Improvements of WRF Simulation Skills of Southeast United States Summer Rainfall: Focus on Physical Parameterization and Horizontal Resolution

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Motivation

Accurate regional climate simulation is important for the Southeast US (SE US)

- SE US is one of the fastest developing regions in the nation, and the warm season precipitation becomes increasingly important.

- Accurate regional climate simulations for the SE US are vital to predicting the seasonal rainfall and creating effective climate policy.

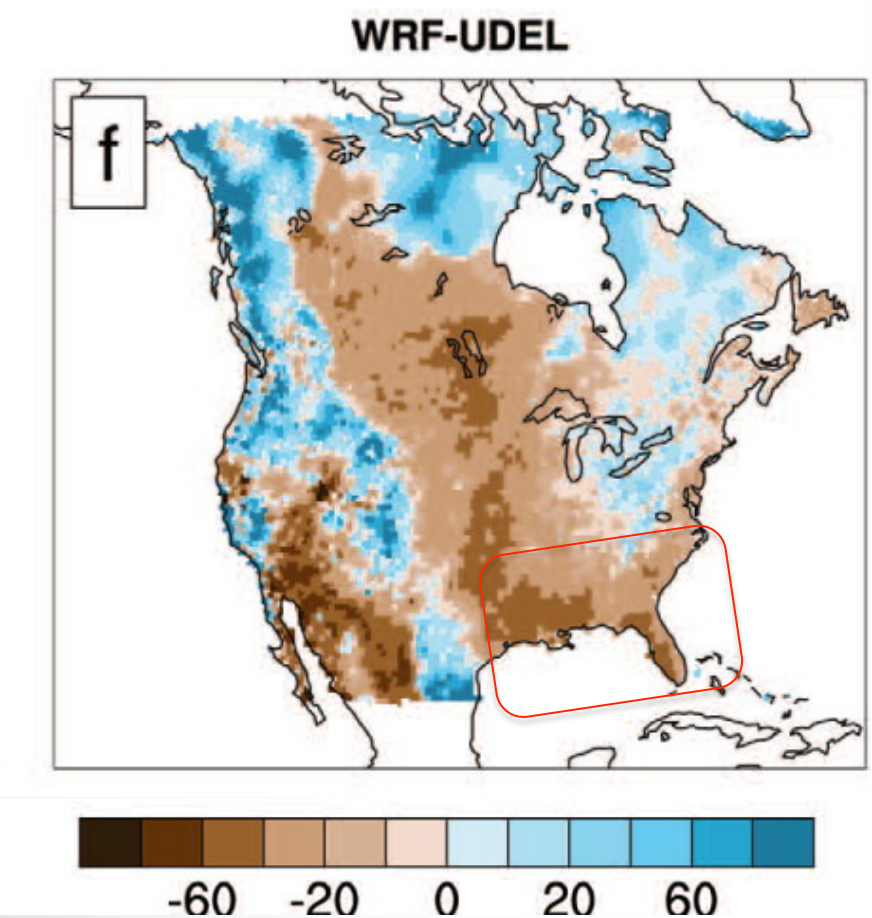
2007 SE US Drought

http://www.cbsnews.com

Motivation

However, simulation skills for SE US summer rainfall are low.

NARCCAP: North American Regional Climate Change Assessment Program



Q: What hampered WRF simulation skill of SE US summer rainfall?
How to make improvement?

Percentage of WRF simulation JJA rainfall bias compared to observation (Mearns et al. 2012, BAMS: 1337-1362)

Objectives

Improve WRF skills in simulating SE US summer rainfall

- Lateral Boundary Condition (LBC)
  - North Atlantic Subtropical High (NASH) circulation dynamically contributes to the WRF simulation skill in SE US summer precipitation (Poster Presentation P30)

✓ Physical Parameterization Schemes
  - How sensitive is the simulation to physics schemes?
  - Why some schemes outperform some others?

