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

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Photo by @KenGeiger

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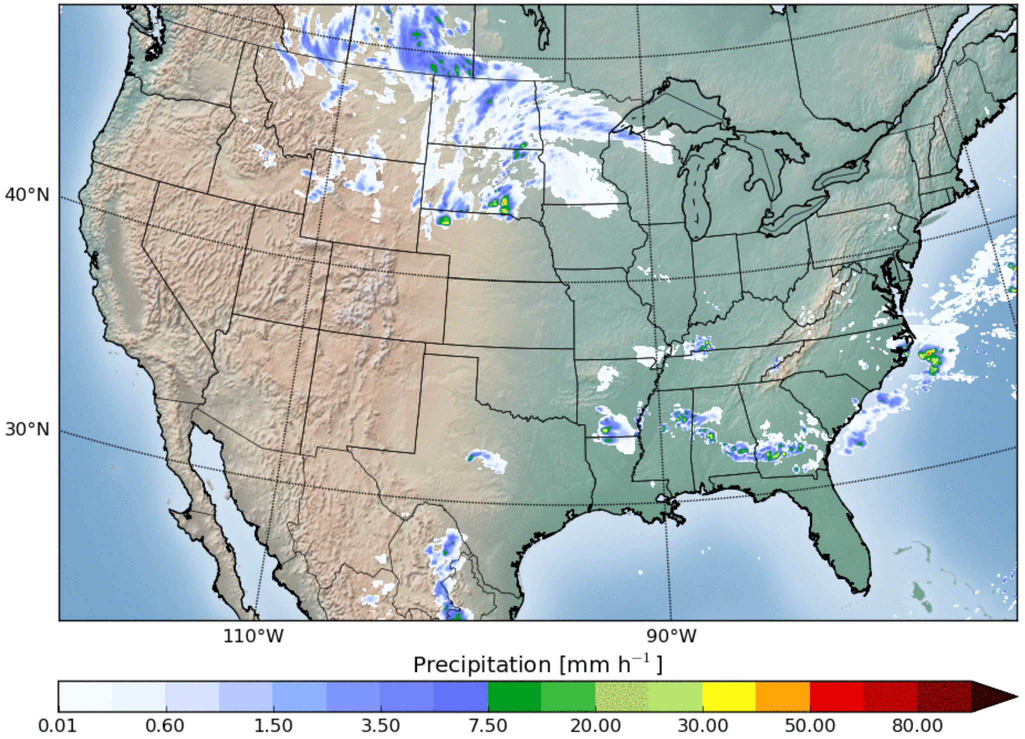
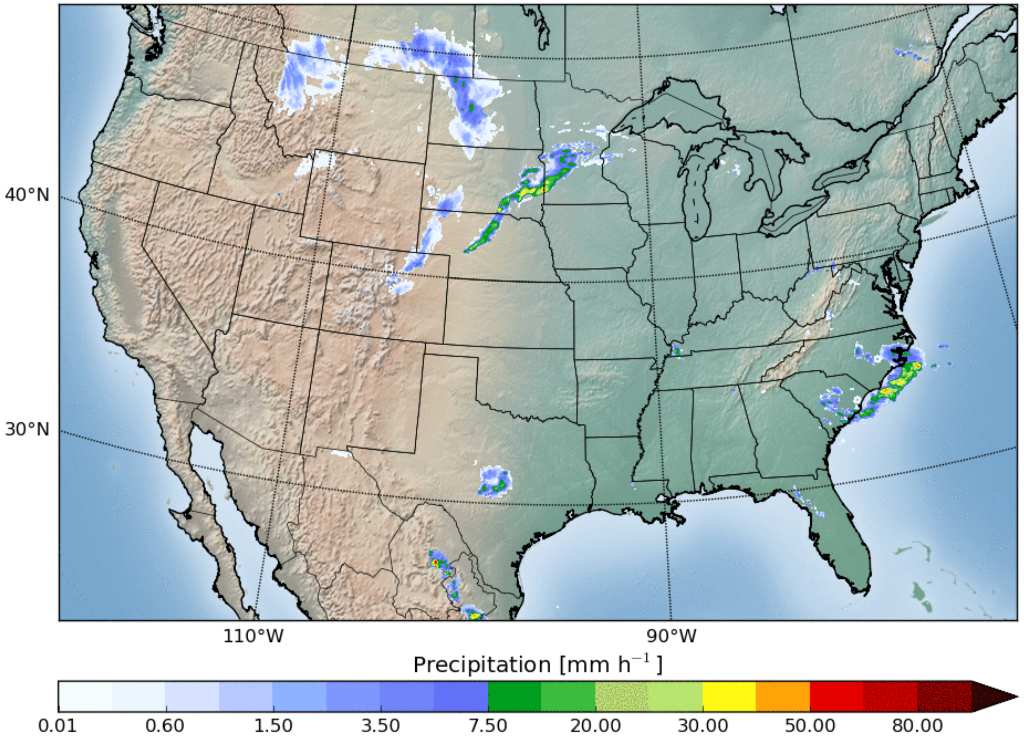
# Convective outbreak

## Model




## Observation

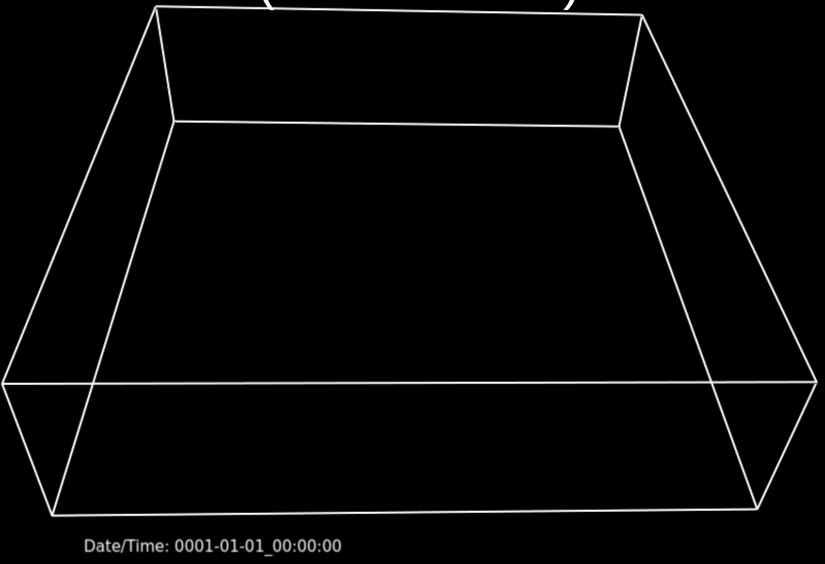


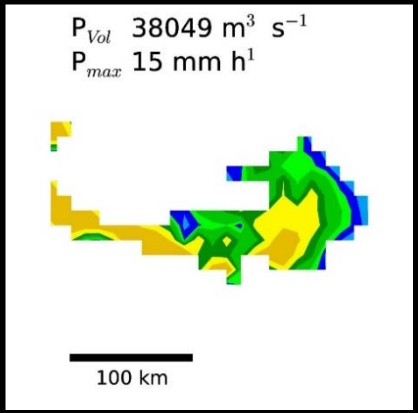

**Correct representation of:**

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

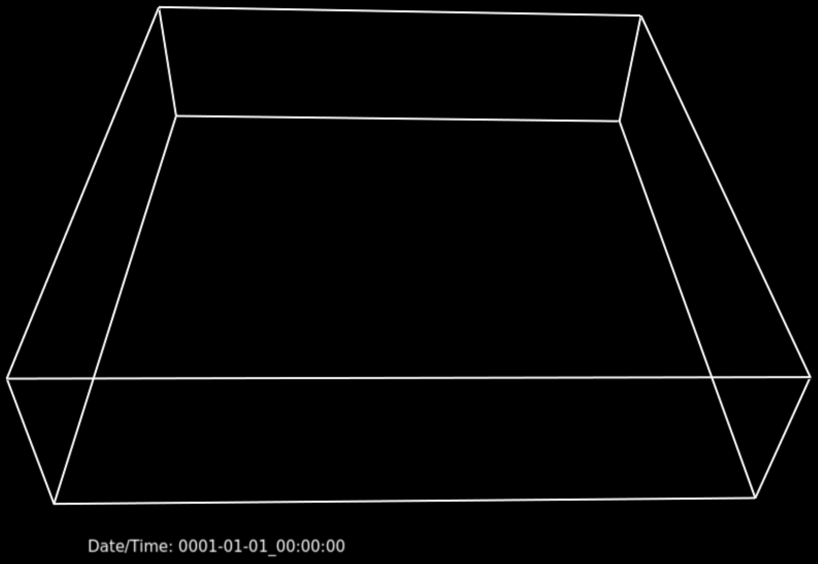
# Step Improvement in Simulating Intense Rainfall Storms

