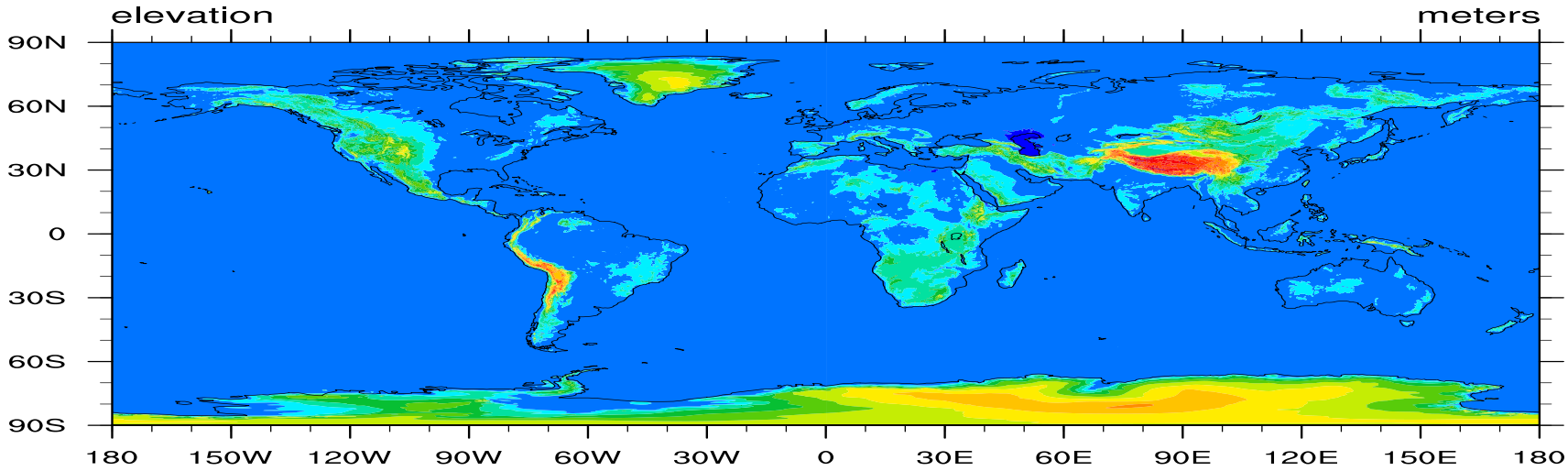
SciDAC
Scientific Discovery through Advanced Computing

CGD Climate & Global Dynamics

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

New topography software for CAM

Peter Hjort Lauritzen[§], Julio Bacmeister[§], Mark Taylor[*] and Rich Neale[§]



CESM AMWG meeting, February 1-3, 2012

§ NCAR *Sandia National Laboratories

(thanks to Andy Mai for doing all the runs and diagnostics)

NCAR Earth System Laboratory NESL

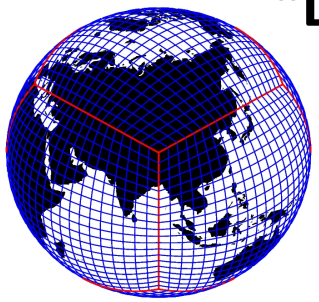
Surface variables

- **PHIS**: surface geopotential
- **SGH30**: standard deviation of topography on scales approximately < 3 km.
  Used for turbulent mountain stress (TMS) parameterization
  (sub-grid-scale orographic drag)
- **SGH**: standard deviation of topography on scales approximately > 3km (and < grid scale)
  (momentum flux deposition due to unresolved gravity waves)
- **LANDFRAC**: land-ocean mask
- **LANDM_COSLAT**: "smoothed" LANDFRAC
  (not used in CAM5)

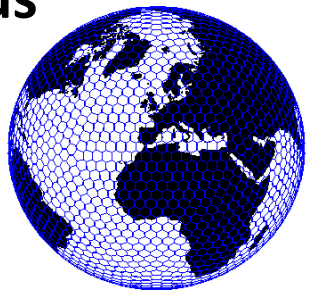
Default topo-data generation for regular lat-lon grids

A. Bin USGS 30 arc seconds (~1 km) data to 10 arc minutes grid (~15 km)
B. While doing A. compute SGH30
   (code in /atm/cam/tools/definehires/ does A. and B.)
C. Bin 10 arc minutes data to target lat-lon grid (compute SGH)
D. Filter PHIS (dynamical core dependent)

"Default" topo-data generation for non lat-lon grids



Default software does not support non lat-lon grids so CAM-FV topo-variables at similar lat-lon resolution are linearly interpolated to target grid (and smoothed further)



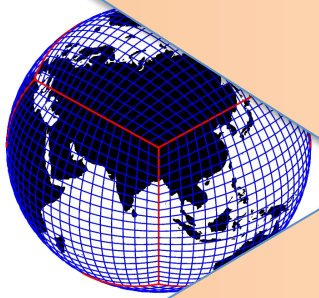
Issues with "default" procedure

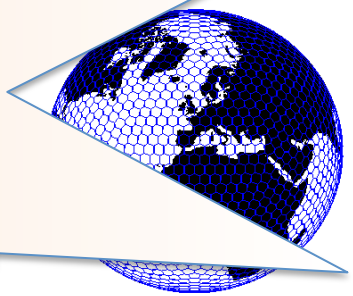
- Computing SGH and SGH30 on a lat-lon grid (as done currently) leads to *anisotropic* separation of scales
- SGH is not recomputed to include the extra sub-grid-scale variance in the sub-grid-scale due to interpolation and explicit smoothing/filtering of PHIS
- Interpolation of PHIS is not volume conserving (conservative remapping may introduce desirable/consistent "smoothing")

Default topo-data generation for reg r lat-lon grids

A. B USGS 30 arc seconds (~1 km ta to 10 arc mi d (~15 km)
B. Whi A. compute SGH3
(code in /ath es/ does A. and B.)
C. Bin 10 ar ta to ta id
D. Filter PHIS (c

Software to generate topo-data has been completely rewritten to directly accommodate unstructured grids and enforce more physical consistency





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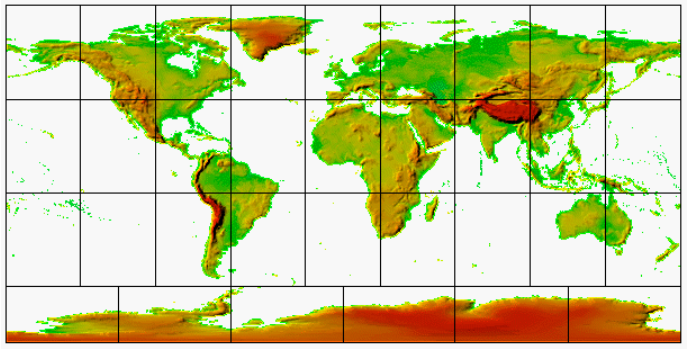
- Interpolation of PHIS is not volum nserving (conservative remapping may introduce desirable/consistent "smoothing")

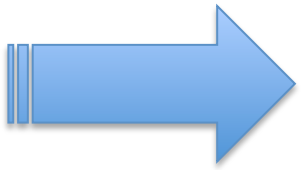
New software (3 Fortran programs)

1. **GEN_NETCDF_FROM_USGS:** Reads USGS 30 arc seconds terrain dataset in 33 tiles and converts it a single NetCDF file (7.5GB; elevation stored as integer)

(only changes to raw data is for the Caspian sea)



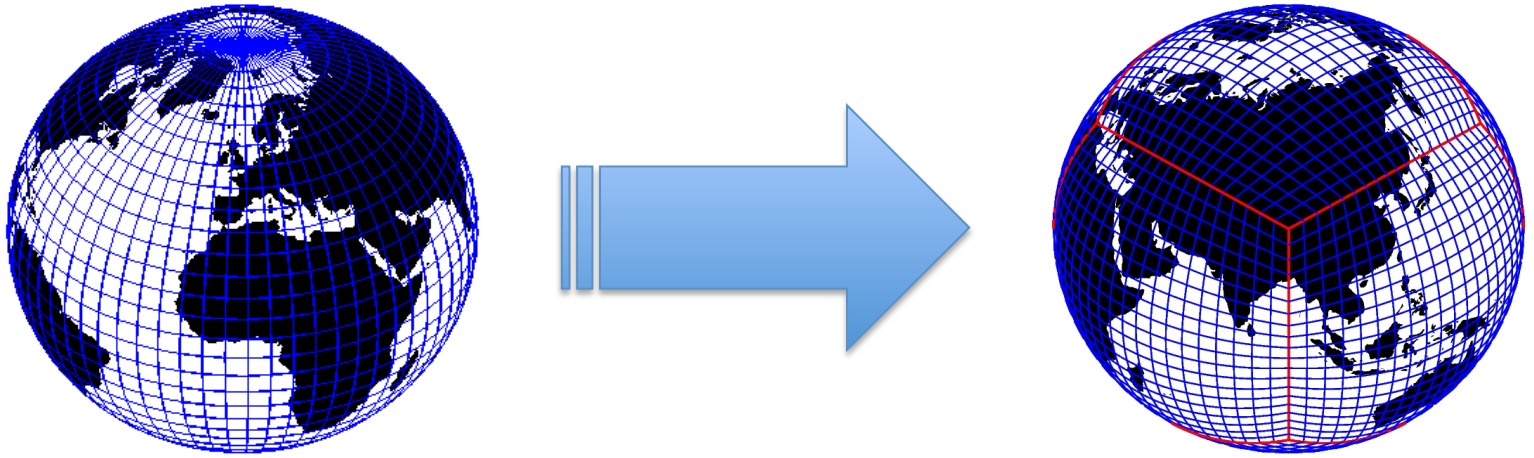
http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info



New software (3 Fortran programs)

