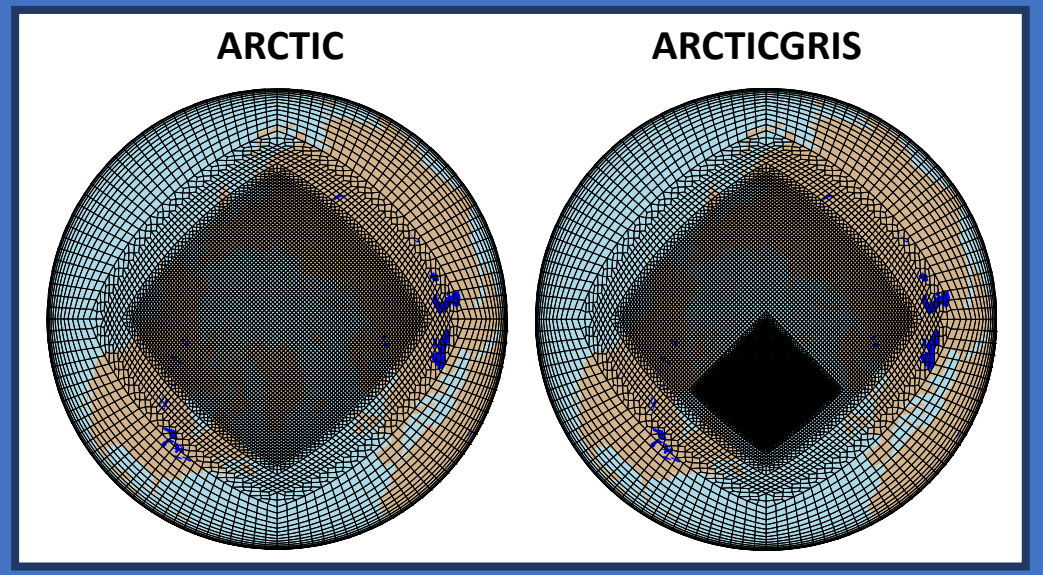
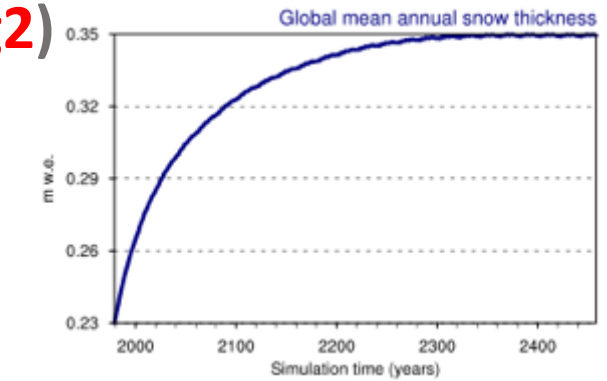
Impact of **horizontal resolution** on the meteorology and climate of Greenland

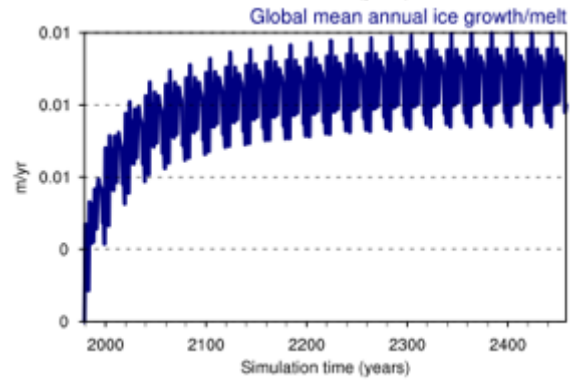


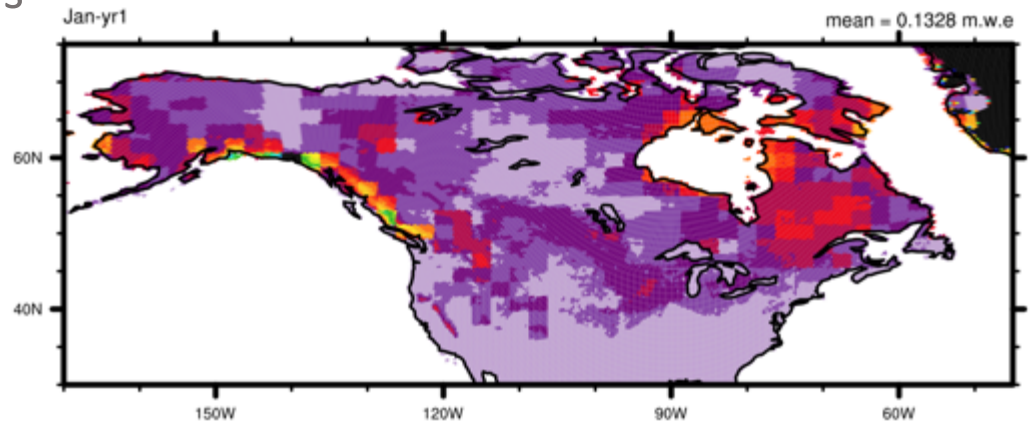
Adam R. Herrington, Peter H. Lauritzen, Marcus Lofverstrom (Univ. of AZ),
Andrew Gettelman, Bill Lipscomb, Chery Craig, Brian Eaton, Chris Fischer, Erik Kluzek

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)



