How well can Kilometer -Scale Models Capture Recent Intense Precipitation Events?

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Photo by @KenGeiger

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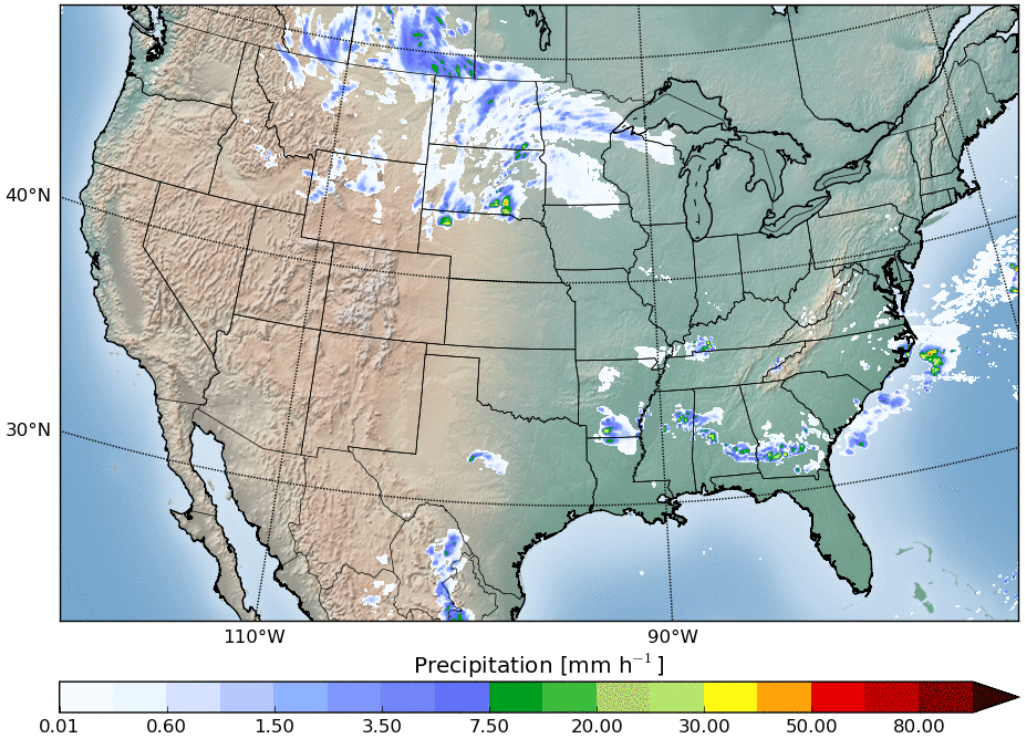
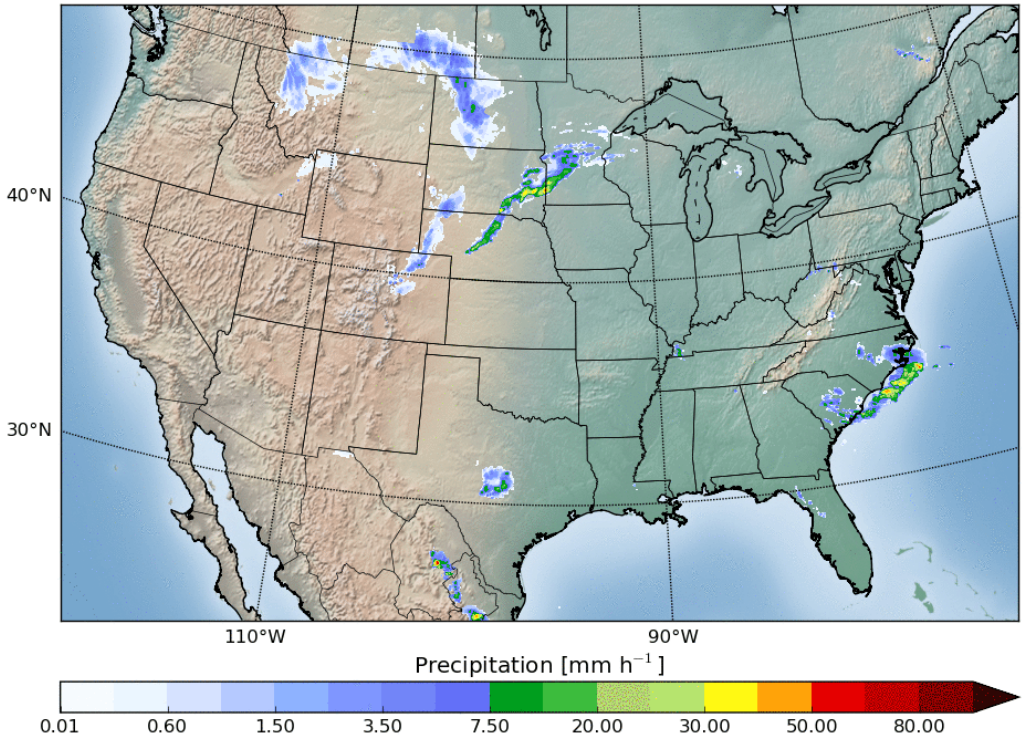
Convective outbreak

Model



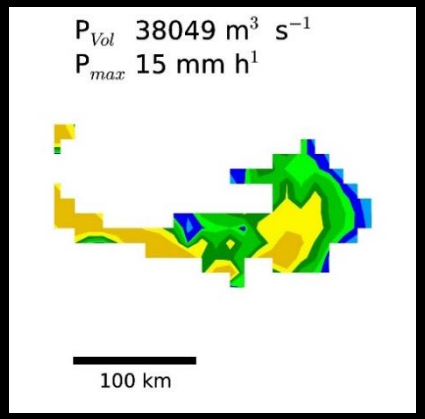
Observation

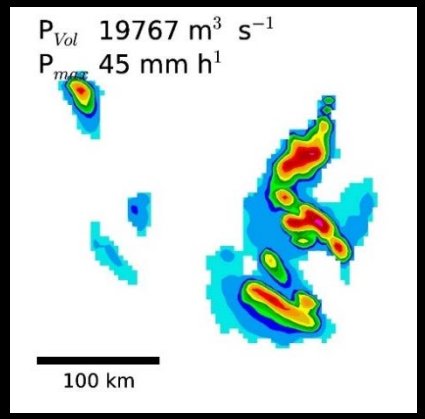


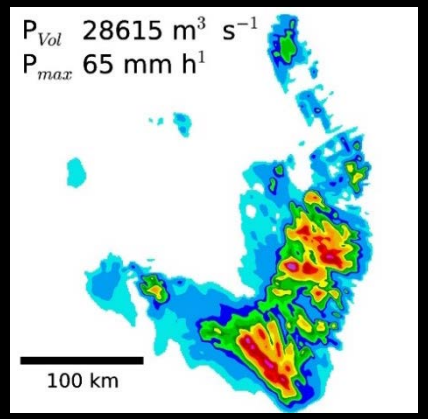
Correct representation of:

