Robustness and sensitivities of central U.S. summer convection in SP-CAM: Multi-model intercomparison with a new regional EOF index

Kooperman et al. 2013
GRL

Gabriel J. Kooperman
Michael S. Pritchard
Richard C. J. Somerville

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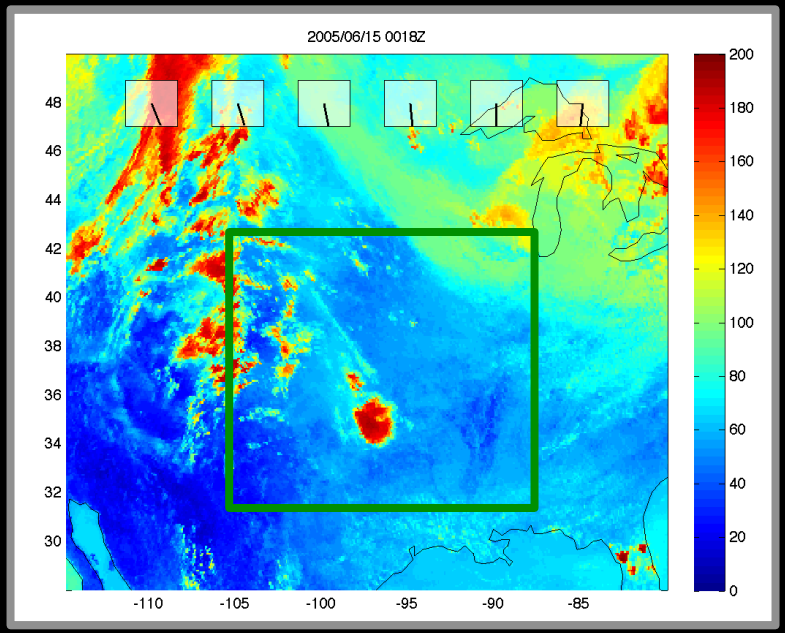
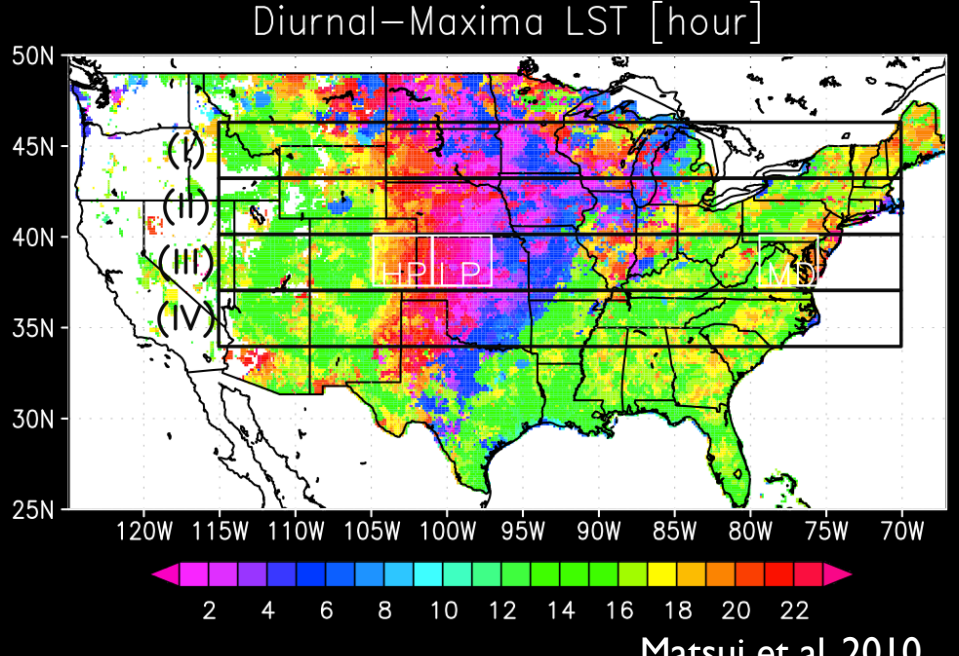
Propagating mesoscale convective systems in the Central US shift diurnal timing of rainfall

GOES 11 micron IR



- Large organized storm systems propagate east across the Central US and grow over night.

