Forecasting the Madden Julian Oscillation with SPCAM

Preliminary results from a new CMMAP contribution to the international MJO Diabatic Heating Intercomparison Project.

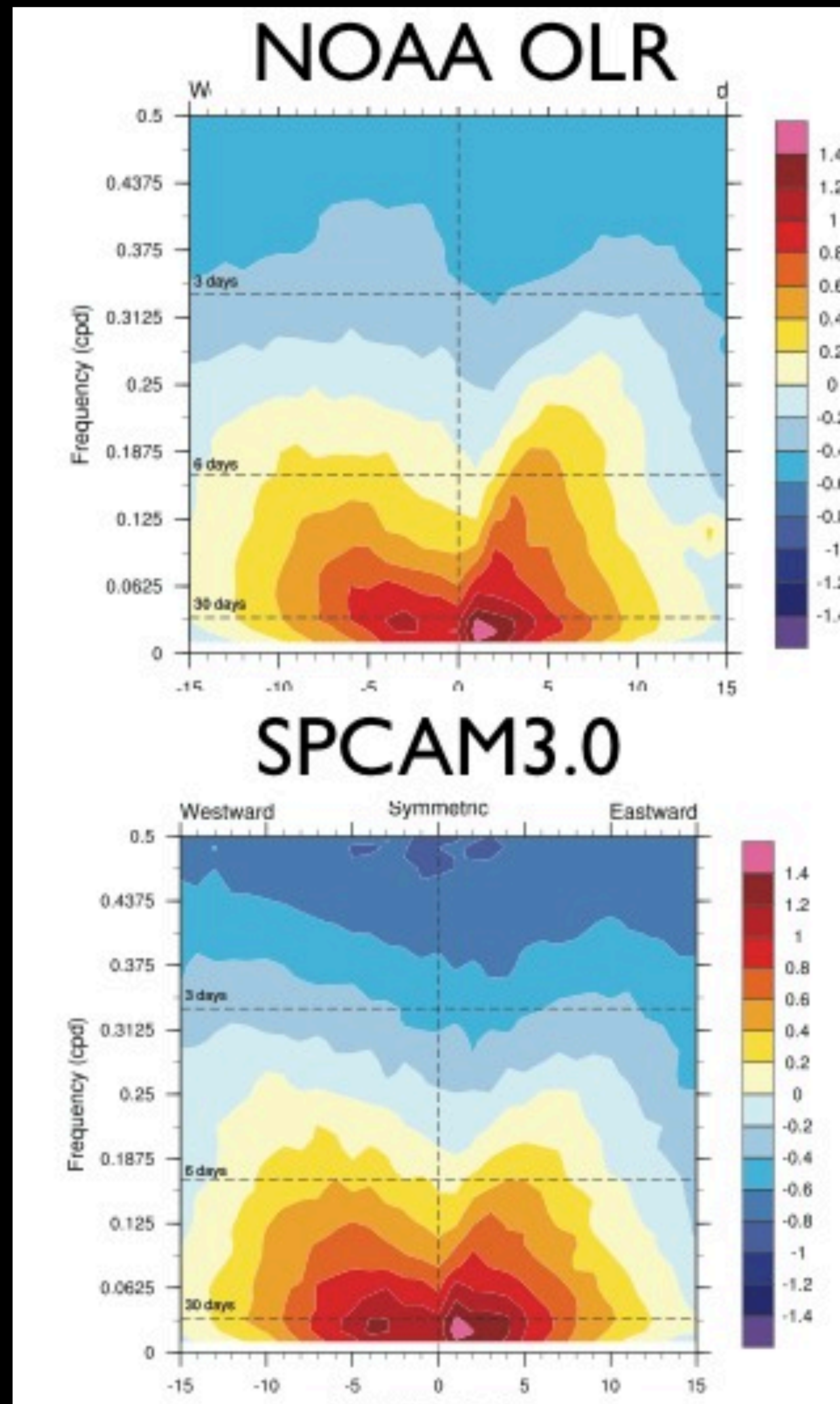
Mike Pritchard
University of Washington

Chris Bretherton & Tom Ackerman
(postdoc hosts)

Nicholas Klingaman, U. Reading
Gabe Kooperman, Scripps
(collaborators)

NOAA Climate & Global Change Fellowship
(funding)

The statistical composite signal of the MJO in multidecadal simulations of free-running SPCAM3.0 is remarkable.



Analysis of SPCAM has suggested several hypotheses about the physics of the real MJO.

- Sub-200km cloud thermodynamics are essential.
- Convective momentum transport may not matter much.
- Ocean coupling is secondary but still important.
- The moisture mode paradigm may be relevant to nature* (symmetric aquaplanet)

Lots of interesting questions come to mind.

- Why does SPCAM have a nice MJO while other GCMs don't?
- How realistic is the MJO in the *new* versions of SPCAM?
- Can SPCAM realistically *forecast* real-world MJOs?
- Might convective momentum transport matter to the SP-MJO?
- What are the dominant pathways of SP moisture mode destabilization in its *real-world* configuration?

Including SPCAM in a new international MJO model intercomparison project is a chance to explore these questions.

Vertical Structure and Diabatic Processes of the MJO

A Global Model Evaluation Project

http://climate.ncas.ac.uk/pmwiki/MJO_Diabatic_Hindcast/

MULTIPLE COMPONENTS:

- Climate simulations (component 1)
- Two-day hindcasts (component 2)
- 20-day hindcasts (component 3)

EXAMPLE OF OUTPUT REQUIREMENTS
CLOSING T,Q,U,V BUDGETS:

Budget terms of T $\frac{\partial T}{\partial t} = \frac{\partial T}{\partial t}\Big|_{LS} + \frac{\partial T}{\partial t}\Big|_{phys}$

12	Total rate of change of temperature	$\frac{dT}{dt}$ (K s^{-1})	tnt	6 hrly mean
13	Shortwave radiative heating rate	Q_R^{SW} (K s^{-1})	tntrsw	6 hrly mean
14	Longwave radiative heating rate	Q_R^{LW} (K s^{-1})	tntrlw	6 hrly mean
15	Rate of change of temperature due to convection	$\frac{\partial T}{\partial t}\Big|_{conv}$ (K s^{-1})	tntc	6 hrly mean
16	Rate of change of temperature due to Boundary layer	$\frac{\partial T}{\partial t}\Big|_{BL}$ (K day^{-1})	tntpbl	6 hrly mean
17	Rate of change of temperature due to large scale cloud, precipitation	$\frac{\partial T}{\partial t}\Big|_{LSCprecip}$ (K s^{-1})	tntlscp	6 hrly mean
18	Rate of change of temperature due to advection	$\frac{\partial T}{\partial t}\Big|_{adv}$ (K s^{-1})	tnta	6 hrly mean
19	Rate of change of temperature due to horizontal diffusion +gravity wave drag+ any other terms	$\frac{\partial T}{\partial t}\Big|_{diff}$ (K s^{-1})	tntd	6 hrly mean

Questions

What version of SPCAM makes sense to contribute to the intercomparison?

It is tempting to run one of the **newer** versions of SPCAM with upgraded CRM physics for the intercomparison...

	New model feature	Host GCM*	GCM dynamical core	GCM hor. res. **	SSTs	Known bugs	CRM microphysics
SPCAM3.0		CAM3.0	Semi-Lagrangian	T42 (~ 500 km**)	AMIP		SAM single-

* Approximate; these models were branched out of CAM development code close to these releases.
** Half wavelength of shortest resolved zonal wave at equator.

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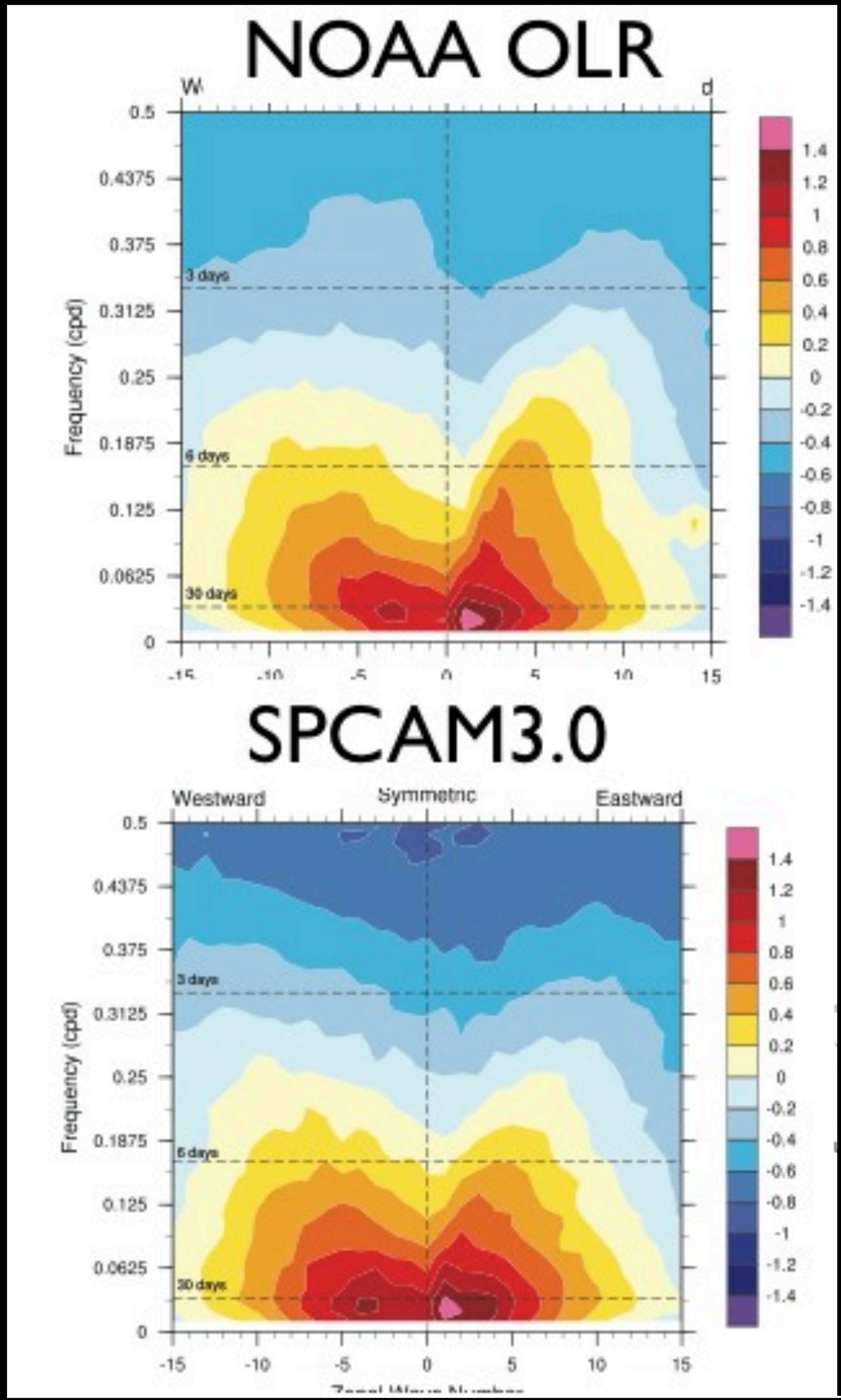
PNNL MMF	Enhanced CRM microphysics & aerosol handling	CAM5	Finite-Volume	1.9 x 2.5 (~250 km)	climo.		Morrison double-moment

* Approximate; these models were branched out of CAM development code close to these releases.
** Half wavelength of shortest resolved zonal wave at equator.

But we don’t yet know how robust SPCAM’s MJO is to recent model development and to details of SP implementation.

On closer inspection, the new versions of SPCAM do not have good composite MJO signals compared to the original model.



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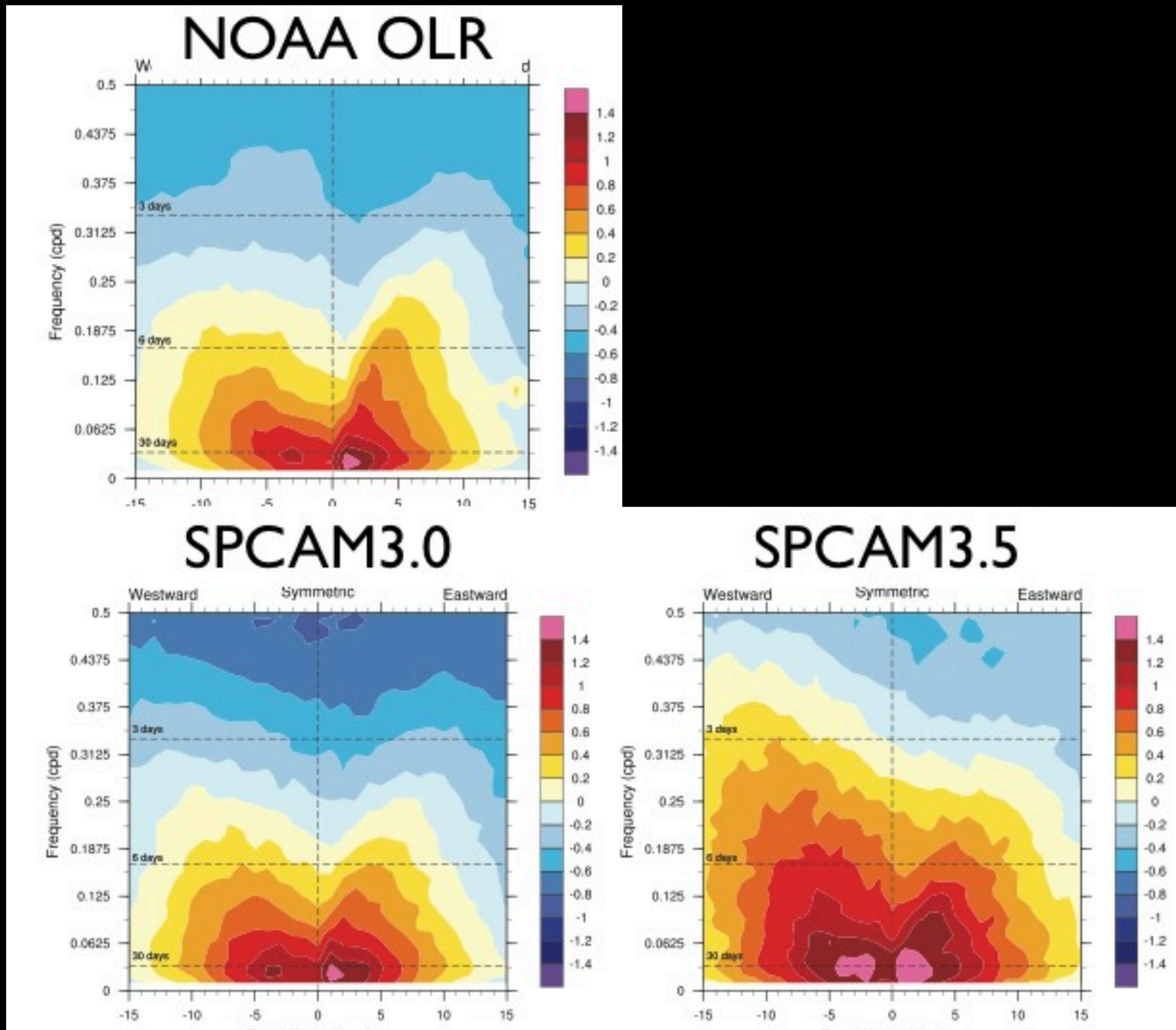

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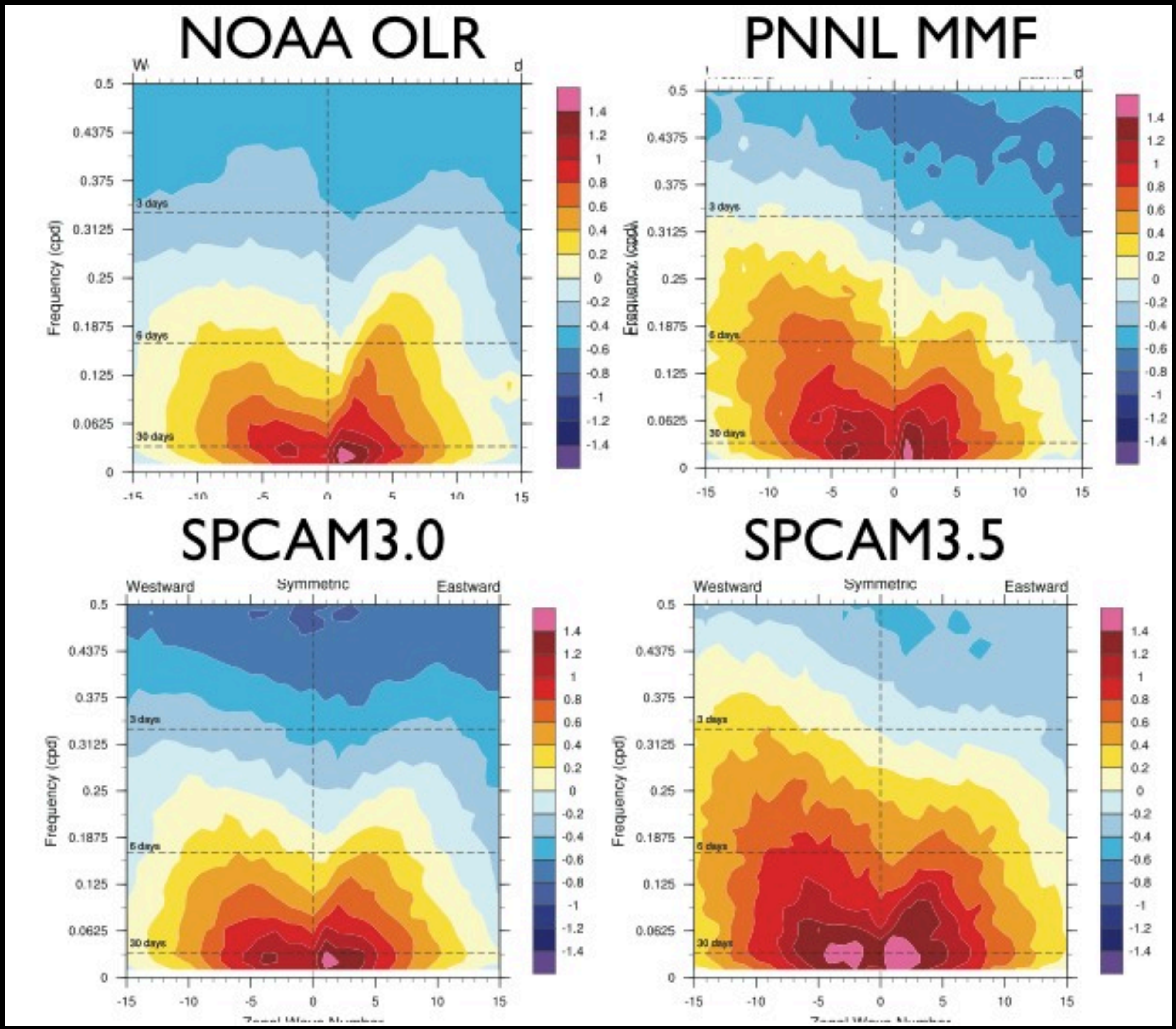
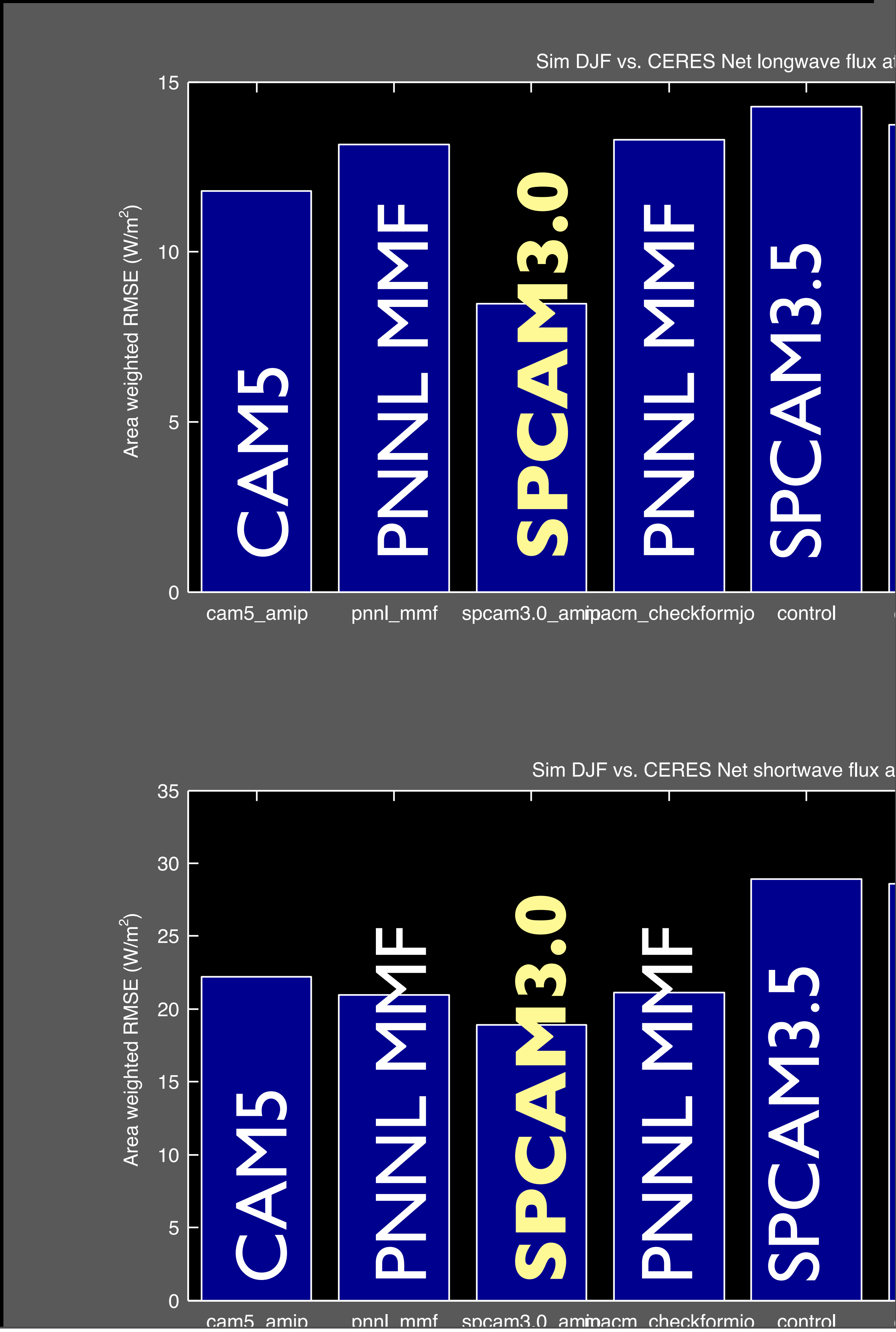


Issues with the MJO in prototype versions of SPCAM may be partly related to insufficiently tuned mean climate.

