# Discussion topics

- Model Top
- Vertical Resolution  (30 min max for above)
- Dynamical Core (10 min)
- Physics Ideas (10 min)
- Model Biases (20 min)

# Model Top & Vertical Resolution: Thoughts for Discussion

Thanks to: Richter, Medeiros, Bacmeister, Garcia

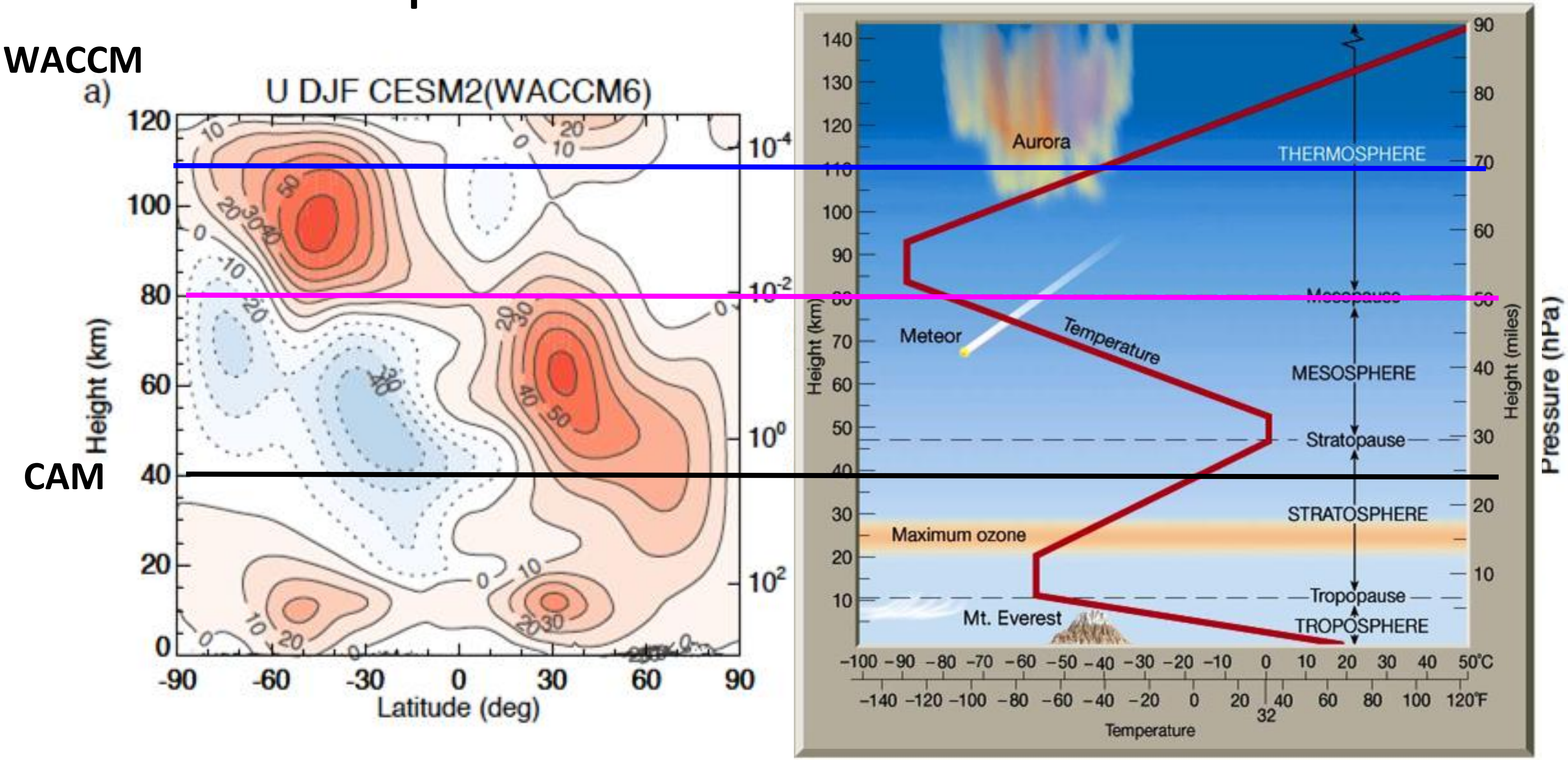
# Motivation

- Model top and vertical resolution are separate issues
- 32L CAM and 70L WACCM seem like too much of a compromise now
- Want to meet more science objectives
- Constraints for a community model
  - Minimal number of configurations
  - Maximum computational efficiency where needed
- Assumption: Atmosphere cost scales linearly with vertical levels?

