PERTURBED-PARAMETER SIMULATIONS OF THE MJO WITH CAM5

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APPROACH

- Modelers would like to understand how their climate models could better simulate an MJO
  - CAM5 is noticeably worse than CAM4 which was quite good (*Subramanian et al. 2012*). *Why?*
- We systematically explore the dependencies of CAM5's MJO simulation on uncertain parameters, with a "perturbed-parameter ensemble" technique
  - To what extent, do the parameters control the interactions of the parameterized processes and influence the MJO?
  - *Are better MJOs within tuning ranges? Or are new parameterizations needed?*
- We wish to more fully explore the range of model MJO behaviors as a function of parameters

PERTURBED PARAMETER SIMULATIONS

- **<u>“Climate”:</u>**
  - CAM5.1 @ 2° resolution
  - 5-year “AMIP” simulations (i.e. prescribed SSTs for 2000-05)
  - Two ensembles:
    - Perturbed each of 22 parameters in CAM’s physical parameterizations ONE-AT-A-TIME (“OAT”) (# of simulations = 2*22 + 1 = 45)
    - Simultaneously perturb 22 parameters using Latin Hypercube Sampling (“LHS”) (# of simulations = 1100)
  - These simulations were performed for another project → Only hourly (total) precipitation is available for our analysis

PARAMETERS VARIED

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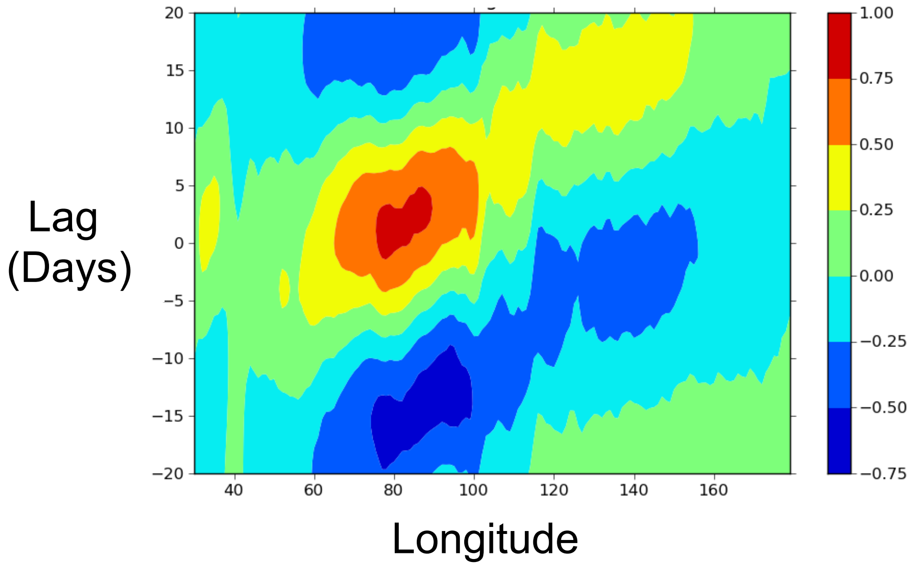
	modelSection_modelVariable	variable description	low value	default	high value
Large-Scale Cloud	cldfrc_rhminh	Threshold RH for fraction high stable clouds	0.65	0.8	0.85
	cldfrc_rhminl	Threshold RH for fraction low stable clouds	0.8	0.8875	0.99
	cldwatmi_ai	Fall speed parameter for cloud ice	350	700	1400
	cldwatmi_as	Fall speed parameter for snow	5.86	11.72	23.44
	cldwatmi_cdnl	Cloud droplet number limiter	0	0	1e+06
	cldwatmi_dcs	Autoconversion size threshold for ice to snow	0.0001	0.0004	0.0005
	cldwatmi_eii	Collection efficiency aggregation of ice	0.001	0.1	1
	cldwatmi_qcvar	Inverse relative variance of sub-grid cloud water	0.5	2	5
Aerosol	dust_emis_fact	Dust emission tuning factor	0.21	0.35	0.86
PBL Turb.	eddydiff_a2l	Moist entrainment enhancement parameter	10	30	50
Large-Scale Cloud	micropa_wsubimax	Maximum sub-grid vertical velocity for ice nucleation	0.1	0.2	1
	micropa_wsubmin	Minimum sub-grid vertical velocity for liquid nucleation	0	0.2	1
Shallow Conv.	uwshcu_criqc	Maximum updraft condensate	0.0005	0.0007	0.0015
	uwshcu_kevp	Evaporative efficiency	1e-06	2e-06	2e-05
	uwshcu_rkm	Fractional updraft mixing efficiency	8	14	16
	uwshcu_rpen	Penetrative updraft entrainment efficiency	1	5	10
Deep Conv.	zmconv_alfa	Initial cloud downdraft mass flux	0.05	0.1	0.6
	zmconv_c0_lnd	Deep convection precipitation efficiency over land	0.001	0.0059	0.01
	zmconv_c0_ocn	Deep convection precipitation efficiency over ocean	0.001	0.045	0.1
	zmconv_dmpdz	Parcel fractional mass entrainment rate	0.0002	0.001	0.002
	zmconv_ke	Evaporation efficiency parameter	5e-07	1e-06	1e-05
	zmconv_tau	Convective time scale	1800	3600	28800

MJO METRICS

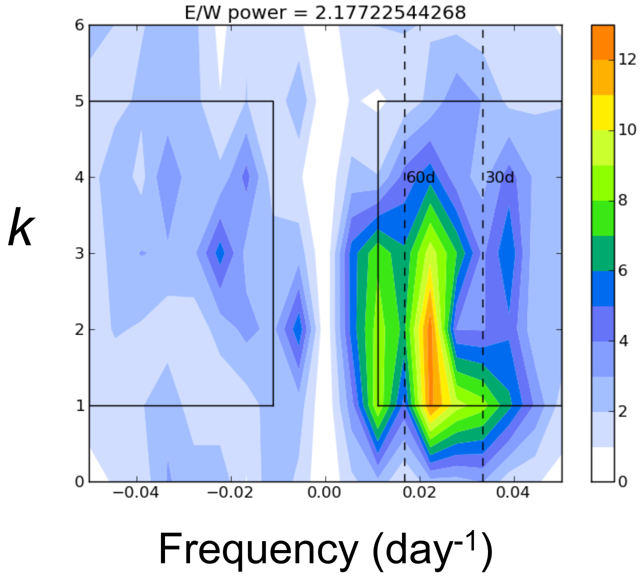
a) correlation coefficient with the pattern of lead-lag correlation coefficients of band-passed filtered 5°N-5°S averaged precipitation with that in the Indian Ocean (70°-90°E)

b) east-west power ratio of precipitation variance in wavenumbers 1-5 and periods 20 – 90 days