The old model, SPCAM3.0 has the least TOA radiation biases

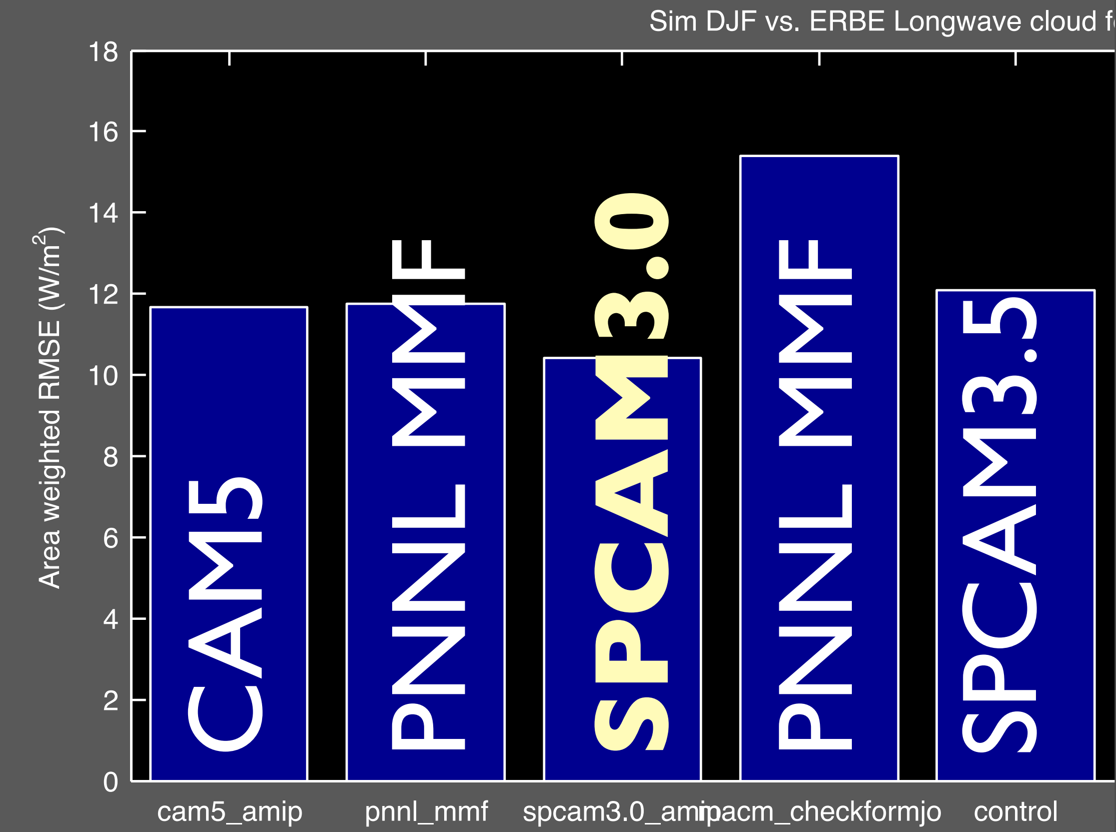
RMSE of DJF net longwave at TOA

RMSE of DJF net shortwave at TOA

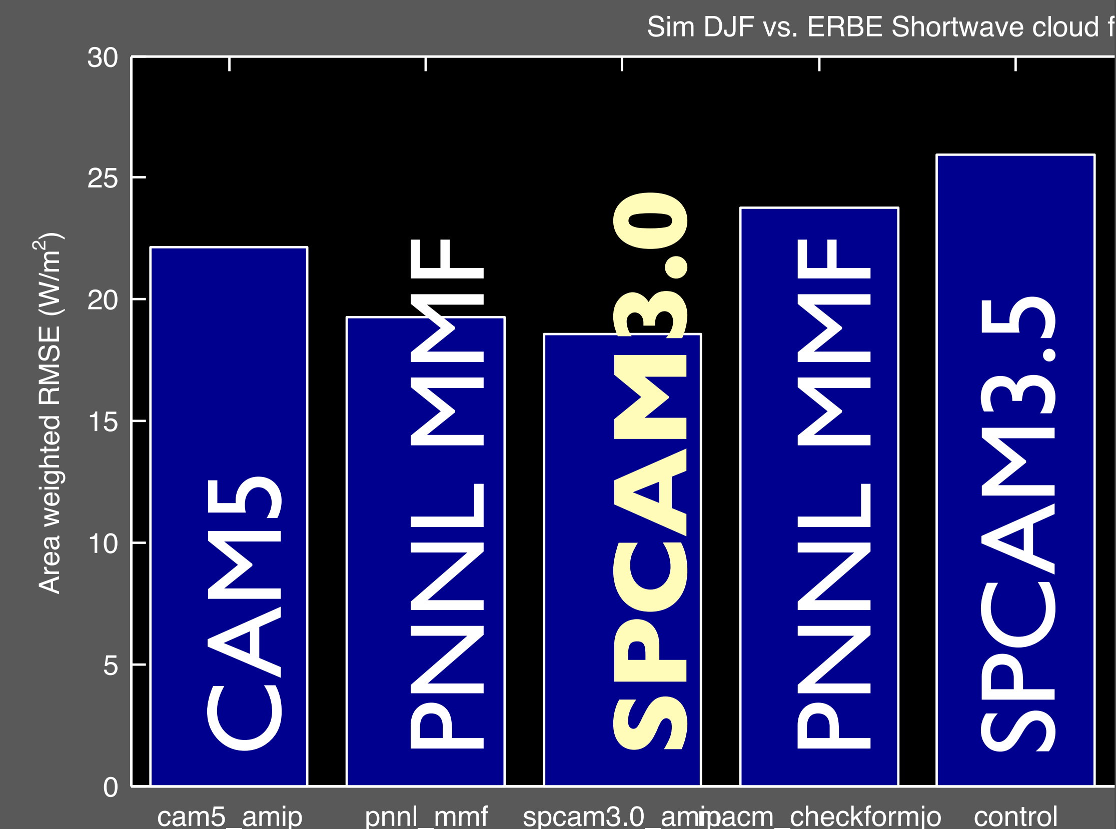


SPCAM3.0 also has the best LW and SW cloud forcing.

RMSE of DJF longwave cloud forcing

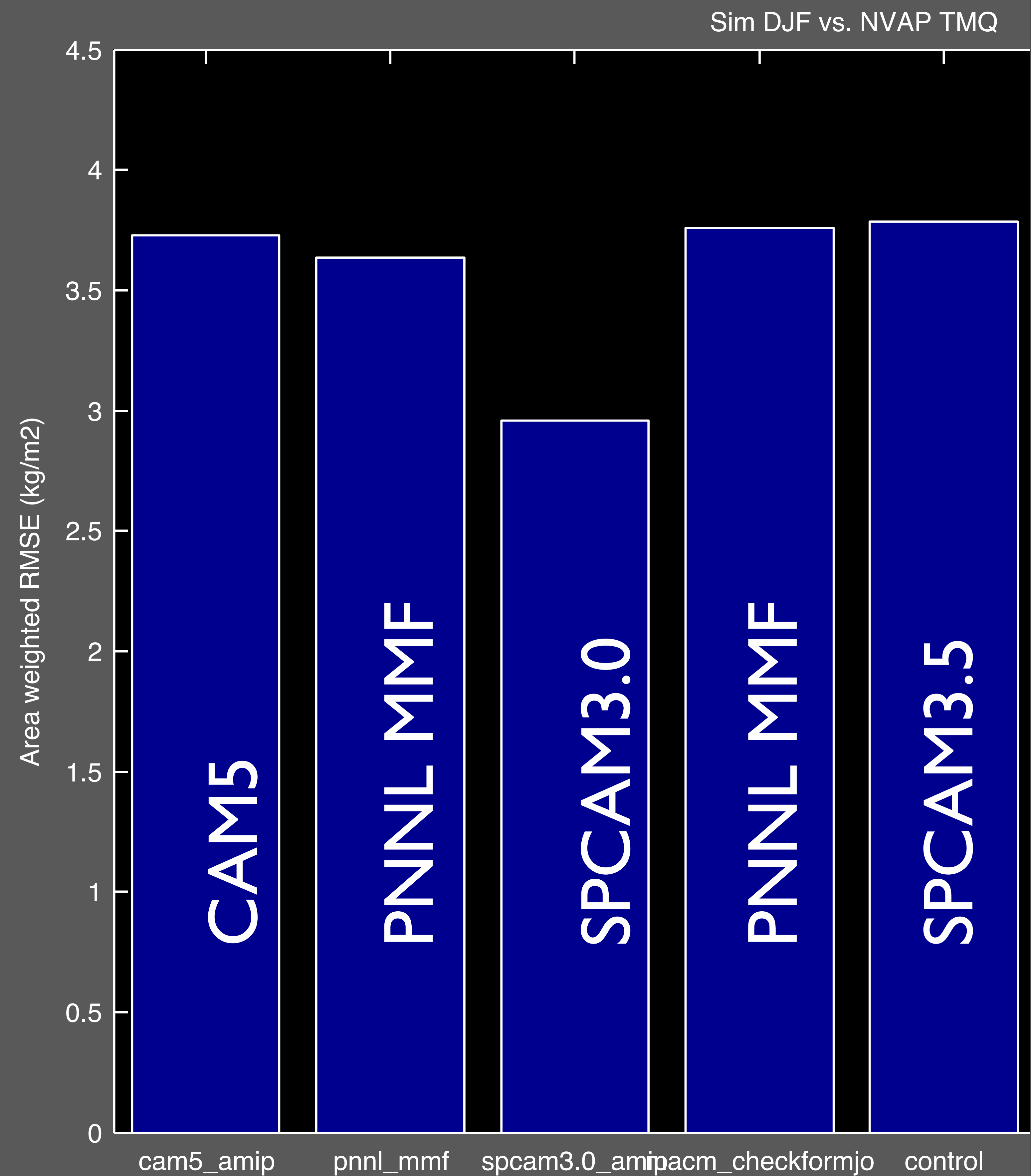


RMSE of DJF shortwave cloud forcing



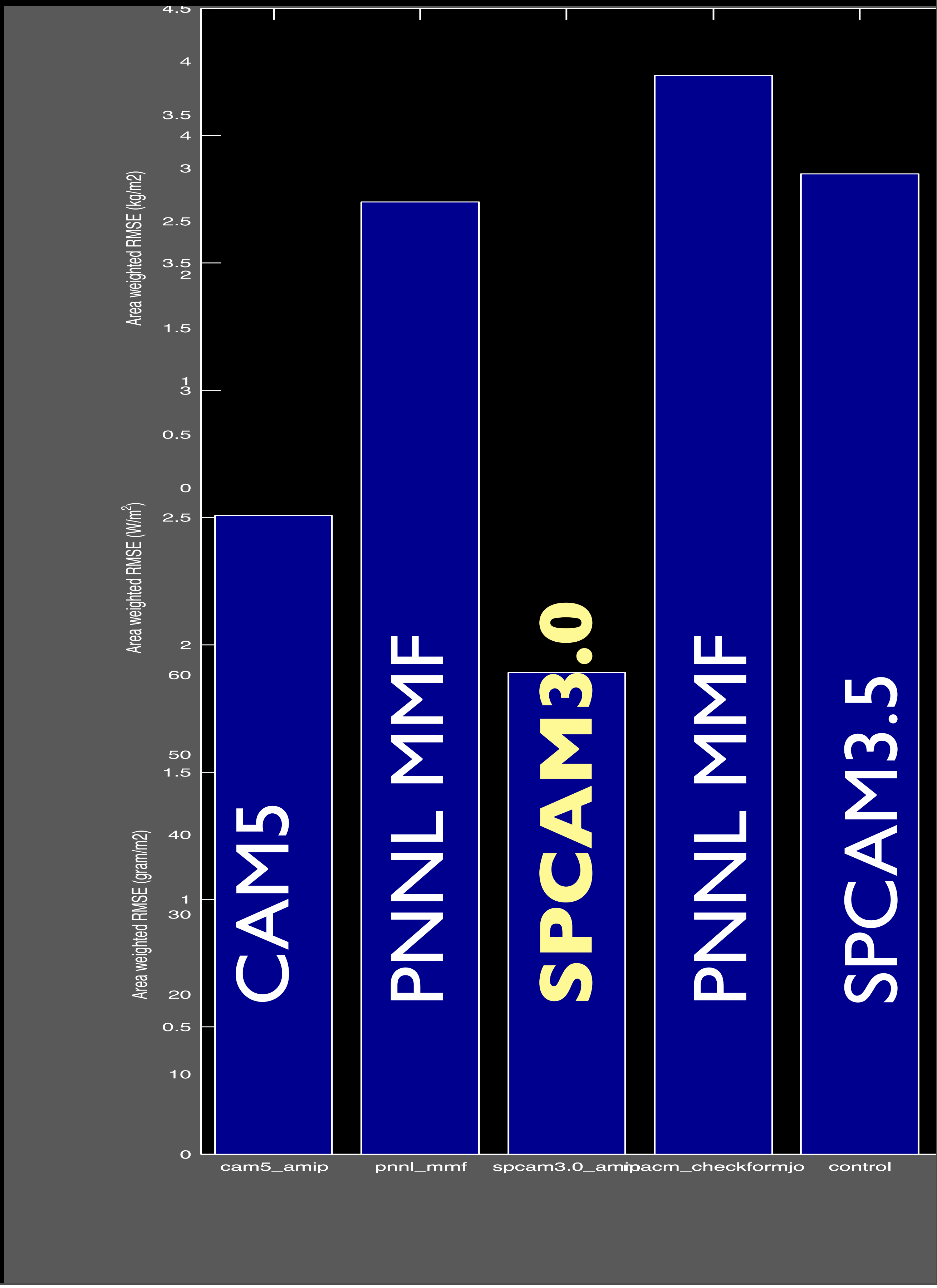
Precipitable water errors are least for SPCAM3.0sld

RMSE of DJF column water compared to NVAP.



The U850 basic state pattern is also most realistic in SPCAM3.0 compared to the other models.

(A realistic low level wind field is important for WISHE to behave appropriately)



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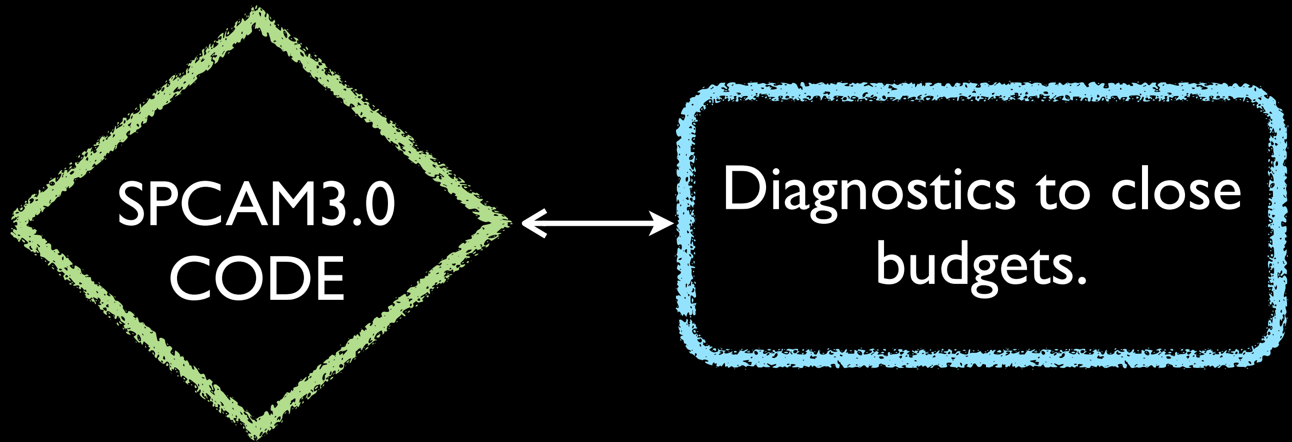
New code additions:



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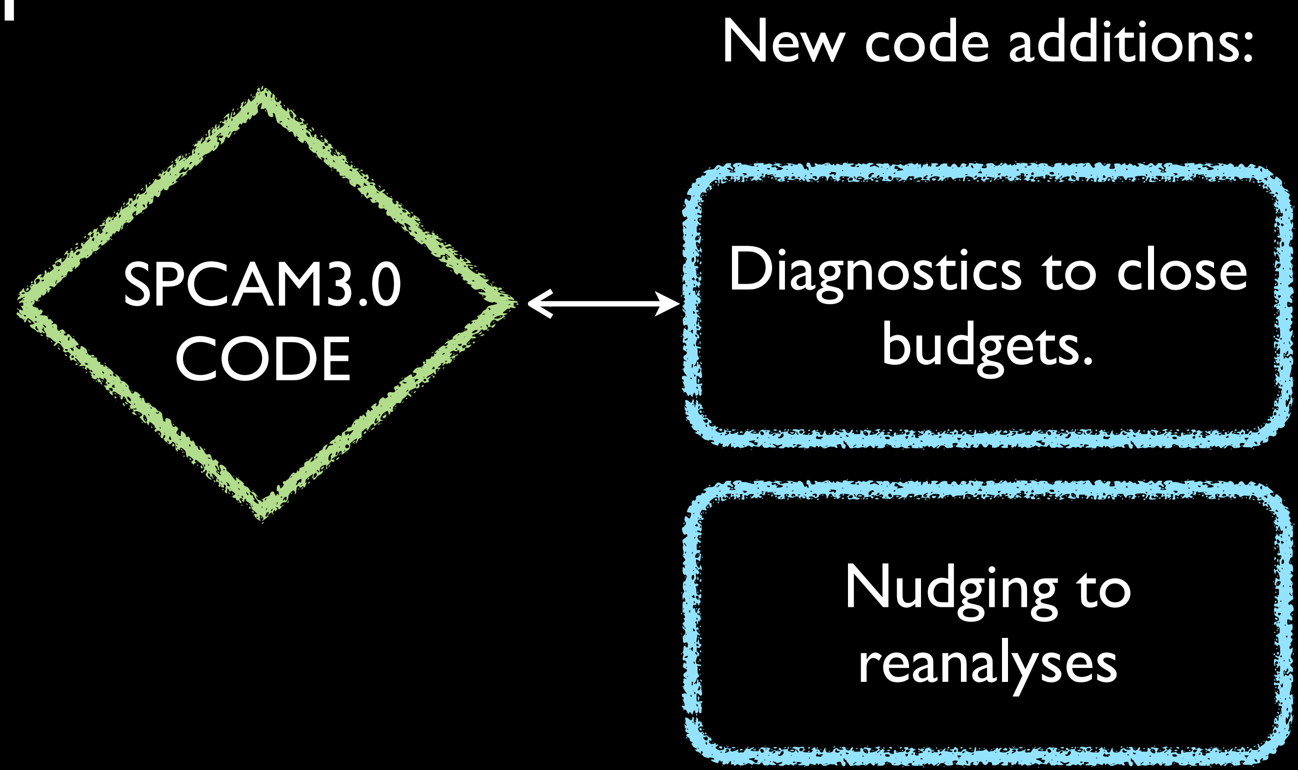