2. BIN_TO_CUBE: bin USGS 30 arc seconds data to ~3km quasi-isotropic cubed-sphere grid and compute SGH30

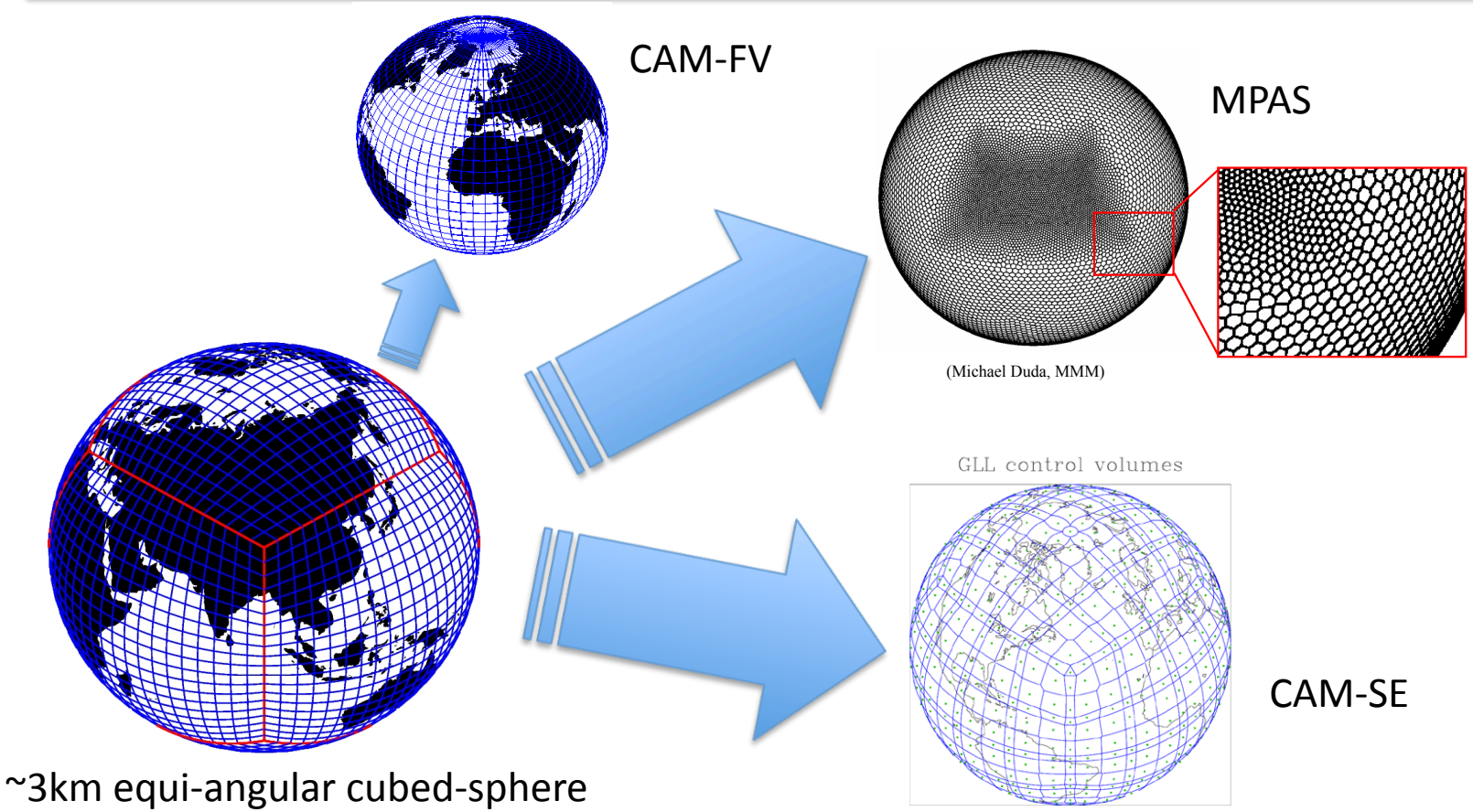
Adjustments to land fraction: Extend land fraction for Ross Ice shelf by setting all landfractions south of 79S to 1



-> quasi-isotropic separation of scales (for SGH30 and SGH).

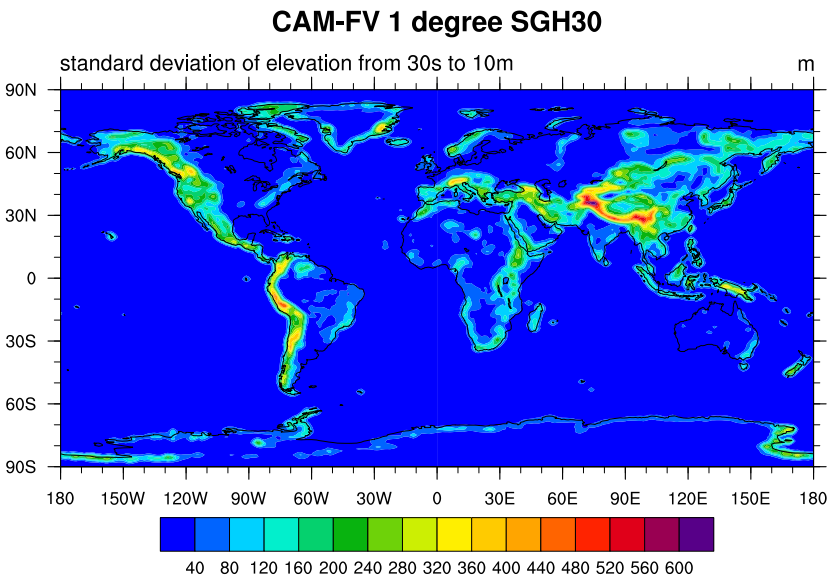
3. CUBE_TO_TARGET: Rigorously remap (volume conserving) variables from ~3km cubed-sphere to any structured or unstructured target grid (compute SGH)

If PHIS is smoothed (externally or internally) SGH is re-computed to account for smoothing in sub-grid-scale variance

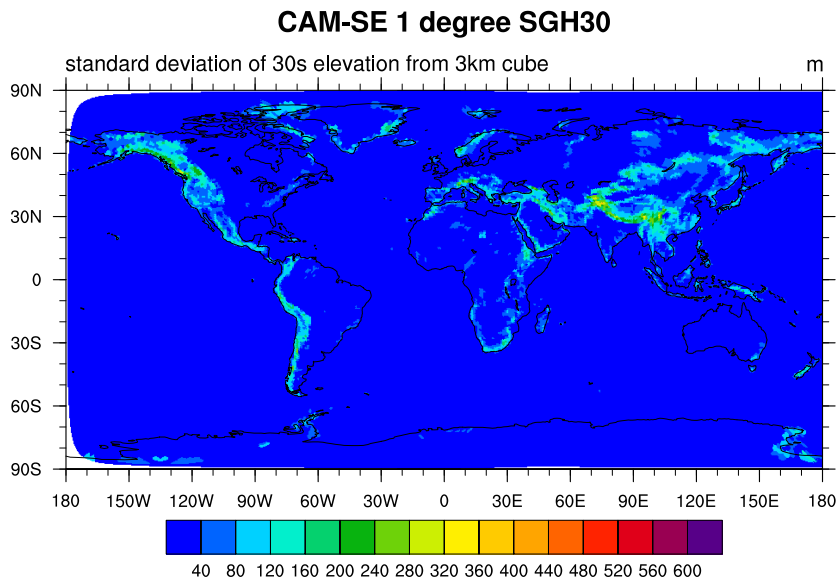


SGH30

Default software used



New software used

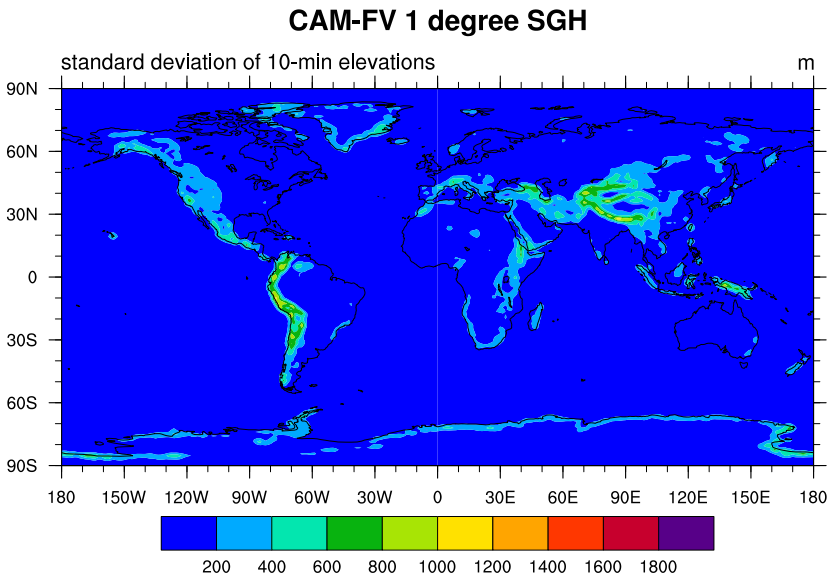


More isotropic filtering (different cut-off scale):

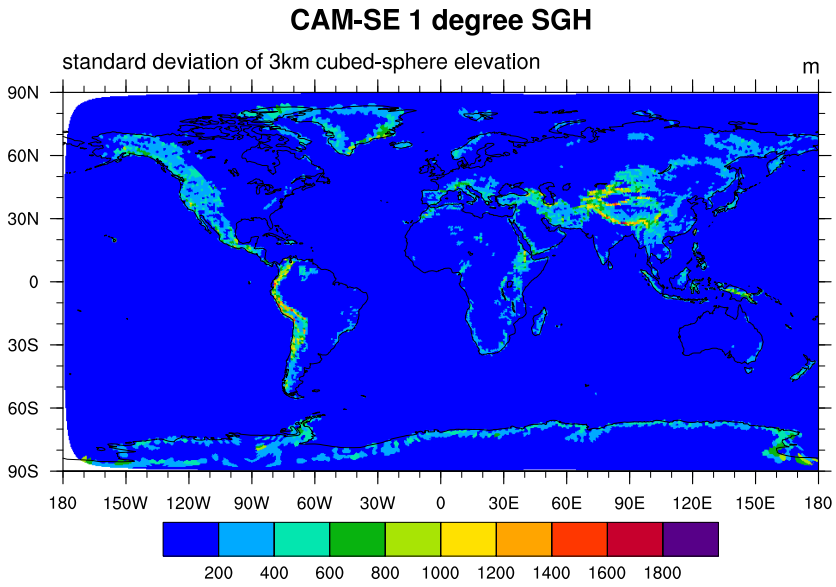
-> significantly less “energy” in SGH30 with new topo software

SGH

Default software used



New software used



More isotropic filtering (different cut-off scale):

-> significantly more “energy” in SGH with new topo software

Exploratory simulations with CAM-FV and CAM-SE (at 1 degree resolutions) to assess the effect of "consistent" SGH and SGH30

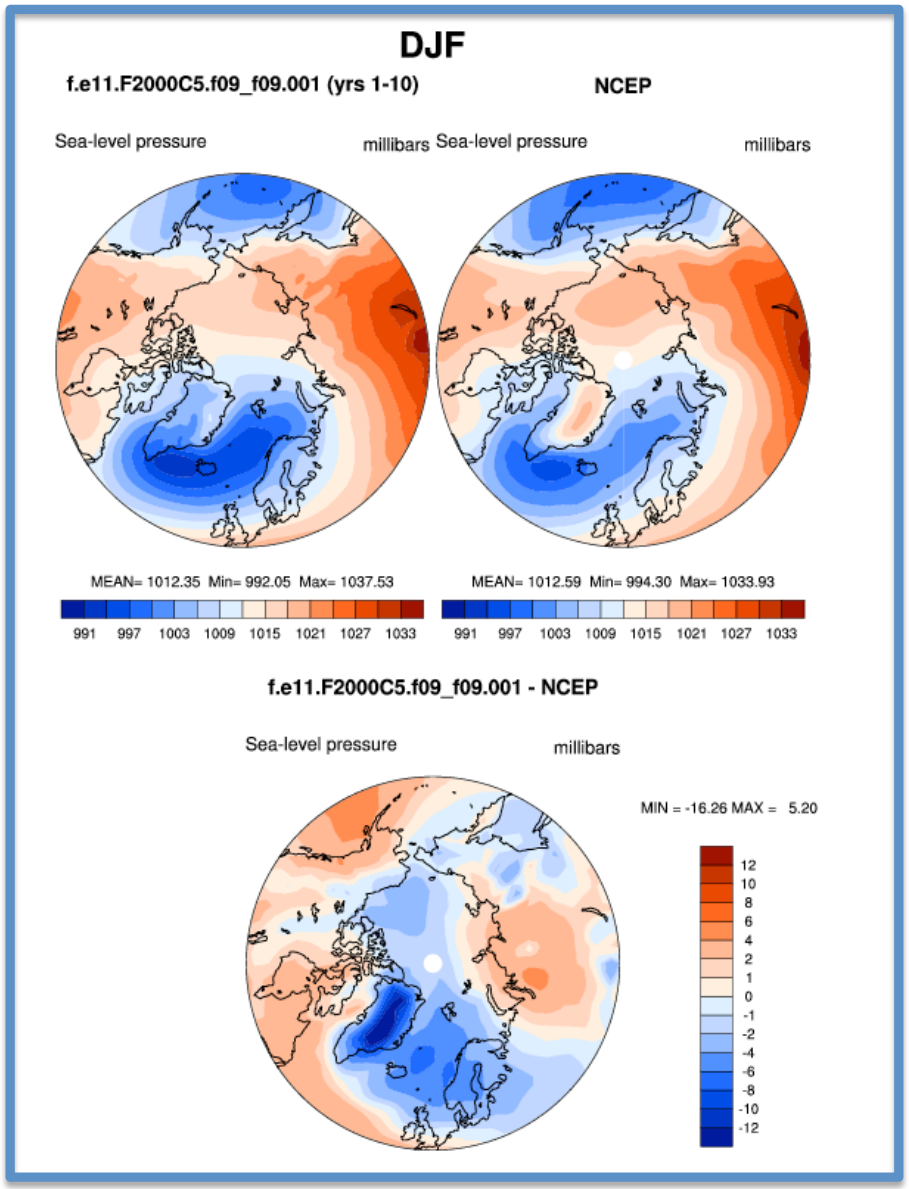
- Will primarily show results for CAM-FV, however, the CAM-SE simulations show similar changes to the climate for this experiment setup

