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Simulating Convective Storms

An Object Based Evaluation of a Continental-Scale Convection-Permitting Climate Simulation

Andreas F. Prein, Kyoko Ikeda, Changhai Liu, Roy Rasmussen, Randy Bullock

GEWEX Convection-Permitting Climate Modeling Workshop
National Center for Atmospheric Research, Sept. 6th 2016
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Motivation

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“The **largest potential for added value** in convection-permitting climate simulations can be found on **small spatial and temporal scales**…”

AGU PUBLICATIONS

Reviews of Geophysics

REVIEW ARTICLE

10.1002/2014RG000475

Key Points:
- Convection-permitting climate models reduce errors in large-scale models

A review on regional convection-permitting climate modeling: Demonstrations, prospects, and challenges

Andreas F. Prein[1,2], Wolfgang Langhans[3], Giorgia Fosser[4], Andrew Ferrone[5], Nikolina Ban[6], Klaus Goergen[7,8,9], Michael Keller[6,10], Merja Tölle[11], Oliver Gutjahr[12], Frauke Feser[13], Erwan Brisson[14], Stefan Kollet[9,15], Juerg Schmidli[6,10], Nicole P. M. van Lipzig[16], and Ruby Leung[17]

Simulating on the Storm-scale

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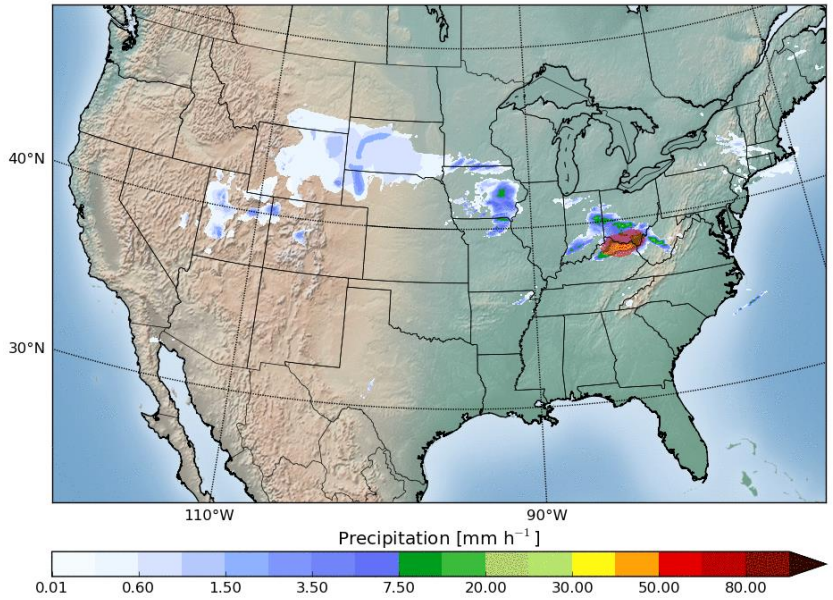
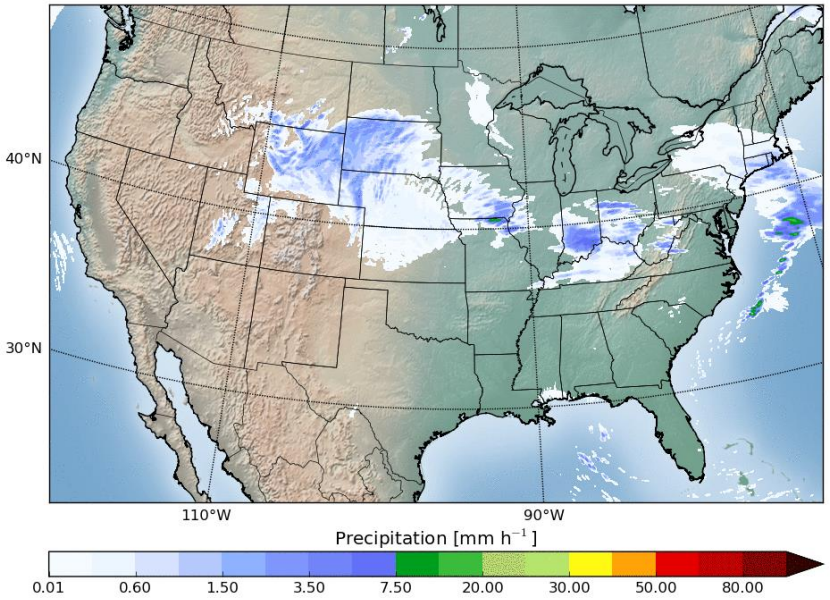
Convective outbreak in May 2010

Observation

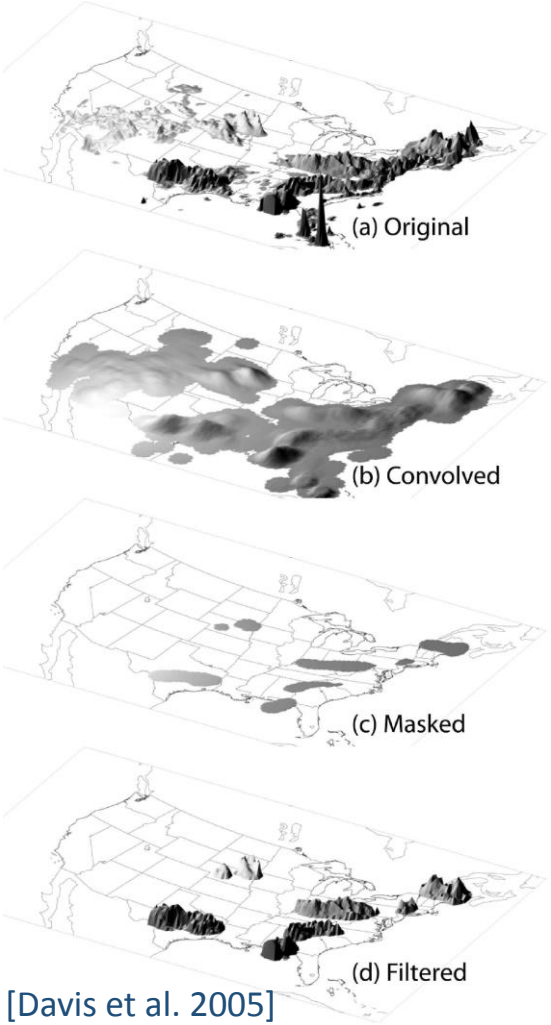


WRF 4 km



- Objective based analysis allows to evaluate model on the storm scale

Method for Object-based Diagnostic Evaluation (MODE) Time Domain (MODE-TD)