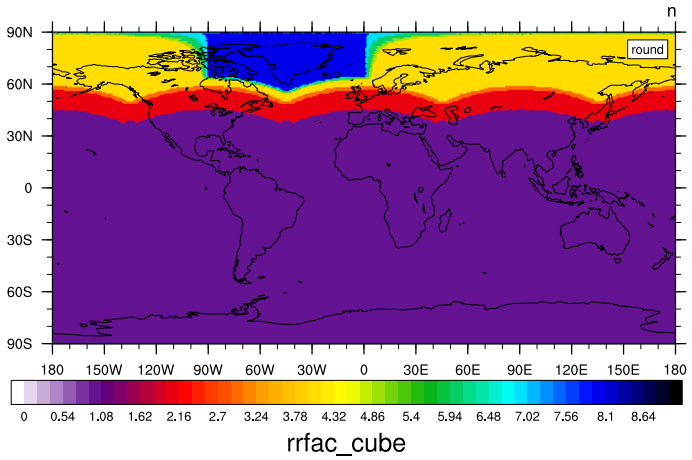


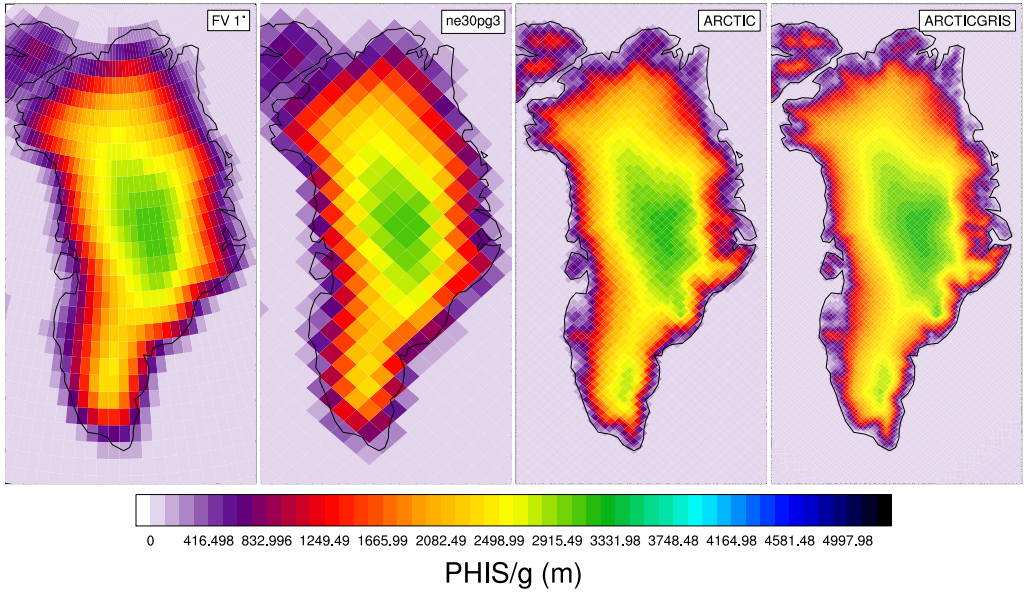


Right: snow-depths averaged over first month of a hi-res simulation using low-res initial conditions leads to ugly aliasing