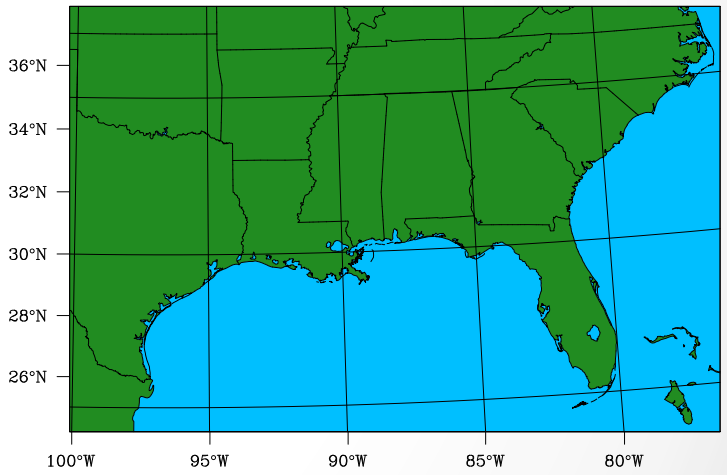
✓ Horizontal Resolutions
  - Can convection resolving models improve the simulation skills?

What are the physical mechanisms?

Influence of Physical Parameterization: Sensitivity Experiment

- ✓ ***WRF ARW version 3.4***
- ✓ ***Horizontal Resolution:*** 15-km
- ✓ ***LBC***: CFSR (6-hr)
- ✓ ***Land Surface Model:*** Noah
- ✓ ***Physics Schemes(Control Exp.):***
  - Micro Physics: Thomposon
  - Cumulus: BMJ
  - Shortwave: Dudhia
  - Longwave: RRTM
  - PBL: YSU
- ✓ ***SST update:*** True

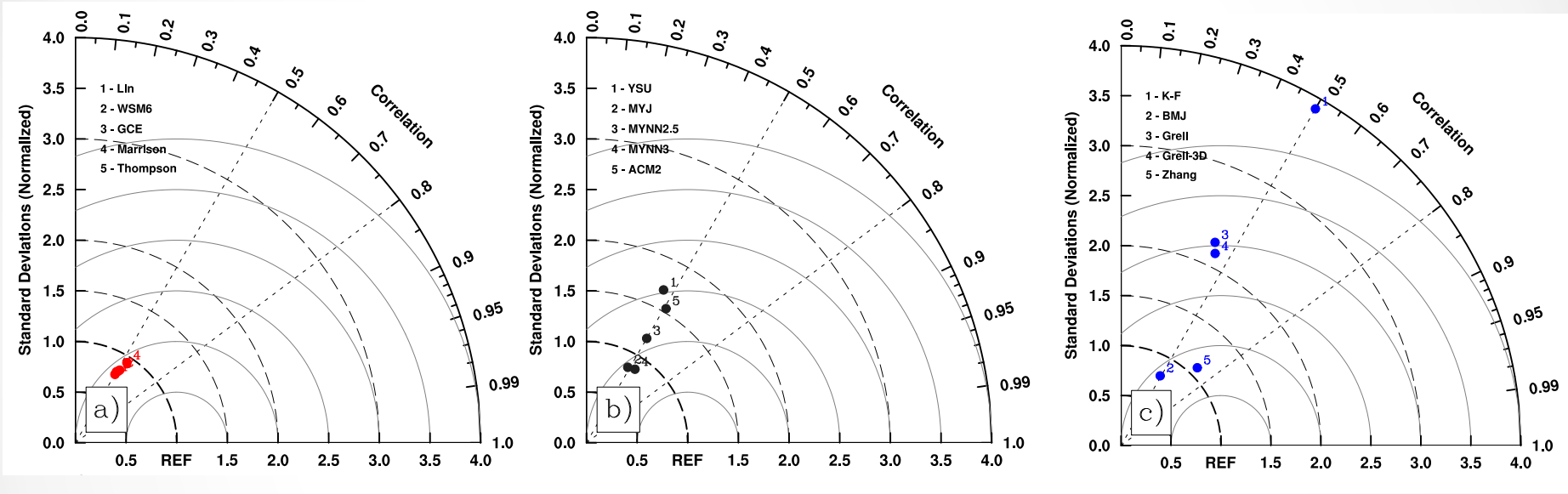
Experiment domain: SE US



Experiment Case: Aug. 01-Aug.15, 2009
Initialize on Jul.27, 2009; simulations for first 5 days were discarded as spin-up