- **Spatial structures**
- **Intensities**
- **Time evolution**

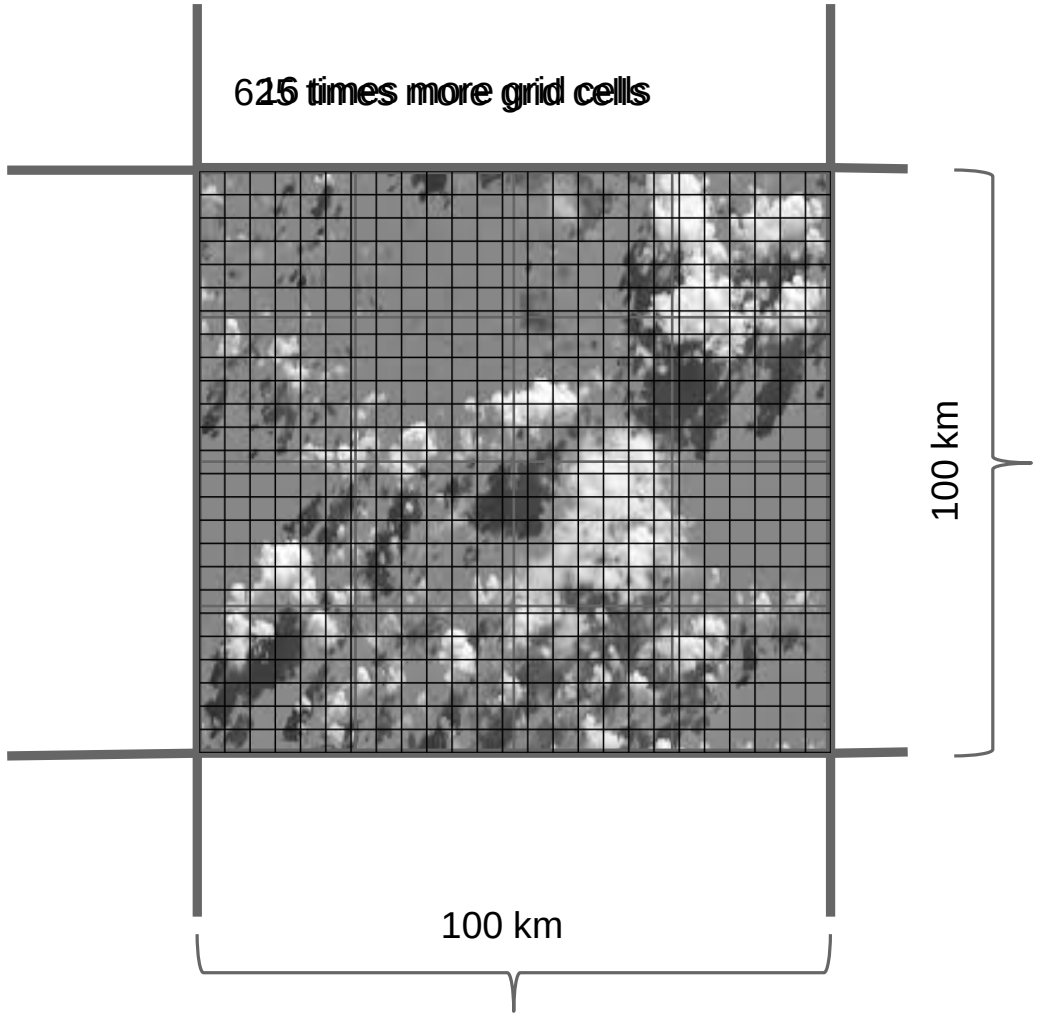
Step Improvement in Simulating Intense Rainfall Storms







Deep convection in atmospheric models



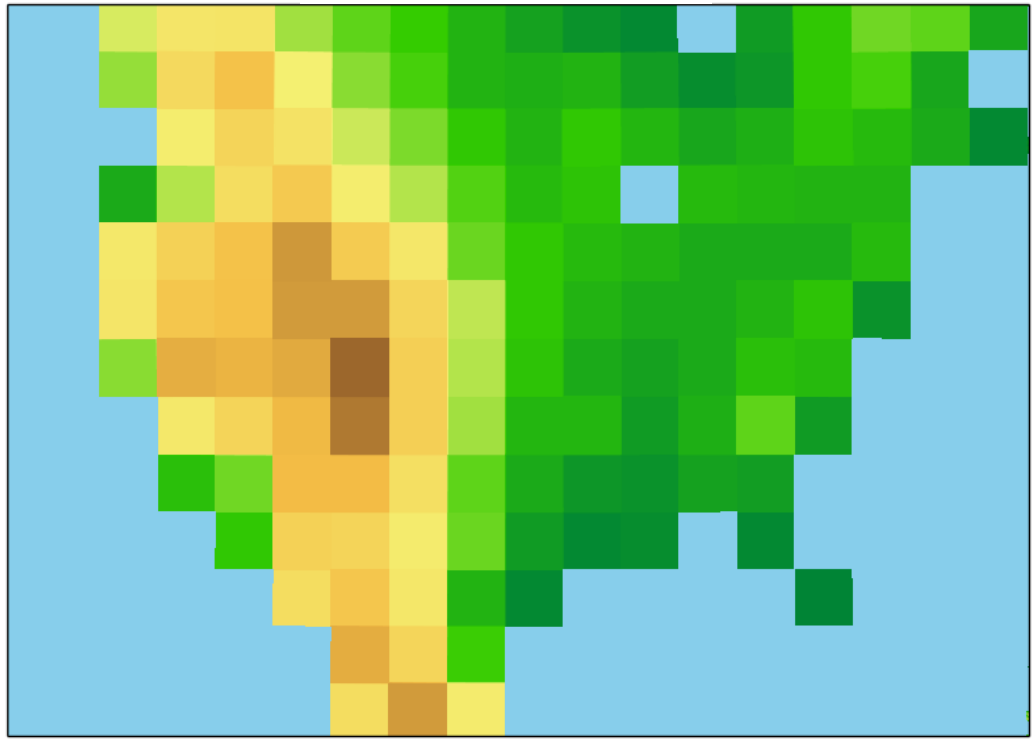
GCM grid spacing (~100 x 100 km)

- Deep convection is sub-gridscale process
- Needs cumulus parameterization

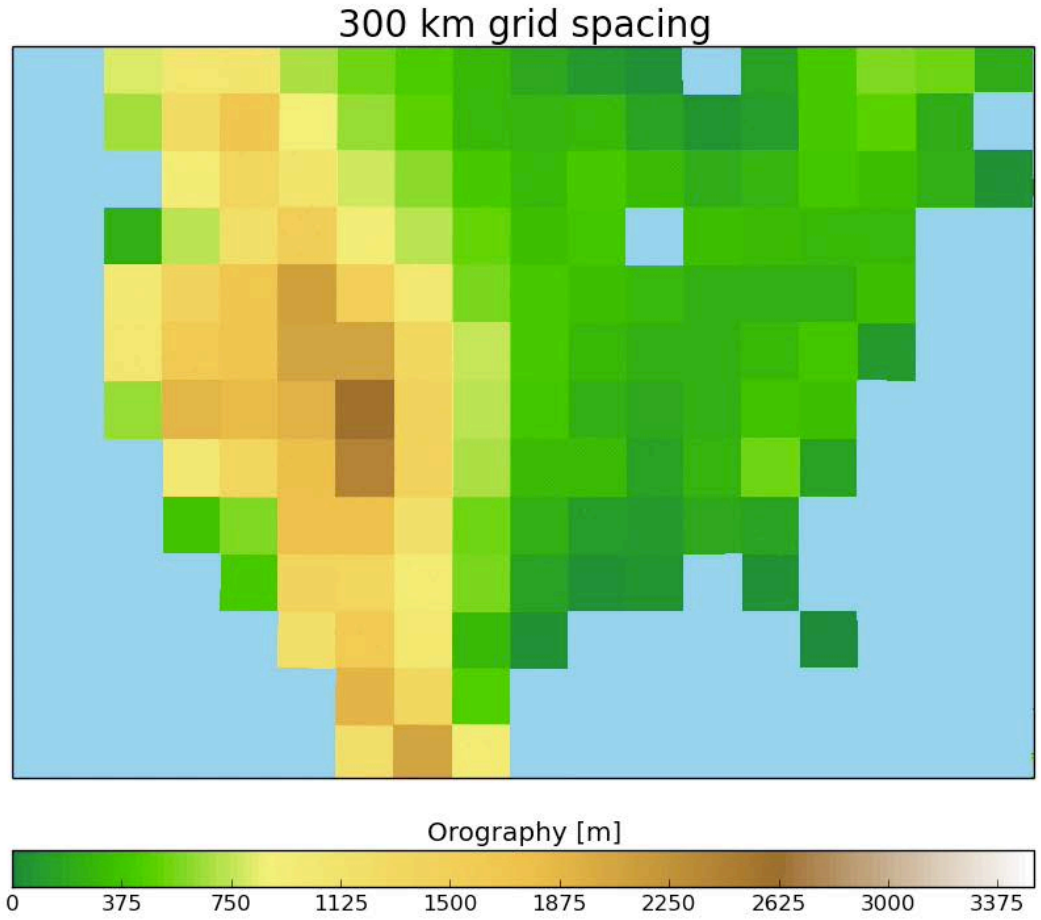
When do we start to resolve deep convection?