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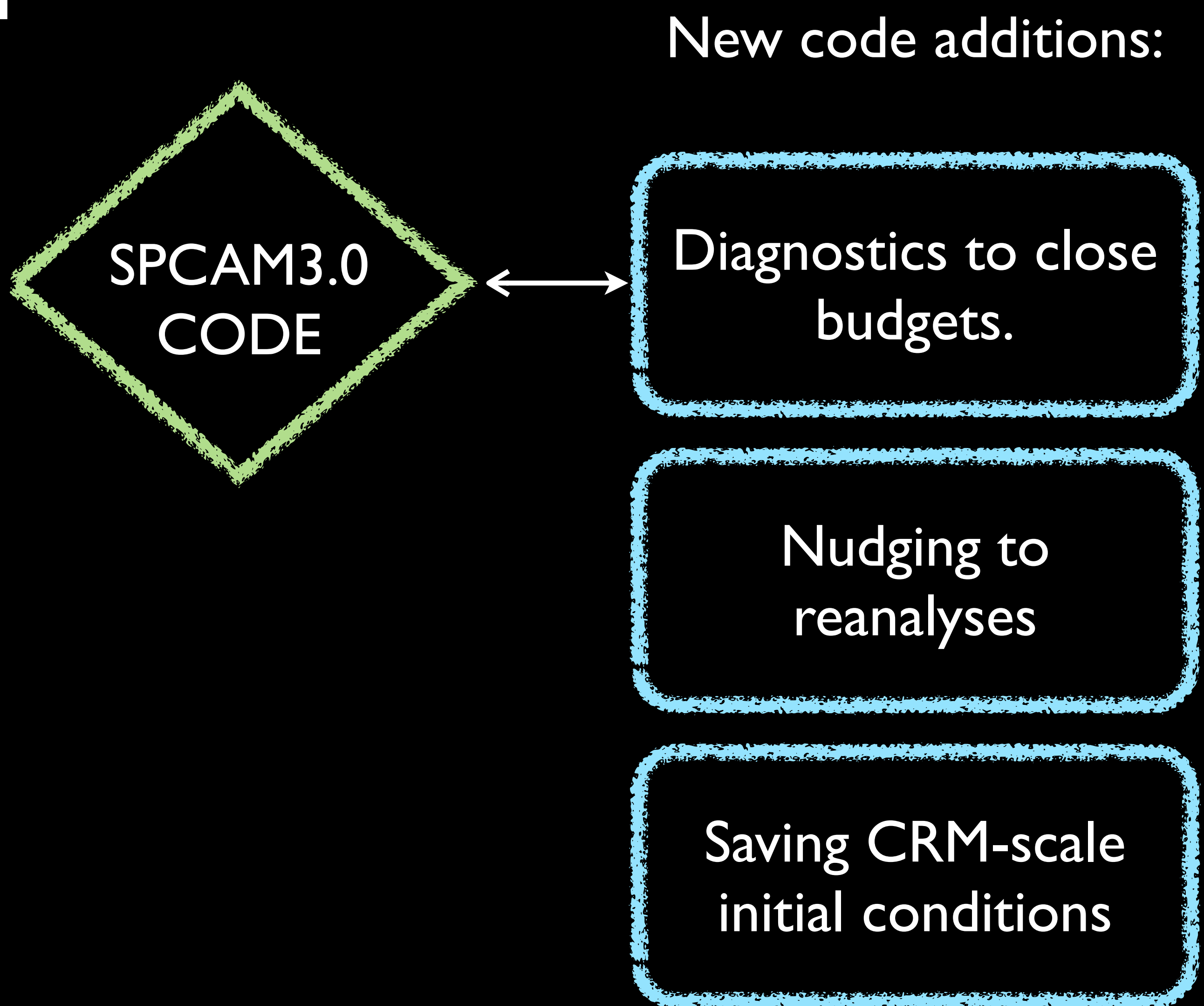

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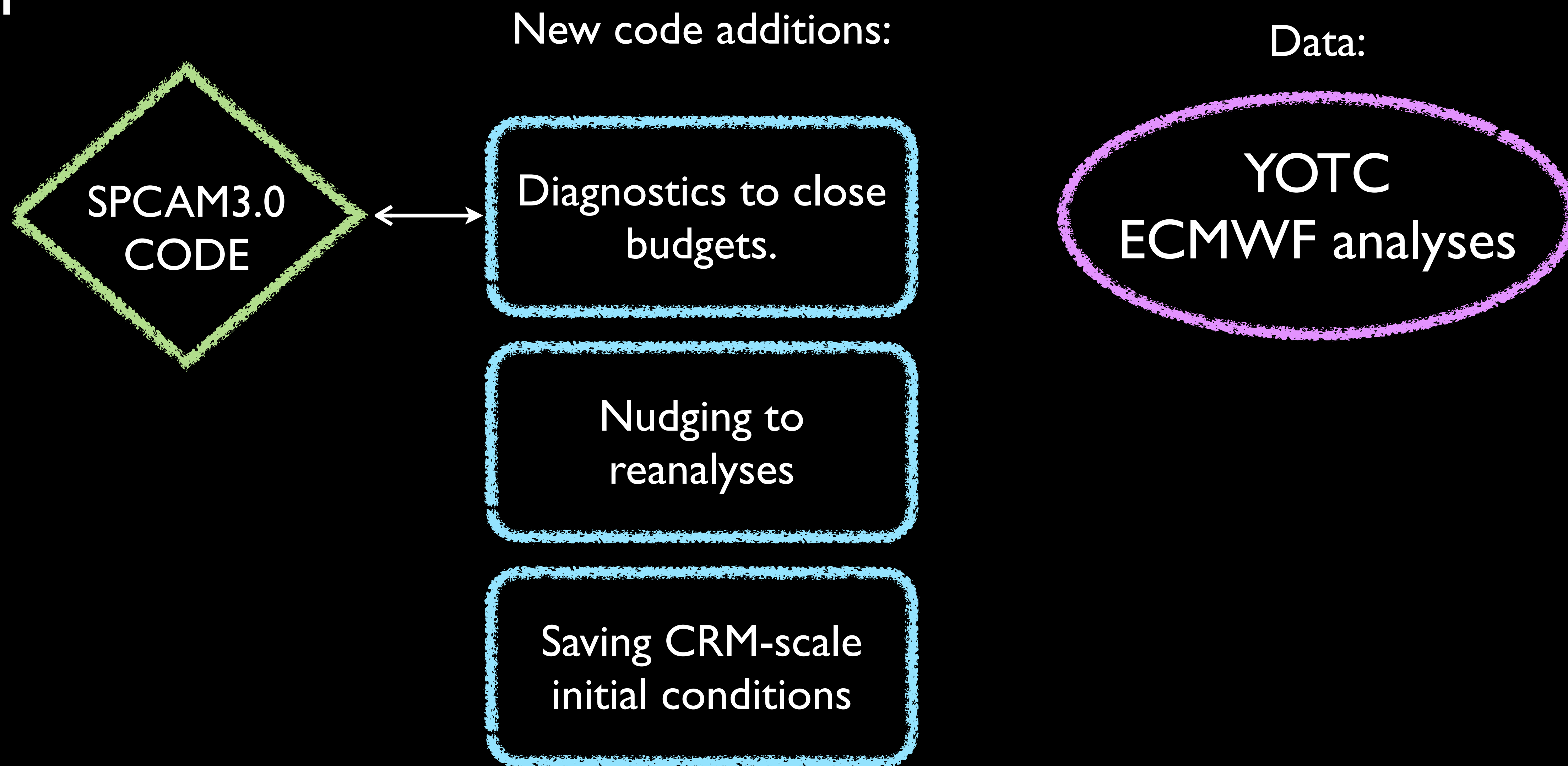

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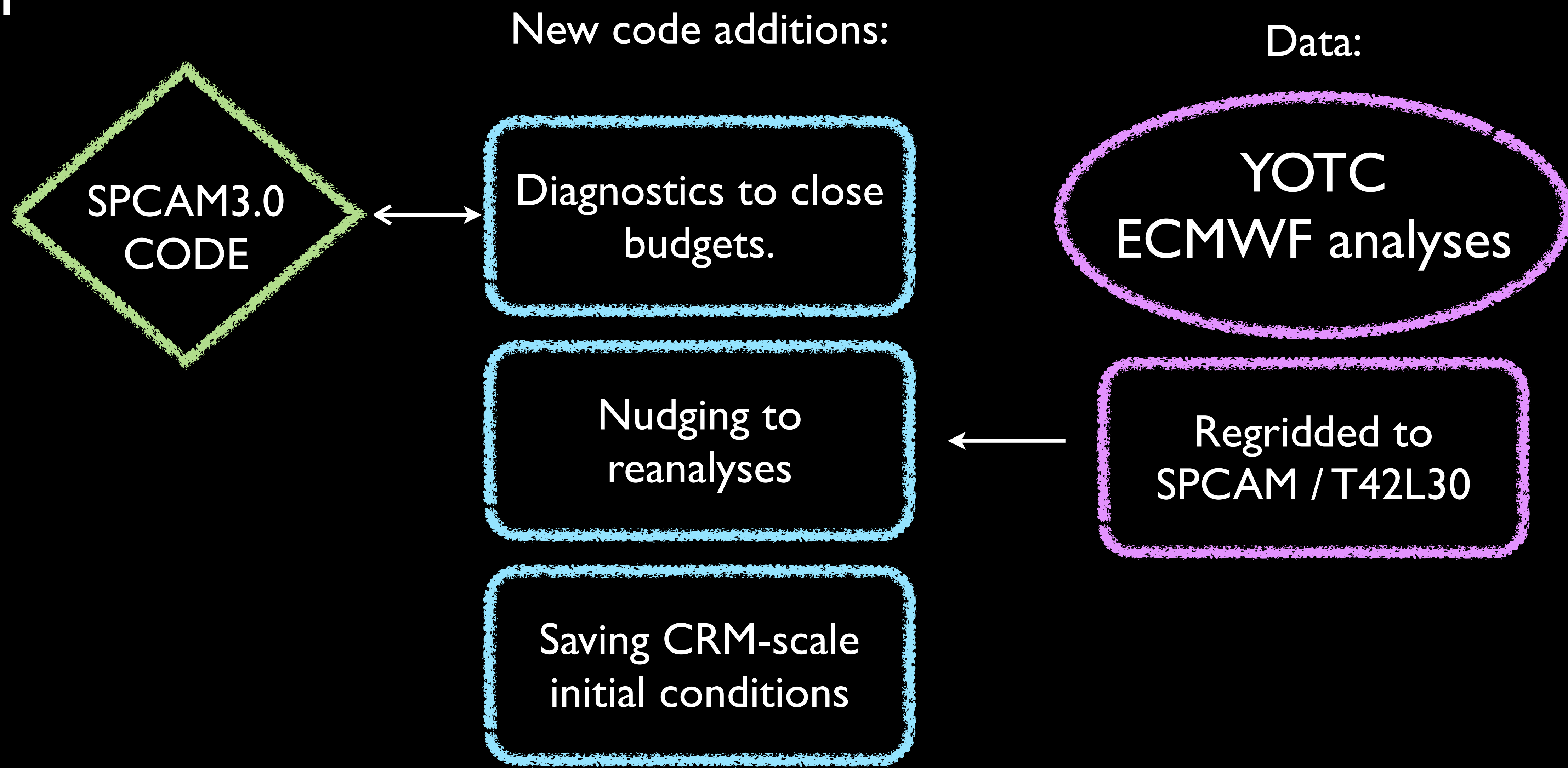

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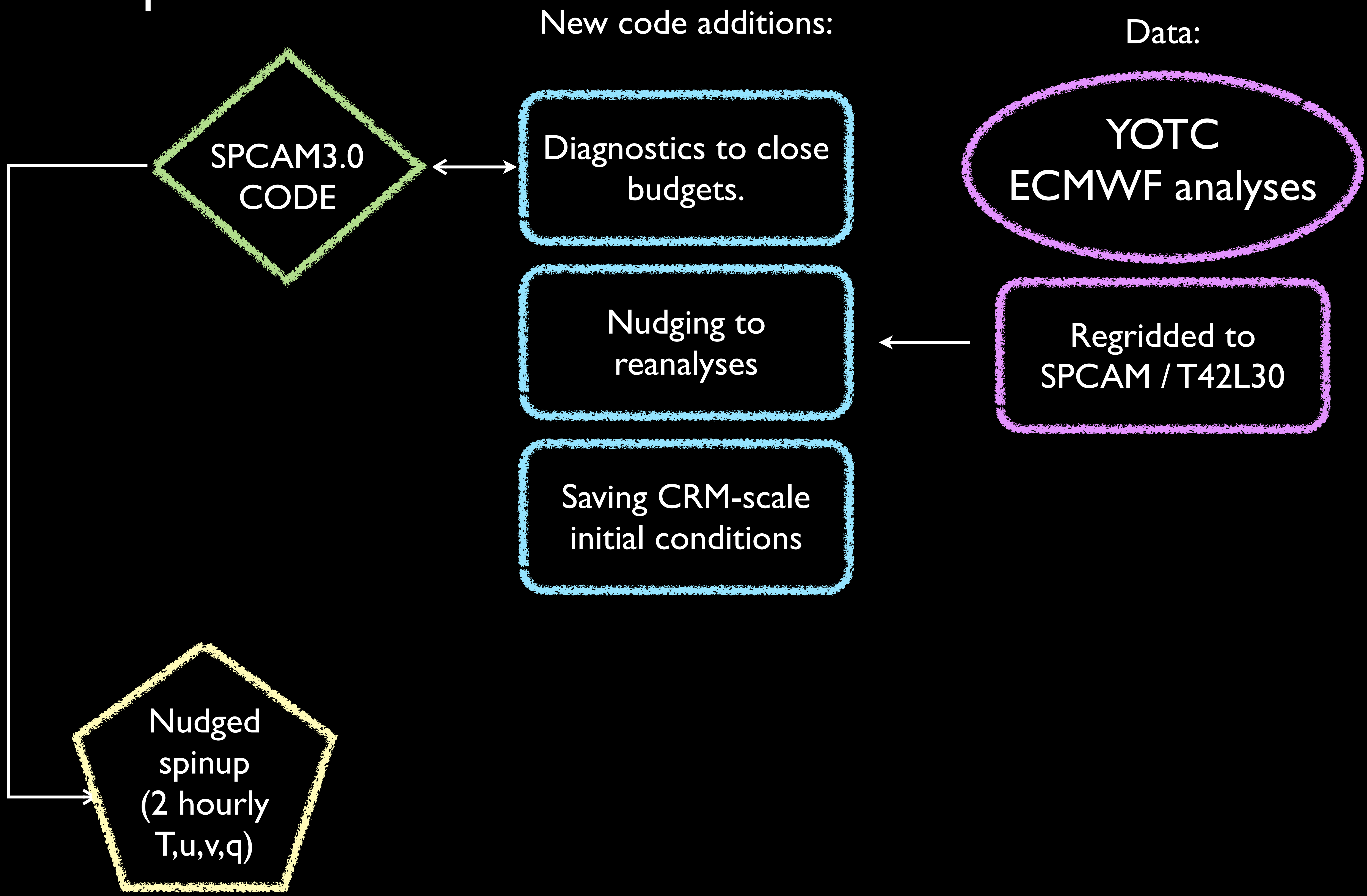

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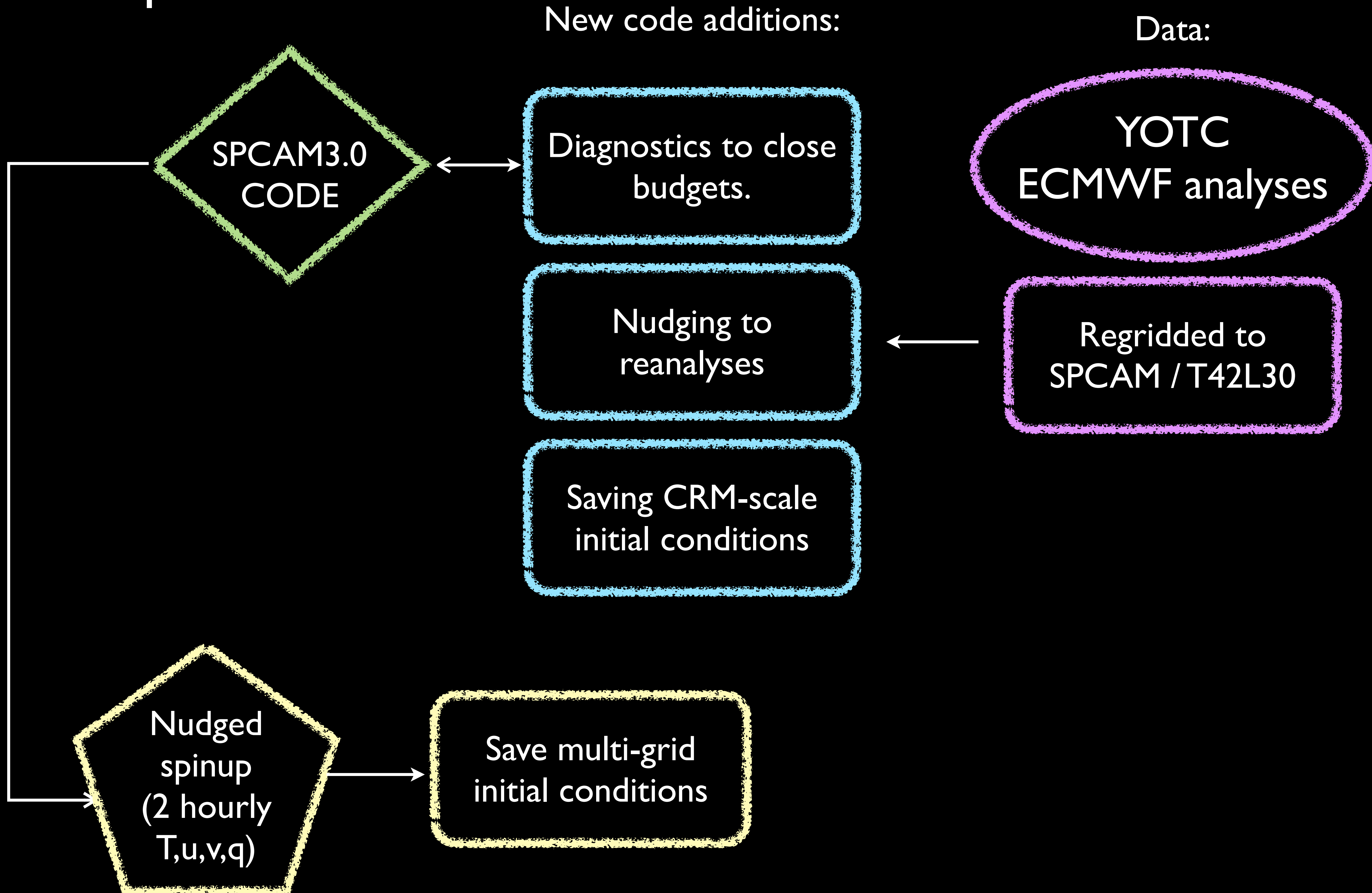

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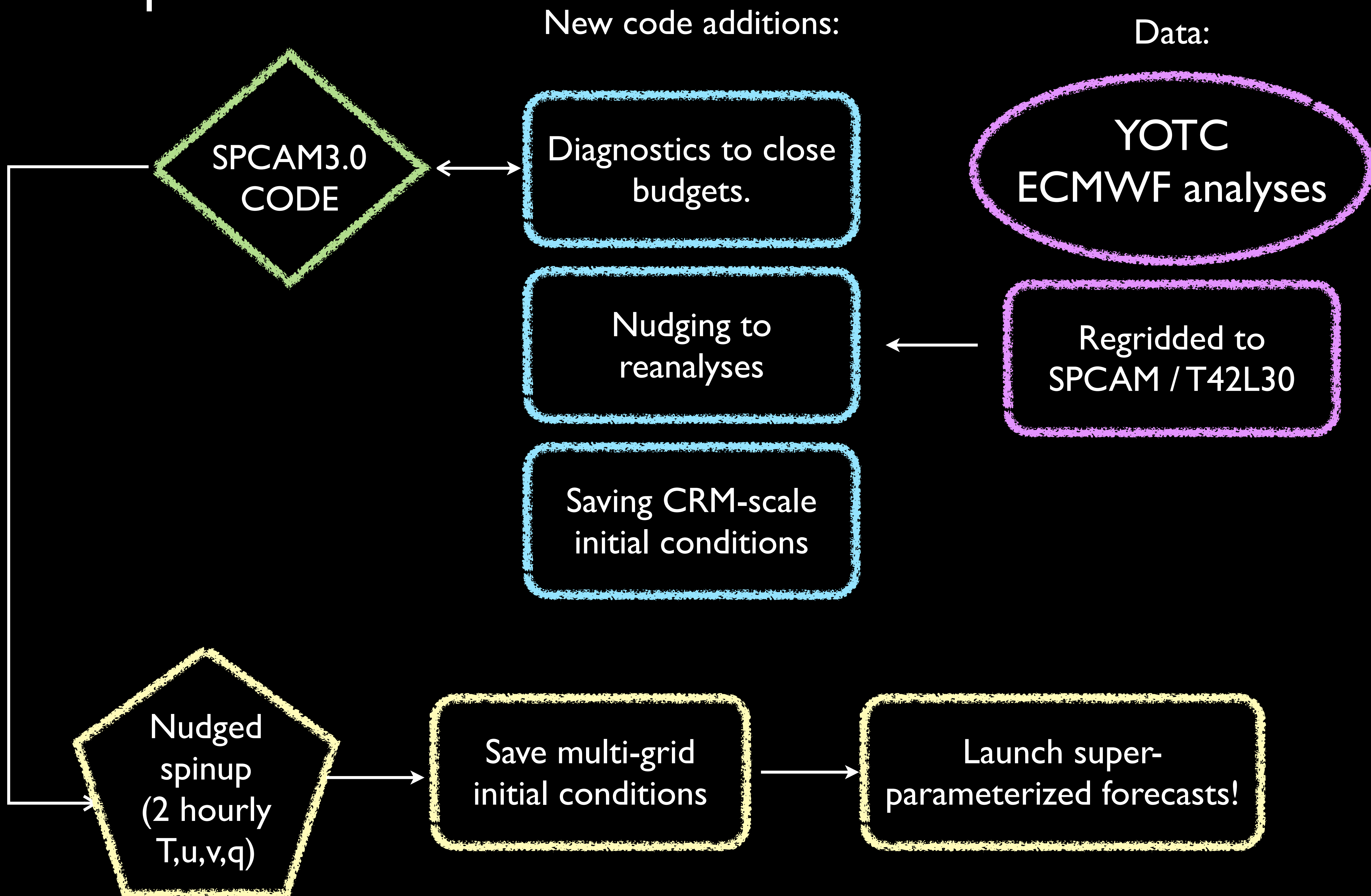

How "forecast skill" is defined in the model intercomparison.