# Model Top

- Most ‘surface’ applications do not want a high top (CAM6 fine): max efficiency
- WACCM science:
  - Want a lid at 110 (turbopause) to 140km.
  - WACCM-X Higher
- Middle atmosphere
  - Impacts all the way into the UTLS and even surface in polar regions.
  - Most other global models have a lid at ~80km
  - 80 km does not close off the jets (leaves GW momentum & other issues). 110km better.
- This could argue for a baseline @80 or 110km (110km minimum for ‘WACCM’)
  - Special applications higher and lower
  - What WACCM parameterizations go into 80-110km model? GW, maybe not Aurora.
  - Does CAM then become WACCM-SC with a 80km top?

# Model Top….


WACCM
a)
U DJF CESM2(WACCM6)
Height (km)
Latitude (deg)
CAM
Aurora
THERMOSPHERE
Mesopause
Meteor
Temperature
MESOSPHERE
Stratopause
STRATOSPHERE
Maximum ozone
Tropopause
Mt. Everest
TROPOSPHERE
Height (km)
Height (miles)
Pressure (hPa)
Temperature

# Vertical Resolution

## Requirements vary by height

- PBL: arguments for more resolution in the lower troposphere.
  - Current = 9 levels below 700hPa, Ideal might be 25
- Free trop: currently dz = 1.2km, probably half that is ideal (0.6km)
- WACCM: UTLS and stratosphere: want ~500m up to 25-30km for GW propagation (QBO, strat-trop interactions).
  - Need to test what dz is needed, and how high it should go (e.g. SAO impact)
  - 110L WACCM is a reasonable model for this….
  - Also recall Garcia talk on QBO

# PBL versus free-troposphere

- Proposals to increase # of levels in CAM/WACCM in the free-troposphere and stratosphere by around a factor of 2
  - Impact on model physics tuning is modest
- Proposed increases in PBL resolution are +25% of total levels
  - cost not as big an issue
  - major impacts on physics - significant development effort (think this is deep convection, can build on other efforts)

# Ideas

- How much slow down for vertical levels will CESM tolerate?
- Sacrifice run time or # ensembles for better science?
- Long-running discussion: *~2x cost vs potential improvements*
- What are different models for (science), how many do we have?
- Have said: ‘don’t do BDC, SSWs, QBO in CAM’, use WACCM.

# Ideas (2)

- Could we aim for a ‘standard’ model (or is this too much of a compromise)?
  - Lid : ~80 or 110km (110km = Turbopause). Note 80-->110km is ~10 levels
  - Resolution: ~20 levels below 700 hPa in PBL, ~0.6km in free trop through UTLS
  - WACCM GW parameterizations
- Maintain as optional configurations (functional support with compsets):
  - ‘WACCM’ version with 140 km and ~110L (or more) + Ions, Aurora, etc
  - Low resolution, low top CAM (40km, 32L)
  - WACCM-X
    - 500-750km, Geomagnetic coordinate coupling, eventually deep atmos core
- Or: is current structure better (High top, low top)?
  - CAM/AMWG go to 80km, 70-80L, WACCM to 110 or 140L? Standard or options?
  - Both CAM and WACCM maintain a ‘standard’ and ‘high’ vertical resolution?