<u>Runs (10 year):</u>

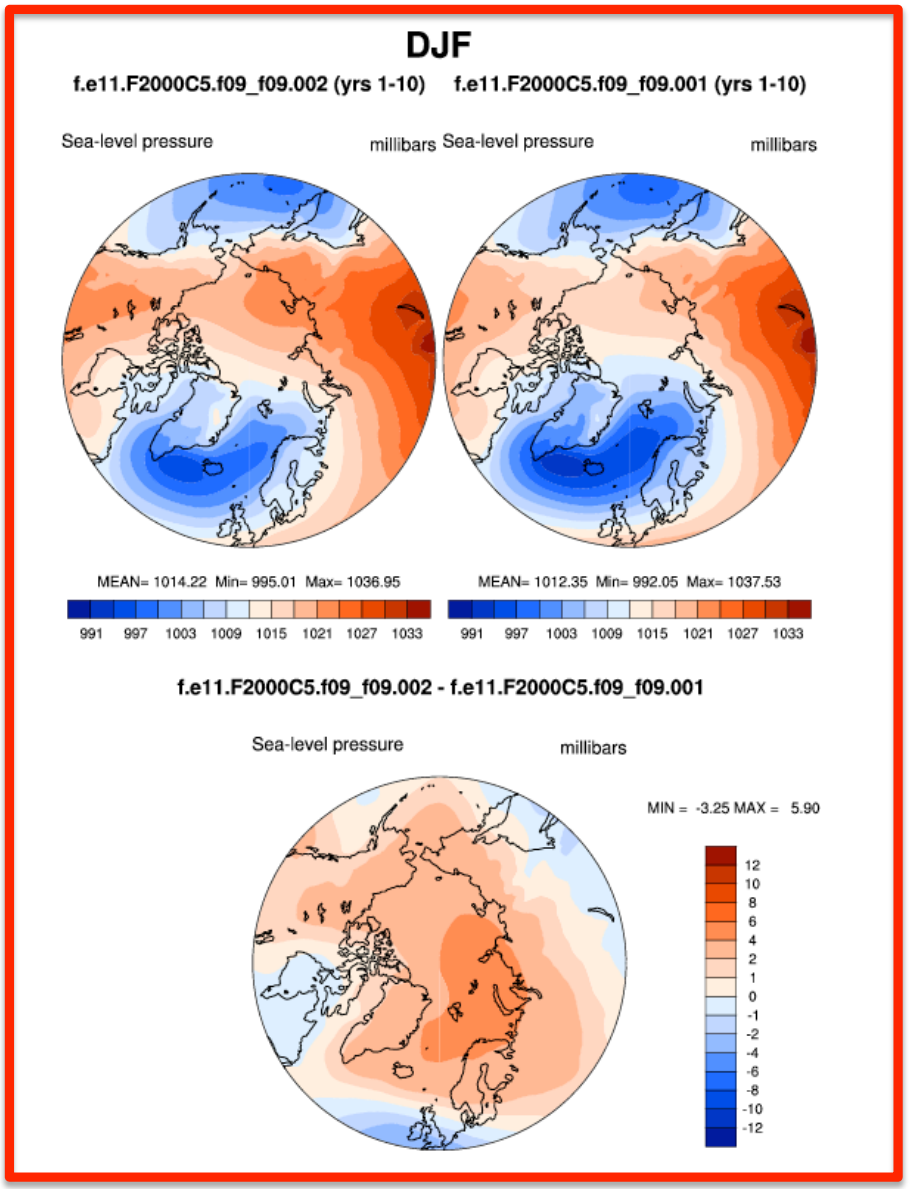
- Control: default topo files
- Consistent: PHIS from control but consistent SGH and SGH30 computed using new software

