# A New Convective Trigger for Better Capturing the Diurnal Cycle of Precipitation in Weather and Climate Models: Observational Evidence and Modeling Results

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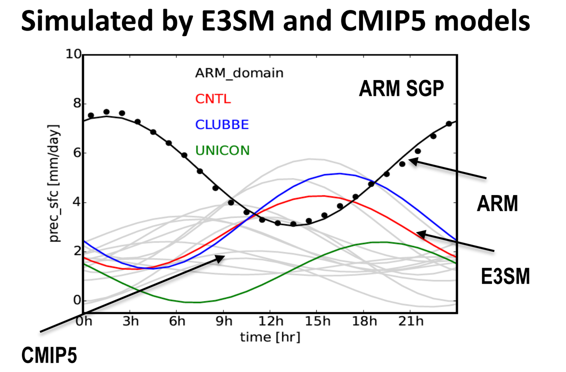
## Errors in Modeling Diurnal Cycle of Precipitation

### Common errors

- Rainfall occurs too early after sunrise and "too frequent, too weak"
- Fail to capture the nocturnal peak over the central Great Plains
- No eastward propagation of MCSs from the Rocky Mountain to the central Great Plains
- No significant improvement with increasing model resolution

Errors are larger over land than ocean

Summertime Diurnal Cycle of Precipitation Simulated by E3SM and CMIP5 models

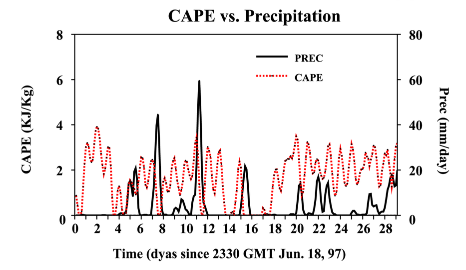



Colors for E3SM with different convection schemes

### Deficiencies in convective triggers

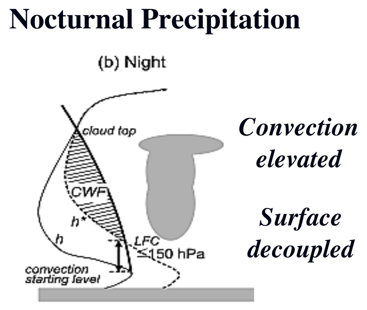
- Unrealistically strong coupling of convection to surface heating
- Lack of convection inhibition
- Lack of additional large-scale dynamic & thermodynamic controls (e.g., tropospheric moisture, low-level convergence)
- Roles of cold pool in convection initiation
- Elevated convection is not considered

Issues with CAPE-based trigger




==> Convection would be triggered too often over land during warm season

Nocturnal Precipitation




Lee et al. 2008

## Two Key Areas to Improve

1. *To prevent convection from being triggered too frequently*
2. *To capture elevated nocturnal convection, which occurs from moist conditionally unstable layers located above the boundary layer*

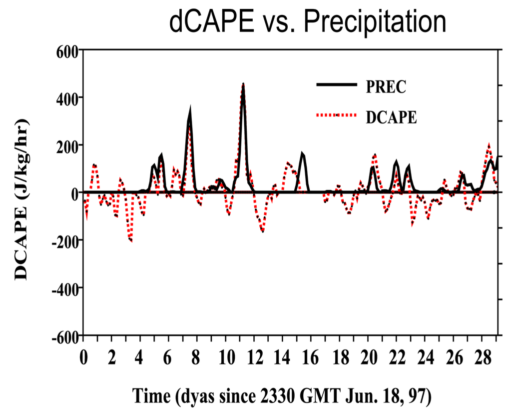
### Proposed Solutions

- The dynamic CAPE generation rate (**dCAPE**) introduced by Xie and Zhang (2000) to control the onset of deep convection:

$$\mathrm{DCAPE} = [\mathrm{CAPE}(T^*,\ q^*) - \mathrm{CAPE}(T, q)]/\Delta t,$$

*Where*
$T^* = T + (\partial T/\partial t)_{adv} * \Delta t$; and $q^* = q + (\partial q/\partial t)_{adv} * \Delta t$

