Office of Science (BER) and NERSC and
DOE/UCAR Co-operative Agreement
US Department of Energy
NCAR-Wyoming Supercomputer Center
National Science Foundation

A new century-long high-resolution global climate run using the Community Earth System Model .

An Accelerated Scientific Discovery Simulation.

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Thanks also to Adam Phillips, John Truesdale, Gary Strand

Motivation

- Resolve or permit atmosphere and ocean mesoscale
  - and any consequent influence on larger scale climate system
- Test CAM5 at high resolution in a coupled context
  - Some drift issues with CAM4 in high-res coupled runs

Community Earth System Model (CESM) high-resolution model

- Model components
  - 1/4deg. Community Atmosphere Model (CAM5) spectral element ne120
  - 1/4deg. Community Land Model (CLM4)
  - ~1/10deg. Parallel Ocean Program (POP2), 62 vertical levels
  - ~1/10deg. Community Ice CodE (CICE)

External forcing, Initial Condits, coupling

- "Present day" (year 2000) conditions
- Short (1 year) ocean-ice spin up from Gouretski and Koltermann (2004) climatology of WOCE and other data, forced by CORE
- 6 hour ocn-atm coupling

Simulation performed on Yellowstone

- Yellowstone (NCAR-Wyoming Supercomputer Center, at Cheyenne, WY)
- IBM iDataPlex architecture with Intel Sandy Bridge processors.
- 1.5-petaflops high-performance computing system with 72,288 processor cores, 144.6 TB of memory,
- Accelerated Scientific Discovery (ASD) phase used 25M core hours

Yellowstone

Planned Papers/Projects

- Overview Paper (ASD group).
- Pacific climate variability in high-res coupled model (Kwon, Schneider, Tseng)
- Storm tracks, connection between surface and troposphere (Kwon, Booth, Small)
- Air-sea coupling over ocean eddies (Small, Bryan, Tomas, Schneider, O'Neill)
- Extremes (Saravanan, Kwon, Jochum, SØrensen, Neale)
- Near-inertial waves and mixing (Jochum, SØrensen)
- Tropical Atlantic (Small, Mechoso, Jochum, Keenlyside, Munoz)
- Southern Ocean (Doney, Lima, Long, Youngs)
- Ice sheet melt/AMOC at high resolution (Le Bars, CESM1.0.4 at 0.5 degree atmosphere (FV) and 0.1 degree ocean)

Climate Drift (1)