Sea level pressure (PSL): CAM-FV 1 degree

Control and OBS



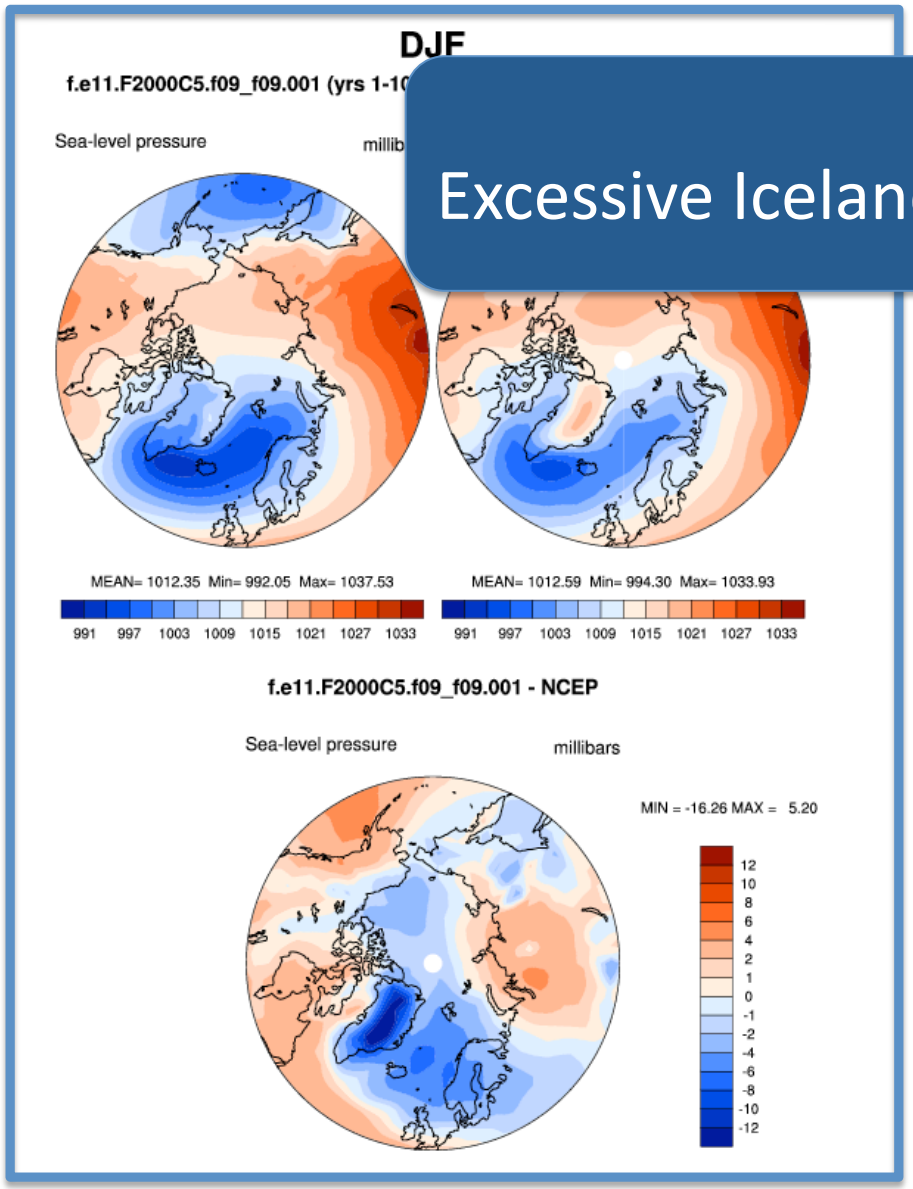
Consistent (SGH & SGH30) and Control

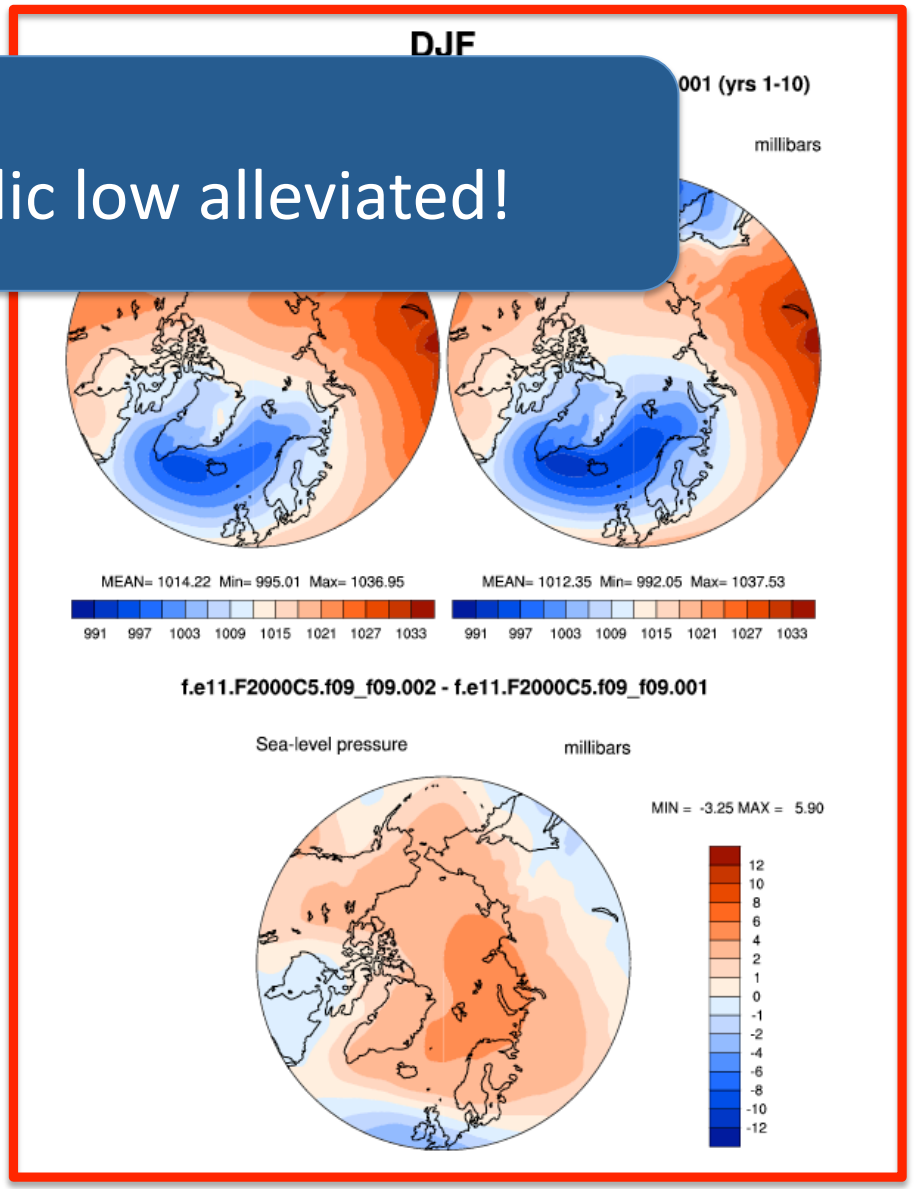


Sea level pressure (PSL): CAM-FV 1 degree

Control and OBS

Consistent (SGH & SGH30) and Control

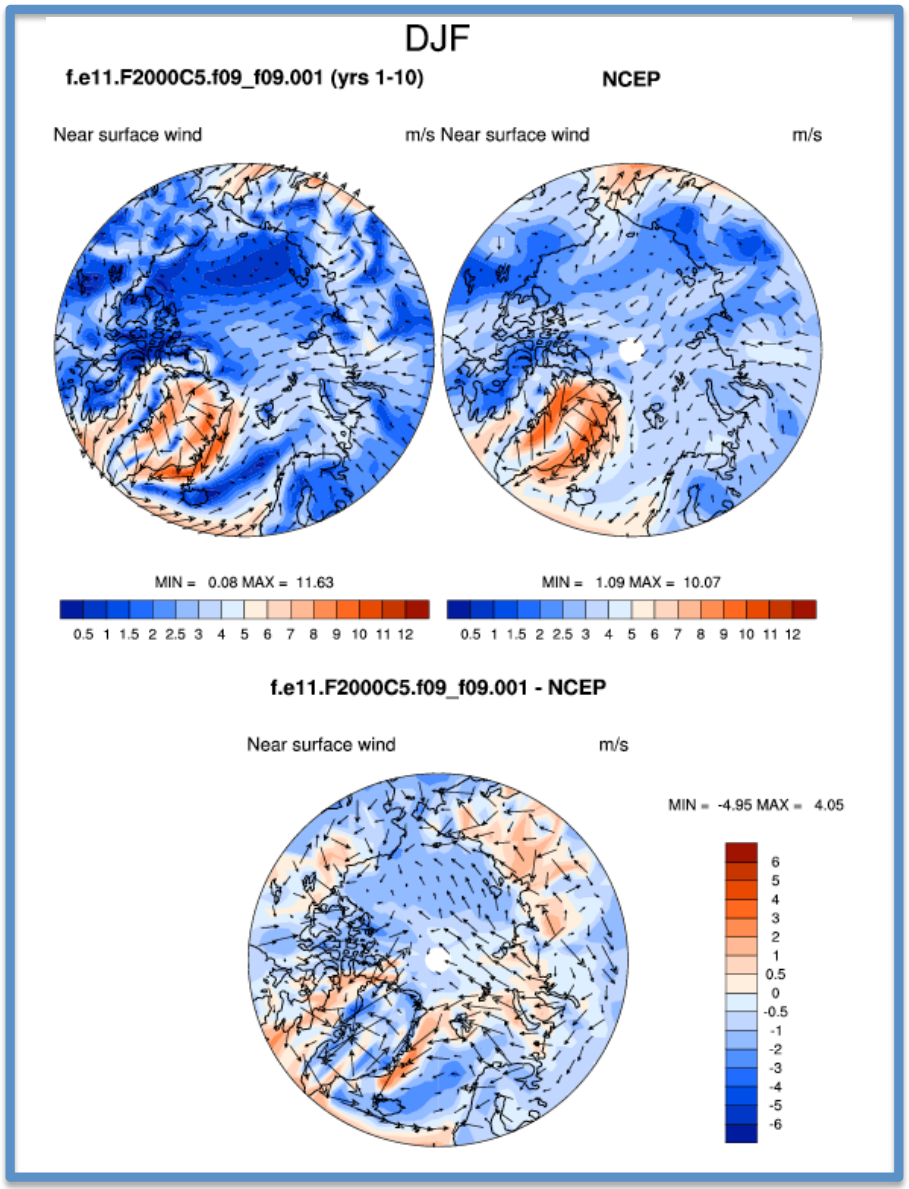




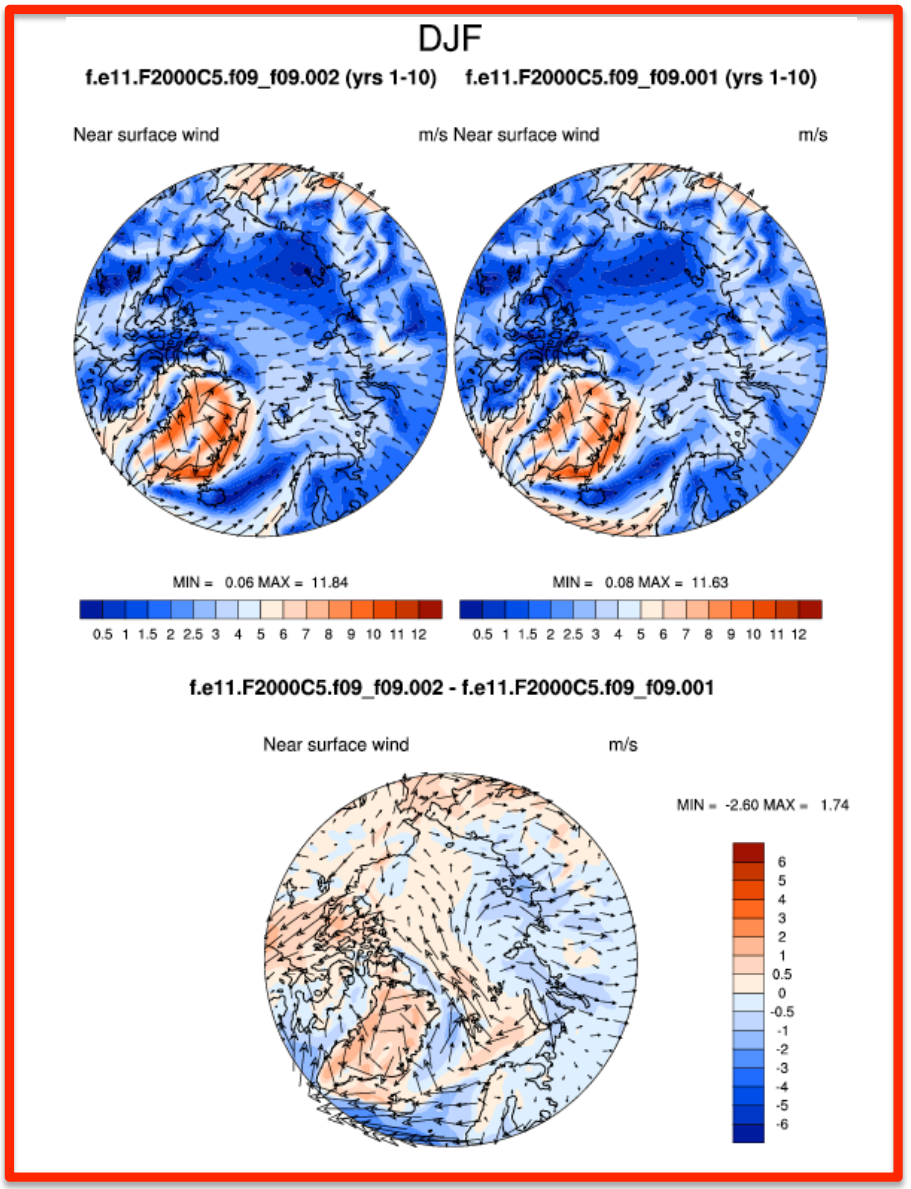
Excessive Icelandic low alleviated!

