NCAR(CESM) Center Report

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NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH   NESL's Climate & Global Dynamics CGD   U.S. DEPARTMENT OF ENERGY   NSF

WGNE Meeting, Melbourne Australia, 11 March 2014

Overview

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Infrastructure:

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- Sub-columns
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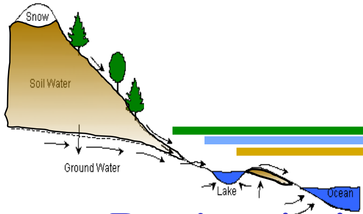


Changes for CLM4.5 for CESM1.2

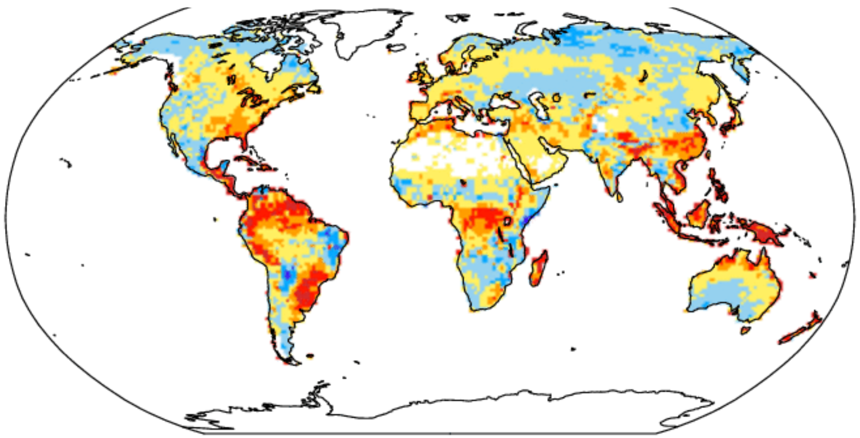
(David Lawrence)

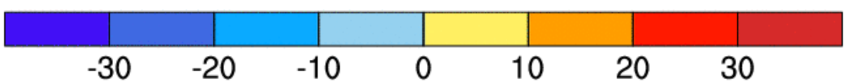
- Revised photosynthesis model, multilayer canopy, temperature acclimation, iterative calculation fix (Bonan et al., 2011, 2012; Sun et al., 2012)
- Cold region hydrology and snow fix (Swenson et al. 2012, Swenson and Lawrence, 2012)
- CENTURY-like vertically resolved soil biogeochemistry and revisions to nitrogen dynamics (Koven et al., 2013)
- New lake model (Subin et al., 2012)
- CH_4 emissions (Riley et al., 2011; Meng et al. 2012)
- Revised fire model (Li et al., 2012; 2013)
- Fertilization, irrigation, organs pool, and other updates to crop model (Drewniak et al., 2013; Levis et al., 2012; Sacks et al. 2009)
- Prognostic wetland distribution model (Swenson and Lawrence, in prep)
- CLM/RTM interactions, flooding (default off) (Swenson and Lawrence, in prep)
- VIC hydrology (alternative hydrology) (Li et al., 2012)
- ^{13}C, ^{14}C enabled
- Multiple urban classes
- … and several minor and major bug fixes, speedup of BGC spinup

Reduced biases in CLM4.5

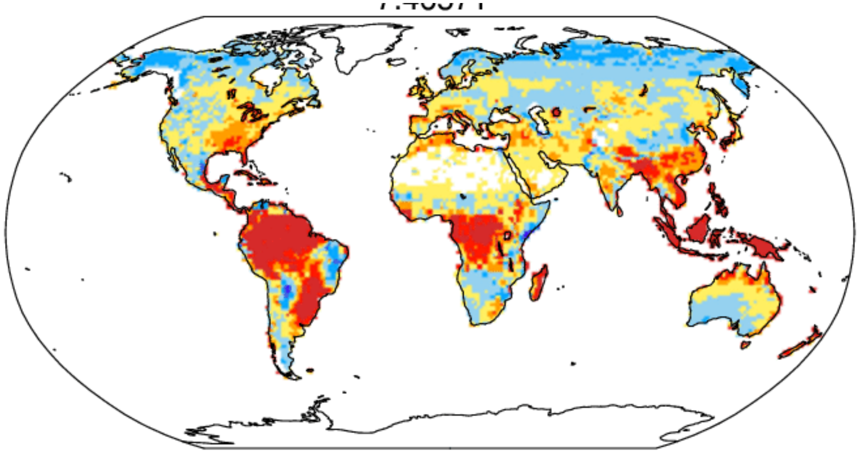
ANN Latent Heat bias (obs: FLUXNET MTE)

CLM4.5BGC

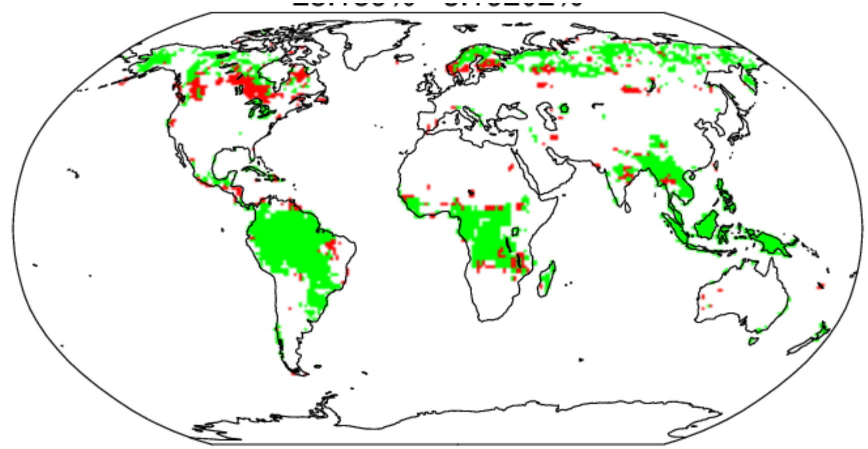




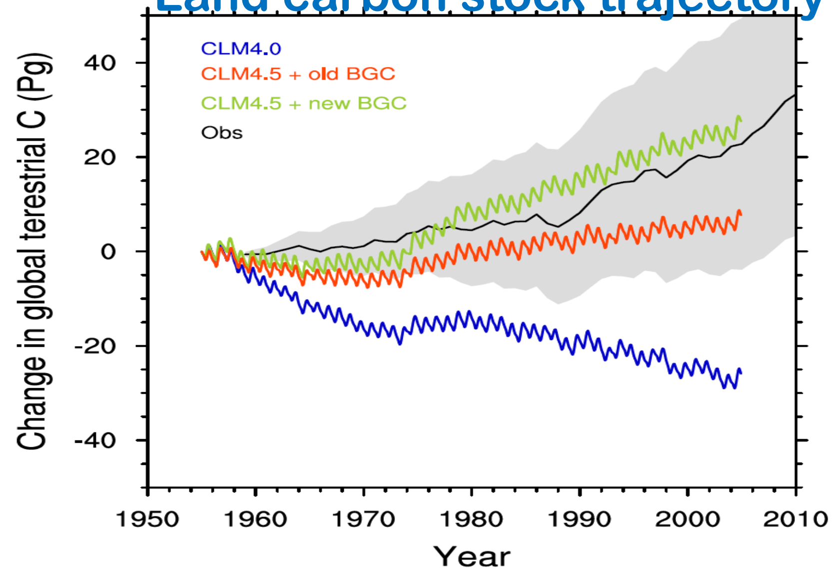
CLM4CN



Green: Improved in CLM4.5
Red: Degraded in CLM4.5

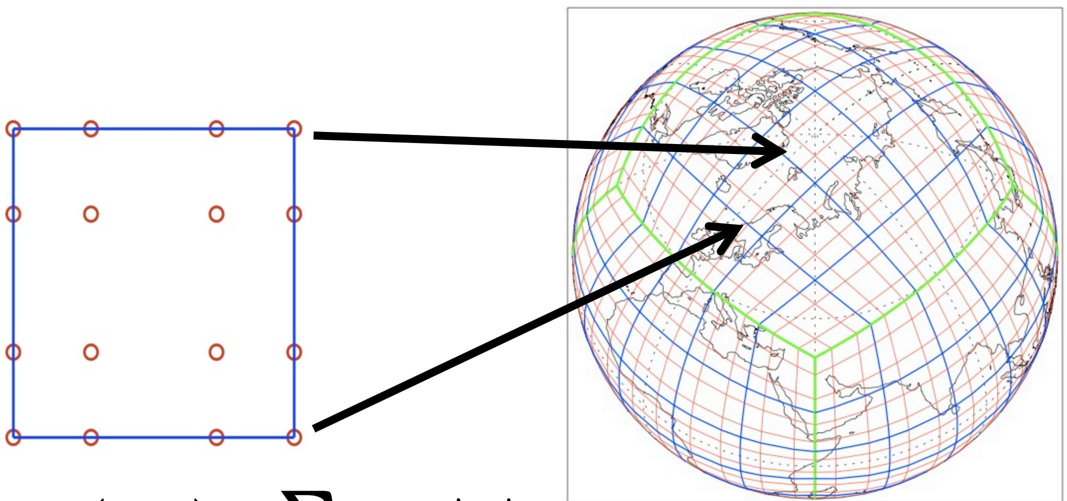


Land carbon stock trajectory



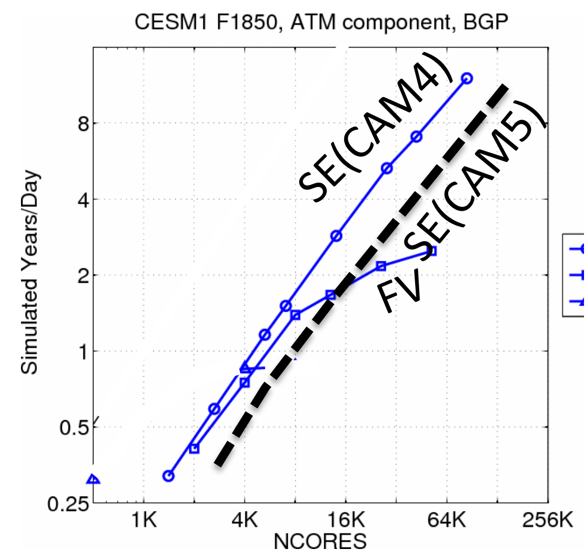
CAM-SE (spectral element) dynamical core

(M. Taylor, DoE Sandia Lab
Peter Lauritzen NCAR AMP)



$$\Psi_k(x,y) = \sum_{i+j\le 3} c_{i,j}x^i y^j$$

25 km timings



- **Current performance on Yellowstone ~150,000 to 200,000 cpu hrs/SY (high-frequency output adds 15-30%) on 20,000 cpus → 2.5 SY/day**
- **Currently ~1.5x slower per processor than FV (*for CAM5*), but scales linearly to 1 cpu/element. New tracer advection code "CSLAM" should make SE comparable to FV**
- **Why go to SE? *Scalability, regional refinement, better code design***

SE Development 2012-2014

- Lagrangian vertical advection as in FV
    - Explicit divergence damping
- ***Traceable (and general) procedure for generating surface topography and consistent subgrid topo variances with flexible topographic smoothing***

(As important as dycore swap itself)

On-going but not yet implemented

- *Conservative semi-lagrangian tracer advection in the horizontal (CSLAM)*
- *Flexible physics grid*

SE "milestone" simulations

- AMIP runs at 100 km
  - SE/FV climates are close
- Coupled runs 100km atmos/1^o ocean *on-going*
  - SE ➔cooler ocean than FV (low-level wind?)
- AMIP runs and time-slice runs at 25 km
  - 25 km FV and SE AMIPs are close, more TCs/year globally in SE
- Coupled 25km atmos/0.1^o ocean
  - *Ocean warms!!?? (reduced clouds in 25km atmos)*

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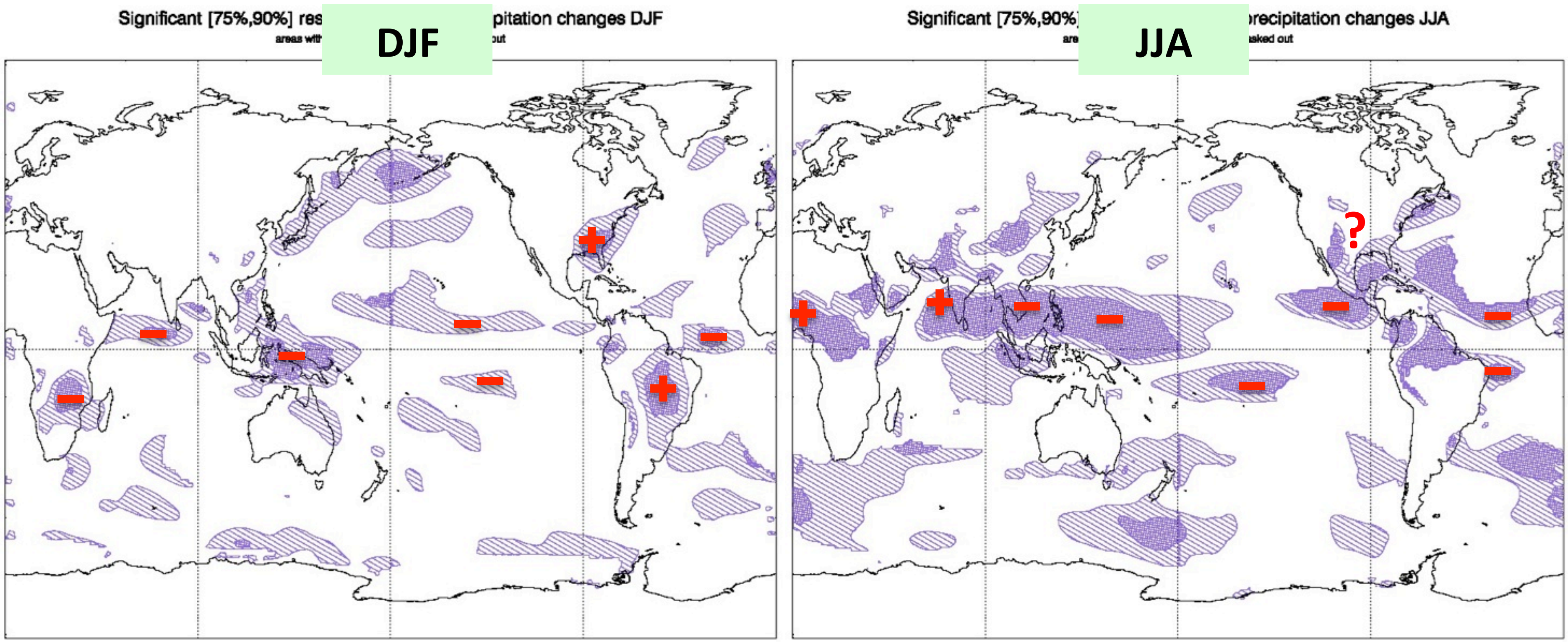
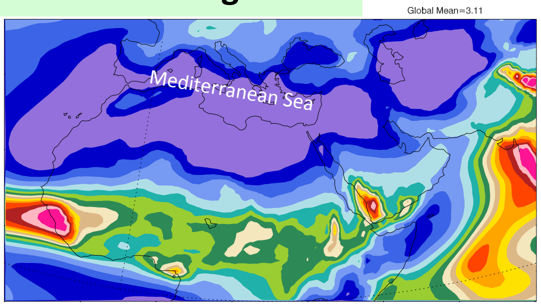
Significant (75%, 90%) precipitation changes going from 1° to ¼° resolution



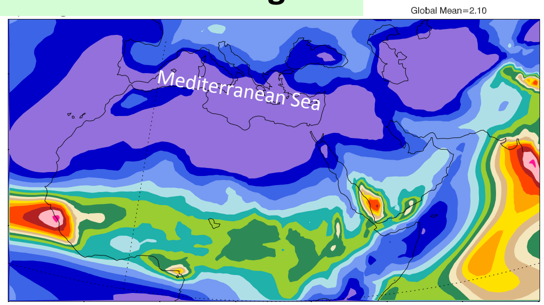
- **+** Better at 25km resolution
- **–** Worse at 25km resolution
- **?** ***Central US summer precip unchanged by resolution***.