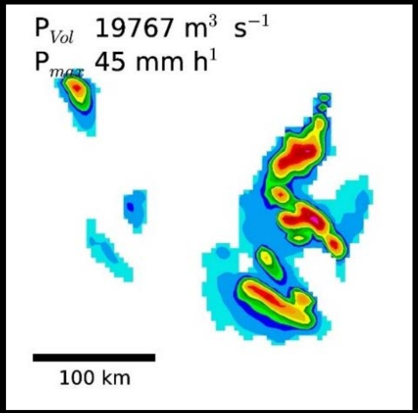
Δx = 12 km
(K-F scheme)



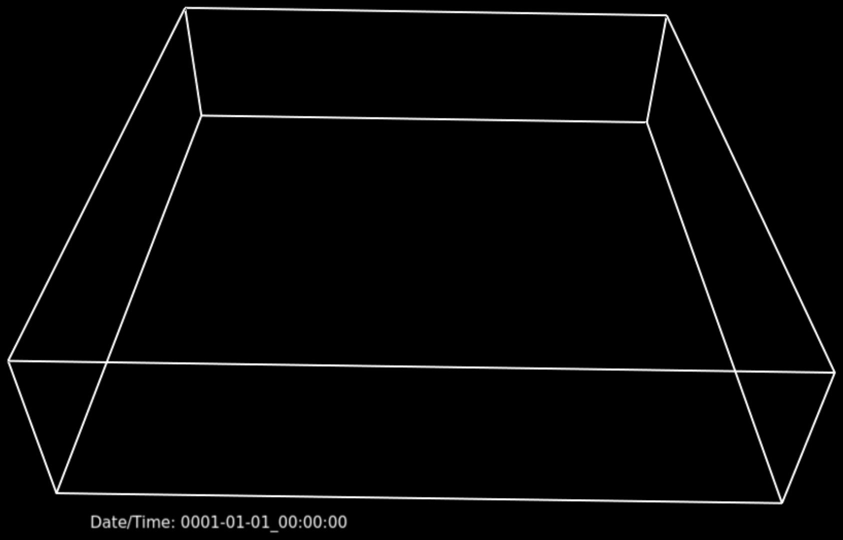



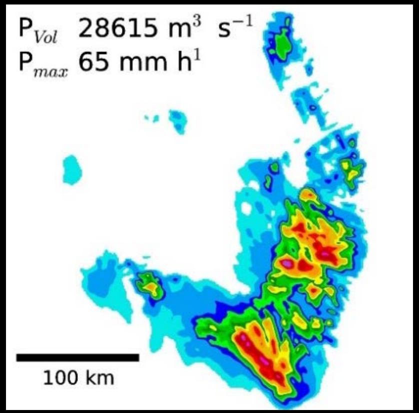

Δx = 4 km



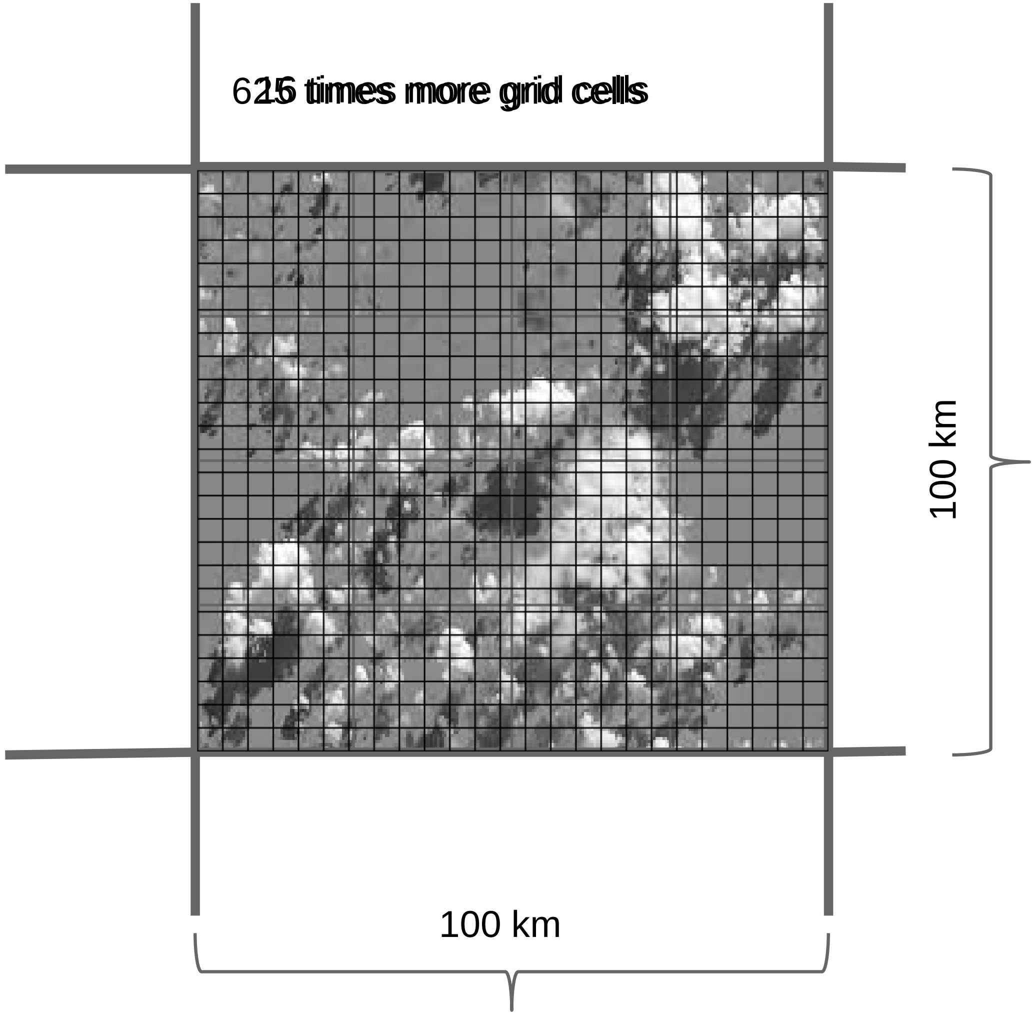




Δx = 1 km



# Deep convection in atmospheric models



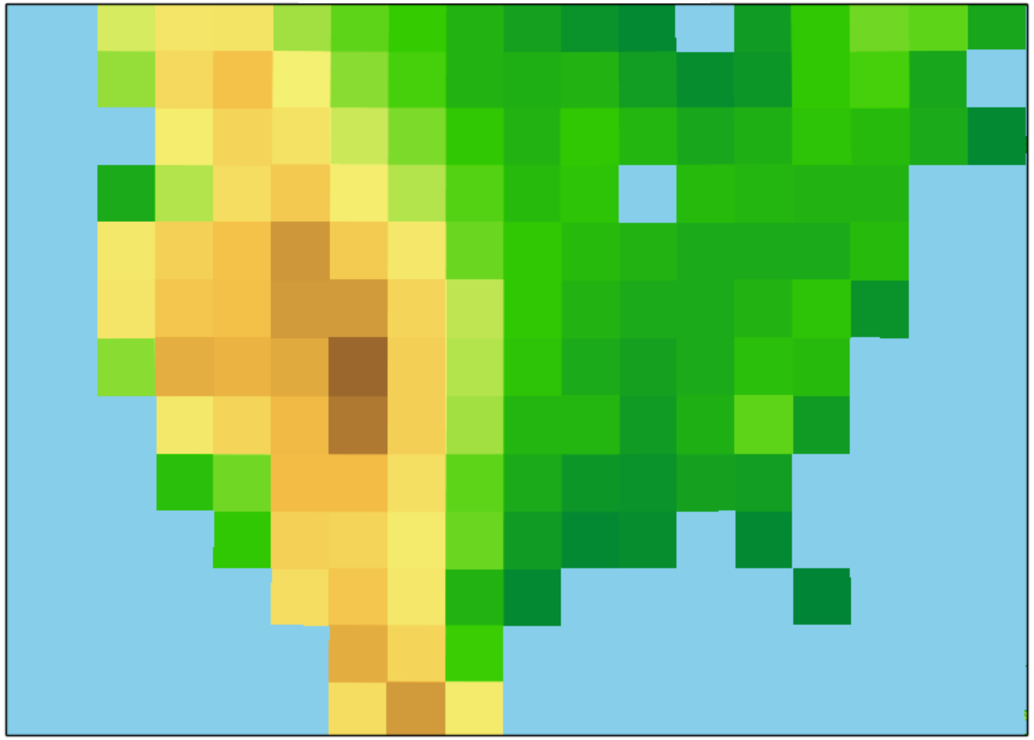