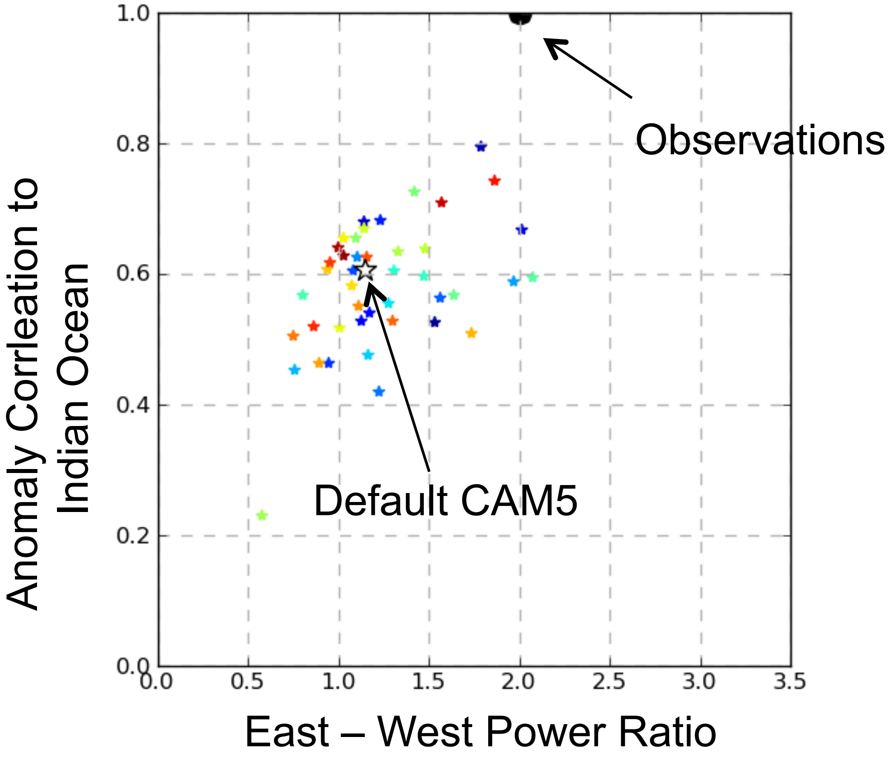
Hovmöller

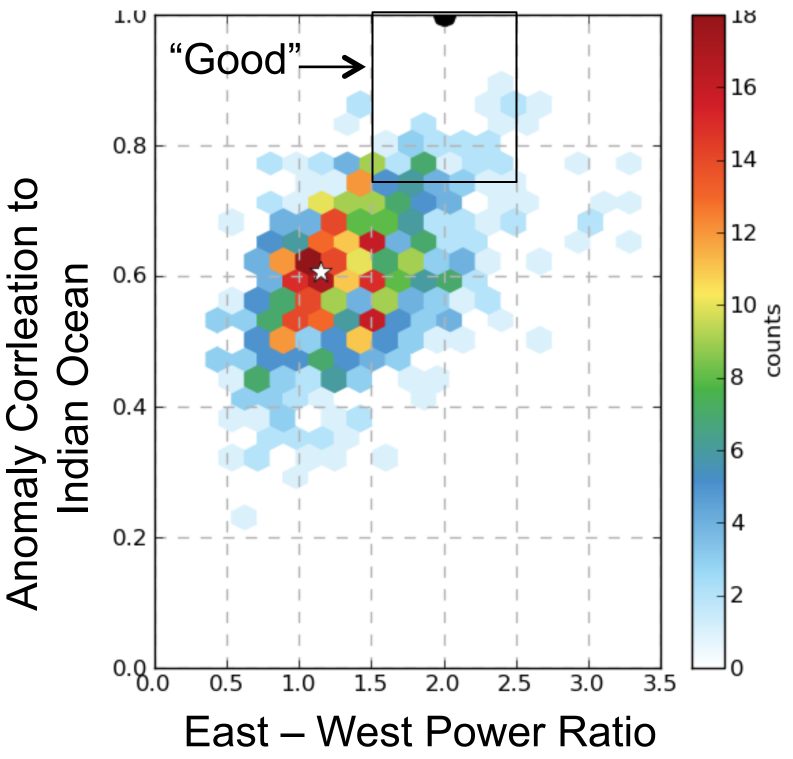


Power Spectra



VARIABILITY IN METRICS

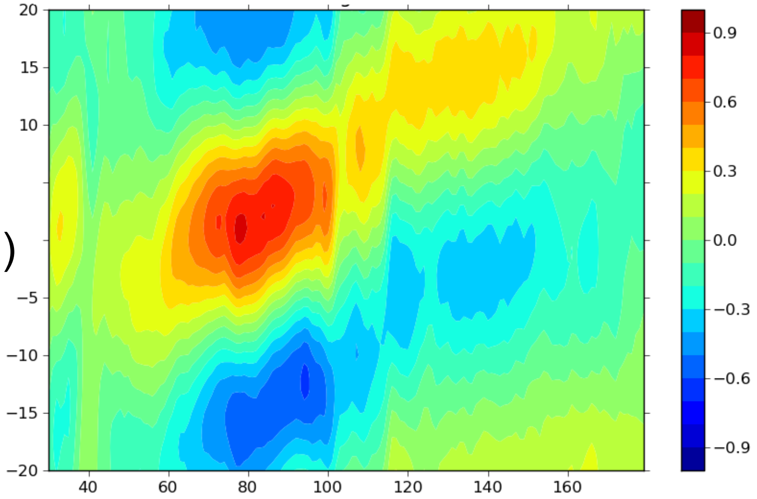

One-At-a-Time


Latin Hypercube Sampling

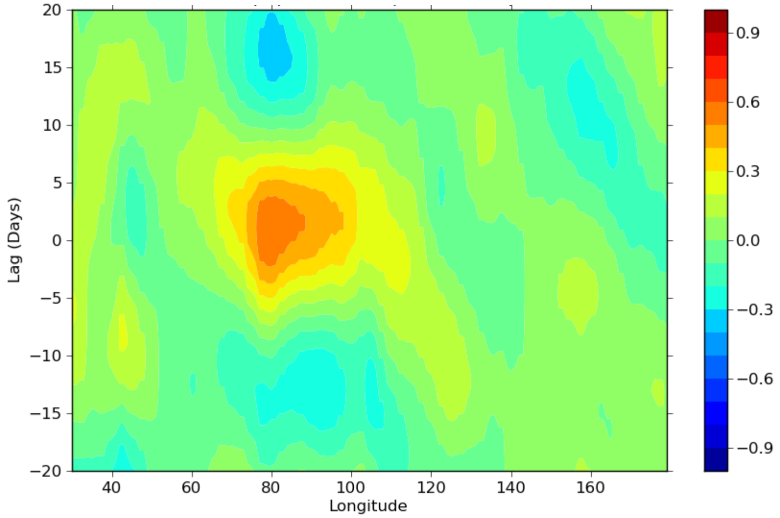
LEAD-LAG CORRELATIONS PATTERNS

Observations

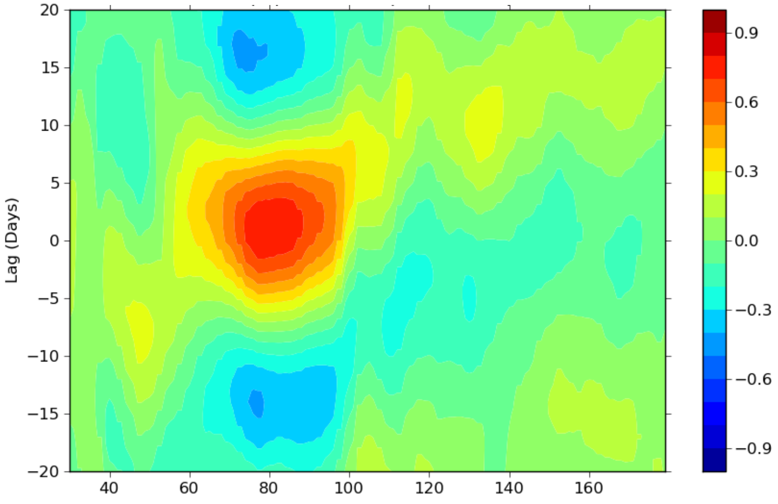
Lag (Days)