Near surface winds: CAM-FV 1 degree

Control and OBS



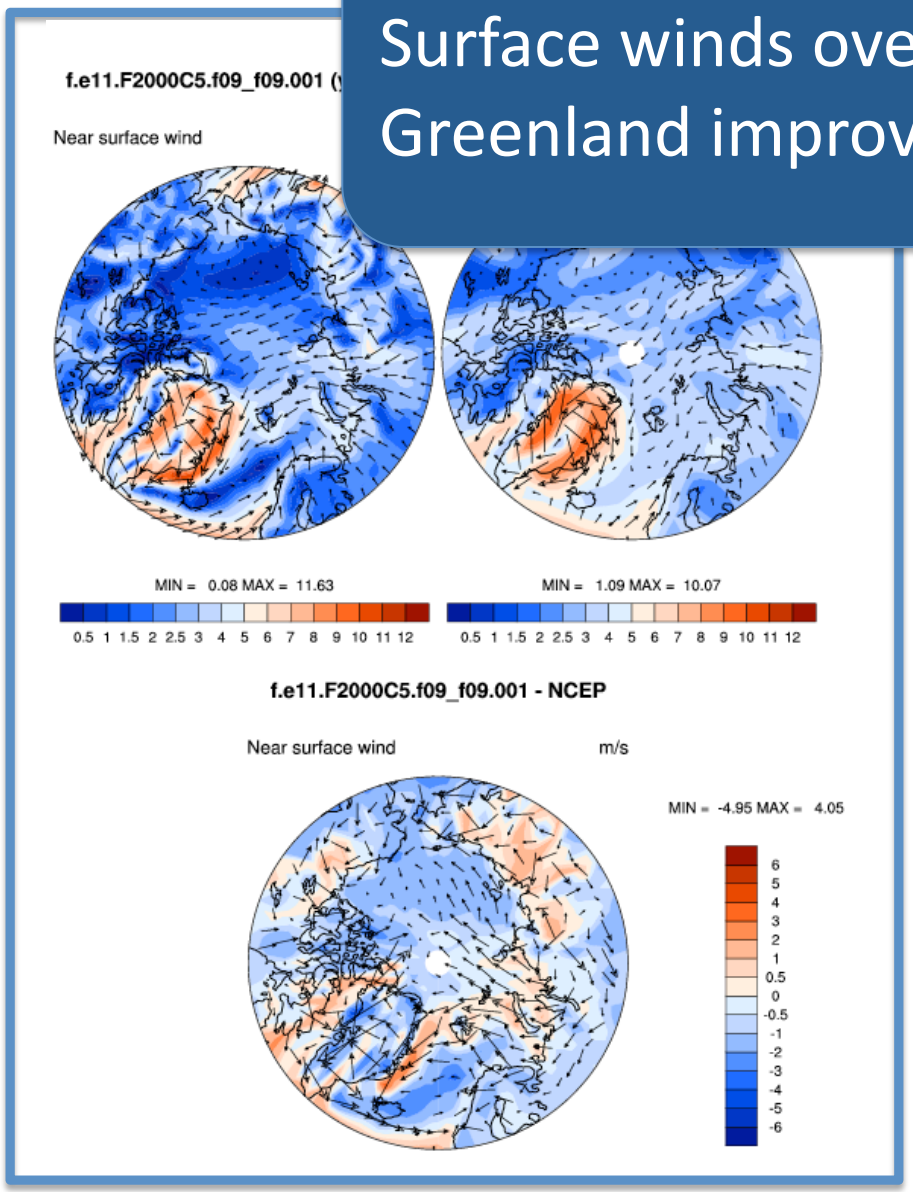
Consistent (SGH & SGH30) and Control

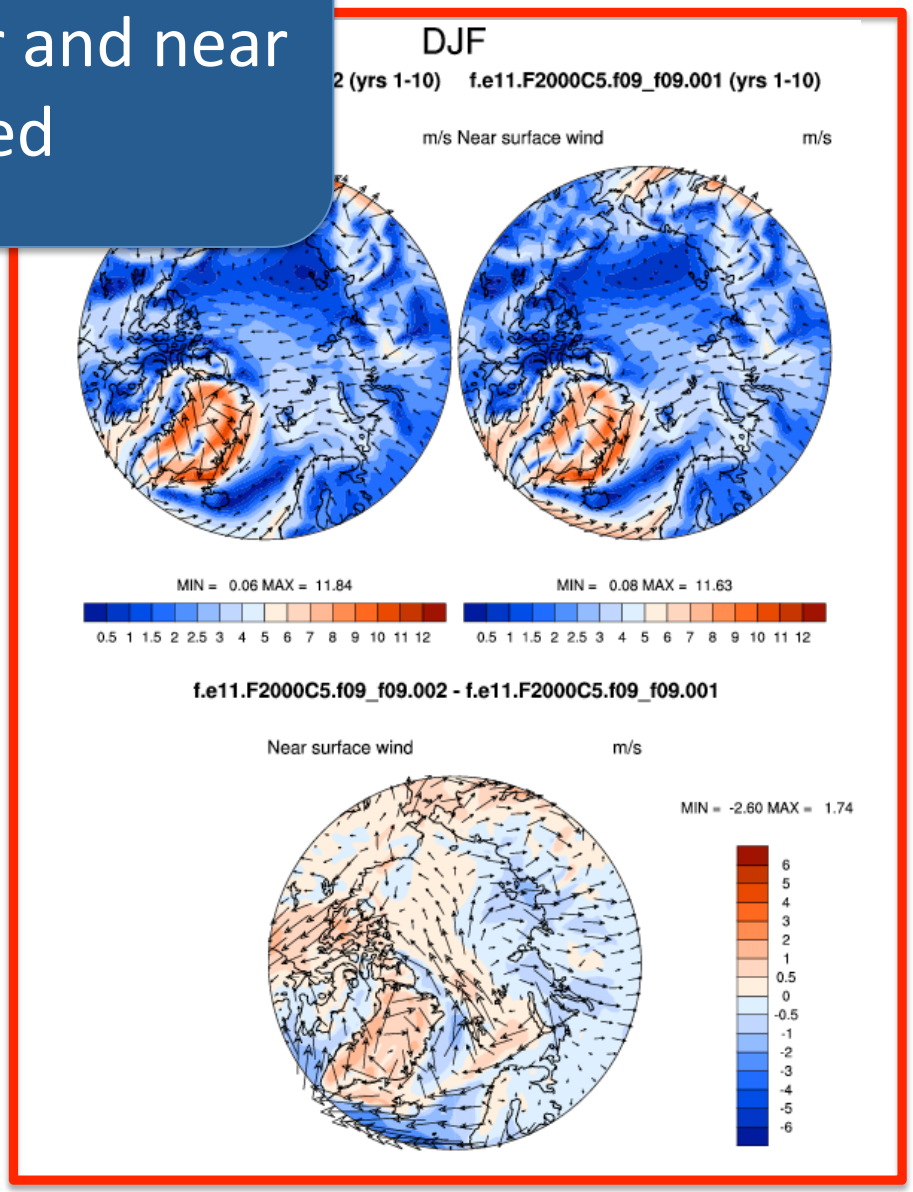


Near surface winds: CAM-FV 1 degree

Cont GH & SGH30) and Control

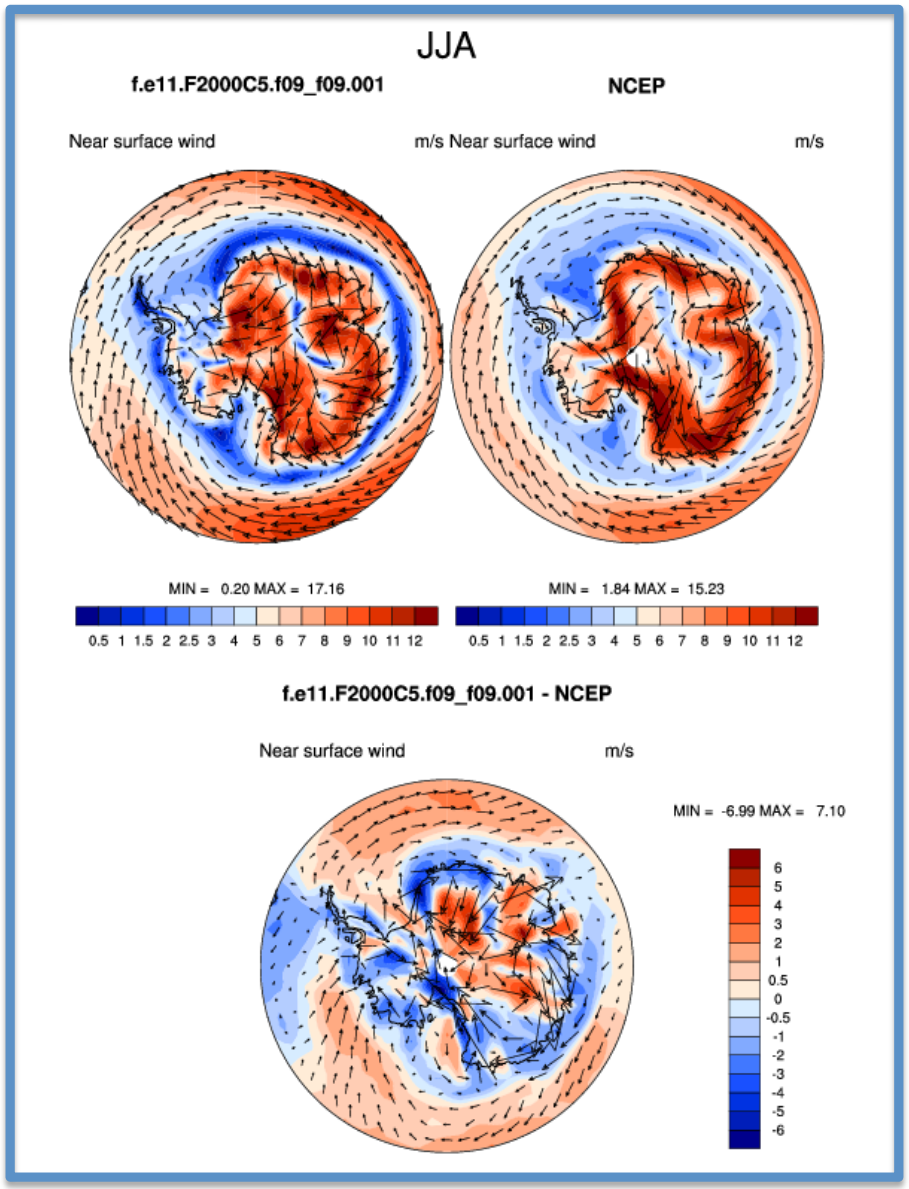
Surface winds over and near Greenland improved





Near surface winds: CAM-FV 1 degree

Control and OBS



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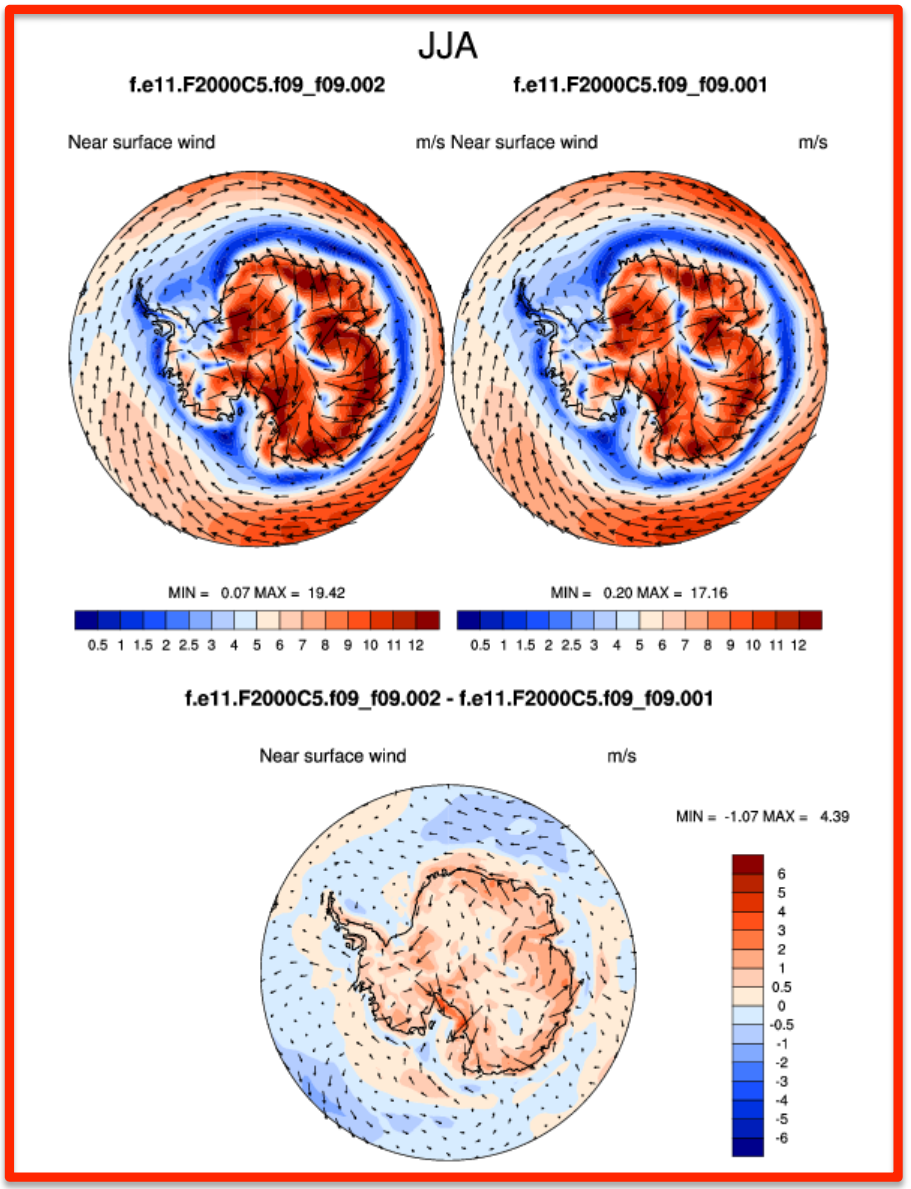