**GCM grid spacing (~100 x 100 km)**

- 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



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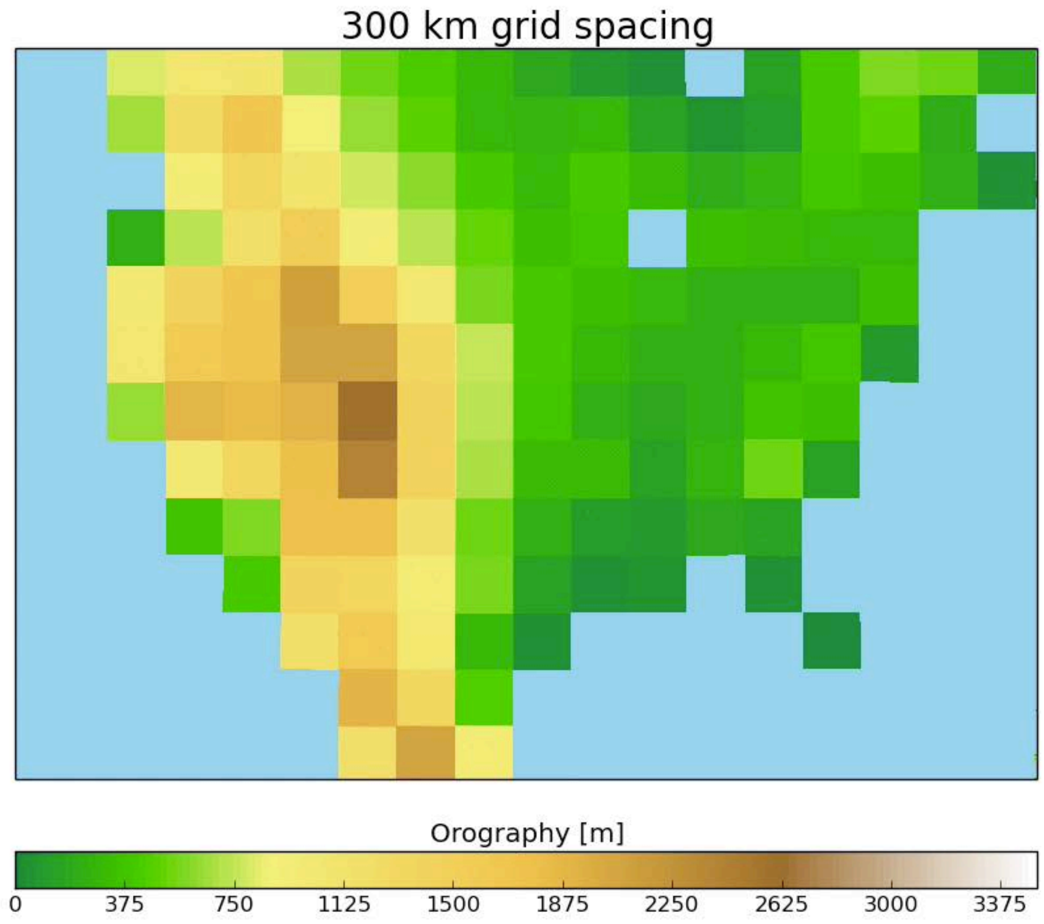

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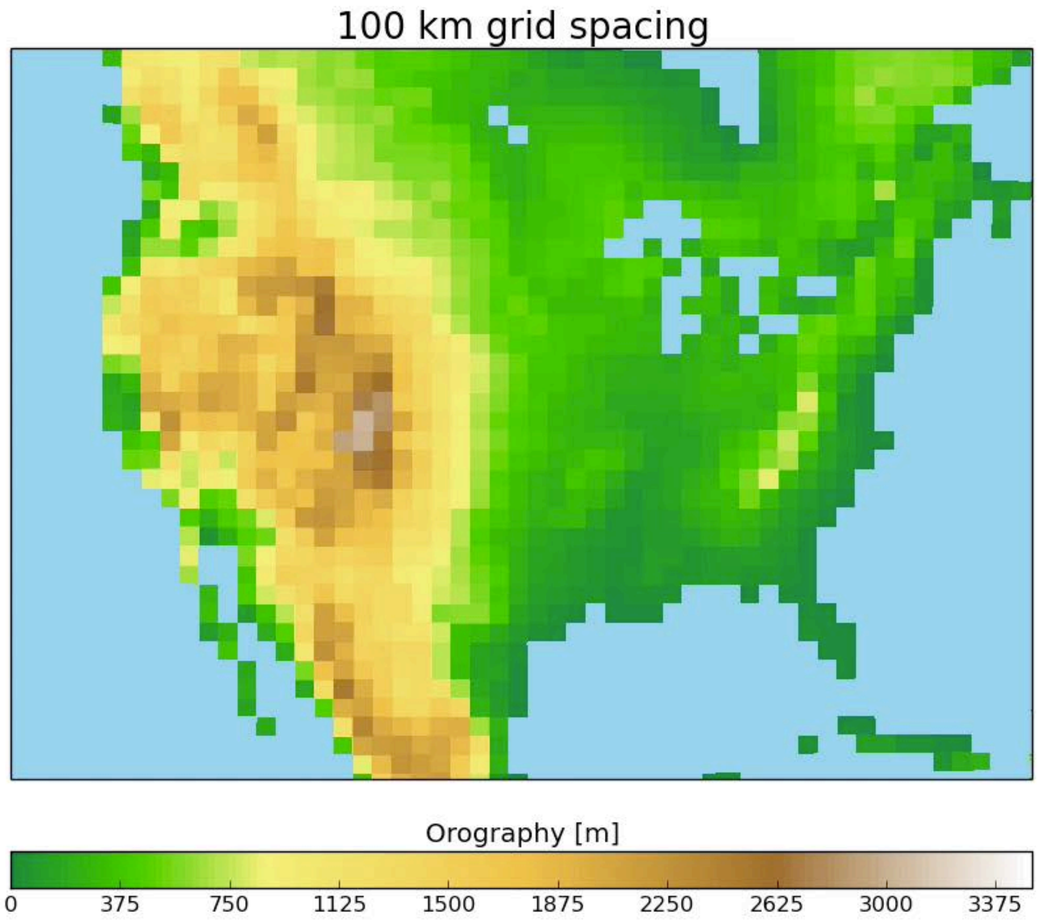

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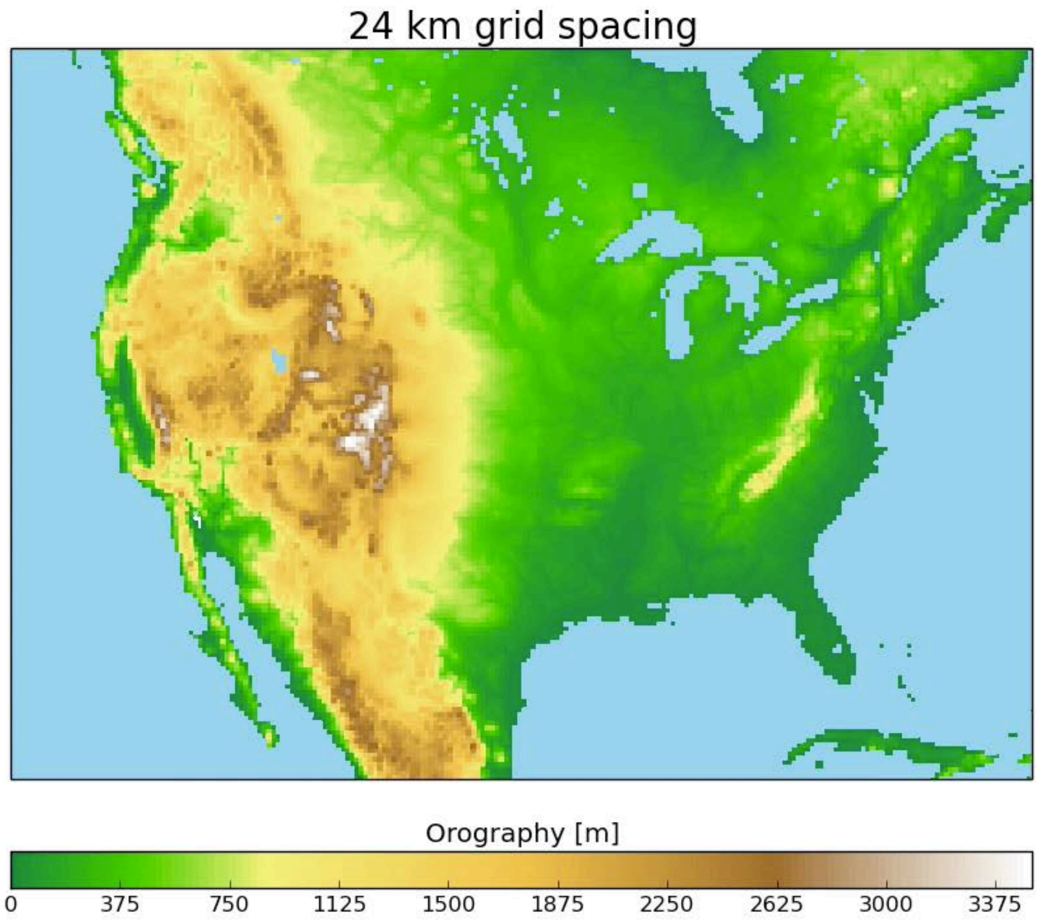