Default CAM5

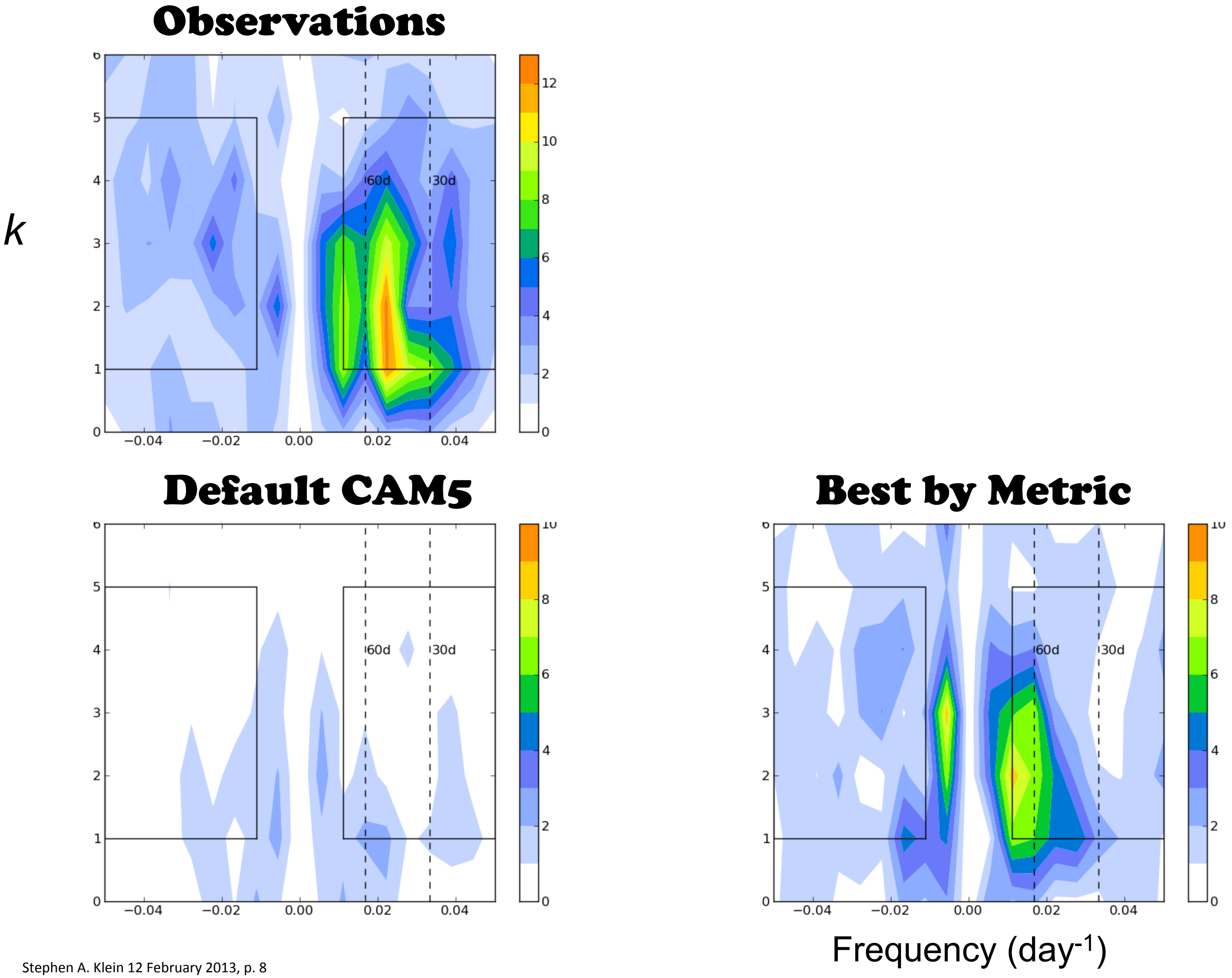


Best by Metric



Longitude

POWER-SPECTRA



Observations

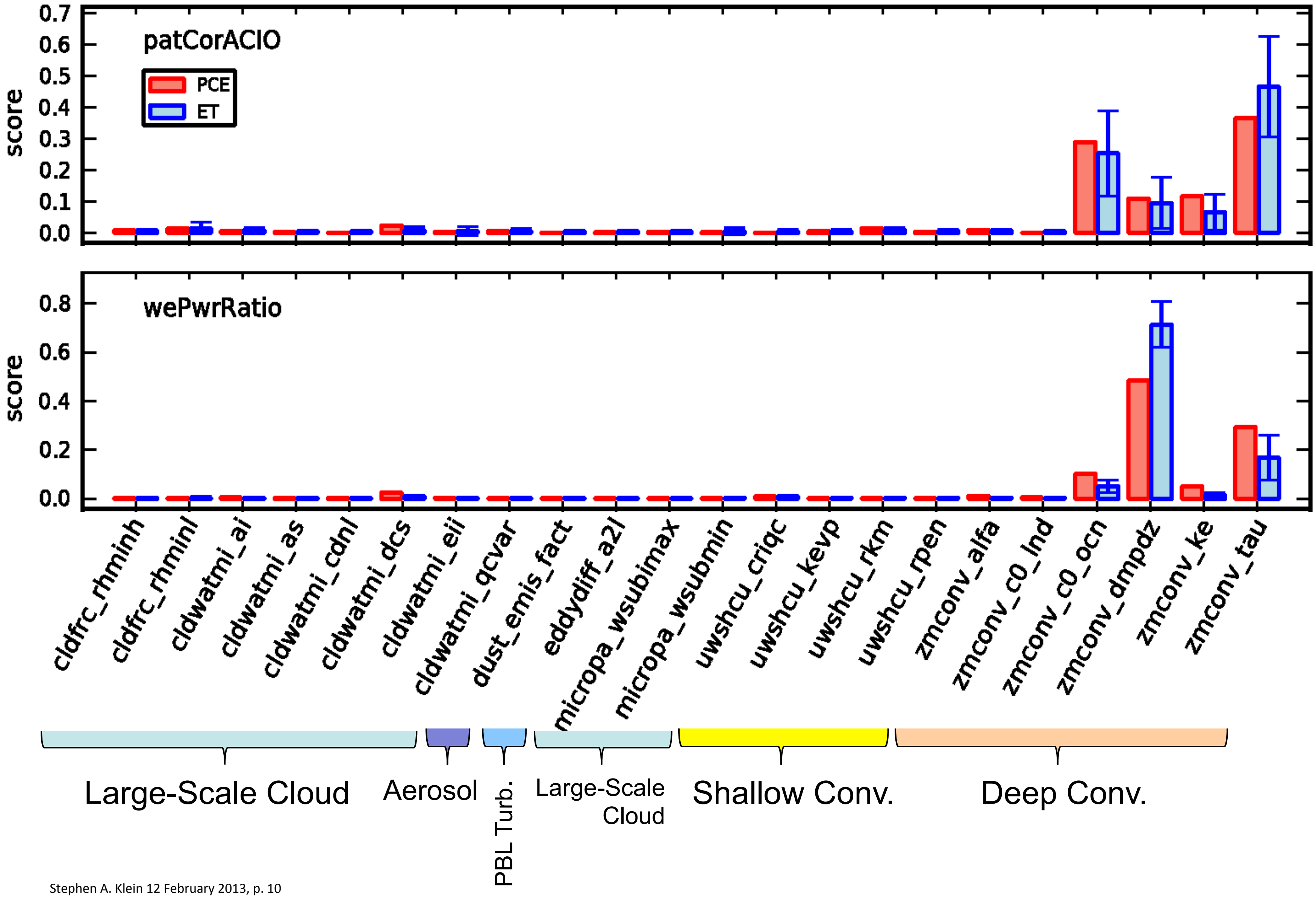
Default CAM5

Best by Metric

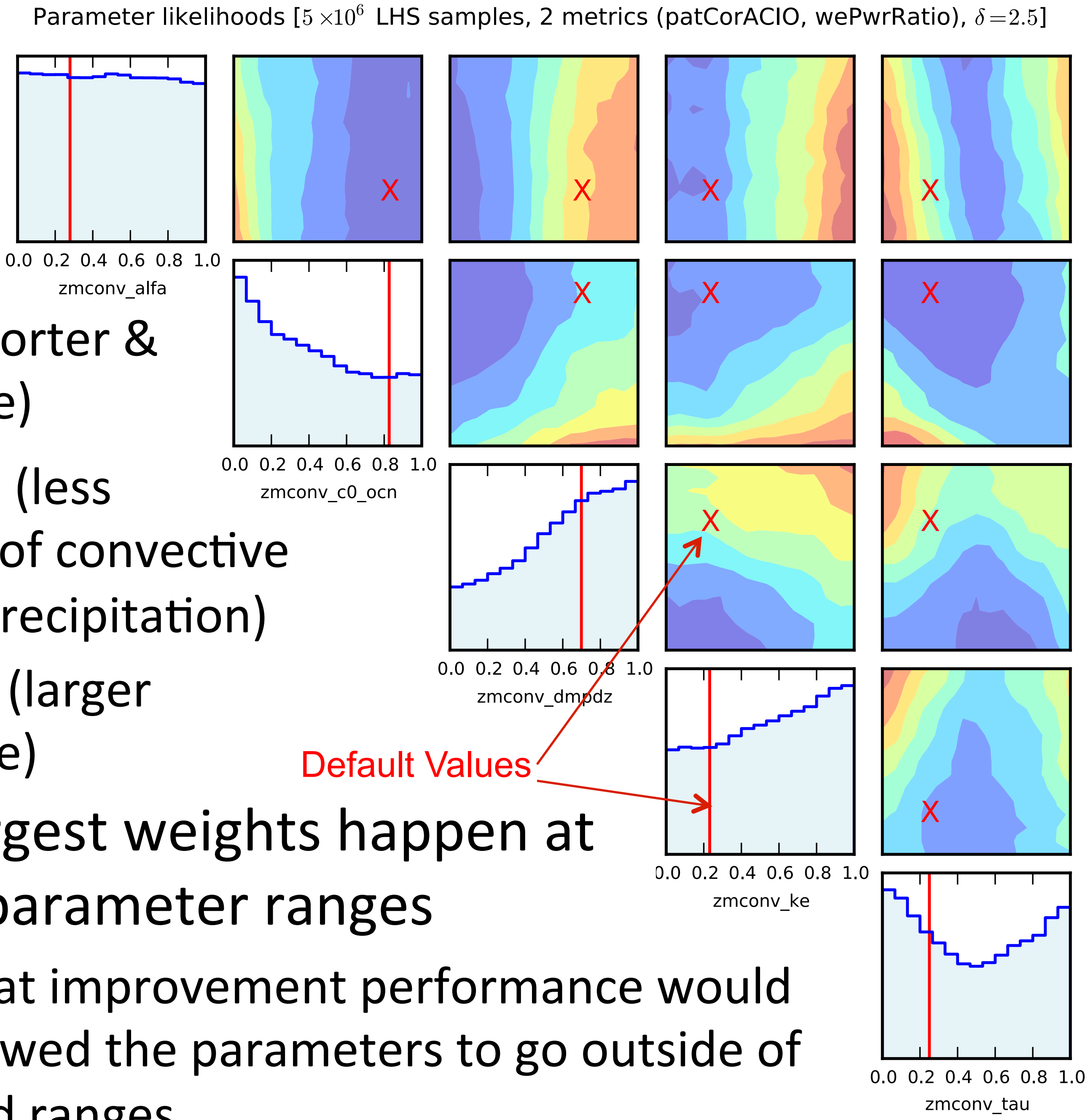
WHAT PARAMETERS MATTER? WHAT VALUES IMPROVE THE SIMULATIONS?

- General approach
  - Fit a mathematical "surrogate" model that relates the predictands (metrics of MJO simulation) to the predictors (physics parameters perturbed)
  - Use "surrogate" model to tell you which predictors have influence and which are immaterial
  - Create a new "surrogate" model with only the important predictors
  - Use the new "surrogate" model and the observed predictand values to create likelihood estimates of the predictors
- Specific methods used
  - Sparse Polynomial Chaos Expansion (3^{rd} order) (PCE)
  - Random Forest Regression (ET) *(Breiman 2001)*

DEEP CONVECTION PARAMETERS MATTER



- Suggested parameter improvements
  - Zmconv_tau (Shorter & Longer timescale)
  - Zmconv_c0_ocn (less autoconversion of convective condensate to precipitation)
  - Zmconv_dmpdz (larger entrainment rate)
- Note that the largest weights happen at the ends of the parameter ranges