Sensitivity to Physical Parameterizations

- **mp_physics**
- **bl_pbl_physics**
- **cu_physics**



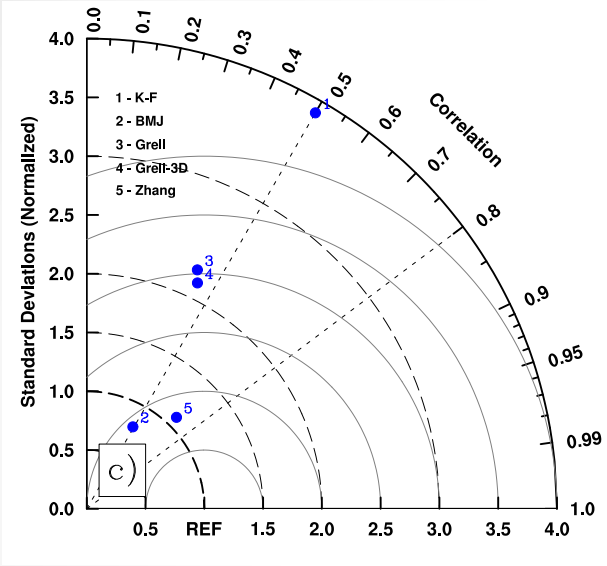
SE US summer precipitation:

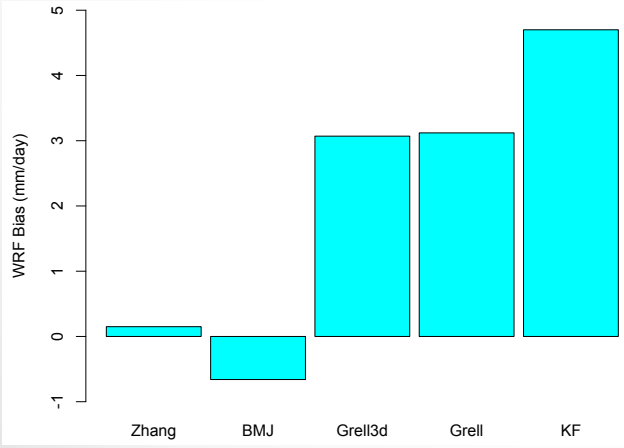
Insensitive to mp_physics

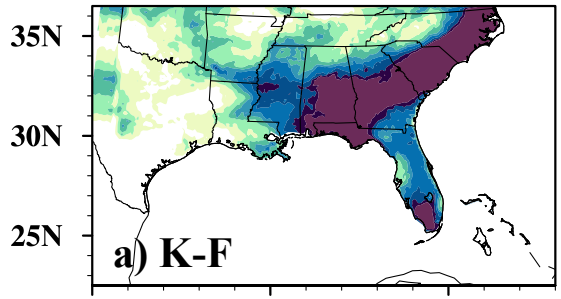
Sensitive to cu_physics

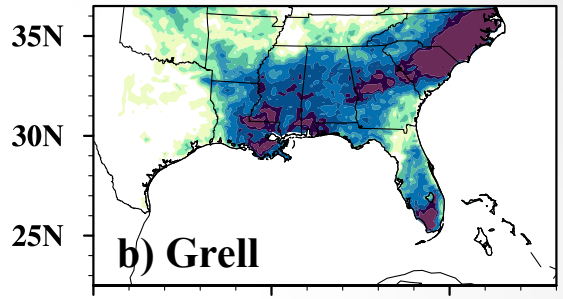
Less Sensitive to bl_pbl_physics

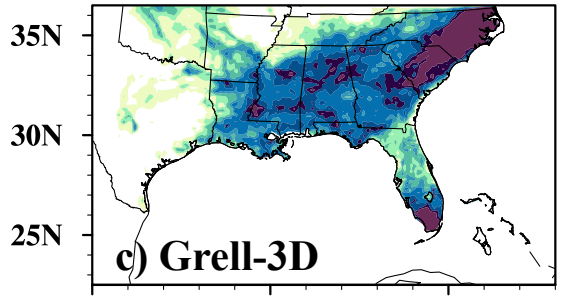
Uncertainty: Caused by cu_physics

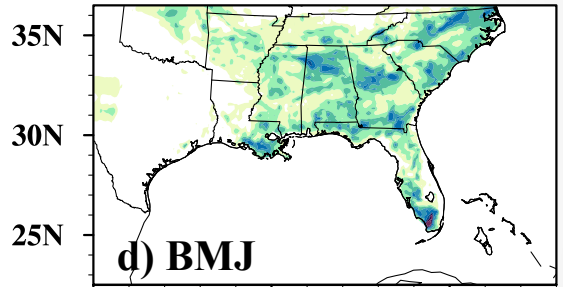


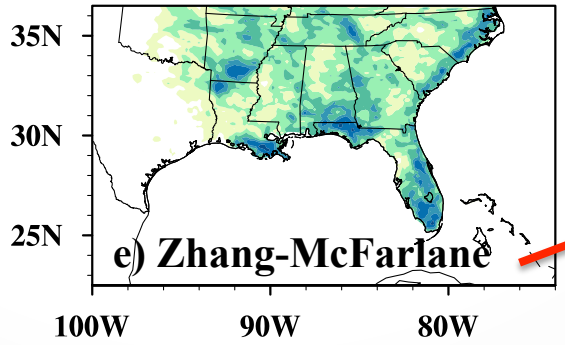


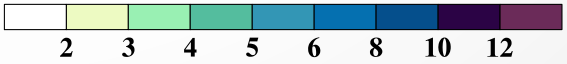










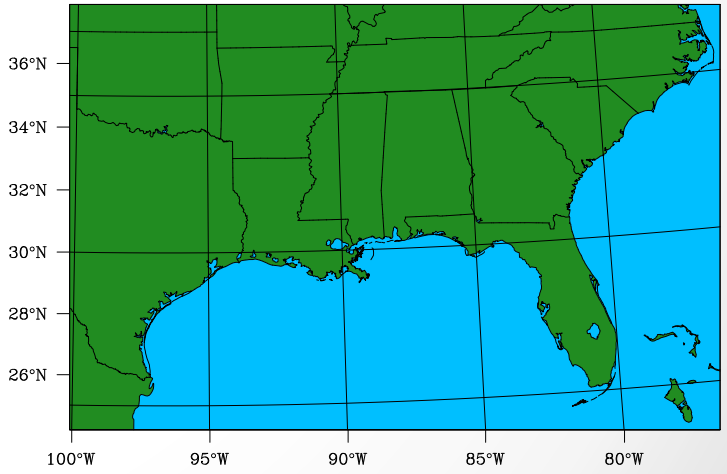


Production Run

Influence of Physical Parameterization: 10-yr Production Run

- ✓ ***Horizontal Resolution:*** 15-km
- ✓ ***LBC***: CFSR (6-hr)
- ✓ ***Land Surface Model*:** Noah
- ✓ ***Physics Schemes(Control Exp.):***
- MicroPhysics: Lin
- Cumulus: BMJ/Zhang-McFarlane
- Shortwave: Dudhia
- Longwave: RRTM
- PBL: MYNN3
- ✓ ***SST update*:** True

Experiment domain: SE US



Experiment Period: 2001-2010 summer

Initialize on May.01; simulations for the first month were discarded as spin-up.

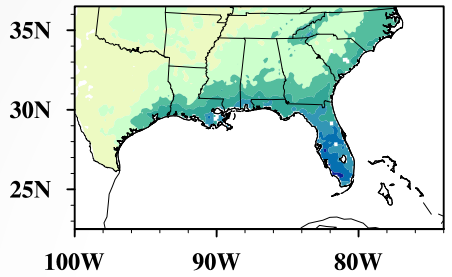
WRF 10-yr Production Run (2001-2010)

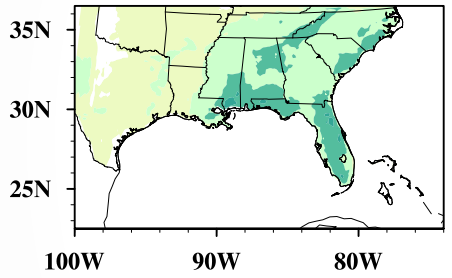
The Zhang-McFarlane scheme well simulates the observed SE US summer rainfall.