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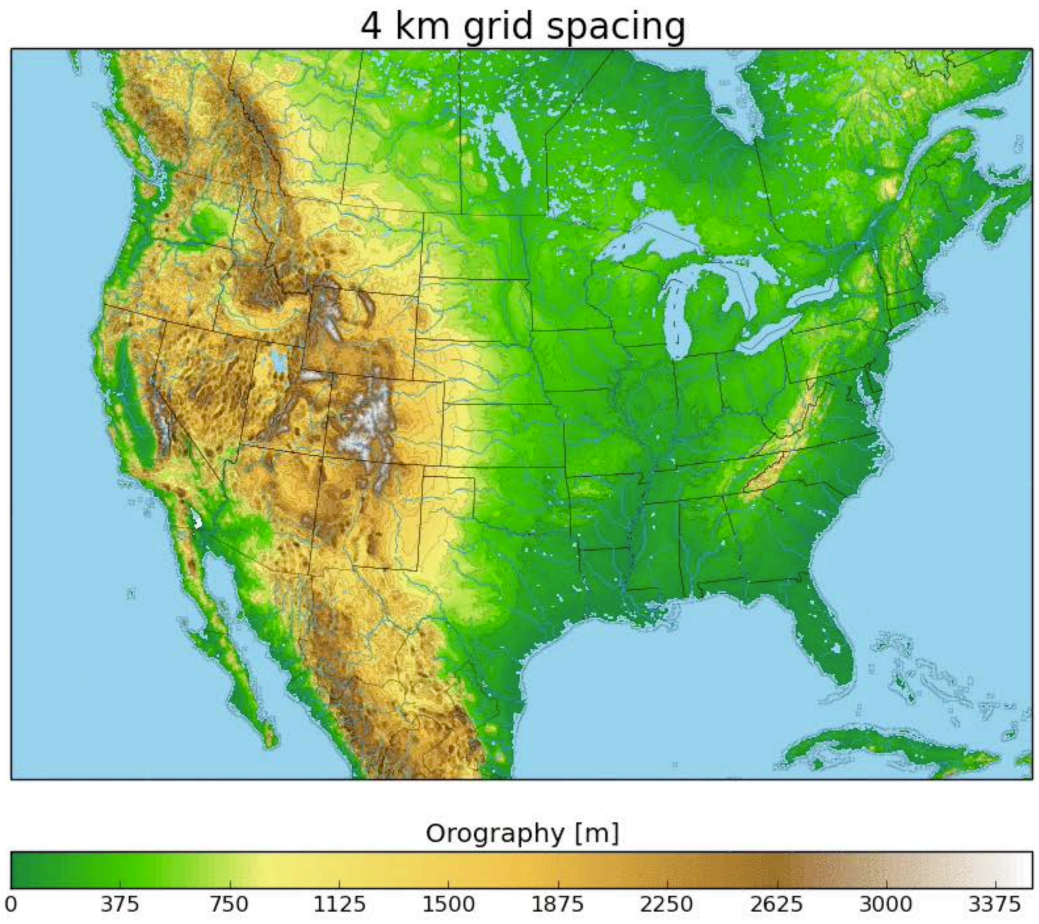


NRC project NR. 31310019S0015

# ”Convection-Permitting Modeling for Intense Precipitation Processes”

**Probable Maximum Precipitation (PMP)**

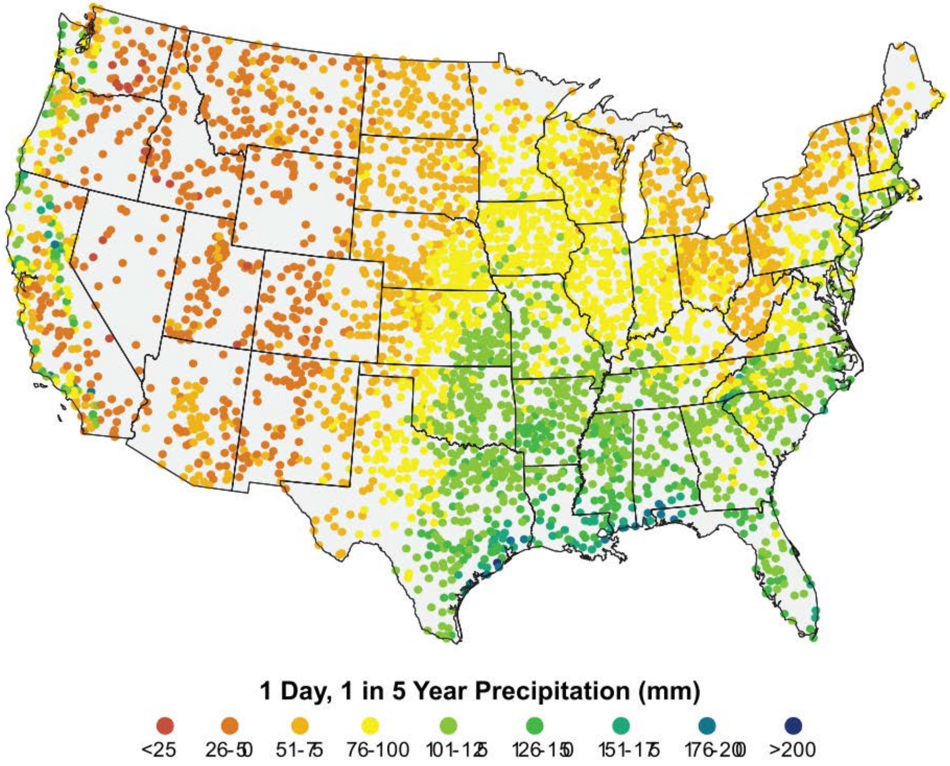
Does not allow quantification of uncertainties in hazard estimates in either a physical or a risk sense.

**Convection-Permitting Models**

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

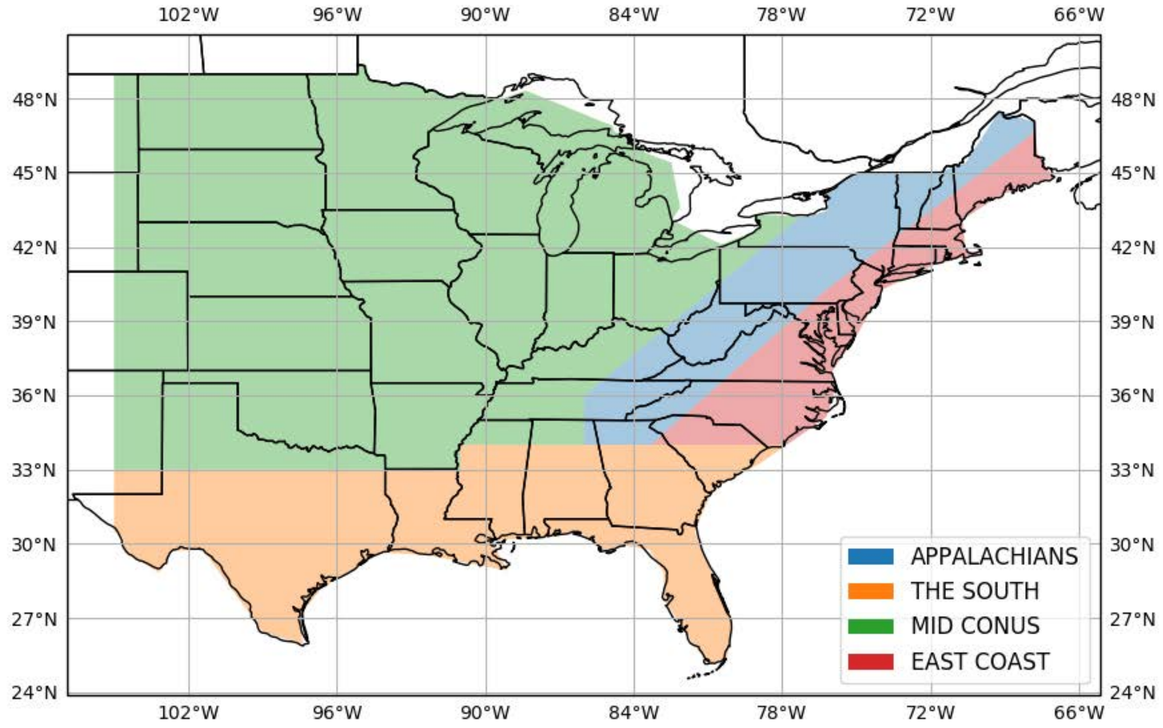
# Intense Precipitation Events in Eastern CONUS