Near surface winds: CAM-FV 1 degree

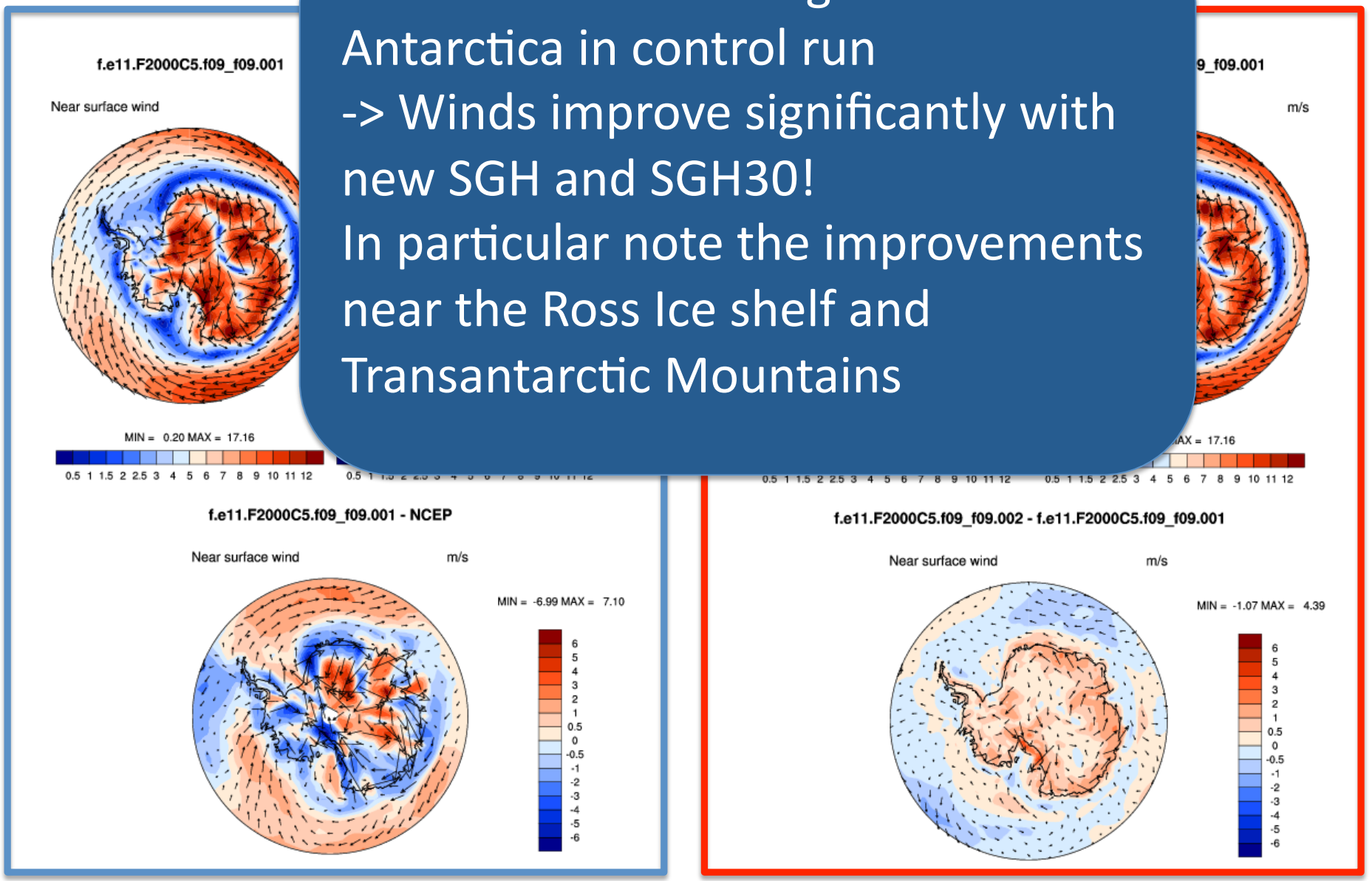
Control

Control

Winds too weak along coast of Antarctica in control run

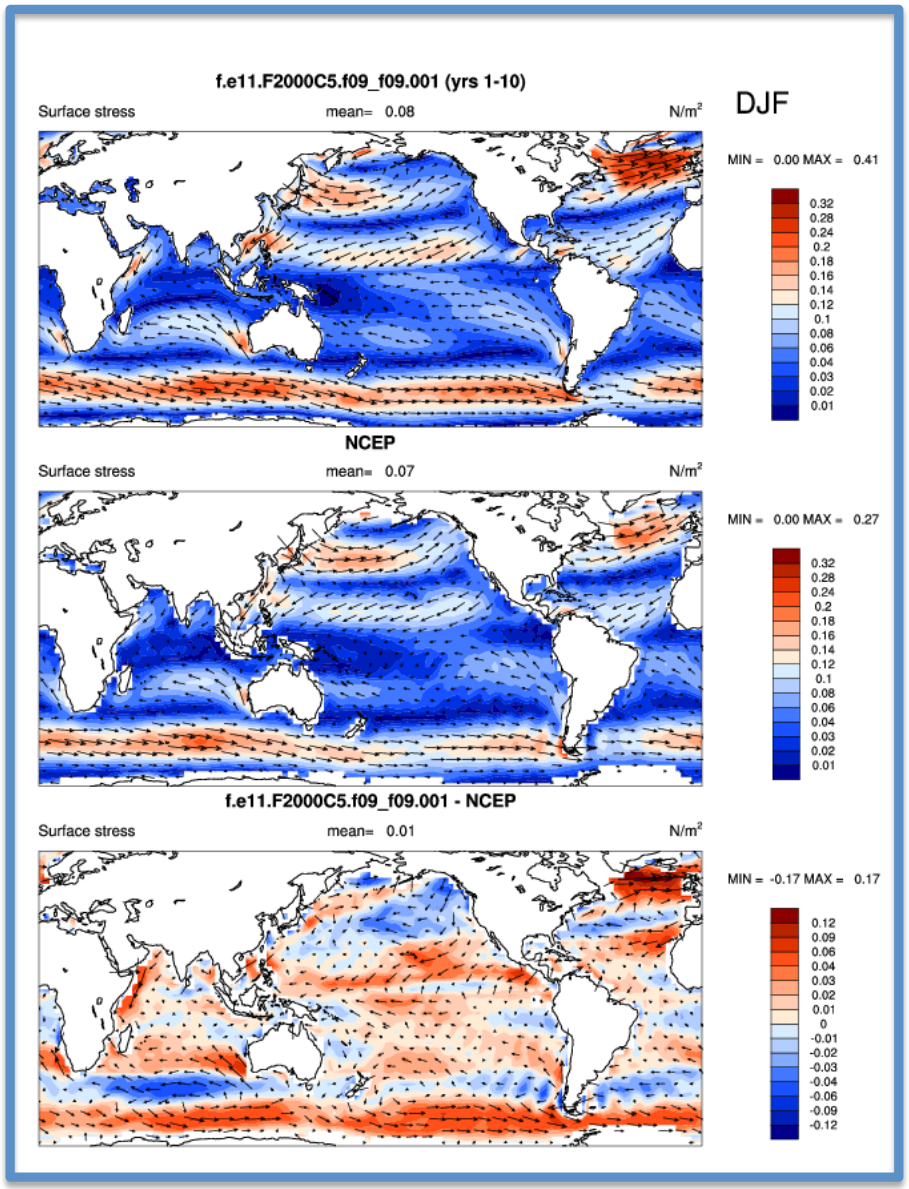
-> Winds improve significantly with new SGH and SGH30!

In particular note the improvements near the Ross Ice shelf and Transantarctic Mountains



Surface wind stress: CAM-FV 1 degree

Control and OBS



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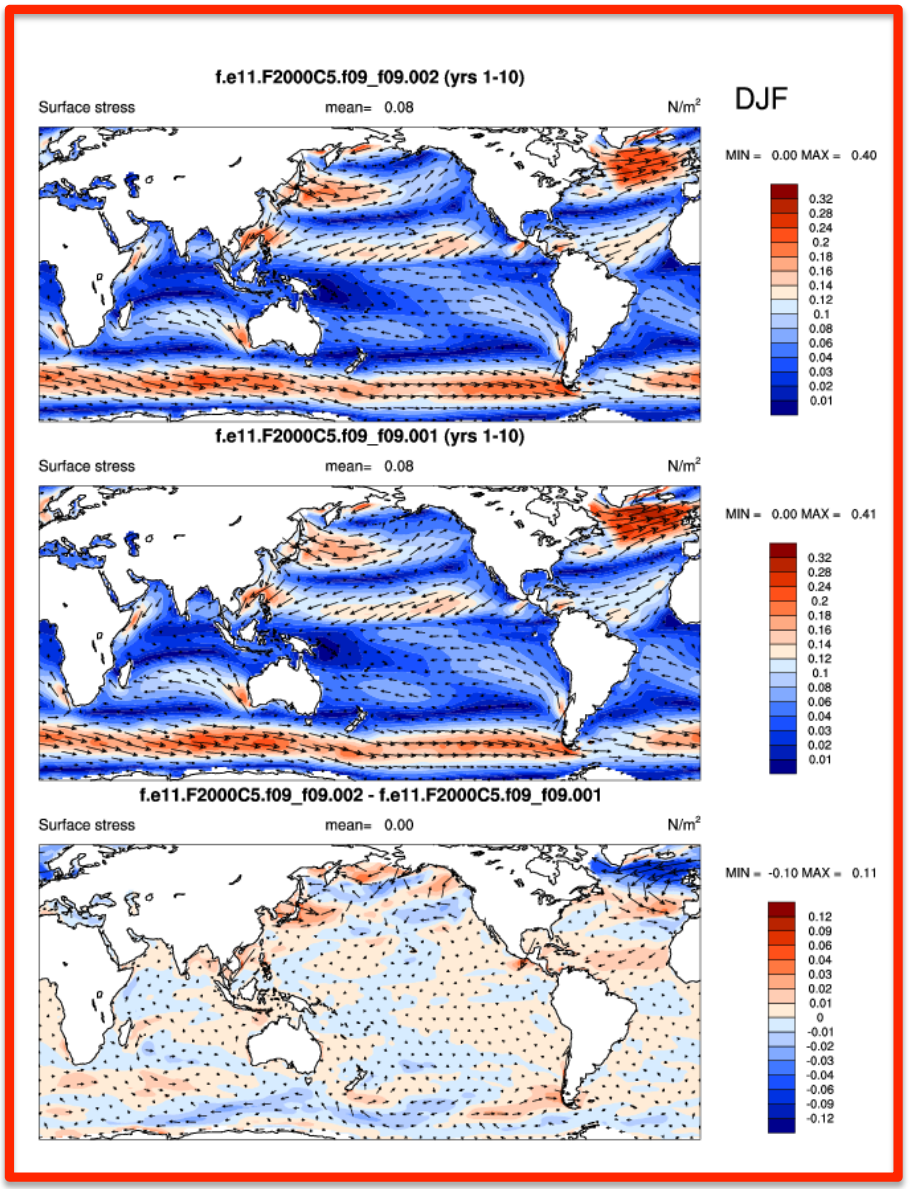
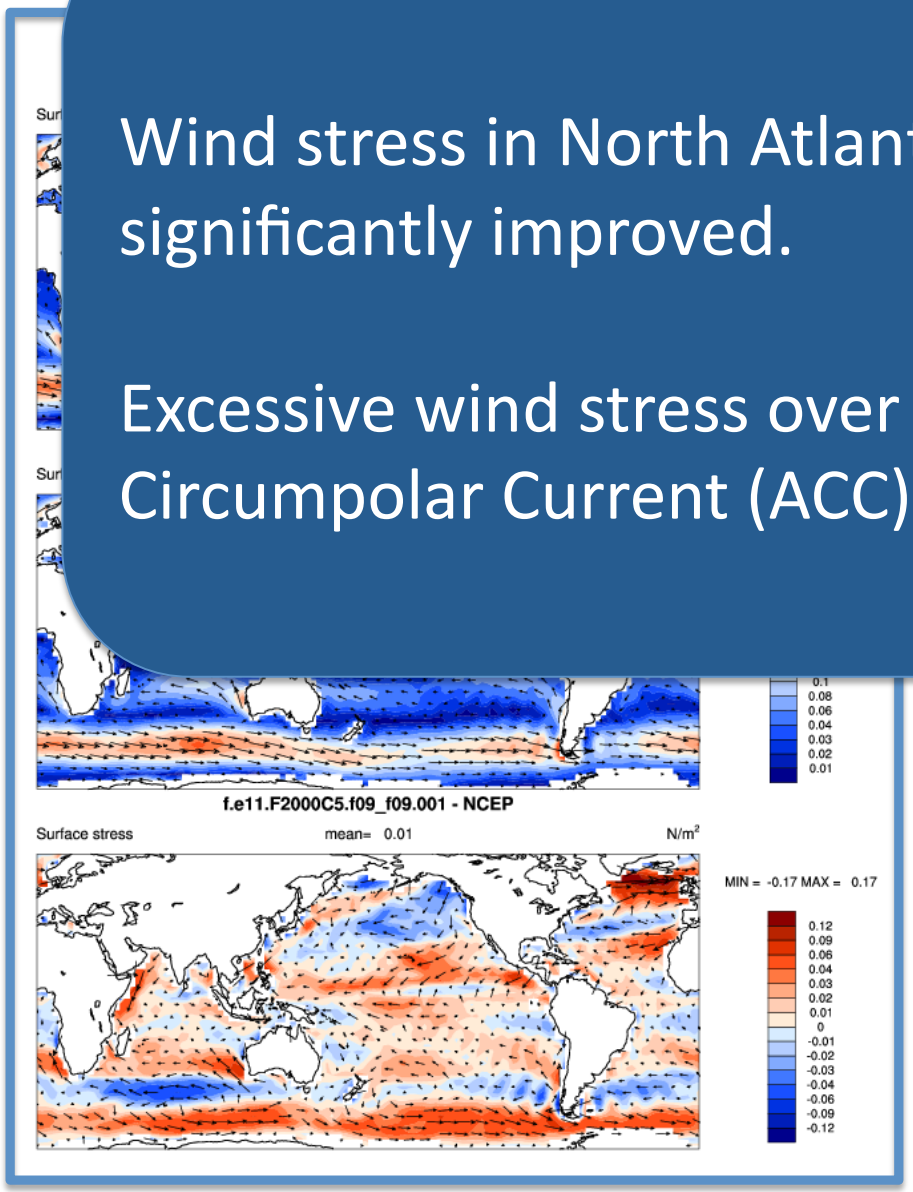