[Davis et al. 2005]

Gridded precipitation

↓

"Smoothed"

↓

Masked with threshold

↓

Original data gets filtered by mask → objects

Evaluation of WRF 4 km CONUS climate simulation

Simulation Domain and Setup

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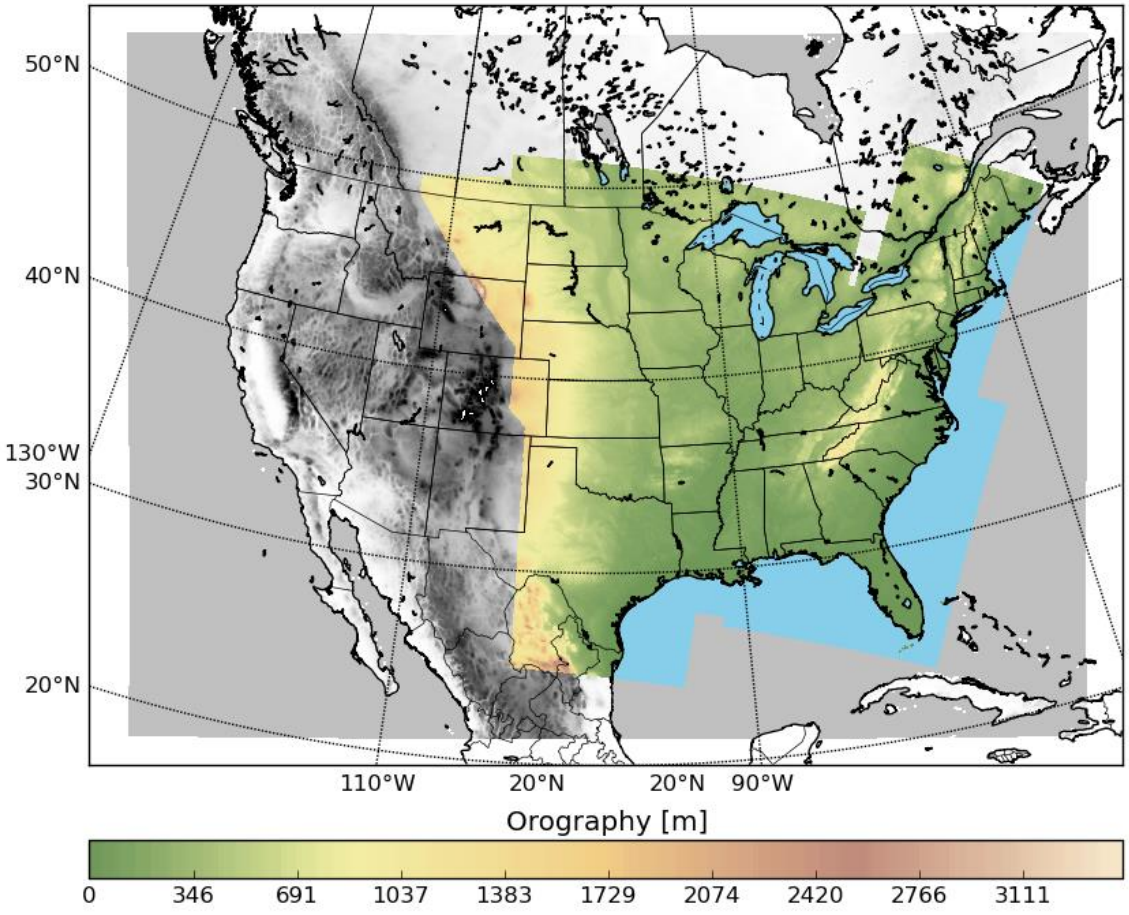
WRF 4 km | 1359 x 1015 grid cells
12 years (2002-13)



Physics

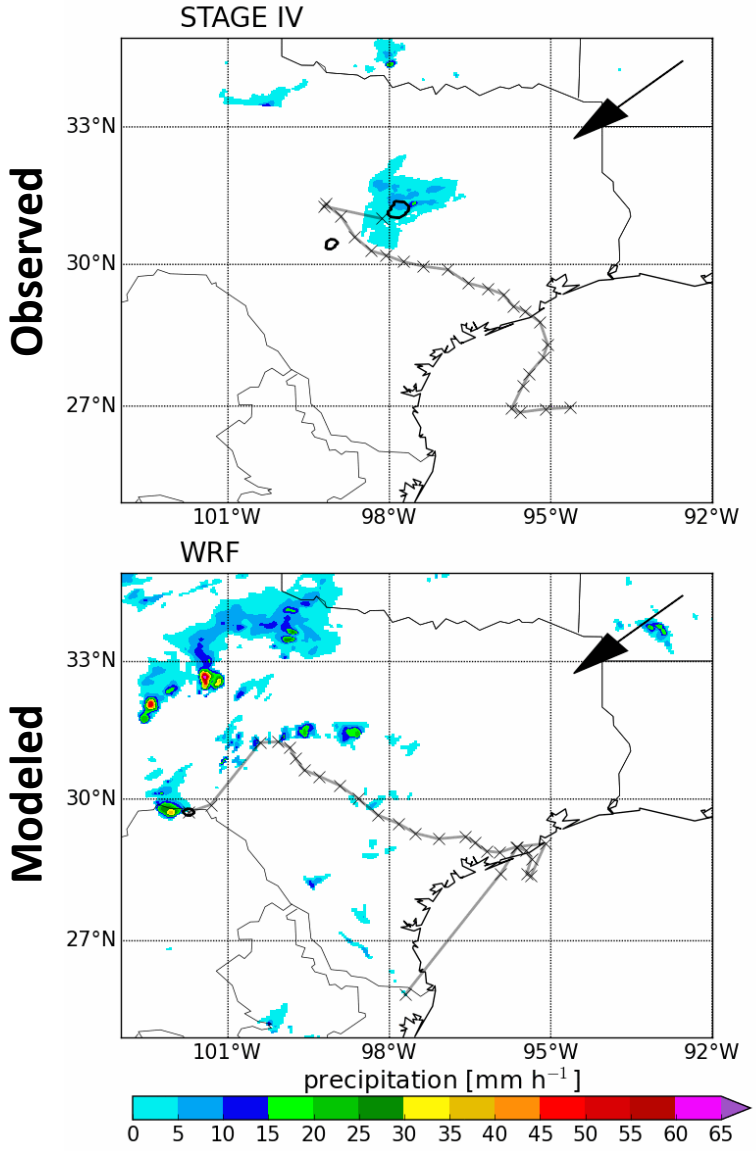
- Microphysics
  Thompson aerosol-aware
  [Thompson and Eidhammer 2014]
- Radiation RRTMG
  [Iacono et al. 2008]
- Land-surface model
  NOAH-MP
- Boundary layer YSU
  [Hong et al. 2006]

