

Effects of Idealized Ocean-Atmosphere Coupling on MJO Structure in the Superparameterized CAM

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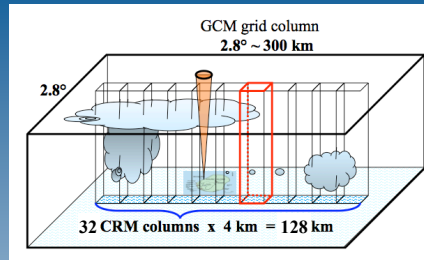


Background

- Most global climate models (GCMs) poorly depict the Madden-Julian Oscillation (MJO), such that the MJO signal is too weak... *Lin et al. (2006), Kim et al. (2009, in press)*
- GCMs that implement “superparameterization” have an increase in MJO variability, intensity, eastward propagation... *Khairoutdinov et al. (2005, 2008), Thayer-Calder and Randall (2009, in press), Zhu et al. (2009, in press), Benedict and Randall (2009, in press)*
- Overestimation of MJO variability/intensity in the Superparameterized CAM (SPCAM) and its possible ties to atmosphere-ocean interactions... *Benedict and Randall (2009, in press)*
- Importance of atmosphere-ocean interactions on the MJO... *Flatau et al. (1997), Waliser et al. (1999), Hendon (2000), Inness and Slingo (2003)*
- Current investigation involves coupling the SPCAM to an idealized slab ocean model

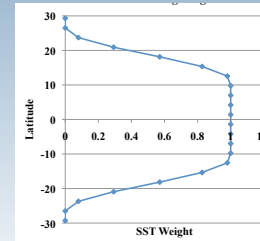


Model Setup



- Control run (SPCAM-p): 19-yr AMIP-style simulation forced by prescribed SSTs
- Experimental run (SPCAM-s): 5-yr simulation with idealized atmosphere-ocean coupling
- Slab ocean model (adapted from Waliser et al. 1999):

$$\frac{dT'}{dt} = \frac{F'}{\rho CH} - \gamma T'$$



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T' : departure of SST from prescribed value

F' : departure of total surface flux from smoothed climatology (based on SPCAM-p 19-yr AMIP run)

H : Time- and space-dependent ocean mixed layer depth

γ : damping coefficient = 1/(50 days)

Results: General Statistics

Radiation Balances and Global-Mean Precipitation

	Years	TOA [W m ⁻²]	Surface [W m ⁻²]	TOA–SFC [W m ⁻²]	Precip [mm d ⁻¹]
CAM	1986-1999	+3.19	+0.66	+2.53 (atm heated)	2.830
SPCAM	1999-2004	+0.03	-1.86	+1.89 (atm heated)	2.814
SPCAM-SOM	1999-2004	-0.47	-2.53	+2.06 (atm heated)	2.768
GPCP	1999-2004				2.612



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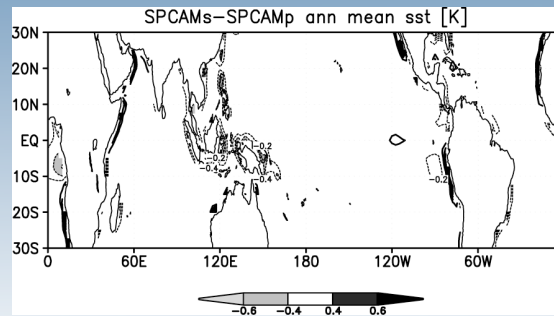
TOA: (net LW)–(net SW)

Surface: (net SW)–(net LW)–(SHFLX)–(LHFLX)

Results: Mean State

- The character of the simulated MJO is closely associated with the simulated mean state... *e.g., Salby and Hendon (1994), Kim et al. (2009, in press)*
 - Large differences in the mean state affect the environment in which the MJO operates
- Mean state differences between control and experimental simulations are small