A FRAMEWORK FOR ASSESSING OPERATIONAL MADDEN–JULIAN OSCILLATION FORECASTS

A CLIVAR MJO Working Group Project

BY J. GOTTSCHALCK, M. WHEELER, K. WEICKMANN, F. VITART, N. SAVAGE, H. LIN, H. HENDON, D. WALISER, K. SPERBER, M. NAKAGAWA, C. PRESTRELO, M. FLATAU, AND W. HIGGINS

Multiple operational centers helped develop and apply a diagnostic to track the state of the MJO and skill of real-time numerical MJO forecasts.

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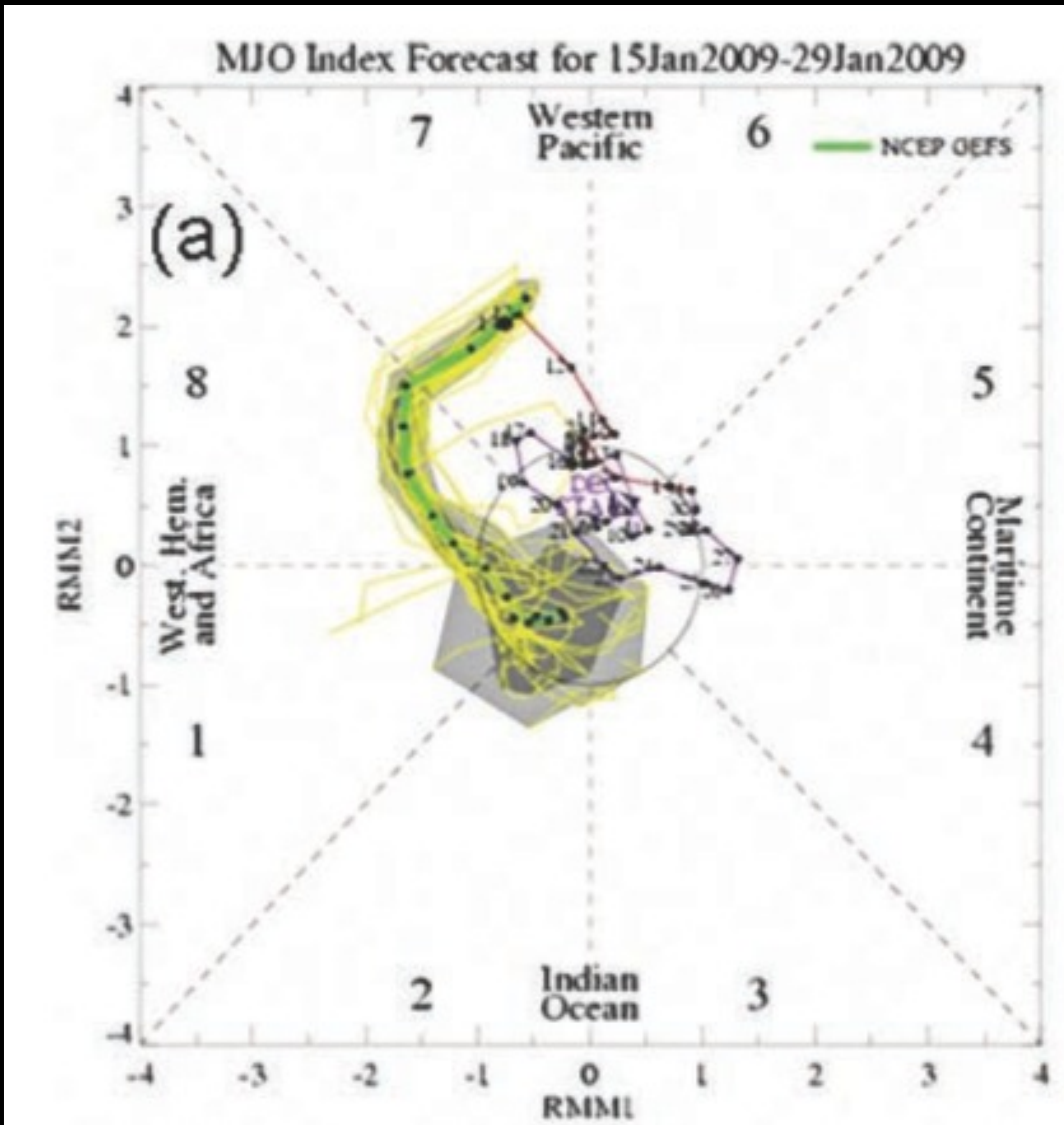
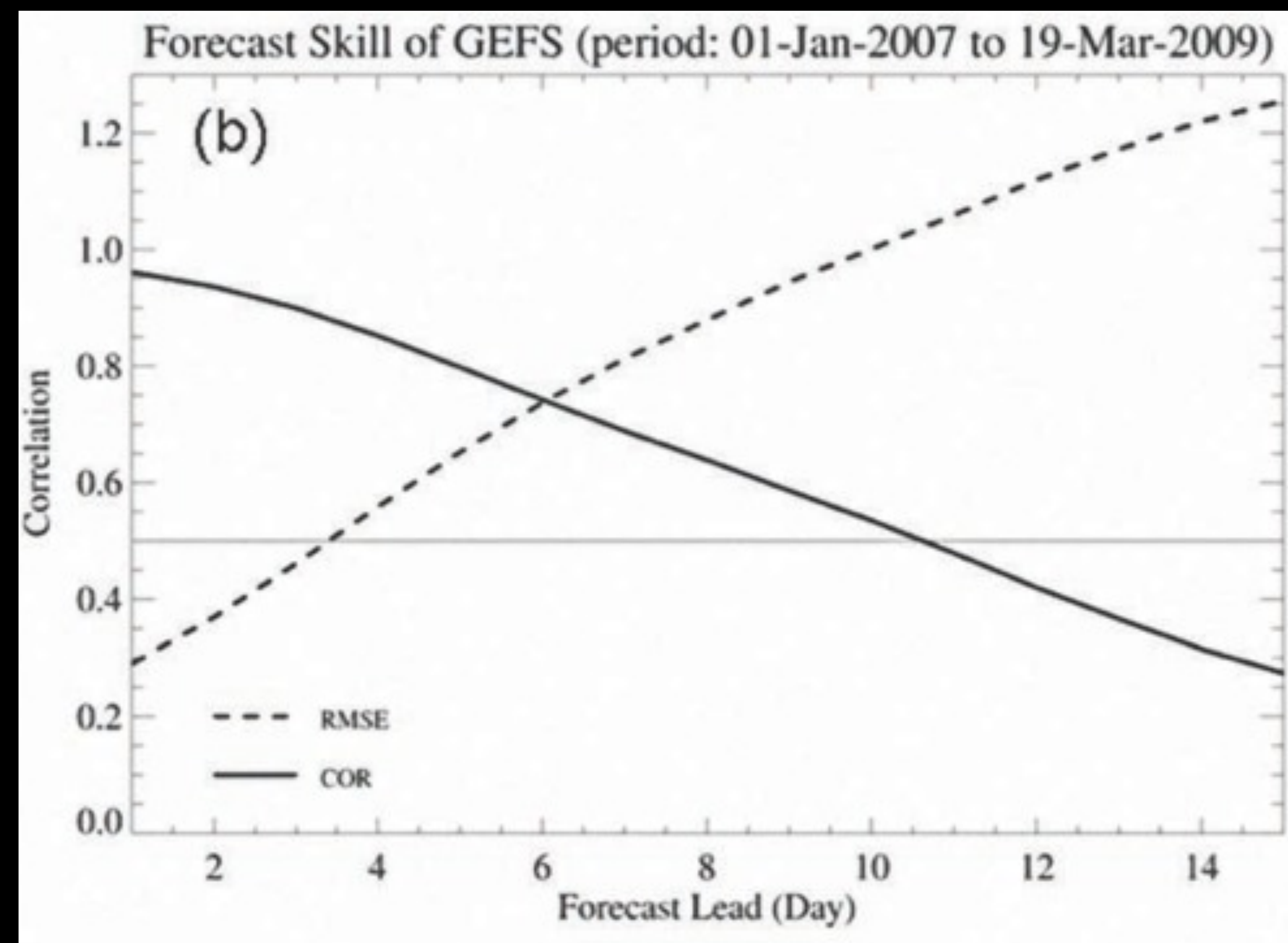


$$\mathrm{COR}(\tau)=\frac{\sum_{t=1}^{N}[a_1(t)b_1(t,\tau)+a_2(t)b_2(t,\tau)]}{\sqrt{\sum_{i=1}^{N}[a_1^2(t)+a_2^2(t)]}\sqrt{\sum_{i=1}^{N}[b_1^2(t,\tau)+b_2^2(t,\tau)]}},$$



Examples of the "skill limit" from other GCMs and forecast models.

1) Kang & Kim 2009

20 days for 0.5 correlation limit in the SNU AGCM T42 L20

(Same season)
Caveat 1: They used a much longer analysis period (26 winters).
Otherwise, similar Gottschalk et al. RMM protocol.

2) Vitart et al. 2007

16-17 days for 0.6 correlation limit in their modified-physics ECMWF monthly forecast CGCM, cycle 28R3 @ T159 L40.

Caveat 1: They used 10S-10N instead of 15S-15N
Caveat 2: They used velocity potential instead of U200 in RMMs
Caveat 3: Different way of defining "anomaly" wrt. model drift.
Caveat 5: Theirs were daily 5-member ensembles, and their skill limit was from the ensemble mean.

3) Vitart and Jung 2010

22 days for 0.6 correlation limit
ECMWF IFS Cy36r1 TL255 L60

A first forecast case: Year of Tropical Convection Case "E"

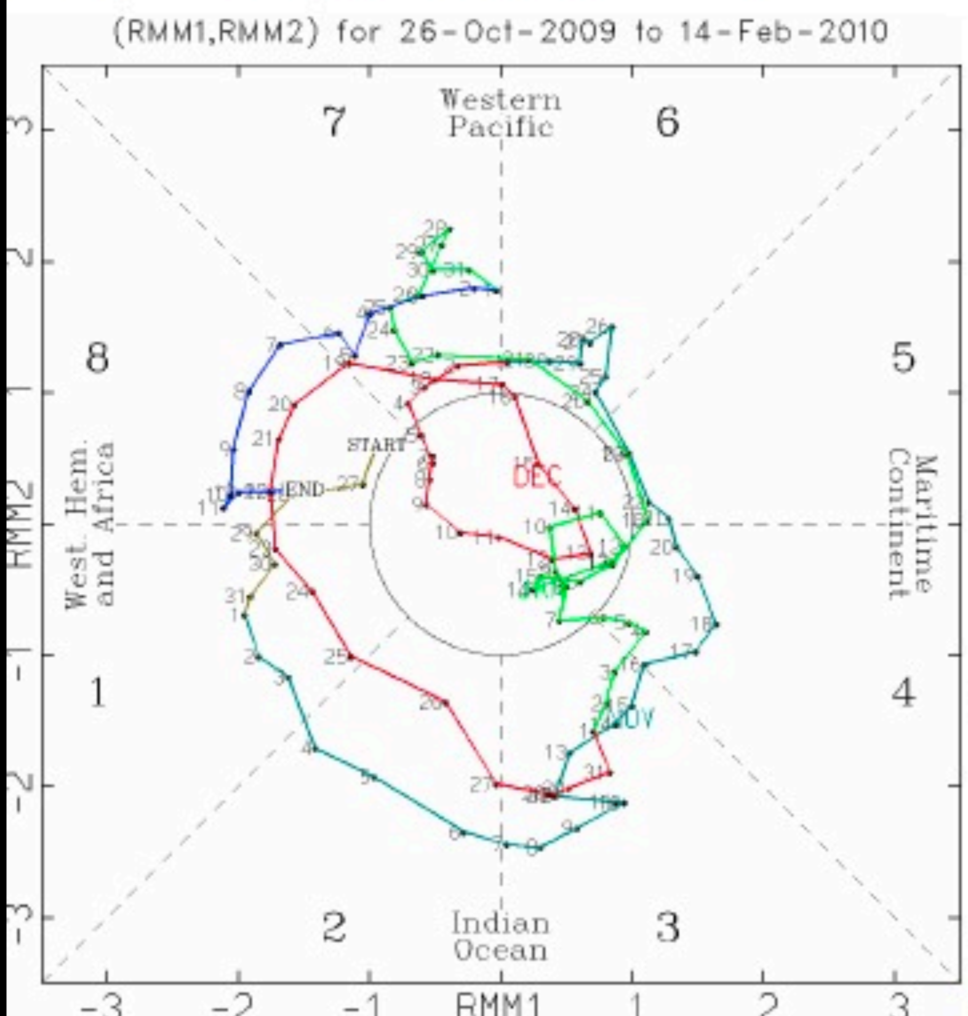
MJO cases: (e) Oct-Dec 2009

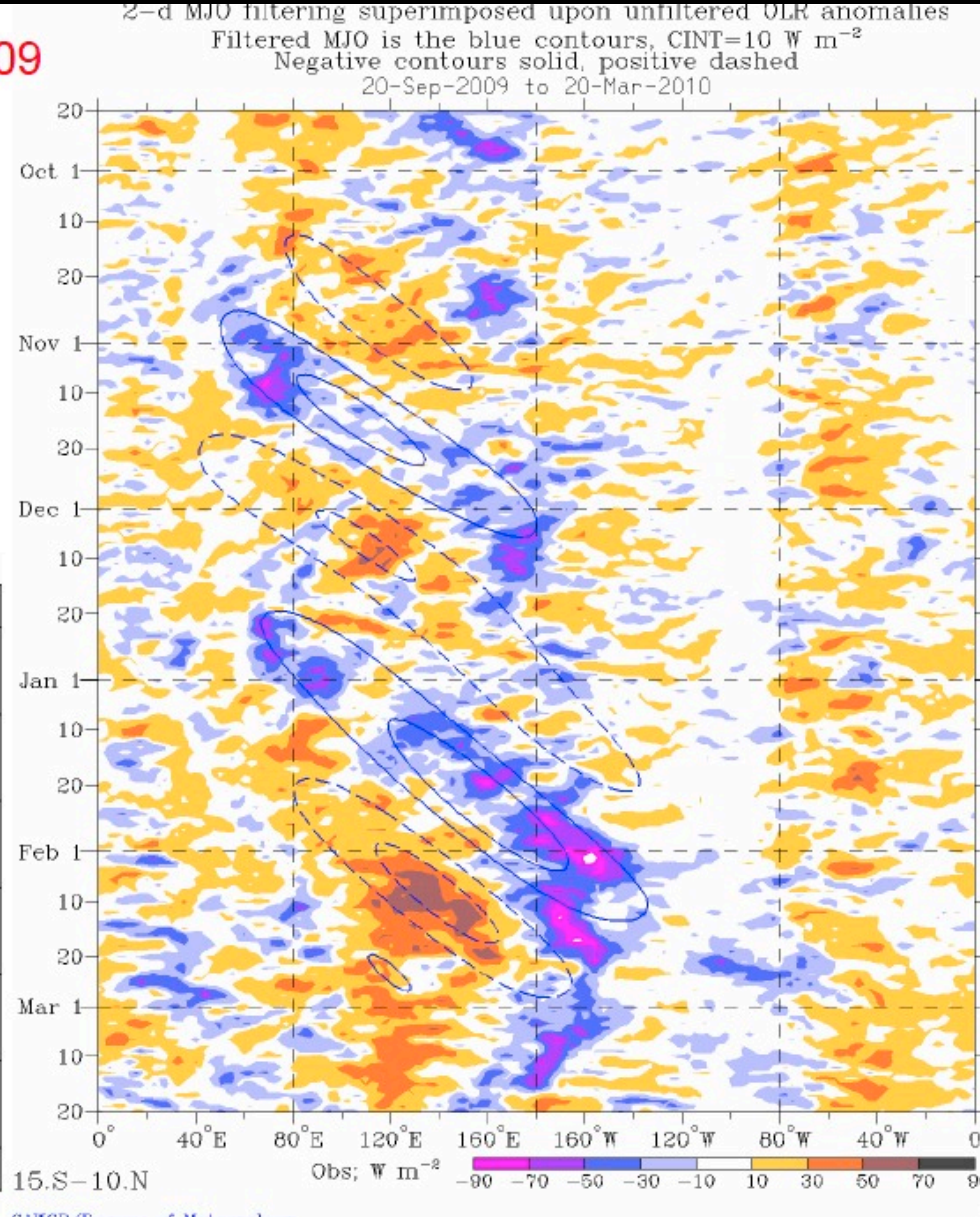
(f) Dec 2009-Feb 2010

Together, these cases comprise more than two full cycles of the MJO.

Convection associated with 2nd MJO cycle reached further eastward.

Main amplification of both events occurred well before the initiation of convection in the Indian Ocean.





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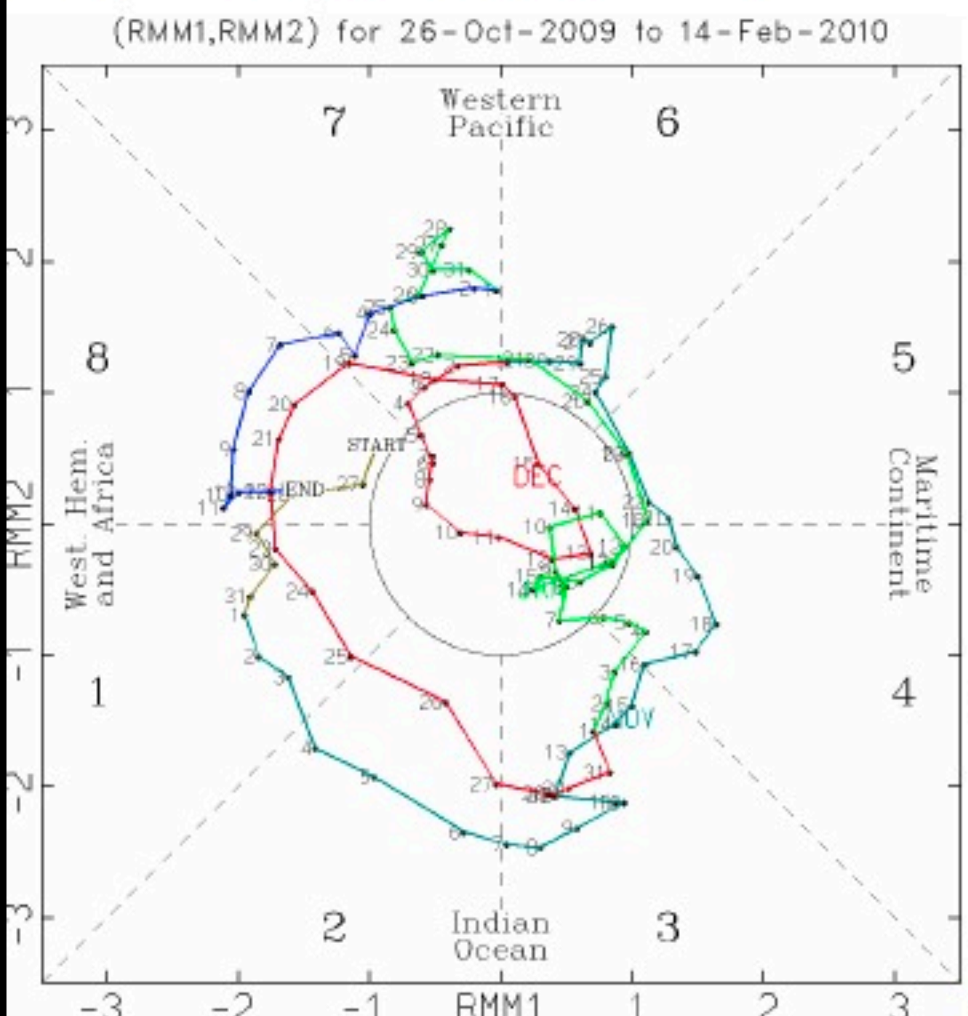