  - This suggests that improvement performance would result if one allowed the parameters to go outside of the pre-specified ranges


Parameter likelihoods [5×10^6 LHS samples, 2 metrics (patCorACIO, wePwrRatio), $\delta=2.5$]

Default Values

PRELIMINARY CONCLUSIONS

- Perturbed-parameter technique allows a more thorough exploration of model sensitivities than normally done
- Improved simulations result from making it harder for deep convection to occur but when it occurs reducing the drying tendency of convection while trying get the convection over faster
- Issues:
  - 5 years is a bit short and introduces noise
  - 1100 simulations is insufficient for a 22 dimensional space

PRELIMINARY CONCLUSIONS

- Next steps
  - More diagnostics from longer simulations for selected runs
  - Would an improved simulation result if we just change the parameters that are important, rather than all 22 simultaneously
  - Would we get a different impression from coupled-ocean atmosphere modeling?
- Comparison with hindcasts results (not shown today):
  - Difference: c0_ocn is unimportant for precip in hindcasts (it matters for OLR/WVP)
  - Similarity: shorter tau is a better solution

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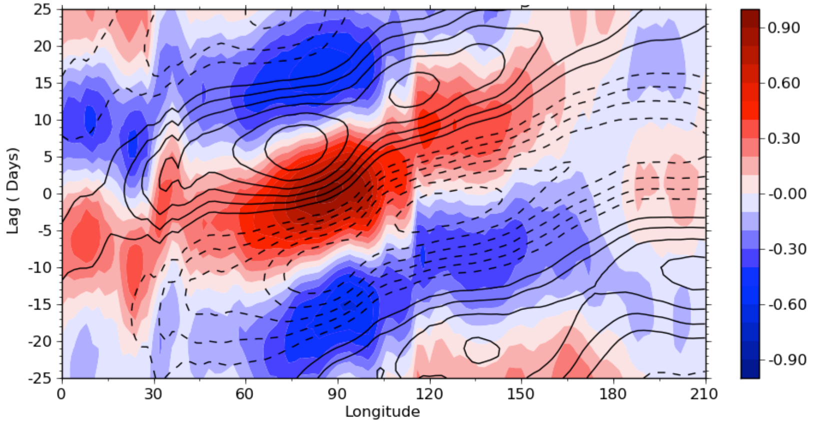
Thanks for your Attention!

