Convection Permitting Modeling of Mesoscale Convective Systems in North America

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Modeling MCSs and their large-scale environment

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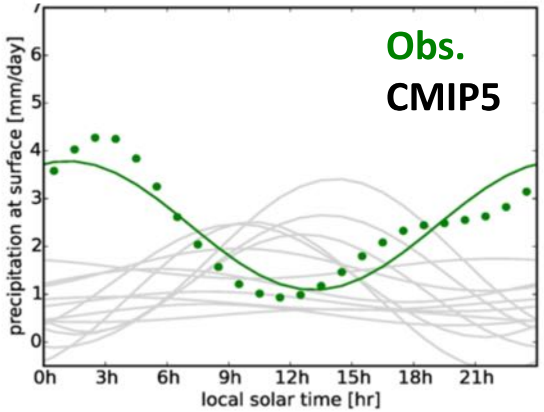
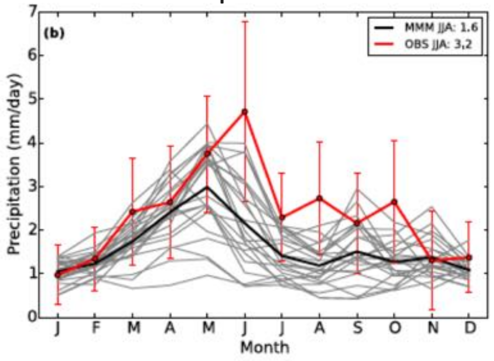
- Most climate models with parameterized convection fail to represent MCSs, as reflected in precipitation biases
- Three modeling approaches with computational requirements within reach:
  - Limited area models
  - Global variable resolution models
  - Multiscale modeling framework (MMF)

Chengzhu Zhang (LLNL)

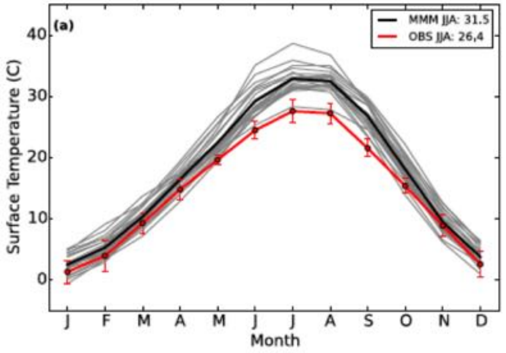
Diurnal cycle of precipitation

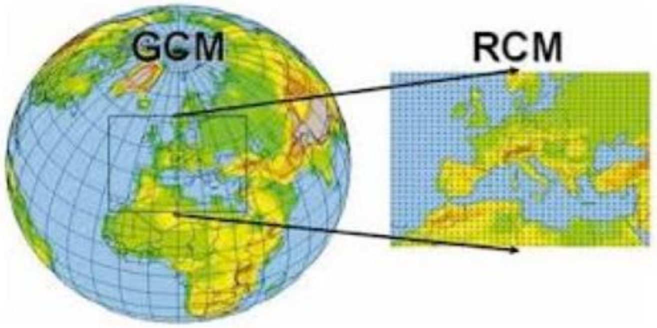


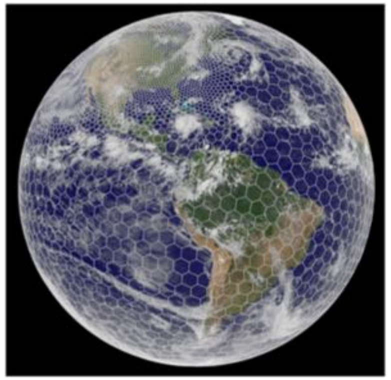
Precipitation

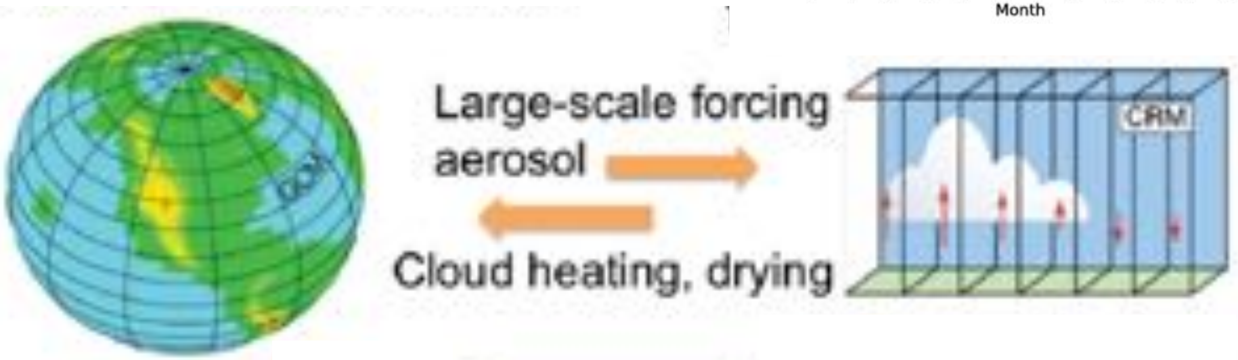


2m Temperature



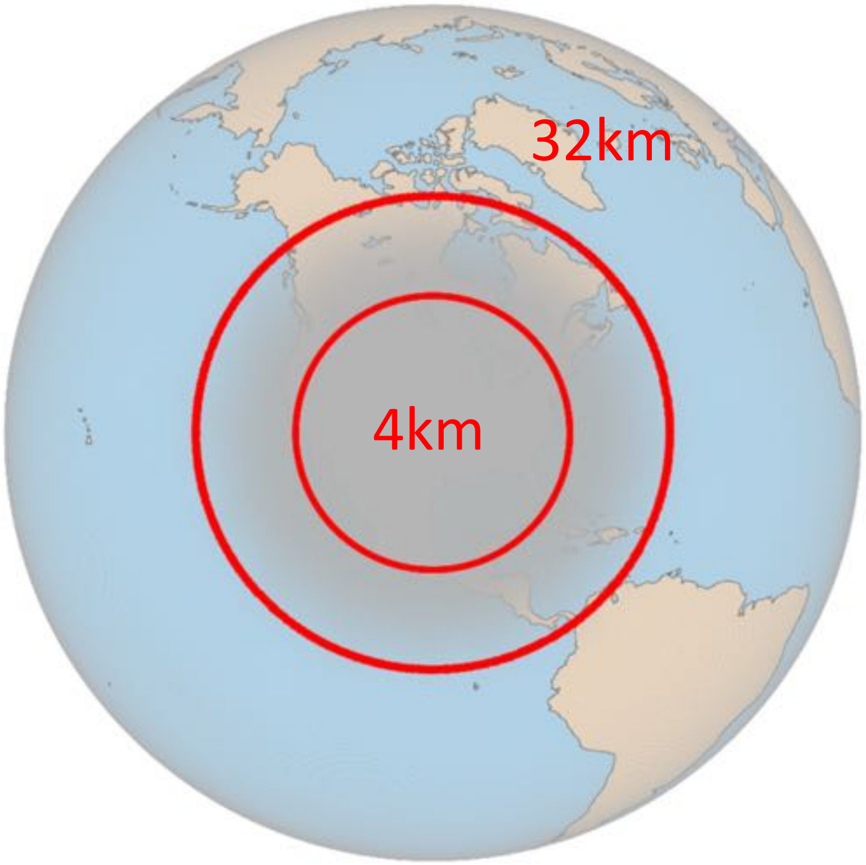






Convection permitting modeling using MPAS

- In a variable resolution domain with a transition across the grey zone, a scale-aware convection parameterization is needed to represent deep convection outside the convection permitting region
- Use initialized hindcasts to compare simulations:
  - Zhang and McFarlane (ZM) – not scale aware
  - Grell-Freitas (GF) – scale aware
  - No convection parameterization (CP)