Radar-gauge Hourly Rainfall

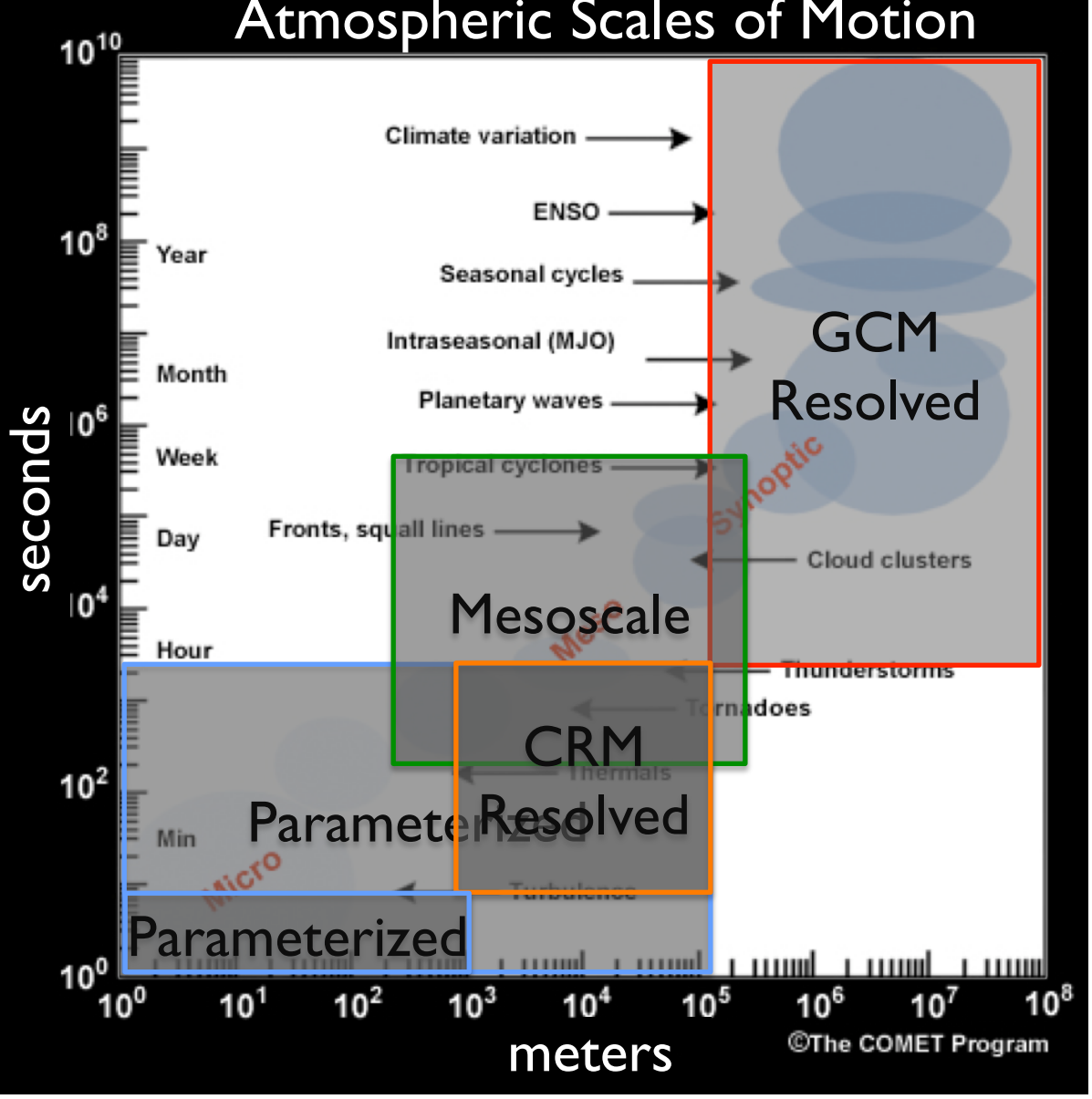


Matsui et al. 2010

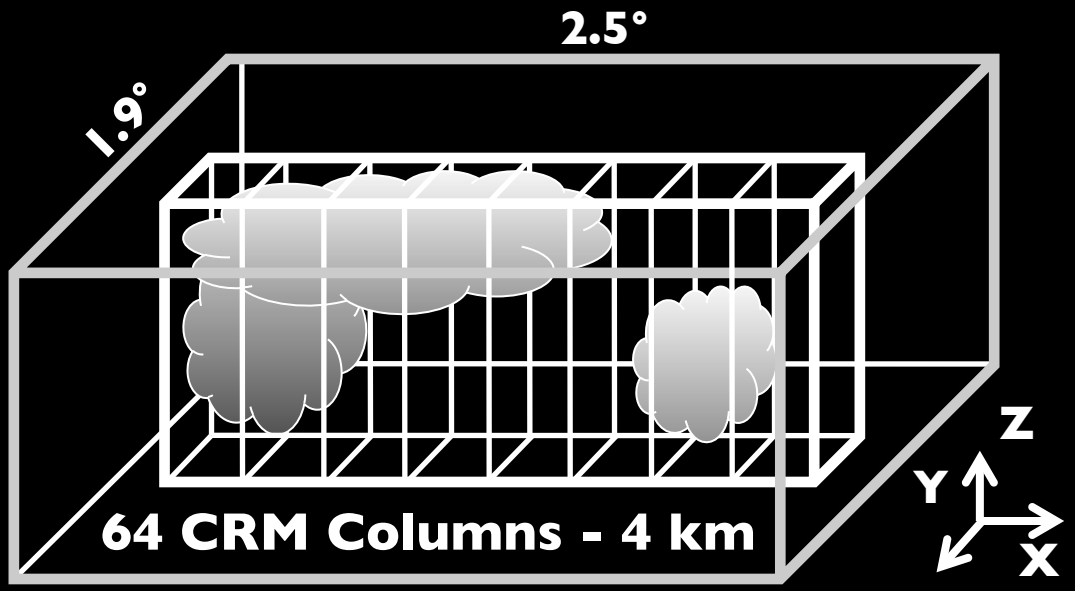
- MCSs generate up to 60% of summer rainfall.
- Overall diurnal rainfall is dominated by MCS signal.
- The MCS rainfall maximum occurs over night.

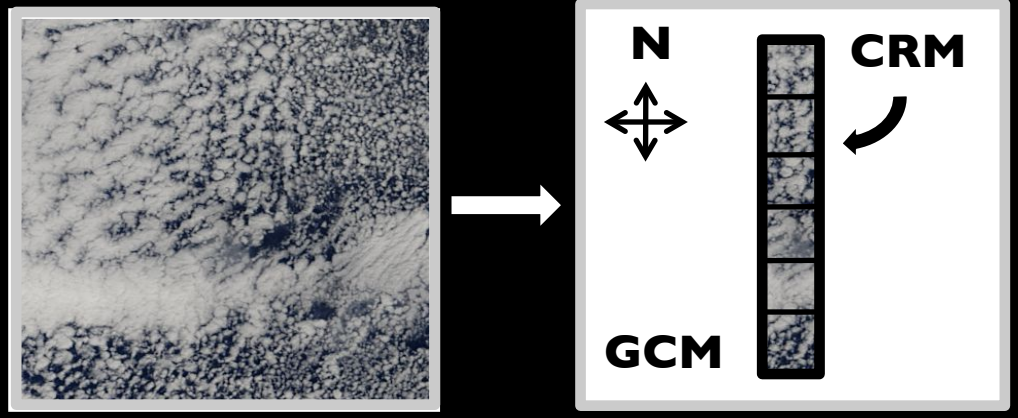
The mesoscale straddles the divide between resolved and parameterized processes

- Conventional GCMs resolve large-scale (> 200 km) motion.
- Processes on scales less than grid boxes are parameterized.
- Mesoscale processes are neither resolved nor parameterized.
- A new type of GCM attempts to capture both by combining a GCM and a cloud-resolving model.



SP-CAM simultaneously resolves both small- and large-scale processes related to clouds





a.k.a.
"super-parameterization"

Idealized 2D cloud resolving models (CRMs) are embedded in each grid column of a GCM to replace conventional cloud parameterizations and explicitly represent sub-grid convection.

MMFs are 200x more expensive computationally than GCMs, but scale 10x more efficiently.

The host GCM is the NCAR Community Atmosphere Model.

