The use of a constant physics time-step in both the coarse and refined regions is a nuisance
• Refining the Greenland Ice Sheet facilitates upstream blocking, and DJF warming
• Refining the Greenland Ice Sheet captures narrow ablation zones and orographic precipitation, reducing model bias