Numerical experiments

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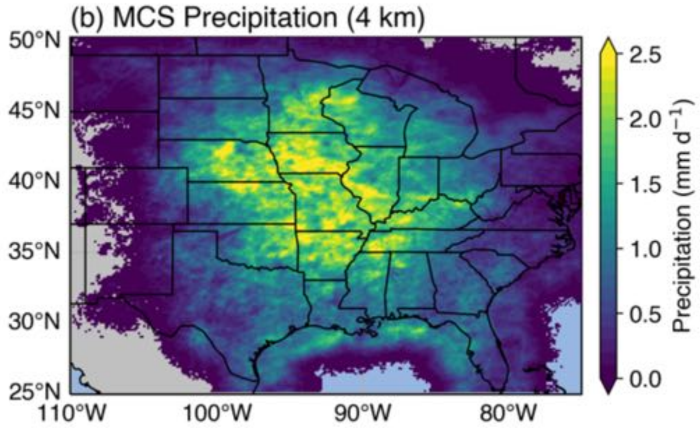
- MPAS with CAM5.4 and CLM4
- Three variable resolution configurations: 25-100 km, 12-46 km, and 4-32 km
- Hindcast simulations: 7 days, with first 2 days removed from analysis of each 5-day non-overlapping segments
- Initial conditions: atmosphere (ERAI), land (from a continuous climate run)
- Simulations: April and August for contrasting spring and summer

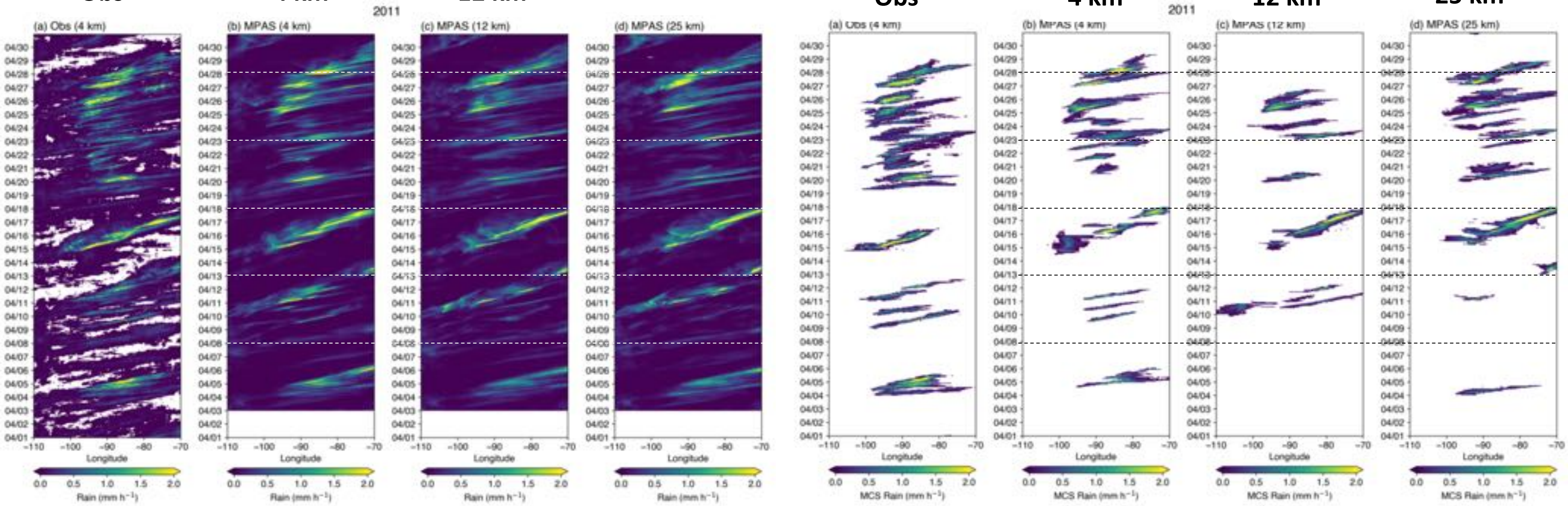


MCSs in April

Large precipitation events and some MCSs embedded within are well captured even at 12 km and 25 km resolution

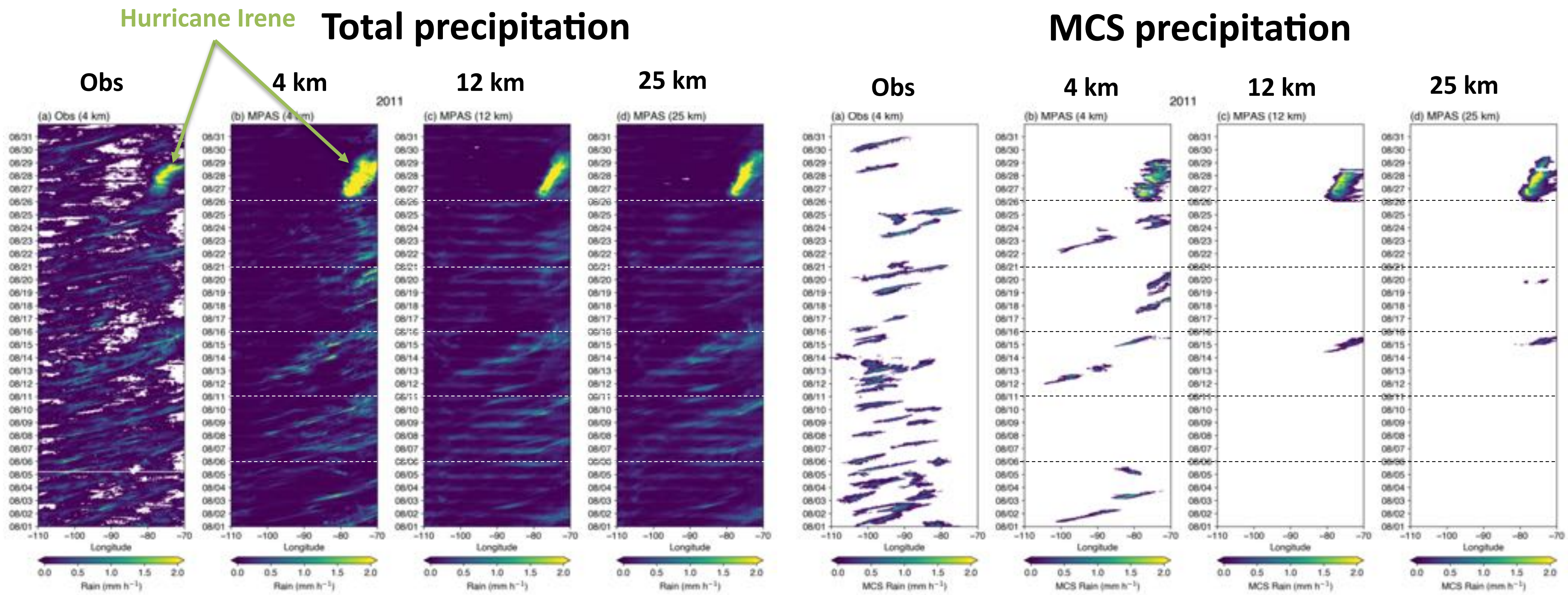
Total precipitation | **MCS precipitation**

Obs | **4 km** | **12 km** | **25 km** | **Obs** | **4 km** | **12 km** | **25 km**



MCSs in August

- MCSs are much weaker in August; simulations at 4 km are significantly better in capturing the propagating events than simulations at 12 km and 25 km resolution