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




Kunkel et al. 2012

## Evaluation in Four Regions



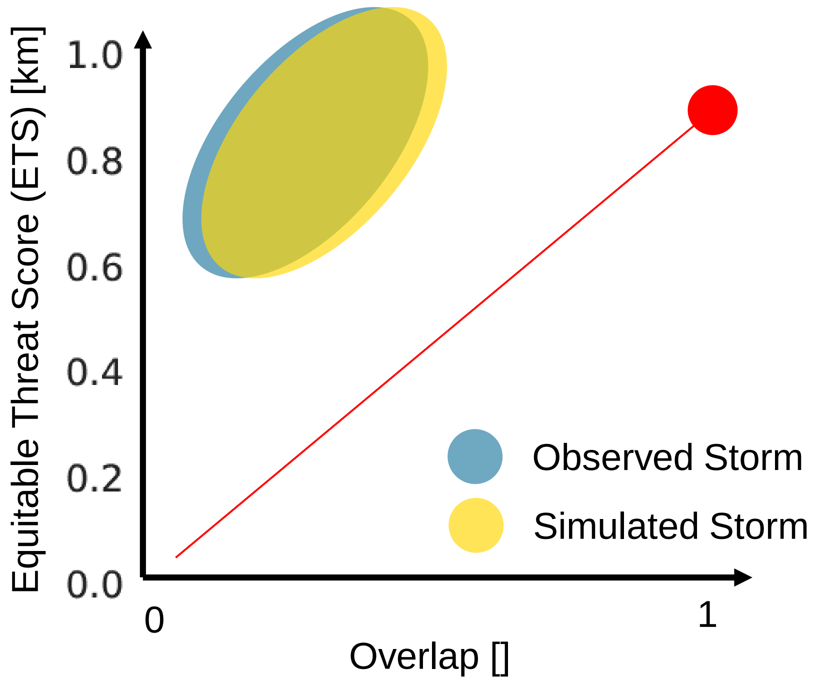
# Convection-Permitting Model Simulations

| 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)

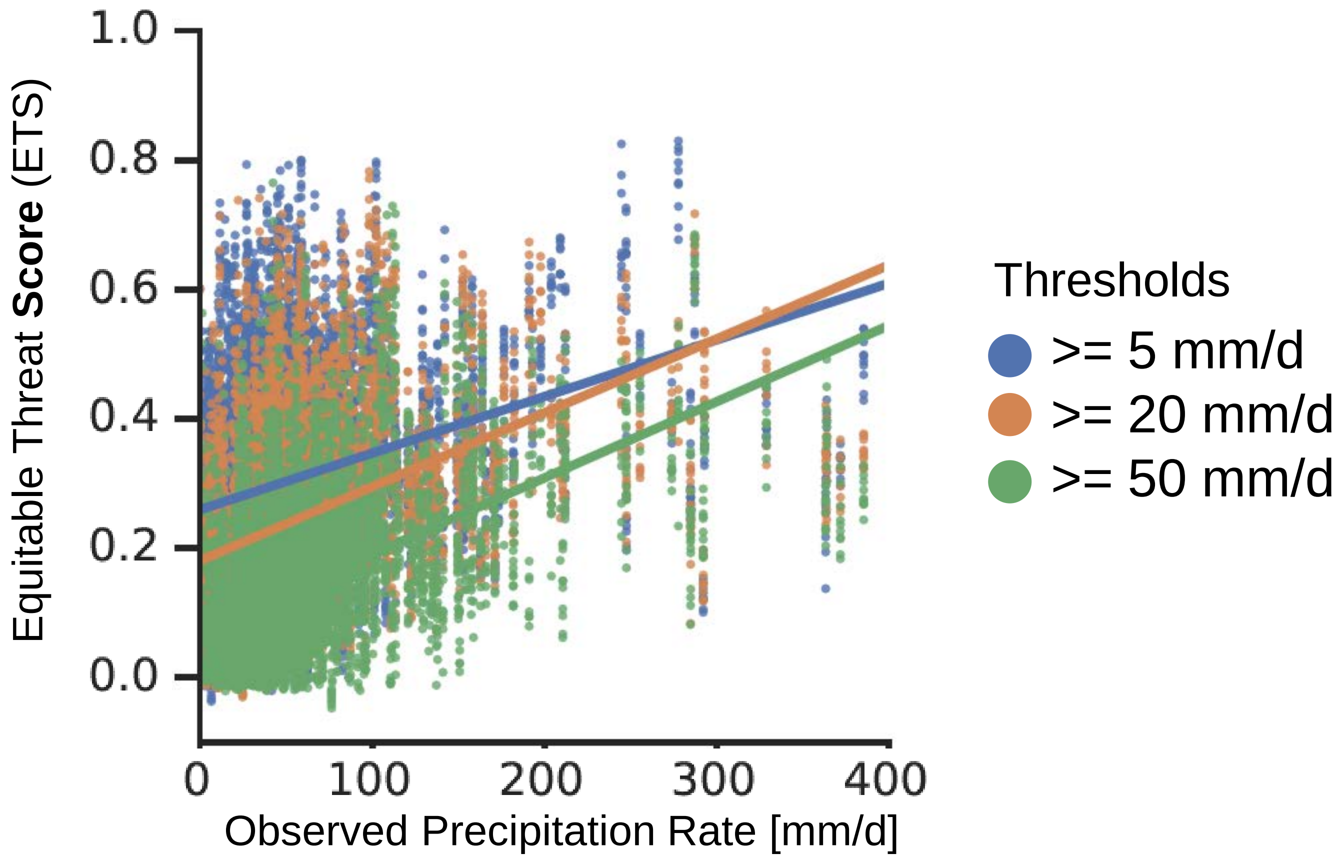
# Are Intense Precipitation Events Harder to Simulate?