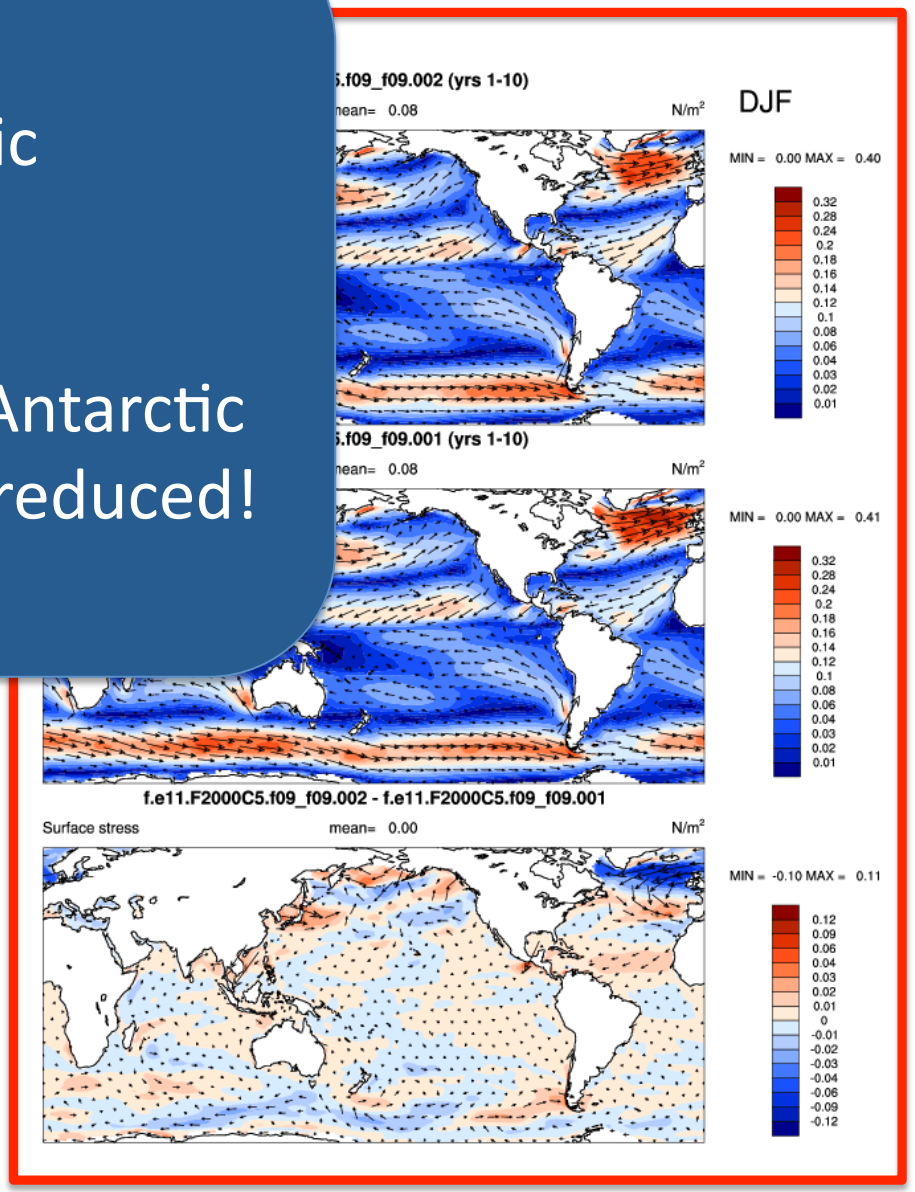
Surface wind stress: CAM-FV 1 degree

(SGH & SGH30) and Control

Wind stress in North Atlantic significantly improved.

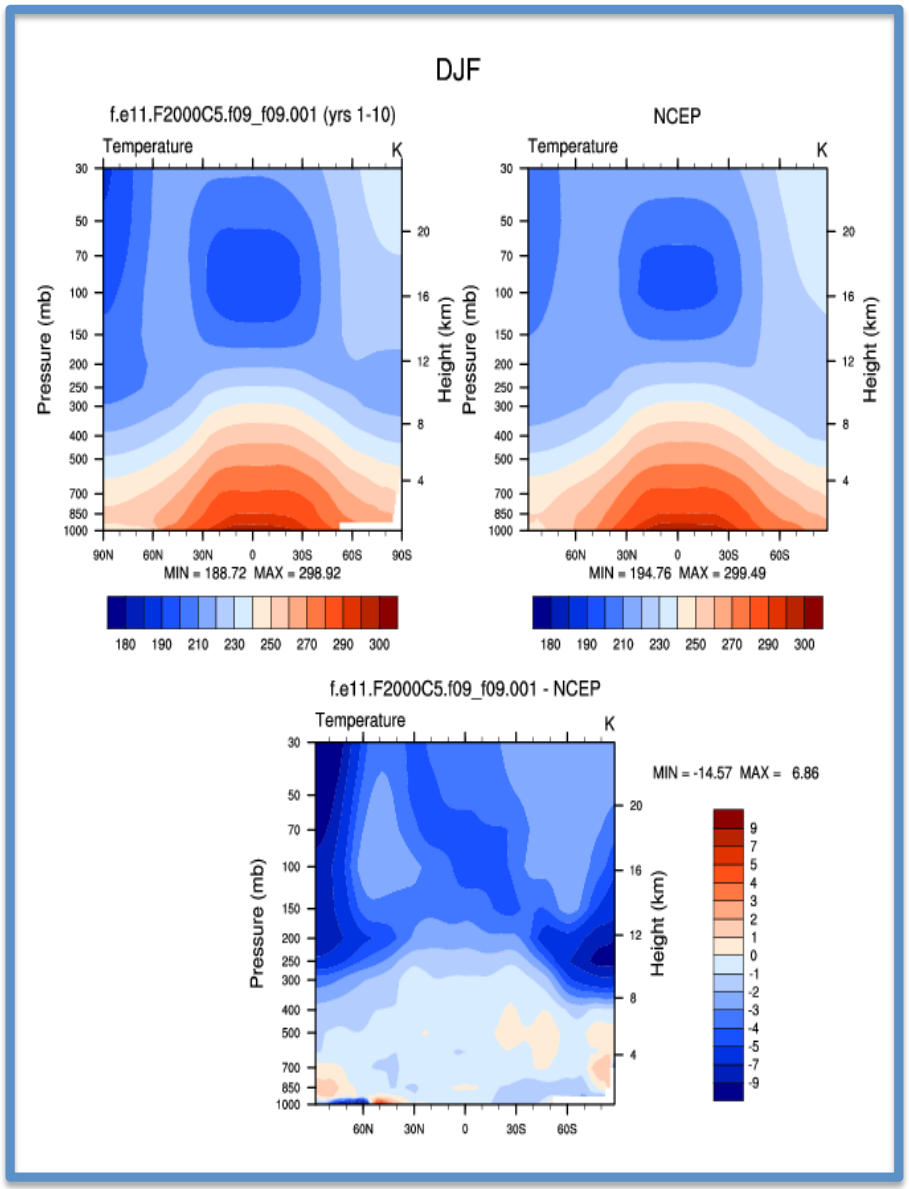
Excessive wind stress over Antarctic Circumpolar Current (ACC) reduced!