Multiscale Modeling Framework

CMMAP
Reach for the sky

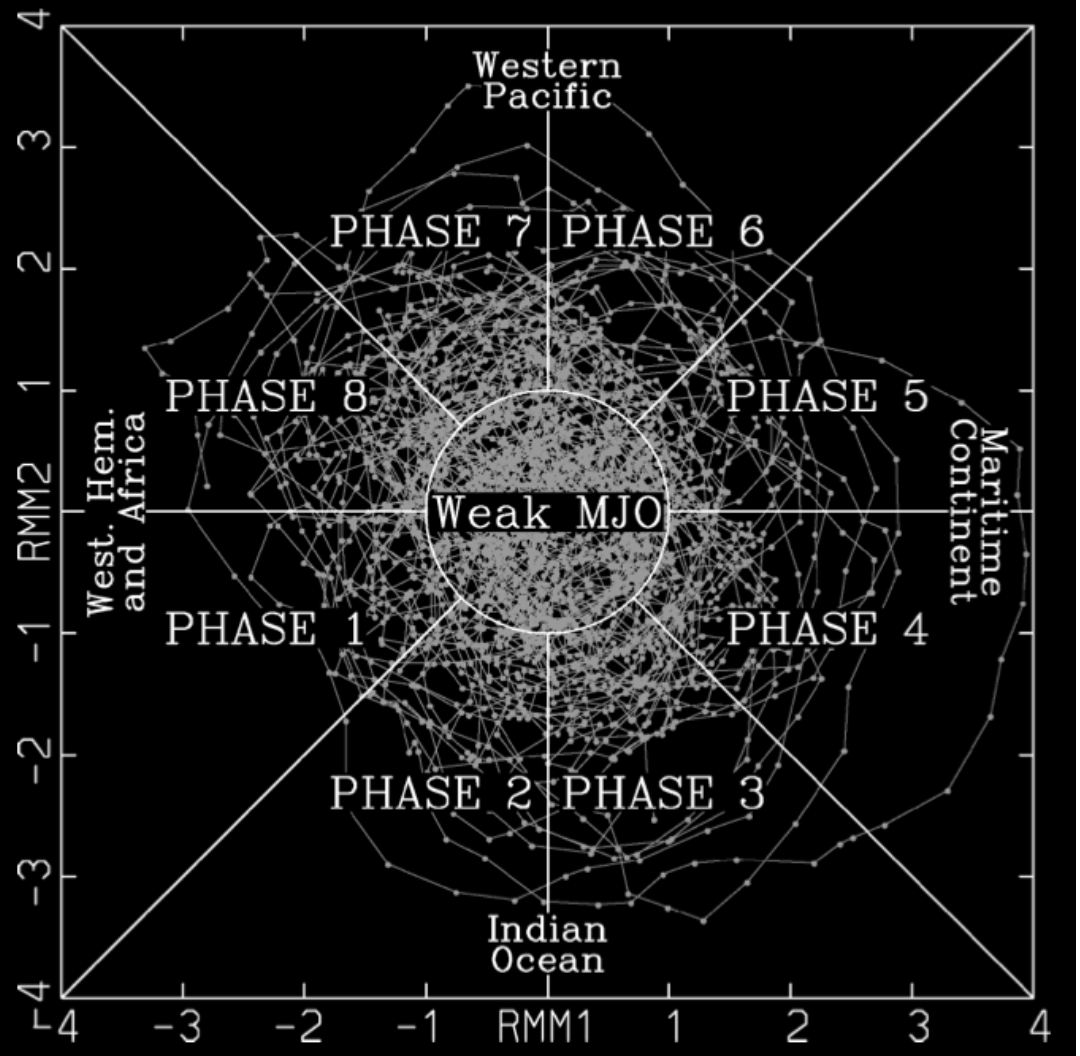
Questions:

1. How realistic is the SP MCS signal in version 3.5?
2. Can SP-CAM reproduce the timing, spatial structure, and intensity of observed events?
3. Does the signal exist and improve in other versions of SP-CAM (3.0 and 5.0)?

Evaluating robustness and sensitivities using a new regional MCS index.

A Wheeler and Hendon type EOF index for Central US mesoscale convection

1. Organized convection in the tropics and mid-latitudes is a major source of variability.
2. And a major challenge for many GCMs.
3. The signal has a clear zonal propagation in both regions.
4. An EOF based index has been a useful tool for evaluating the MJO.