- ~4 km horizontal grid spacing (Weisman et al. 1997)

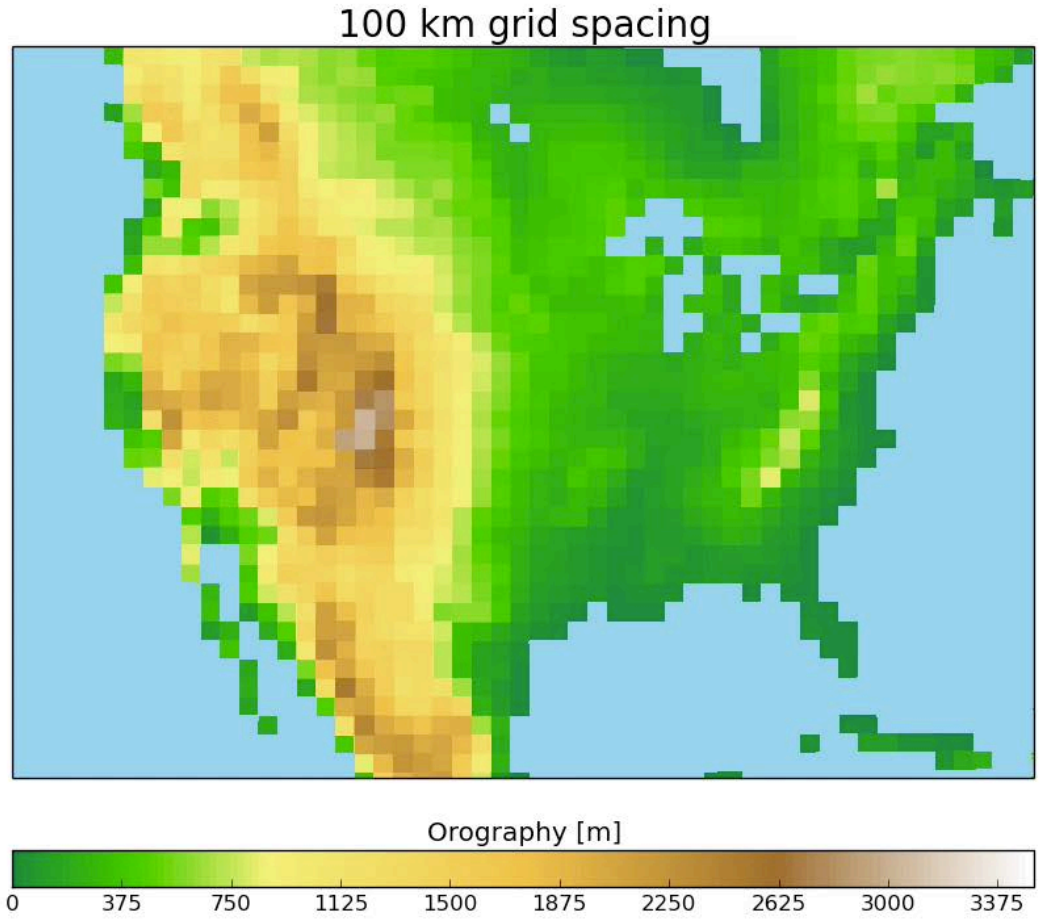
Resolution of State-Of-The-Art Climate Models



Resolution of State-Of-The-Art Climate Models



Resolution of State-Of-The-Art Climate Models



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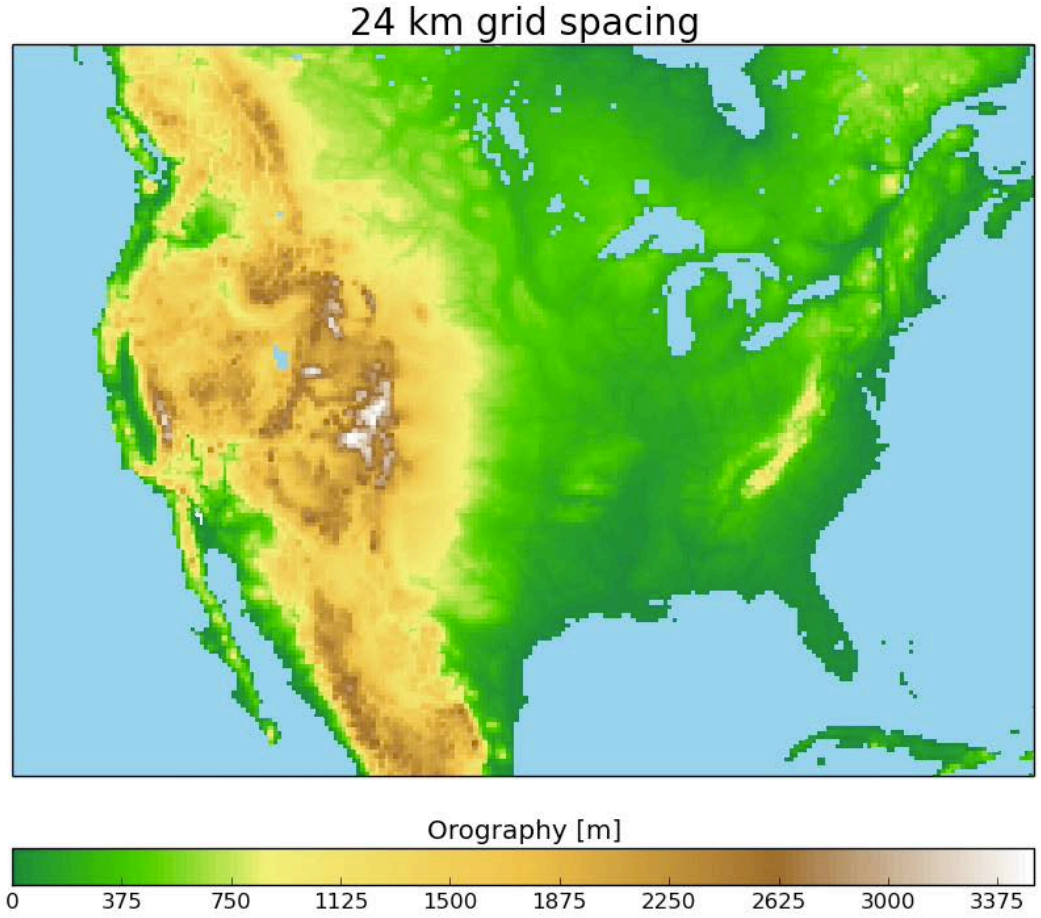
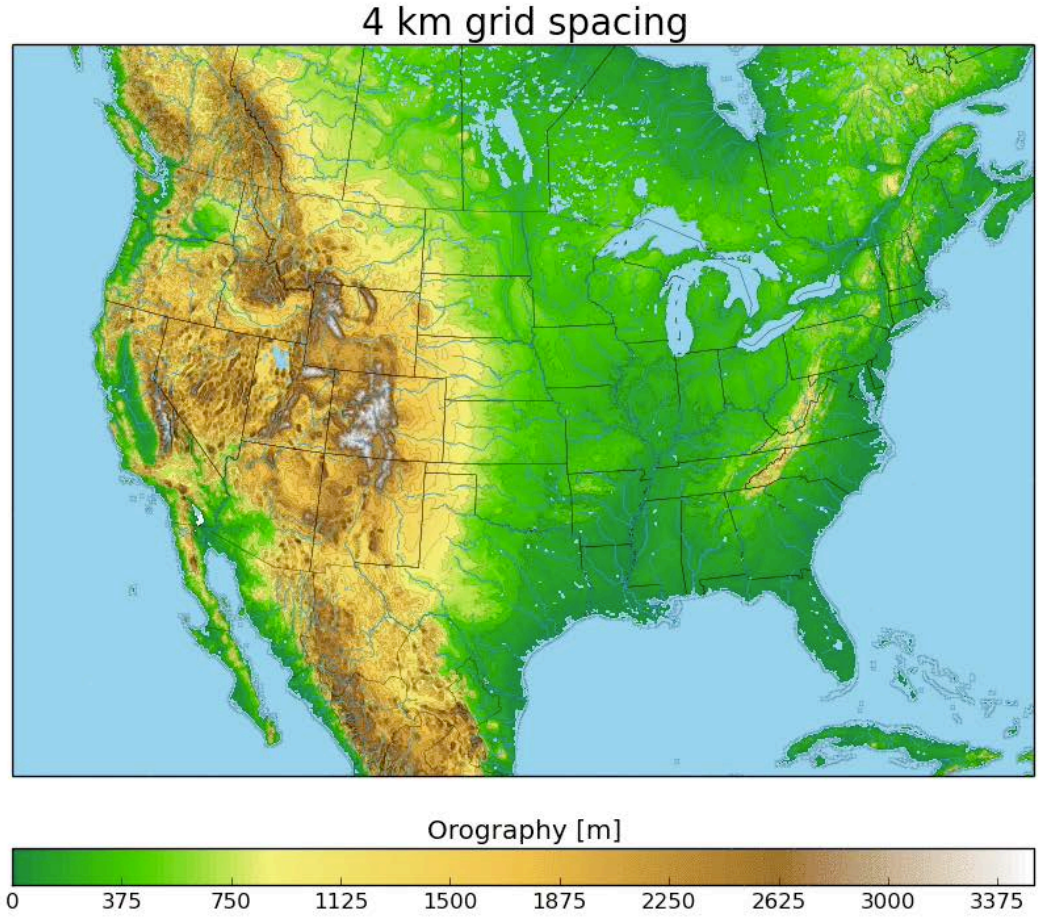


Resolution of State-Of-The-Art Climate Models



NRC project NR. 31310019S0015

”Convection-Permitting Modeling for Intense Precipitation Processes”

Probable Maximum Precipitation (PMP)

Does not allow quantification of uncertainties in hazard estimates in either a physical or a risk sense.