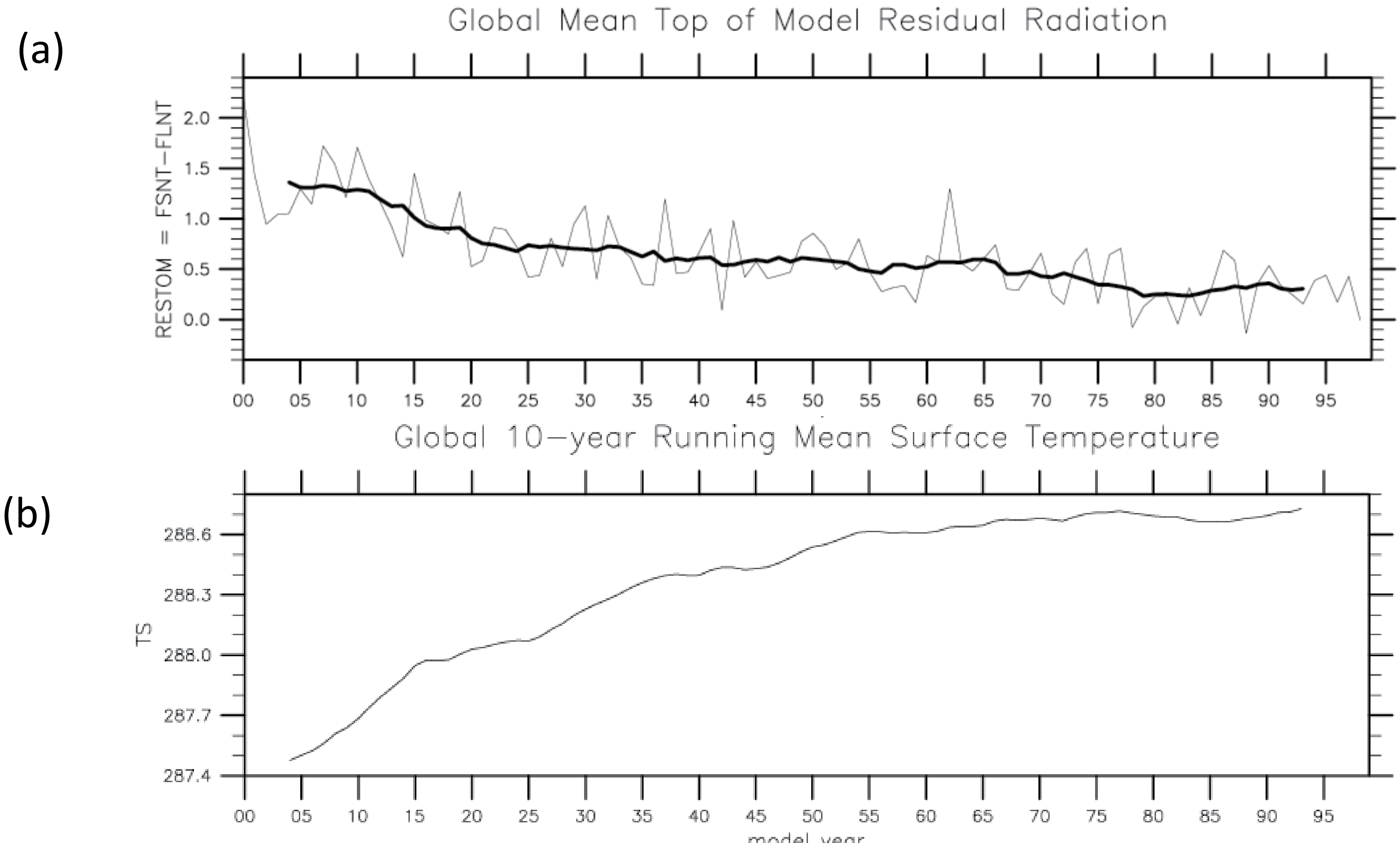
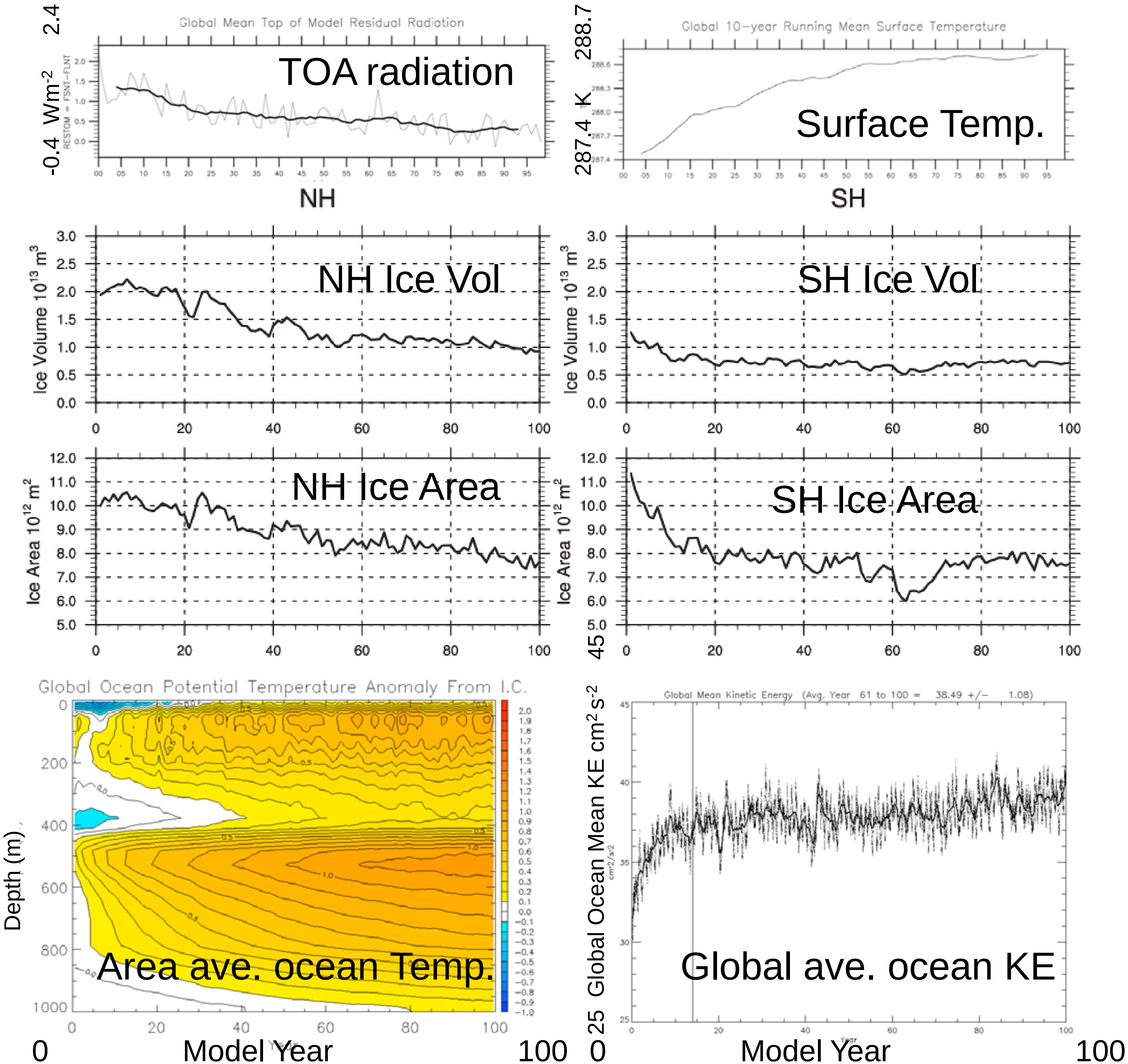
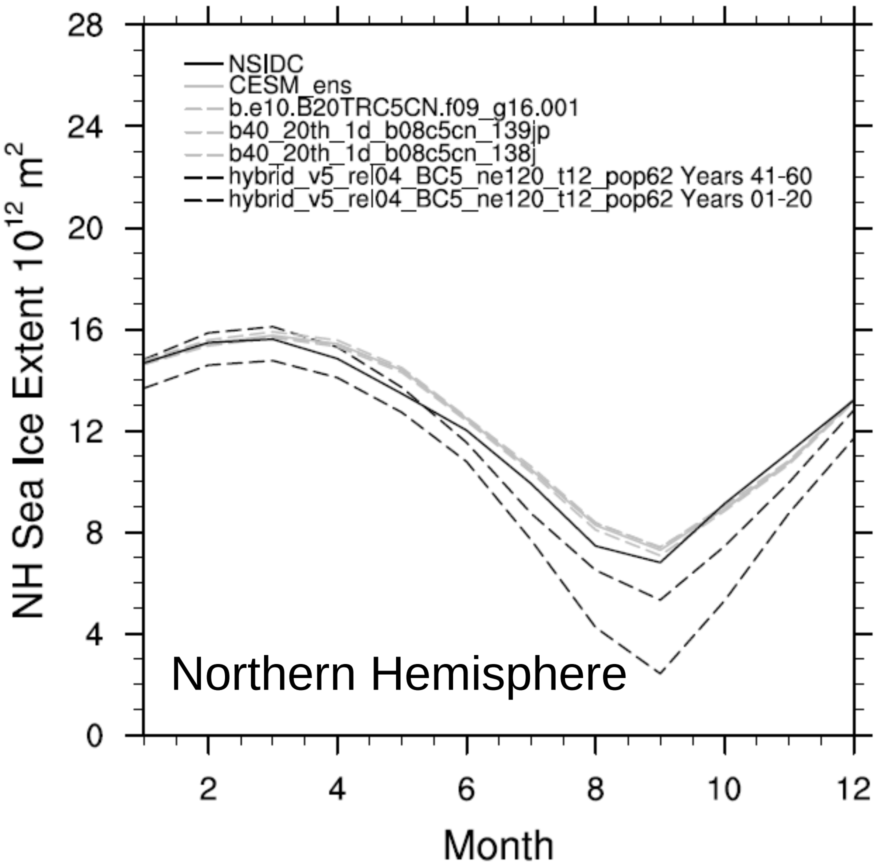