MCSs in August

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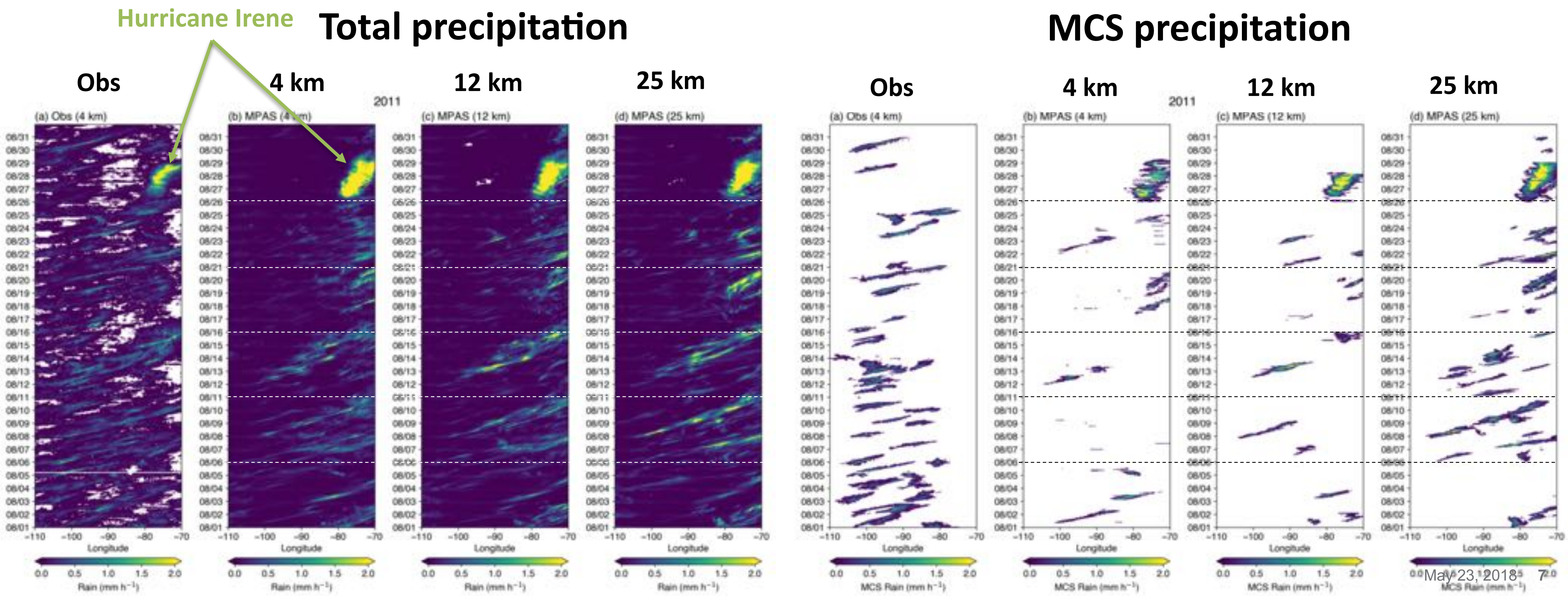
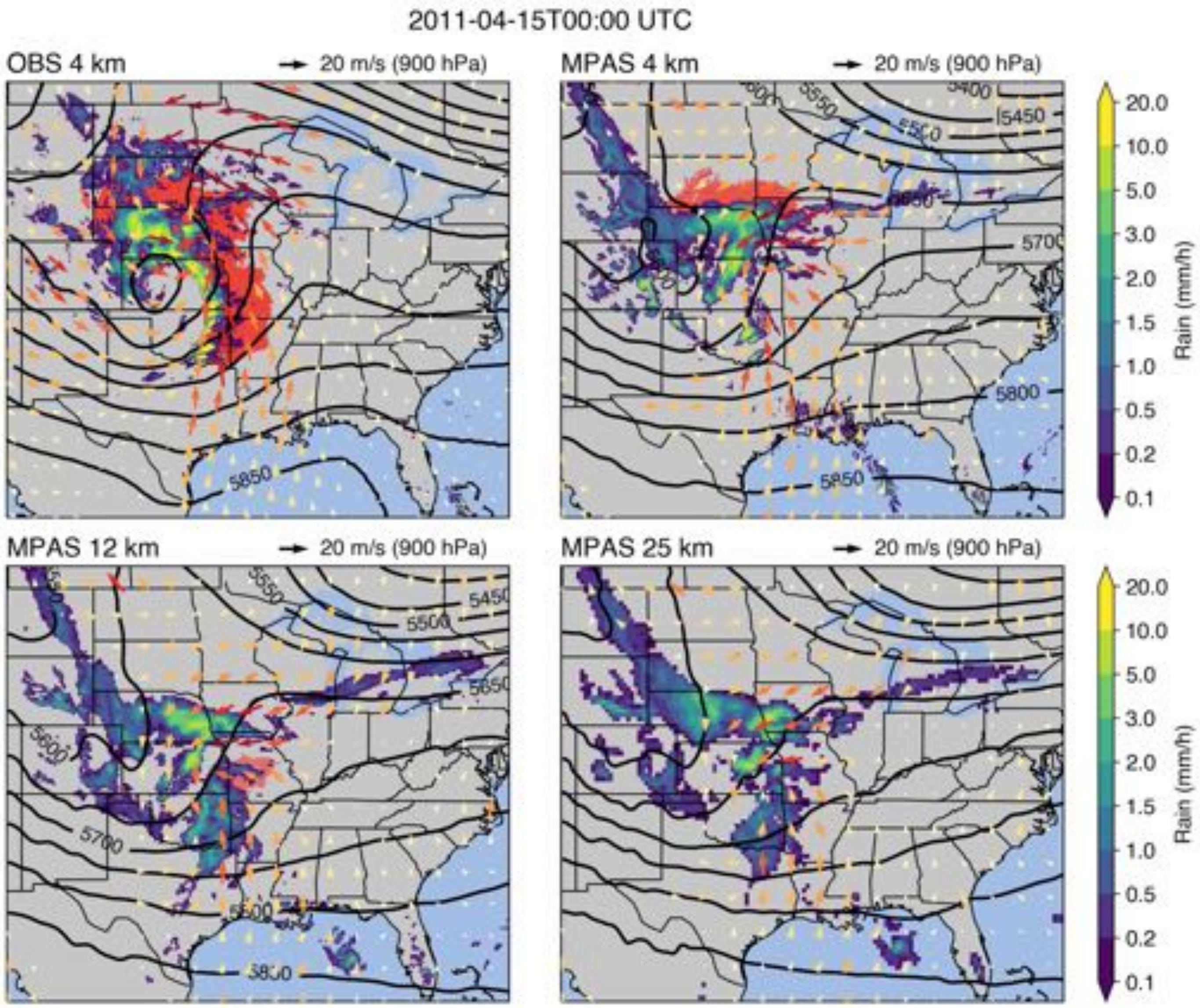
Turning off the convection scheme increases the number of MCSs in the simulations at 12 km and 25 km resolution (MCS detection criteria are relaxed)



An MCS event in April

- Strong synoptic scale forcing associated with baroclinic waves, strong LLJ and moisture supply from the Gulf



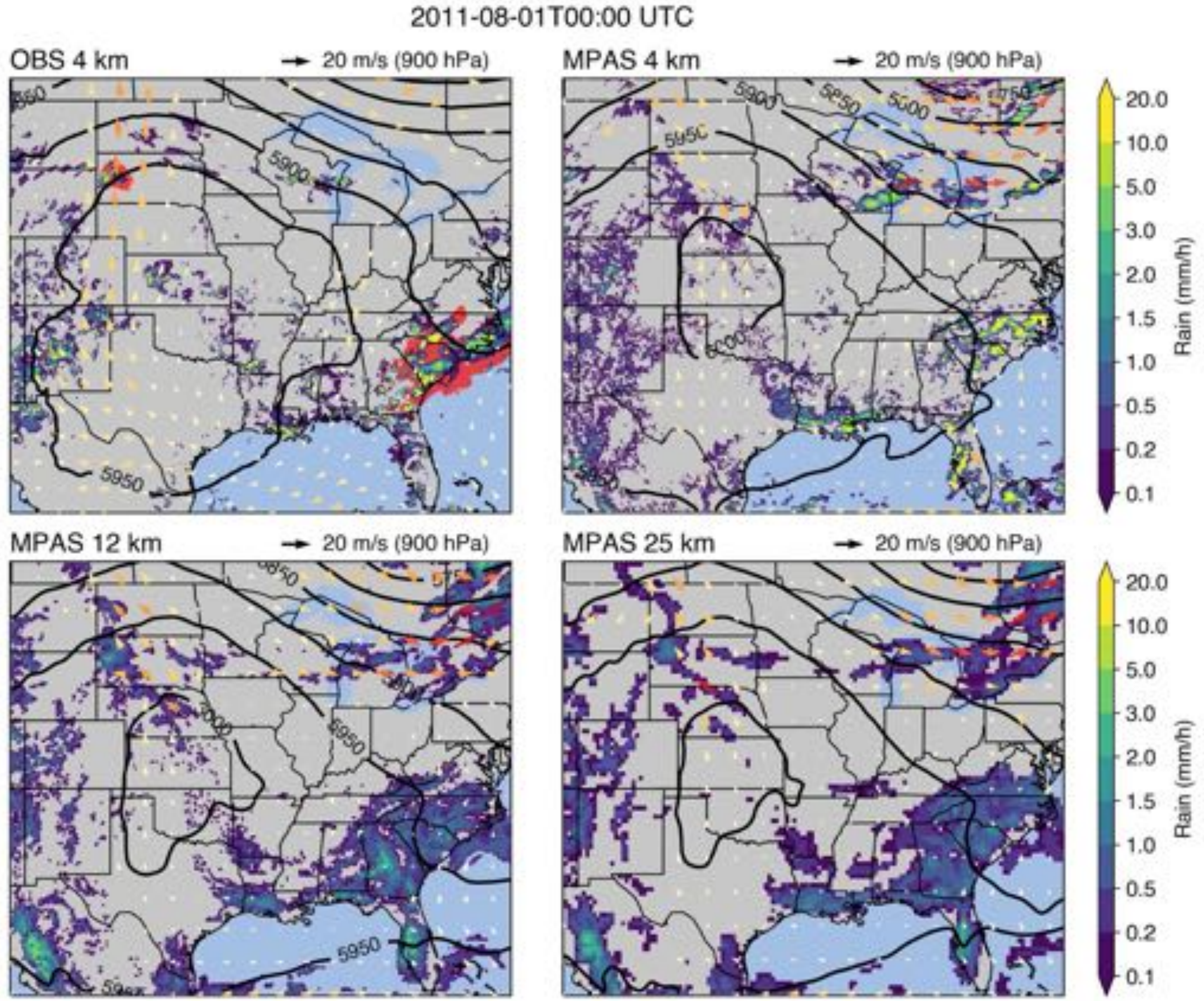
Contour: 500 hPa geopotential
Vector: 900 hPa wind
Red shading: MCS cloud shield
Color shading: precipitation