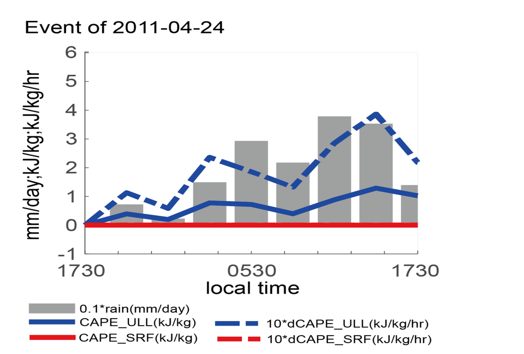
dCAPE vs. Precipitation



*Xie and Zhang (2000), JGR*

- Unrestricted Launch Level (**ULL**) introduced by Wang et al. (2015) to allow air parcel launching above PBL to capture elevated convection

Elevated Nocturnal Convection Case in ARM MC3E




*Wang and Xie (2019), submitted*

**New Trigger: (CAPE>0 & dCAPE>0) + ULL**

## Model and Experiment Design

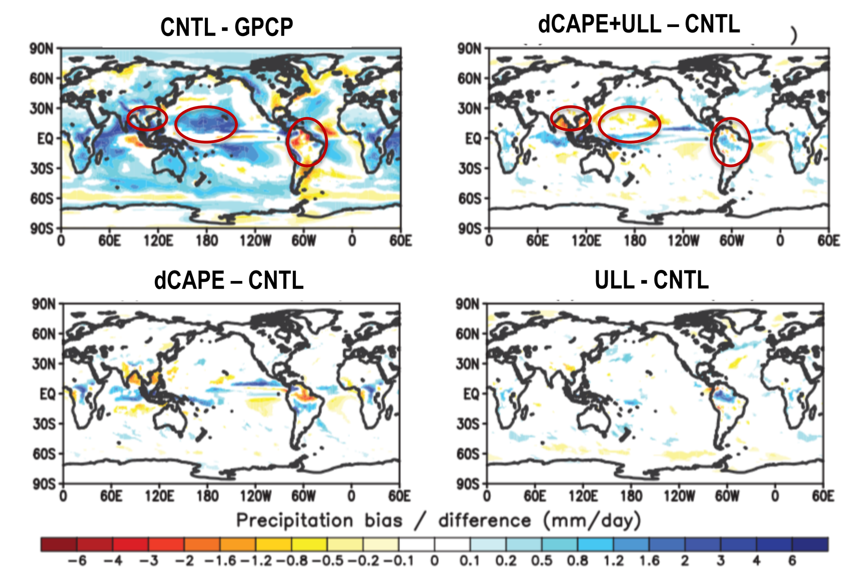
11 year AMIP simulations with the newly developed US DOE Energy, Exascale, and Earth System Model (E3SM) Atmosphere Model Version 1 (**EAMv1**); 2–11 year simulations are analyzed. Model resolutions are $1^0$ and 72 levels

| Case | Description | Convective Trigger |
|---|---|---|
| CNTL | Default low-resolution ($1^0$) EAMv1 ( Rasch et al. 2019) | CAPE > 70 J/kg |
| dCAPE+ULL | EAMv1 with the proposed new convective trigger | 1) CAPE > 0 & dCAPE>0<br>2) Allow unrestricted launch level (ULL) |
| dCAPE | EAMv1 with dCAPE trigger only | CAPE > 0 & dCAPE>0 |
| ULL | EAMv1 with ULL | Same as CNTL, but allow unrestricted launch level (ULL) |