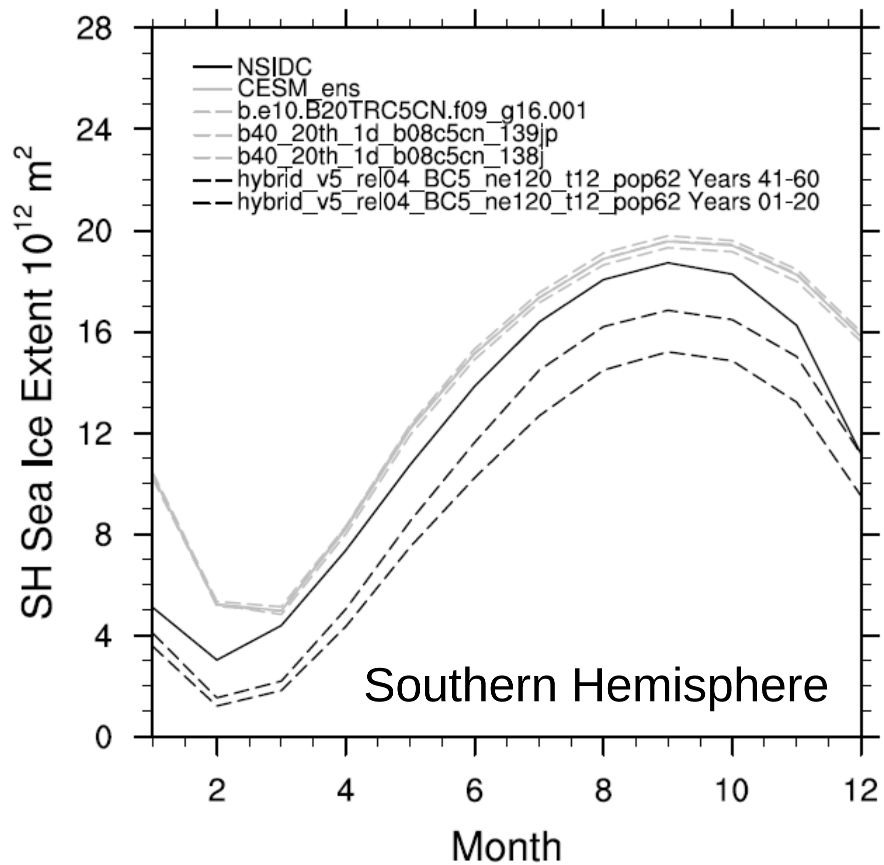
Fig. 1 Timeseries of globally-averaged quantities. a) Top of atmosphere net radiation, positive incoming to Earth. Thin solid line is annual mean timeseries and thick solid line is 10-year running mean. B) surface (ocean, land, ice) temperature, 10-year running average.

Climate Drift (2)

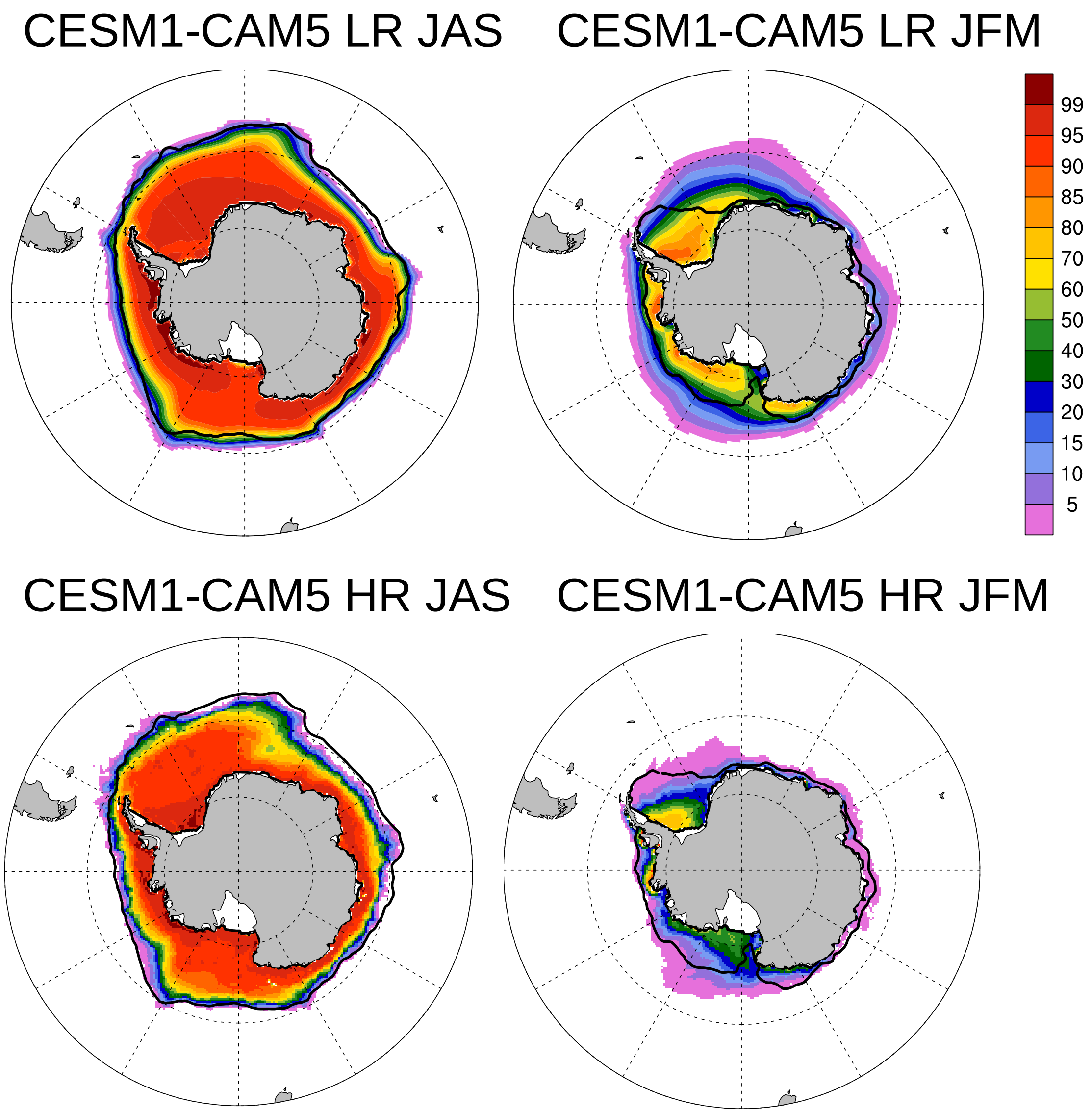


Sea Ice Extent Climatology





Ice Area



Top panels: standard res CESM1
Bottom panels: high-res CESM1

Data Access

- Data available
  - On hpss and spinning disk (/glade/p/ncgd0001)
  - on Earth System Grid (ESG)
  - http://www.earthsystemgrid.org/
- Data:
  - 14 year coupled spin up
  - 86 year main run