EXTRA SLIDES

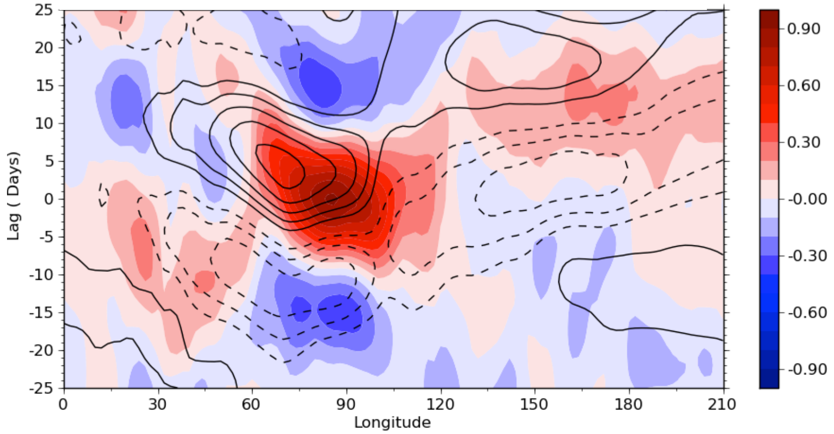
IS THIS AN MJO?

Observations

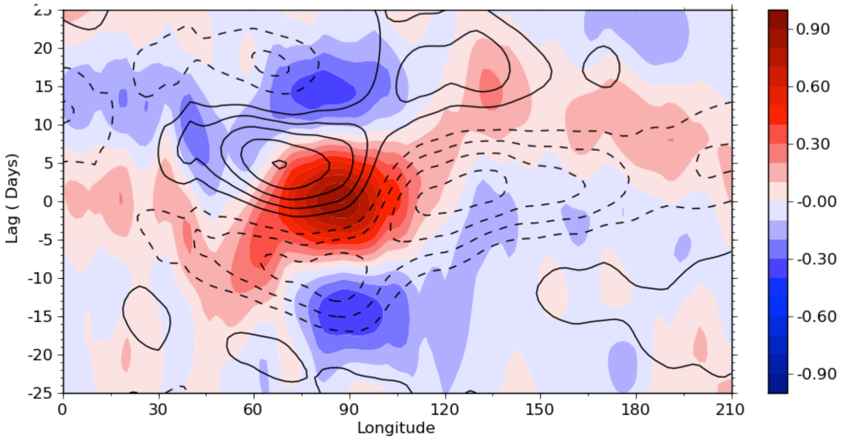


- ➢ Composite precipitation (shading) and 850 hPa zonal wind (contours) anomalies reveal some slight improvement