## Equitable Threat Score (ETS)

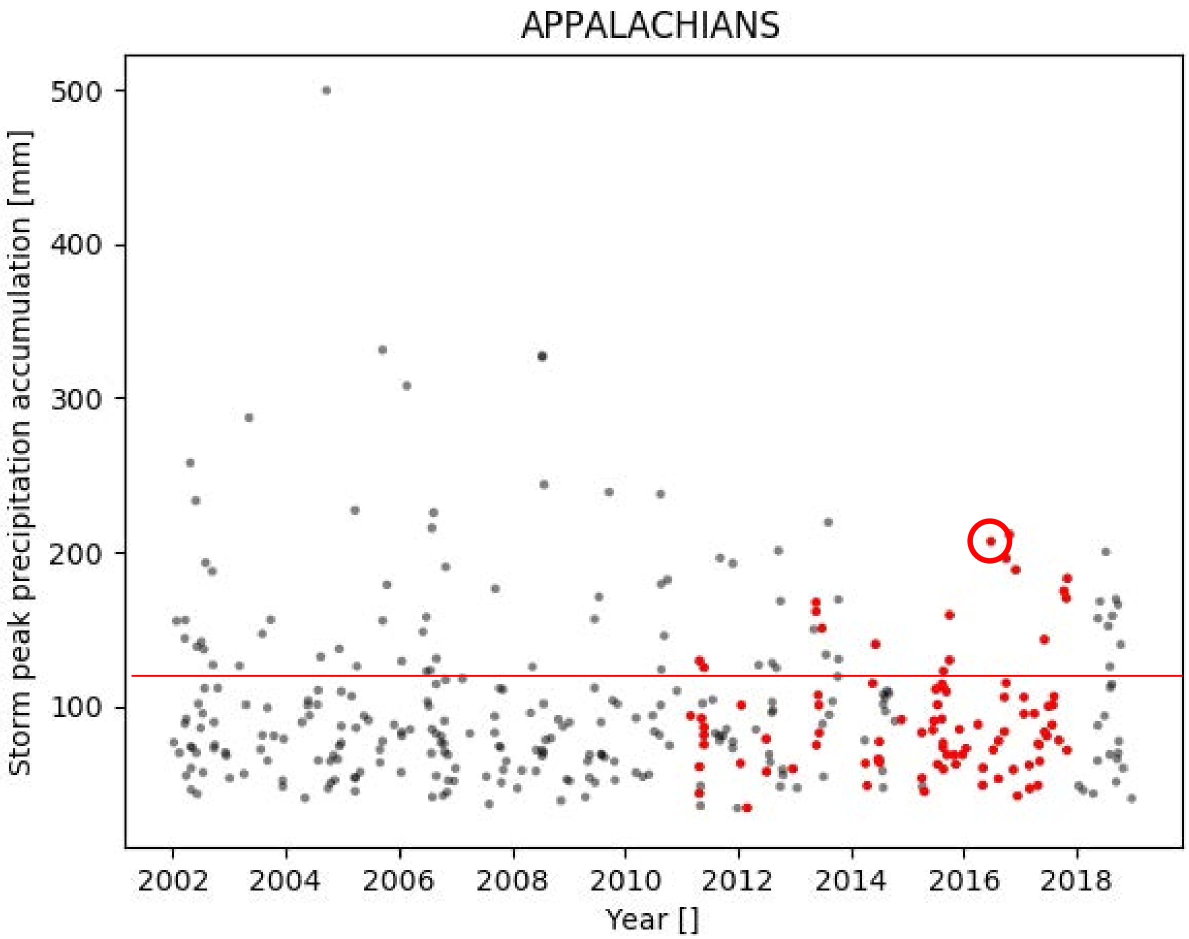



Model skill increases with intensity of event

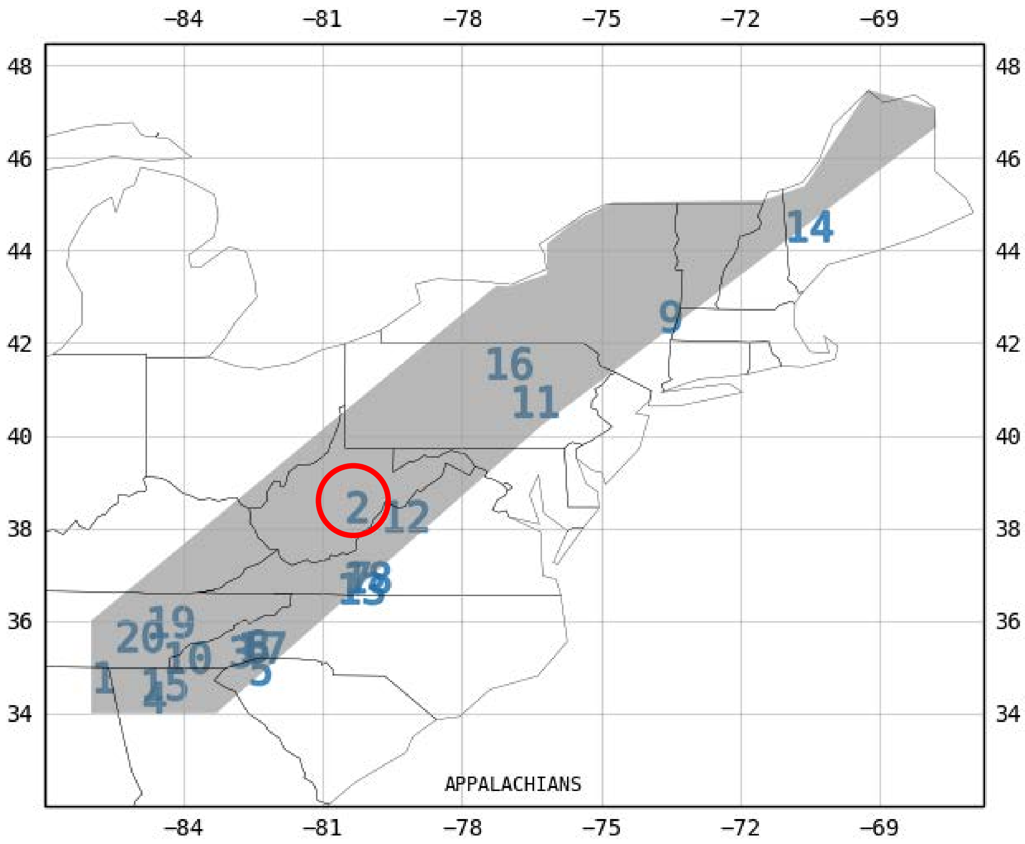
## Southern U.S.



