# Simulations of Mesoscale Convective Systems in a Regional Climate Model and a Global Variable Resolution Model: Effects of Model Resolution and Convective Parameterizations


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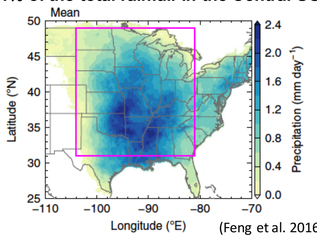
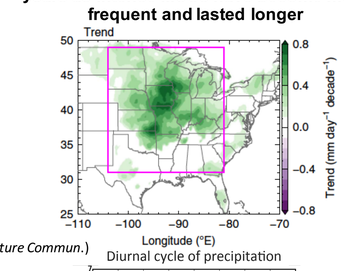
## 1. Motivation

**Mesoscale convective systems (MCSs) are ubiquitous worldwide and contribute to 30%-64% of the total rainfall in the Central US**

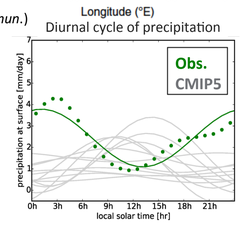



(Feng et al. 2016 *Nature Commun.*)

**MCS rainfall has increased in the past 35 years as intense MCSs have become more frequent and lasted longer**




**Climate models with parameterized convection mostly fail to represent MCSs, as reflected in biases in the simulated precipitation diurnal cycle**



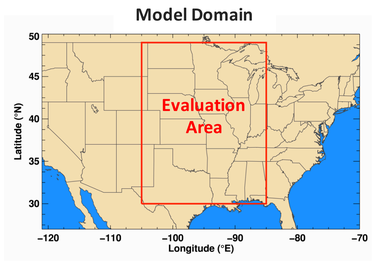

(Source: Chengzhu Zhang LLNL)

## 2. Objectives

- Develop metrics to evaluate climate simulations of MCSs
- Evaluate how well regional convection permitting simulations can capture characteristics of MCSs and sensitivity to model parameterizations
- Explore convection permitting modeling in a global variable resolution framework and address modeling challenges

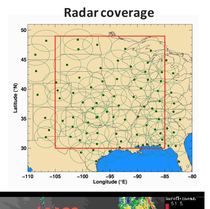
## 3. Regional convection permitting simulations

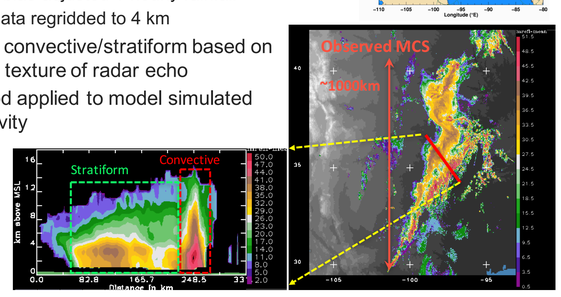
- WRF simulations with 4 km horizontal grid spacing and 65 vertical levels
- Summer season (JJA) simulations initialized on May 1 for 2011 and 2012 driven by GFS reanalysis
- Cumulus parameterization is turned off; two microphysics parameterizations are compared – Morrison and Thompson



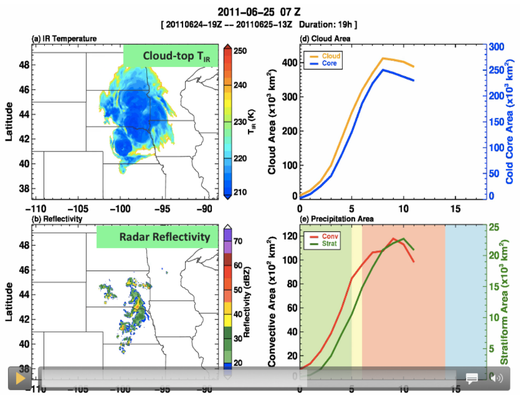

## 4. Observations

- **NASA Goddard satellite data**
  - Δx = 4 km, 30 min $T_{IR}$
- **NSSL MRMS National Radar Product**
  - 3-D Mosaic Reflectivity data
  - Δx = 1 km, 31 vertical level: 0.5-18km
  - Q2 gauge bias-adjusted 1-hourly rainfall
  - All radar data regridded to 4 km
- Partition into convective/stratiform based on intensity and texture of radar echo
- Same method applied to model simulated radar reflectivity