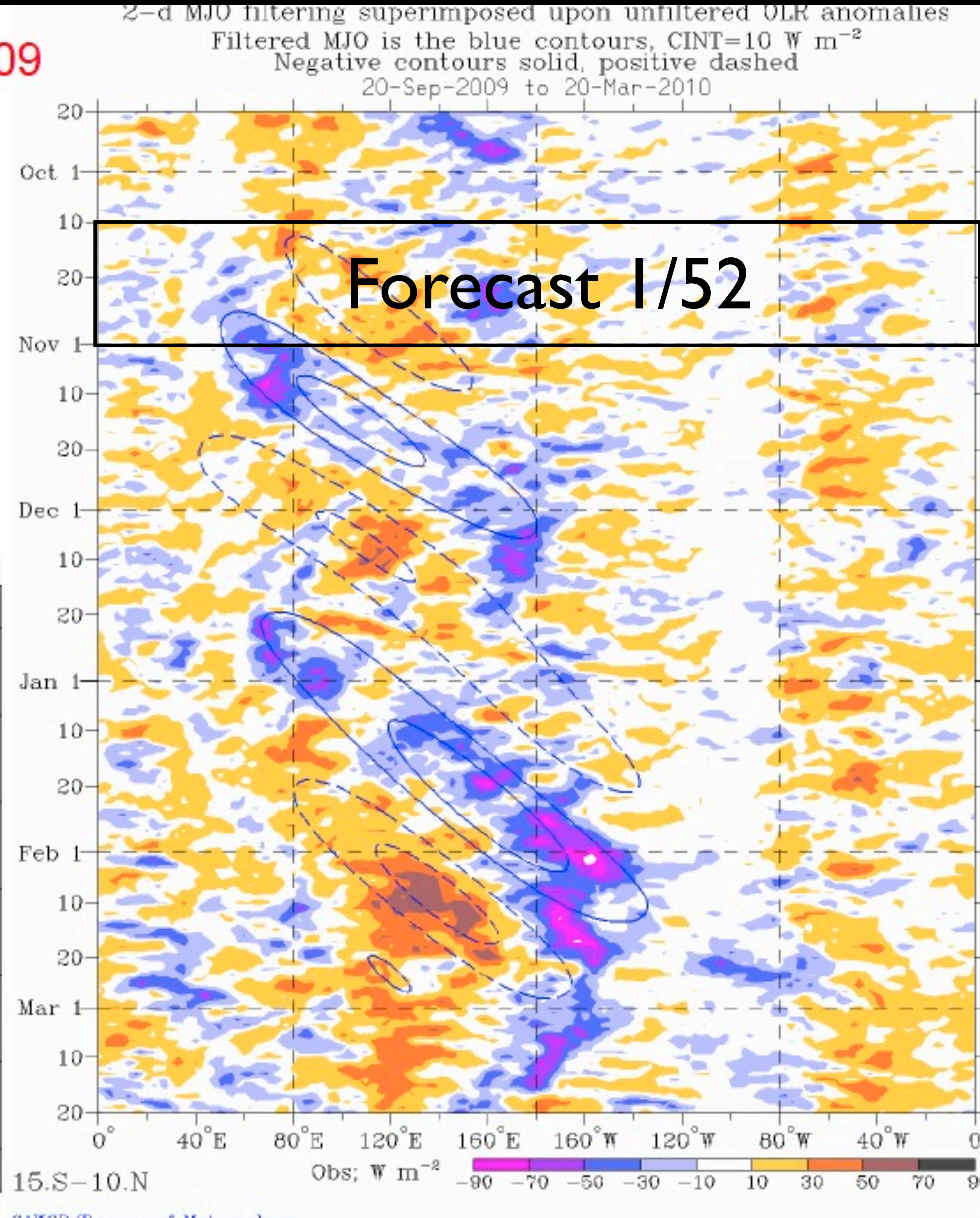

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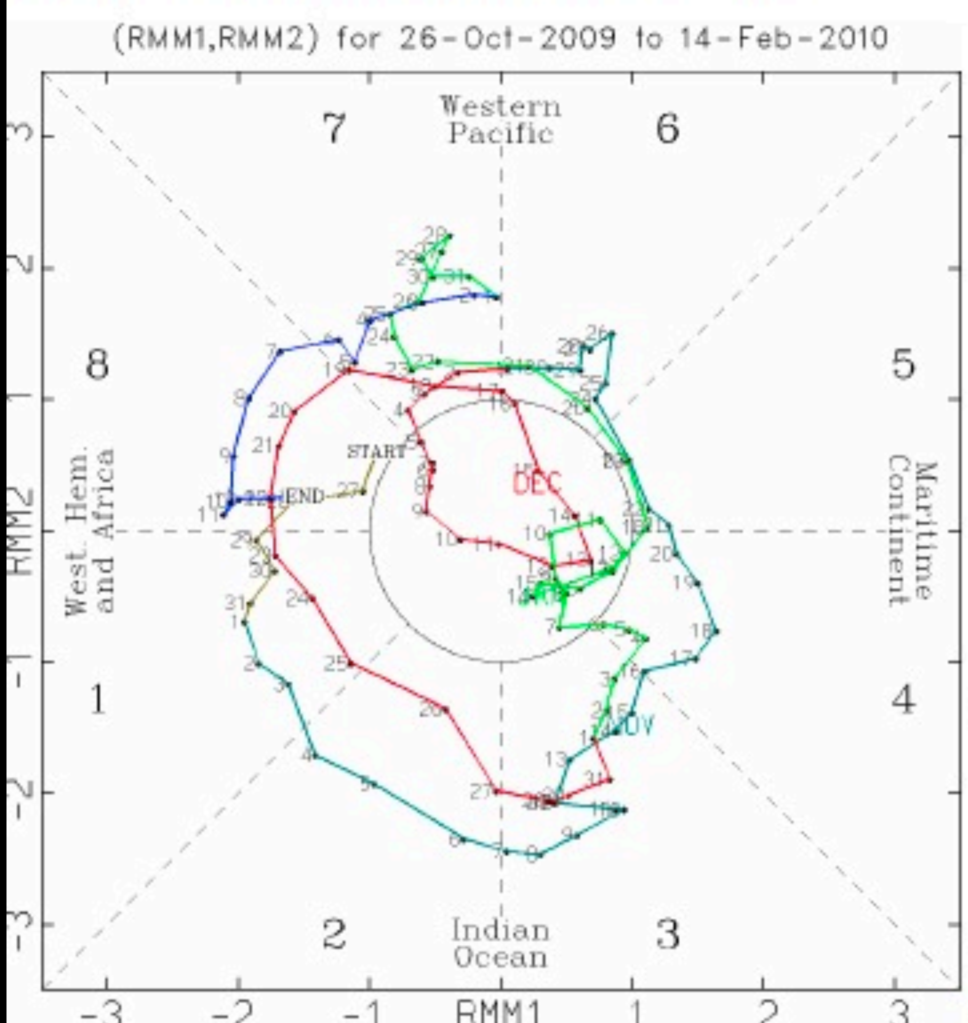
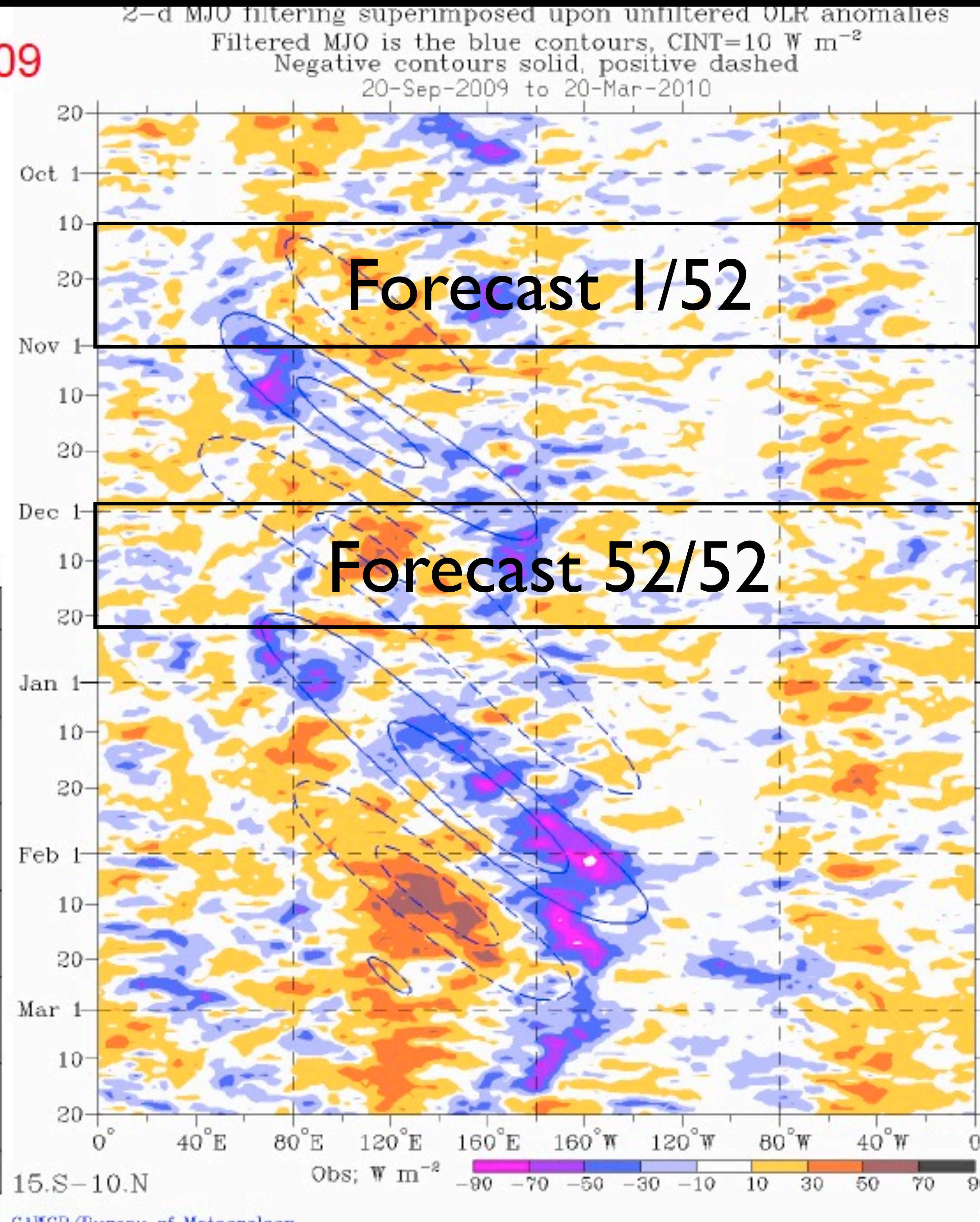




Analysis by intercomparison coordinators indicates SPCAM's preliminary RMM skill limit is ~12 days.

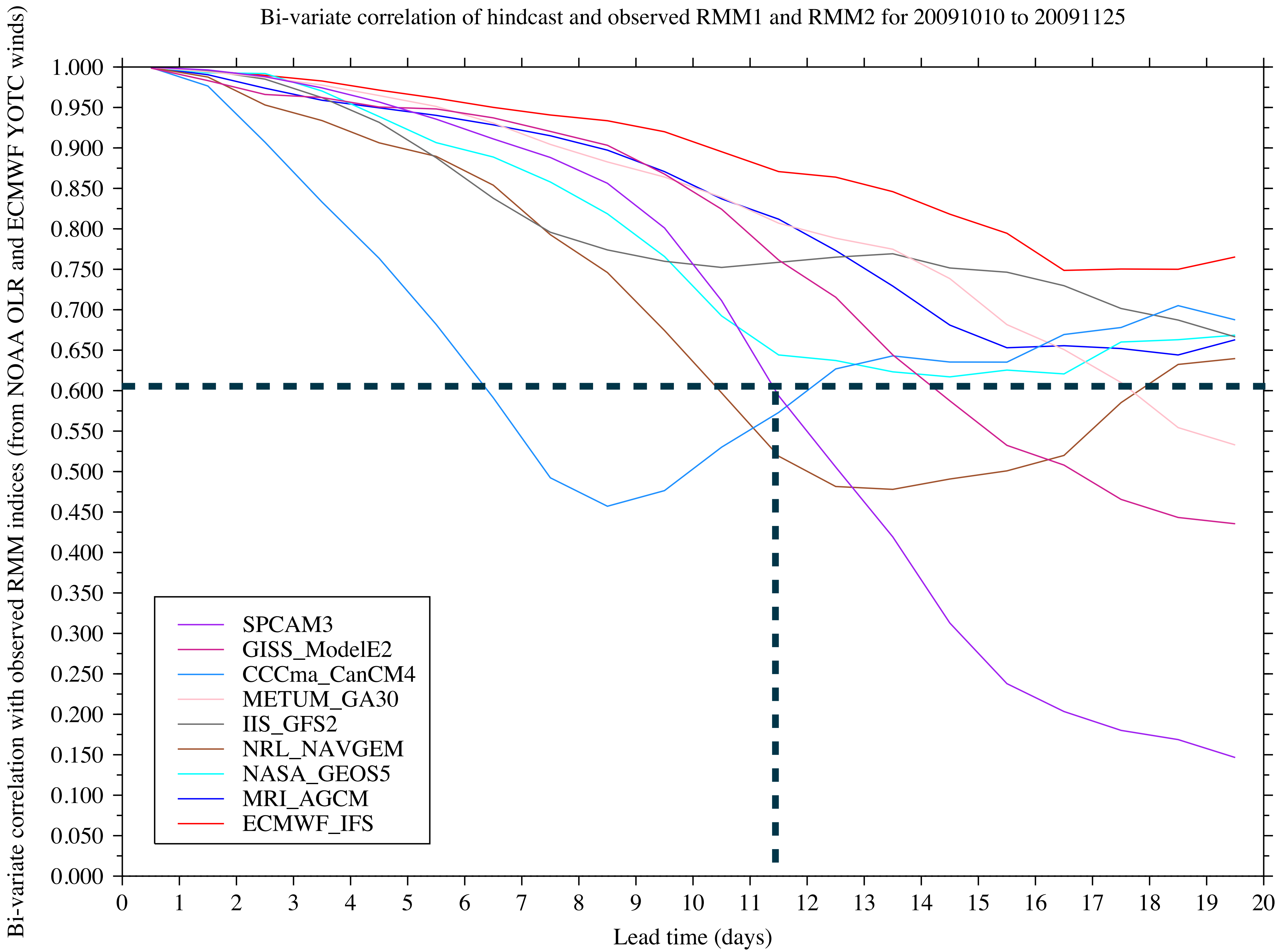
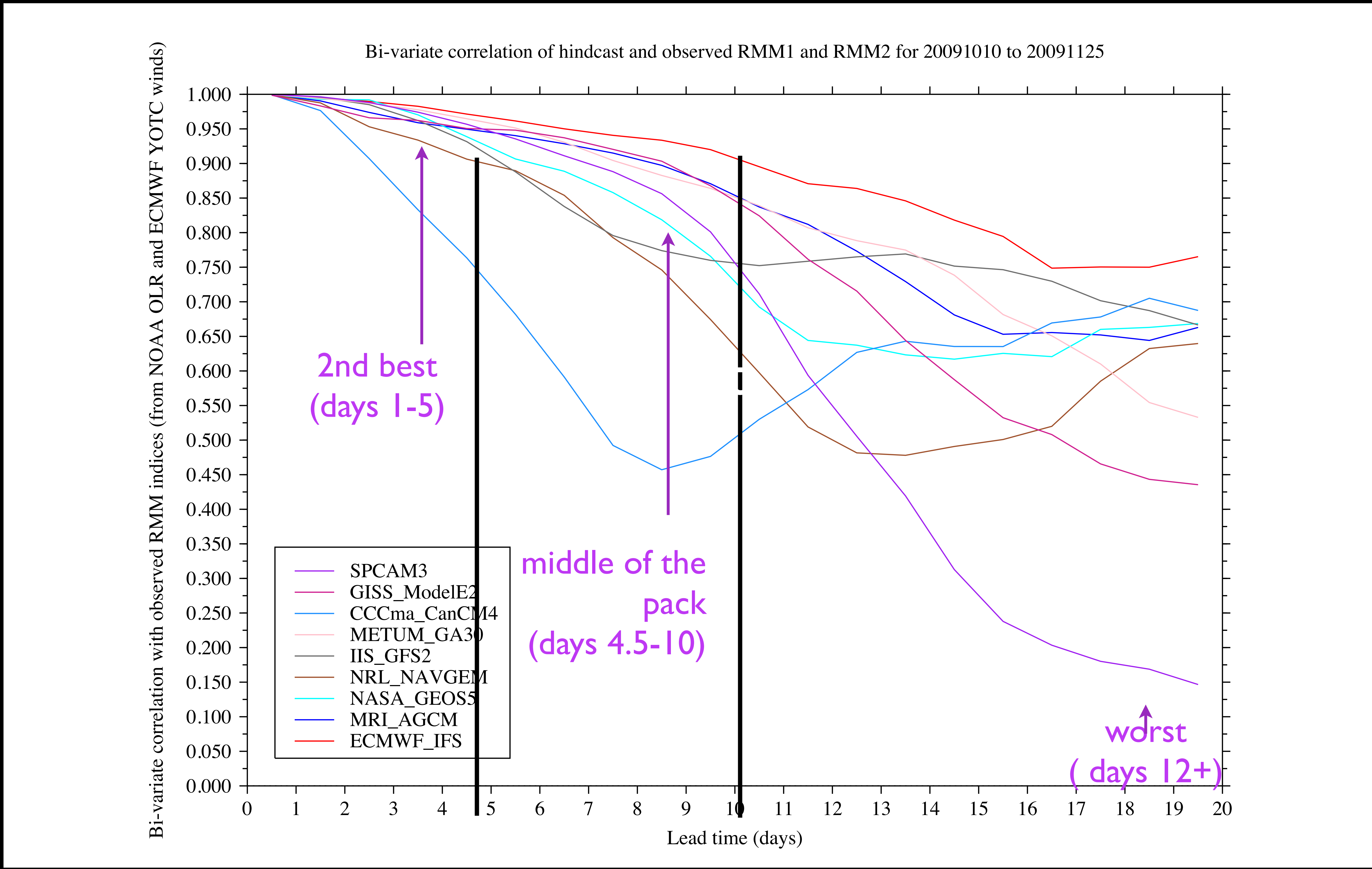


Figure courtesy of Nicholas Klingaman, U. Reading.

How does SPCAM's forecast skill compare to other models?



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The original model, SPCAM3.0 has a much better MJO and mean climate than its new sister models.

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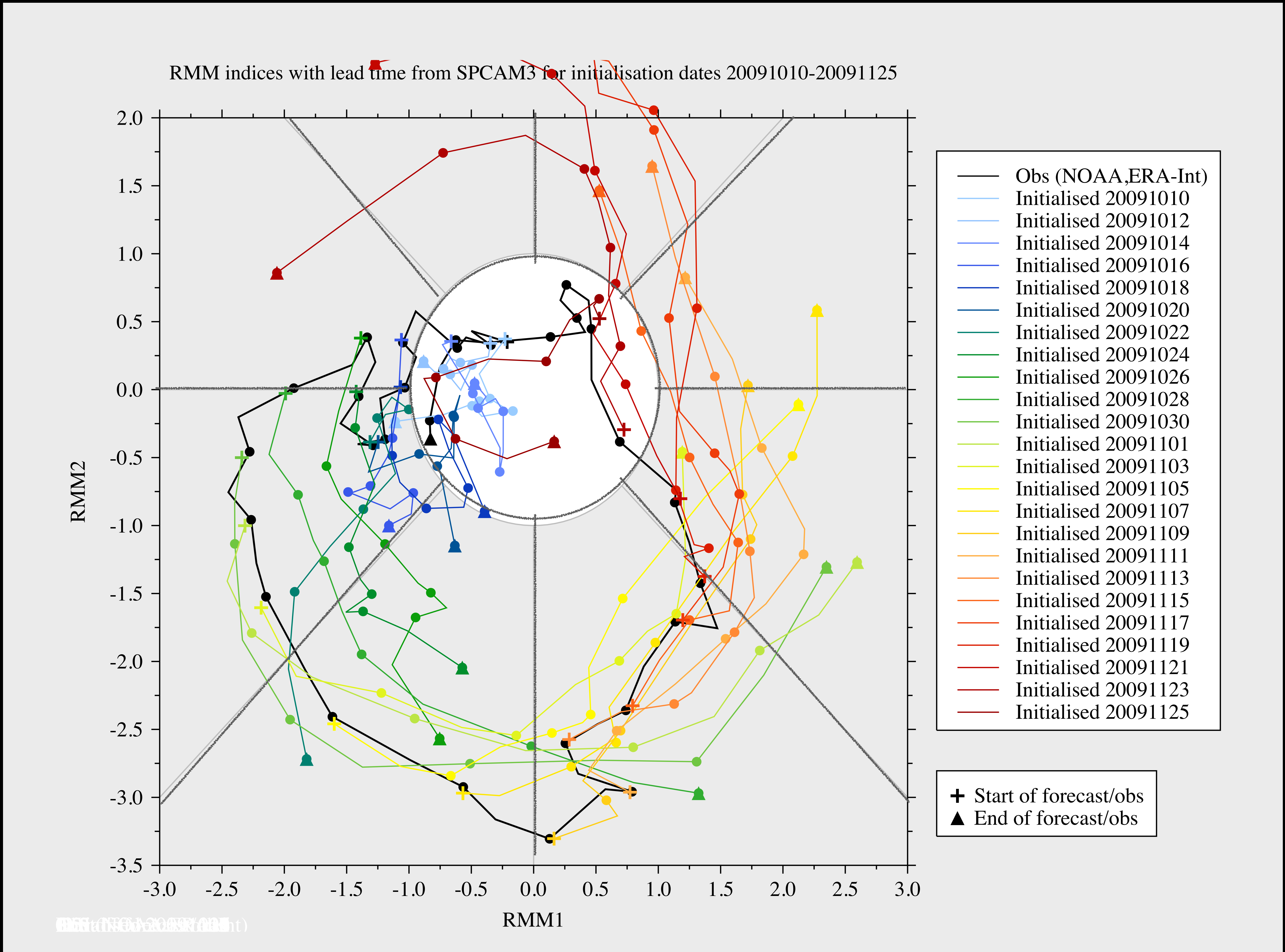
What is the phase-dependence of SPCAM's MJO forecast skill?