## Mean Climate

### Annual Mean Precipitation

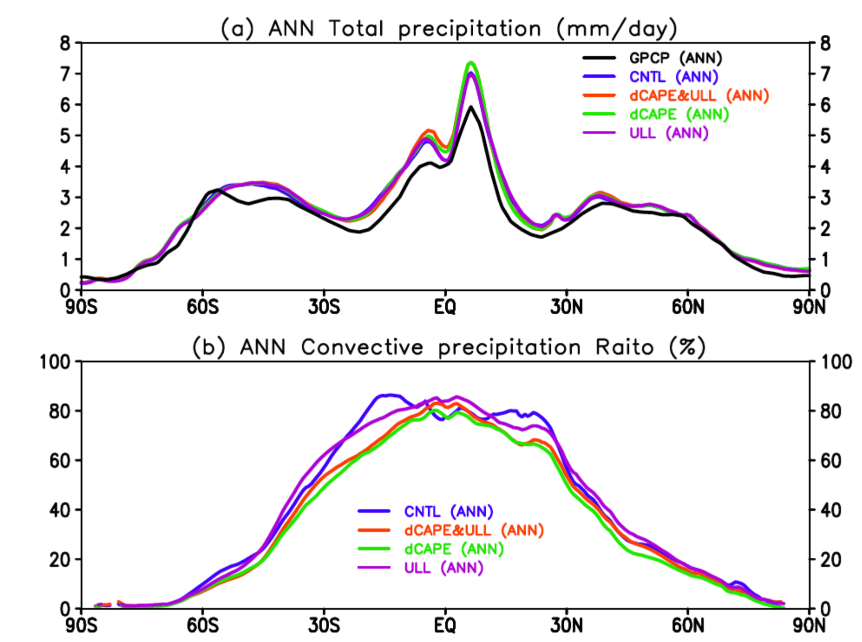
Only show the differences that are statistically significant




Overall impact on mean state is minor

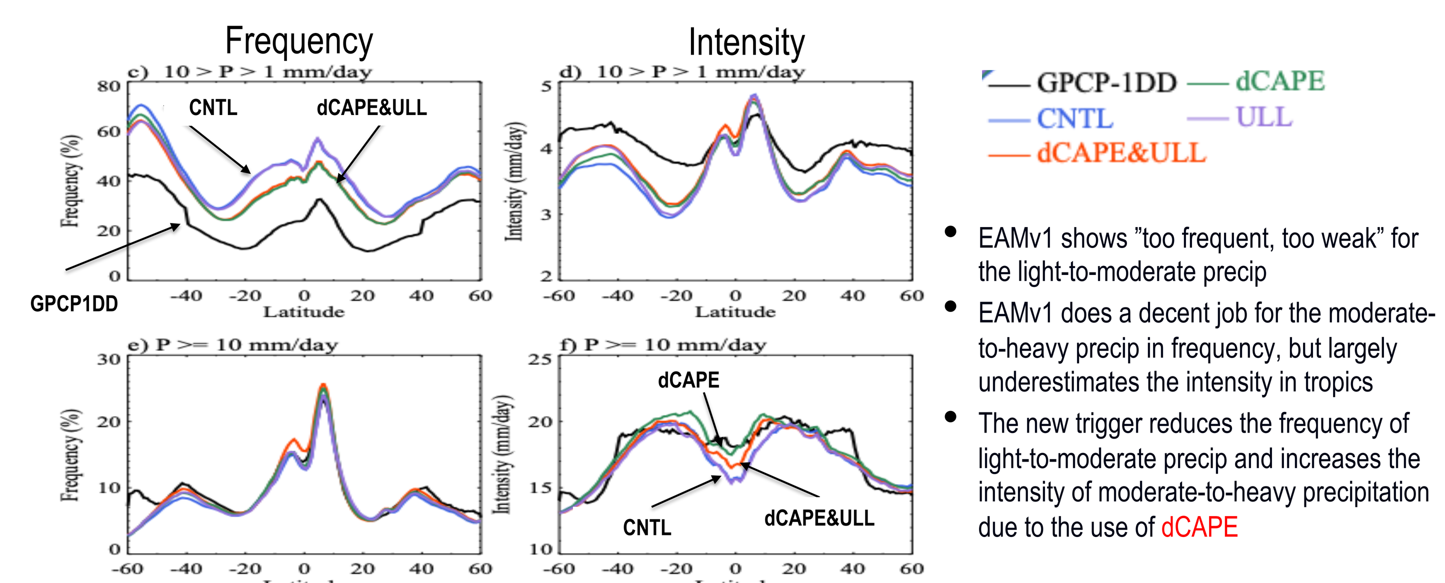
- Slight improvements over equatorial and subtropical Pacific and Atlantic, the Indian peninsula and surrounding oceans, South America
- A slight degradation is seen in the northern ITCZ in the eastern Pacific
- dCAPE plays a major role in changes seen in mean state