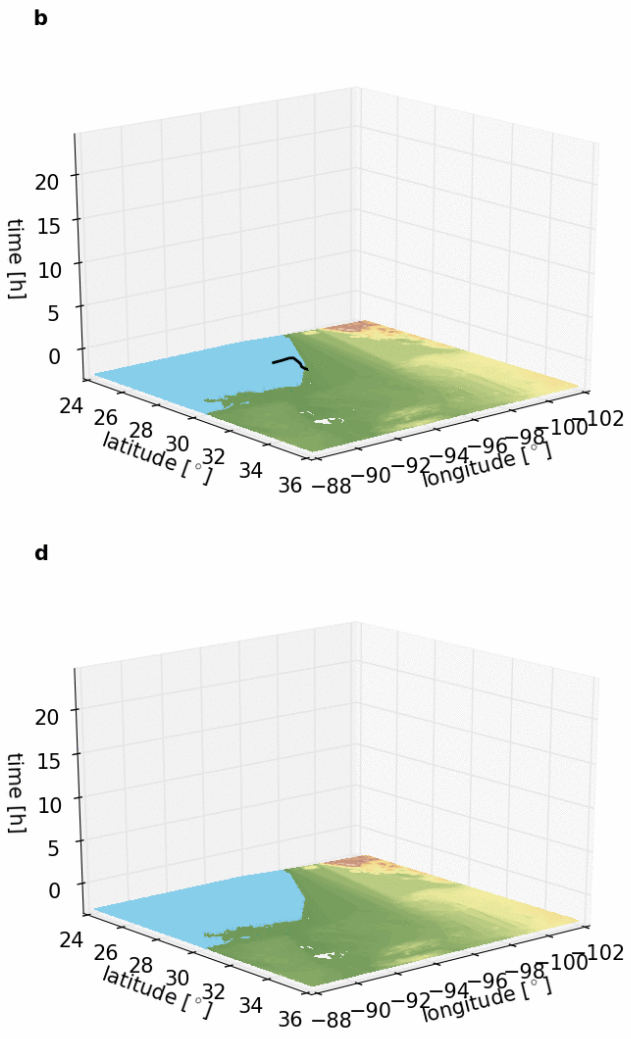
Spectral Nudging

U, V, T, and ZG above the PBL

Liu et al. 2016

MCS in Texas during March 2007





MCS in Texas during March 2007

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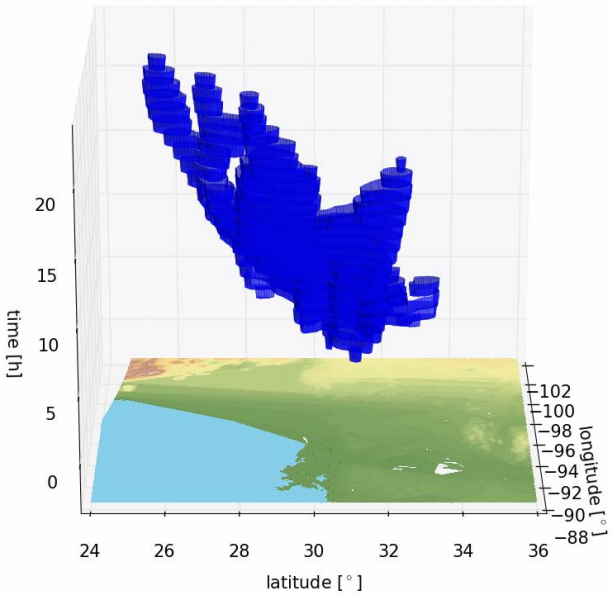
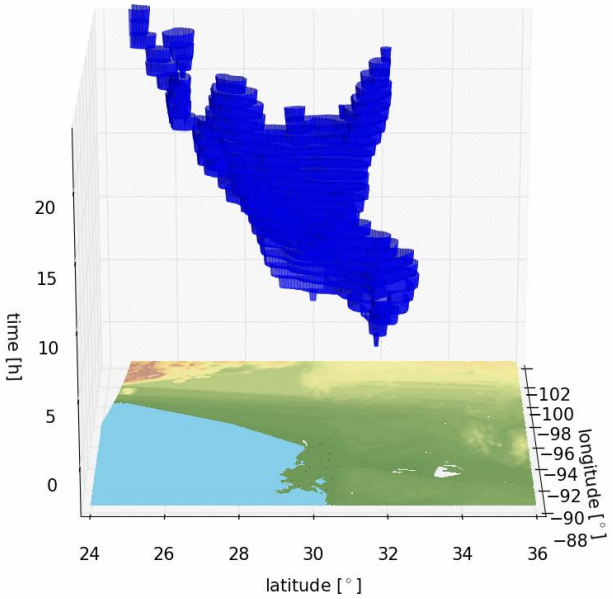
Observed