# Possible Path Forward

- Test a 110km, ~90L version
  - Lid ~110km
  - Close to 110L WACCM resolution (but 10-20 levels less since lower)
  - ~0.6km in free trop
  - ~0.6km in UTLS then less resolution in upper stratosphere and above
  - WACCM GW parameterizations
- Separately: Increase PBL resolution
  - ~20 levels below 700hPa in PBL
- Goal is to merge these threads, but not have one hold up the other
- Discuss a factor of 2x with the CESM community
  - Recognizing ’options’ for higher (WACCM) and lower (L32) lids and resolution

# Dycore for next version of CESM

- Letter to Gokhan Danabasoglu, JF Lamarque, and SSC

…

We would like to start a conversation with you about choosing a dynamical core for the next version of CAM/CESM, and about the SSC's potential input on that decision. We agree that it is important to choose a new dycore for CAM now, but we think MPAS and FV3 still need a lot of work before they are ready for use in CAM. In contrast, the spectral element (SE) dycore is far enough along in its implementation in CESM that only a small additional effort is required to make this an excellent choice for the next phase of CESM development. The SE dycore is highly scalable, possesses flexible regional refinement capability, and has state-of-the-art tracer transport in the CSLAM algorithm, which is now fully implemented. Finally, we would note that there is significant in-house expertise within CGD on both technical and scientific aspects of this dycore.

In the near future, once MPAS and FV3 are fully implemented and tested in CESM, it will make more sense to revisit CAM's choice of dycore. Unlike for convection, we don't believe the best way to do this is by tuning/running the model with the various dycores and comparing climate statistics. All dycores evaluated have very low error compared to physics parameterizations, so simulation differences will probably be slight and luck in tuning will probably determine the winner in such an evaluation. Instead, we advocate evaluating the dycores based on inherent properties, such as computational performance, energy and momentum conservation, robustness across a wide spectrum of flow phenomena, diffusion characteristics, regional refinement capability and general compatibility with the interests of the CESM community.

Yours truly,

AMWG Co-chairs

- SE is good short term choice
    - scalable
    - flexible refinement capability
    - excellent tracer advection scheme
    - in-house expertise
- FV3 and MPAS will be integrated within 1 to 1.5 years
    - Evaluation should focus on inherent dycore properties r