JJA mean precipitation 1980-2005 (Africa)

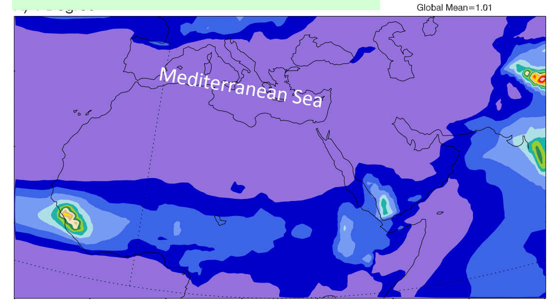
Total 1 degree

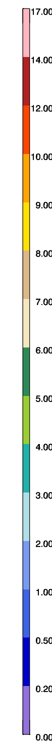


Convective 1 degree

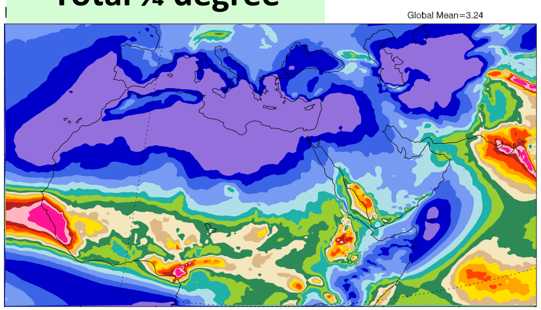


Large-scale 1 degree

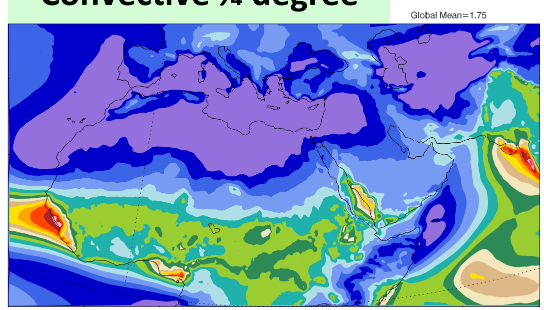




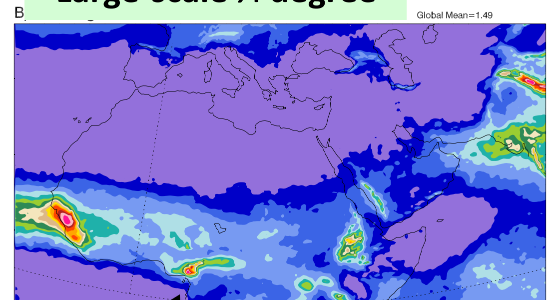
Total ¼ degree



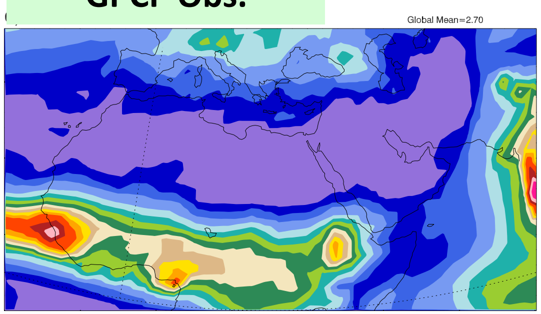
Convective ¼ degree



Large-scale ¼ degree

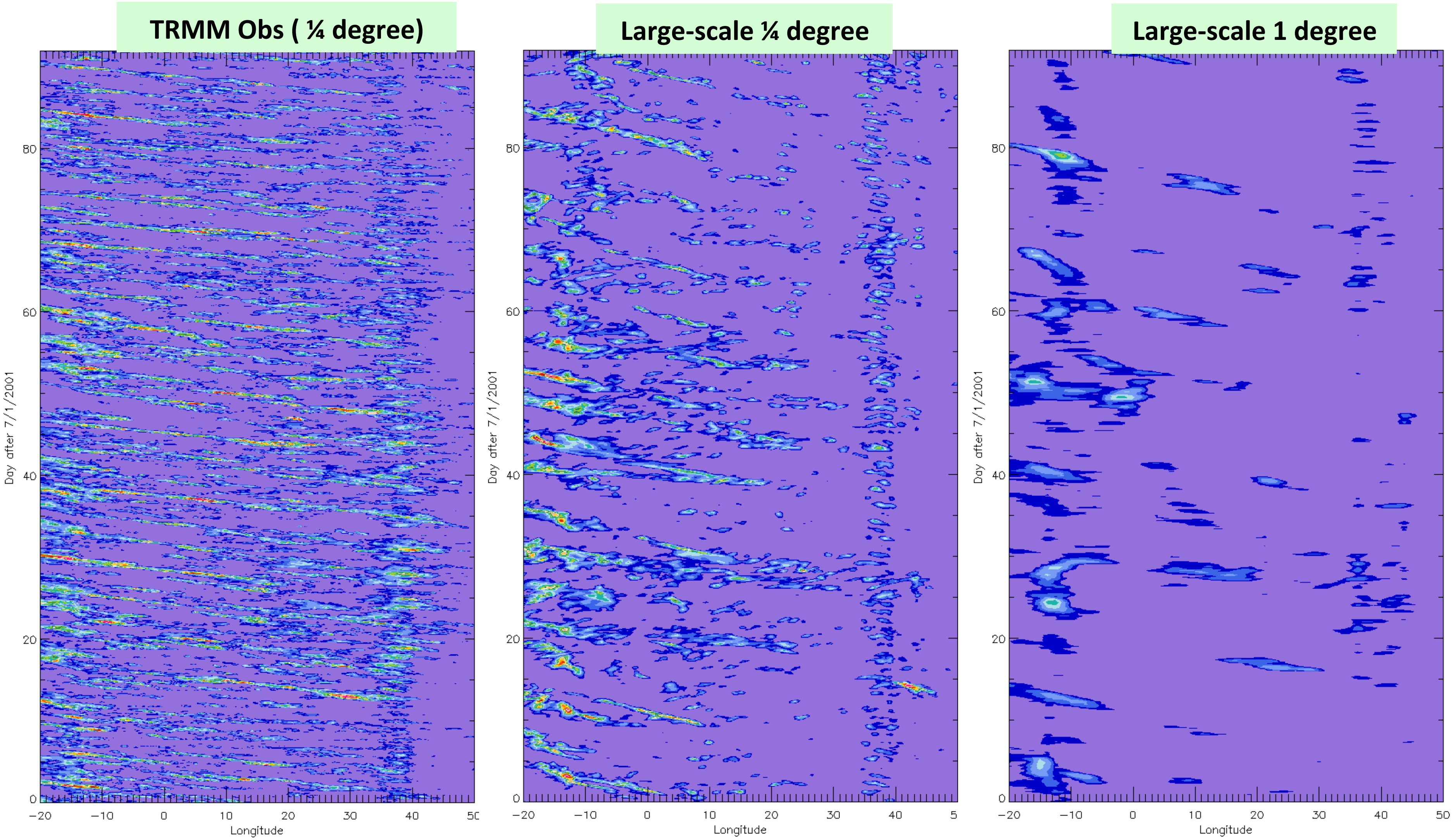


GPCP Obs.



Reduction in dry bias is brought about by increased large-scale precipitation

Precipitation Hovmuellers; June 1-Aug. 31, 2001; 7ºN-18ºN average



Westward-propagating systems appear in large-scale precipitation

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Tuning: *Convective timescale*

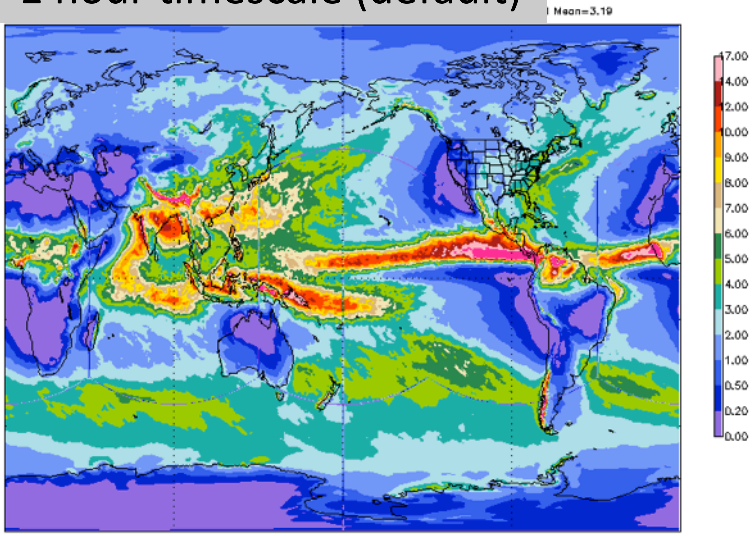
$$\phi = \frac{\Delta t}{\boxed{\tau}} \phi^*$$

Controls activity of parameterized deep convection

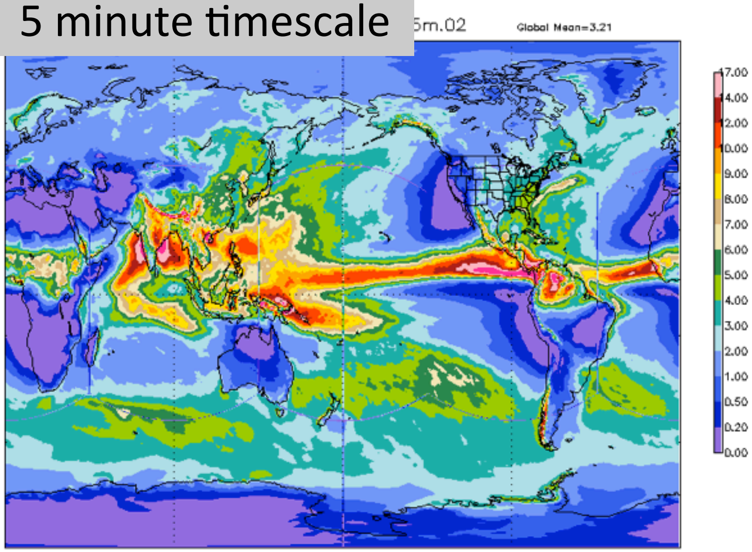
shorter timescale ➔ convection acts quicker, does "more work" in the simulation

Total precipitation

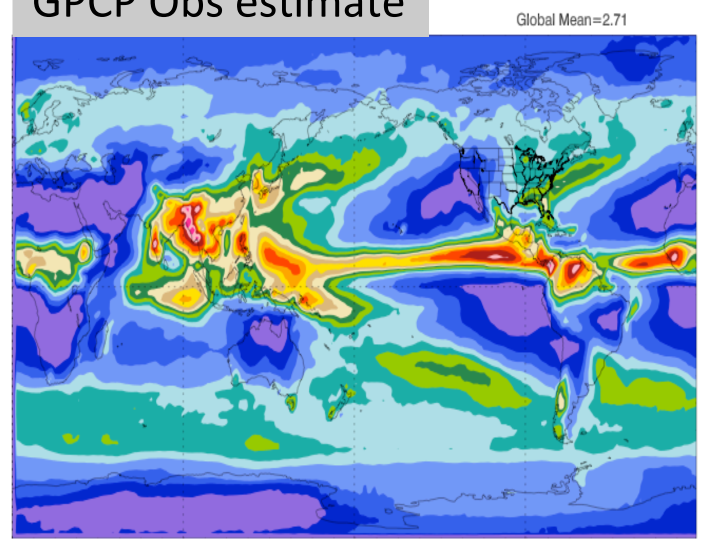
1 hour timescale (default)



5 minute timescale

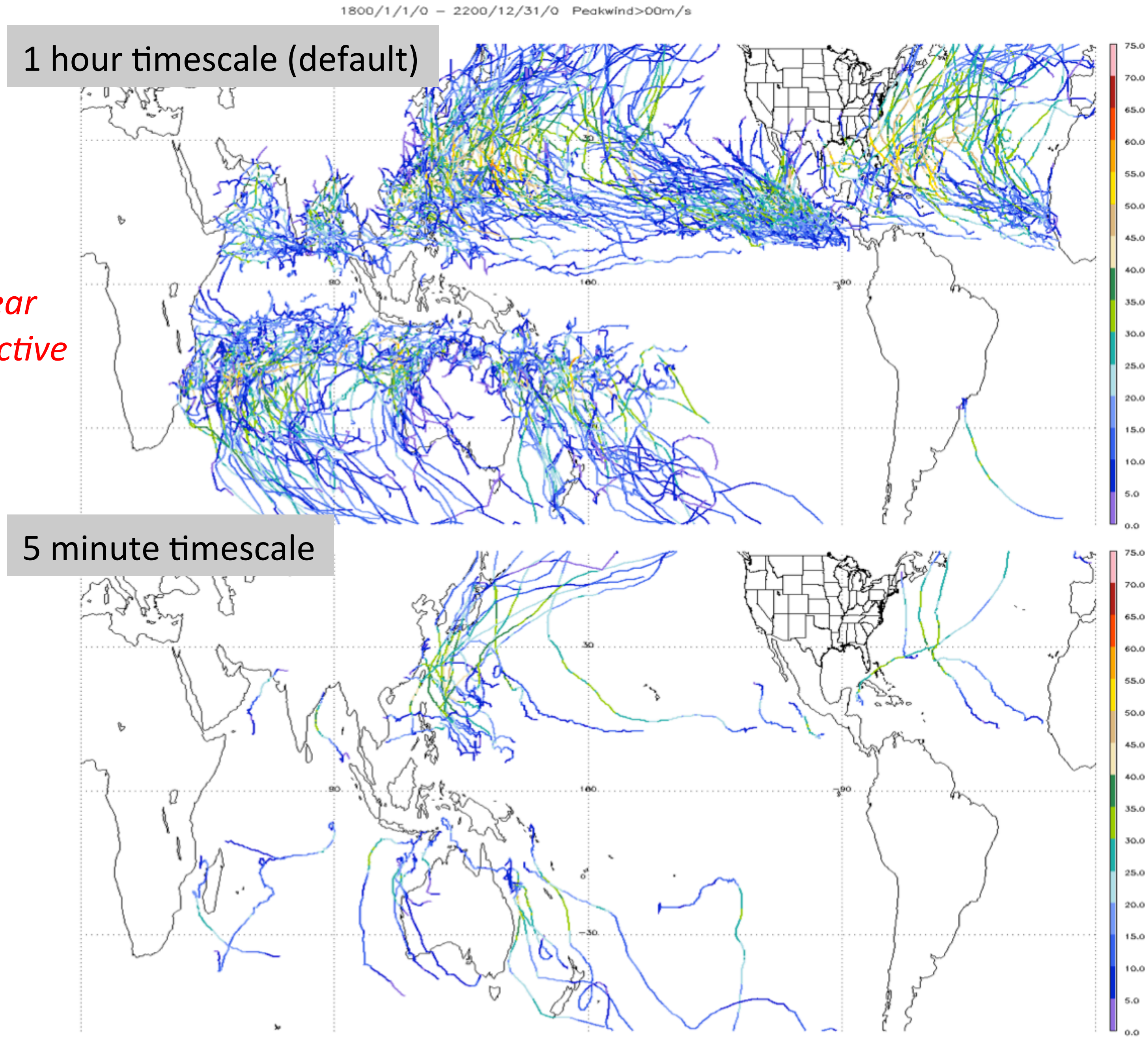


GPCP Obs estimate



Seasonal mean patterns appear to improve somewhat with shorter convective timescale