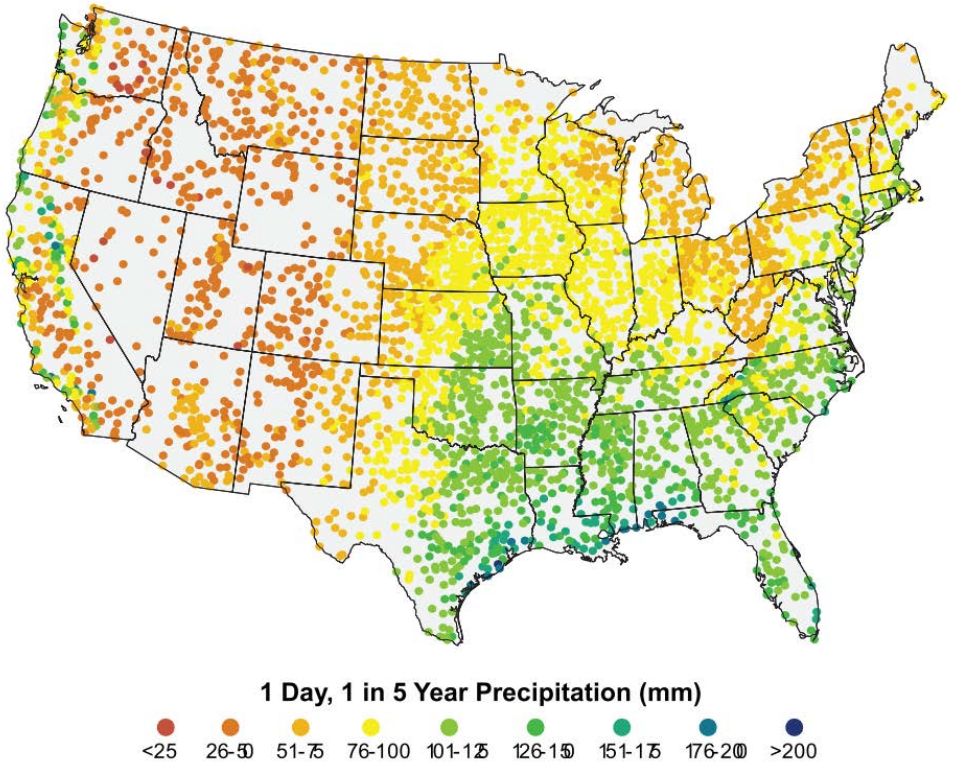
Convection-Permitting Models

Can they facilitate a more physically-based probabilistic flood risk assessments?

NCAR
UCAR

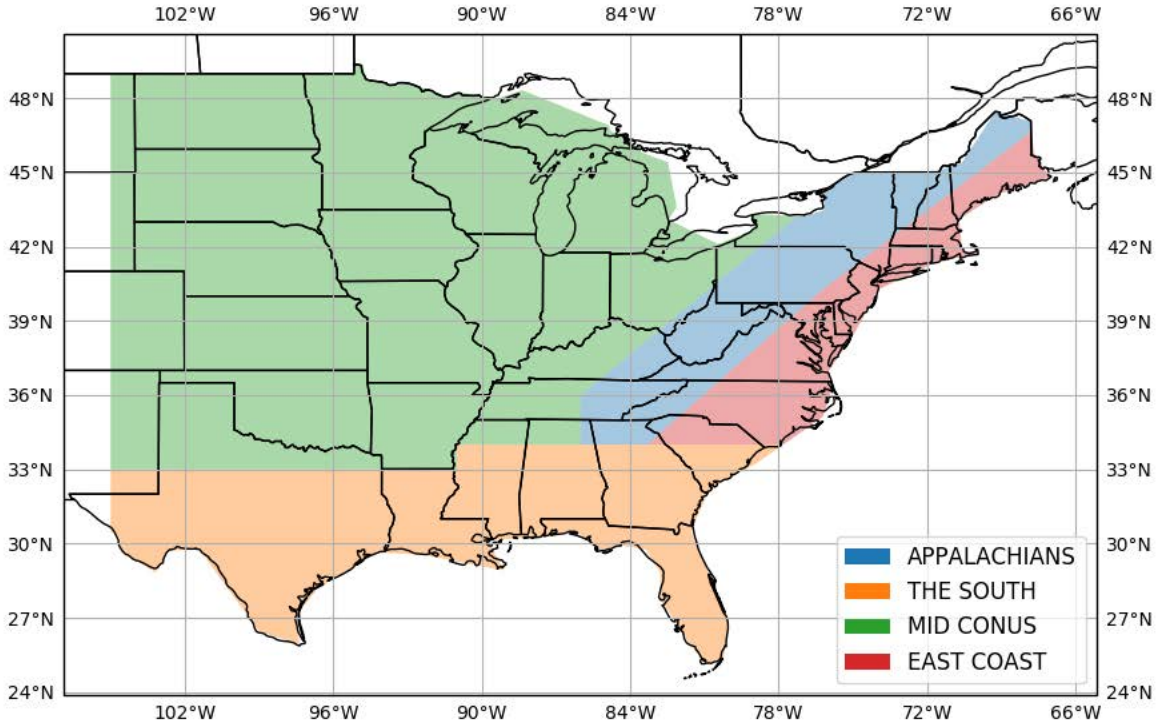
Intense Precipitation Events in Eastern CONUS

Daily, 1-in-5-yr precipitation amount for 3646 stations for the period of 1950–2010



Kunkel et al. 2012

Evaluation in Four Regions



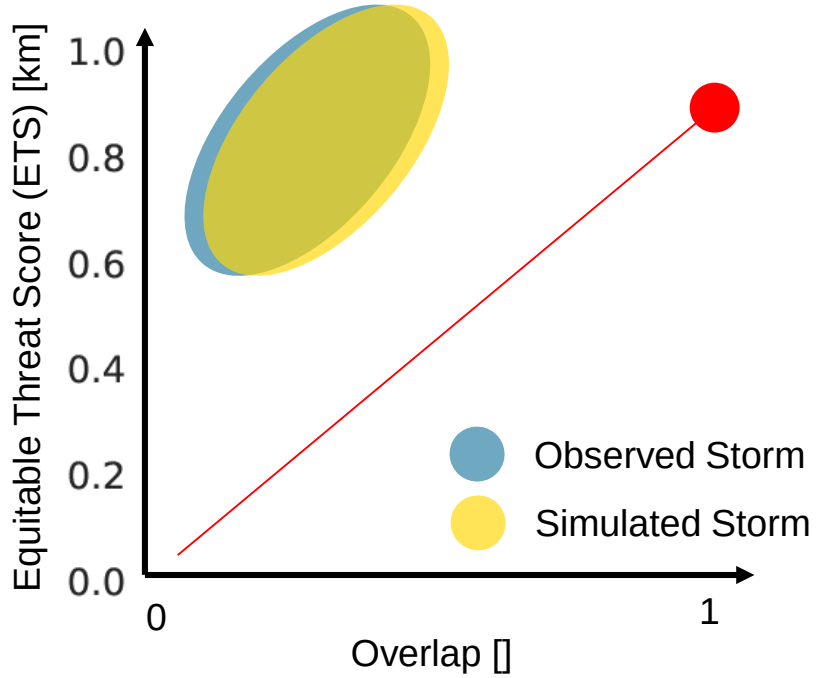
Convection-Permitting Model Simulations

Dataset	Δx	Elements	Period	Region	References
NCAR Real-time Ensemble	3 km	10-member ensemble forecasts	5/1/2015-12/31/2017	CONUS	Schwartz et al. (2014, 2015a, 2015b), Romine et al. (2014)
NCAR MPEX Ensemble	3 km & 1 km	10-member ensemble forecasts	5/15/2013-6/15/2013	Central / eastern U.S.	Schwartz et al. (2017)
NCAR Severe Weather Study	3 km & 1 km	Deterministic forecasts; 500 cases	2010-2017	Central / eastern U.S.	Sobash et al. (2019), Schwartz et al. (2019)

- 10,570 36-hour WRF simulations/forecasts at 3-km horizontal grid spacing (1.8 mi)
- 810 36-hour simulations at Δx=1 km (0.6 mi)