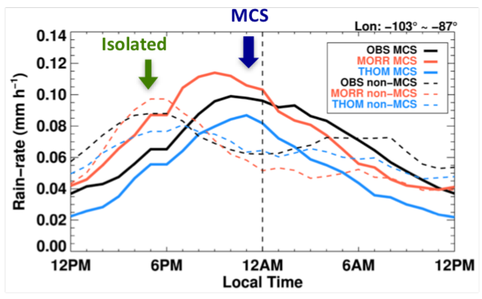



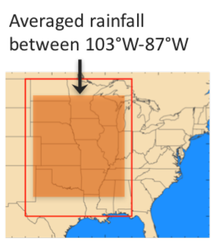

## 5. Tracking of a simulated MCS




- **Automated tracking of MCS with $T_{IR}$:** (Feng et al. 2012, 2016)
  - Cold cloud shield area ≥ 60,000 km²
  - Duration ≥ 6 h
  - Define robust MCS (Coniglio et al. 2010): Precipitation Feature length > 100 km, contains 50dBZ area, persists > 5 h

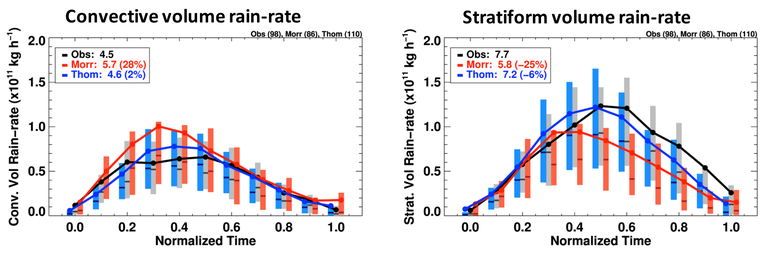
## 6. Diurnal precipitation well simulated




- Isolated precipitation peak just before sunset
- MCS precipitation from the two simulations straddle the observations
- MCS precipitation with the Morrison scheme peaks 2h earlier than observations and simulation with the Thompson scheme

## 7. MCS volume rain-rate

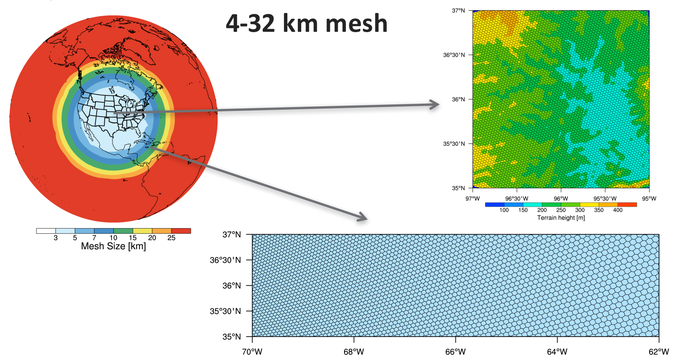



$$Vol_{rainrate} = \overline{rainrate} \times area$$

- **OBS:** stratiform rain accounts for 63% total rain volume
- Convective $Vol_{rainrate}$: Morr: +28%, Thom:+2%
- Stratiform $Vol_{rainrate}$: Morr: -25%, Thom: -6%
- Partitioning of convective vs. stratiform rain has implications to the latent heating profile and large-scale circulation

## 8. Exploring a global variable resolution model for convection permitting simulations

- The non-hydrostatic MPAS dynamical core has been coupled to the physics package of Community Atmosphere Model (MPAS-CAM5) for climate modeling (Zhao et al. 2016 *JAMES*)
- Sakaguchi et al. (2015 *JCLIM*; 2016 *JAMES*) demonstrated the downscaling and upscaling capability of the variable resolution modeling framework