Modeled



4 km WRF model is able to simulate the precipitation form MCSs realistically

Storm Characteristics

- Speed
- Lifetime
- Size
- Maximum Intensity
- Total Precipitation
- …

June, July, and August Storm tracks

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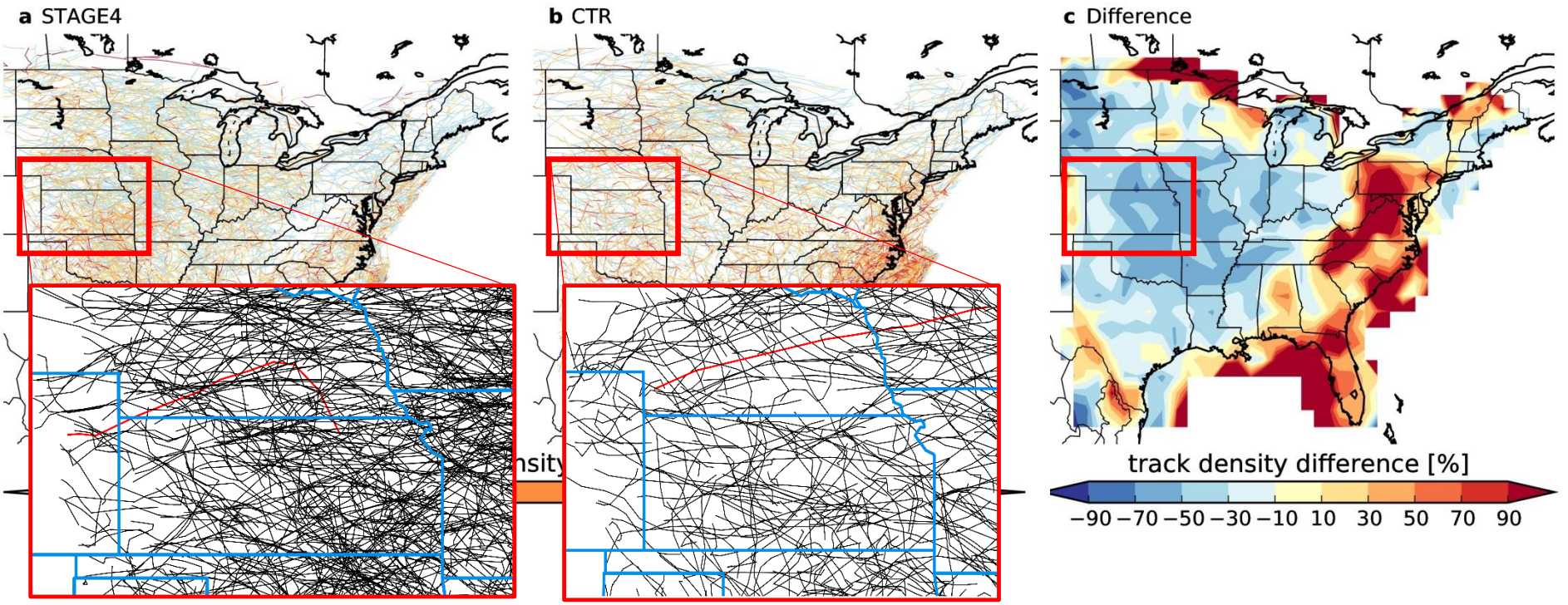
Observed | **Modeled** | **Track density difference**



- Realistic representation of storm tracks
- Underestimation of storms in Central U.S. by up to -70 %

Annual Cycle of Storms

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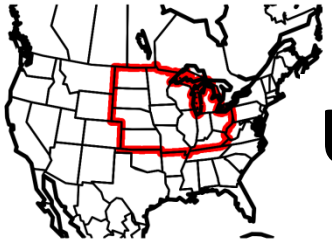
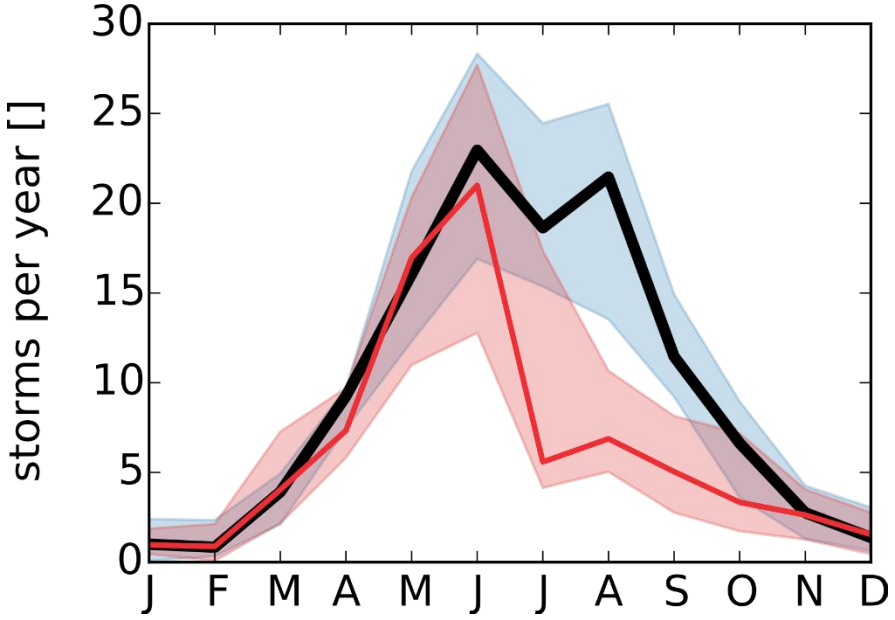
Observation