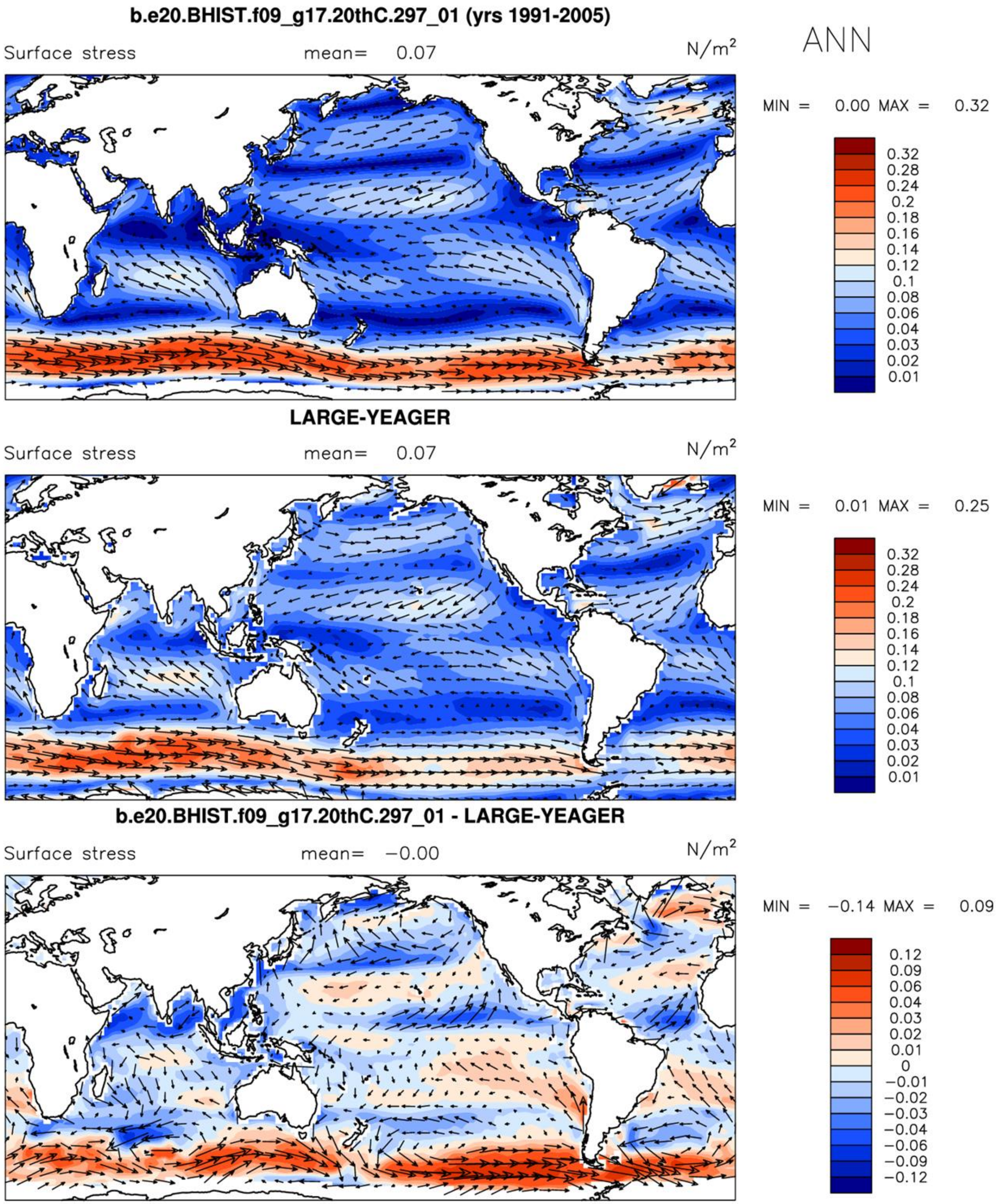
# New Physics

- CLUBB Momentum
- SILHS (sub-columns)
- ULL convection (*S. Xie*)
- Water Isotopes
- MG3 (Graupel) and beyond (unified ice)
- GW (time-dependent orographic waves, *C. Kruse)*

# Critical/resilient biases

- Southern ocean wind stress
- Excessive zonal winds in SH winter/cold bias/late vortex breakup
- March SSWs
- US midwest warm/dry bias (other MCS dominated regions as well)
- orographic precipitation biases (remote impacts; e.g. Amazon)
- Double ITCZ
- … ?
- ***new CESM2 bias ?:*** Sea-level pressure
- Aerosol biases
- Marine StCu better but not gone
- Excessive aerosol/cloud interactions?
- Higher order statistics of precipitation
- Climate sensitivity
- Cold and wet -