An MCS event in August

High pressure over the Great Plains

Weaker nocturnal LLJ

Convection initiates ahead of shortwave trough, feeding from LLJ and propagate along the ridge



Contour: 500 hPa geopotential
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Large-scale environment for MCSs

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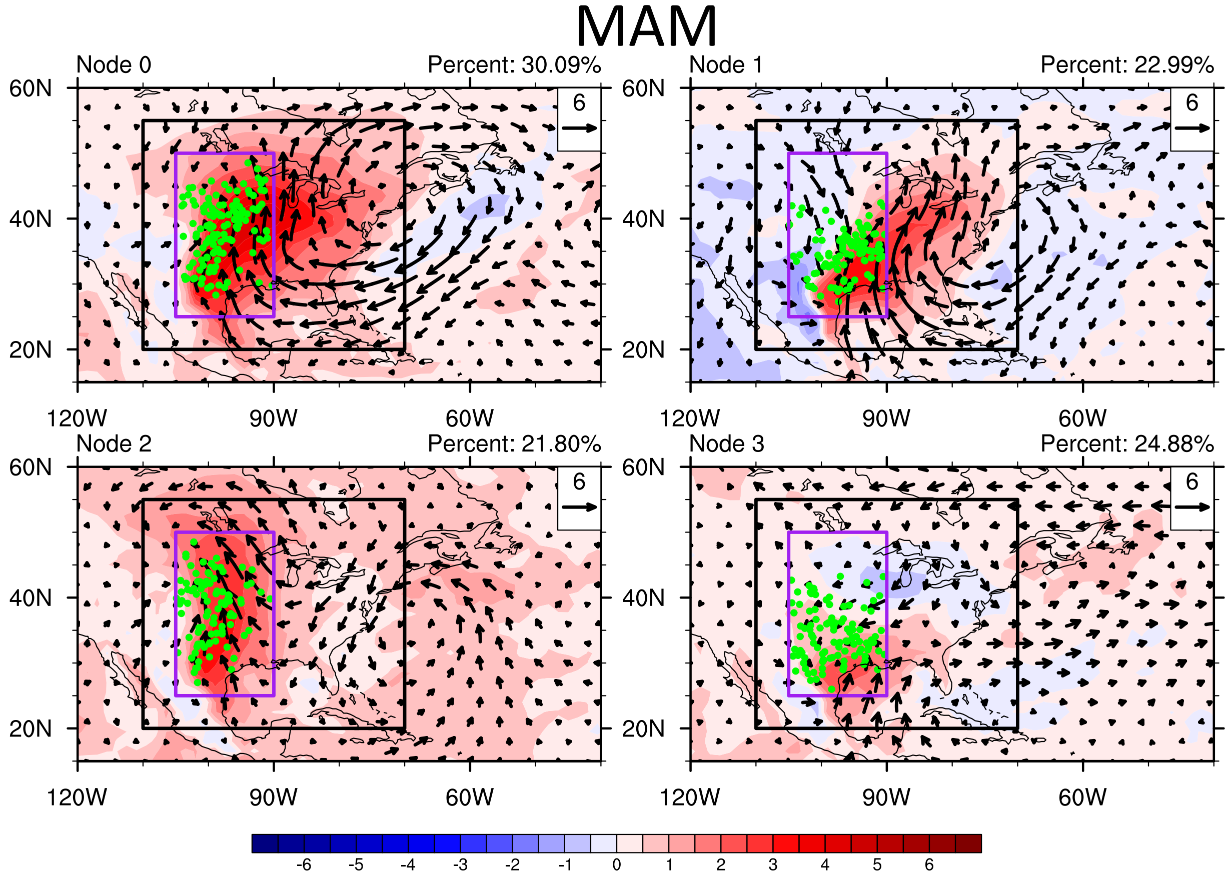
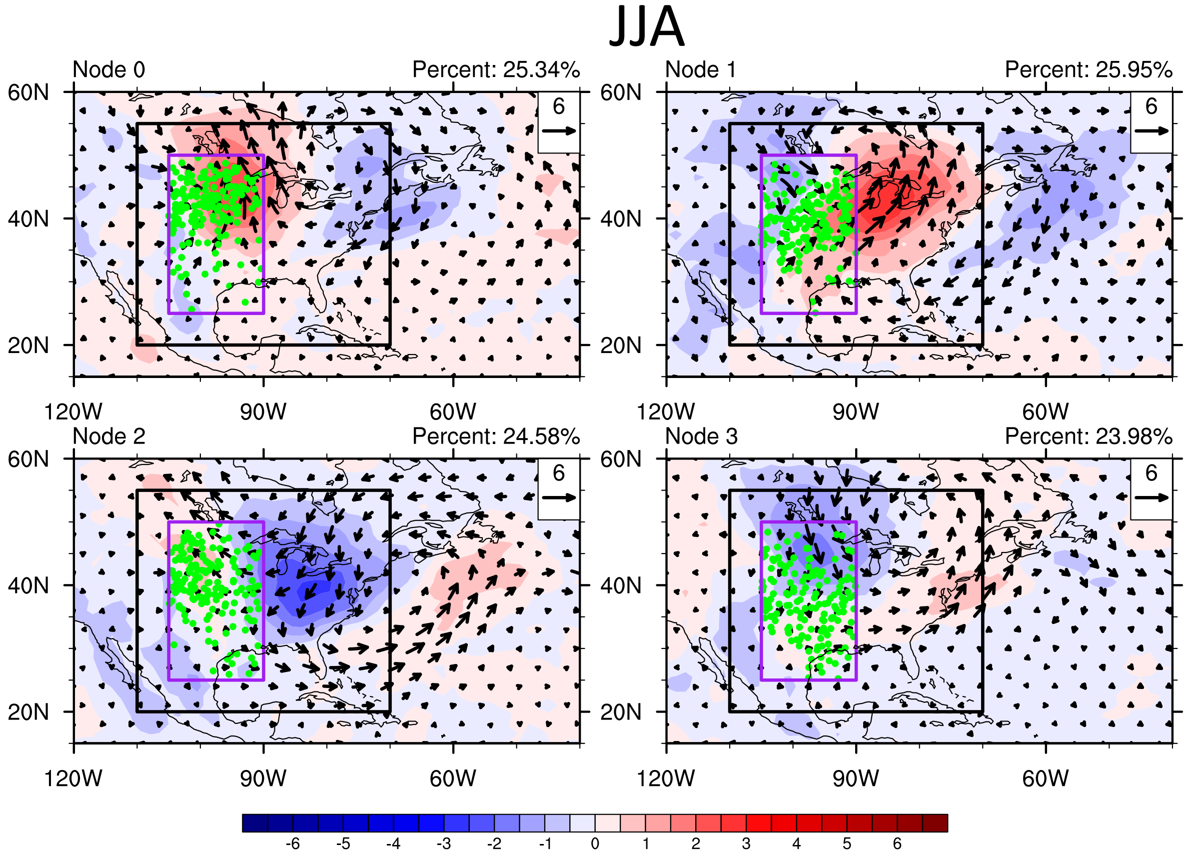
Using self-organizing map (SOM) to determine the dominant large-scale environment of MCSs in ERAI - much weaker large-scale environment for MCSs during JJA than MAM