Wheeler and Hendon 2004

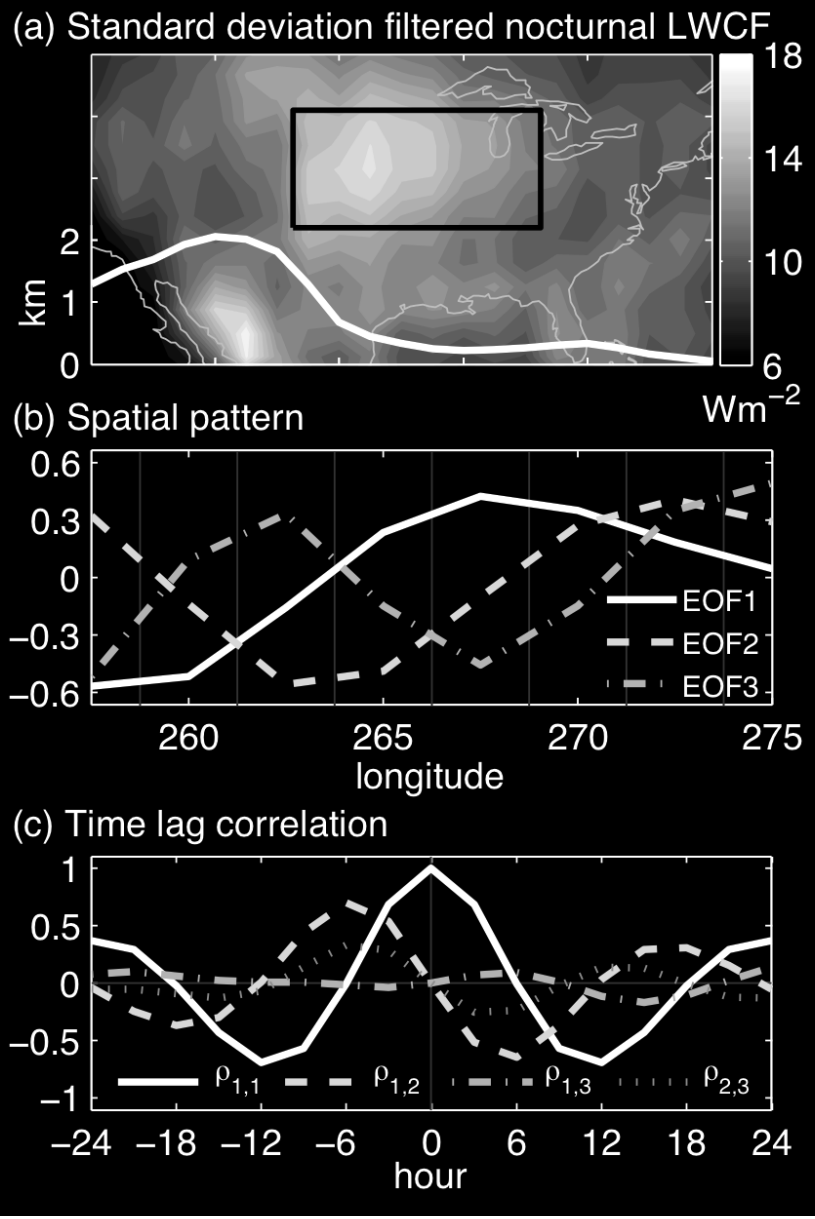
New MCS index to compare six conventional and super-parameterized versions of CAM

- 3 hourly MJJA longwave cloud forcing (LWCF) band-pass filtered for 12 to 48 hours from observations and six model versions.
- Observations are from 23 years (1984–2006) of the NASA GEWEX Surface Radiation Budget (SRB) TOA flux data.
- Hourly precipitation from the NCEP Climate Prediction Center.

Model	GCM resolution	CRM resolution	Microphysics	Aerosol Physics
CAM3.0	T42, 26 levels	N.A.	1 moment	N.A.
SP-CAM3.0	T42, 26 levels	1x32, 4 km, NS	1 moment	N.A.
CAM3.5	1.9x2.5°, 30 levels	N.A.	1 moment	N.A.
SP-CAM3.5	1.9x2.5°, 30 levels	1x64, 1 km, EW	1 moment	N.A.
CAM5.0	1.9x2.5°, 30 levels	N.A.	2 moment	3 mode, 2 mom
SP-CAM5.0	1.9x2.5°, 30 levels	1x32, 4 km, NS	2 moment	3 mode, 2 mom