### Precipitation Partitioning



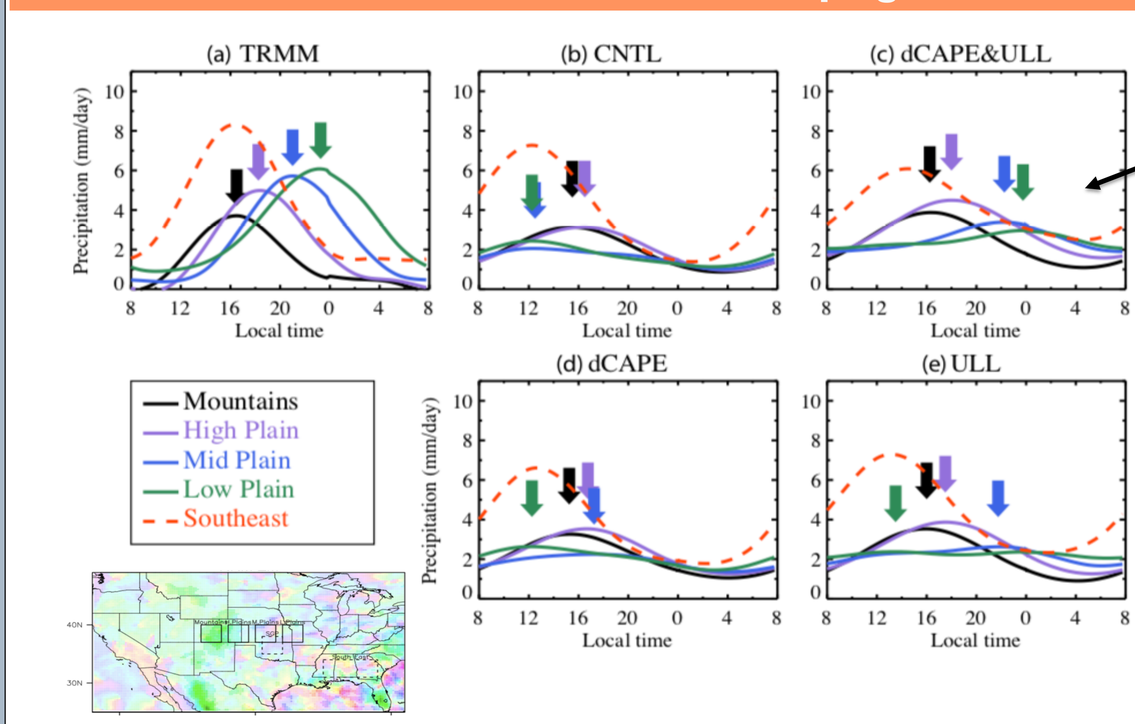

- Changes in total precip are minor
- Considerable reduction of convective precipitation fraction over the subtropical regions with the use of the **dCAPE** trigger.