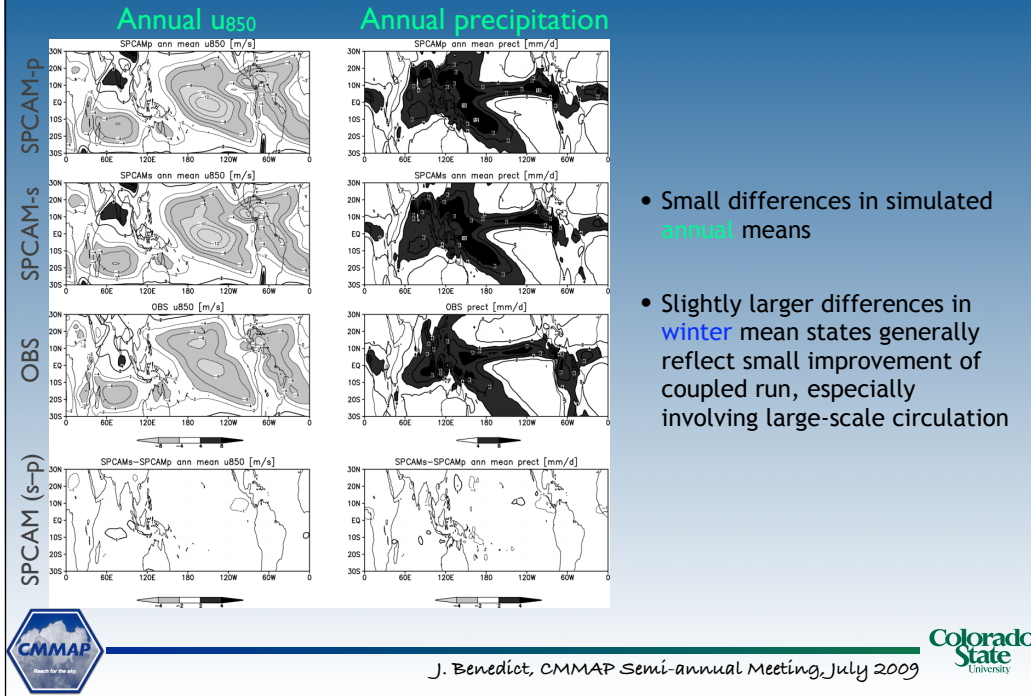
Annual mean SST
difference, coupled
vs. uncoupled runs



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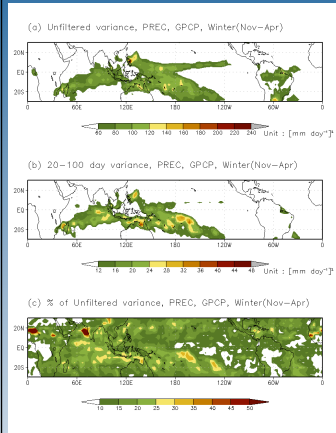
Colorado
State
University

Results: Mean States

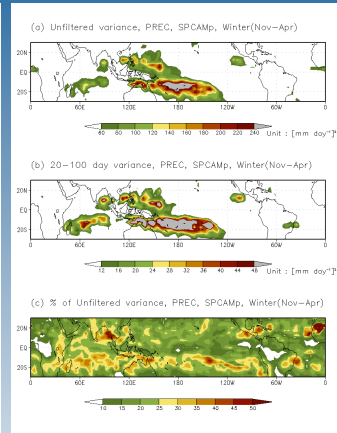


Results: Winter Rainfall Variance

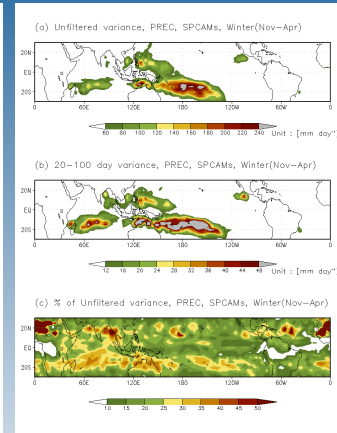
Winter Obs



Winter SPCAM-p



Winter SPCAM-s



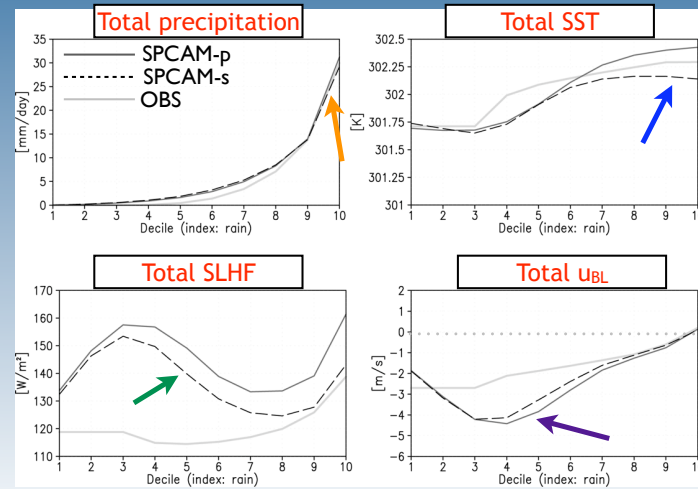
- Simulated 20-100-day variance is generally **slightly lower** in coupled run (SPCAM-s) compared to the uncoupled run (SPCAM-p) for most variables



Results: Rainfall Percentiles

- Deciles of total rainfall, ocean grid cells only in domain 12°S-12°N, 60°E-180°
- Decile average of other variables based on rainfall deciles

- SPCAM-s rainfall slightly reduced for heaviest rain rates
- SSTs notably cooler during heavy rains for coupled run
- SLHF reduced in coupled run
- SLHF max for light rain rates linked to stronger boundary layer easterlies in model