Simulated TC tracks 2000-2005



But …

Hurricanes disappear with shorter convective timescale

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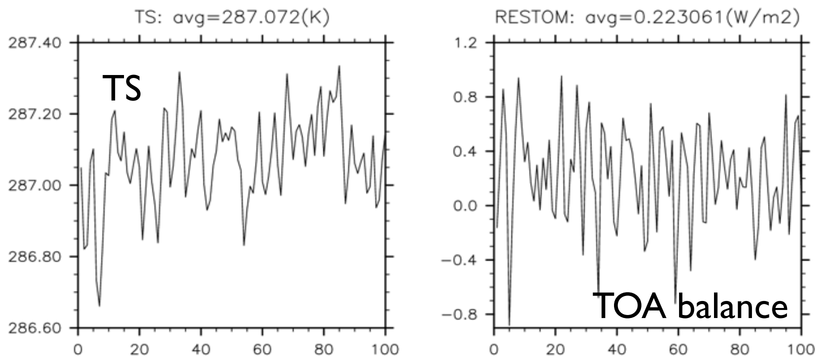
What happens in the first 100 years of the run?

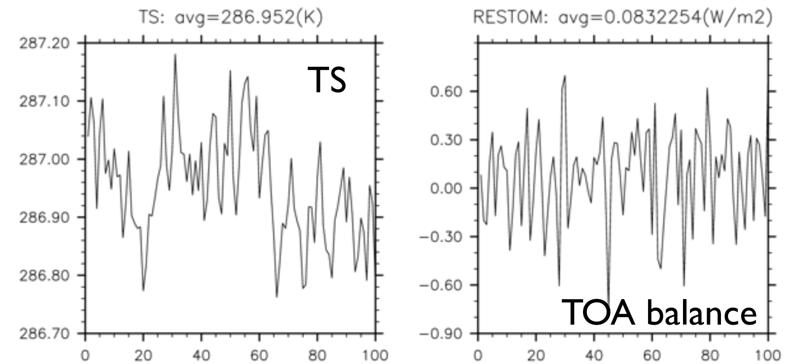
(Cecile Hannay)

CESM1.1: Finite volume (FV)

CESM1.2: Spectral element (SE)

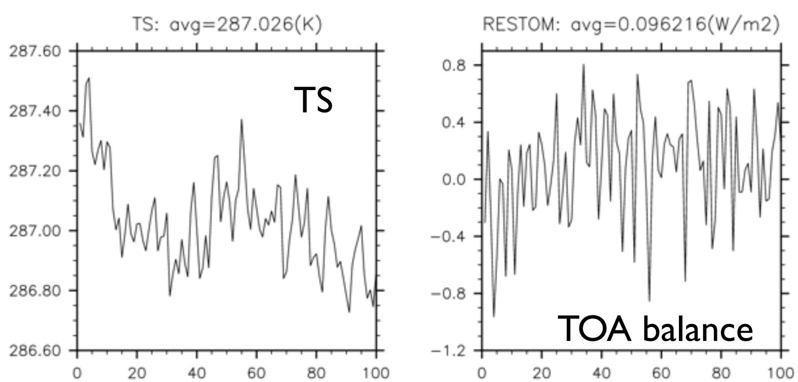
Spunup ocean

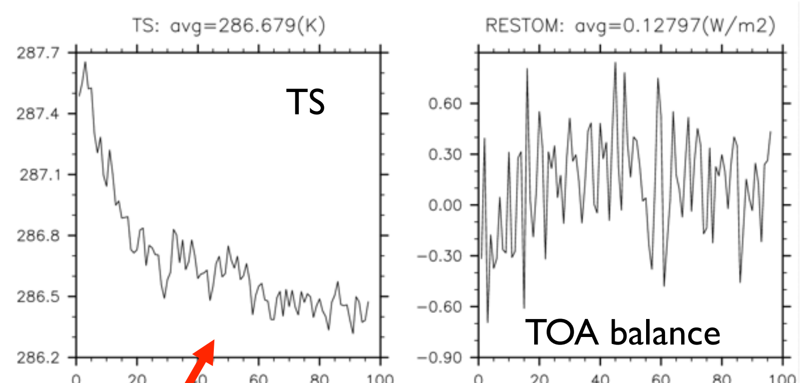




When starting from spunup ocean, model quickly adjusts (20 years)

Levitus

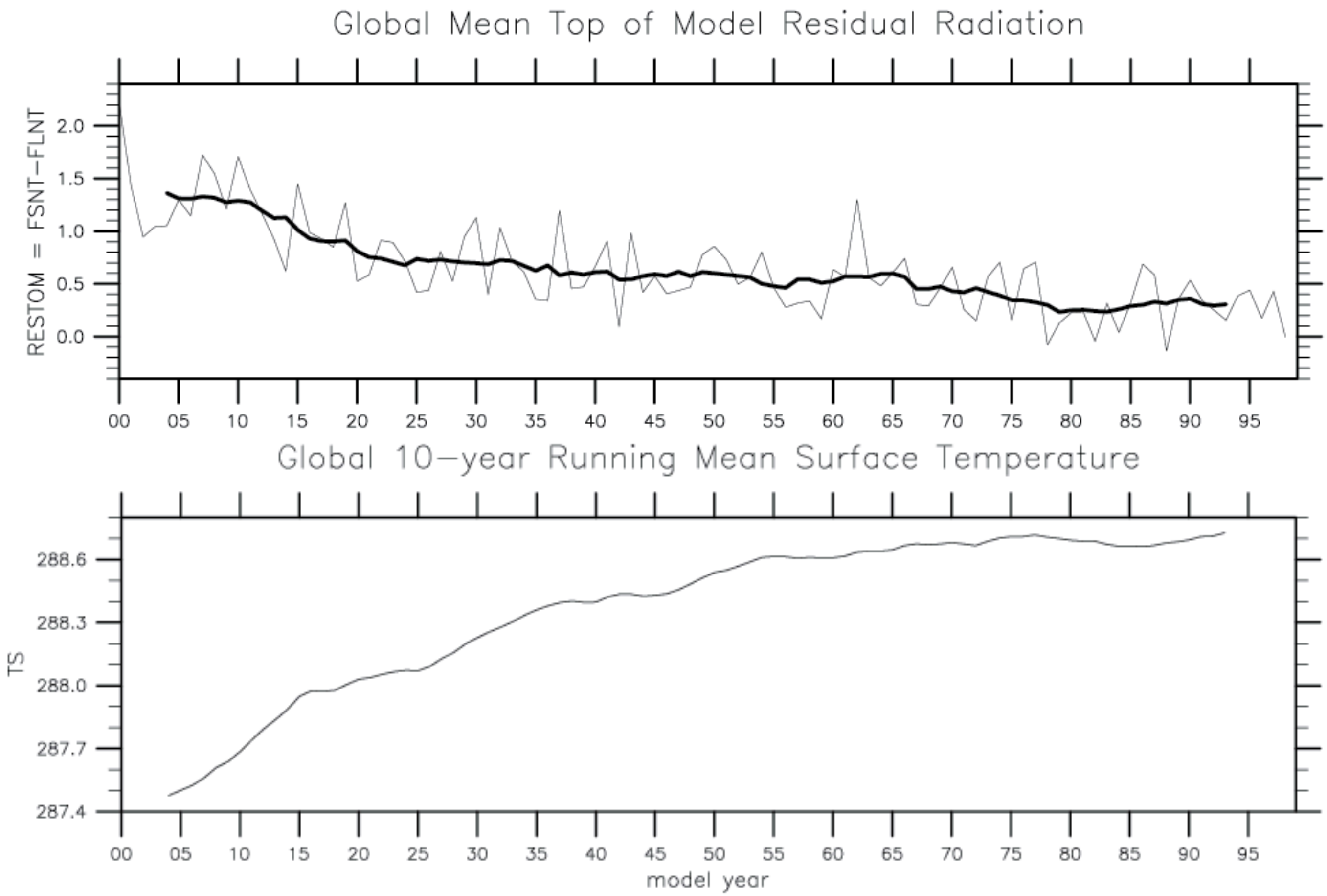




When starting from Levitus, model spinups longer (100 years).

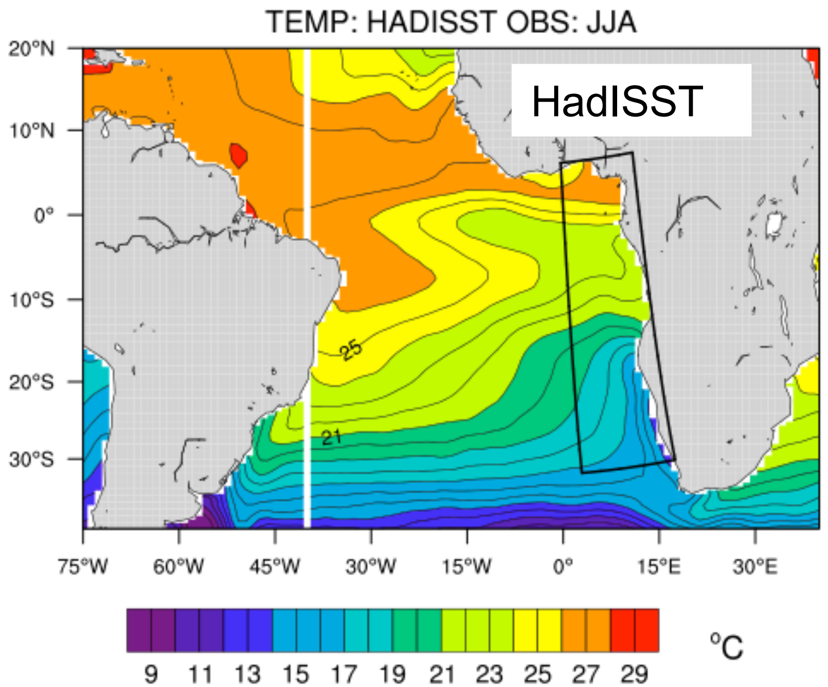
Cooling despite mostly positive TOA radiation balance!

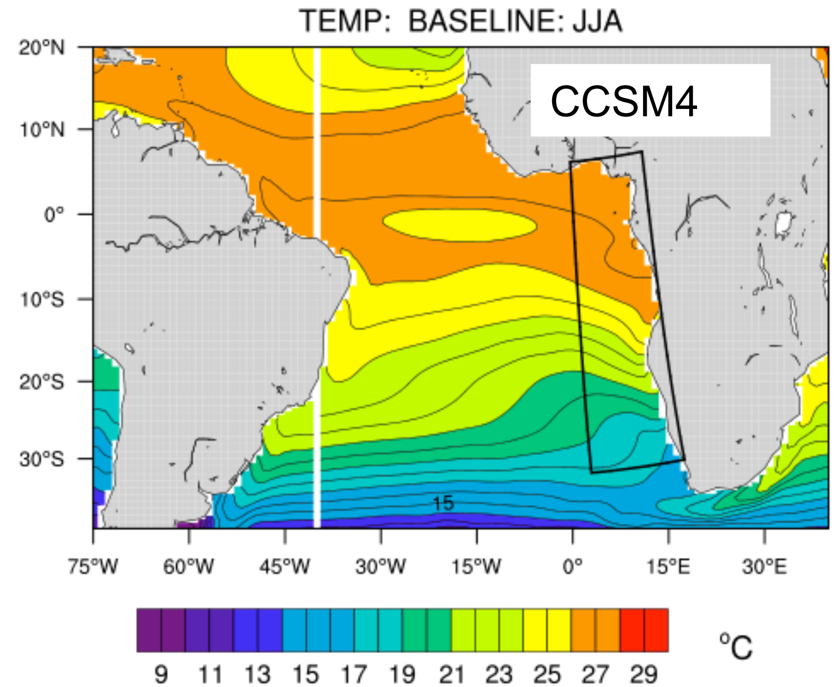
25 km atmos (ne120)-0.1 degree ocean coupled simulation *(Justin Small)*

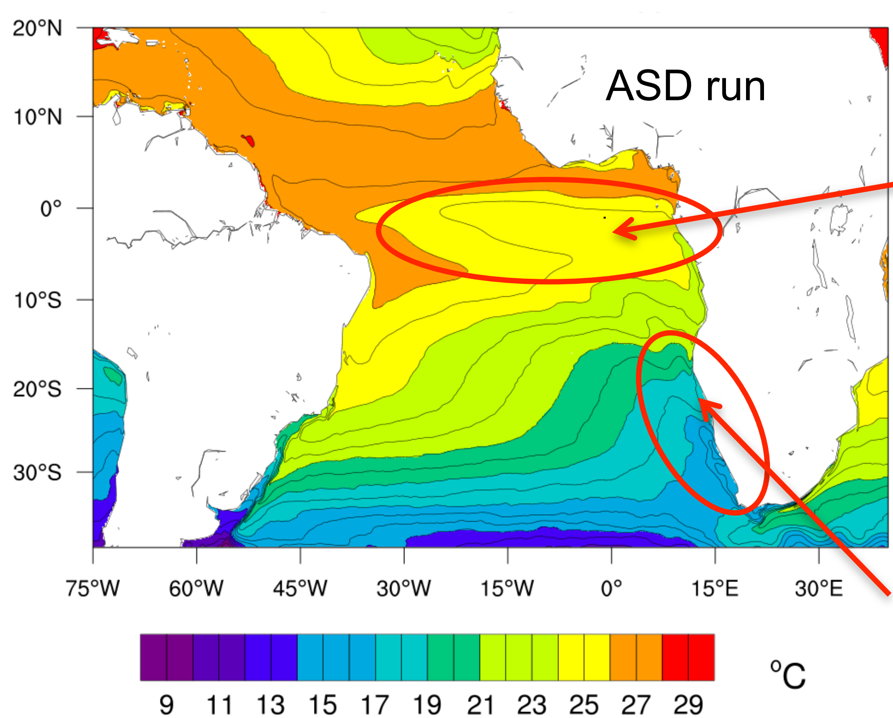


Caveats: SE version predates Lagrangian vertical advection, topo modifications

Note: Changes (yrs 1-40) w/resp FV-AMIP run → clear-sky shortwave (+2.2 Wm^{-2}), SWCF (+1.7 Wm^{-2})







Mean SST field for JJA
Note presence of cold tongue in ASD run, (although it is warmer than observed), very different to CCSM4
First time in NCAR coupled system!