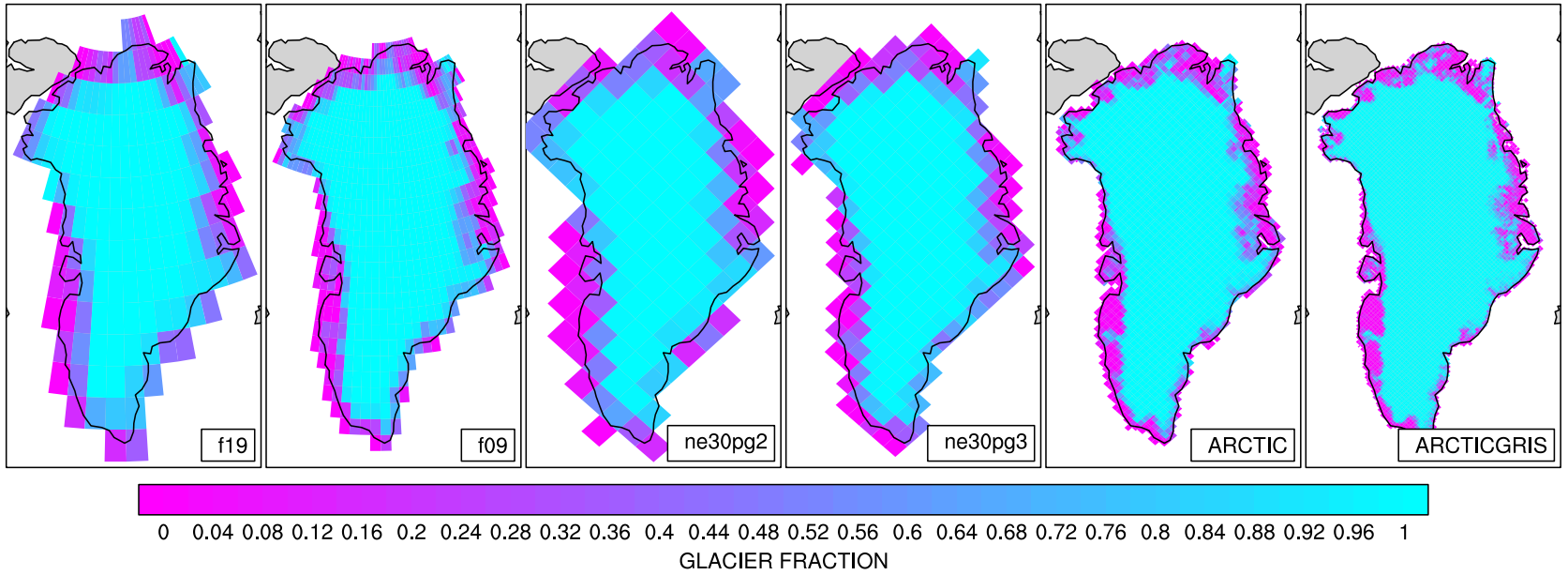
Topography & Ice-mask

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





- 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

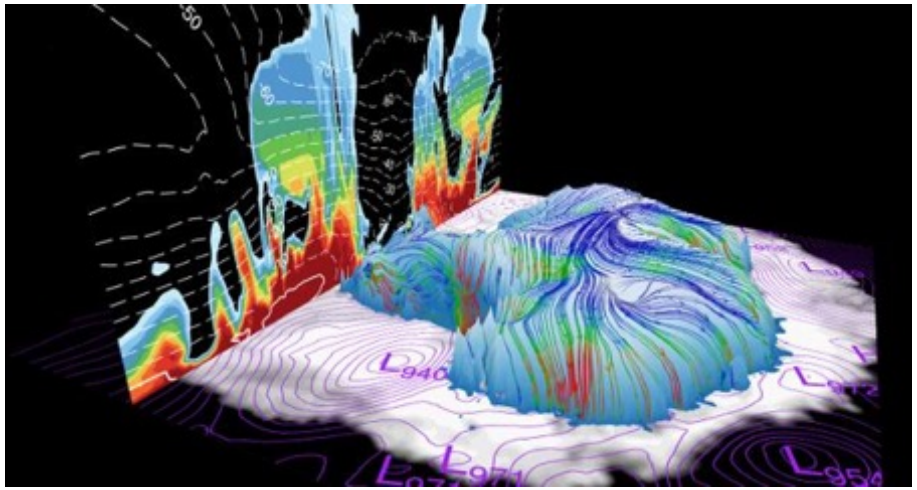
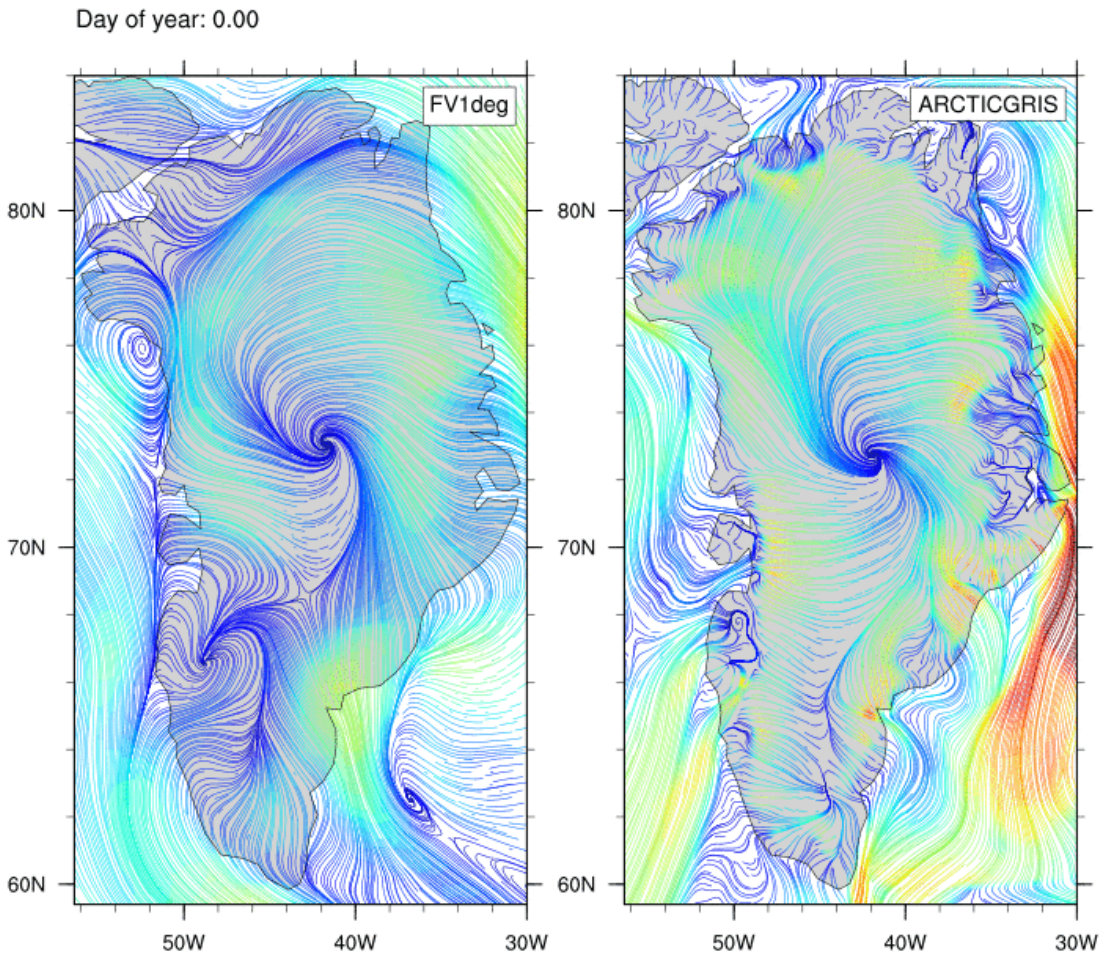


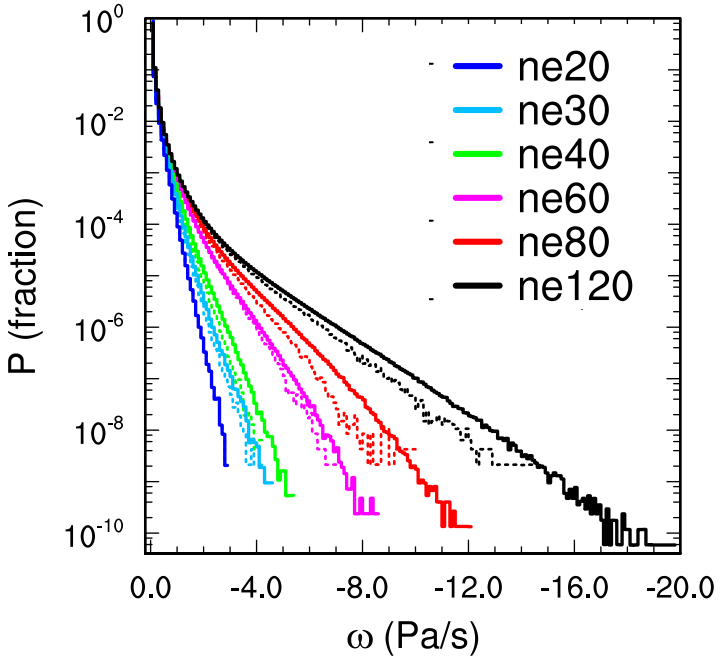
Figure from Dave Bromwich, Polar WRF



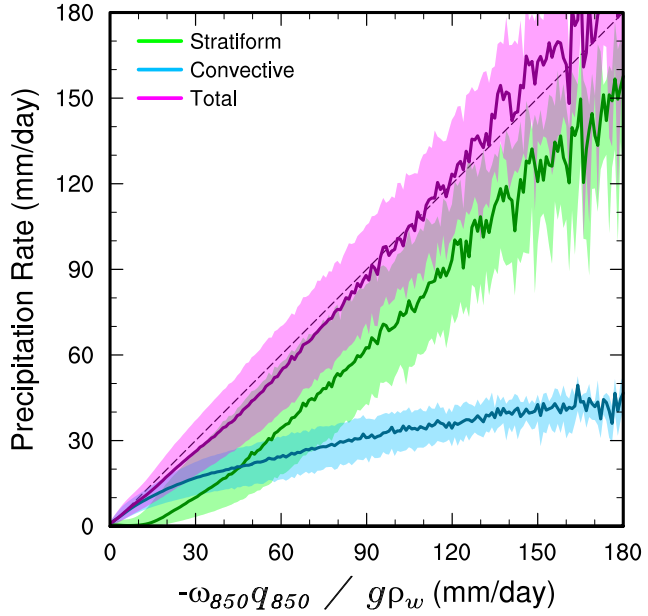
Streamlines at the lowest model level in a single winter