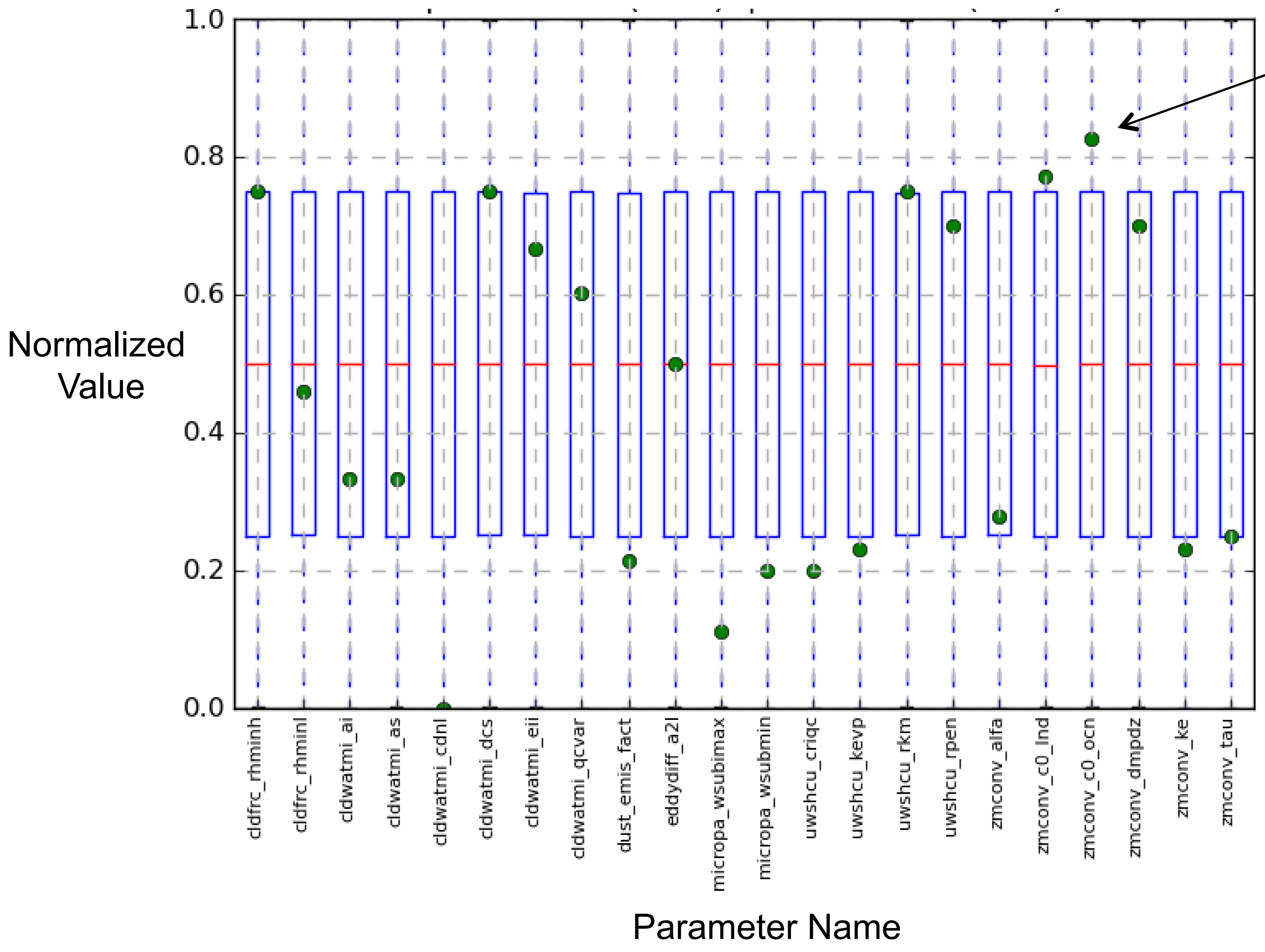
Default CAM5



Best by Metric



PARAMETER VALUES FOR ALL SIMULATIONS



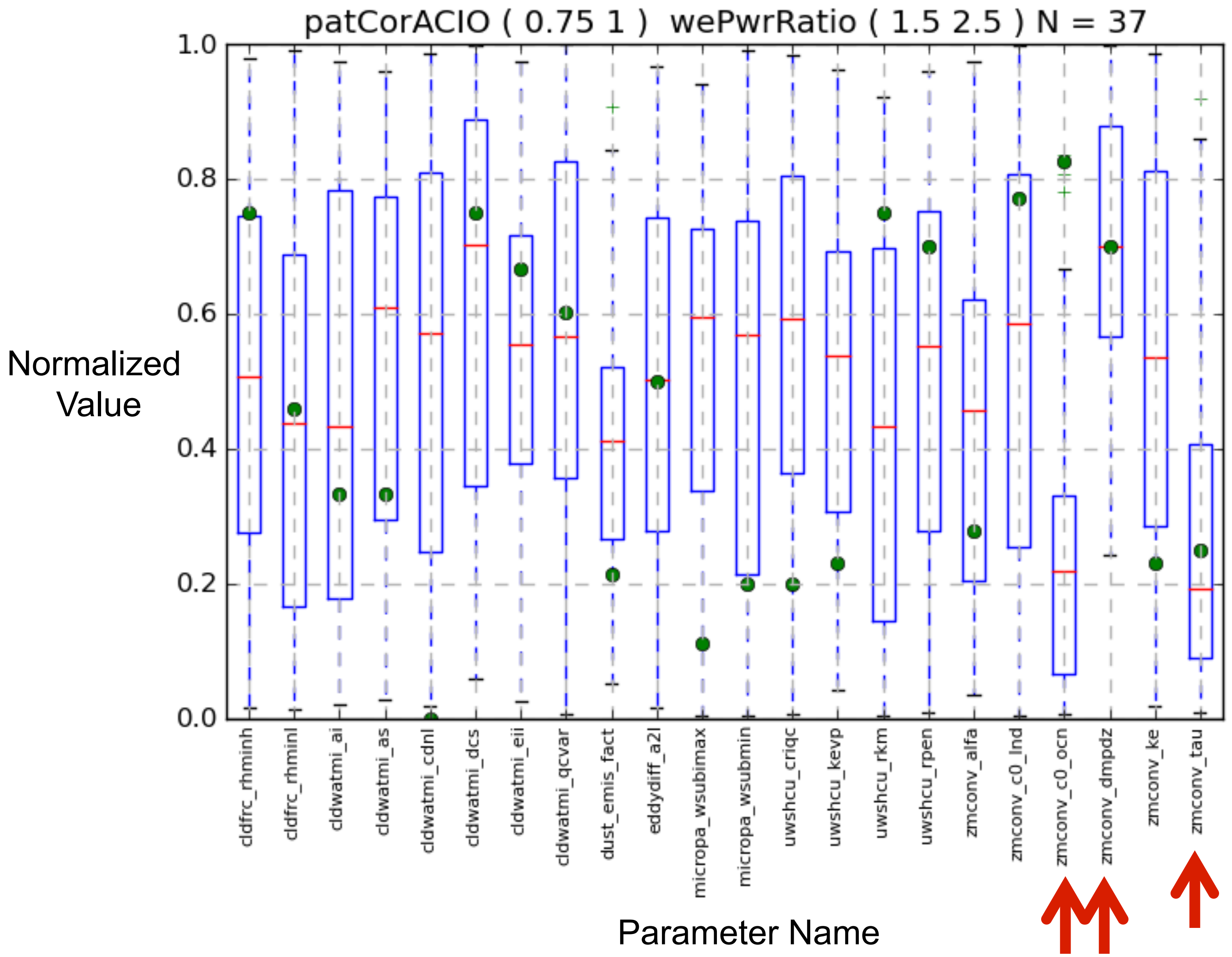
Default Parameter Value

75% Percentile

Median

25% Percentile

PARAMETER VALUES FOR SIMULATIONS WITH “GOOD” METRICS

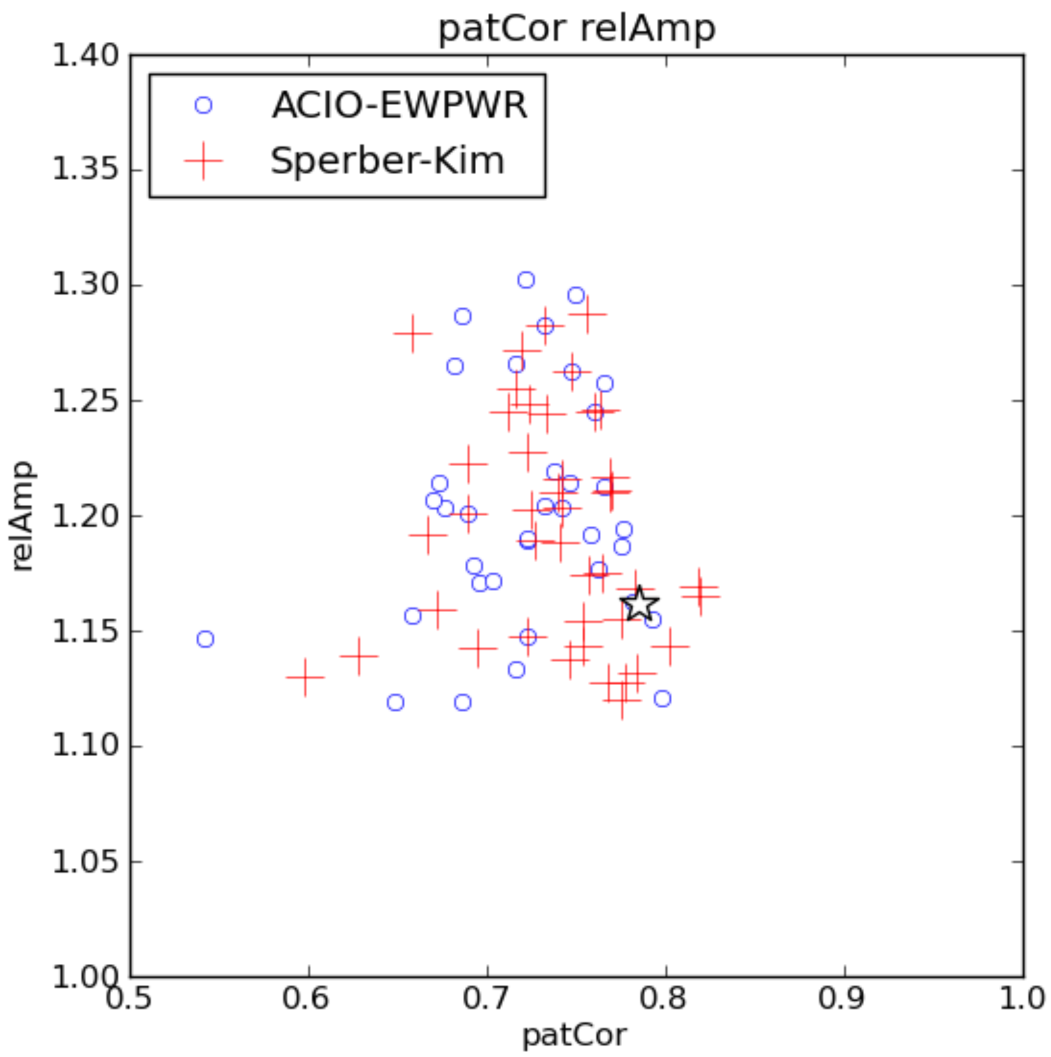


1. *Small* Deep Convection Adjustment Time-Scale

2. *Large* Entrainment Rate for Deep Convection

3. *Small* Autoconversion rate for convective condensate

SIMULATIONS OF CLIMATOLOGICAL-MEAN PRECIPITATION



Wheeler-Kiladis Diagram (Symm.)