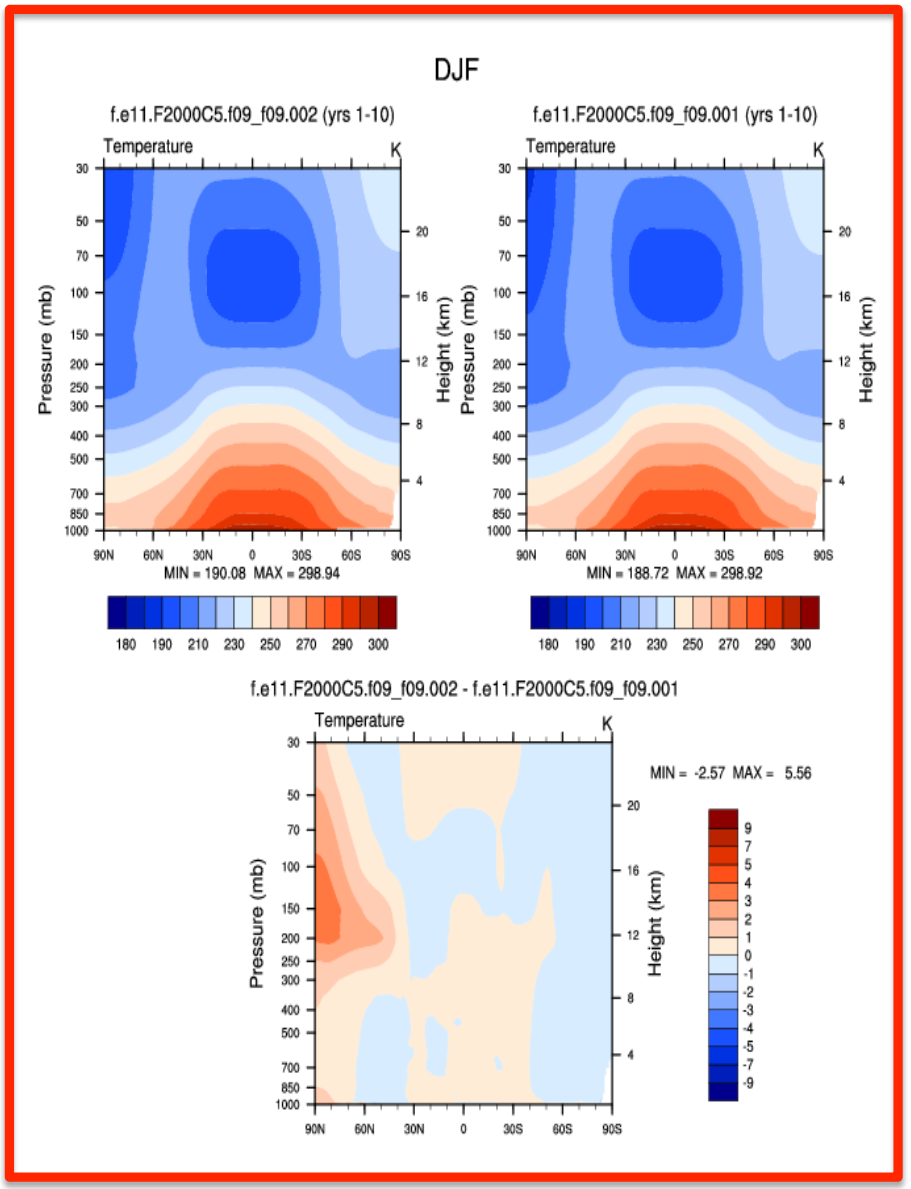


Zonal temperature: CAM-FV 1 degree

Control and OBS



Consistent (SGH & SGH30) and Control



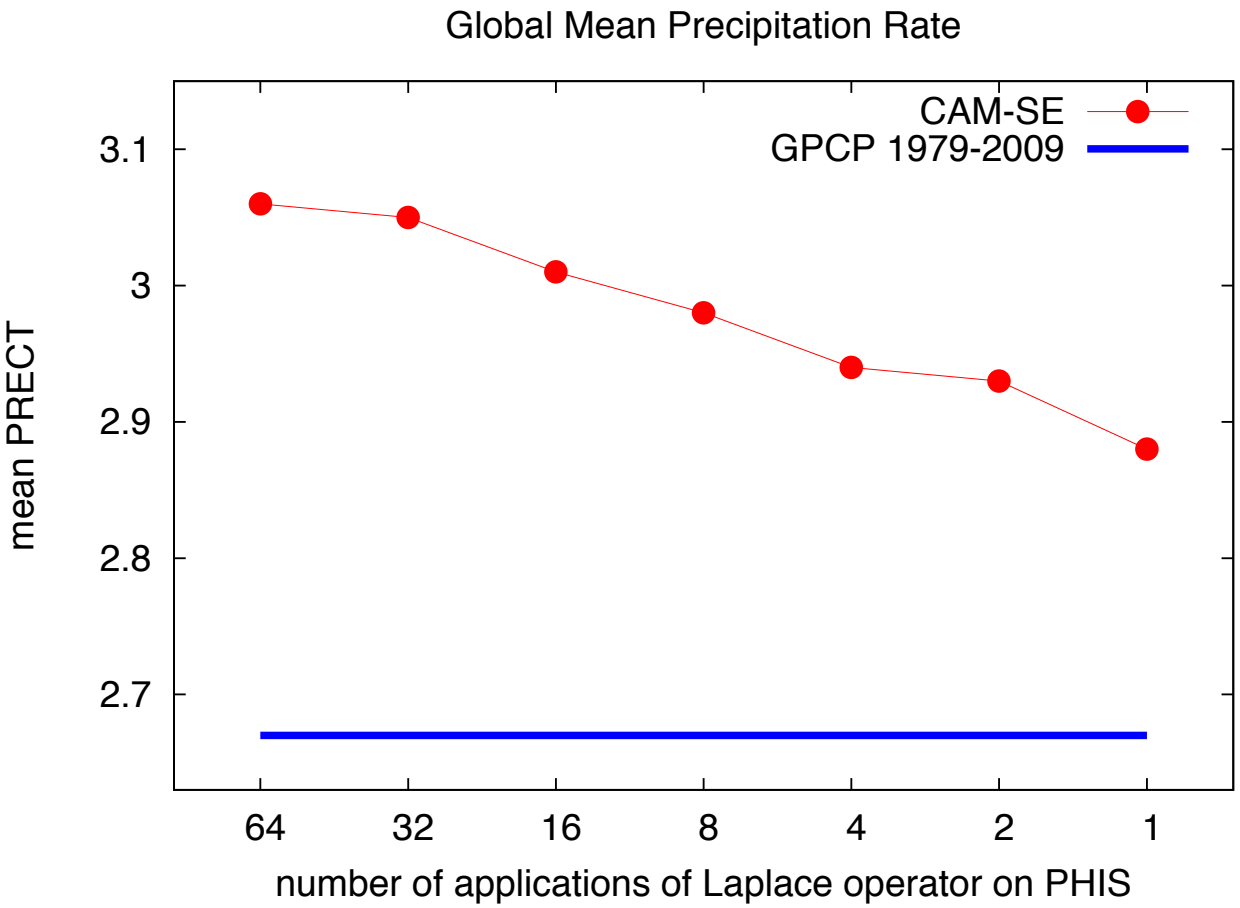
Smoothing PHIS for CAM-SE (and MPAS)

Ongoing project to internally smooth topography in new software:

- remove 2*dx oscillations, force PHIS near coast lines to be zero over ocean, etc. all while preserving PHIS volume
- being done using finite-volume transport scheme technology

How and how much to smooth PHIS is a somewhat “grey area” of climate modeling … but it matters … see next slide

Precipitation Rate (CAM-SE)



Smooth → Rough

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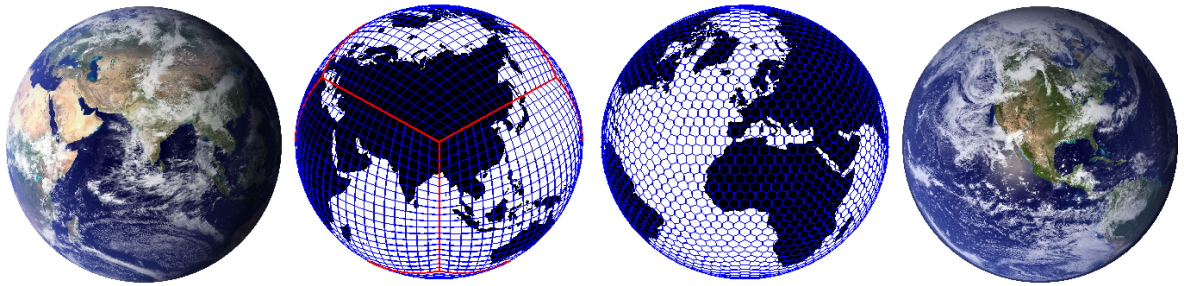
Transport and related ongoing developments in CAM

AMWG, February 1-3

Peter Hjort Lauritzen[§], Christoph Erath[§,†], Trey White[§], Julio Bacmeister[§], and Mark Taylor[*]

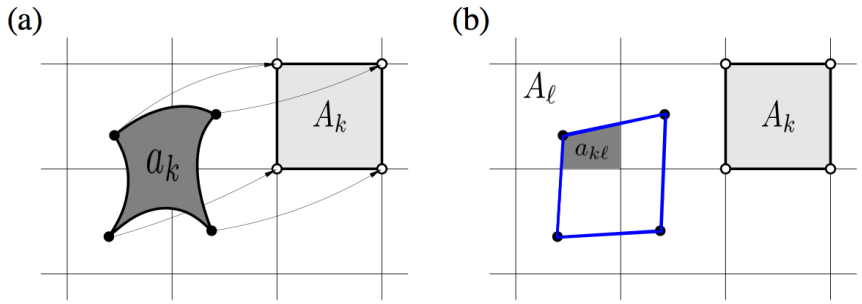
[§]NCAR [*]Sandia National Laboratories [†]University of Colorado, Boulder



CGD Climate & Global Dynamics

NCAR Earth System Laboratory NESL

CSLaM scheme (Conservative Semi-Lagrangian Multi-tracer) is being integrated into CAM-SE; major software engineering effort (Erath, Taylor)
(e.g.,communication infrastructure did not support stencils beyond shared points on element boundaries)



- **2D version running; next: couple to spectral element dynamics**

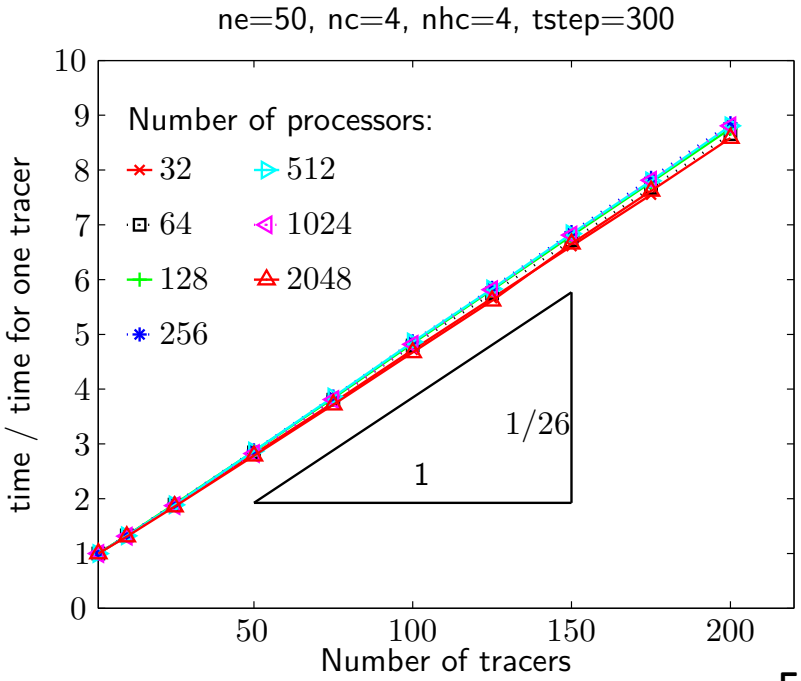


Figure courtesy of C.Erath

CSLaM scheme (**C**onservative **S**emi-**La**grangian **M**ulti-tracer) is being integrated into CAM-SE; major software engineering effort
(communication infrastructure did not support stencils beyond shared points on element boundaries)

Adding specified dynamics capability in CAM-SE (PI: J.-F. Lamarque)

Separate physics and dynamics grids in CAM-SE (PI: J. Bacmeister)

New idealized standard test case suite for transport
(Lauritzen et al., 2012, GMDD)

Results from large ensemble of state of the art transport schemes
(Lauritzen et. al., 2012, in prep)

Summer school on global non-hydrostatic dynamical cores at NCAR
(Organizers: C. Jablonowski, P.H. Lauritzen, M.A.Taylor, R.D.Nair, P.A.Ullrich)