Resolution sensitivity in 3 plots*: aqua-planets

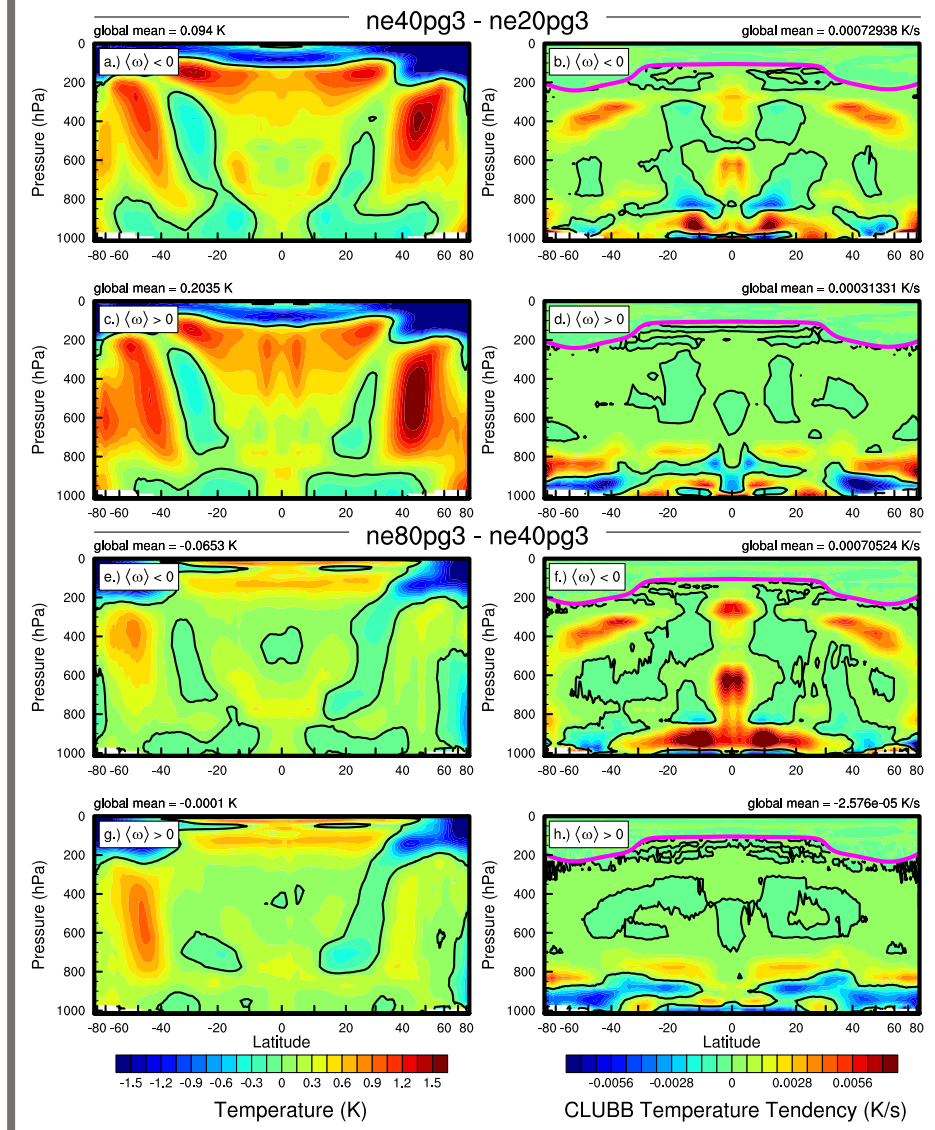
*not incl. additional mechanisms in deep tropics