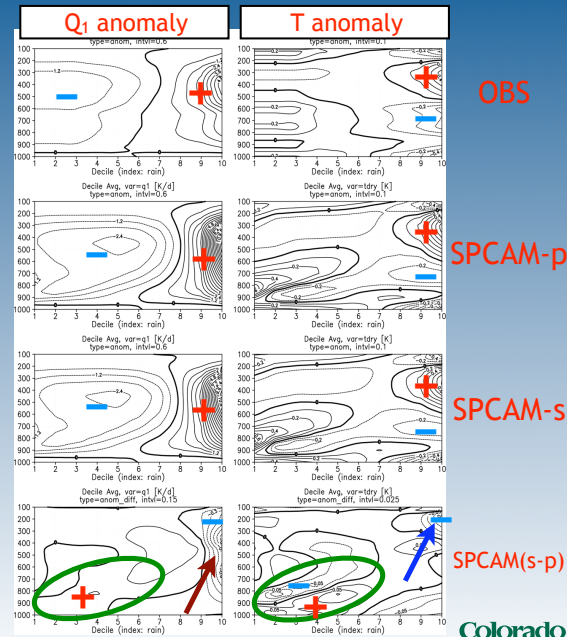
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Results: Rainfall Percentiles

• y-axis: pressure; x-axis: rain decile

- Overall, vertical structures of SPCAM-s similar to SPCAM-p, but some differences are noted...
- Coupled run has reduced deep heating during heaviest rains
- Upper tropospheric warmth is reduced in SPCAM-s relative to SPCAM-p
- General tilted structure between deciles 1-6 in difference plot (bottom) suggests:
 - increased cloud coverage below 700 hPa
 - a more gradual transition between dry and wet conditions in the coupled simulation

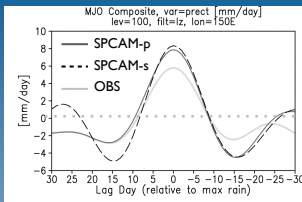


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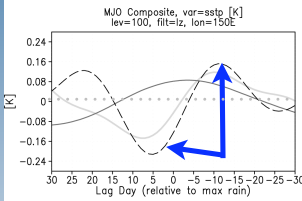


Results: Filtered MJO Composites

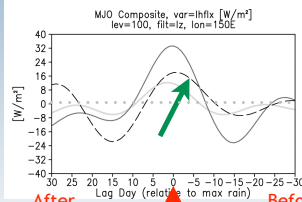
Rain



SST



SLHF



After (West) ↑ Max rain ↓ Before (East)

- MJO events composited based on maximum filtered rain

- 20-100-day Lanczos filter

- Selected longitude: 150°E

- Events visually checked for clear coherence and eastward propagation using unfiltered anomaly fields

- Both runs overestimate peak MJO rain, coupled run is slightly worse

- Significantly more realistic SST evolution in coupled run

- Reduced variability of SLHF during and before heavy rains in coupled run

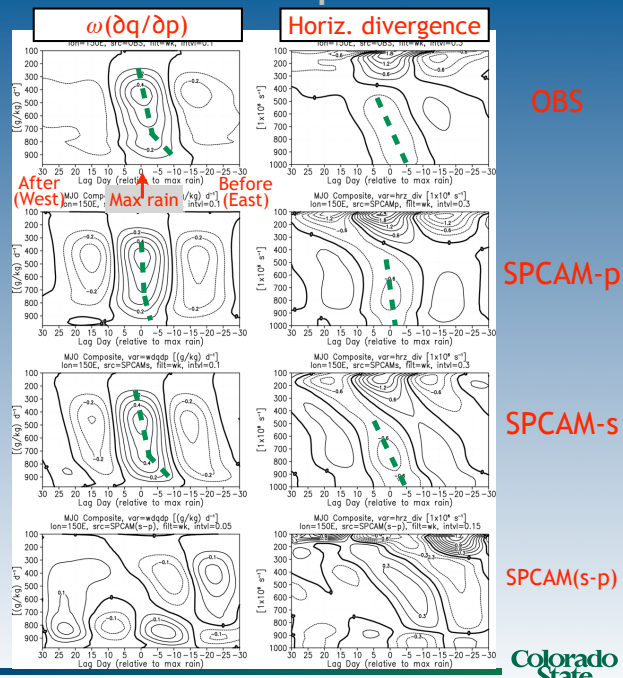


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Results: Filtered MJO Composites

- MJO events composited based on maximum filtered rain
- Filter: 20-100 days, zonal wavenumbers 1 to -6 (eastward)
- Selected longitude: 150°E
- Notable change in westward tilt in SPCAM-s relative to SPCAM-p
- Largest changes related to tilt occur in lower troposphere
- Also seen in moisture, convective heating, θ_e



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Preliminary Conclusions

- Two simulations of the Superparameterized CAM are compared:
 - SPCAM-p: SSTs are prescribed
 - SPCAM-s: Idealized slab-ocean model allows SSTs to deviate from prescribed values according to changes in surface fluxes
- Slightly smaller 20-100-day filtered variability in SPCAM-s in West Pacific, slightly larger in Indian Ocean
- More realistic SLHF and SST profiles during MJO for SPCAM-s
- More realistic westward tilt with height in SPCAM-s likely related to **well-developed boundary layer moisture convergence** and **warmer SST'** within two weeks prior to heaviest rainfall