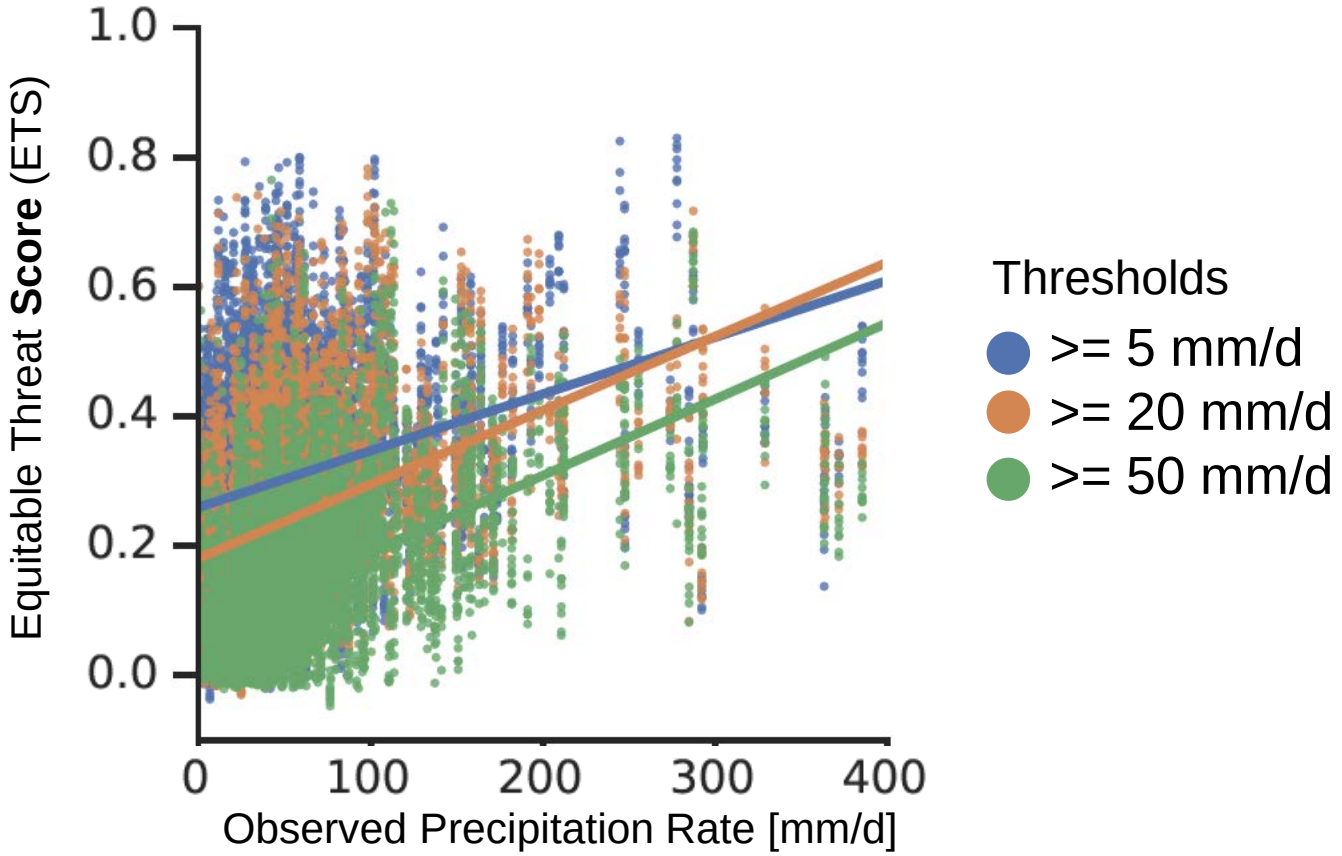
Are Intense Precipitation Events Harder to Simulate?

Equitable Threat Score (ETS)