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

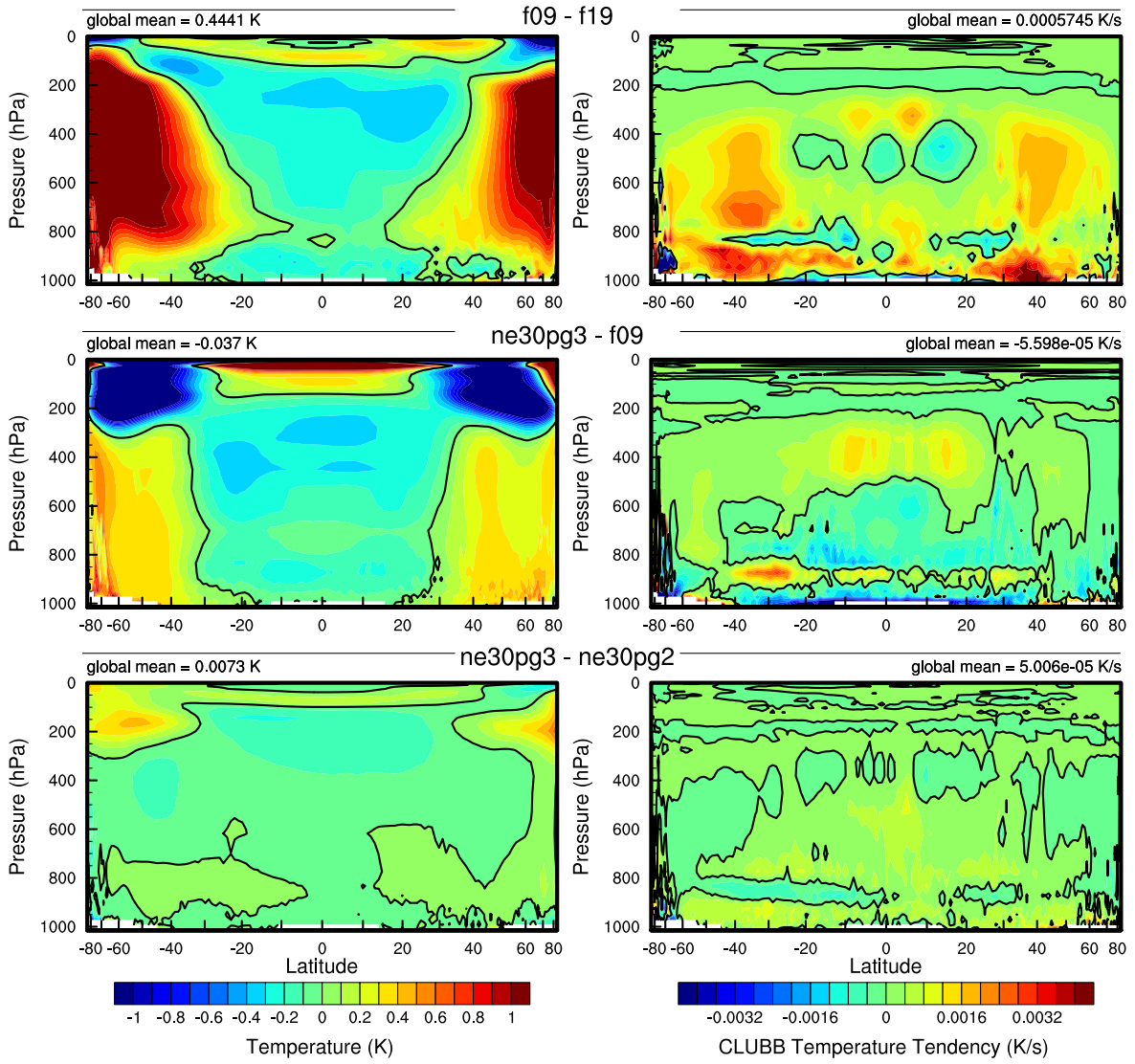
Herrington and Reed, in review

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

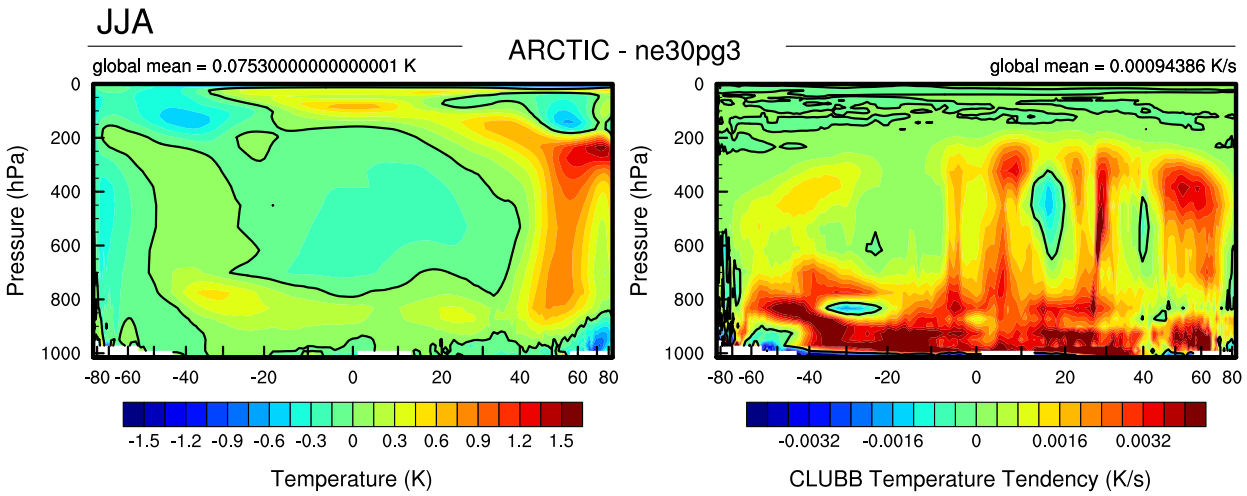
ne30pg3-ne30pg2: tiny increase in clubb tendencies and high latitude / high altitude warming

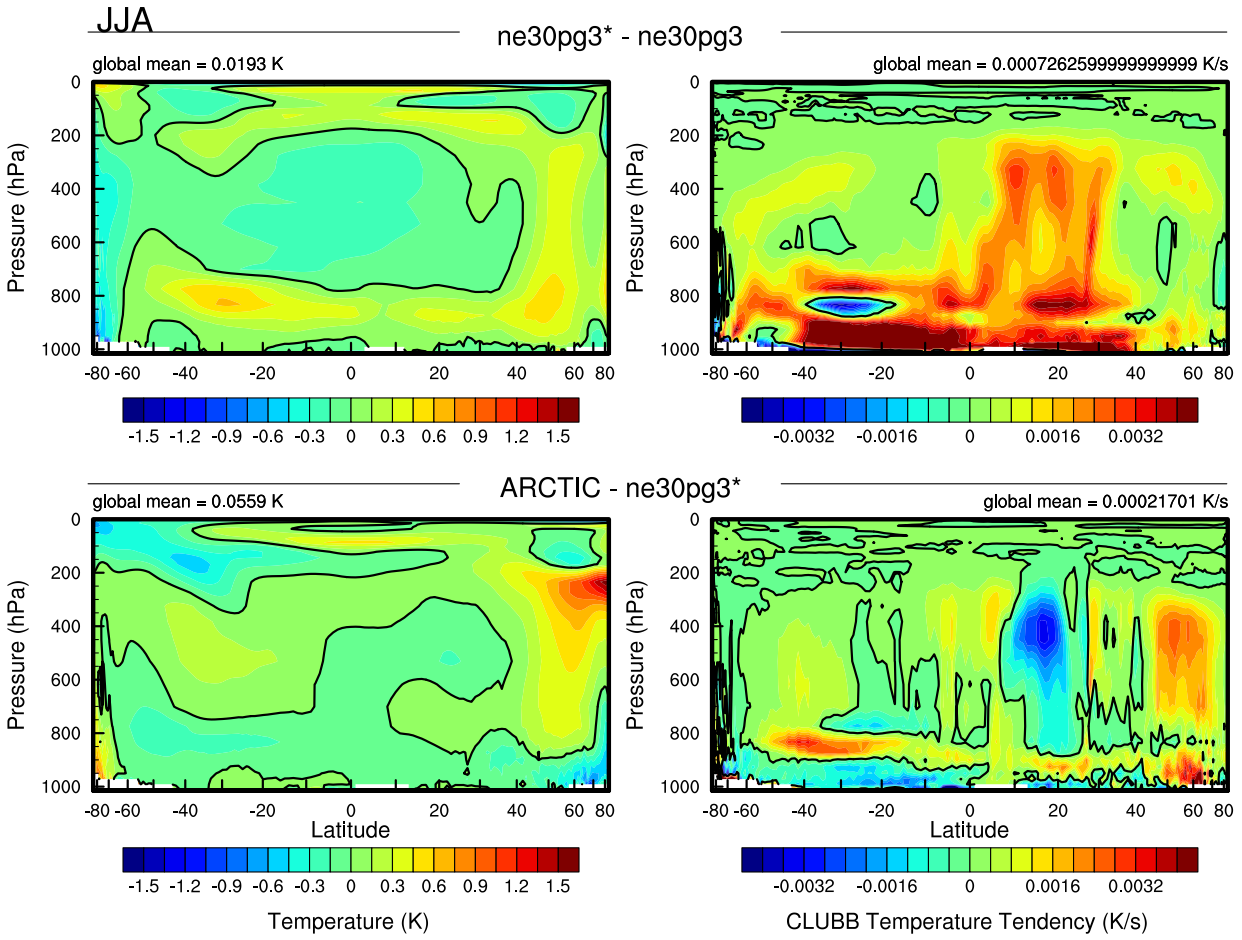


Changes to environment in var-res runs: JJA

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)