925 hPa wind and moisture anomaly of four SOM nodes

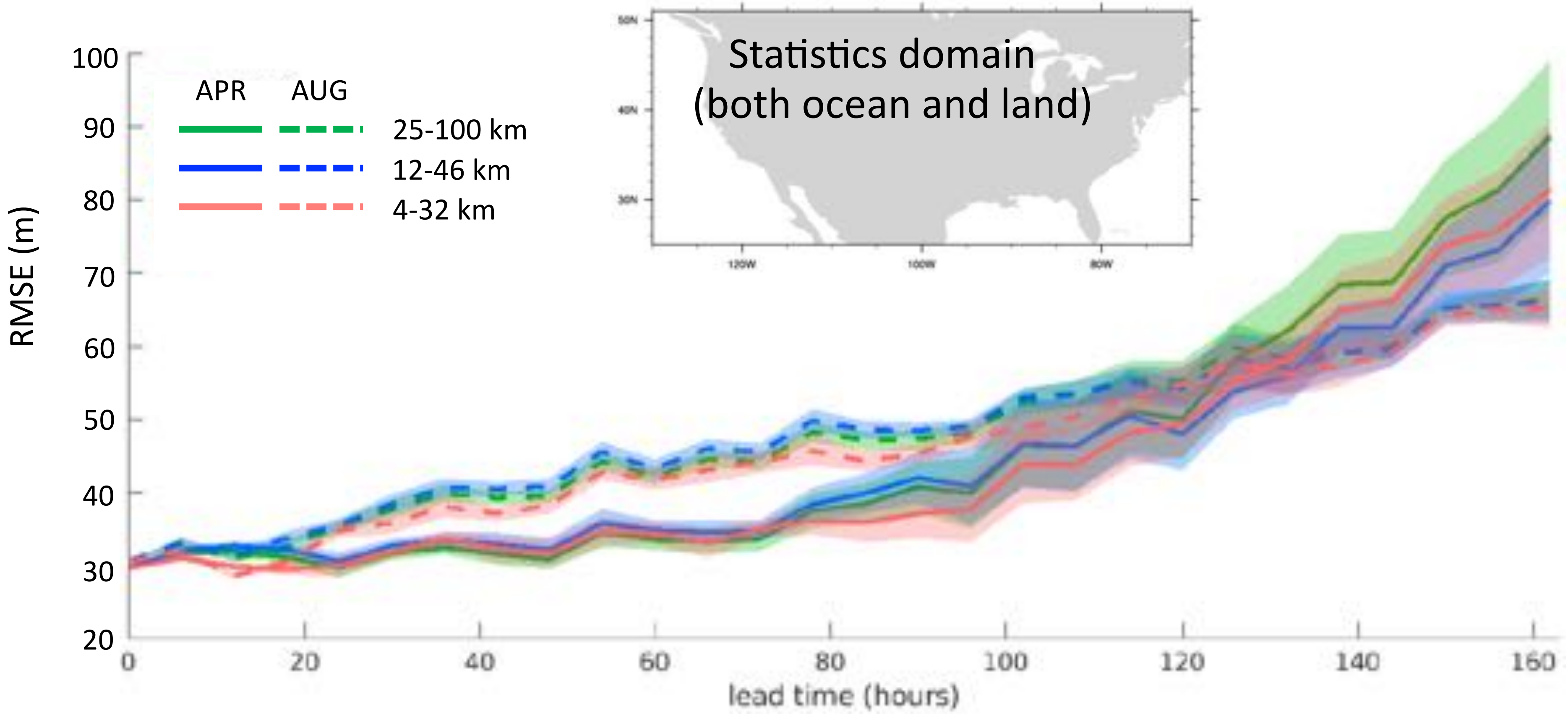




Large-scale environment for MCSs

- Lower predictability of the large-scale environment in August than April for the first 5 days

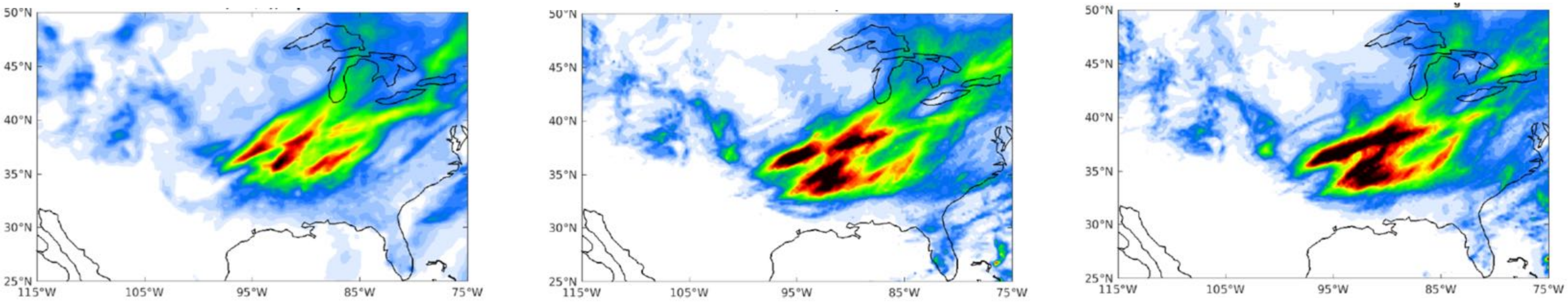
RMSE of 500 hPa height comparing MPAS with ERAI



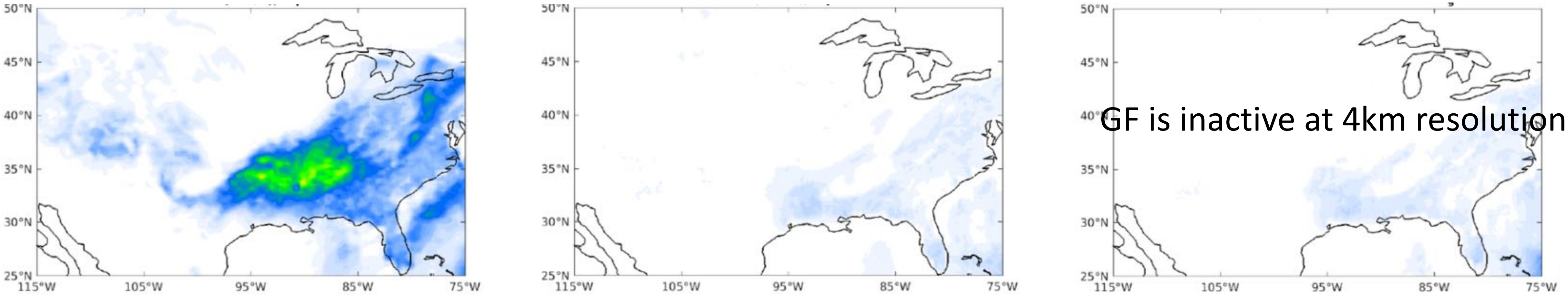
Testing a scale-aware parameterization: Grell-Freitas convection scheme