Intensified wind stress curl in ne120 atmos

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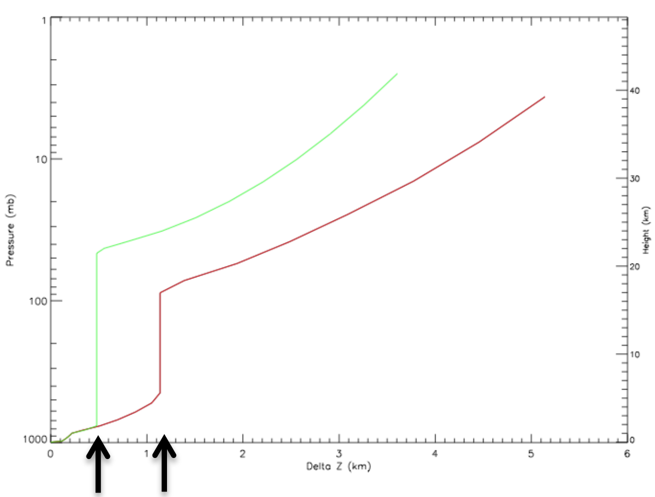
Vertical resolution:
50 year AMIP runs with increased vertical resolution and enhanced GW scheme (non-orographic sources)
(Jadwiga Richter)

60L vs 30L model:



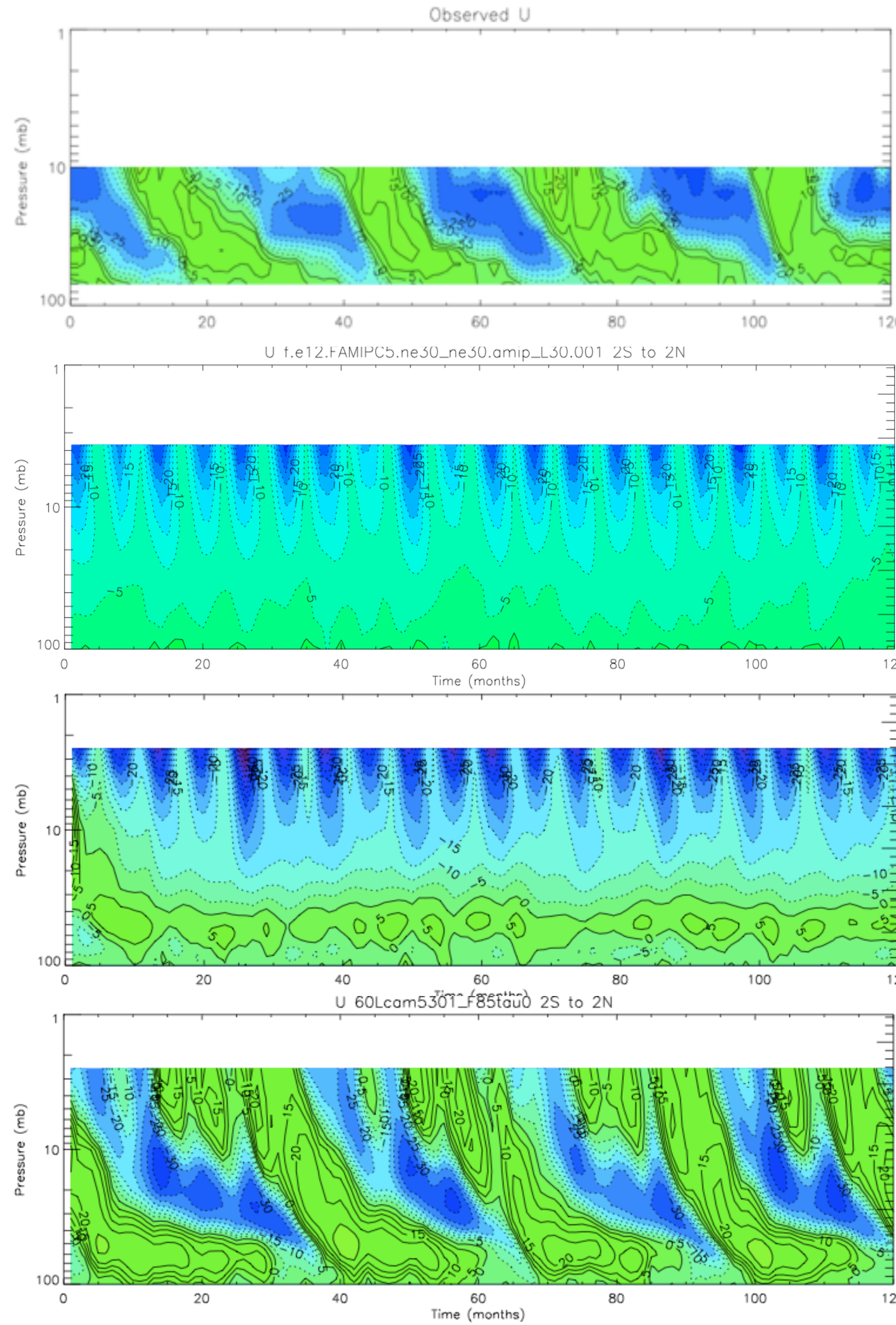
500m 1.2km

OBS

30L

60L

60LGW



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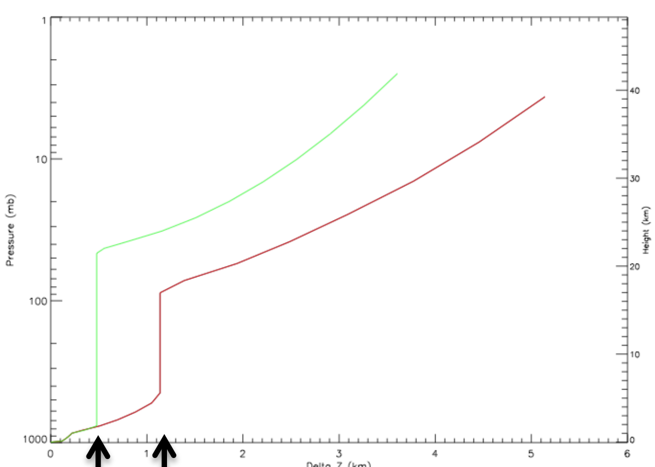


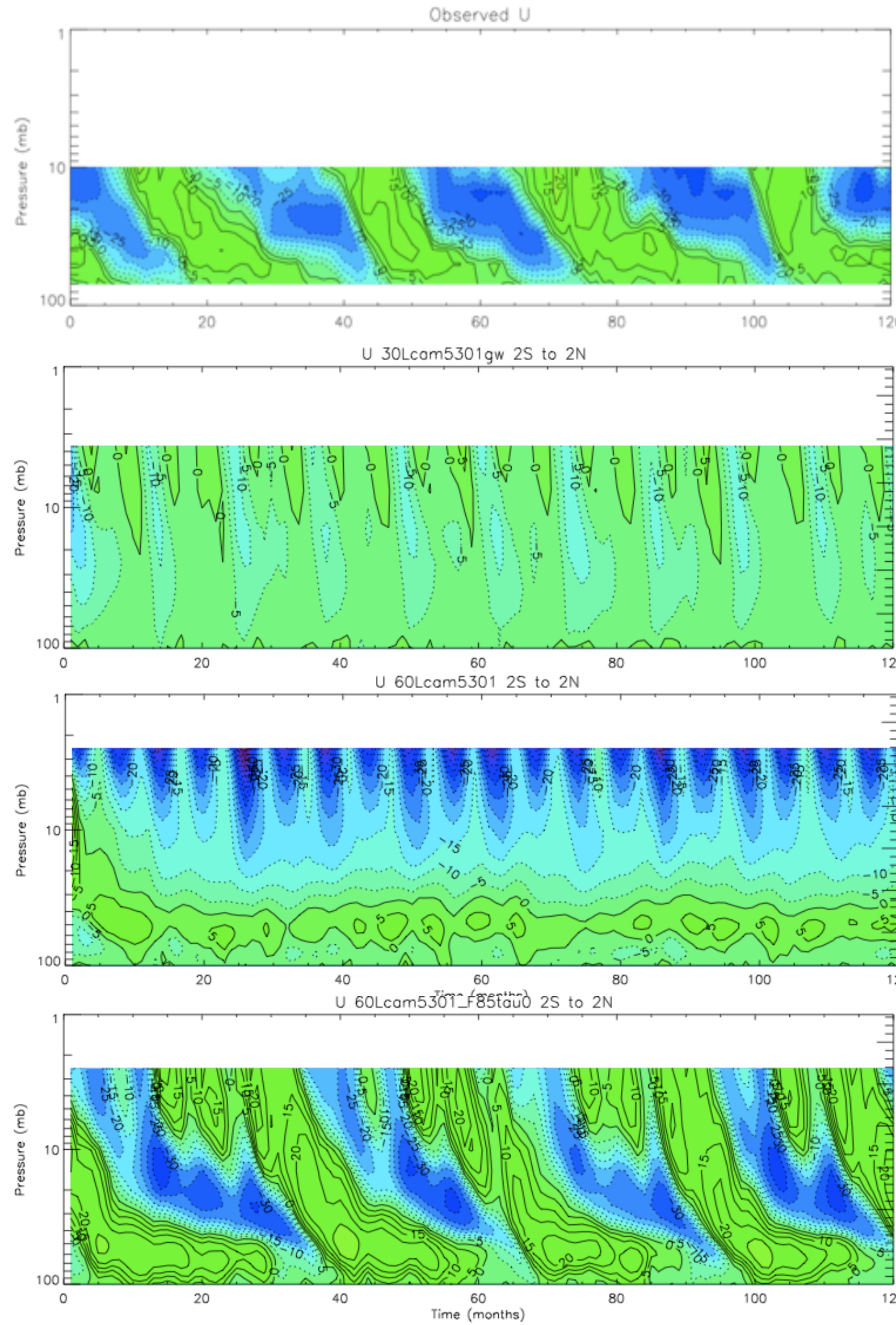
500m 1.2km

OBS

30LGW

60L

60LGW



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Plans-Choices-Indecision

Horizontal resolution for next version – not decided

Vertical resolution

- Any increase at all?
- 60L or (60+*n*)L where *n* is in the PBL
- Just a few more levels in the PBL

Sub-columns (statistically/dynamically generated)

- Use with CRM microphysics
- Deep convection

New PBL, Convection, clouds

- Prognostic precipitation (no hail/graupel)
- *CLUBB* – 2^{nd} order prognostic PBL/ShCu scheme
- *UNICON* – New "unified" shallow/deep scheme
- Other tuning/triggers for ZM deep scheme, e.g.*"organization"*

New orographic drag

- Low-level blocking+anisotropy (Lott Miller)
- Beljaars form drag

All of these trend towards adding new "ingredients" to parameterizations, e.g. stochastic or dynamically-predicted sub-grid variability

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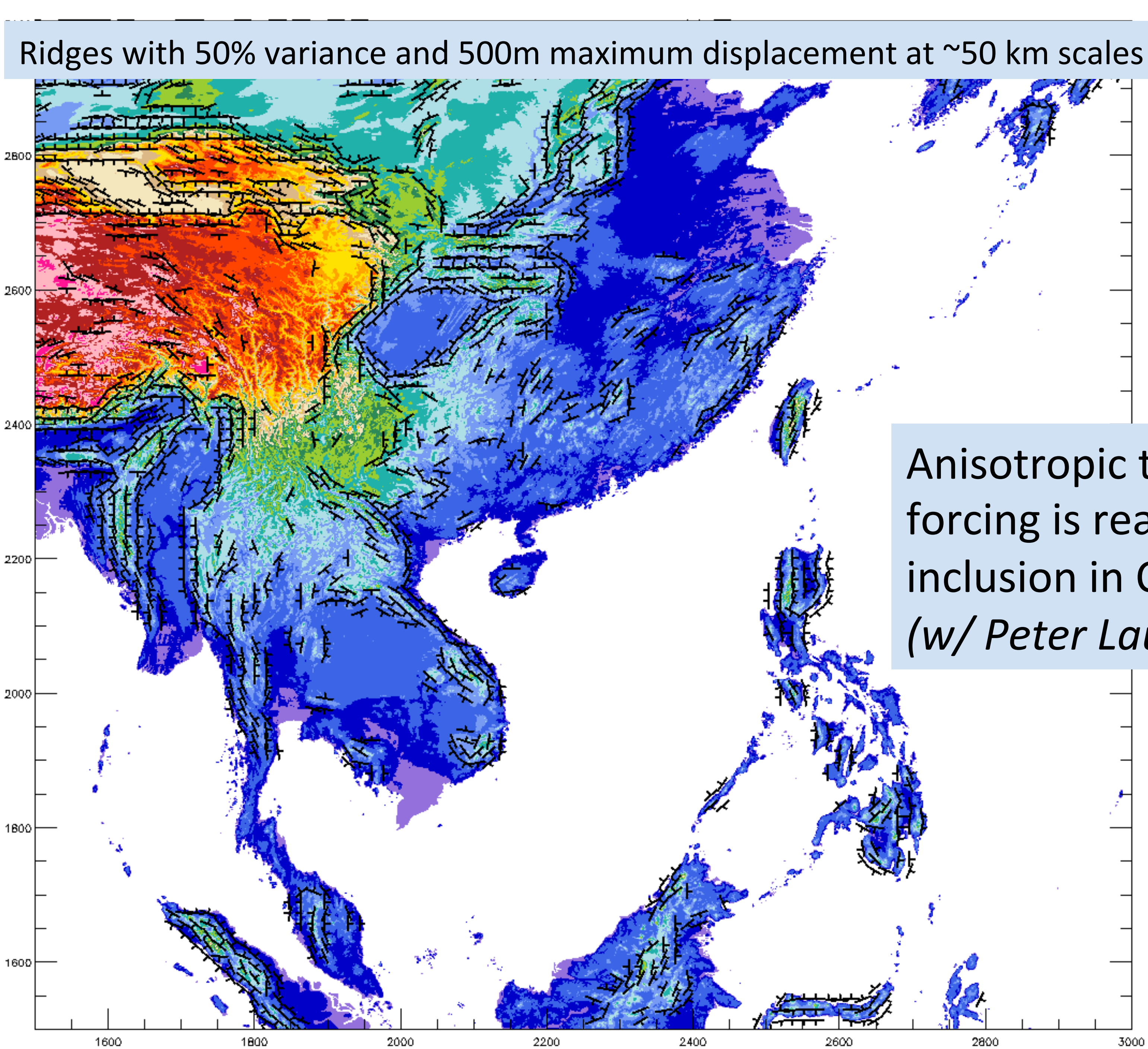
Ridges with 50% variance and 500m maximum displacement at ~50 km scales