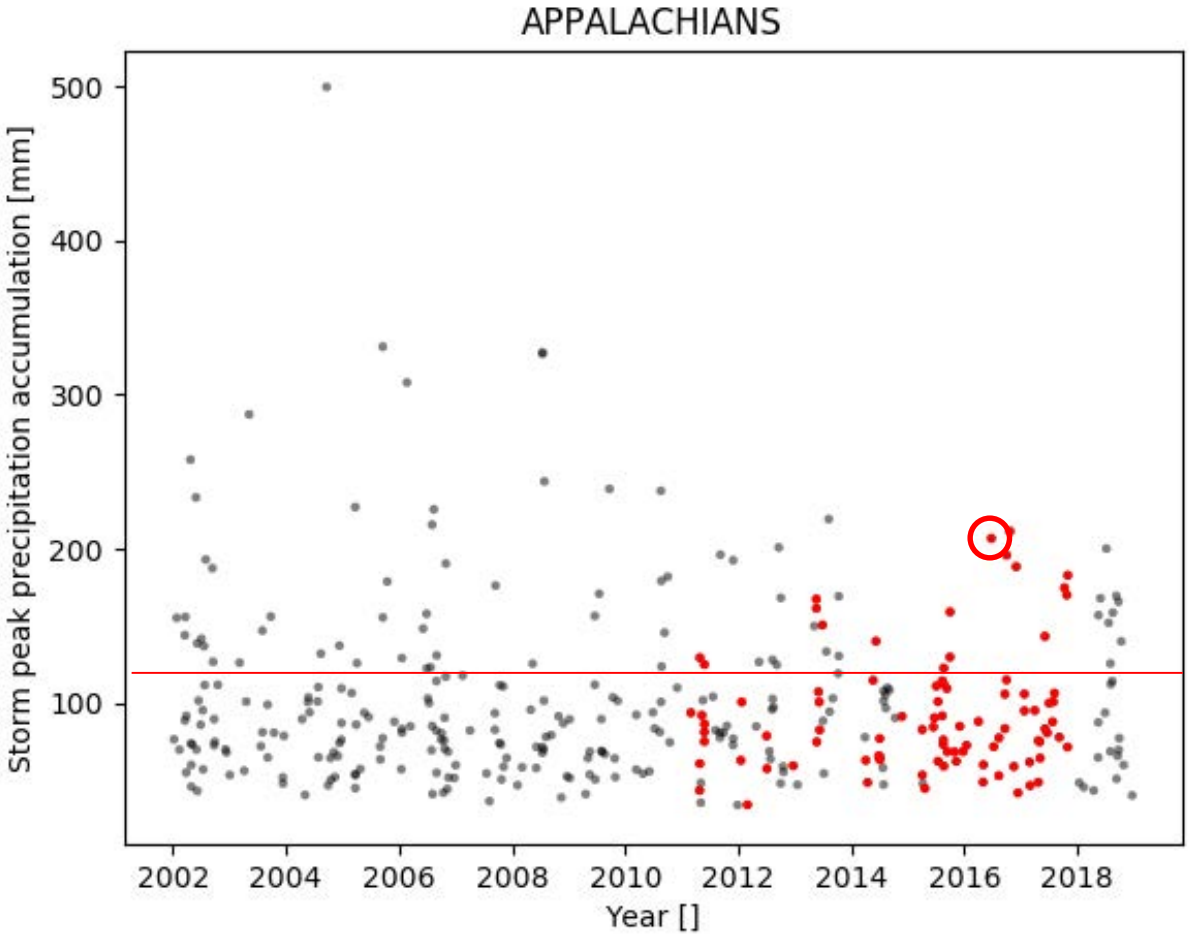


Model skill increases with intensity of event

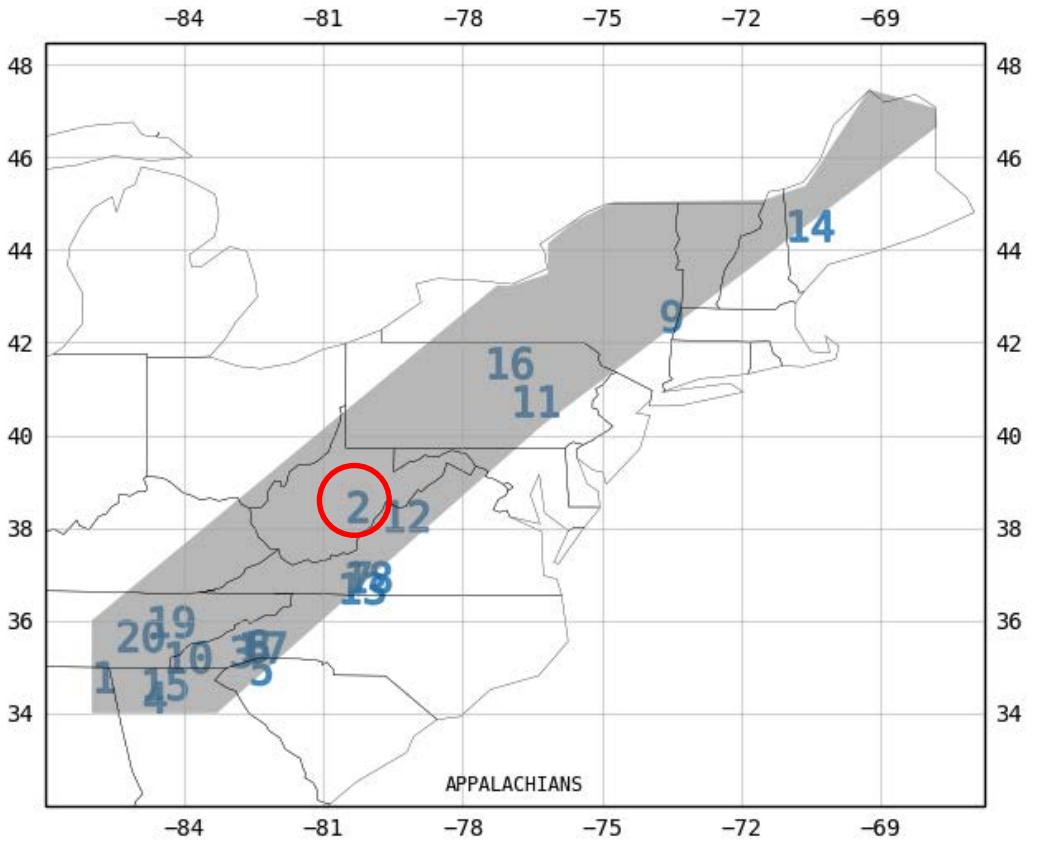
Southern U.S.



Case Selection | Top 20 Events in Each Region

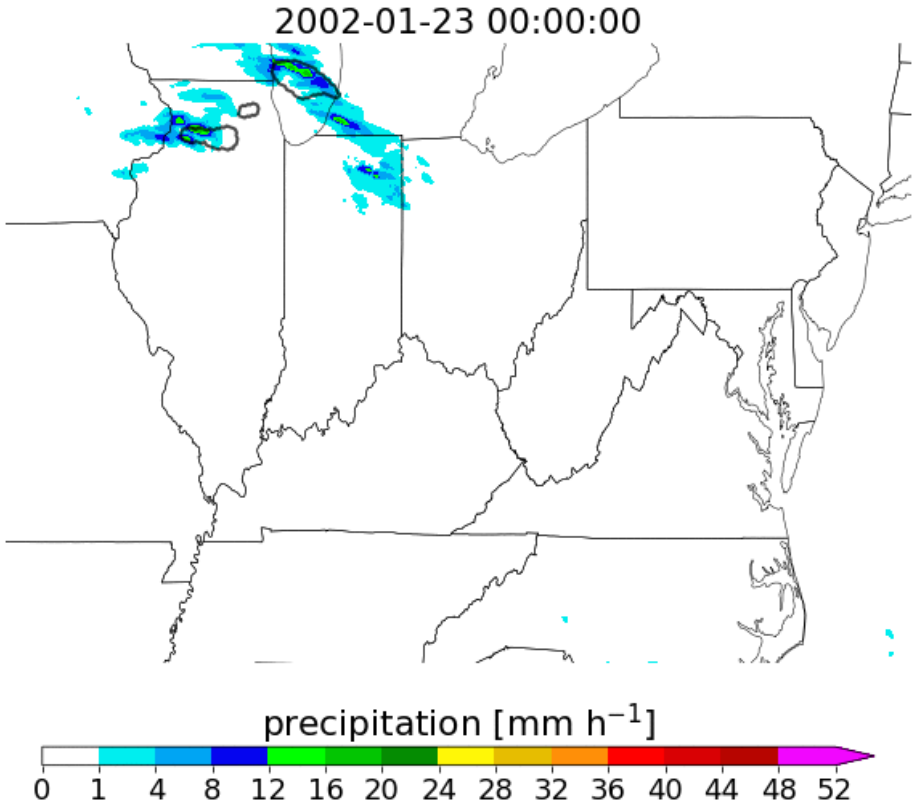


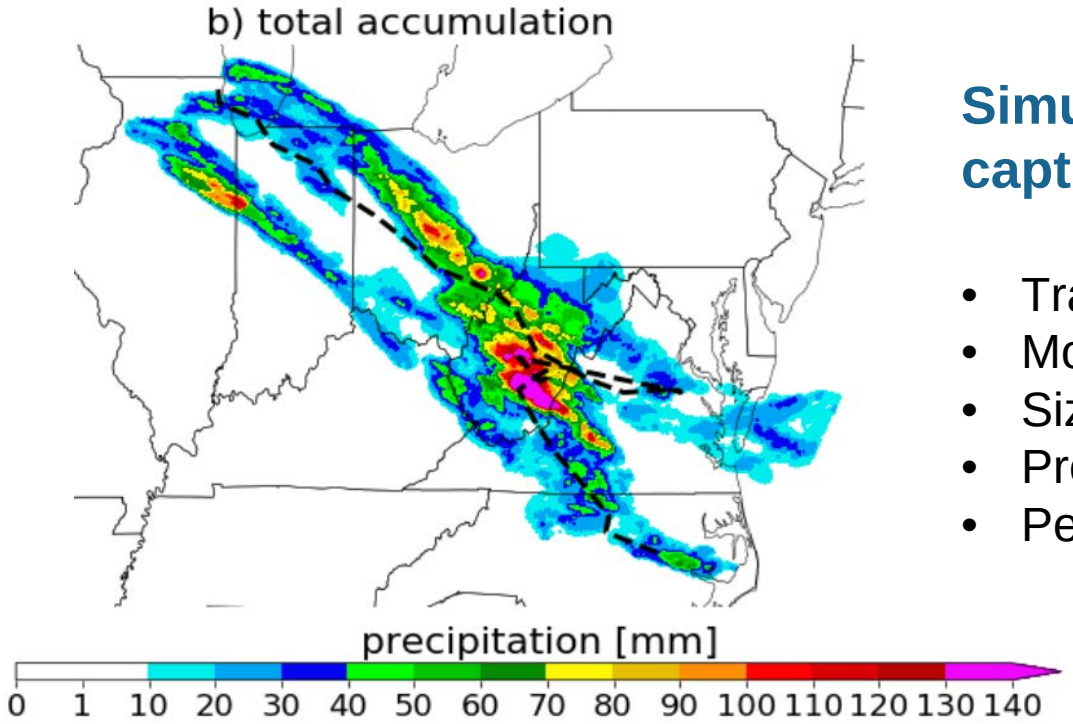
Top 20 Events in Appalachia Region



Lagrangian Evaluation Framework

West Virginia Flooding of 2016



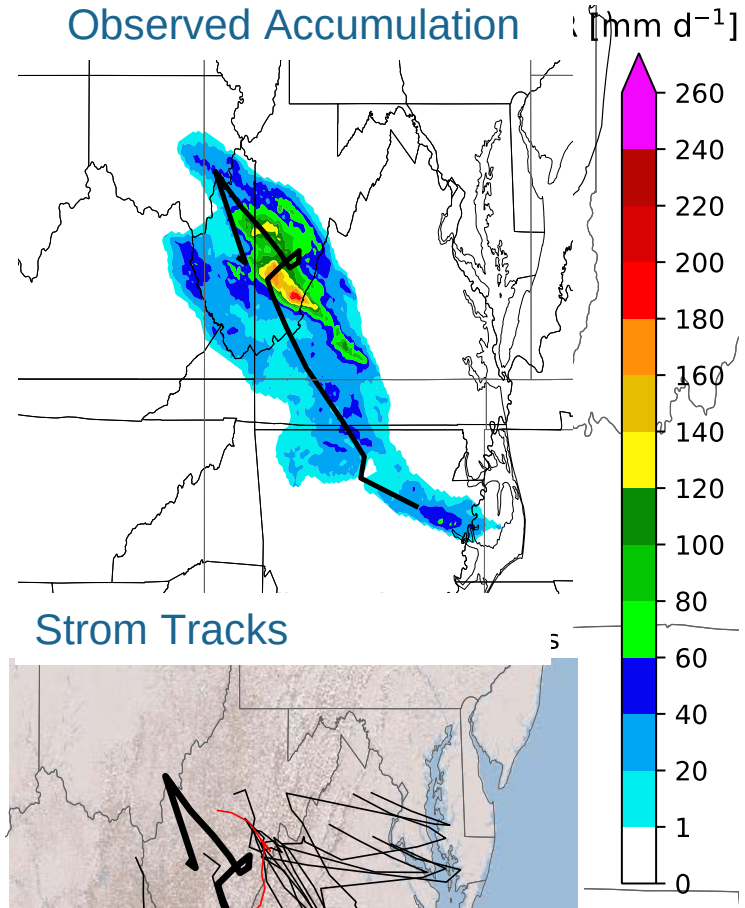


Simulation has to capture:

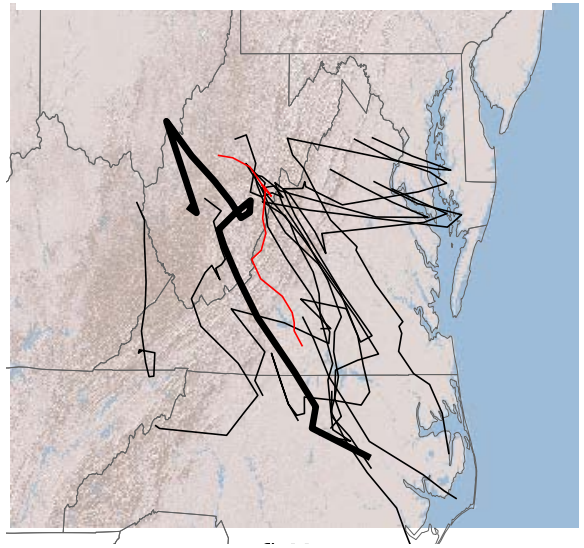
- Track
- Movement speed
- Size evolution
- Precipitation volume
- Peak accumulation

West Virginia Flooding of 2016

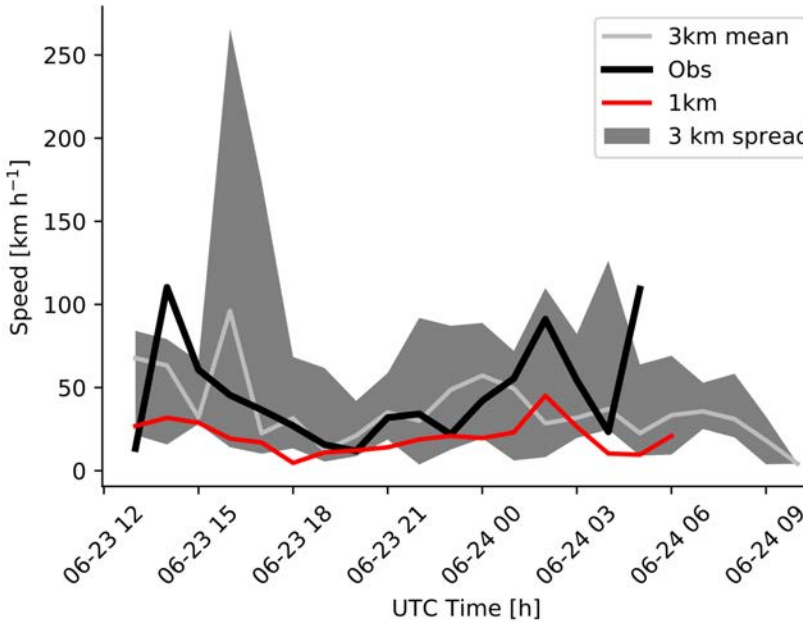
Observed Accumulation



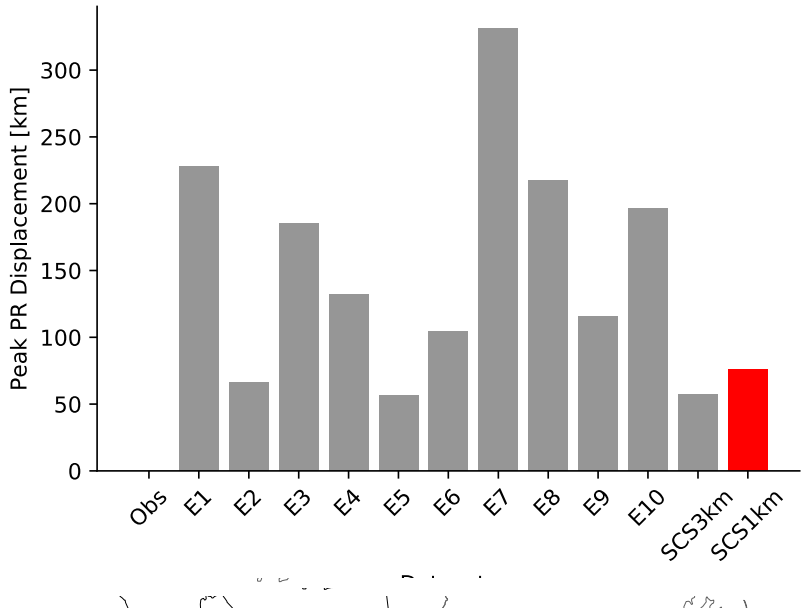
Strom Tracks



Storm Speed

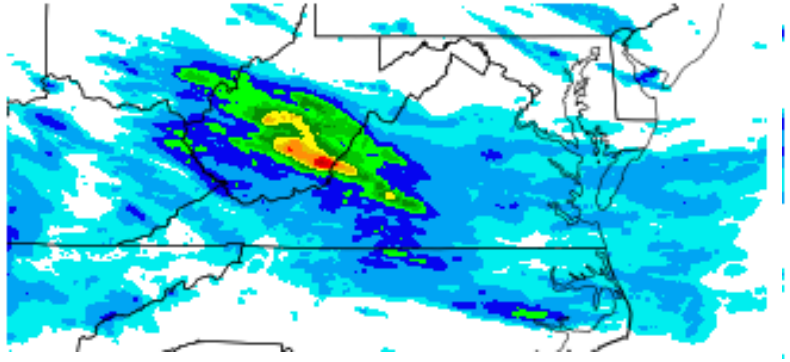


Peak Displacement

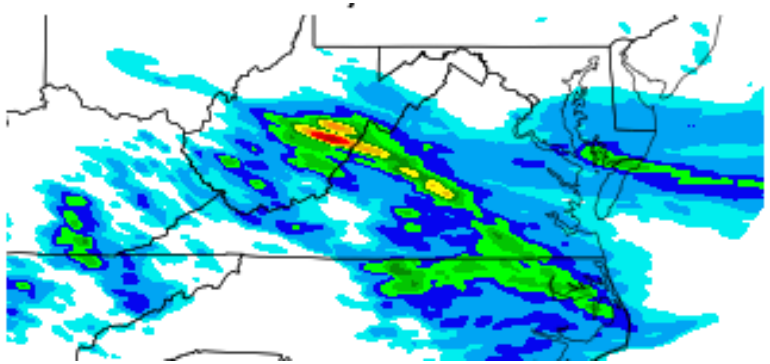


West Virginia Flooding of 2016

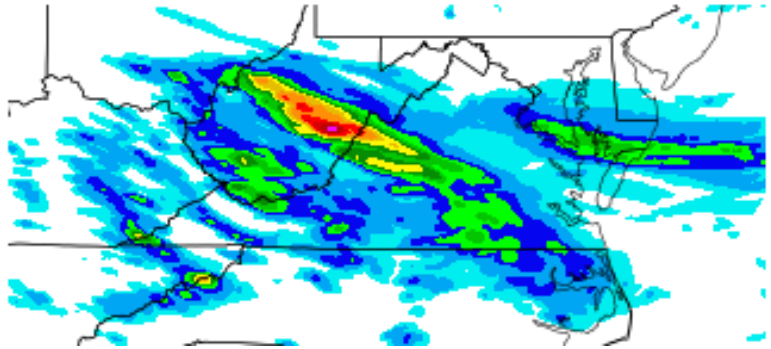
Observed Precipitation



Best Peak Accumulation

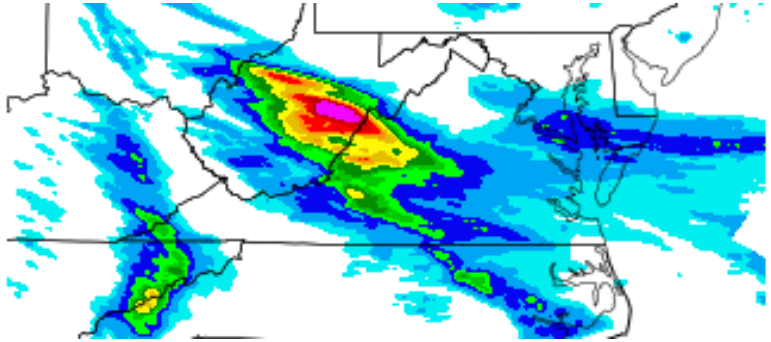


Best Peak Location

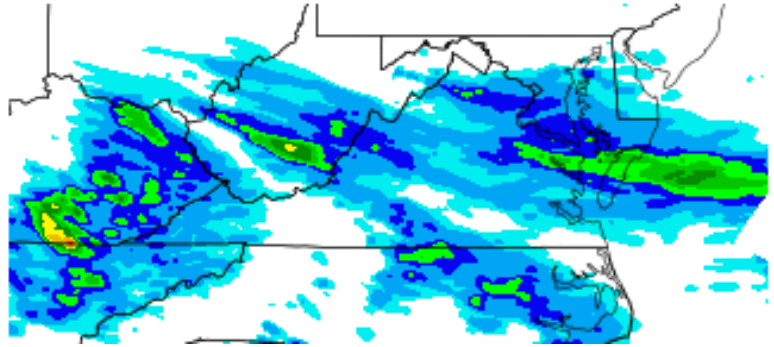


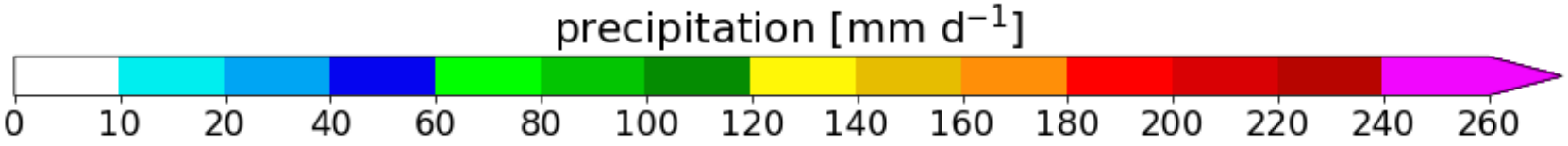
- Large spread due to initial condition perturbations
- 3 km and 1 km results are comparable
- 3 km seem to have too much rainfall on lee-side

Best Volume | 1 km



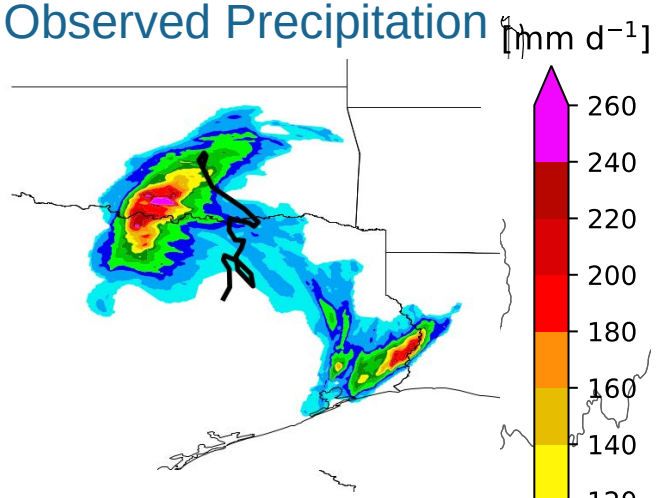
Worst Overall Simulation



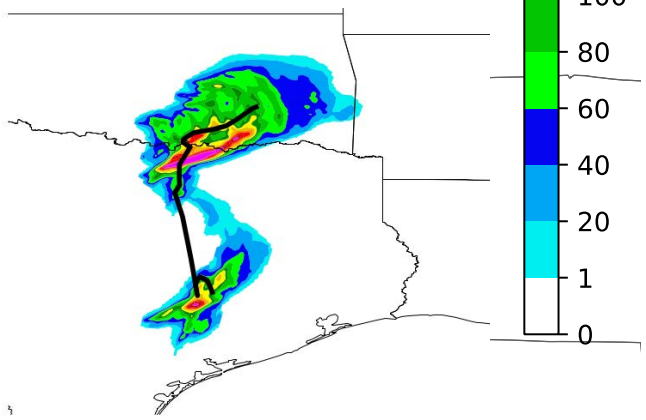


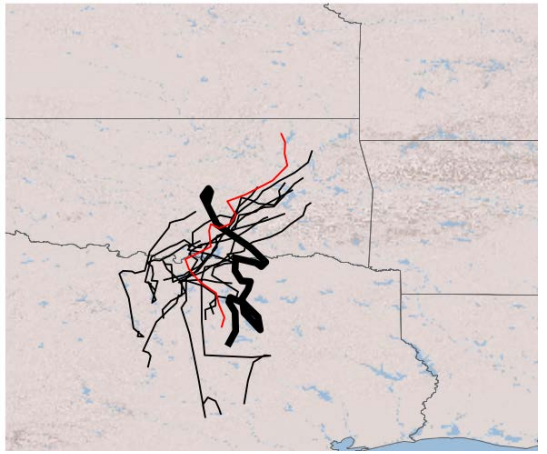
Tropical Storm Bill | June 2015

Observed Precipitation

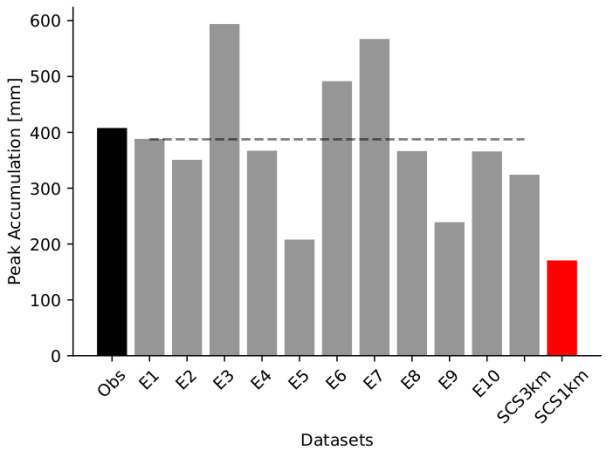


Best Simulation