## 9. Numerical experiments

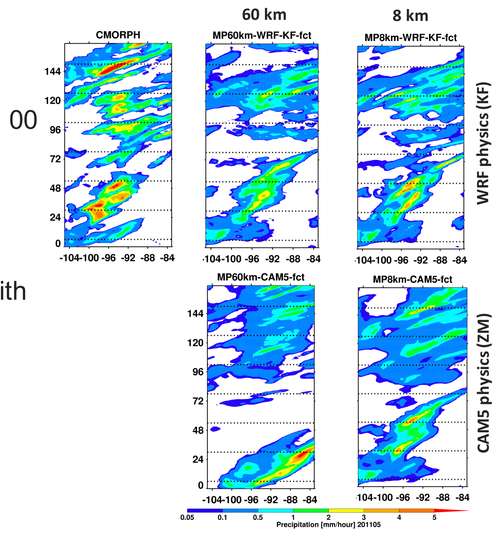
- Simulations performed for the summer of 2011 (initialized on April 15)
  - Global quasi-uniform resolutions of 120 km and 60 km
  - Global variable resolution at 32 km with regional refinement at 4 km over Central US
  - Global variable resolution at 64 km with a regional refinement at 8 km over Central US
- The Zhang-McFarlane (ZM) convective parameterization is used
  - Physics time step is fixed at 600s for all experiments
  - CAPE consumption time scale (*tau*) is fixed at 3600s for all experiments except a sensitivity run with *tau* varying as a function of grid size

```
tau2d(i) = min(tau_max, tau_ref*max(1._r8, grid_size_ref/grid_size(i)))
tau_ref = 3600
grid_size_ref = 200 km
```

## 10. Short forecast simulations

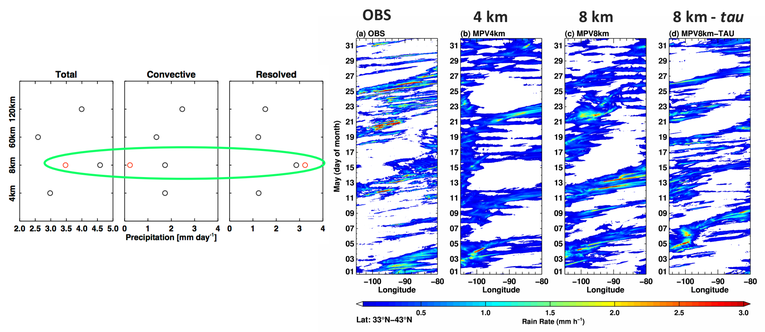
### An MC3E event

- Initialized on May 19 00 UTC
- Some improvements from 60 km to 8 km resolution
- MPAS simulations with CAM5 and WRF physics are comparable



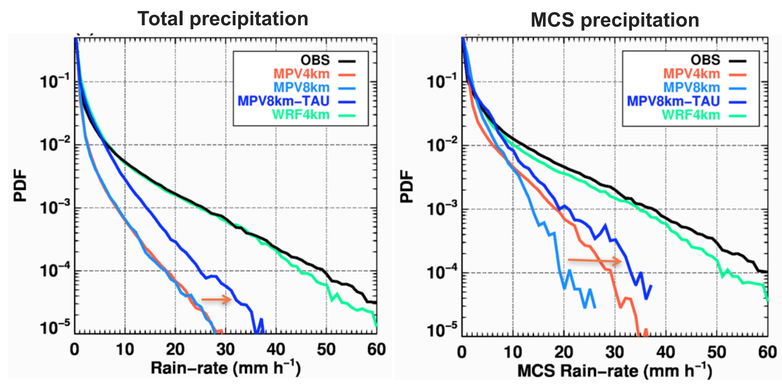

## 11. Impacts of convective time scale

- The simulation with variable *tau*:
  - produced less convective precipitation than the control simulation with a fixed *tau* across resolutions
  - showed small improvements in simulating propagating features




## 12. Large sensitivity of rain rates

- All MPAS simulations produced significantly lower frequency of high rain rates compared to the WRF simulation at 4 km
- MPAS at 8 km resolution with variable *tau* is more skillful compared to simulations with fixed *tau*




## 13. Summary

- Regional convection permitting simulations with WRF are skillful in capturing MCSs and diurnal precipitation in Central US, despite some sensitivity to microphysics parameterizations
- For short forecast simulations, MPAS-CAM5 and MPAS-WRF simulations are comparable, and increasing resolution leads to some improvements
- For seasonal simulations, MPAS-CAM5 shows significant biases in simulating rain rates and MCS propagating features
- Adjusting the convective time scale (*tau*) in the ZM scheme has some positive impacts
- More research is needed to improve scale-awareness in cumulus schemes for convection permitting simulations in global variable resolution models

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