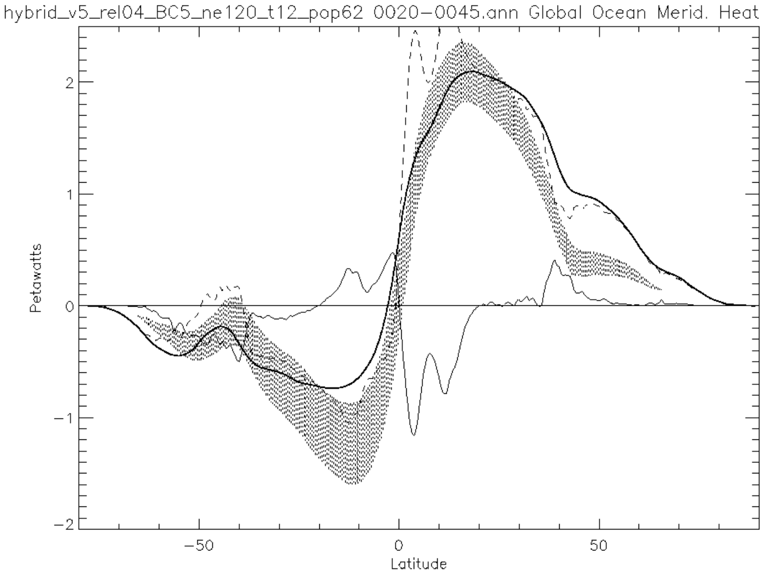
  Can be combined for 100 year run
  - 1 year of hourly data for limited # of fields (not yet posted)
  - 40 years of 6-hour or daily data for a number of ocean, atmosphere, ice, land fields

Animation

- Courtesy Tim Scheitlin (CISL, NCAR)
- Sea ice from year 14 of run.
- Color shows SST

Extra slides

Fig. 19. Heat transport



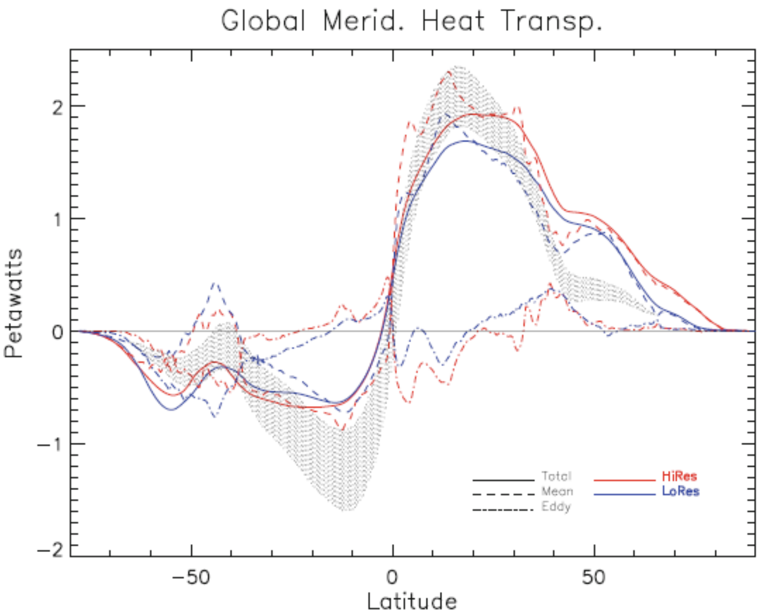


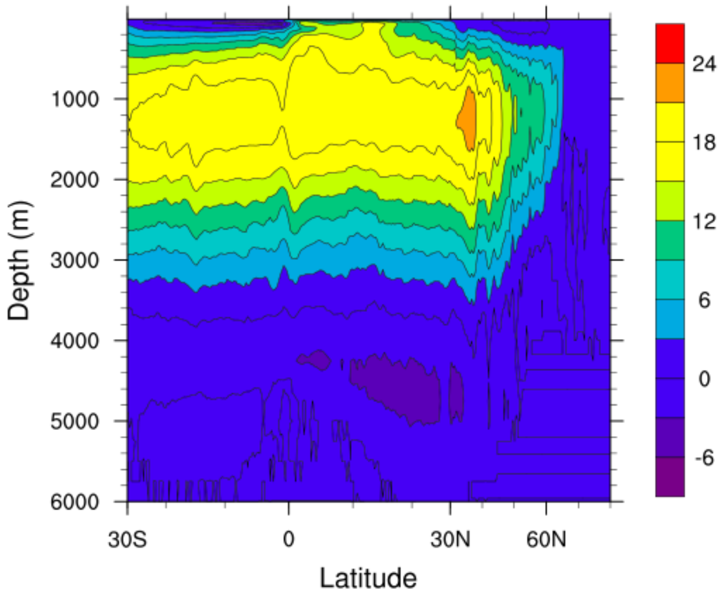
Fig. 16 Global northward meridional heat transport. HRC06 results are in *red* and LRC results are in *blue*. The *solid curves* give the total transport, the *dashed curves* give the mean transport and the *dot-dashed curves* give the eddy transport. The observed estimates are from Trenberth and Caron (2001) and units are in petawatts

ASD run yrs 20-45. Seasonal cycle included in eddy term (thin solid).