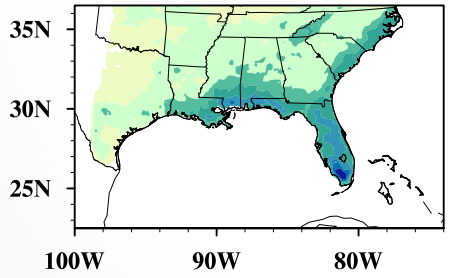
Observation

BMJ

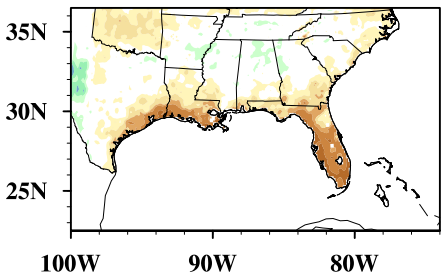
Zhang

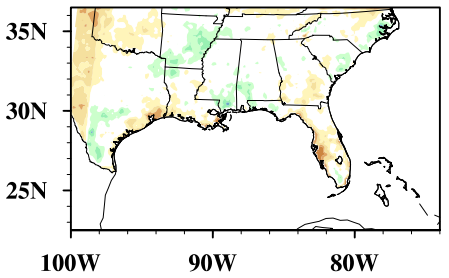




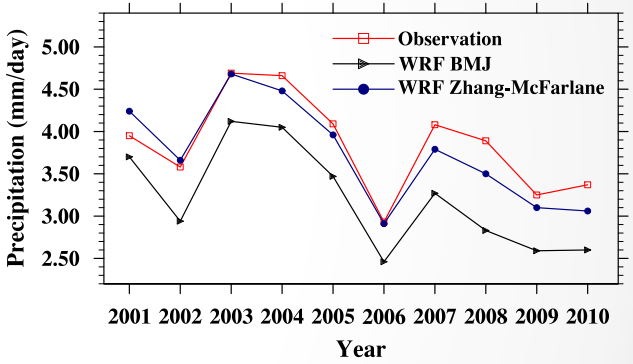


WRF Bias





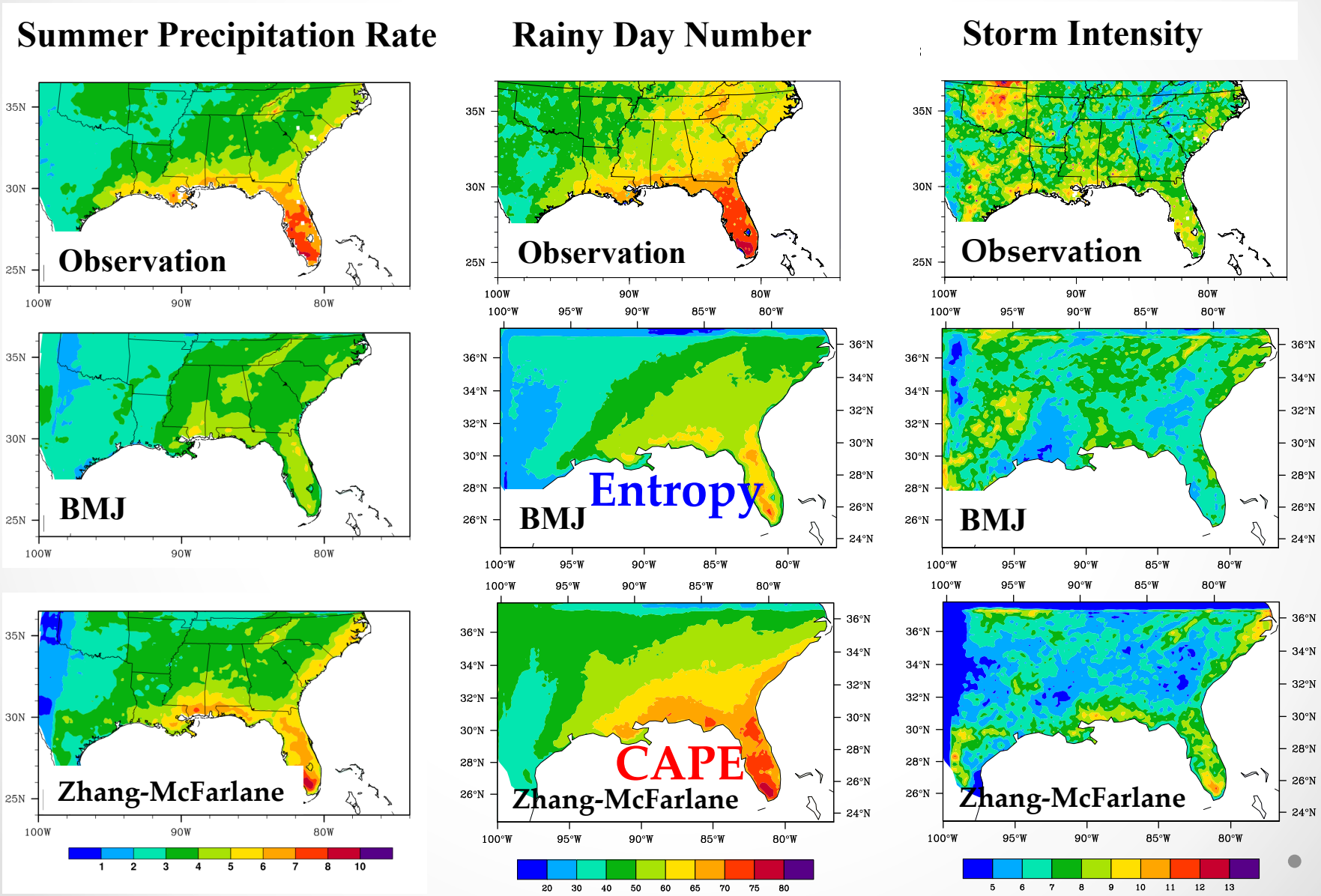