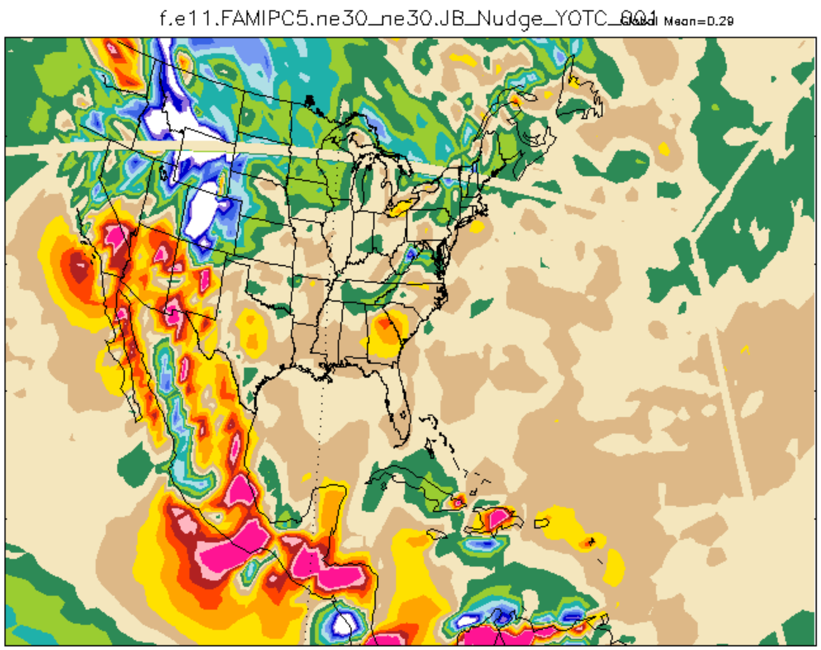


Anisotropic topographic forcing is ready for inclusion in CAM
(w/ Peter Lauritzen AMP)

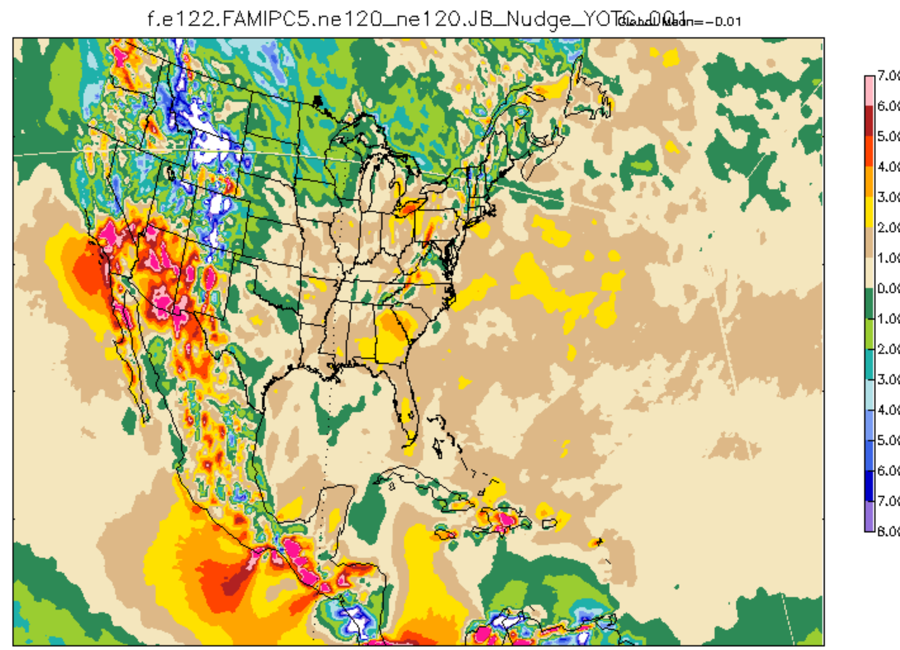
Nudging used to assess physics errors

Dec-Jan-Feb 2009-10 mean U-nudging tendency in 2nd model layer from surface ($ms^{-1}d^{-1}$)

100km resolution



25km resolution

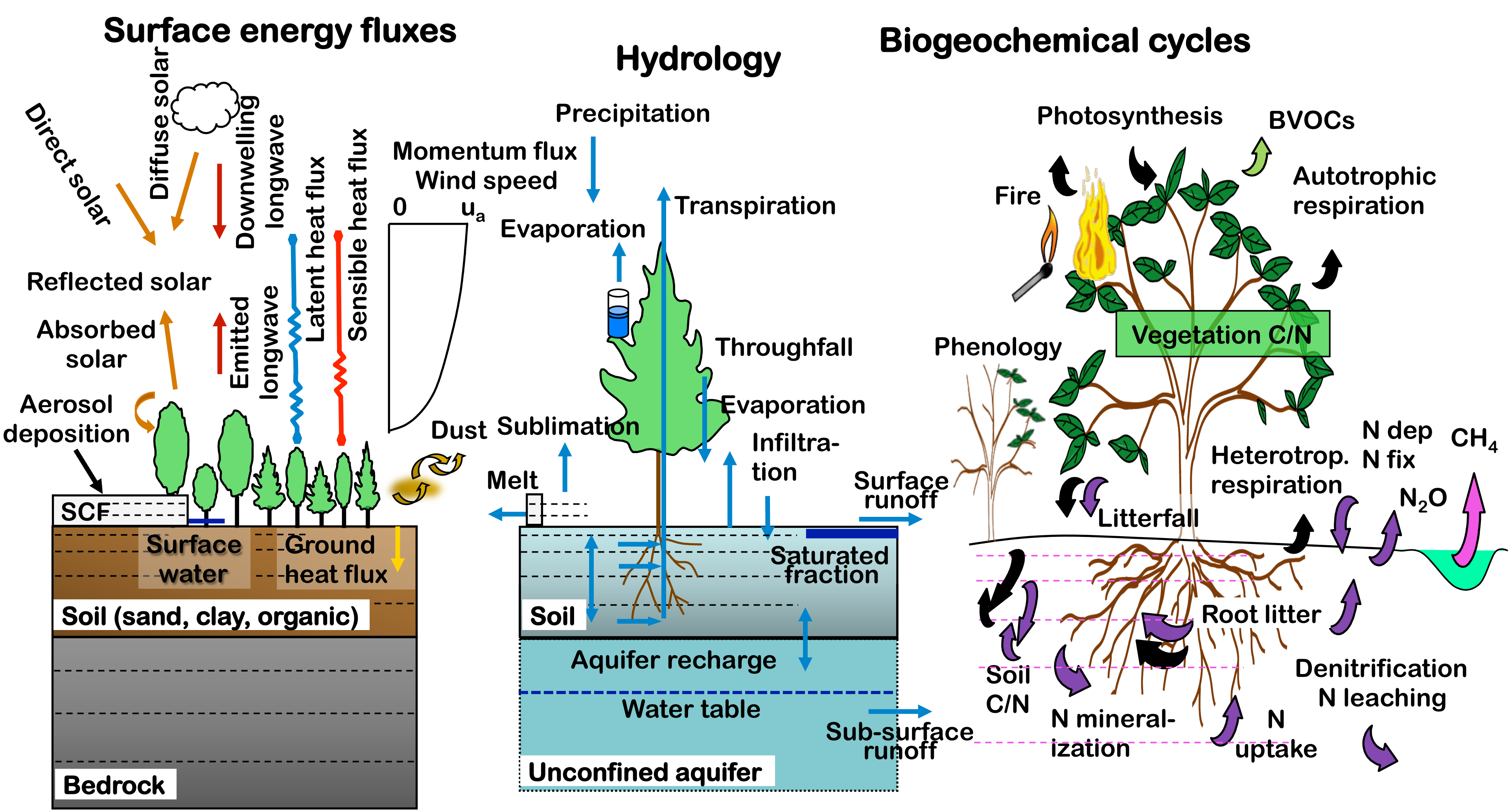


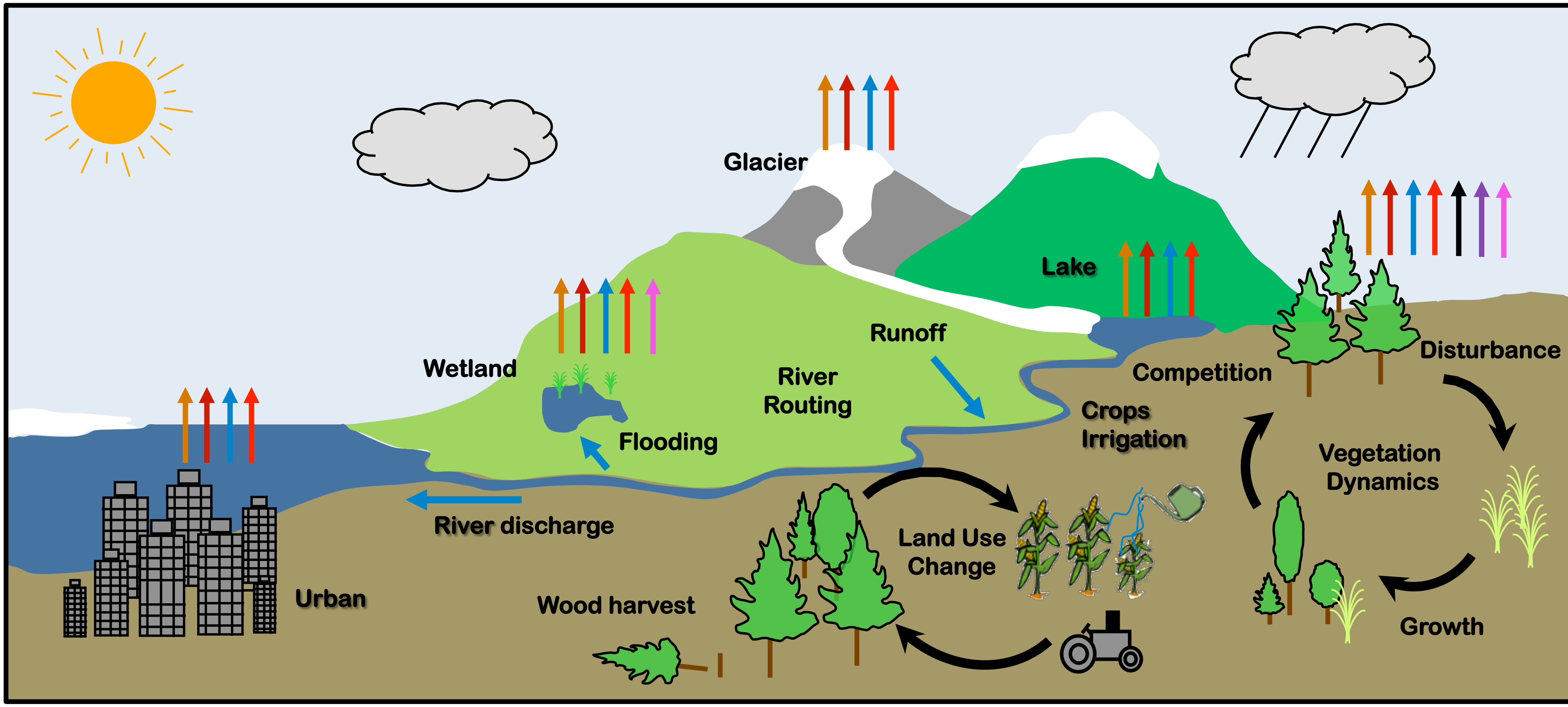
Do smaller tendencies indicate less need for subgrid drag??

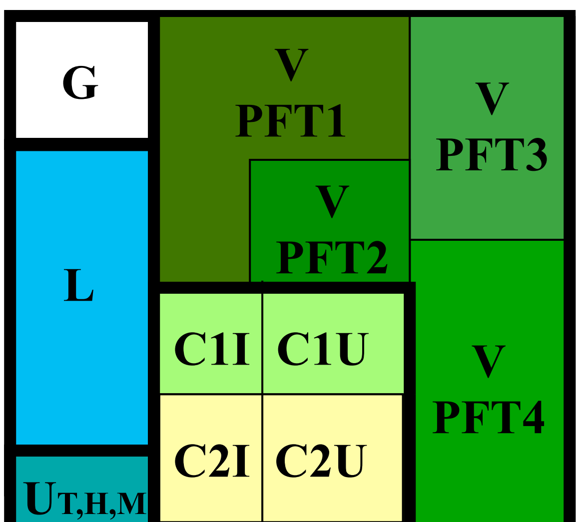
Thank You

EXTRA SLIDES

Community Land Model (CLM4.5)