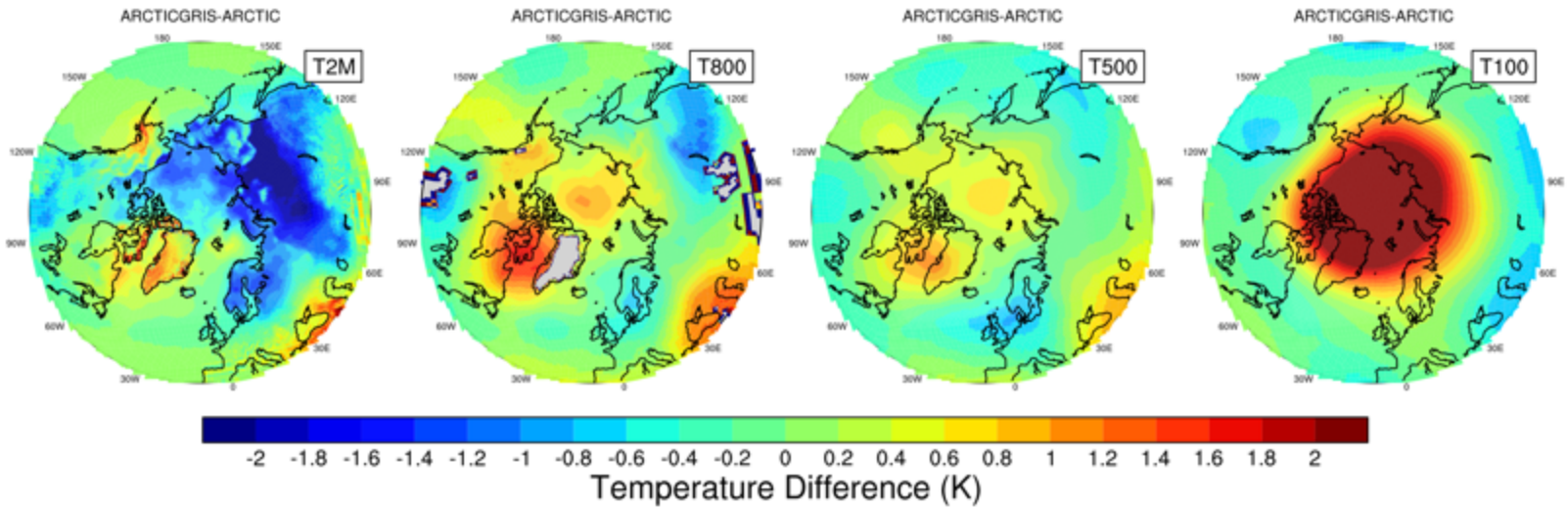




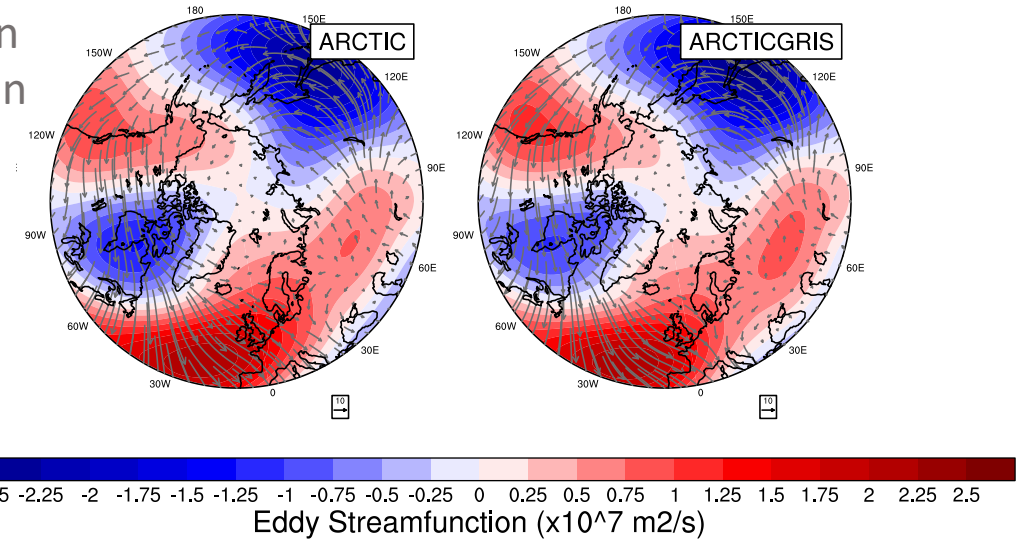
ne30pg3* = ne30pg3 with 4X smaller physics timestep

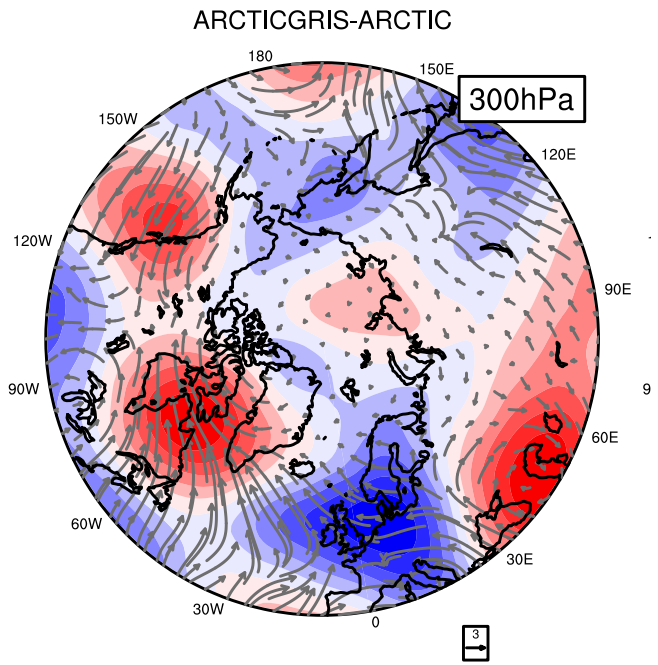
Changes to environment in var-res runs: DJF