Interannual Variation



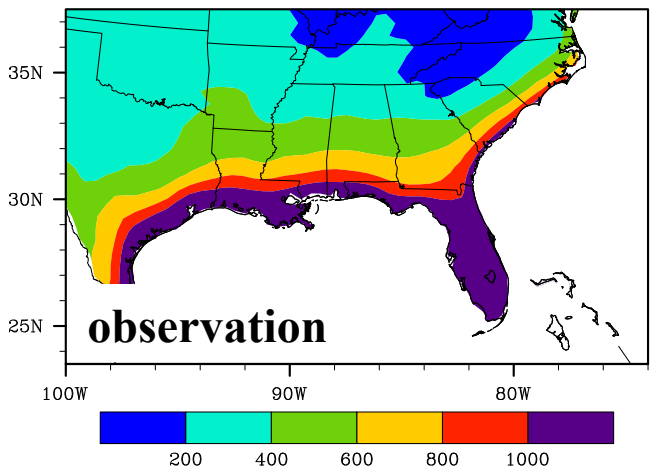
Q: Why Zhang-McFarlane scheme performs better?

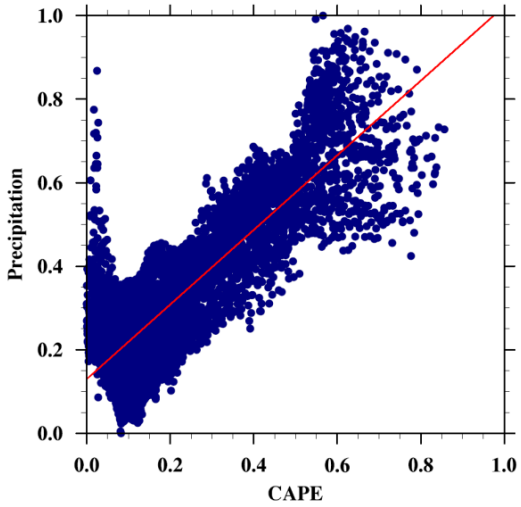
	Pattern Cor.	RMSE	bias
Zhang	0.87	0.62	-0.12
BMJ	0.69	1.07	-0.66