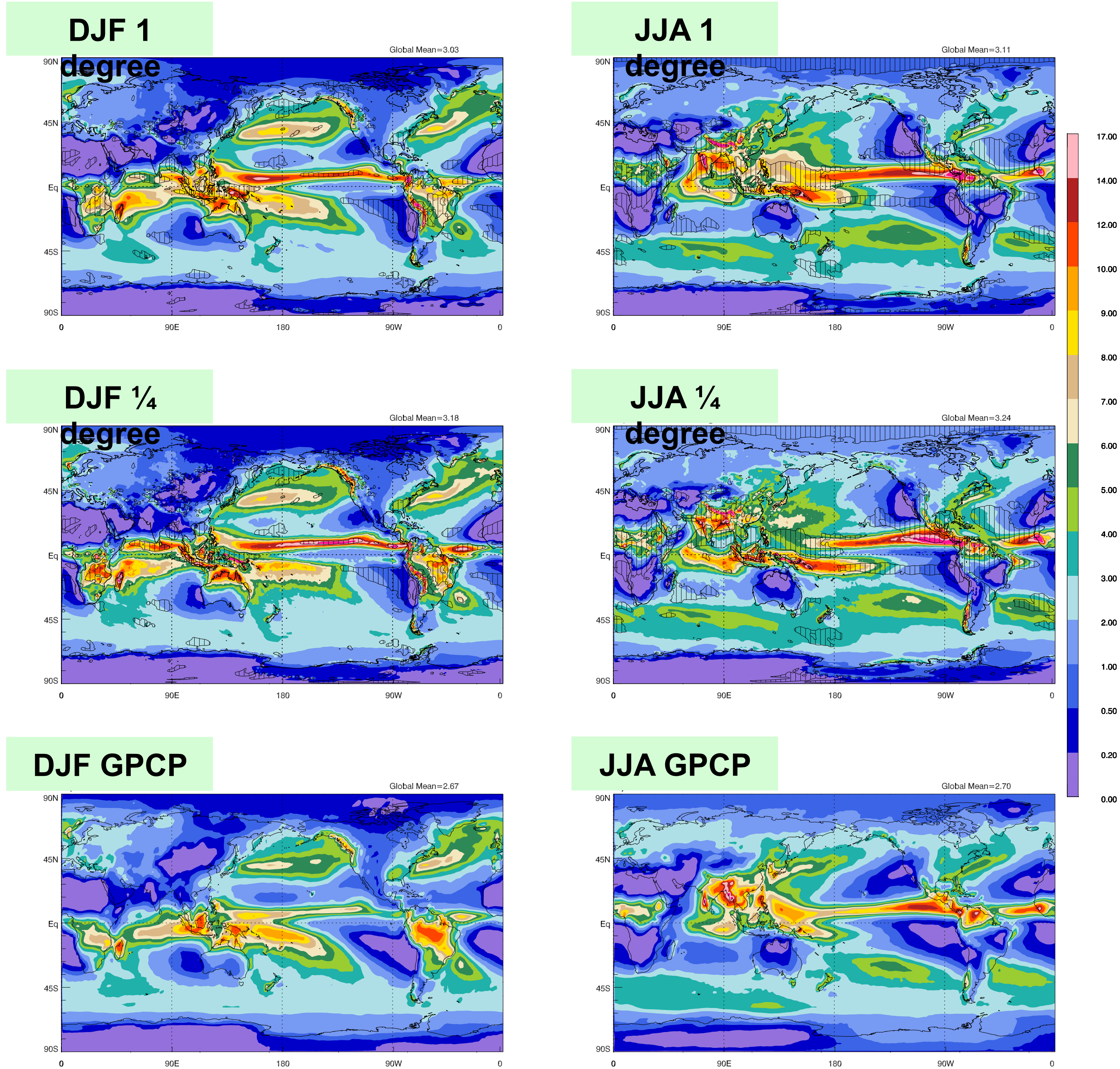


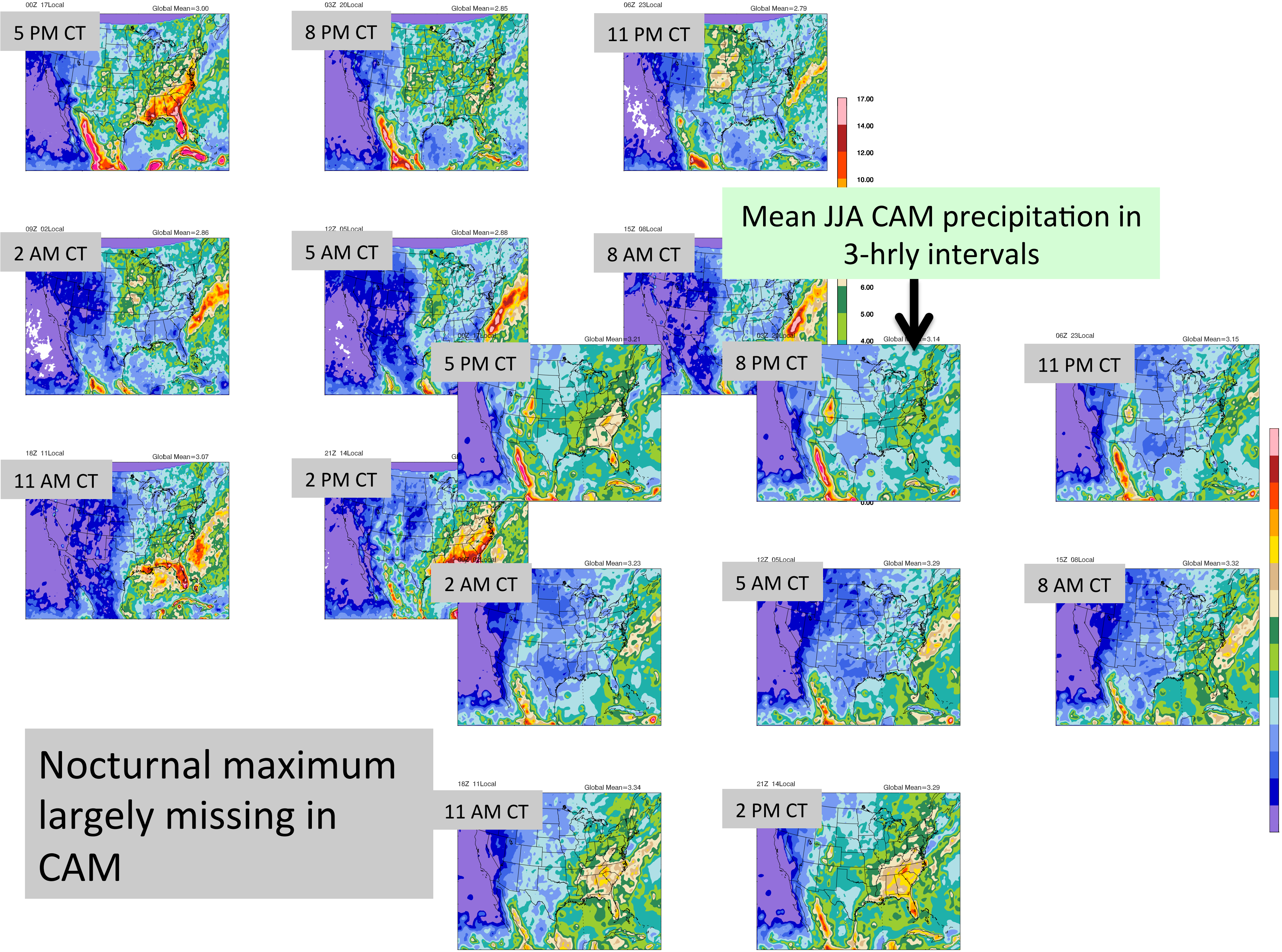


Landscape-scale dynamics

Long-term dynamical processes that affect fluxes in a changing environment (disturbance, land use, succession)

Seasonal-mean precipitation (1980-2005)

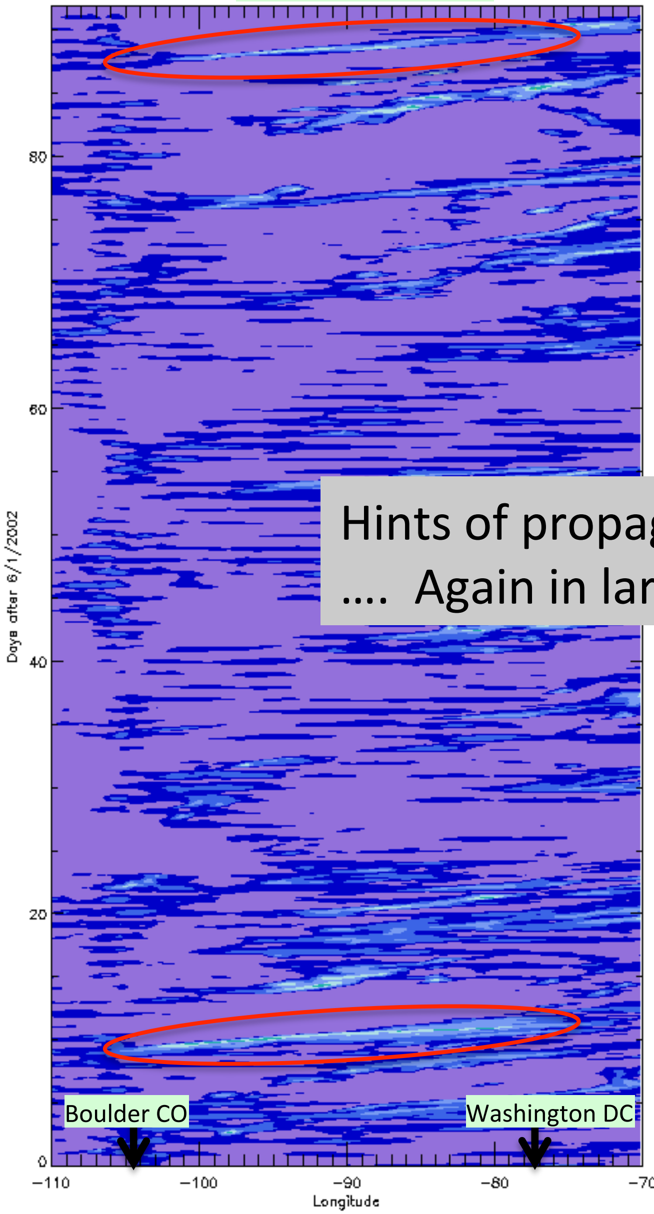



Mean JJA CAM precipitation in 3-hrly intervals
00Z 17Local
Global Mean=3.00
5 PM CT
03Z 20Local
Global Mean=2.85
8 PM CT
06Z 23Local
Global Mean=2.79
11 PM CT
09Z 02Local
Global Mean=2.86
2 AM CT
12Z 05Local
Global Mean=2.88
5 AM CT
15Z 08Local
8 AM CT
18Z 11Local
Global Mean=3.07
11 AM CT
21Z 14Local
2 PM CT
17.00
14.00
12.00
10.00
6.00
5.00
4.00
0.00
Global Mean=3.21
5 PM CT
Global Mean=3.14
8 PM CT
06Z 23Local
Global Mean=3.15
11 PM CT
Global Mean=3.23
2 AM CT
12Z 05Local
Global Mean=3.29
5 AM CT
15Z 08Local
Global Mean=3.32
8 AM CT
18Z 11Local
Global Mean=3.34
11 AM CT
21Z 14Local
Global Mean=3.29
2 PM CT
Nocturnal maximum largely missing in CAM

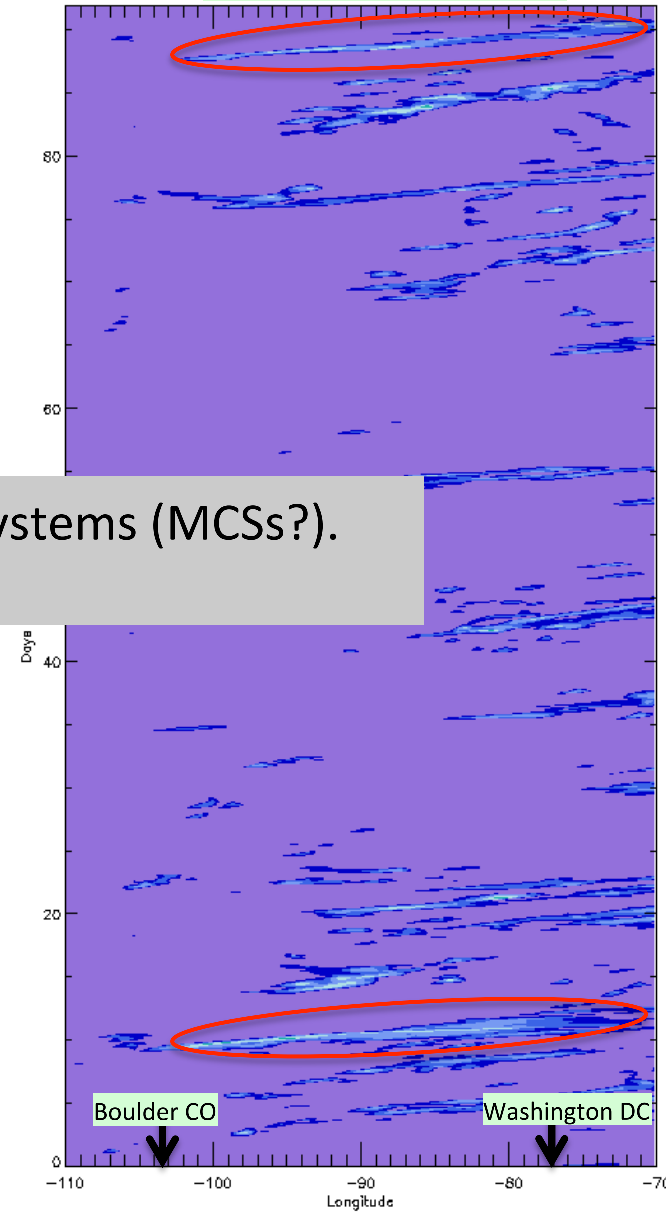
Precipitation Hovmueller diagrams June 1- Aug 31 2002

Averaged 35N-45N

Total Precip.



Large Scale Precip.



Hints of propagating systems (MCSs?).

…. Again in large-scale

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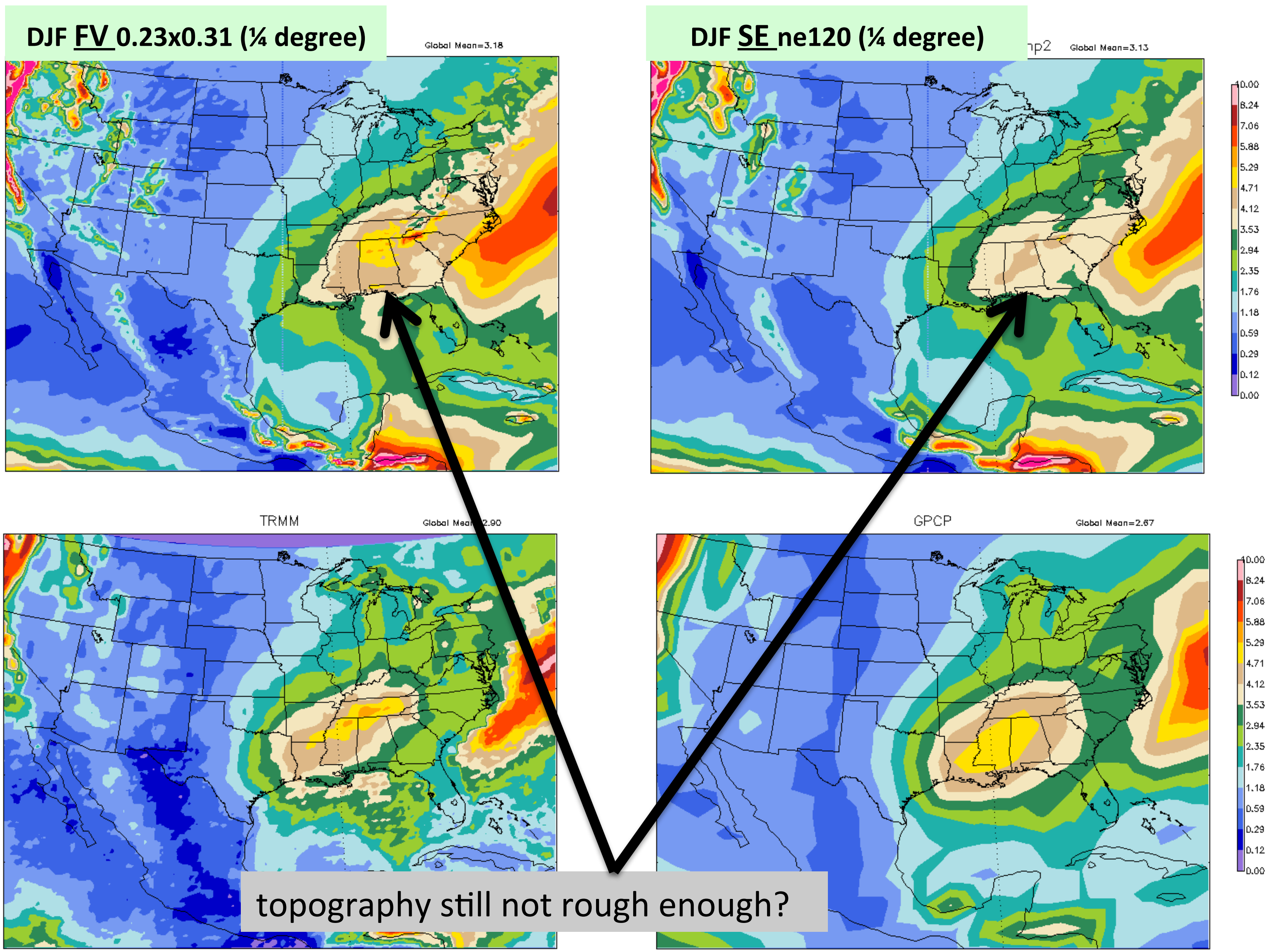
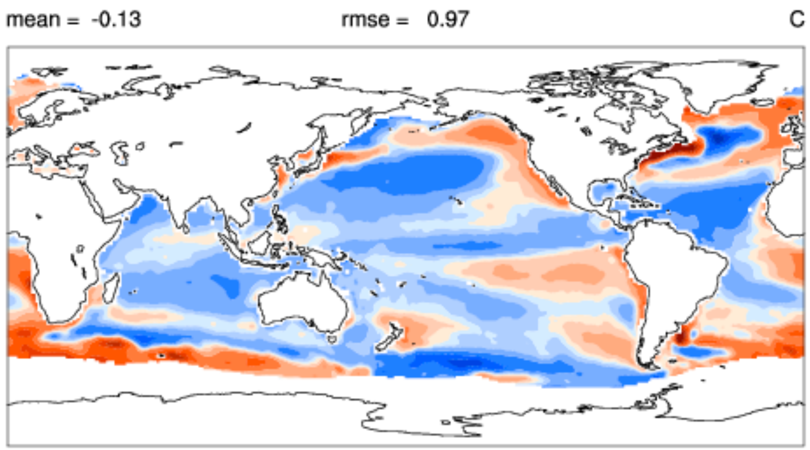