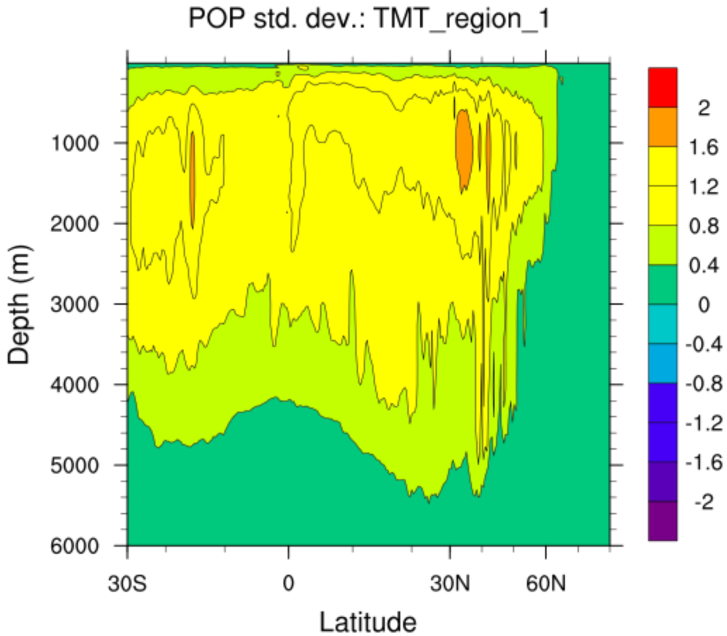
PetaApps runs (Kirtman et al 2012).

Overlay latest Trenberth estimate.

AMOC



Mean overturning streamfunction in Sverdrups



Standard deviation of interannual variability

(g)

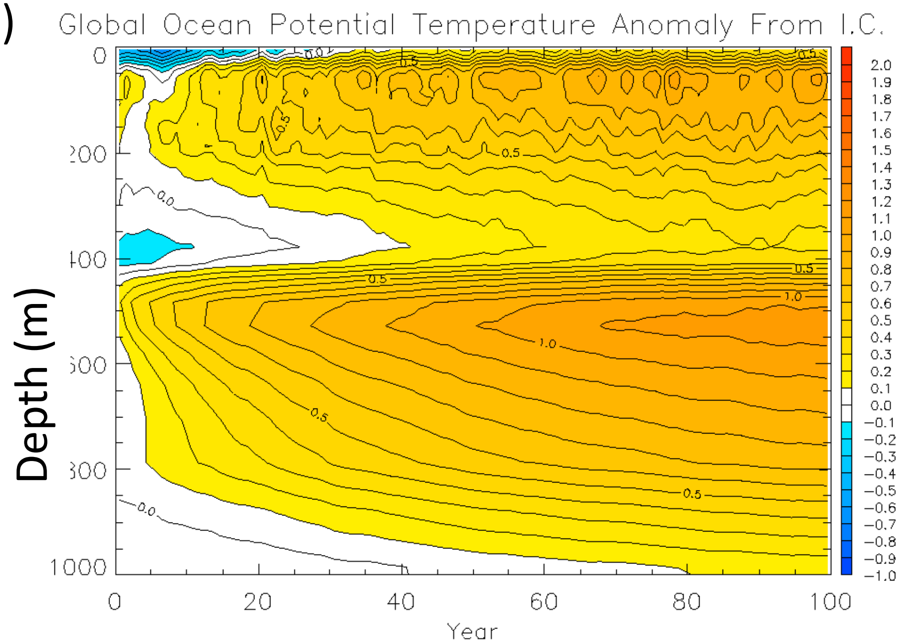


Fig. 1 Timeseries of globally-averaged quantities. g) globally averaged ocean potential temperature, vs depth to 1000m

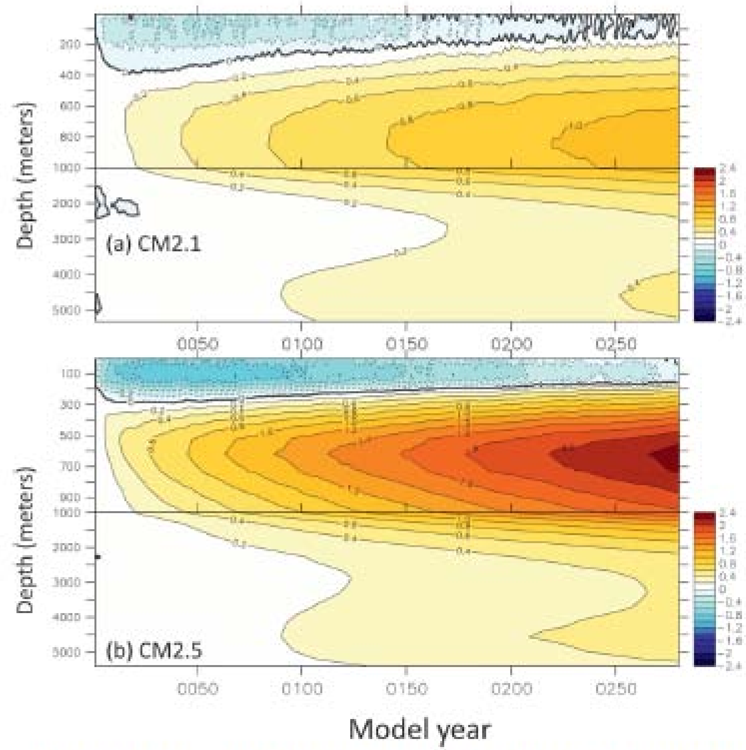


FIG. 3. Subsurface ocean temperature drift from initial conditions for (a) CM2.1 and (b) CM2.5. The values plotted are the differences between the global mean, annual mean temperature at each year minus the global mean, annual mean value at year 1. Units are K. Positive (negative) values indicate the subsurface ocean has warmed (cooled). Note the difference in the vertical scales above and below 1000 m.

Right: As left but from GFDL CM2.1 (standard res) and 2.5 (high res, 0.5deg atm, ~1/4deg ocn), first 250 years. Delworth et al. 2012.
They find big improvement going to 1/10deg ocean (CM2.6).
speculate that parameterizing (CM2.1) or fully resolving ocean eddies (in CM2.6) reduces the subsurface warming, whereas partly-resolving eddies has a detrimental effect (CM2.5).