Model

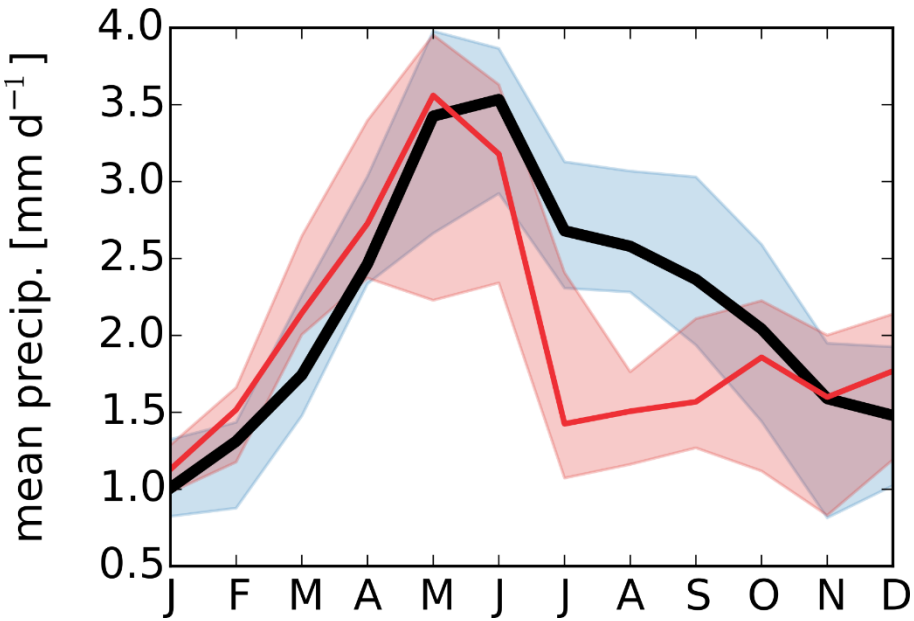


U.S. Midwest

Storms per Year



Mean Precipitation



Underestimation in storm frequency in July and August causes dry bias

Storm Environments in Midwest

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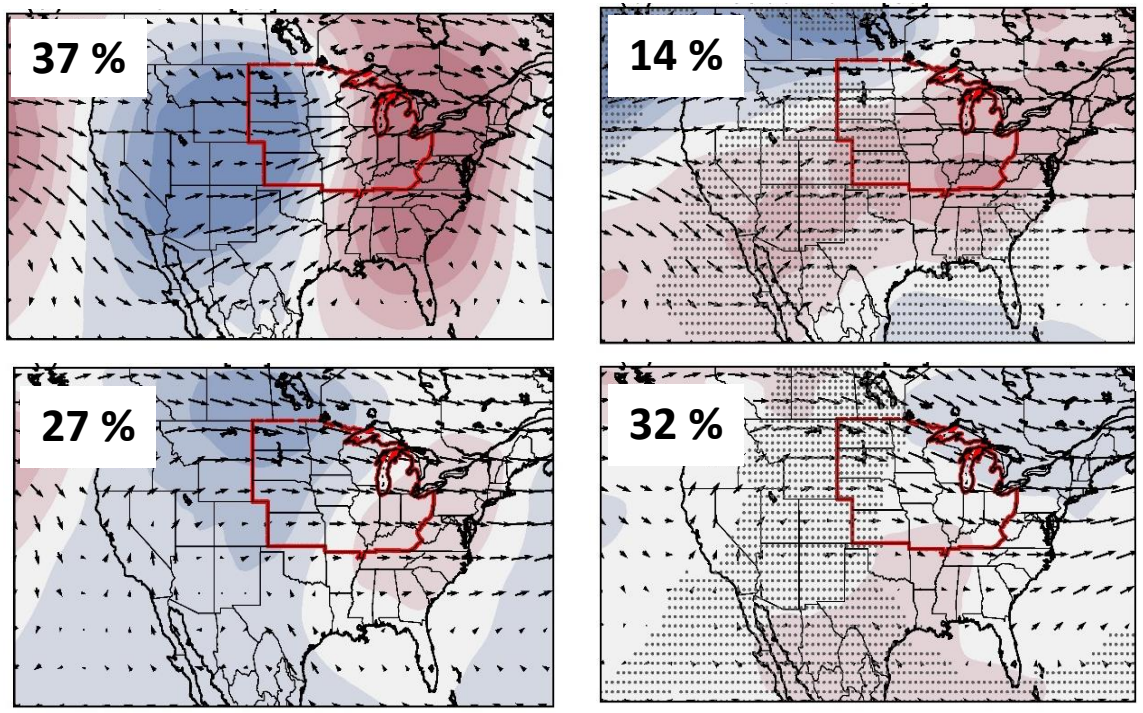
Hit Events

Storms in Obs. and in Mod.

May

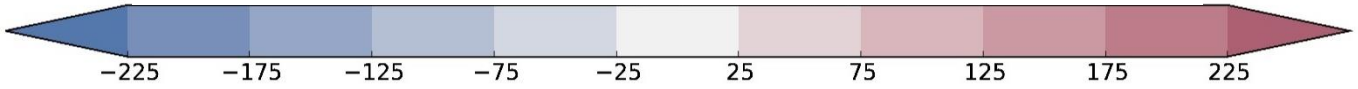
July



Missed Events

Storms in Obs. but not in Mod.