Analyzing Days 1-10 in (RMM1,RMM2) phase for Case E forecasts.



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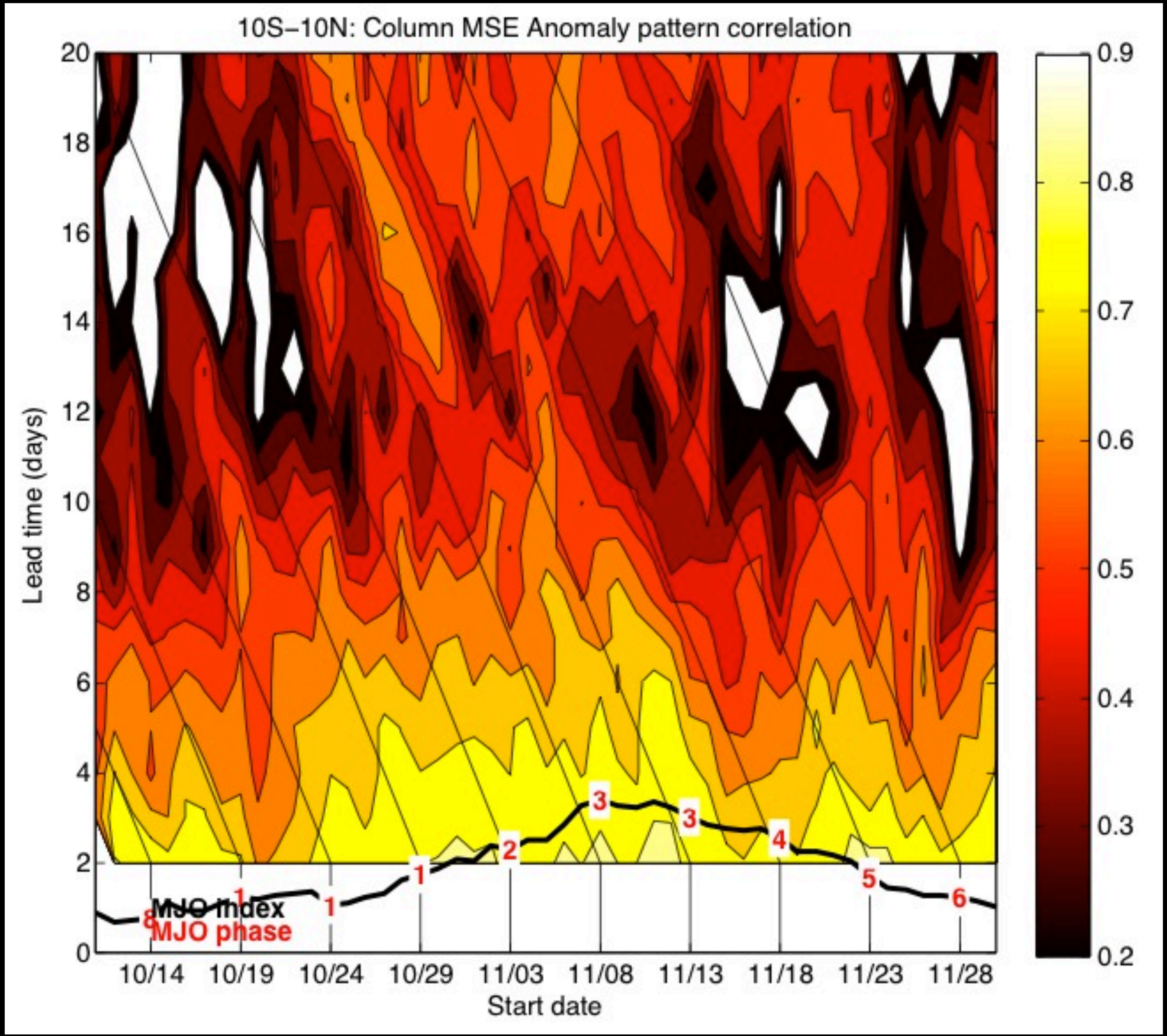
Analyzing the column MSE error growth as a function of MJO phase.

YOTC
Case E



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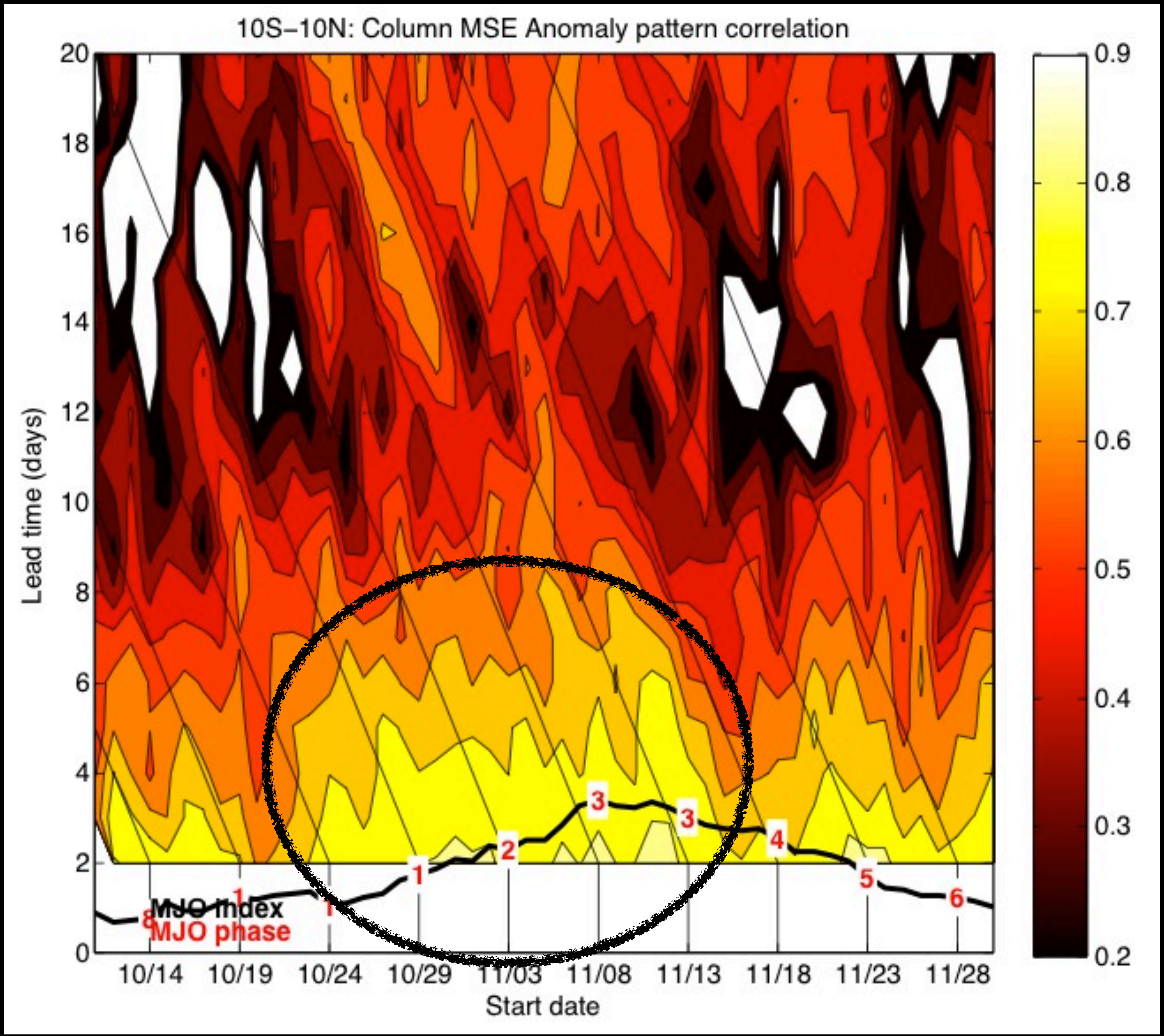
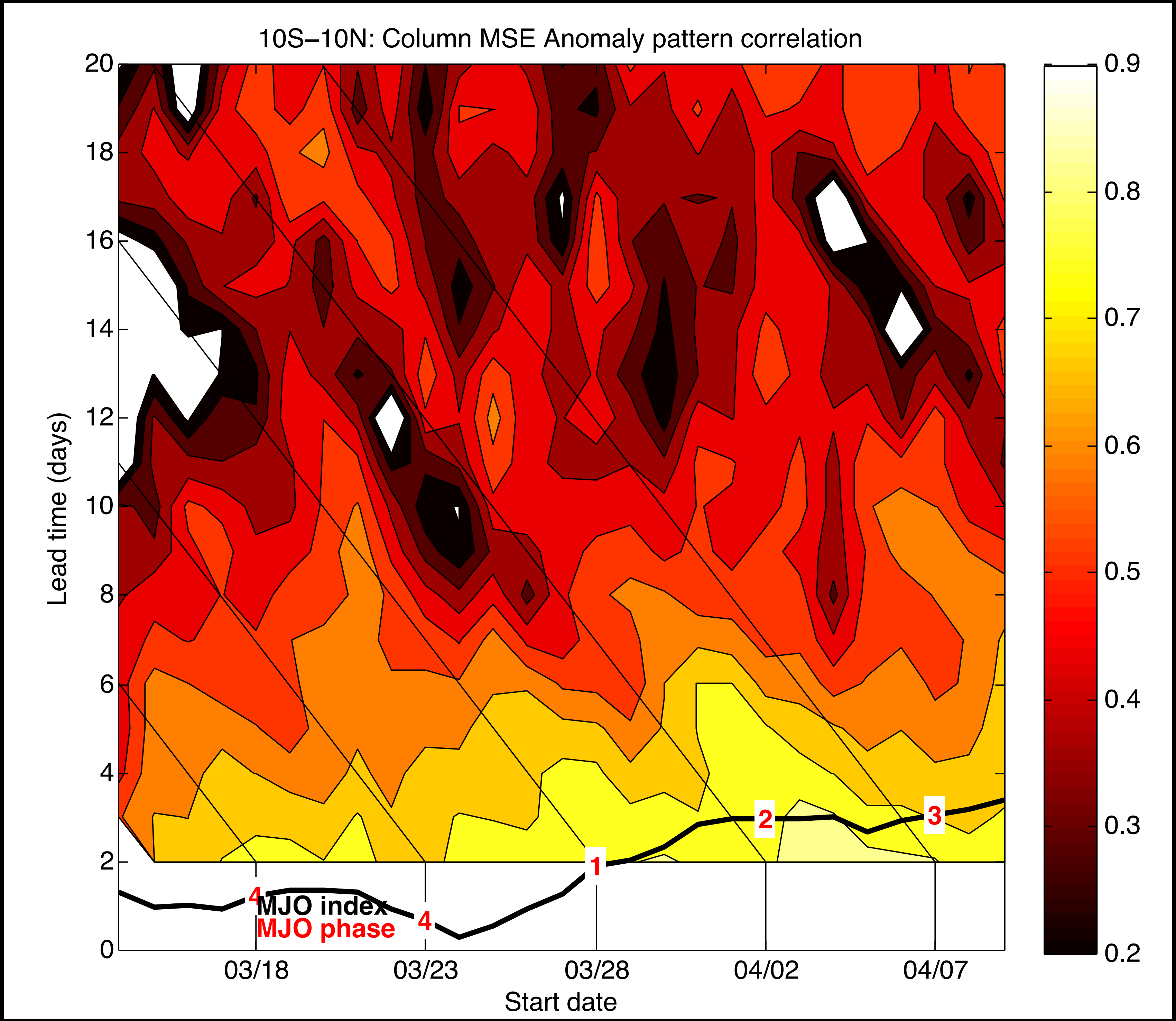


More short-term shortcast skill where MJO index is increasing?

Analyzing the forecast error growth as a function of MJO phase.

YOTC
Case D



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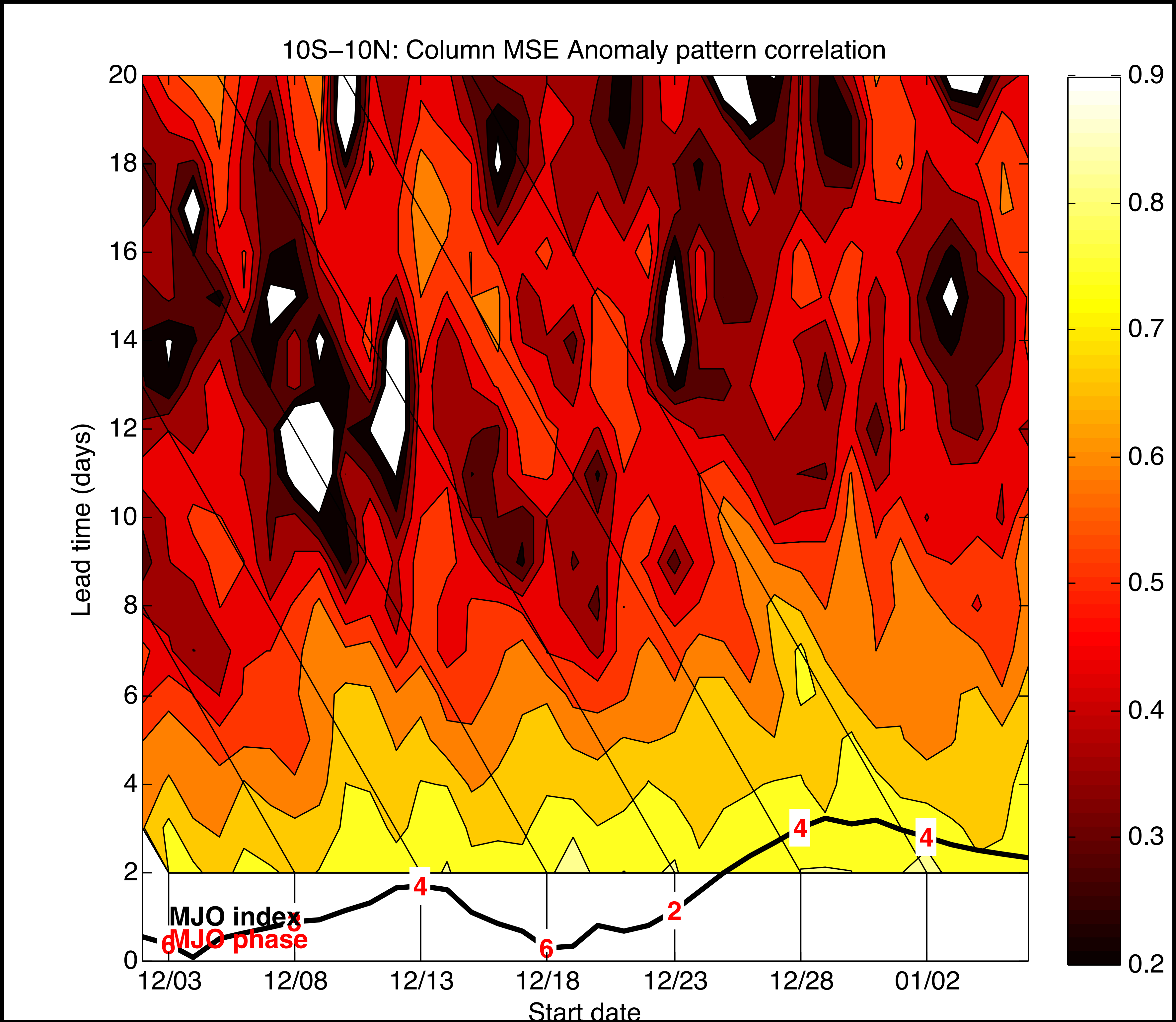
YOTC
Case F



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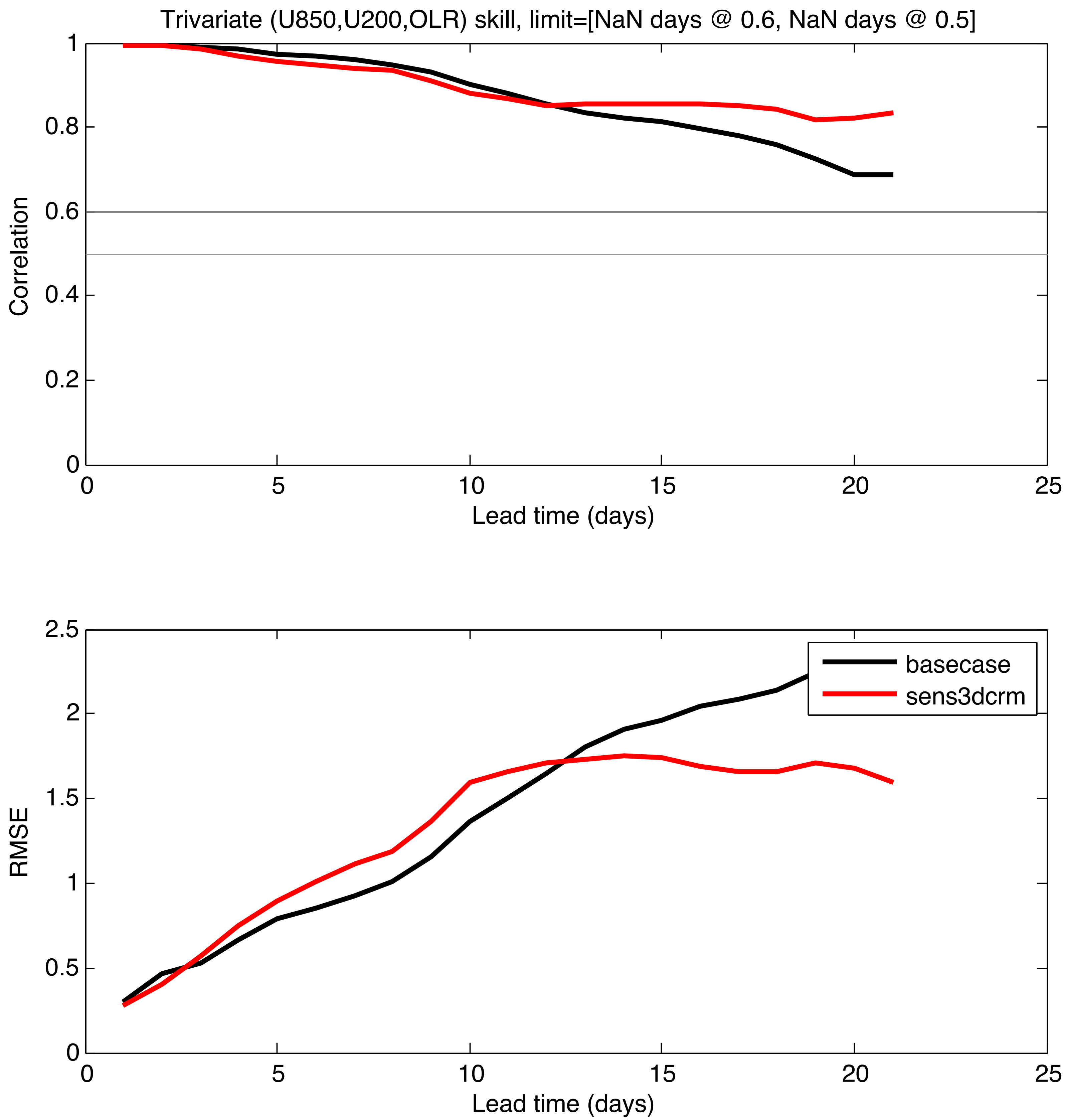
Does convective momentum transport matter to the SP-MJO?

Redoing the YOTC Case D forecasts with a 3D CRM plus convective momentum transport leads to improved skill > day 10.

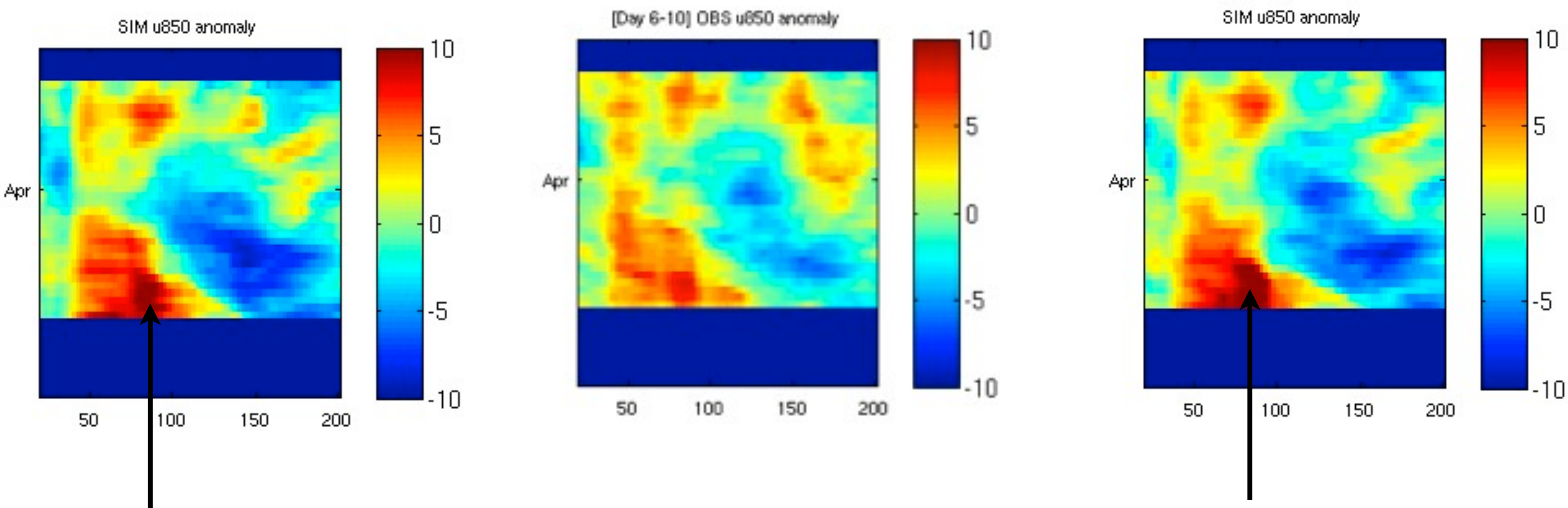


Most of the improved RMM skill came from reduced activity in the westerly wind burst.