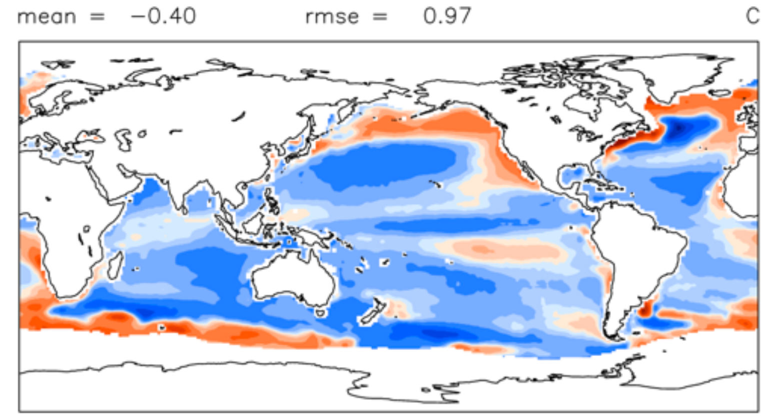
SST biases

Compared to HadISST/OI.v2 (pre-industrial)

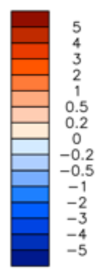
Finite Volume: Spunup ocean



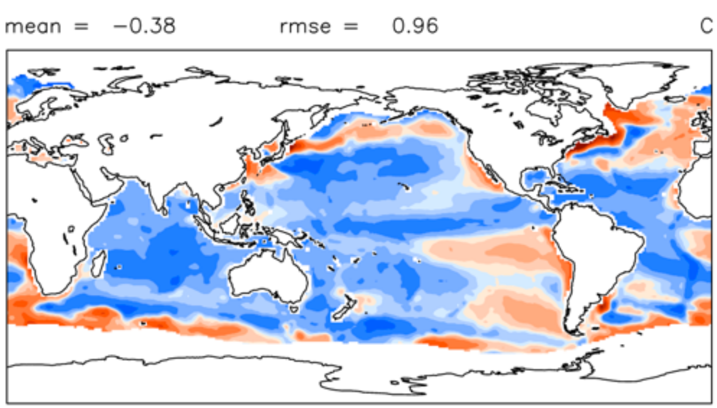
Spectral Element: Spunup ocean



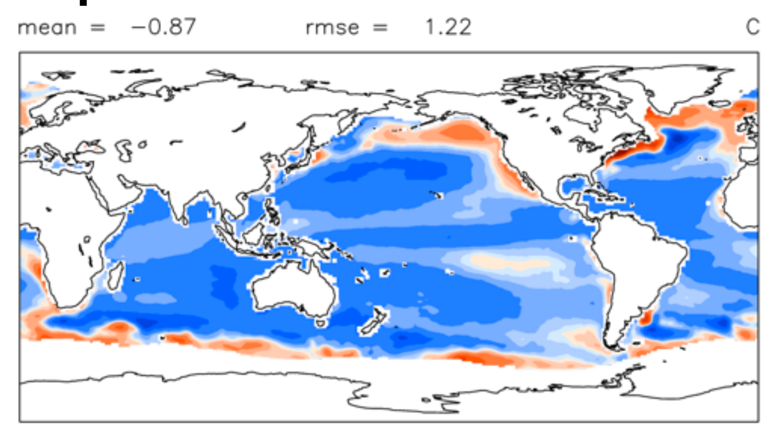
SST Bias similar to FV except SE Pacific.



Finite Volume: Levitus



Spectral Element: Levitus

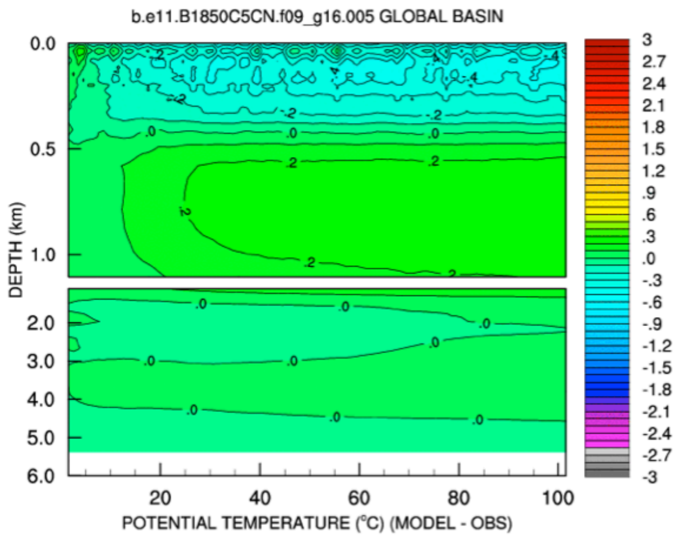


SSTs stabilize but too cold compared to obs
SST: 0.5K colder than FV

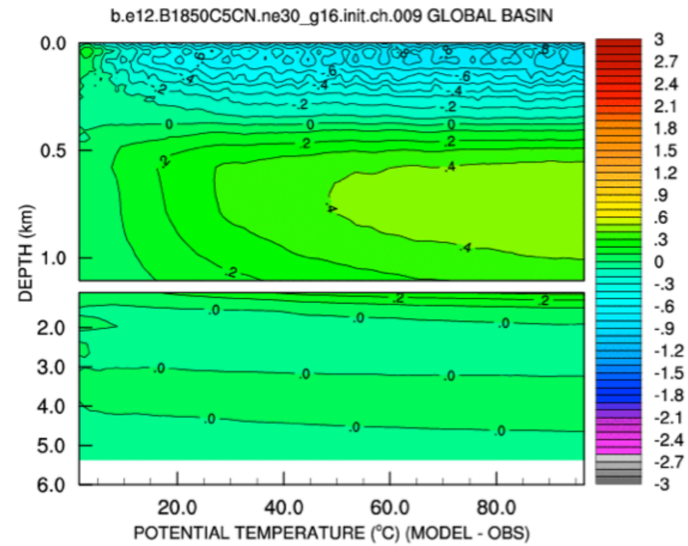
Ocean temperature bias

T bias = Tocn - Levitus

Finite Volume: Levitus



Spectral Element : Levitus

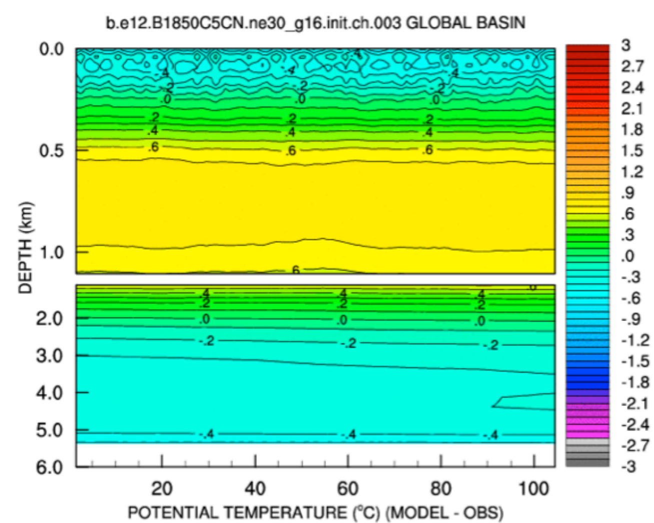


When starting from Levitus:
- cools near the surface
- warms around 750 meter
- exacerbated in SE

When starting from long spunup ocean:
- the 750-meter warm layer is present at initialization

750-meter warm layer is a signature of Spectral Element (present in every run)

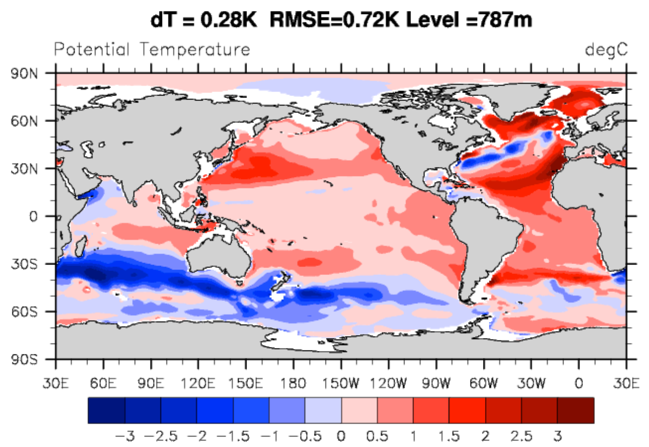
Spectral Element: Spunup ocean



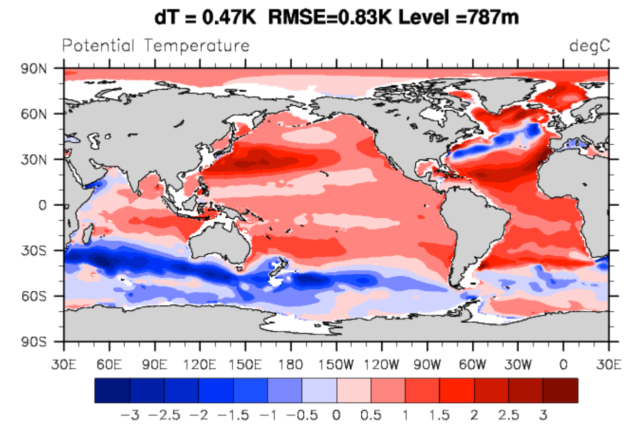
Is 750-meter warming uniform over ocean ?

Bias at 750m = T 750-m - Levitus

Finite Volume (yrs 70-89)



Spectral Element (yrs 70-89)



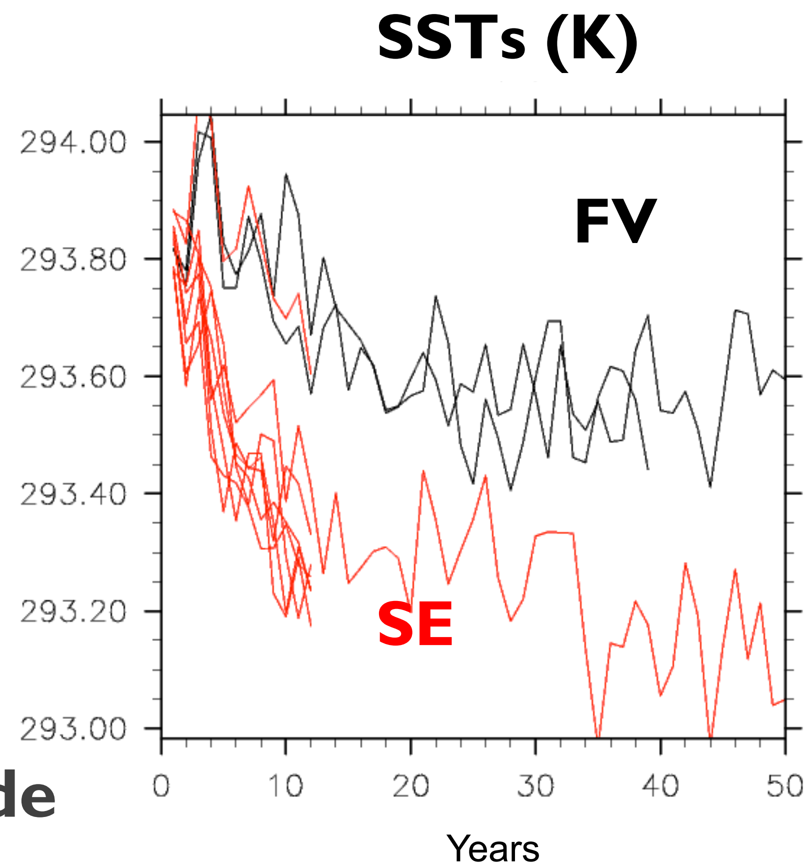
Warming is not uniform: areas of warming and cooling

Warming also exists in Finite Volume but cooling compensates warming globally.

What controls SST cooling in SE ?