# Case Selection | Top 20 Events in Each Region

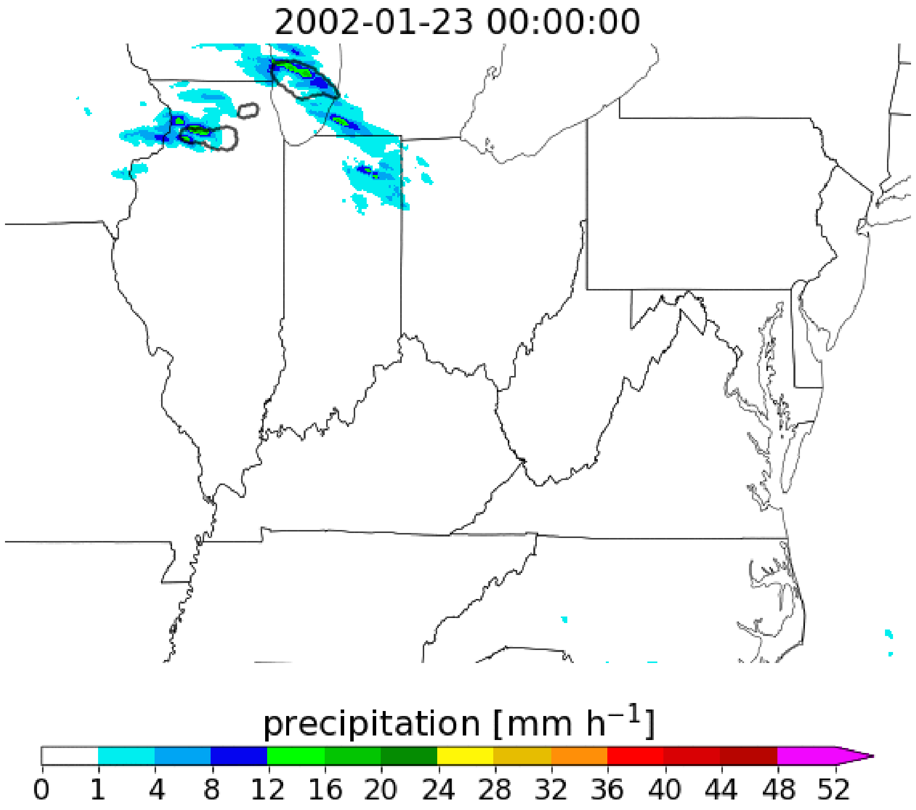


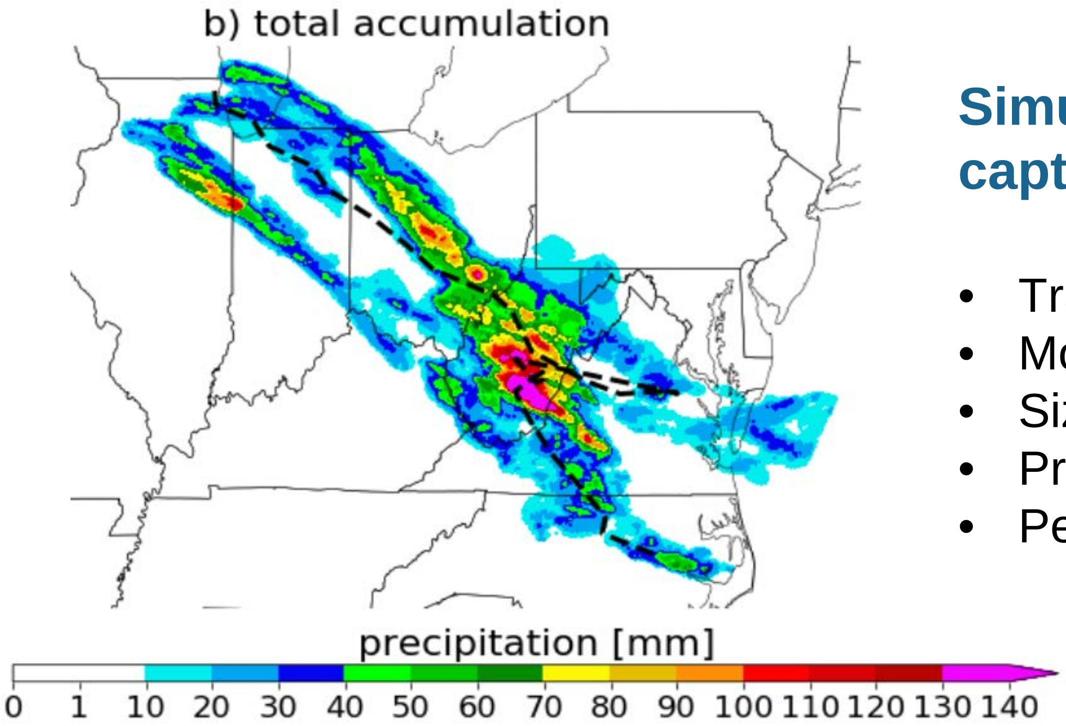

## Top 20 Events in Appalachia Region



# Lagrangian Evaluation Framework

## West Virginia Flooding of 2016



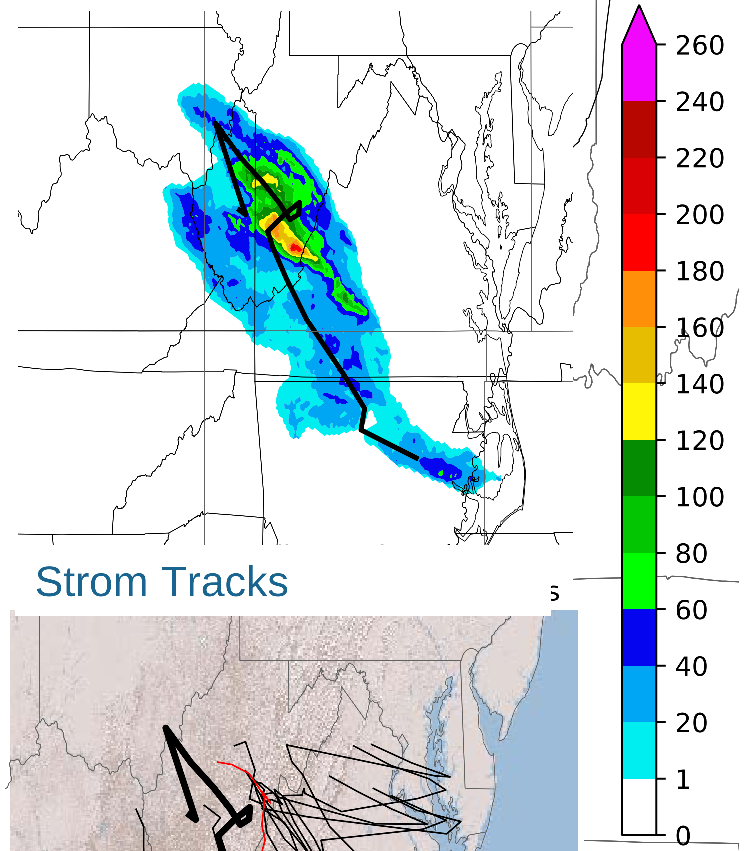




### Simulation has to capture:

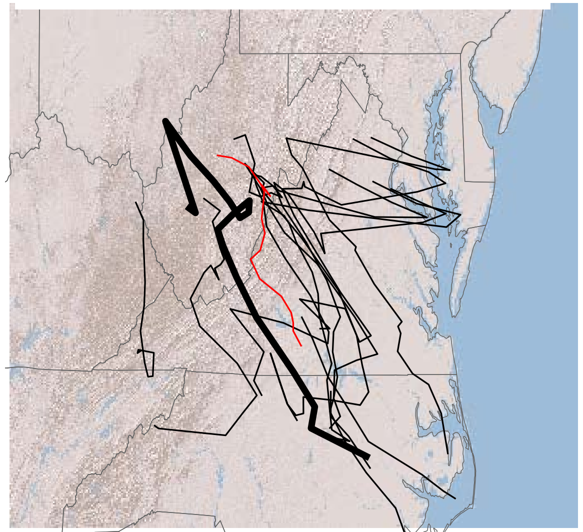
- Track
- Movement speed
- Size evolution
- Precipitation volume
- Peak accumulation