Community Earth System Model (CESM) high-resolution simulations

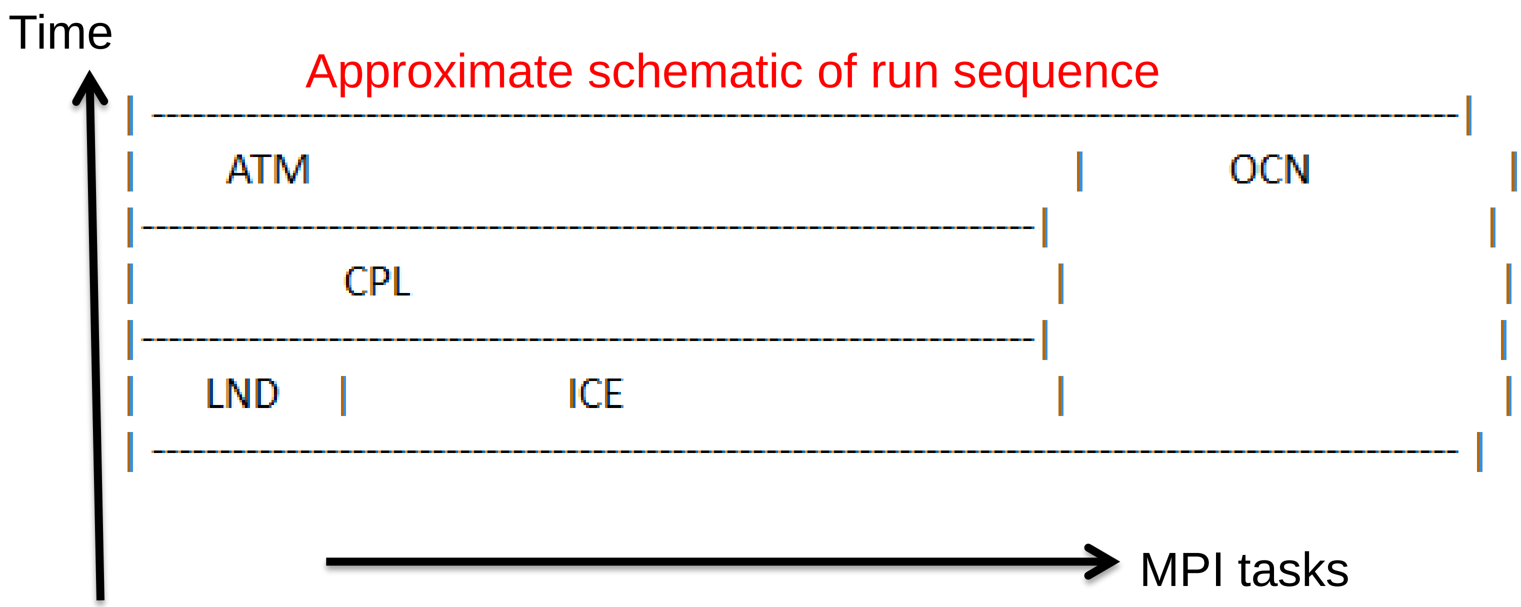
- Main coupled run
  - 100 years of fully coupled simulation for “Present day” (year 2000) greenhouse gas emissions
  - Short (1 year) ocean-ice spin up from Gouretski and Koltermann (2004) climatology of WOCE and other data, forced by CORE
  - 6 hour ocn-atm coupling

Supporting simulations

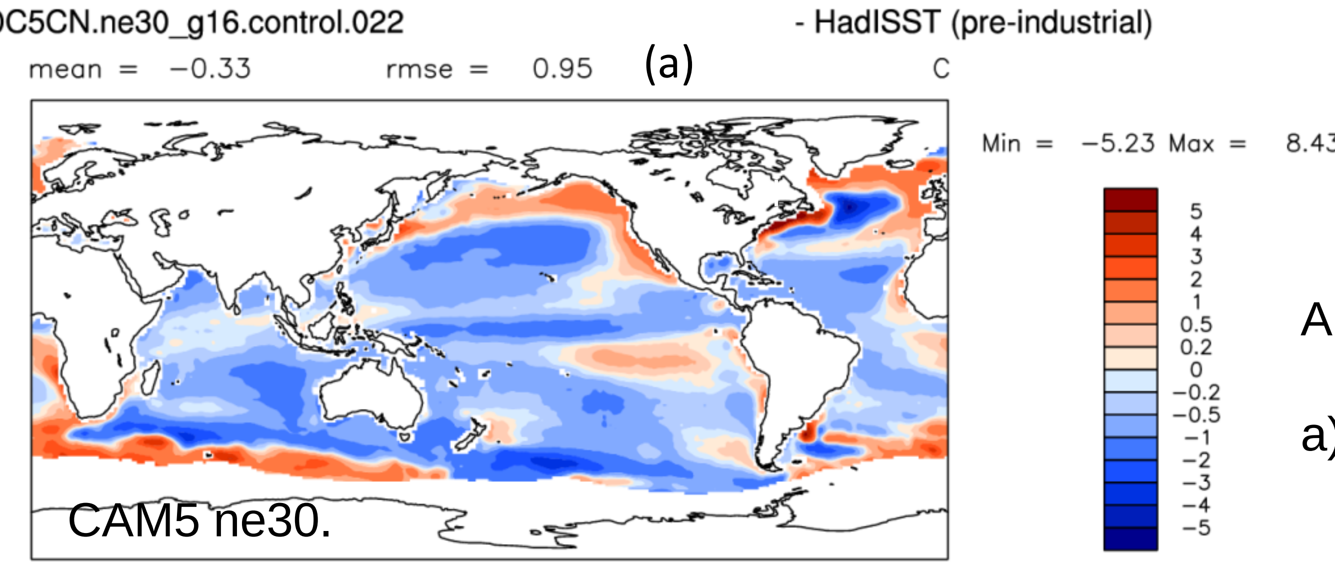
- 15 year CORE forced ocean-ice runs
- 7 year atmosphere-only runs (x2) – high res SST
- 10 year “smoothed SST” coupled run
- 1 year high frequency coupling run (1 hour)
- High vertical resolution CAM5-SE runs