Total precipitation

30km with ZM scheme | 4-32km without CP | 4-32km with GF scheme



Precipitation produced by shallow convection and CP



Evidence of scale-aware behaviors

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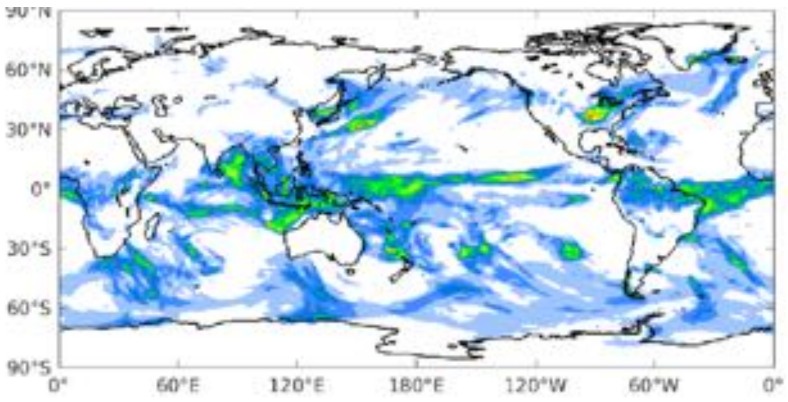
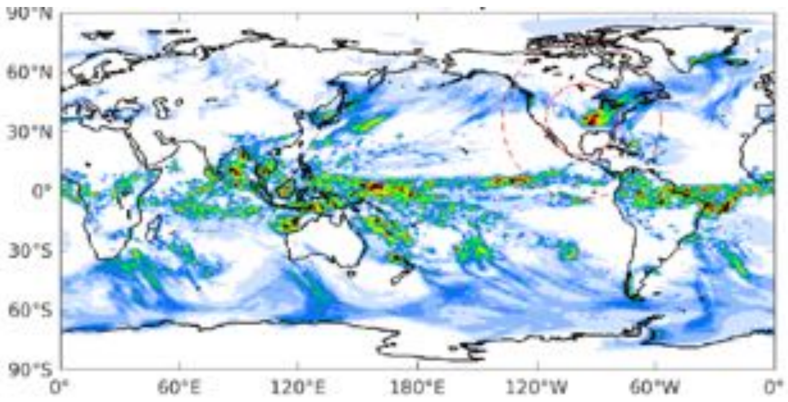
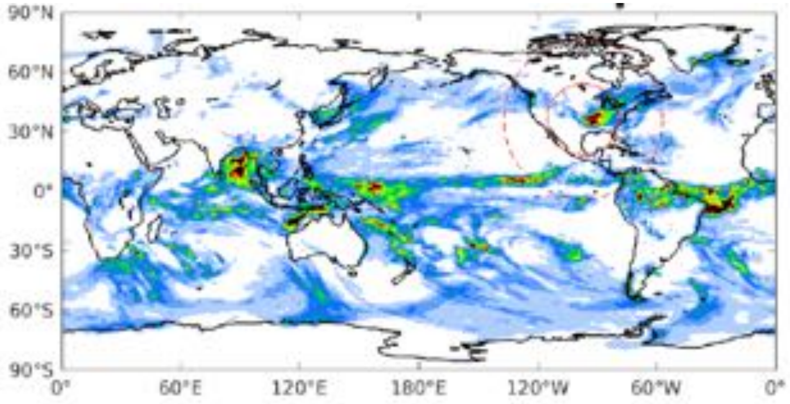
Total precipitation

30km with ZM scheme | 4-32km without CP | 4-32km with GF



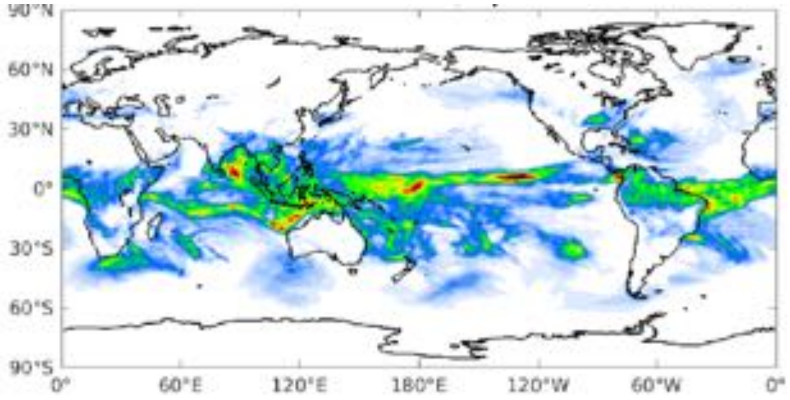


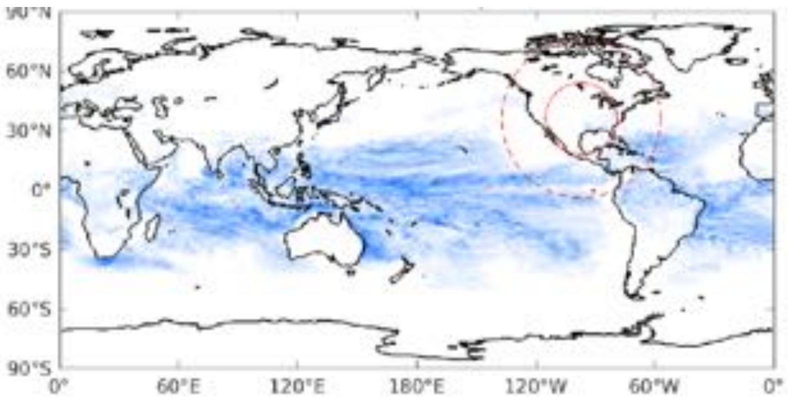


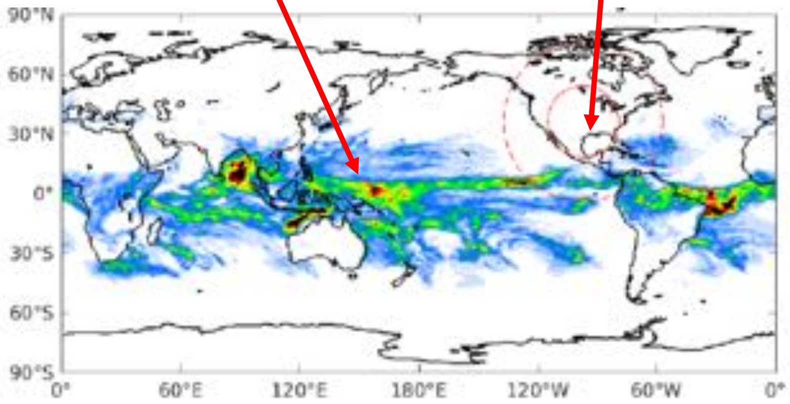
Precipitation produced by shallow convection and CP

GF is active

GF is inactive







Summary

Regional convection permitting modeling is a viable approach for modeling MCS changes, but multiscale interactions are limited by the one-way coupled modeling framework

We are exploring non-hydrostatic global variable resolution models with regional refinement at convection permitting scale for modeling MCSs and their large-scale environment

- MCSs are stronger in spring than summer, supported by stronger synoptic environment – less predictability of MCSs during summer
- Simulations with convective parameterization turned off perform better
- Scale-aware physics are needed for modeling across the grey zone - the GF scheme shows some promises

Continental scale convection permitting regional model reasonably simulates MCS characteristics