Both model configurations **initially** forecast overly strong intensification of surface westerlies over the Indian Ocean....

Days 6-10 composite

sens3dcrm **OBS** **control**

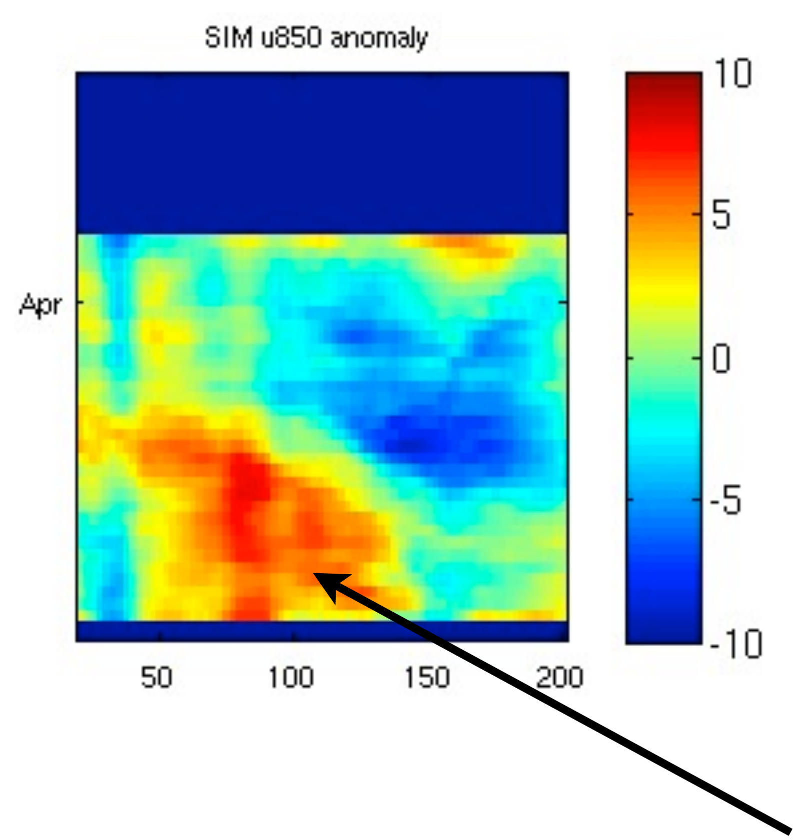


overactive spinup of the low level wind anomaly

But after two weeks, the forecasts with 3D CRM+CMT had self-corrected, reducing low-level wind intensity.

Days 15-19 composite:

sens3dcrm



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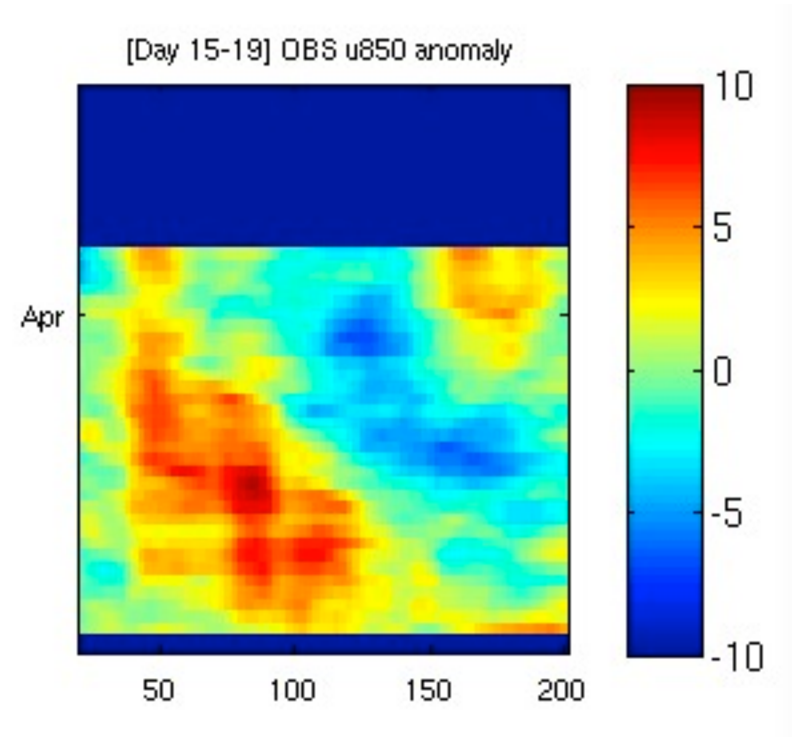

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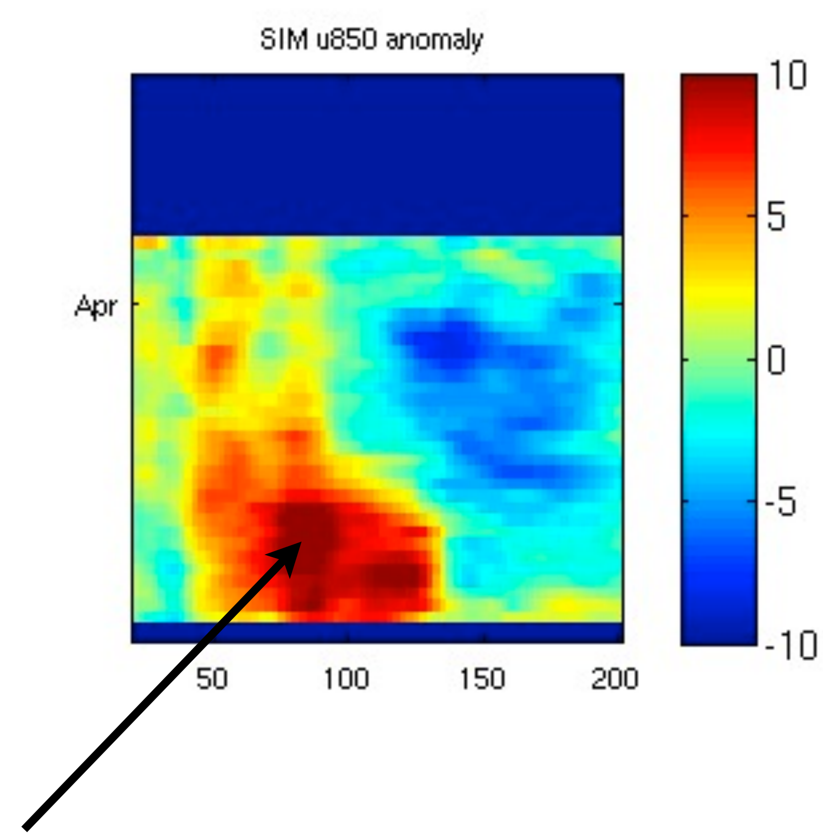
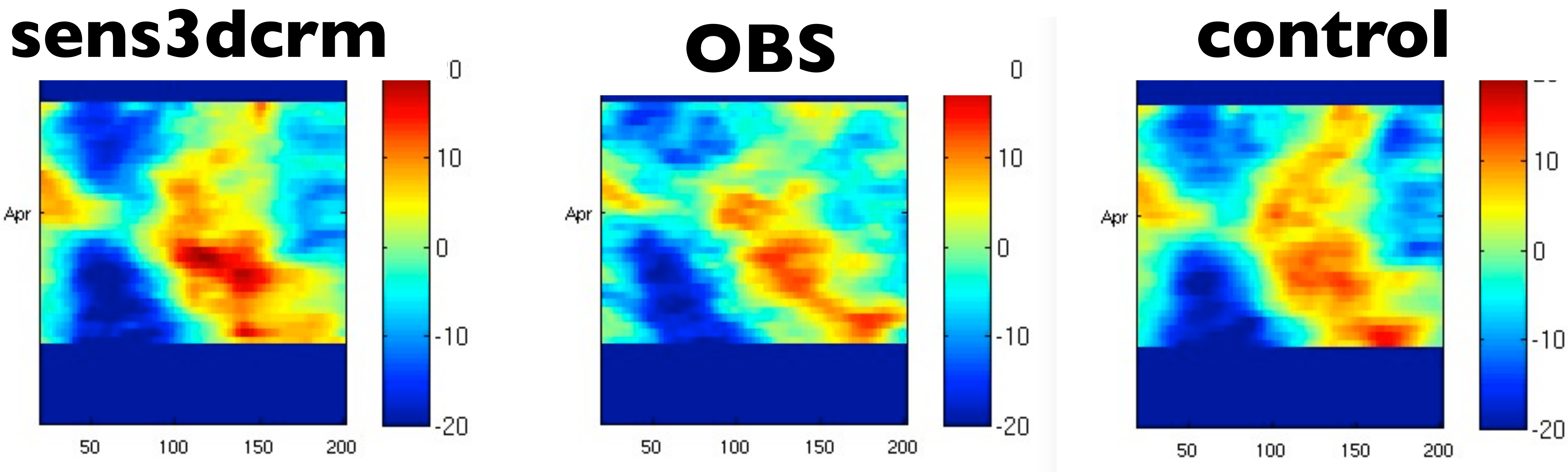


Also some improvement in upper level flow with CMT.

Days 6-10: Initial spinup similar in both models.



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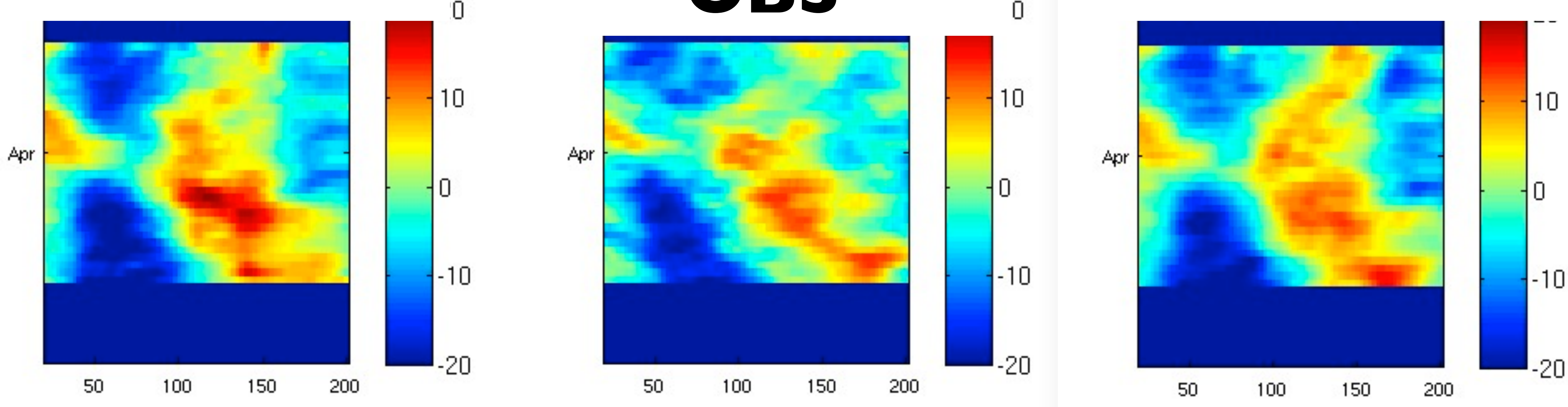
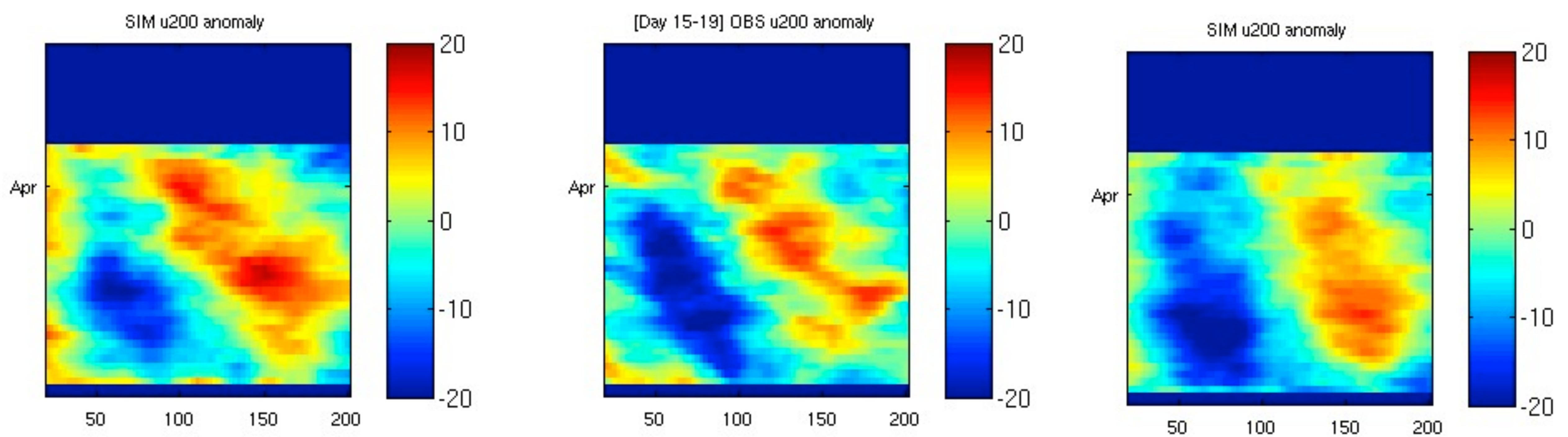


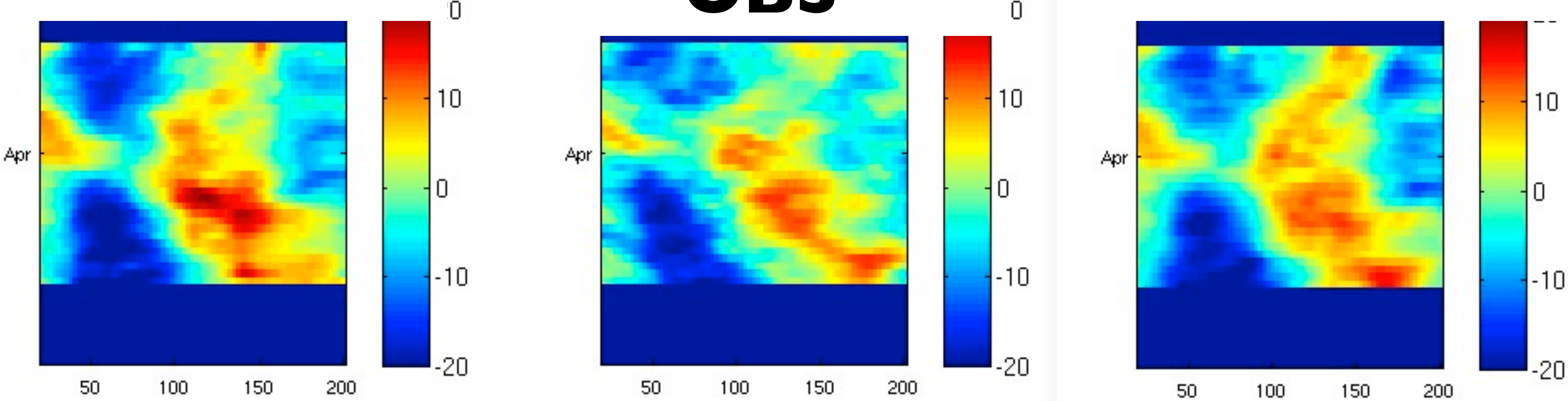
Days 15-19: Eastward propagation only in 3D+CMT.



Also some improvement in upper level flow with CMT.

Days 6-10: Initial spinup similar in both models.

sens3dcrm **OBS** **control**



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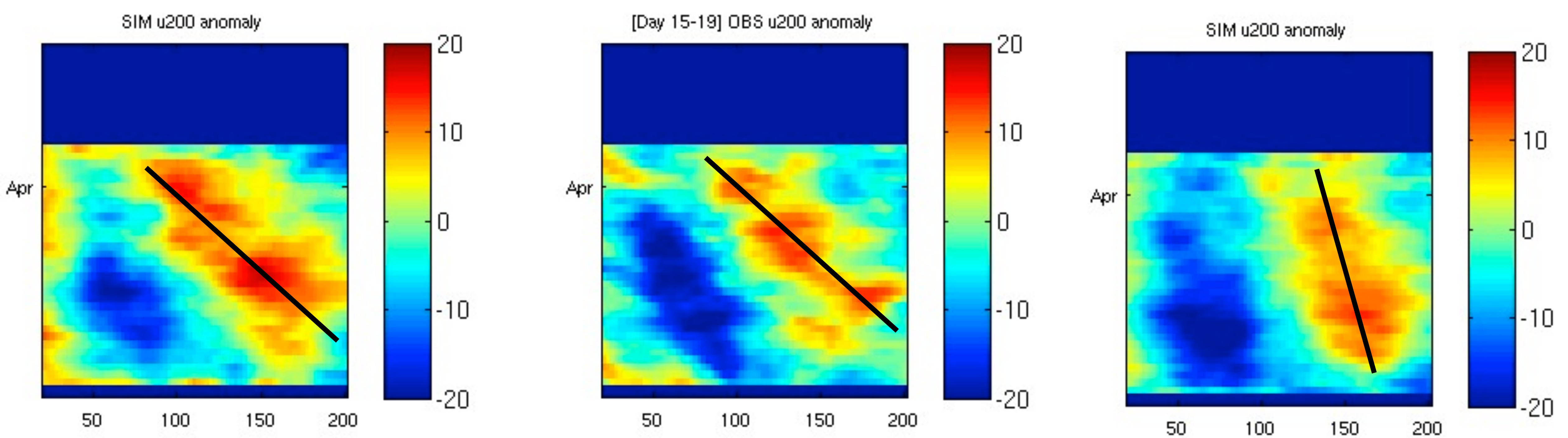
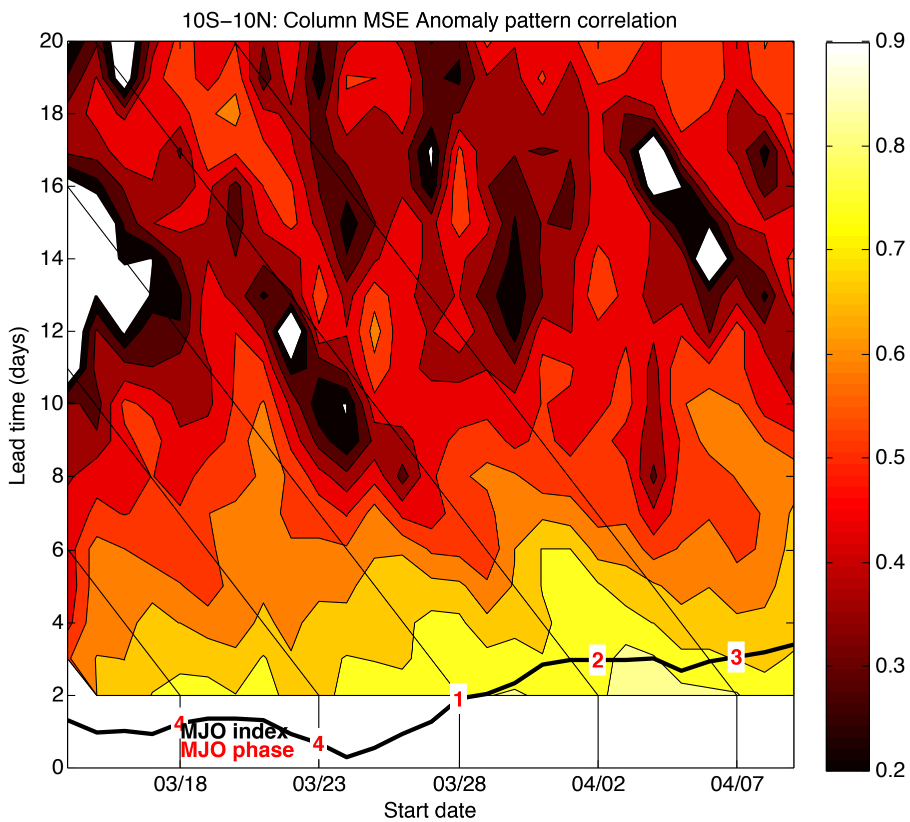
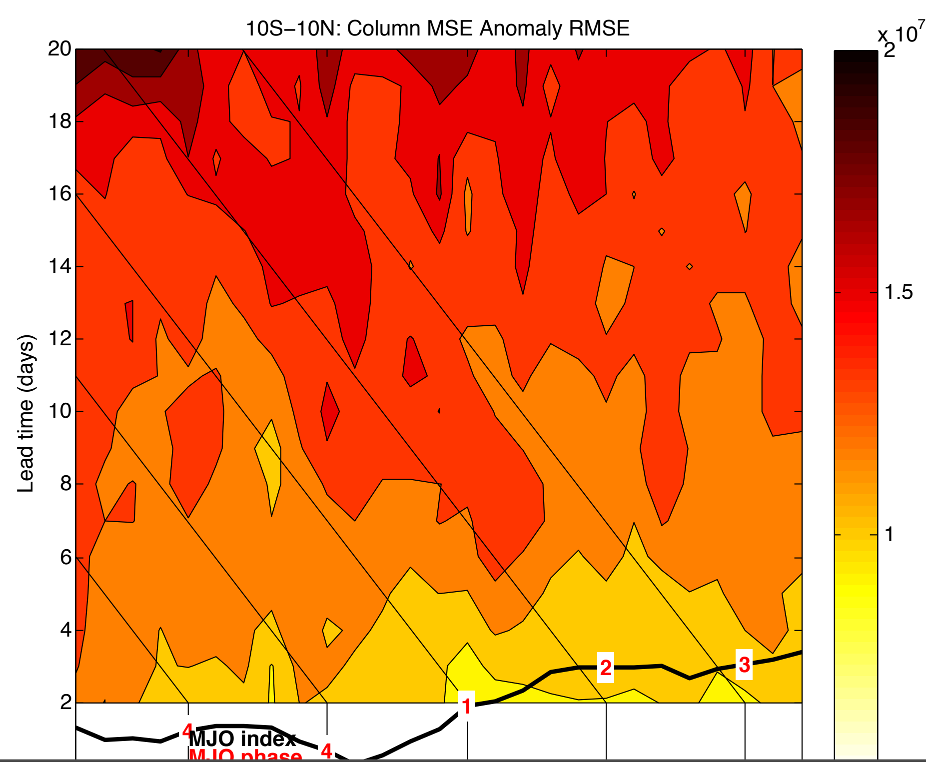


Caveat 1: improved RMM skill came at the expense of poorer forecasts of column MSE under 3D+CMT.