Inventory of differences (SE ⇔ FV)

- Tuning parameters
  - Use FV tuning for dust, rhminl, rpen
- Topography
  - Use smoother topography
- Remapping (ocn ⇔ atm)
  - Use bilinear for state variables
- Grid differences at high latitude
  - Use refined poles grid
- Surface stresses
  - Turn off turbulent mountain stress
  - Increase turbulent mountain stress
  - Change gravity wave



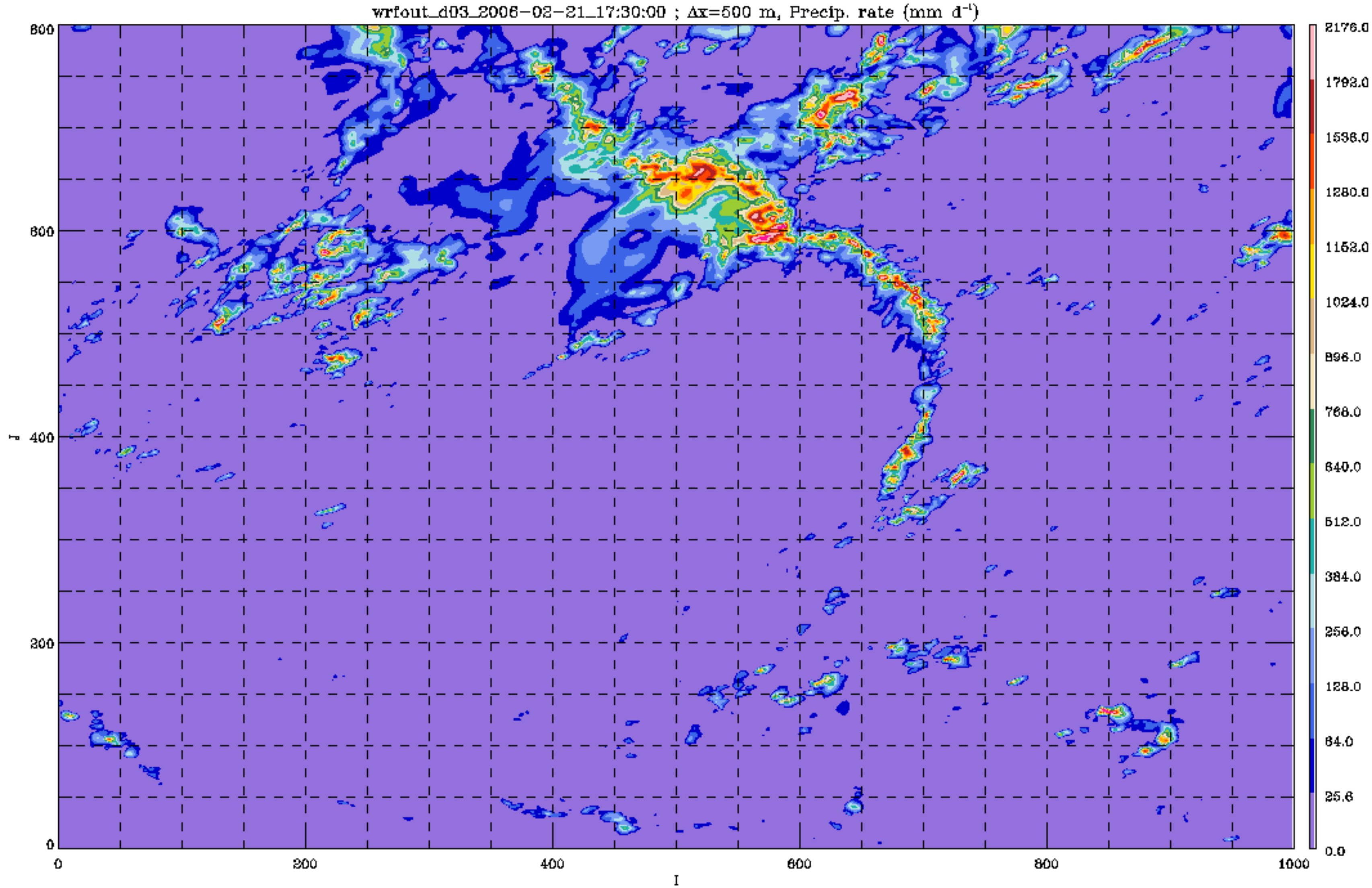
Nugding to FV winds yields to "FV-like SSTs"

Effects of Condensate Loading

Assessed using 0.5x0.5 km non-hydrostatic WRF simulation

Tropical ocean convective case (TOGA domain Feb 2006)

15-min average precipitation rate (*Hong and Lim 2006 microphysics*)



Dashed lines show 50x50 gp (25km x 25km) squares used to coarse grain WRF f
to produce “high-res AGCM” fields

Hydrostatic Balance w/ and w/out condensate loading

$$\pi_{hyd} = \int_{z}^{z_{top}} \frac{g}{c_p \Theta_{\{v,cond\}}} dz' + \pi_{top}$$

$$p_{hyd} = p_{00}\, \pi_{hyd}^{\;1/\kappa}$$

w/out loading:

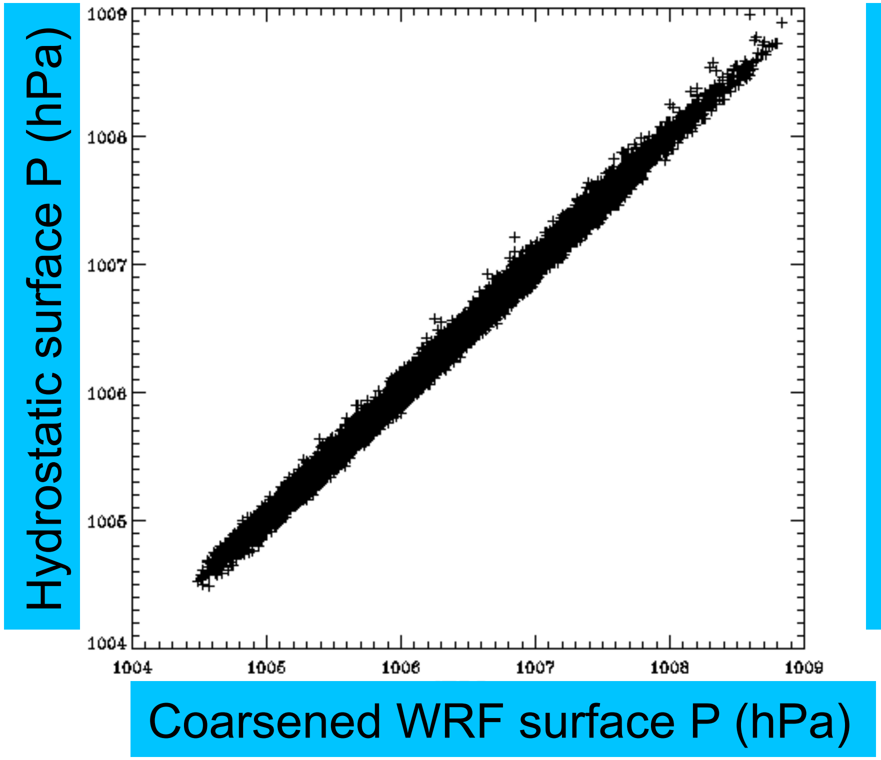
$$\Theta_v = \Theta\left(1. + 0.61q\right)$$

with loading:

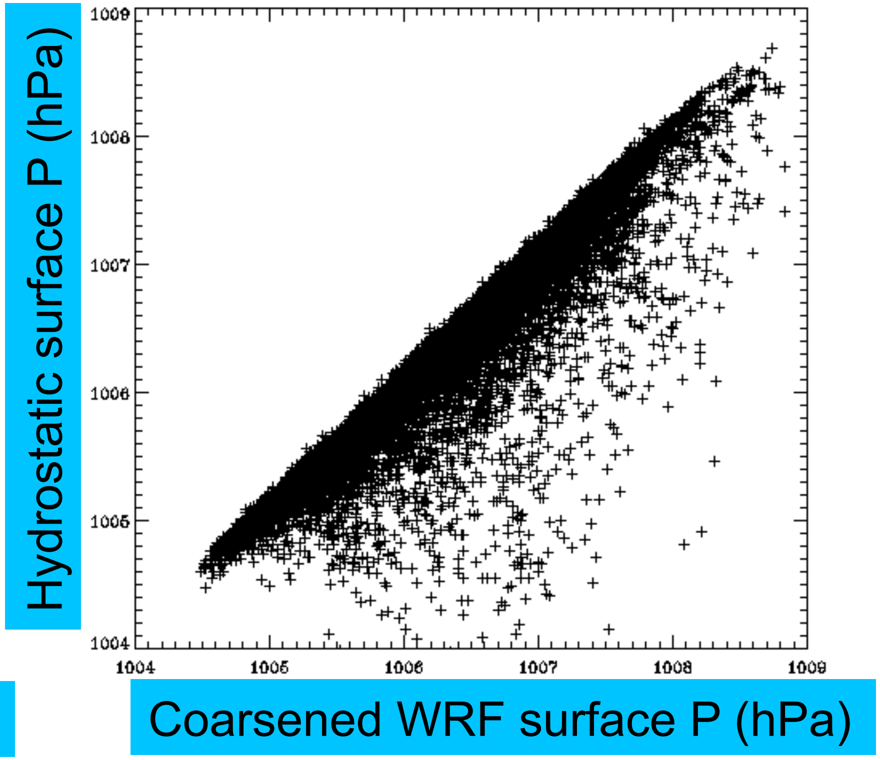
$$\Theta_{cond} = \Theta\left(1. + 0.61q - q_{liq} - q_{ice} - q_{rain} - q_{graup} - q_{snow}\right)$$

Coarse-grained to (25 km)^2

with loading:



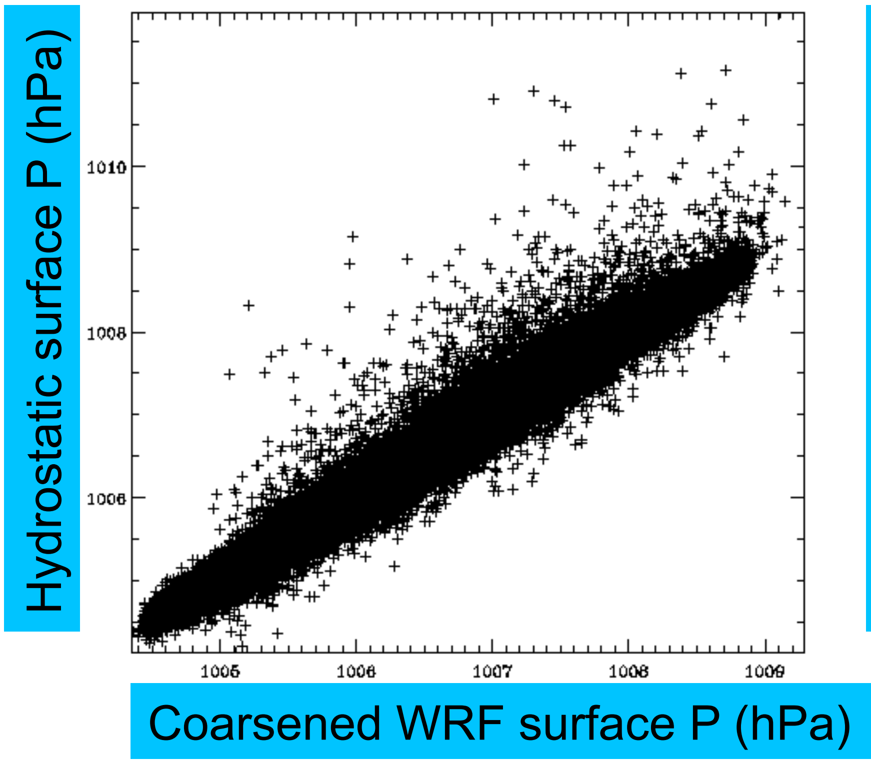
w/out loading:



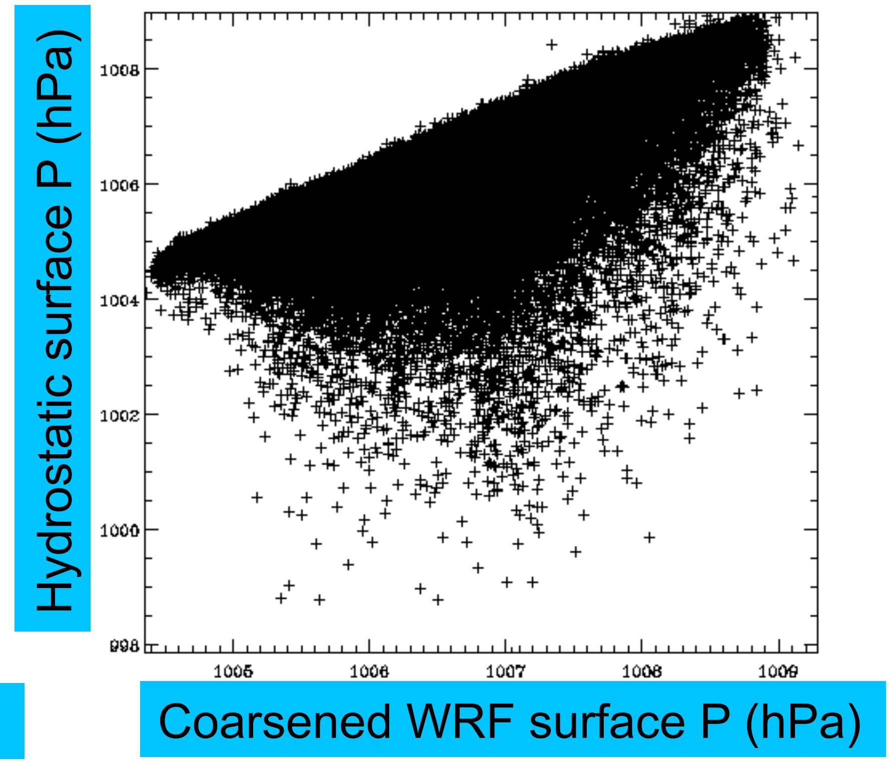
Condensate loading matters – even in (25 km)^2 grid boxes

Coarse-grained to (5 km)^2

with loading:



w/out loading:



Non-hydrostatic effects become detectable

NCAR has supercomputing facilities that are more than adequate to carry out the computing aspects of the proposed work:

Major Equipment:
Recently available is a 1.5-petaflops IBM iDataPlex cluster, called Yellowstone, which has 72,288 2.6-GHz Intel Sandy Bridge processor cores and 144 TB of memory. Yellowstone has an integrated centralized file system and data storage system that will provide 11 PB of usable disk capacity growing to 16 PB in 2014. Two data analysis and visualization systems (Geyser and Caldera) support large-scale data analysis and visualization activities. Yellowstone is also interoperable with the Extreme Science and Engineering Discovery Environment (XSEDE) project enabling. This allows more effective use of HPC resources and supports the rapid site-to-site transfer of large volumes of data via the Globus-online capability.

High Performance Storage System (HPSS): HPSS currently holds more than 15 PB of storage in support of CISL computing facilities and NCAR research activities. The HPSS environment is being expanded with new libraries and tape drives to provide a potential capacity of 100 PB.

High-speed networks: NCAR has deployed dual 10-Gbps network loops connecting its Boulder facilities, the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, and the University of Wyoming in Laramie. The NCAR network also provides high-speed, reliable, secure network connectivity among its five Boulder campuses, supporting over 117 logical networks, approximately 210 monitorable network devices, and over 3000 network-attached devices, plus management commitments to additional municipal and wide-area networks.

Computing Centers: NCAR manages a sophisticated computing center at the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming. The NWSC houses the Yellowstone environment. NCAR provides 24x7 on-site operational support to NWSC.