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



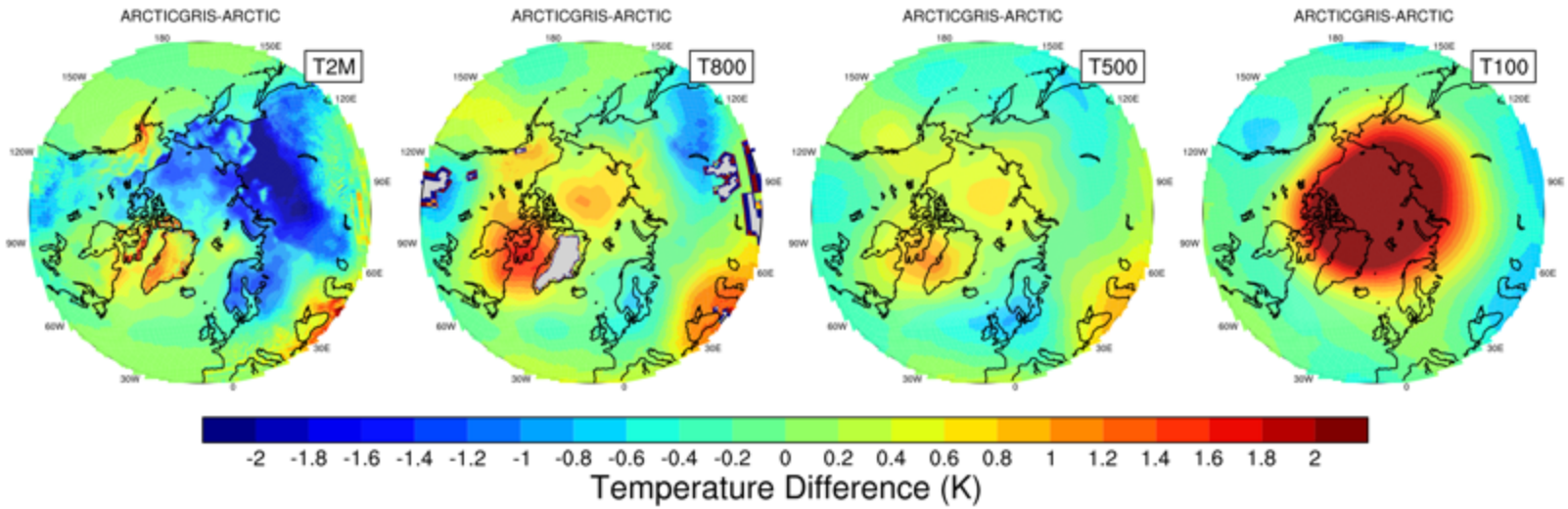


Weaker stationary low in lee of Rockies / west of Greenland creates anomalous northerly flow in eastern Canada & anomalous southerly flow east of Greenland.

*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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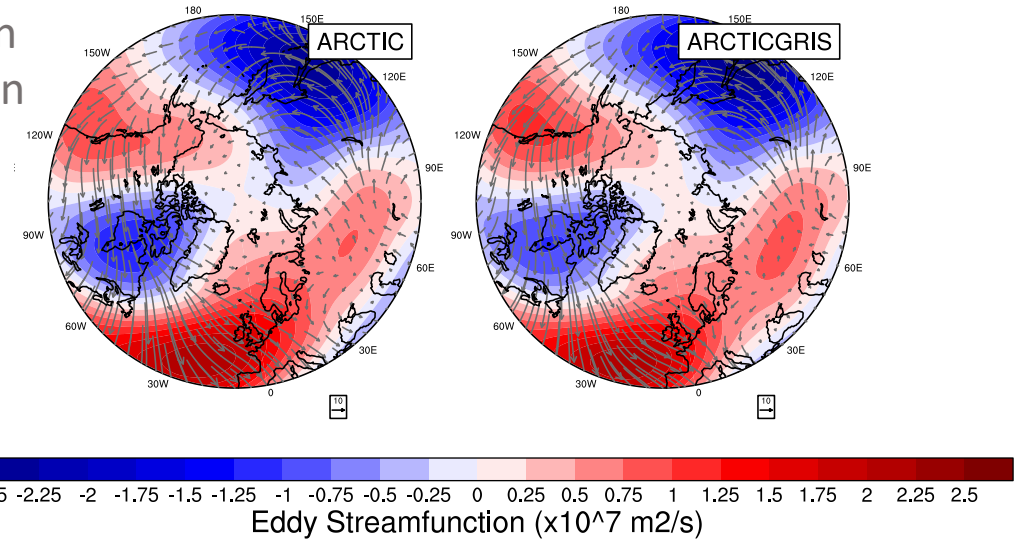
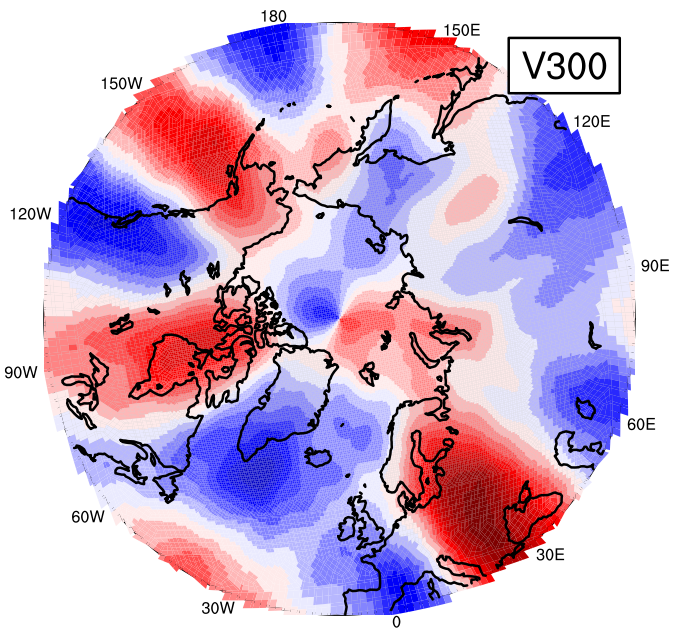
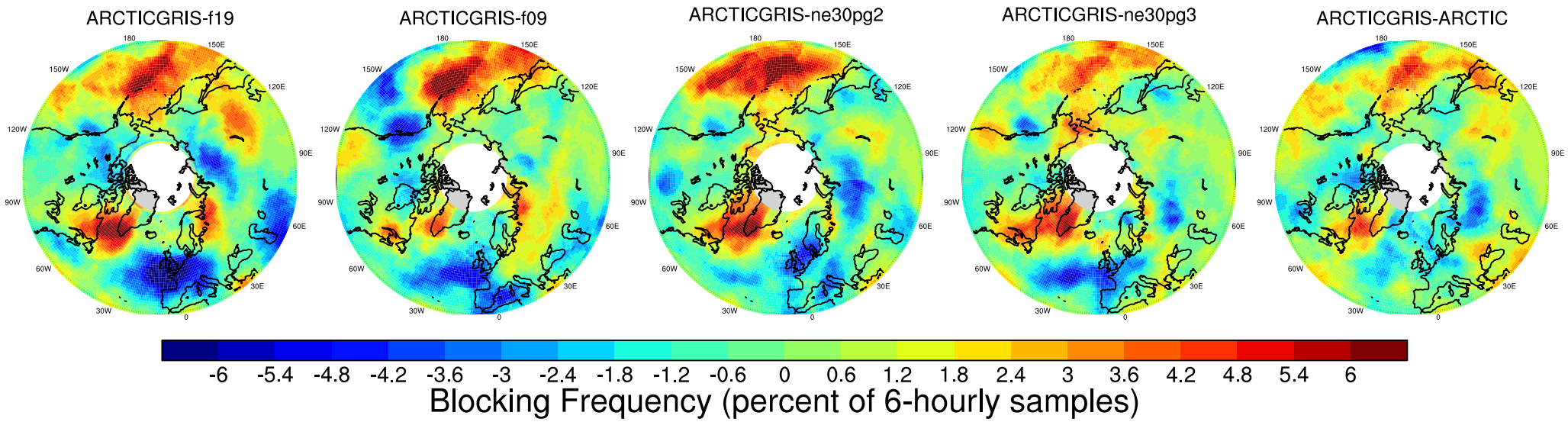