Importance of Rainfall Triggering

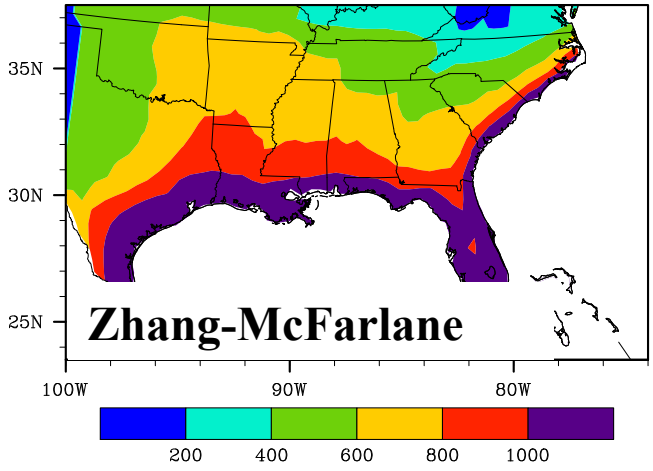


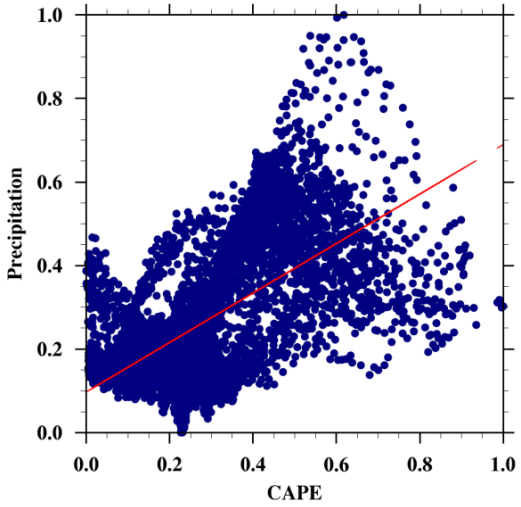
CAPE-Rainfall Relationship in the SE US





Over the SE US, CAPE and rainfall has a positive relationship.





This positive "CAPE-rainfall" relationship is implicit in Zhang-McFarlane scheme.

CAPE: Convective Available Potential Energy

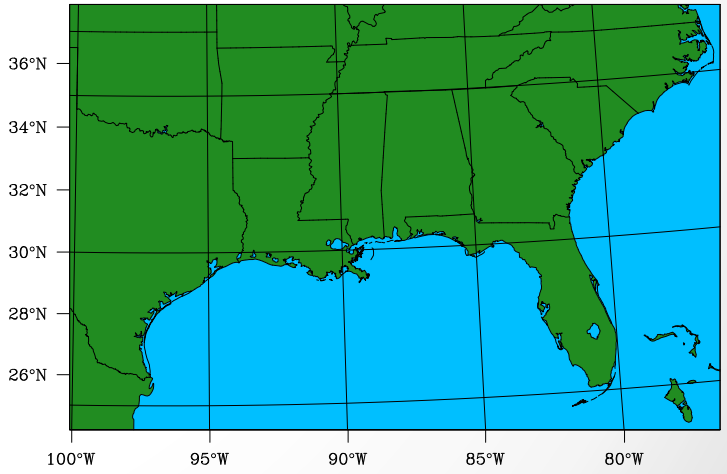
Summary 1: Physical Parameterization

- WRF simulation skills of SE US summer rainfall is impacted by physical parameterization schemes:
  - WRF simulation is **insensitive** to mp_physics
  - WRF simulation is **very sensitive** to cu_physics
  - WRF simulation is **less sensitive** to pbl_physics
- Among the 5 tested cu_physics schemes, ***Zhang-McFarlane scheme*** outperforms the other for SE US summer rainfall
  - Rainfall triggering is more realistic in Zhang-McFarlane scheme
  - The Zhang-McFarlane scheme captures the **positive "CAPE-precipitation" relationship** over the SE US, and thus results in higher skills