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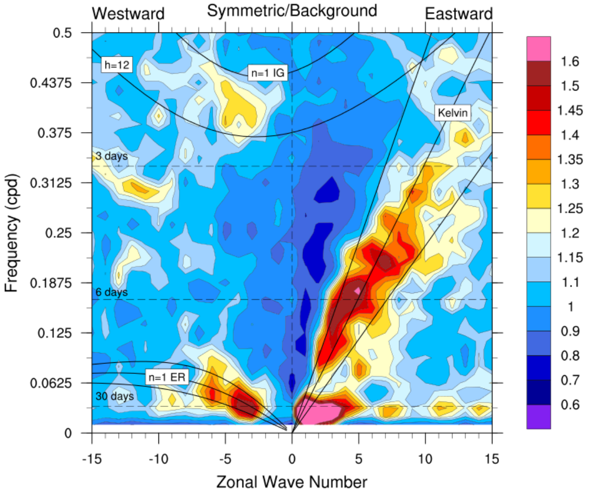
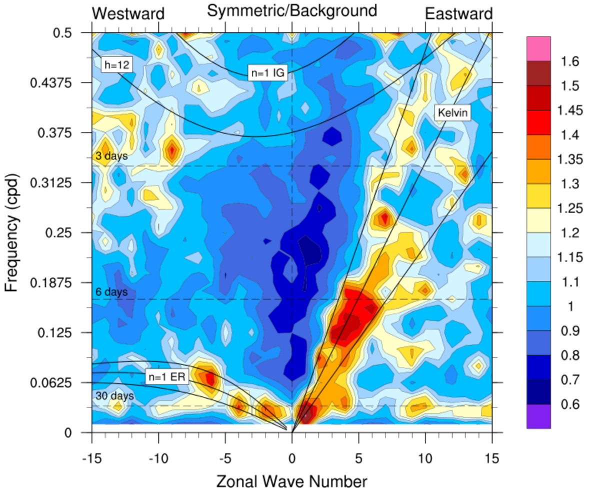
Observations

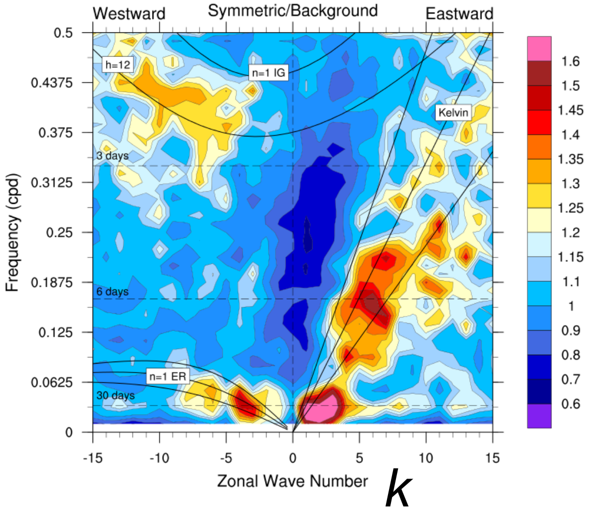
Frequency (day^{-1})



Default CAM5



Best by MJO Metric



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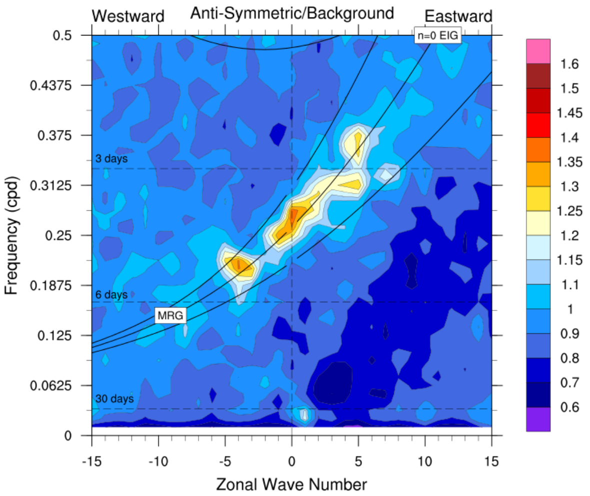
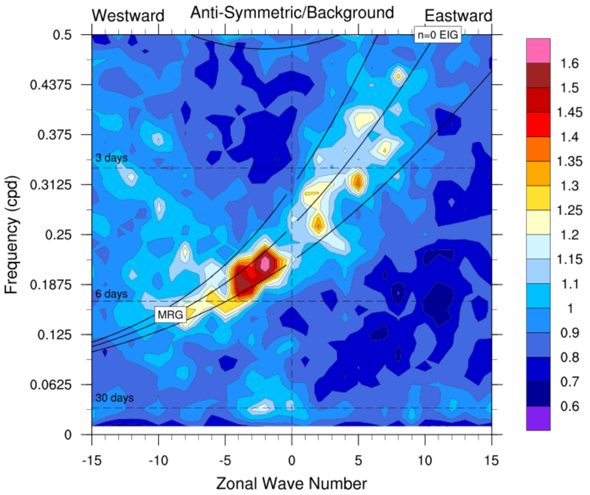
WHEELER-KILADIS DIAGRAM (ANTI-SYMM.)

Frequency
(day^{-1})