Weaker stationary low in lee of Rockies / west of Greenland creates anomalous southerly flow in eastern Canada & anomalous northerly flow east of Greenland.

*DJF meridional wind anomaly, from +3 m/s (red) to -3 m/s(blue)

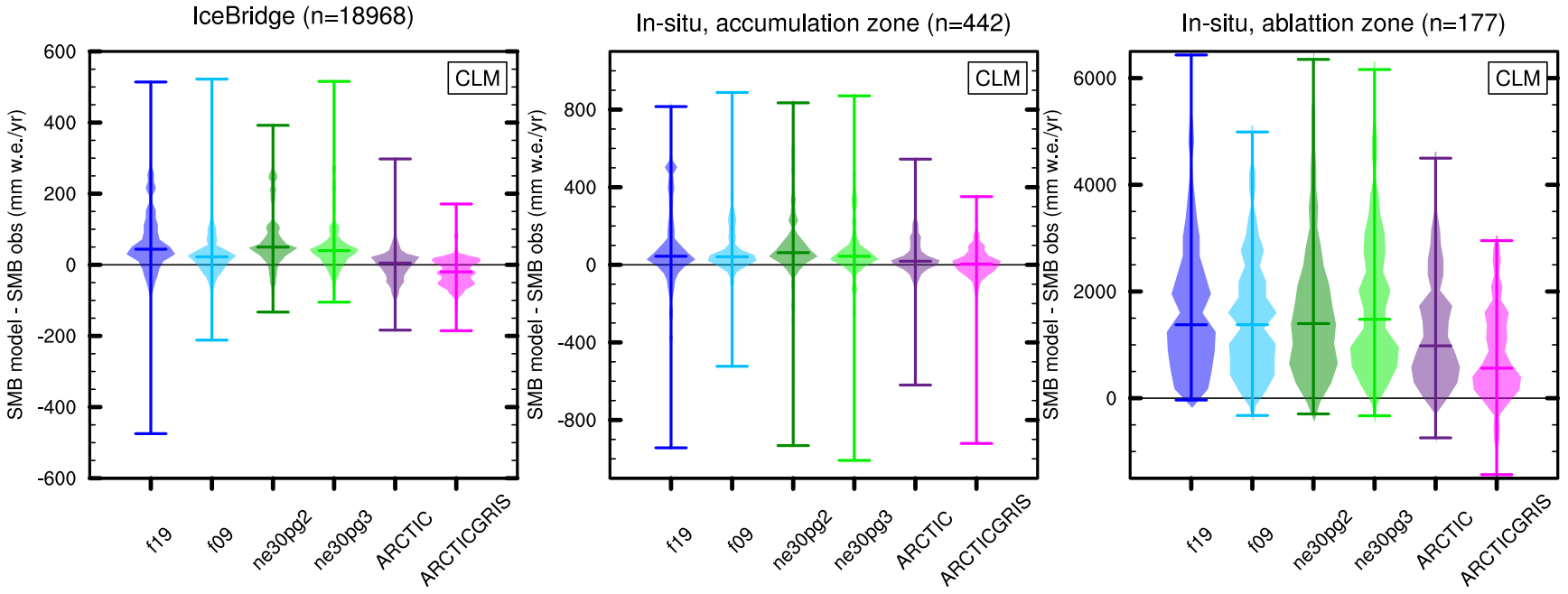
DJF Blocking

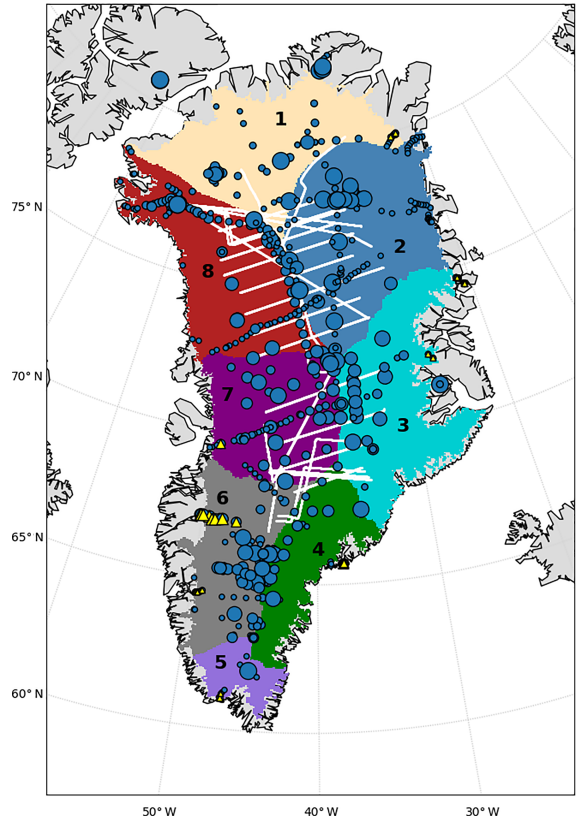


- Z500 anomaly blocking detection algorithm of Dole and Gordon (1983), with modifications described in Pinheiro et al. 2019, implemented in the TempestExtremes package (Ullrich and Zarzycki 2017)
- Blocking criterion: +5 day persistence of +100 m Z500 anomaly
- **ARCTICGRIS differences with respect to 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