### Precipitation Frequency and Intensity




- EAMv1 shows "too frequent, too weak" for the light-to-moderate precip
- EAMv1 does a decent job for the moderate-to-heavy precip in frequency, but largely underestimates the intensity in tropics
- The new trigger reduces the frequency of light-to-moderate precip and increases the intensity of moderate-to-heavy precipitation due to the use of dCAPE

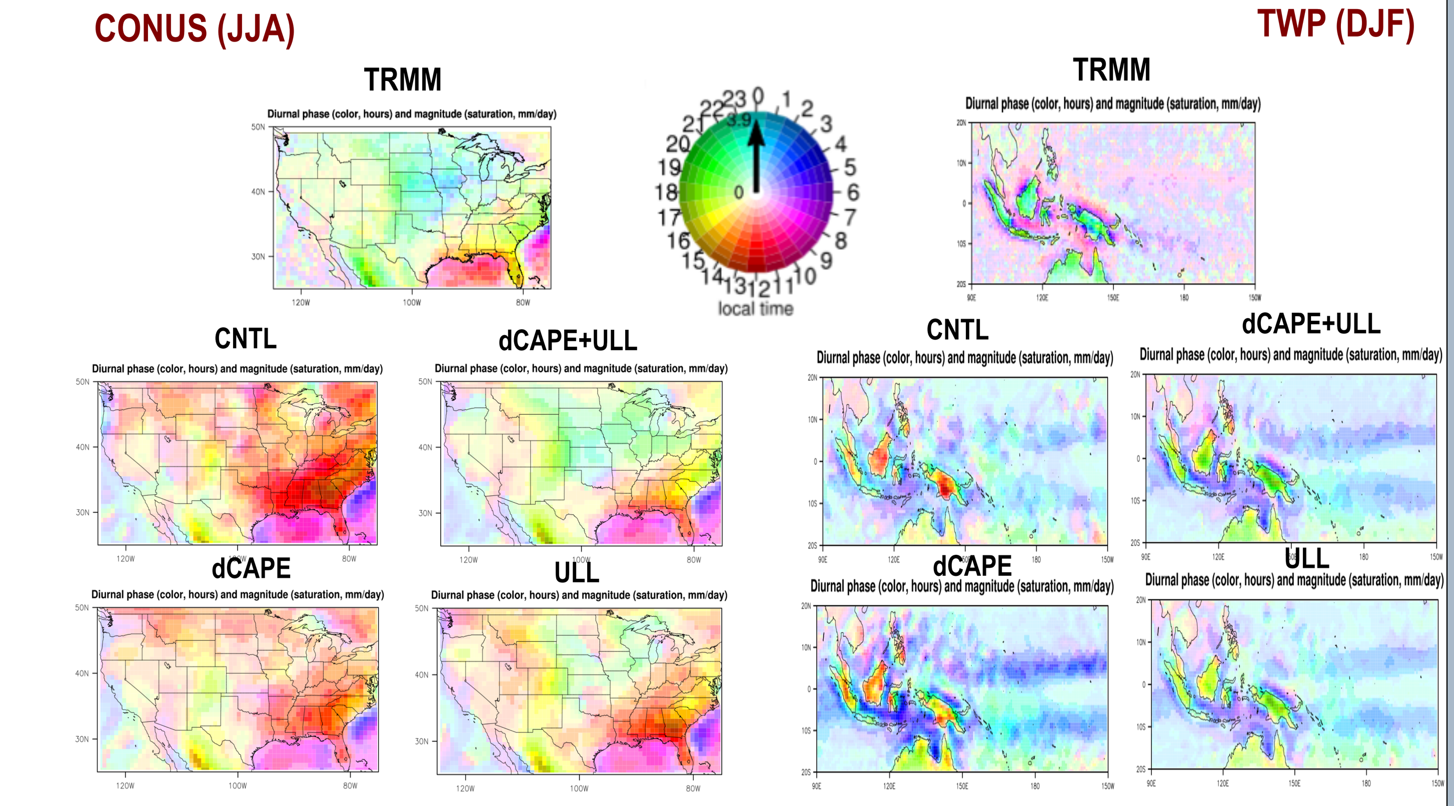
## Eastward Propagation



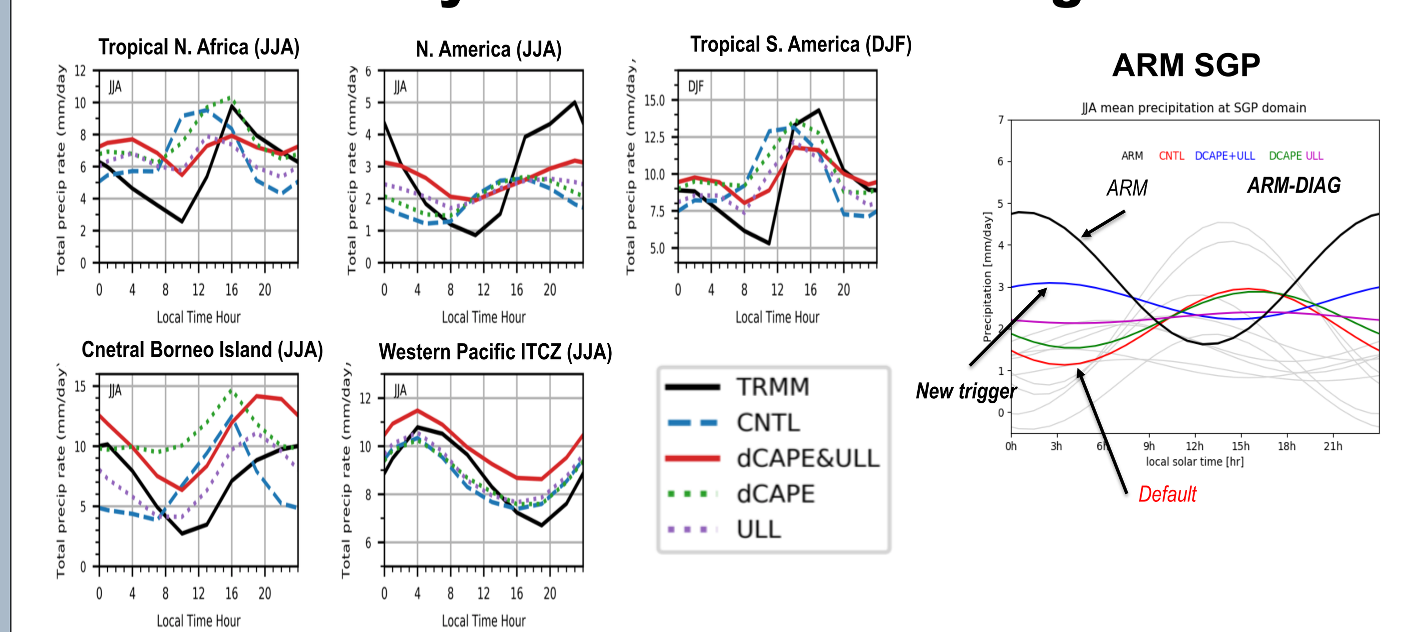

Model starts to show the "Eastward Propagation" with the new trigger

## Diurnal Cycle of Precipitation

Diurnal cycle of precipitation is well captured with the new trigger




### Diurnal Cycle over Selected Regimes




## Conclusion

- A new convective trigger (DCAPE+ULL) was tested with EAMv1.
  - dCAPE used to prevent CAPE being released spontaneously
  - ULL used to remove the restriction of having the air parcel launch level within PBL for elevated nocturnal convection
- The new trigger has a minor impact on the mean state, but it leads to a substantial improvement in the phase of the diurnal cycle of precipitation although its amplitude is still too weak
- dCAPE helps to suppress convection while the unrestricted launch level is key to capturing nocturnal elevated convection
- EAMv1 starts to show the eastward propagation of MCSs, but processes behind it needs to be better understood.
- Only minor changes seen in tropical waves

### References:

Xie, S., Wang, Y.-C., Lin, W., Ma, H.-Y., Tang, Q., Tang, S., et al (2019). Improved Diurnal Cycle of Precipitation in E3SM with a Revised Convective Triggering Function. JAMES, https://doi.org/10.1029/2019MS001702.

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