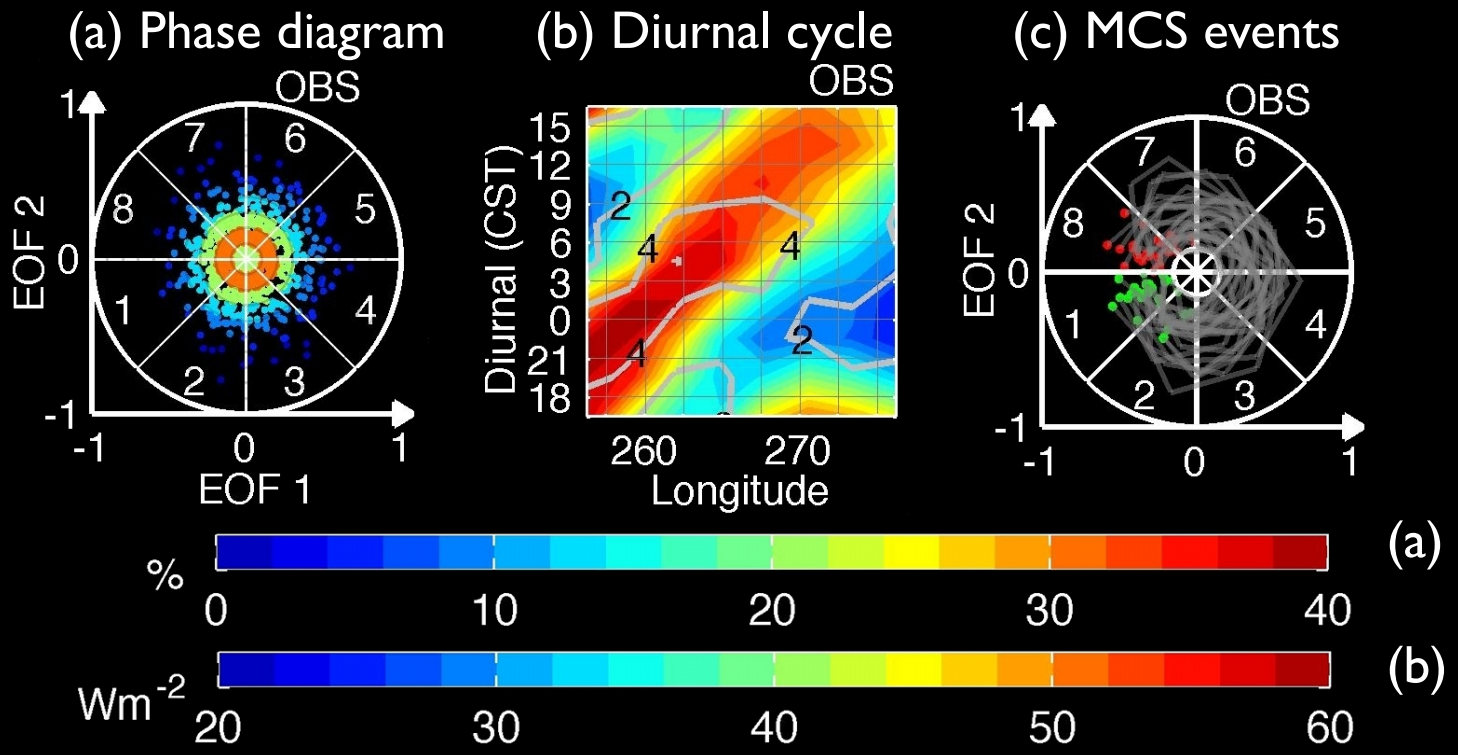
A regional LWCF leading EOF pair represents eastward propagating nocturnal convection

- The nocturnal (00-06 CST) variance of LWCF shows the well known Central US MCS activity zone.
- EOF analysis of meridionally averaged LWCF in black box.
- Leading EOF-pair explains ~ 65% of the variance with 35% from EOF 1 and 30% from EOF 2.
- EOFs 1 and 2 have spatial patterns in phase quadrature and high time-lag correlation.