Performance on Yellowstone

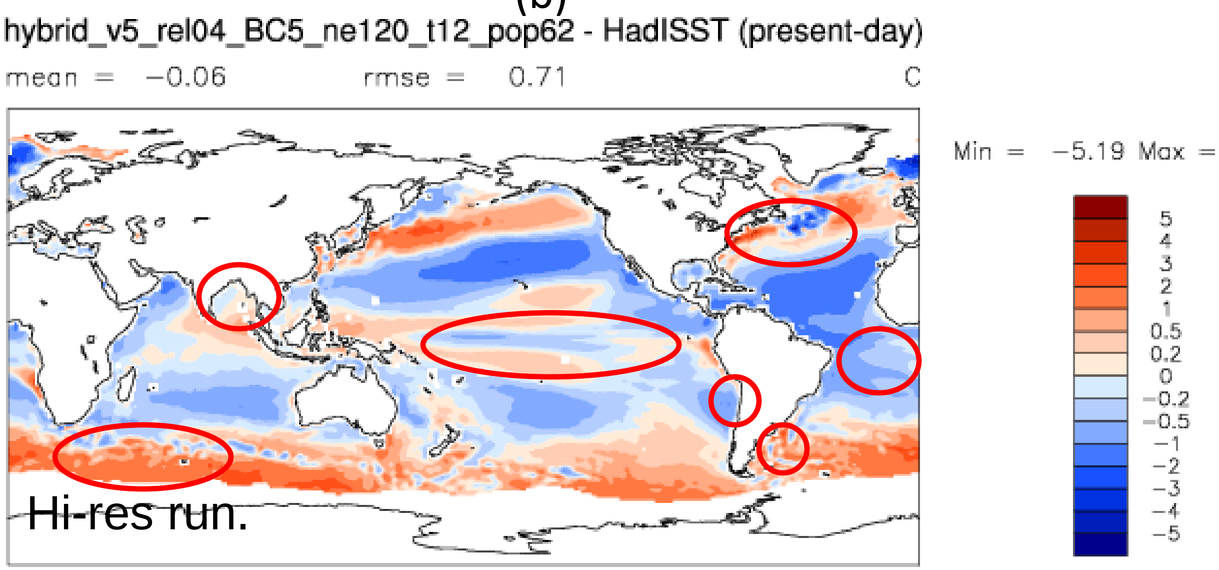
- Statistics:
  - 2.0 simulated years per day
  - 1 TB of data generated per day
  - 23,404 cores of Yellowstone
  - 300K pe-hours per sim. Year
  - Ocean 2 minute timestep
  - Atmos 10 or 15 minute
- Component configuration
  - Ocean model (6,124 cores)
  - Sea-ice model (16,295 cores)
  - Atmosphere (17,280 cores)
  - Land (900 cores)
  - Coupler (10,800 cores)



SST climatology - bias



(b)



Annual mean SST bias.

a) CESM with CAM5 ne30-1v6. 1850 control run. Yrs 111-130

b) High-res global run

a) is relative to HadISST (pre-industrial) and b) relative to HadISST (present day).

Precipitation climatology & bias

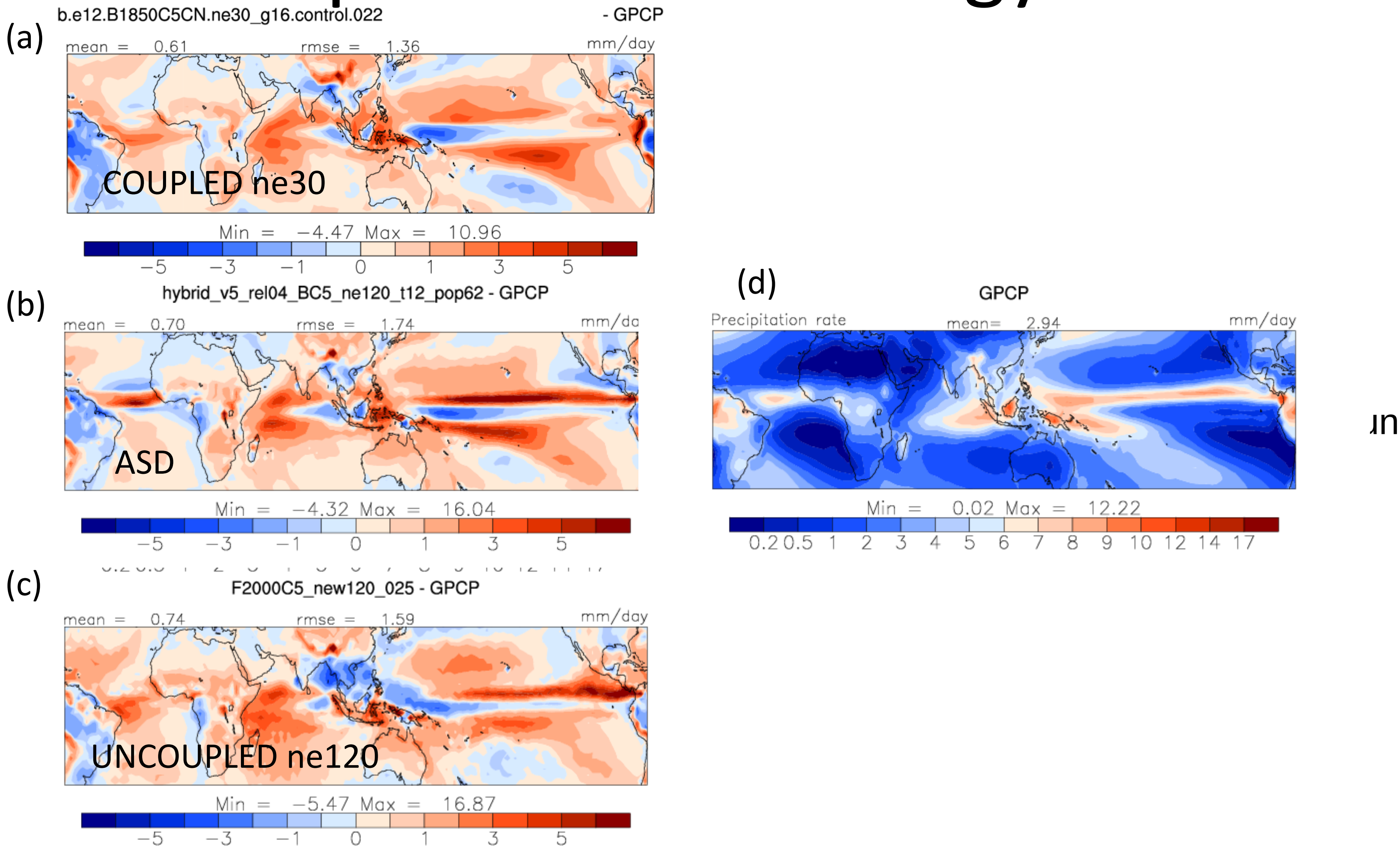
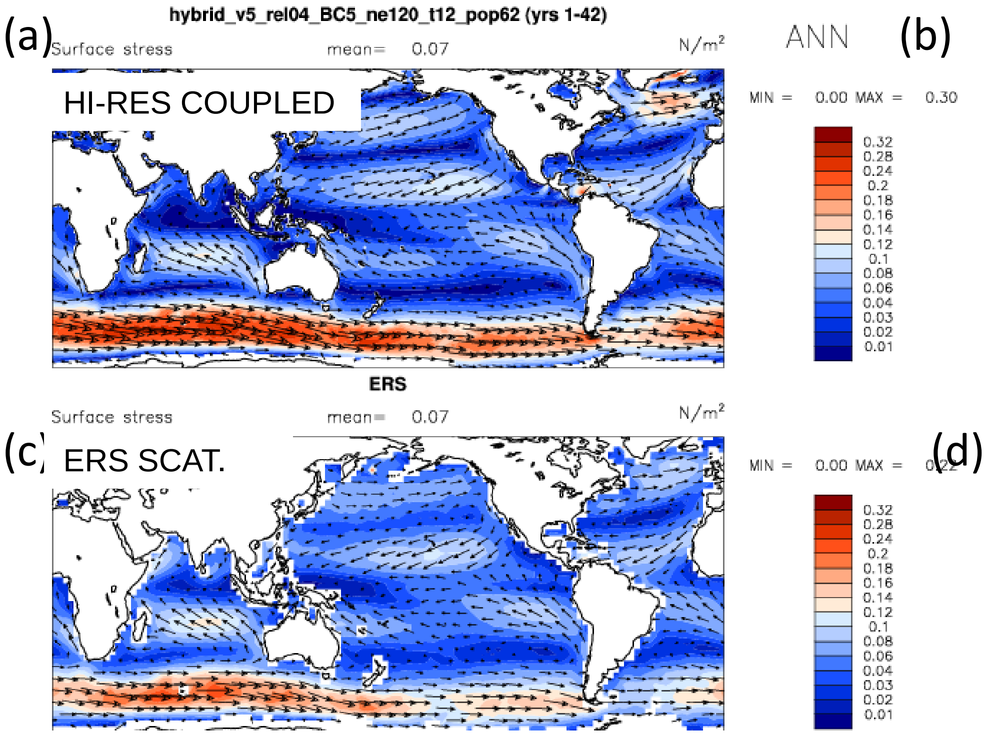