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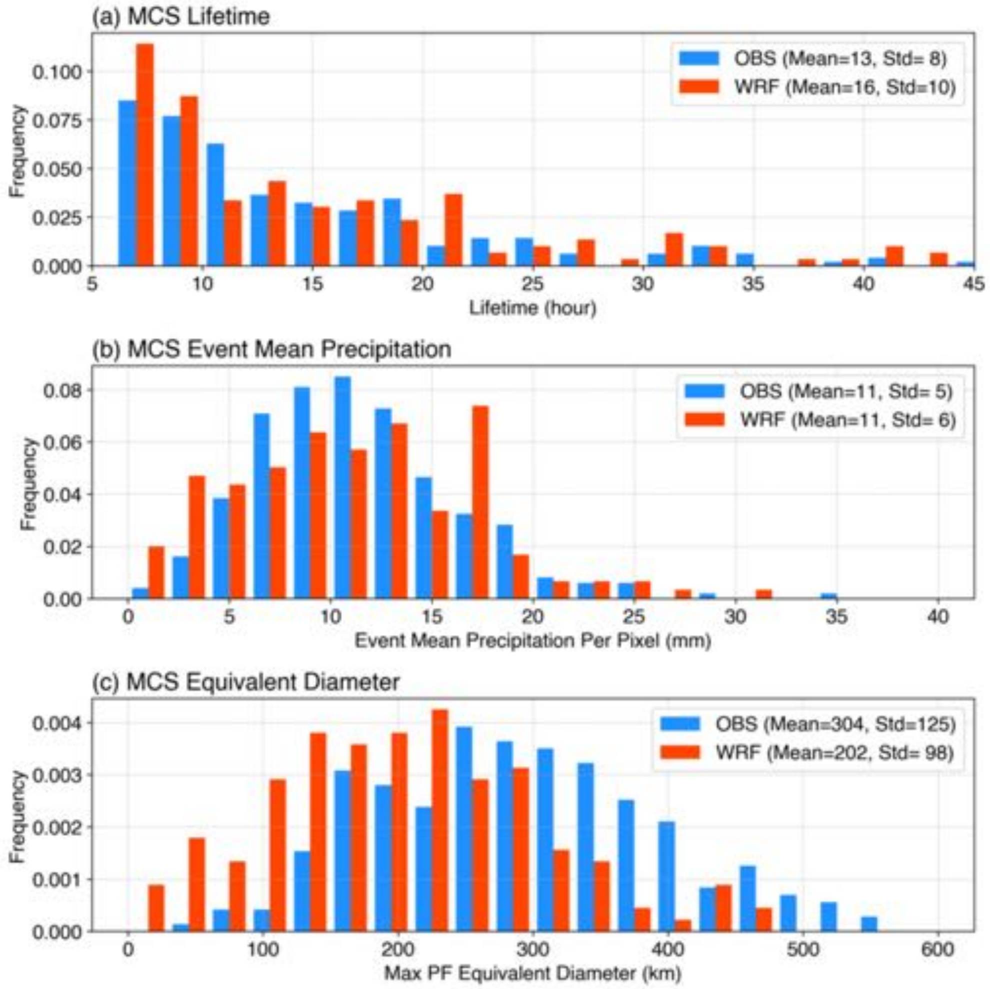
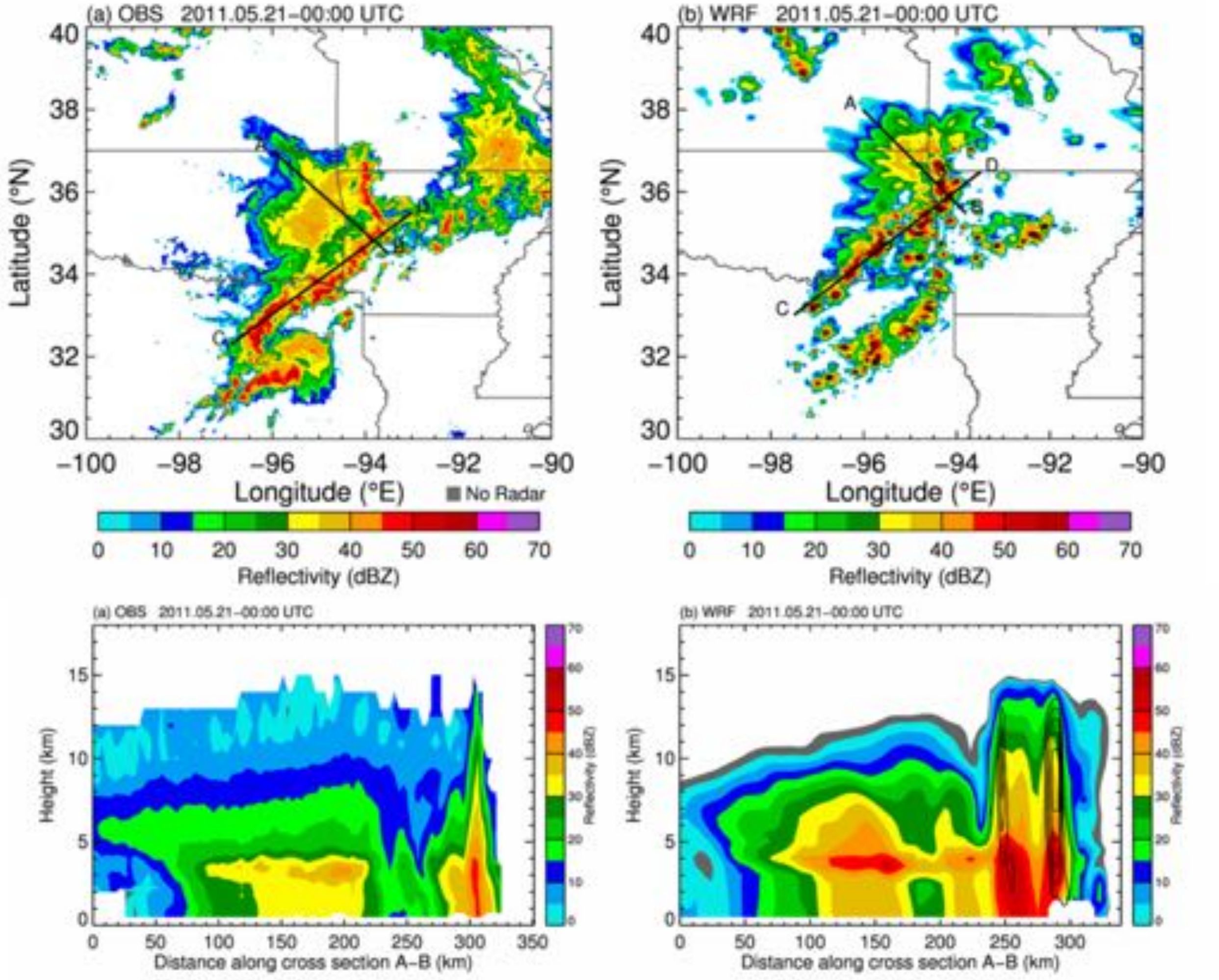
WRF simulations over the US at 4 km grid spacing without cumulus parameterization (CP)



(Yang et al. 2017 JGR)

Observed

Simulated



Environment that supports long-lived MCSs

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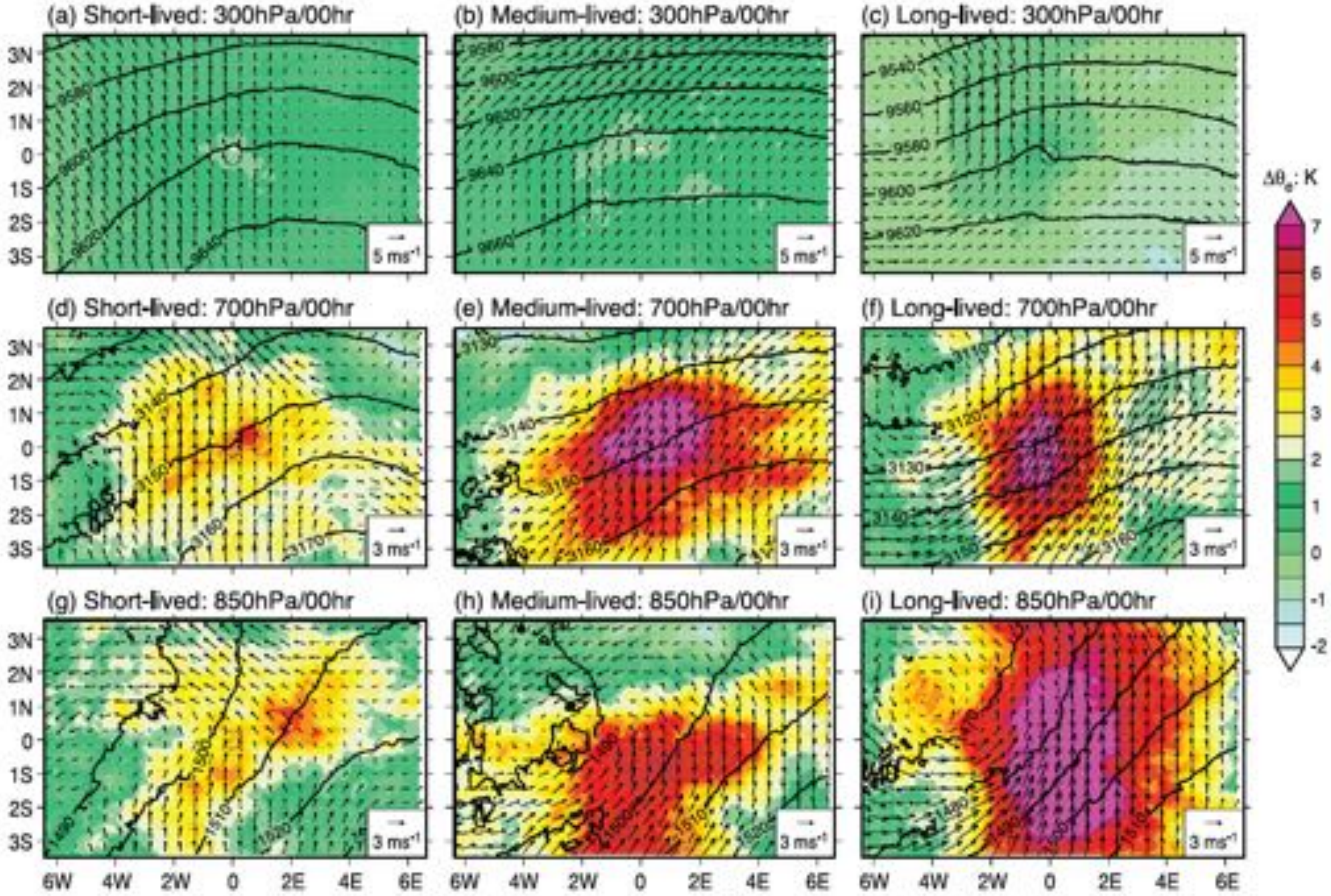
The environmental properties favoring MCSs at the time of storm initiation are most prominent for the MCSs that persist for the longest times