700 hPa geopotential height anomaly

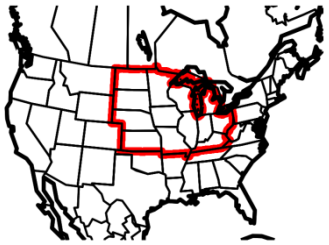


WRF is not able to trigger storms in weakly forced conditions

Storm attributes – Midwest region

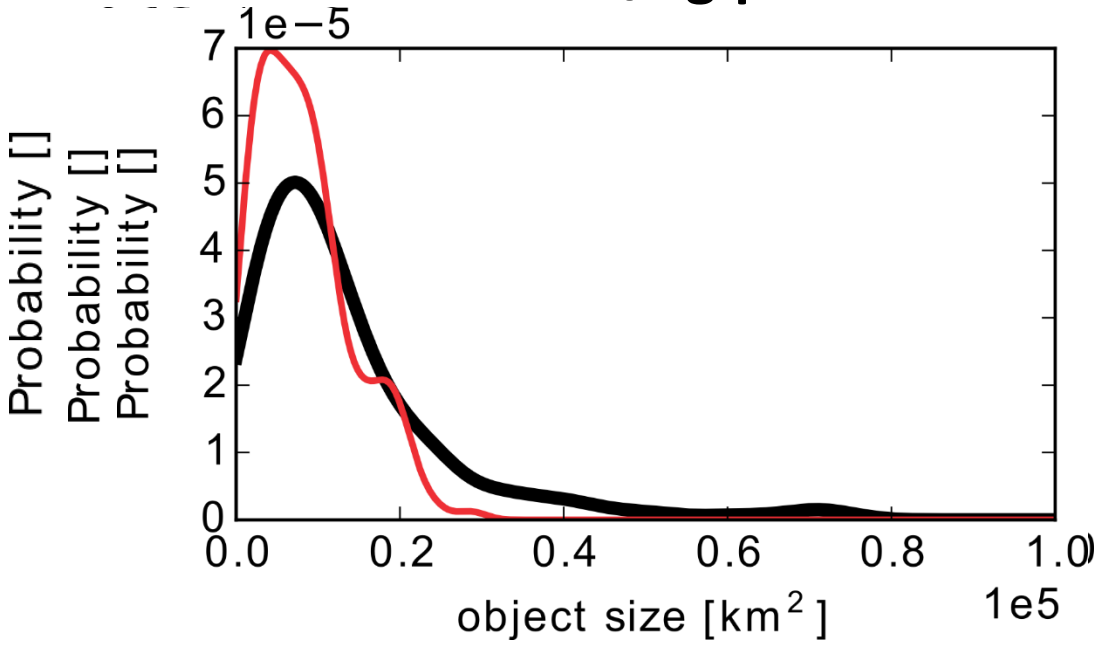
Observation

Model



Superior representation of storm

- Speed
- Maximum Precipitation
- Lifetime
- Track length



Storm development – Midwest region
Storms between 10 to 20 hours Lifetime

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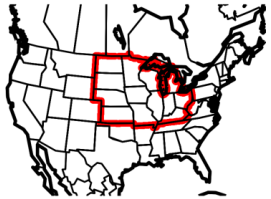
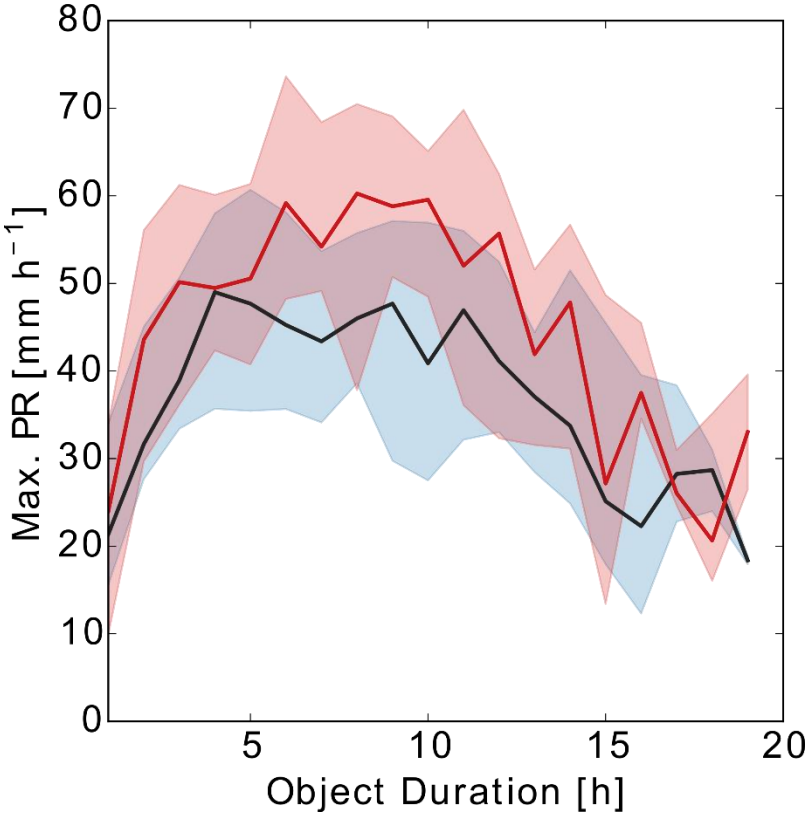
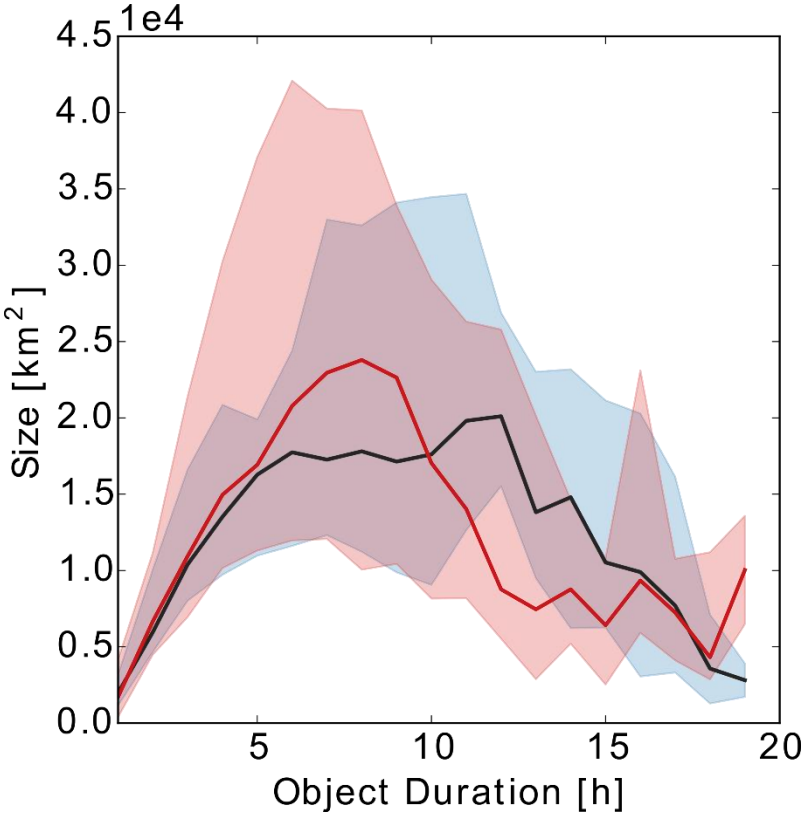
Observation

Model



- Storms reach maximum intensity after 1-8 hours
- Short storms reach maximum size after 3-4 hours long storms after ~7 hours





Conclusion

- We are able to simulate realistic convective storms
- MTD can provide unrepresented insights in model performance
- Investigation of future changes in storm characteristics