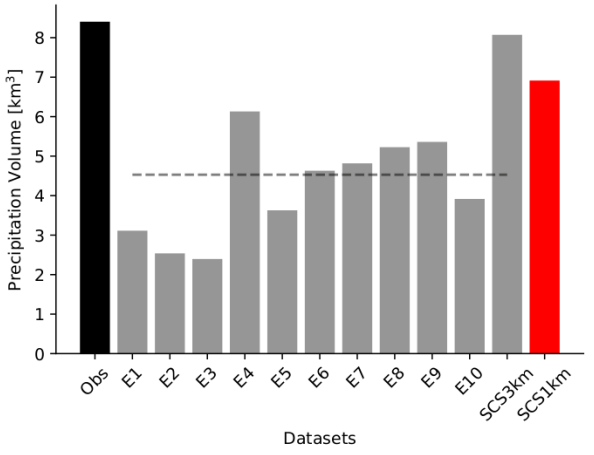




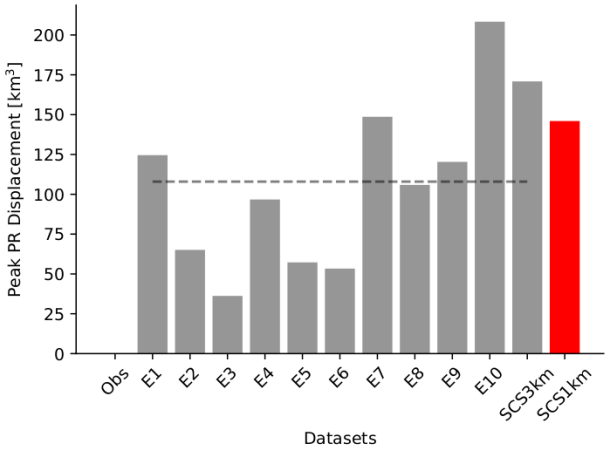
Peak Accumulation



Precipitation Volume



Peak Displacement



Next Steps

- Assessment of model performance based on ensemble of intense events
- Quantification of systematic model biases
- Analyses of uncertainty sources to model performance
- Conceptual framework to use CPM simulations in Monte Carlo rainfall-runoff simulations

Uncertainty Source	Setting
Horizontal grid spacing (Δx)	3 km, 1 km (1.8 mi, 0.6 mi)
Precipitation observations	Stage-IV (Crosson et al. 1996, Fulton et al. 1998) Mosaic WSR-88D (Zhang and Gourley 2018) PRISM (Daly et al. 1994, 2002, 2008) Newman (Newman et al 2015)
Initial Conditions	Ensemble datasets to be used reflect initial condition perturbations

Summary and Conclusions

- Convection-permitting models can capture recently observed intense rainfall events east of the Continental Divide
- Predictability increases with rarity of event
- Sensitivity to initial condition perturbations is large
- 3 km and 1 km simulations show comparable results

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