ANN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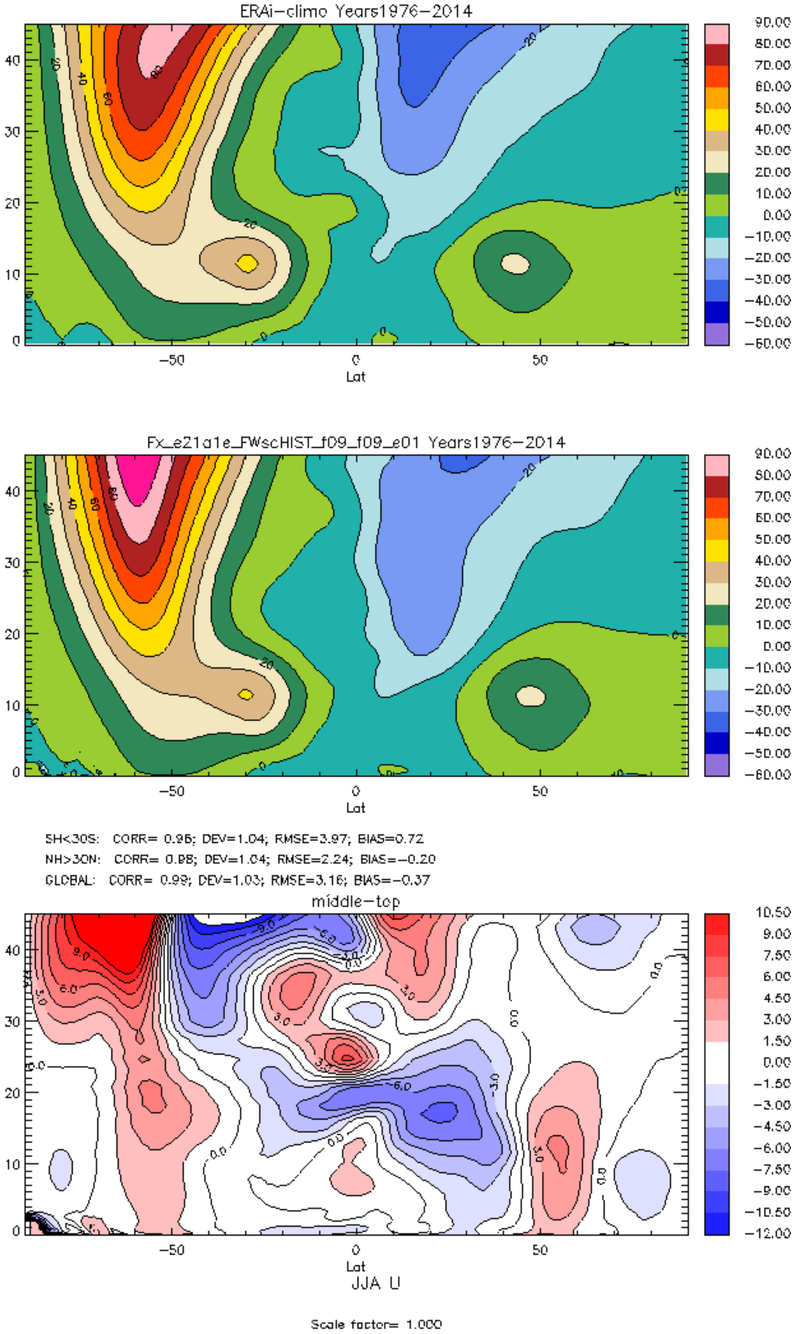
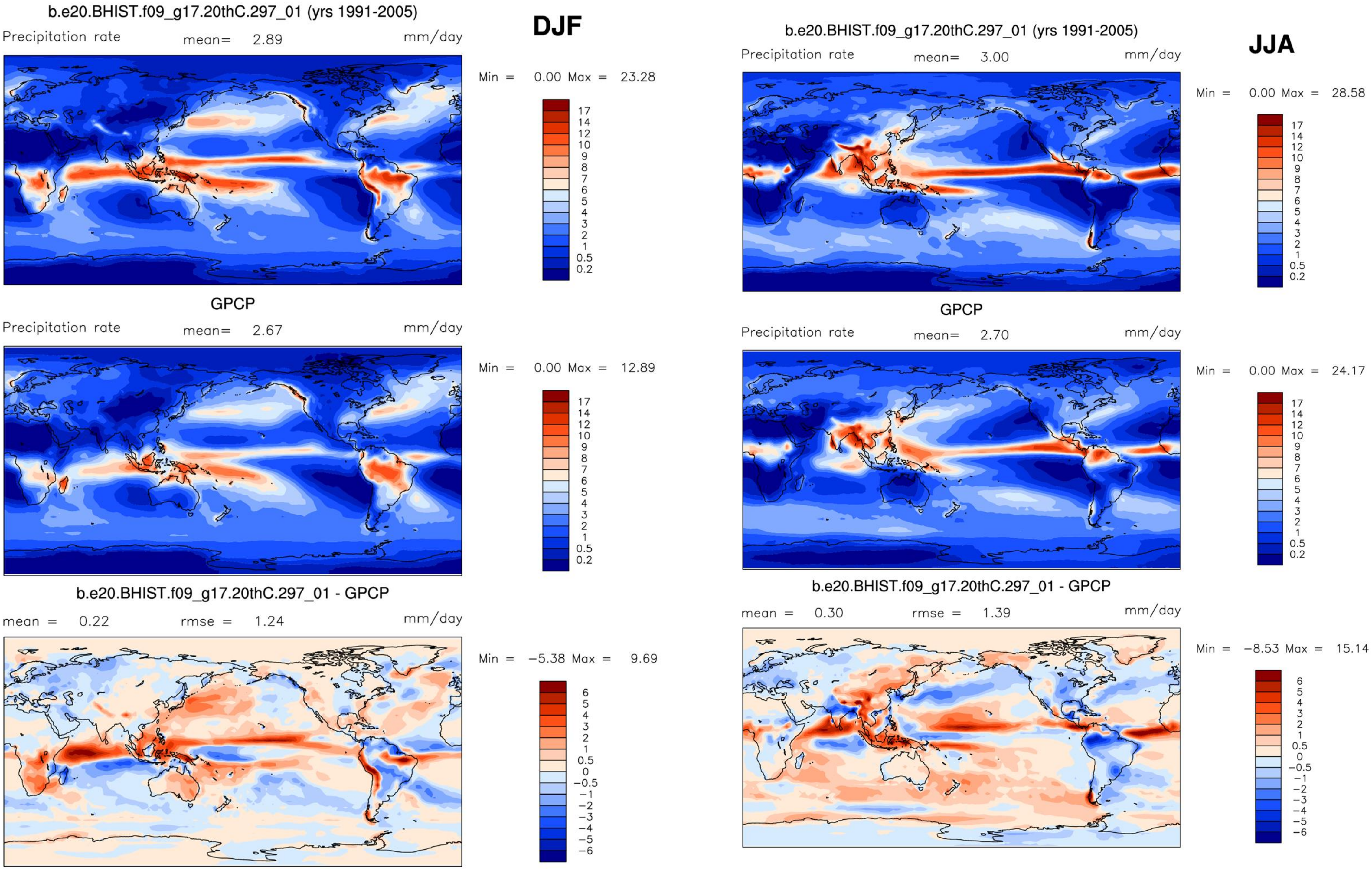
Surface stress mean= 0.07 N/m²
MIN = 0.00 MAX = 0.32
LARGE-YEAGER
Surface stress mean= 0.07 N/m²
MIN = 0.01 MAX = 0.25
b.e20.BHIST.f09_g17.20thC.297_01 - LARGE-YEAGER
Surface stress mean= -0.00 N/m²
MIN = -0.14 MAX = 0.09