MCSs reaching lifetimes of 9 h or more occur closer to the approaching trough than shorter-lived MCSs



Positive feedback from long-lived MCSs to the environment support their longevity

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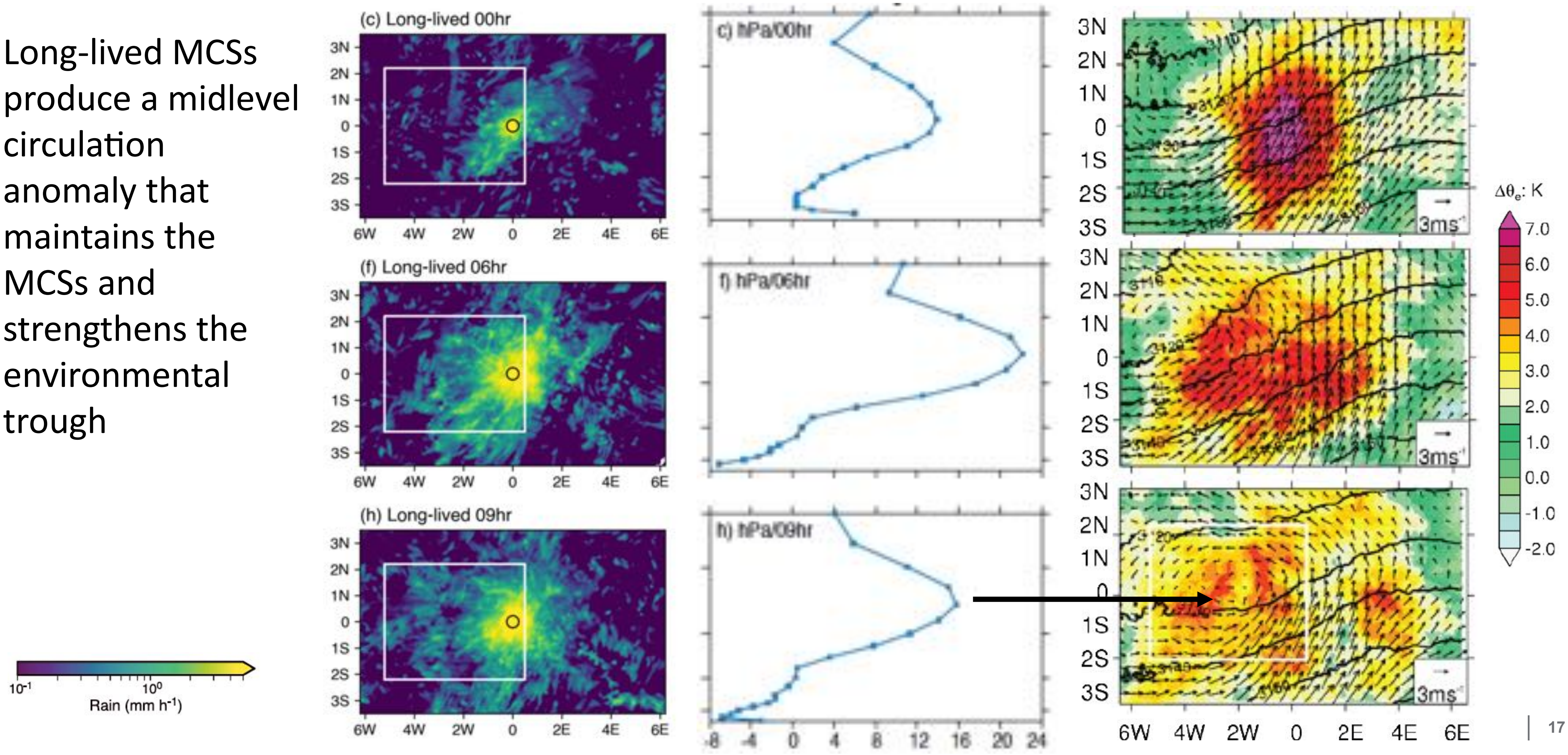
Long-lived MCSs produce a midlevel circulation anomaly that maintains the MCSs and strengthens the environmental trough



Sensitivity to microphysics parameterizations and implications for MCS lifetime and precipitation

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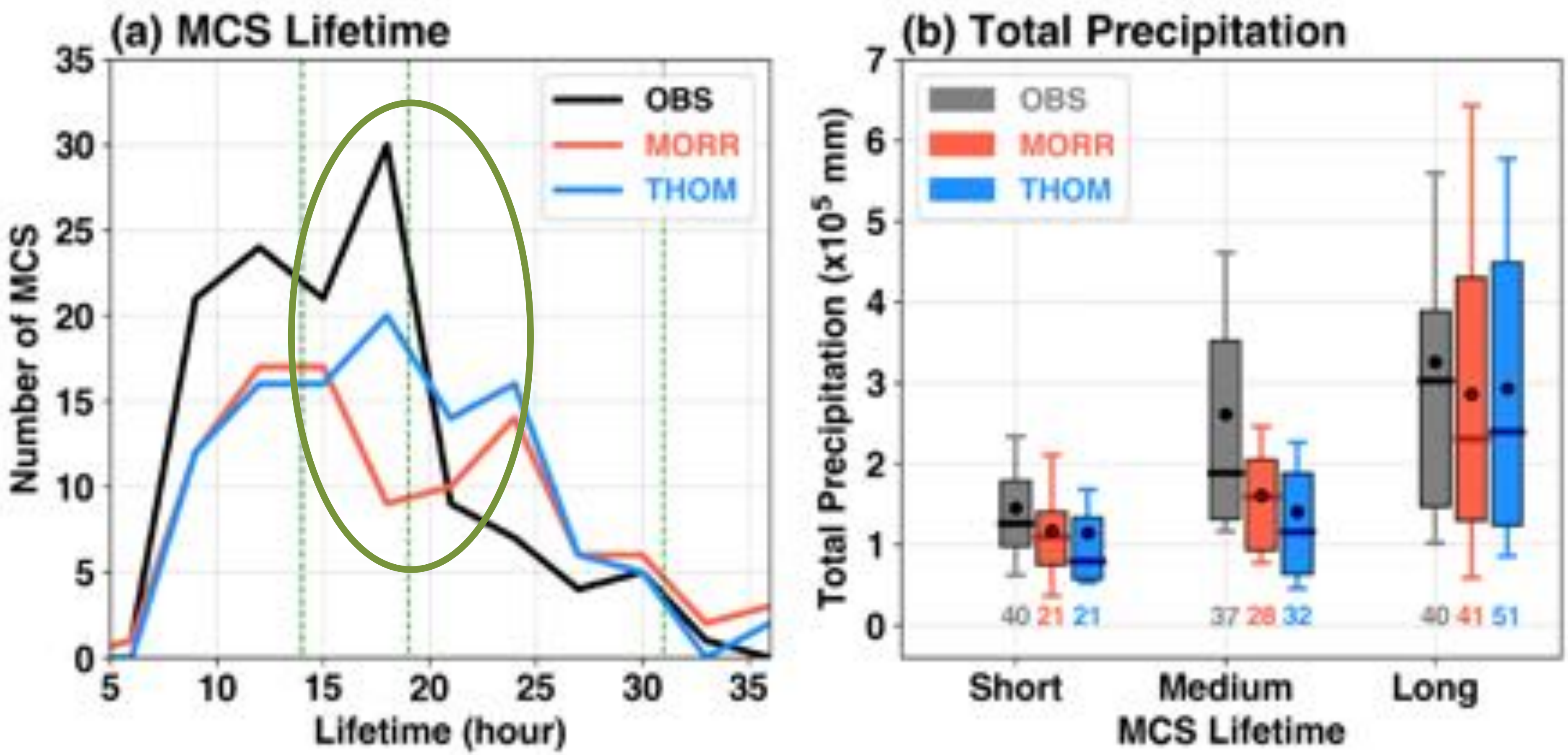
Through impacts on diabatic heating, cloud microphysics parameterizations have important effects on cloud macrophysical properties such as MCS lifetime and precipitation



To use or not to use convection scheme?

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Turning off the convection scheme increases the number of MCSs in the simulations at 12 km and 25 km resolution