Influence of Horizontal Resolution: 3-km Convection Resolving Simulation

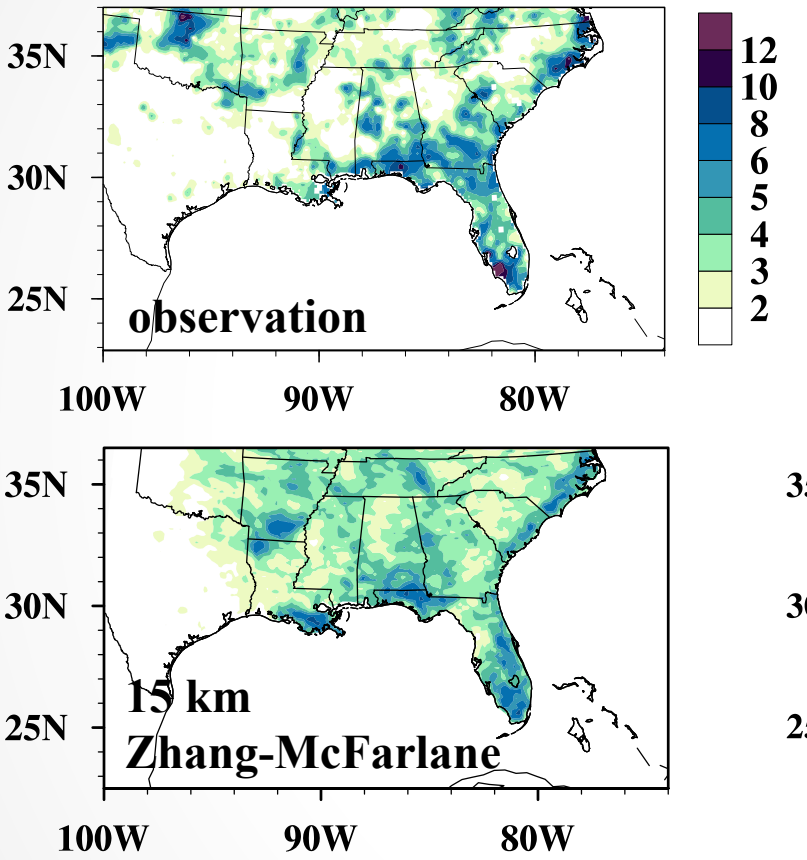
- ✓ ***Horizontal Resolution:*** 3-km
- ✓ ***LBC***: CFSR (6-hr)
- ✓ ***Land Surface Model*:** Noah
- ✓ ***Physics Schemes(Control Exp.):***
- MicroPhysics: Lin
- Cumulus: No
- Shortwave: Dudhia
- Longwave: RRTM
- PBL: MYNN3
- ✓ ***SST update*:** True

Experiment domain: SE US



Experiment Case: Aug. 01-Aug.15, 2009
Initialize on Jul.27, 2009; first 5 days discarded for spin-up

Cloud Resolving Simulation: No Improvement



- *The 3-km simulation does not show improved skills compared with 15-km Zhang-McFarlane simulation.*

	Pattern Cor.	RMSE
3km no cu_physics	0.43	2.38
15km Zhang-McFarlane	0.77	1.32

Conclusions

- WRF simulation of SE US summer rainfall is highly sensitive to the choice of cumulus schemes, in which the modeling of rainfall triggering processes is a key.
- Due to the implicit positive "CAPE-rainfall" relationship, the Zhang-McFarlane scheme reasonably simulates SE US rainfall triggering processes and results in a higher simulation skill.
- Compared with the 15-km Zhang-McFarlane simulation, the 3-km convection resolving simulation does not show obvious advantages.

In conclusion, our study suggests that selecting an optimal cumulus scheme is more effective to improve WRF simulation of SE US summer rainfall than merely increasing horizontal resolutions.

Thank You!

Q&A

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