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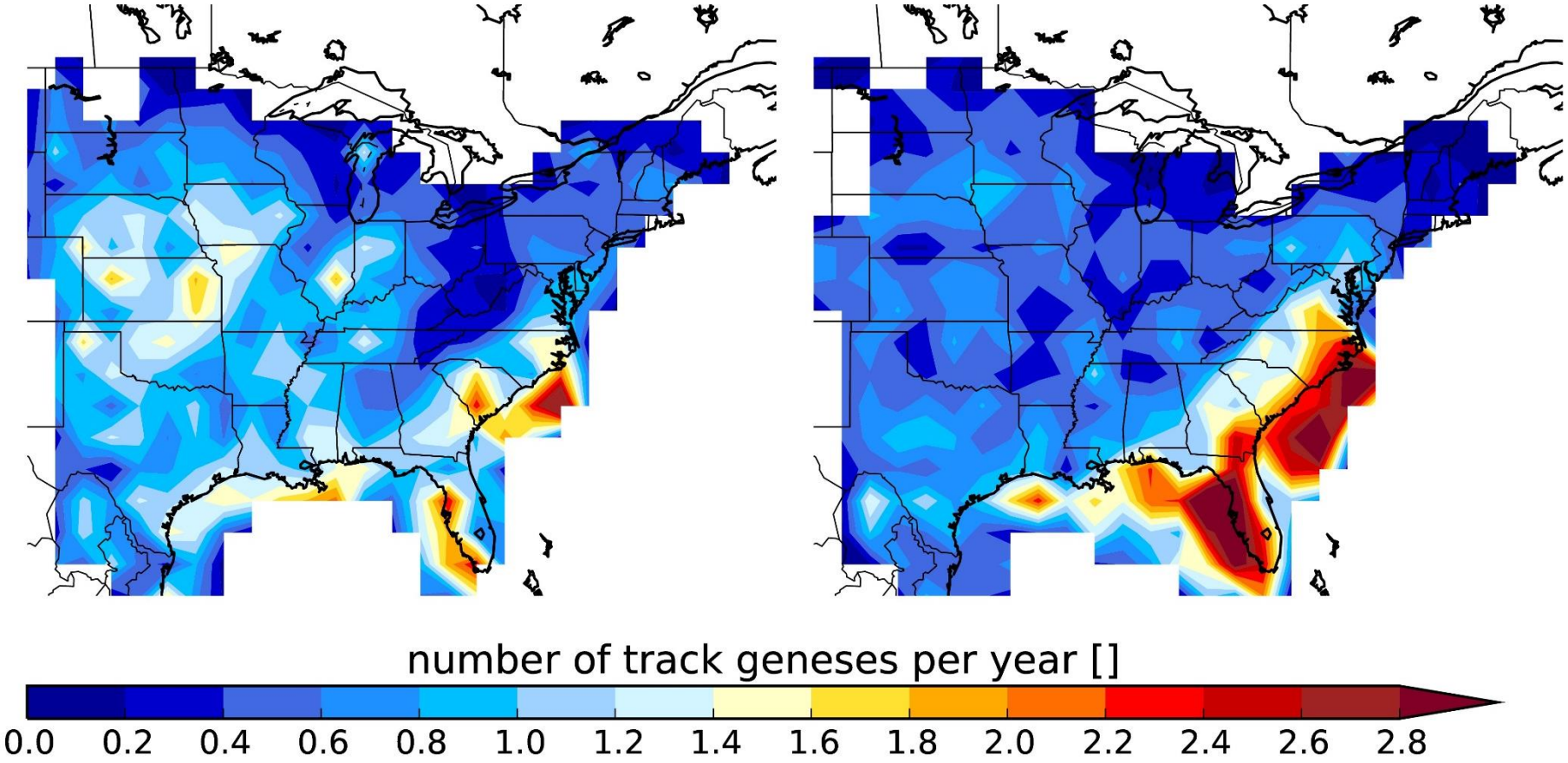
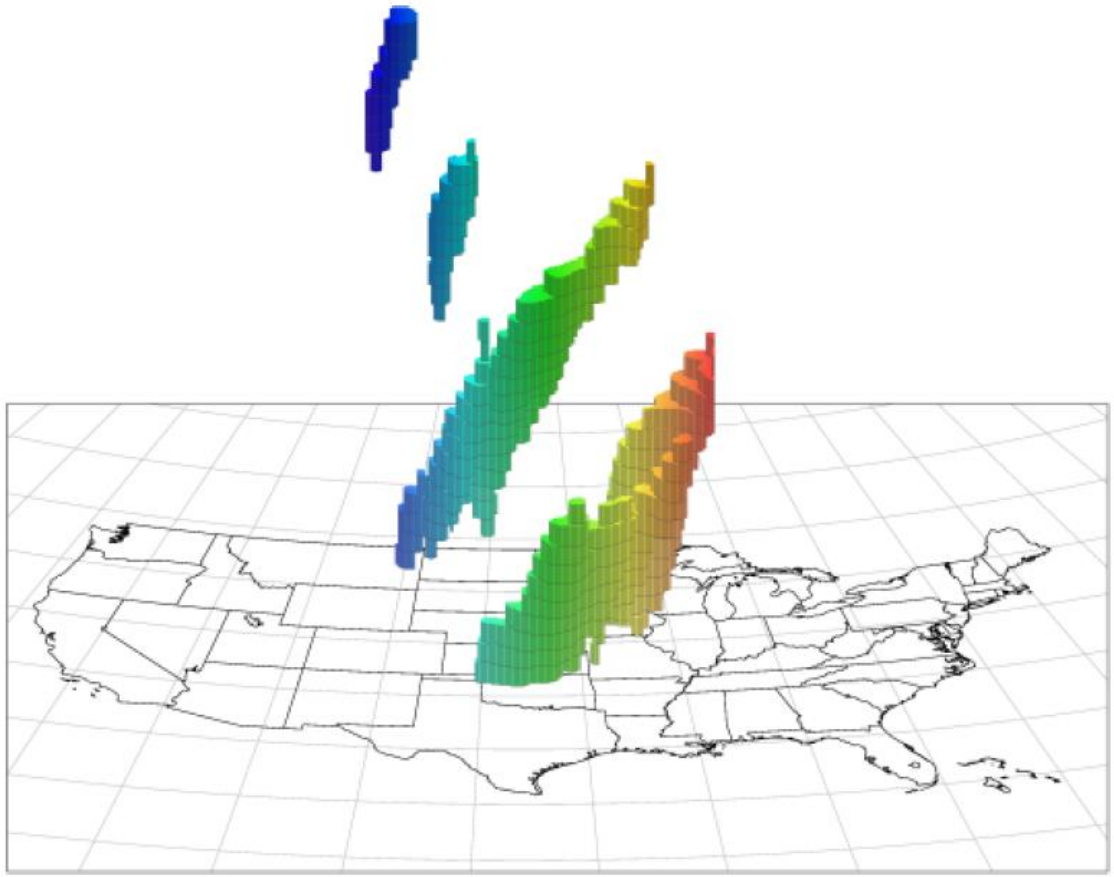
Thank you

Storm Genesis



- Underestimation of storm geneses in central U.S.
- Overestimation along the Golf and Atlantic coast

MODE Time Domain (MTD)



[Randy Bullock, NCAR]