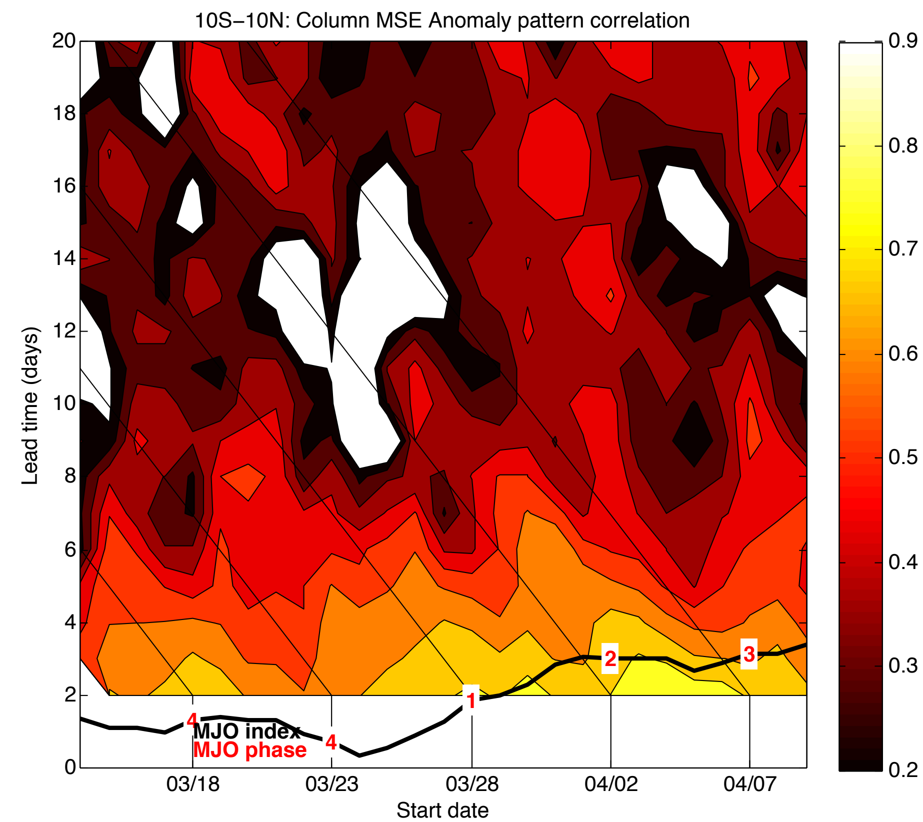
control

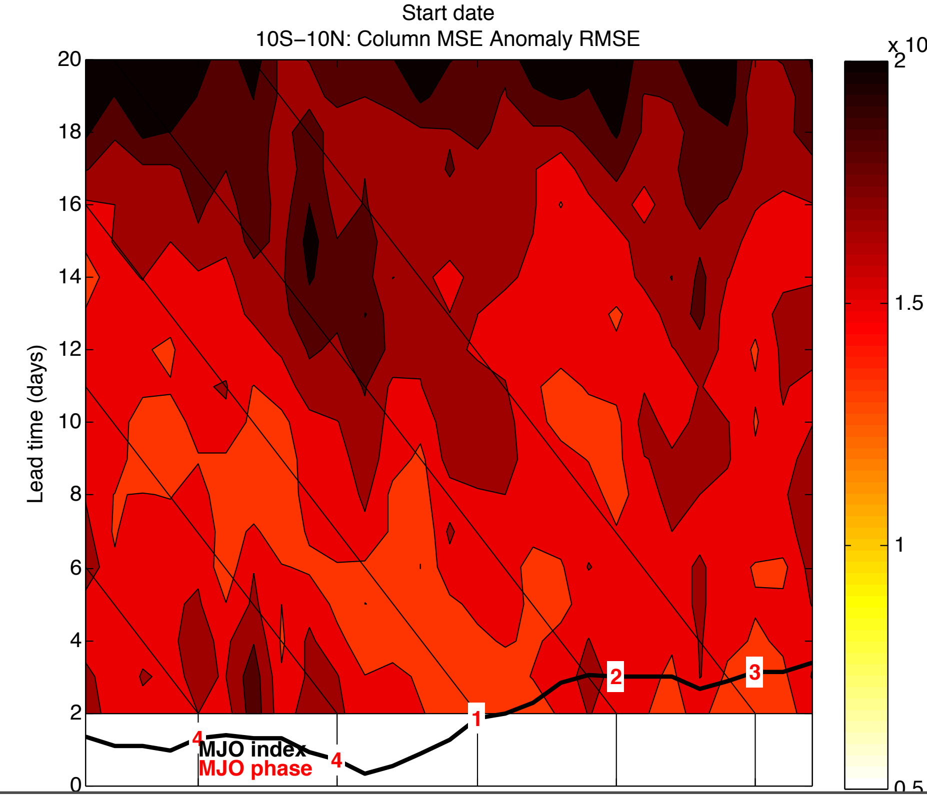




vs.

sens3dCRM+CMT

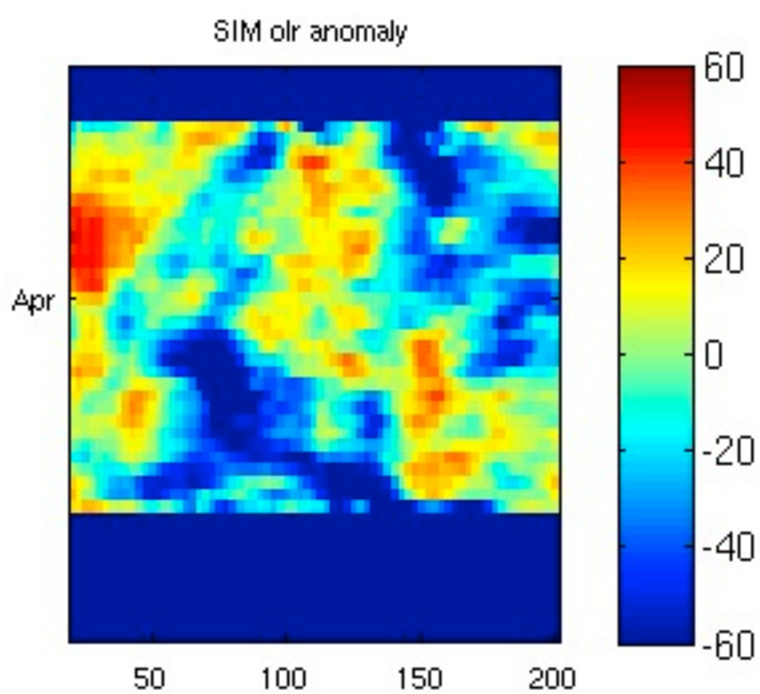




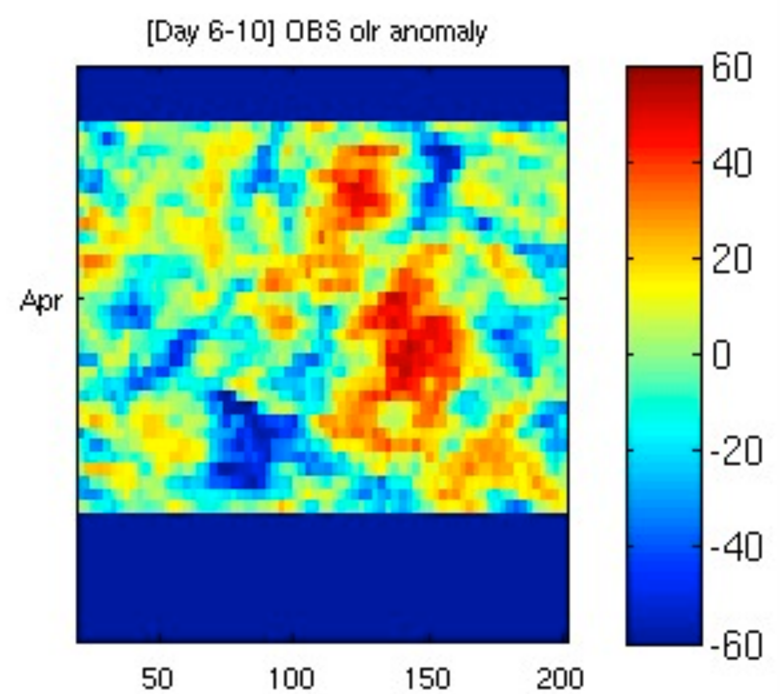
Caveat 2: The magnitude of OLR anomalies was unrealistically high in both simulations, and especially with the 3D CRM.

Days 6-10 composite:

sens3dcrm



OBS



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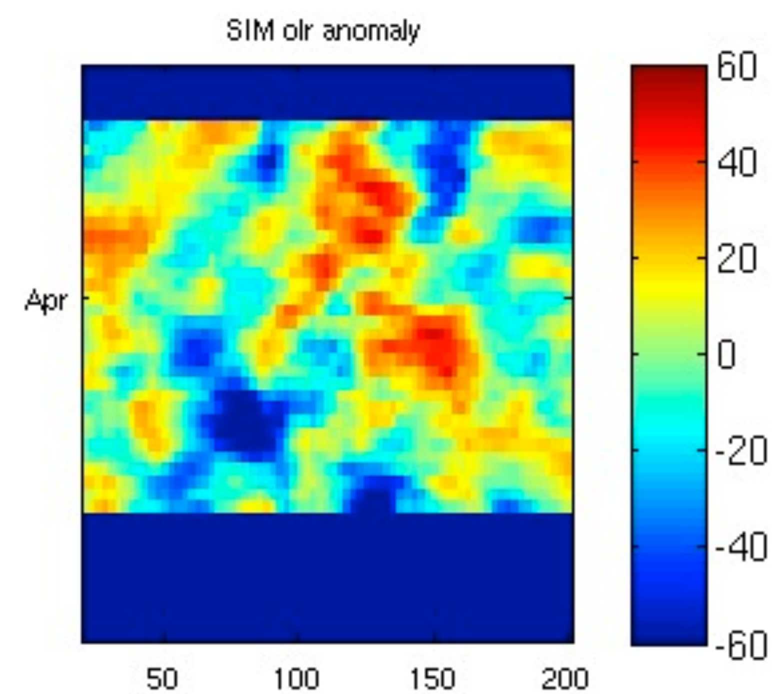
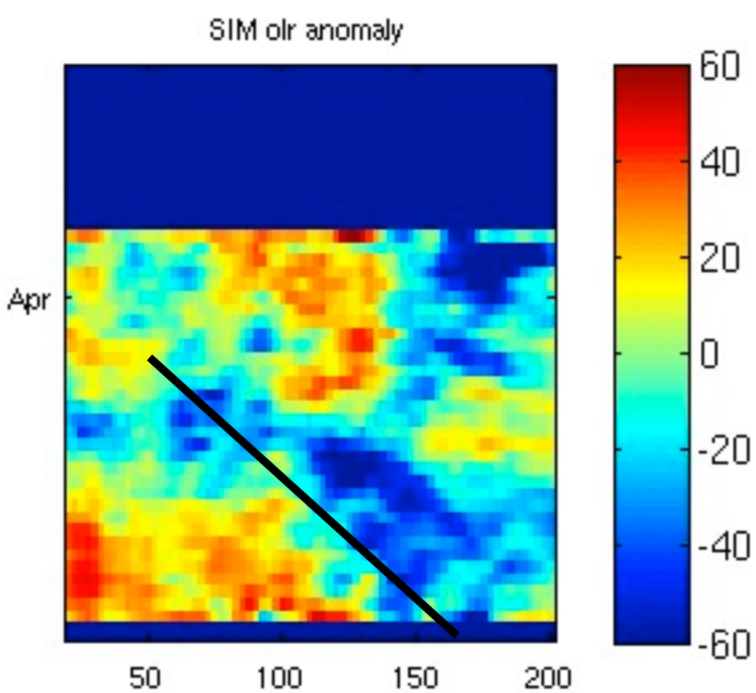


Nonetheless, improved coherence of eastward propagating OLR is suggestive at large lead times in the run with 3D+CMT.

Days 15-19 composite:

sens3dcrm



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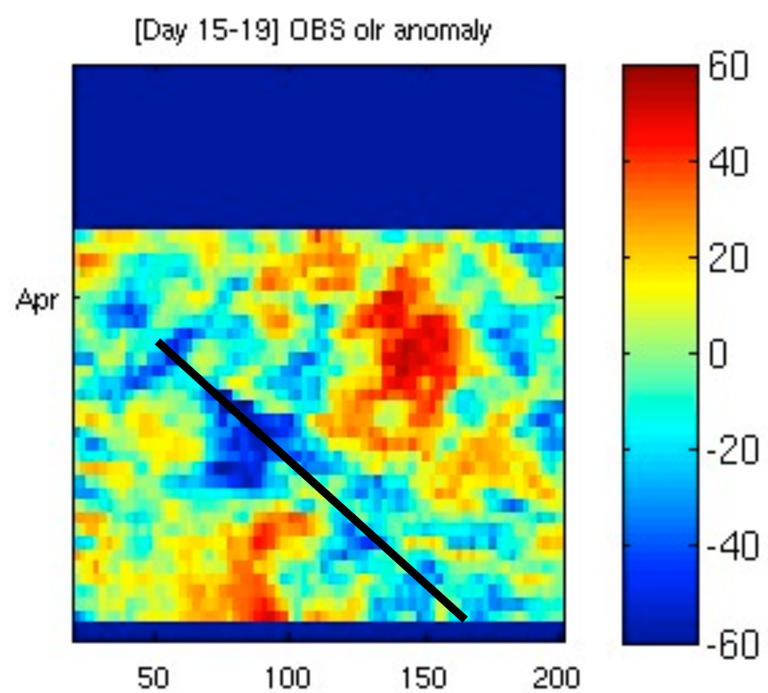

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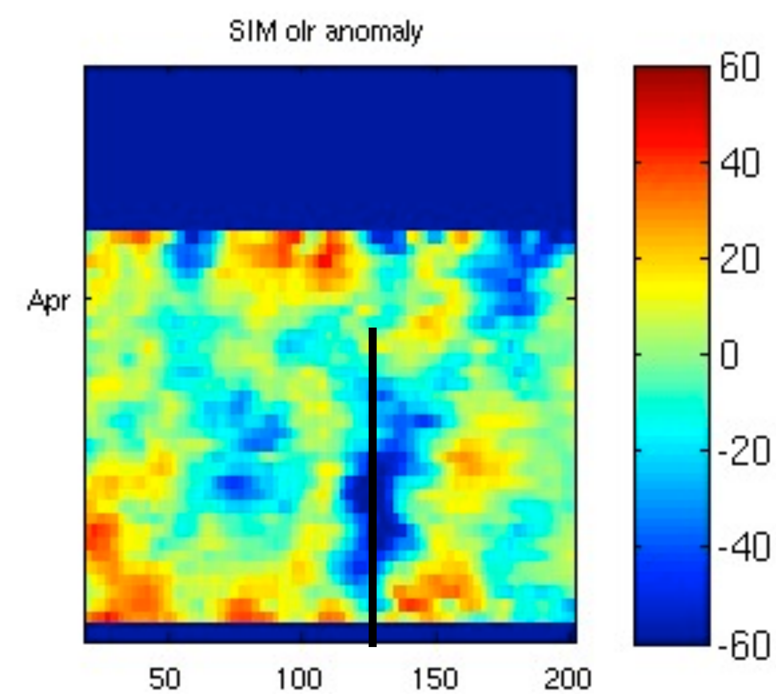

Propagating OLR

stationary OLR

Questions

Conclusions

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Perhaps. Revisiting YOTC Case D using a 3D CRM with CMT suggests potential for improved skill at lead times > 12 days.

Lots of interesting questions are still open.

- Why does SPCAM have a nice MJO while other GCMs don't?
- Why has the MJO deteriorated in SPCAM3.0's prototype sister models?
- How realistic is the MJO in the *new* versions of SPCAM?
- Can SPCAM realistically *forecast* real-world MJOs?
- Might convective momentum transport matter to the SP-MJO?
- What are the dominant pathways of SP-MJO destabilization from the moisture mode paradigm in its *real-world*

Plug for talk tomorrow in physical processes breakout:

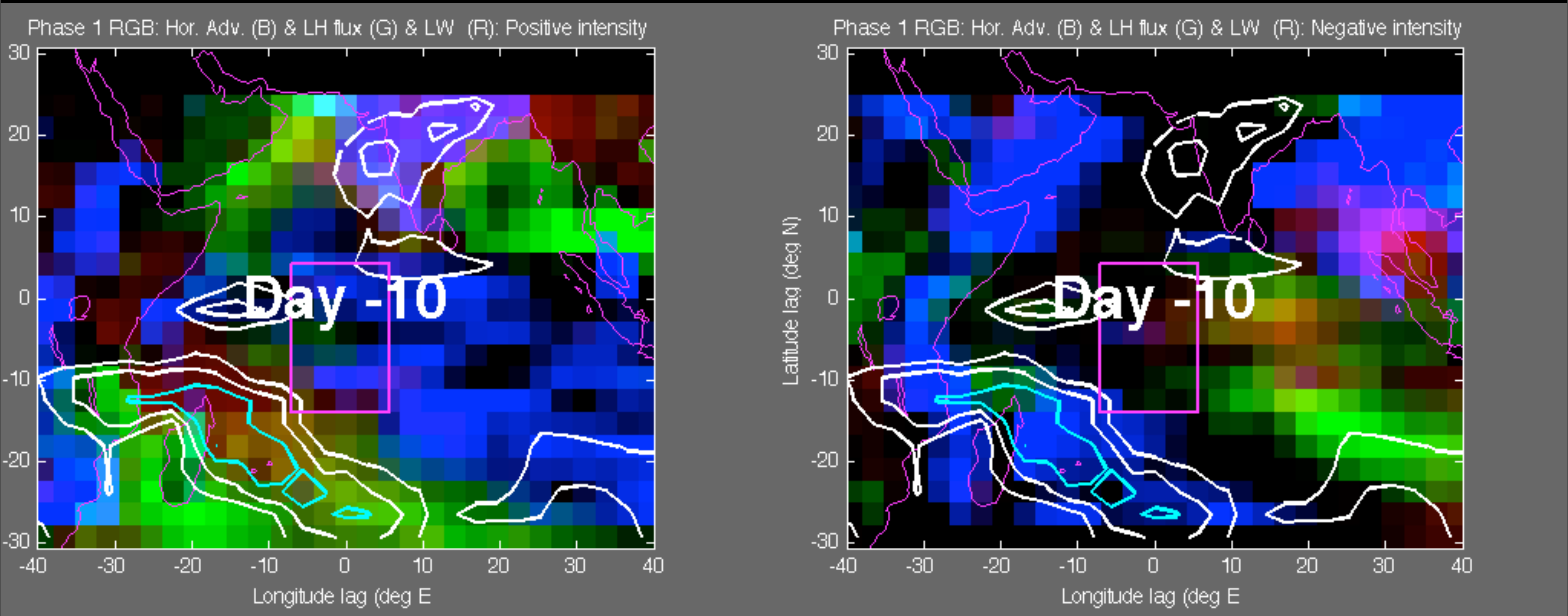
"A moist static energy budget analysis of the MJO in the SPCAM AMIP run"

Information rich view of the initiation of SPCAM's MJO in the Indian Ocean.

The contours show where the column MSE is.

Colors show horizontal advection + latent heat flux + longwave heating

MSE sources **MSE sinks**



Regression time series: 20-100 day column MSE in reference region.