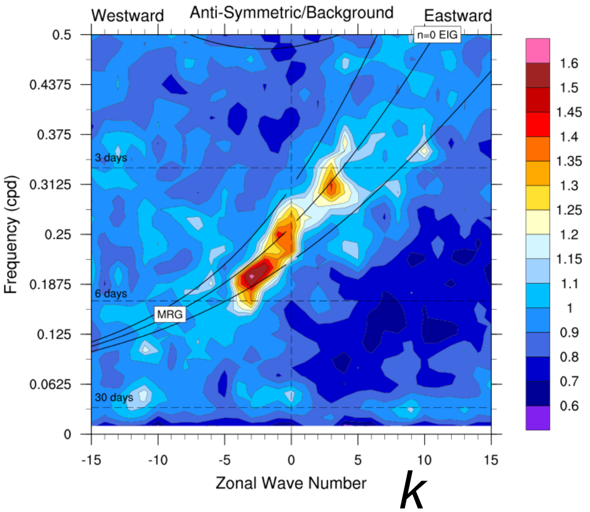
Observations



Default CAM5



Best by Metric



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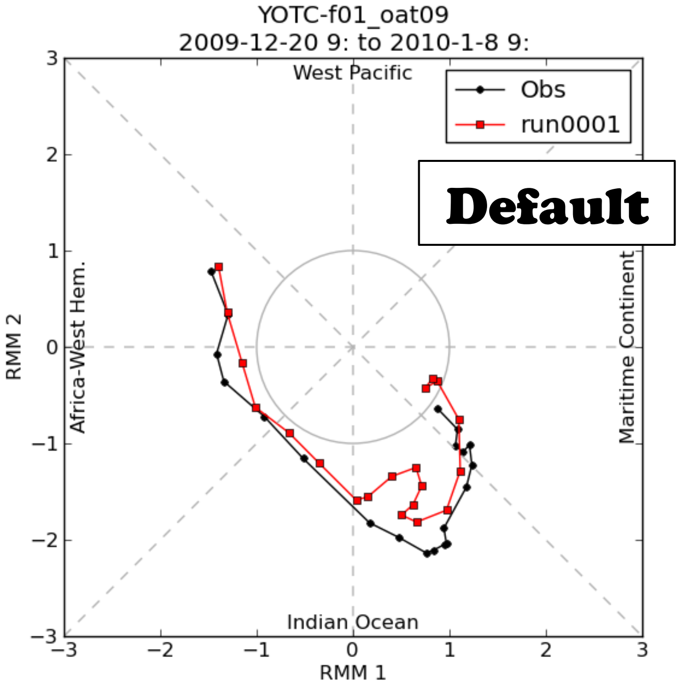
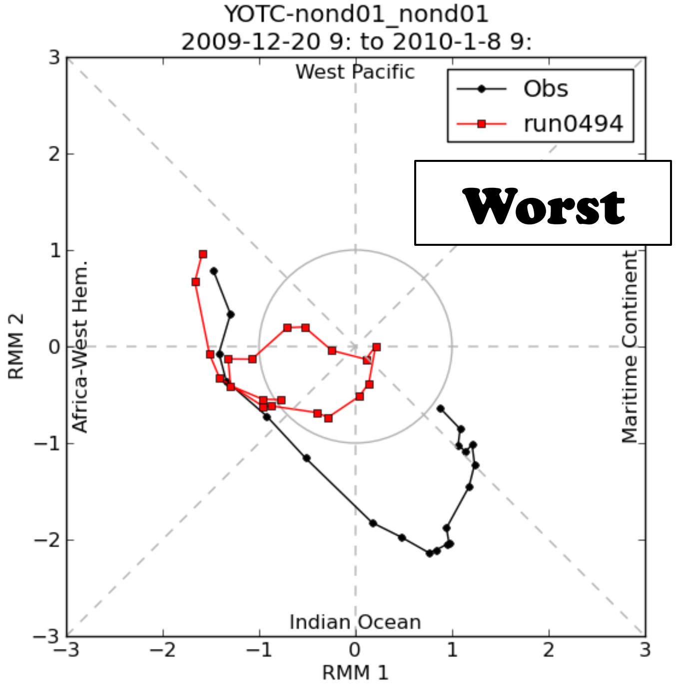
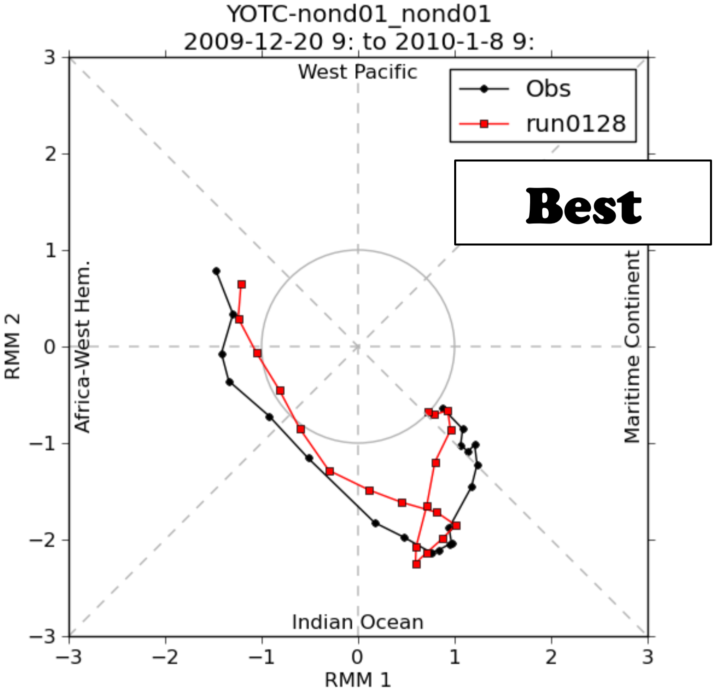


Default



Worst



Best

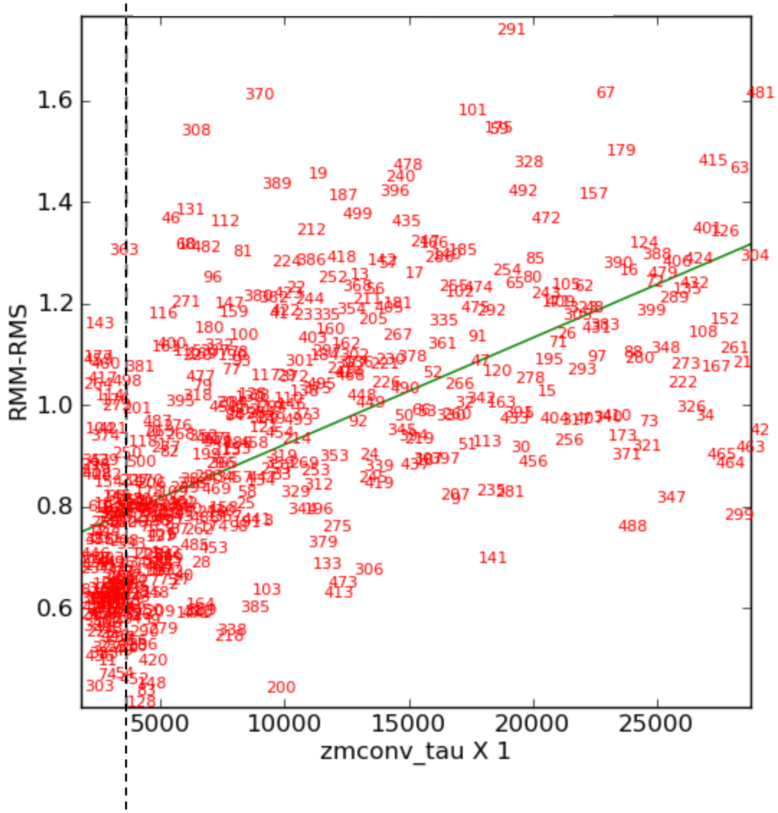
MJO Phase Plots

- Real-time Multivariate MJO Indices (RMM1 and RMM2) *(Wheeler and Hendon 2004, Gottschalck et al. 2010)*
  - Based on anomalies of 200 hPa and 850 hPa zonal wind and Outgoing Longwave Radiation (OLR)

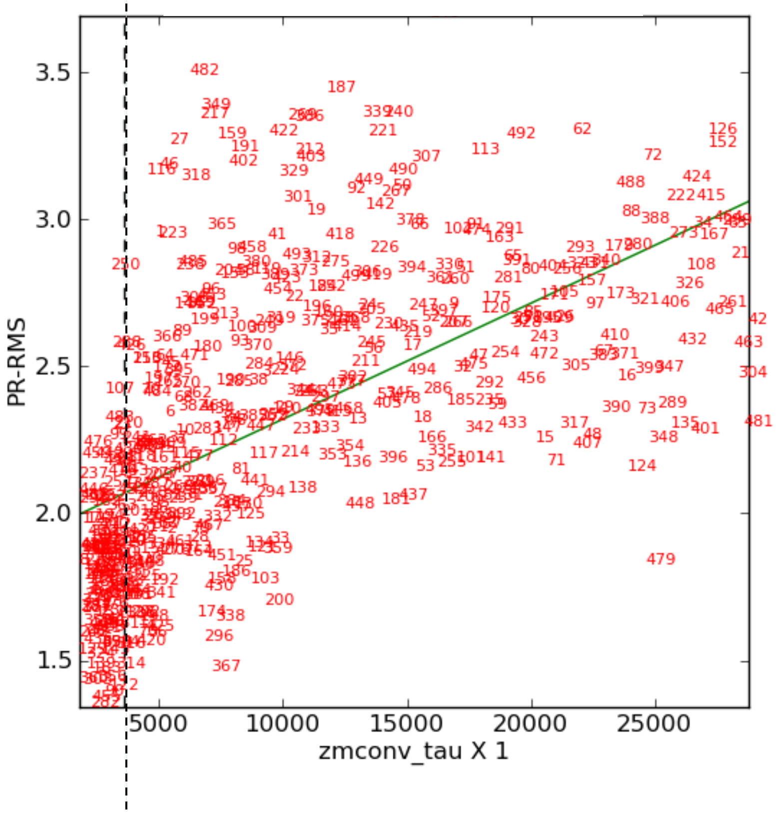
SCATTERPLOTS: RMSE VS. ZMCONV_TAU

Deep Convection Timescale

RMM



Precip



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