Fig. 4. Precipitation bias fields for annual mean climatology, relative to GPCP. A) CESM with ne30 (1850 run) b) coupled high resolution run c) uncoupled ne120 run d) Full GPCP field.

Wind stress climatology & bias



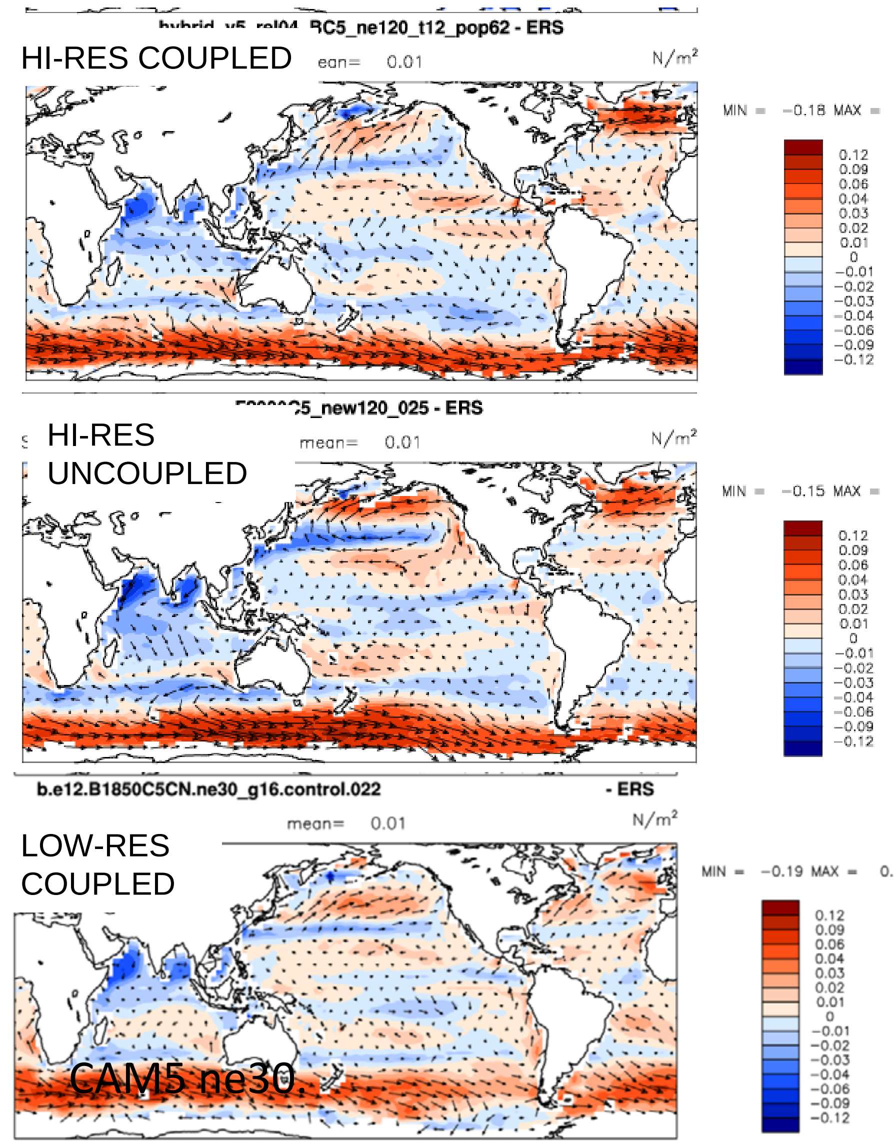


Fig. 5. Surface wind stress (vectors) and magnitude of mean stress vector in color. Annual mean climatology. a) High-res Coupled run c) ERS scatterometer. b, d,e) difference of model and ERS scatterometer, b) High-res coupled d) atmosphere-only and e) low-res coupled (CAM5-ne30-1850 run).