# West Virginia Flooding of 2016

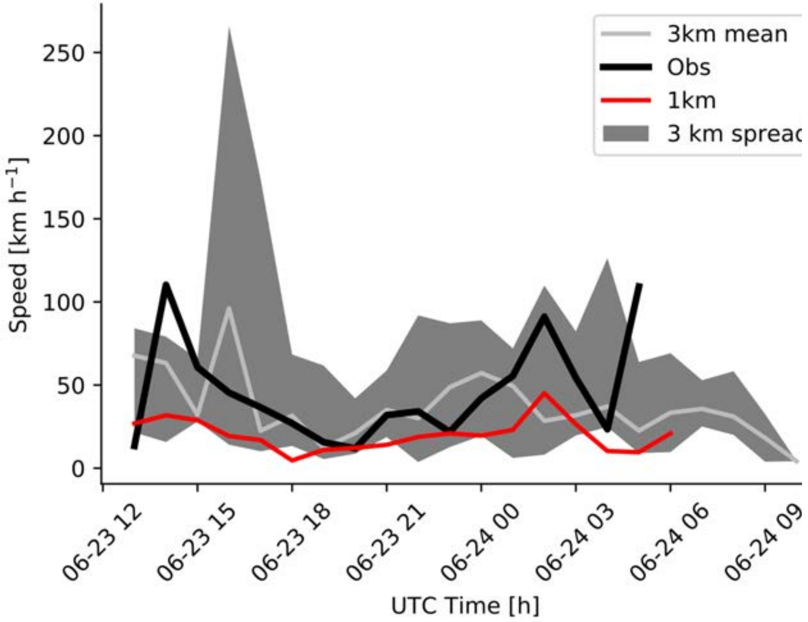
### Observed Accumulation



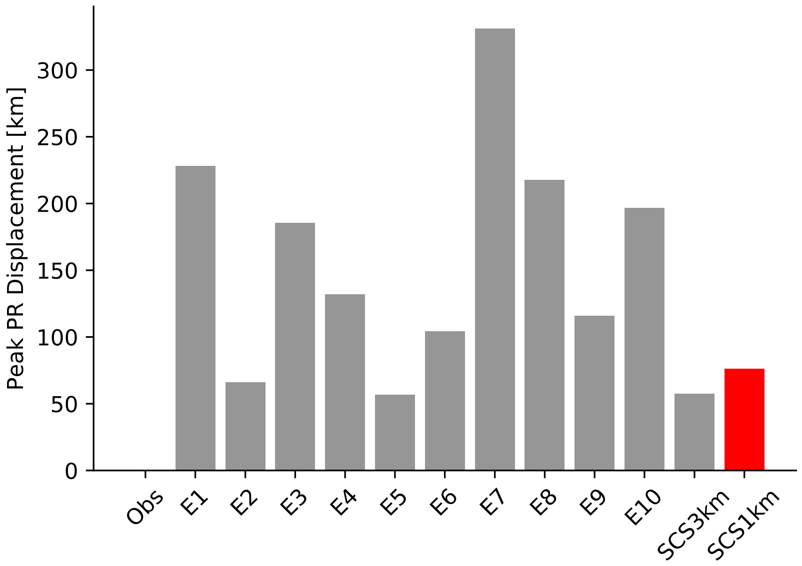

### Strom Tracks



### Storm Speed

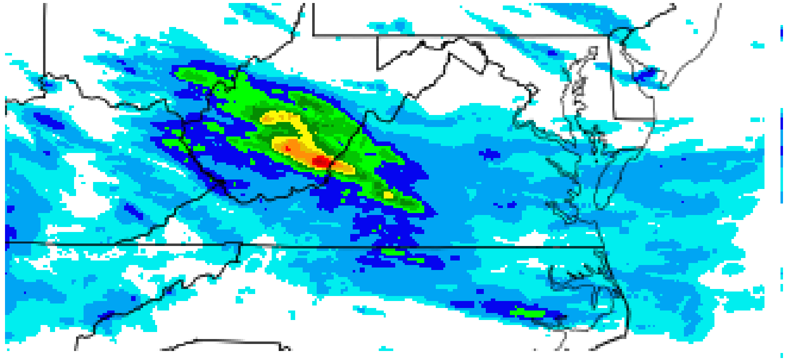



### Peak Displacement

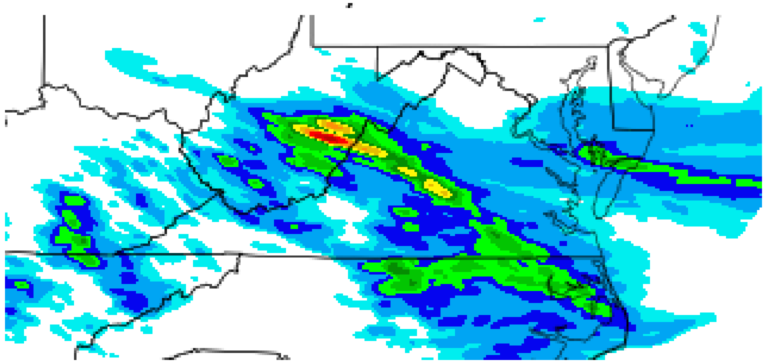


# West Virginia Flooding of 2016

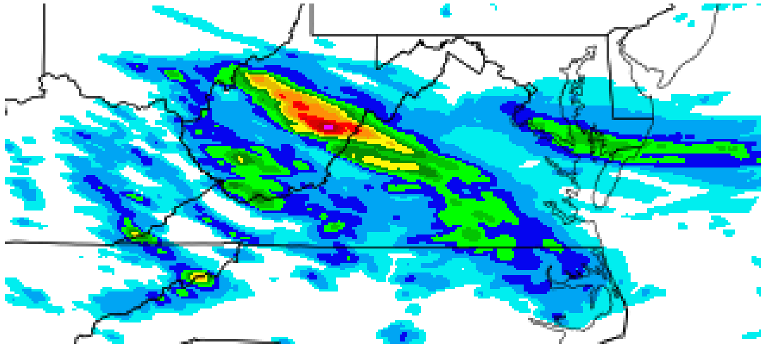
Observed Precipitation



Best Peak Accumulation

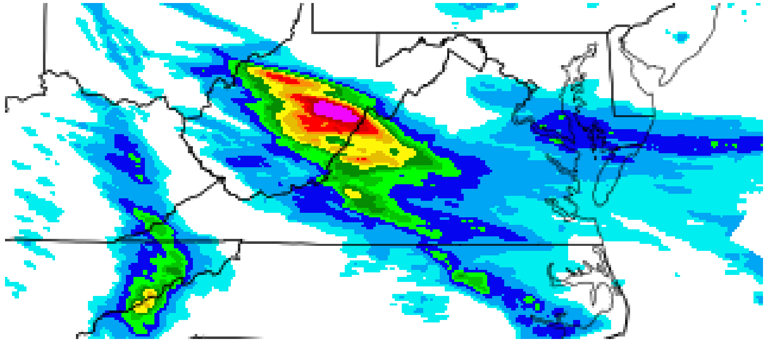


Best Peak Location

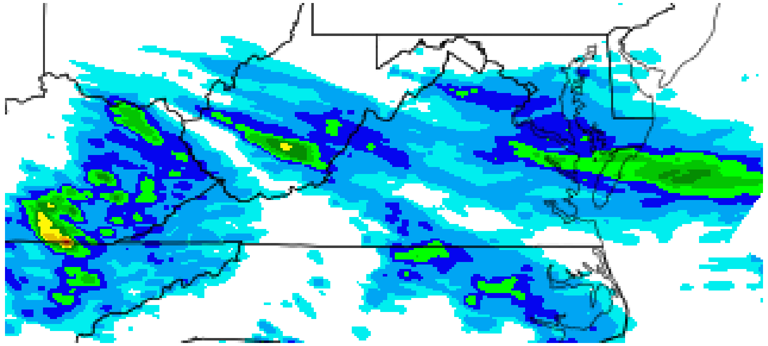


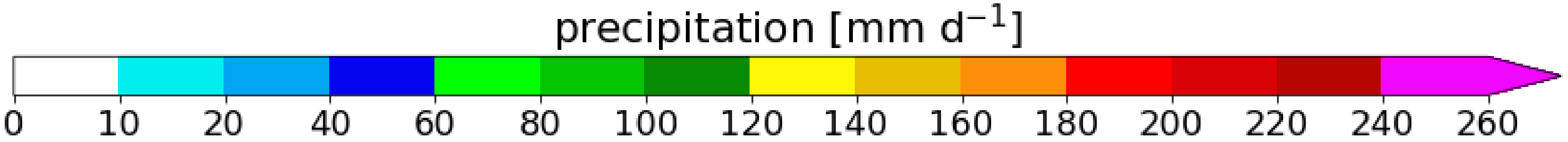
- Large spread due to initial condition perturbations
- 3 km and 1 km results are comparable
- 3 km seem to have too much rainfall on lee-side

Best Volume | 1 km



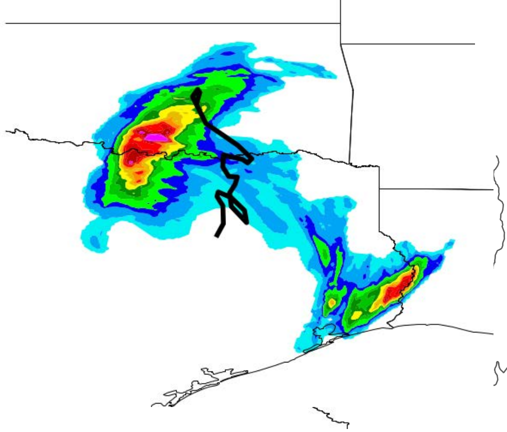
Worst Overall Simulation

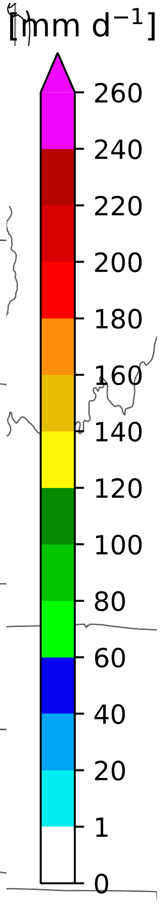




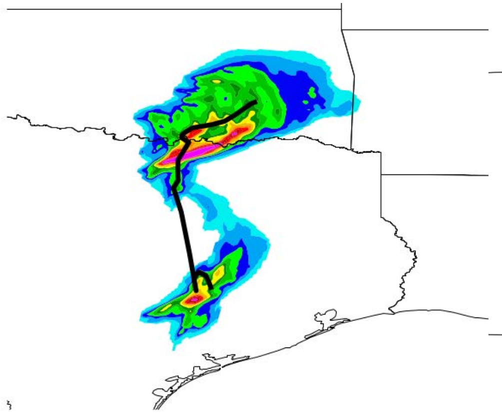
# Tropical Storm Bill | June 2015

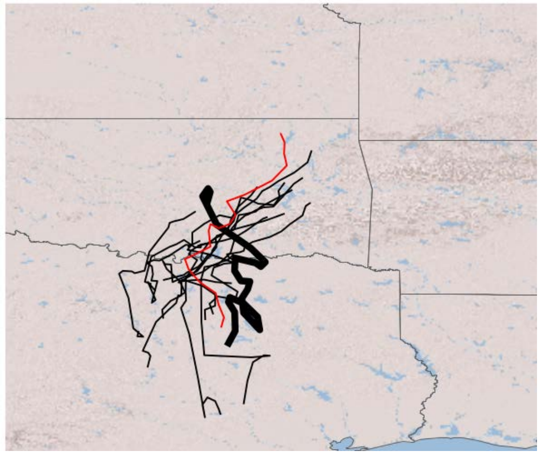
## Observed Precipitation



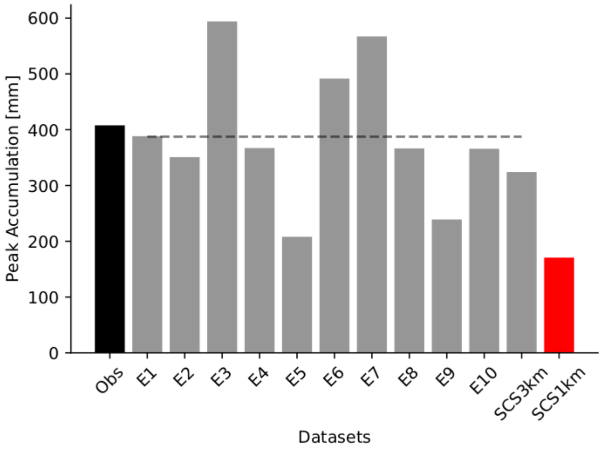



## Best Simulation

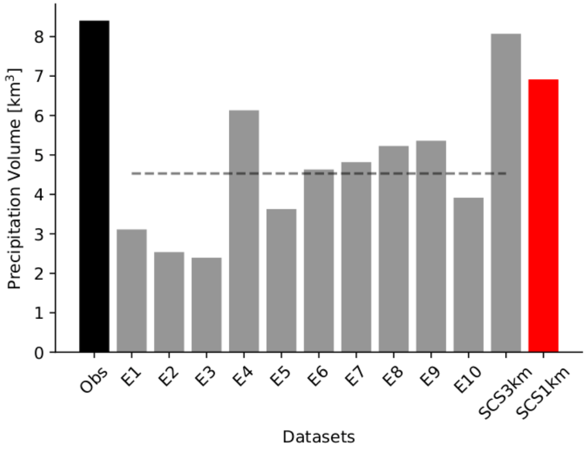




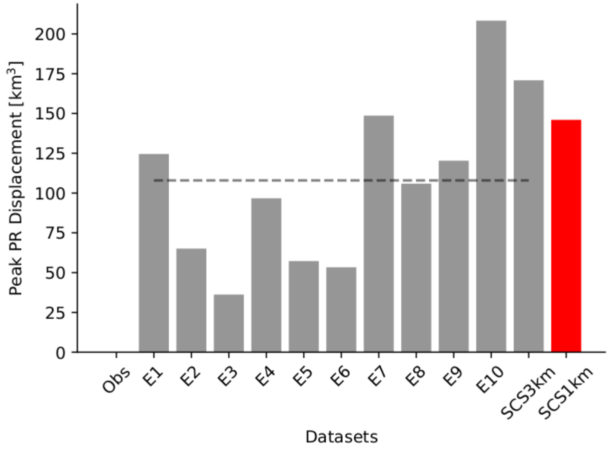
## Peak Accumulation




## 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)<br>Mosaic WSR-88D (Zhang and Gourley 2018)<br>PRISM (Daly et al. 1994, 2002, 2008)<br>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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