ERAi-climo Years1976-2014
Lat
Fx_e21a1e_FWscHIST_f09_f09_e01 Years1976-2014
Lat
SH<30S: CORR= 0.96; DEV=1.04; RMSE=3.97; BIAS=0.72
NH>30N: CORR= 0.98; DEV=1.04; RMSE=2.24; BIAS=-0.20
GLOBAL: CORR= 0.99; DEV=1.03; RMSE=3.16; BIAS=-0.37
middle-top
Lat
JJA U
Scale factor= 1.000


DJF
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Precipitation rate mean= 2.89 mm/day
Min = 0.00 Max = 23.28
17 14 12 10 9 8 7 6 5 4 3 2 1 0.5 0.2
GPCP
Precipitation rate mean= 2.67 mm/day
Min = 0.00 Max = 12.89
17 14 12 10 9 8 7 6 5 4 3 2 1 0.5 0.2
b.e20.BHIST.f09_g17.20thC.297_01 - GPCP
mean = 0.22 rmse = 1.24 mm/day
Min = −5.38 Max = 9.69
6 5 4 3 2 1 0.5 0 −0.5 −1 −2 −3 −4 −5 −6
JJA
b.e20.BHIST.f09_g17.20thC.297_01 (yrs 1991-2005)
Precipitation rate mean= 3.00 mm/day
Min = 0.00 Max = 28.58
17 14 12 10 9 8 7 6 5 4 3 2 1 0.5 0.2
GPCP
Precipitation rate mean= 2.70 mm/day
Min = 0.00 Max = 24.17
17 14 12 10 9 8 7 6 5 4 3 2 1 0.5 0.2
b.e20.BHIST.f09_g17.20thC.297_01 - GPCP
mean = 0.30 rmse = 1.39 mm/day
Min = −8.53 Max = 15.14
6 5 4 3 2 1 0.5 0 −0.5 −1 −2 −3 −4 −5 −6