The new EOF index compactly isolates the mid-latitude MCS signal in observations

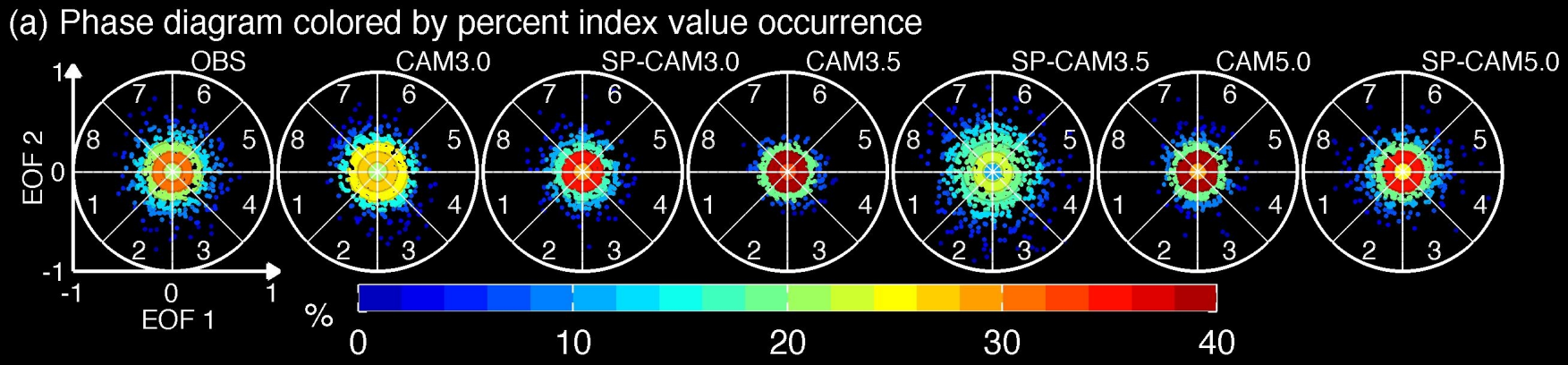
- High index amplitudes.
- Nocturnal-east slant.
- Co-located precipitation.
- Events span phases.



Event selection criteria:

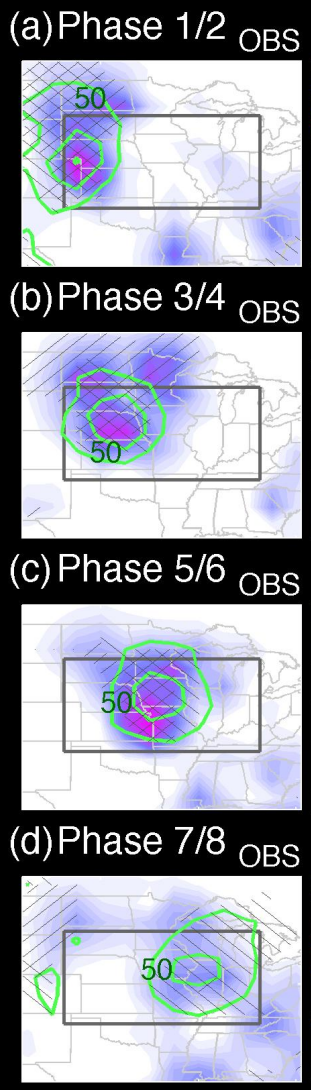
1. At least three (9 hours) consecutive index amplitudes greater than 0.15 propagating forward (east) in phase space,
2. spanning at least 70% of the domain (~1200 km), and
3. starting between 18 and 03 local (CST) time.

Nocturnal eastward propagating MCS signal is captured in all versions of SP-CAM



- SP-CAM3.5 has the highest amplitude values.
- CAM3.5 and CAM5.0 have the lowest values.
- Eastward slant in shows nocturnal propagating convection in observations and all versions of SP-CAM.
- SP-CAM5.0 agrees the best with the observed width and co-located precipitation, although LWCF is too weak.

MCS physics is a robust effect of SP and most realistic in 5.0 with two-moment microphysics



Precipitation (colors), longwave cloud forcing (green), heating tendency (orange)

mm/day

2 4 6 8 10

Conclusions: SP is a useful analog to nature

- A new EOF based index compactly evaluates the mid-latitude MCS signal in conventional and super-parameterized GCMs.
- Forecast simulations may provide a useful method for evaluating against high value measurements of observed events.
- US MCS physics is a robust effect of super-parameterization.
- The signal is most realistic in 5.0 with two-mom microphysics.

Future work investigating the virtual MCS signal using the new regional MCS index

- Detailed analysis of MCS climate change response.
- Investigate two-way aerosol-cloud (MCS) interactions.
- Test model parameter sensitive and forecast skill with MCS index.