Extension of the MODE tool to the time dimension

Storm Environments in Midwest

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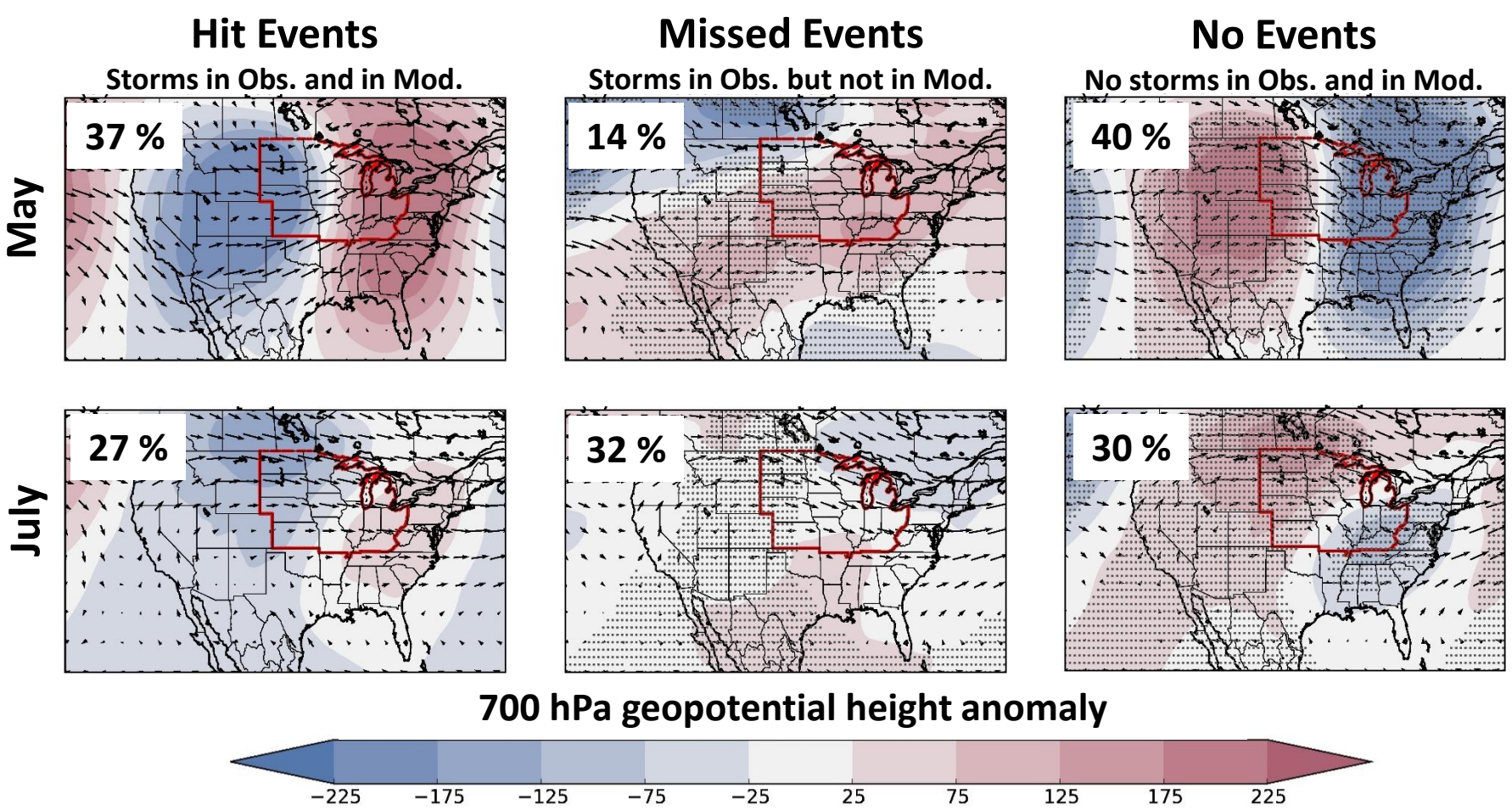

WRF is not able to trigger storms in weakly forced conditions

Method for Object-based Diagnostic Evaluation (MODE) Time Domain (MODE-TD)

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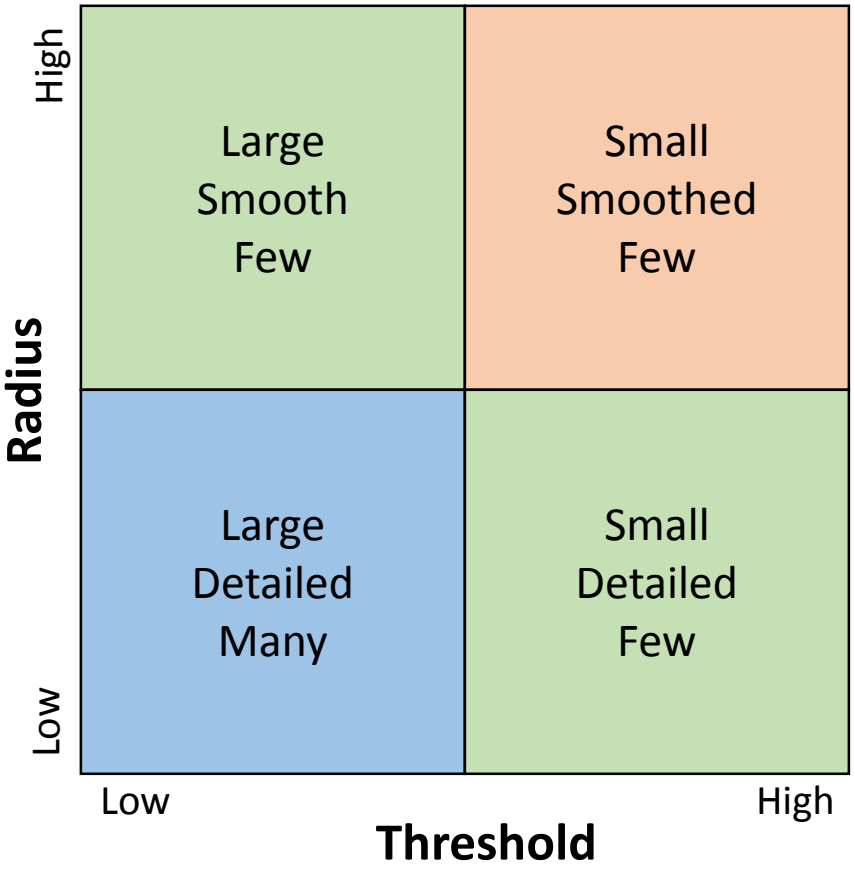
Smoothing Radius:
8, 16, and 32 km



Threshold:
2.5 and 5 mm/h

[adapted form
Randy Bullock]

Storm Movement

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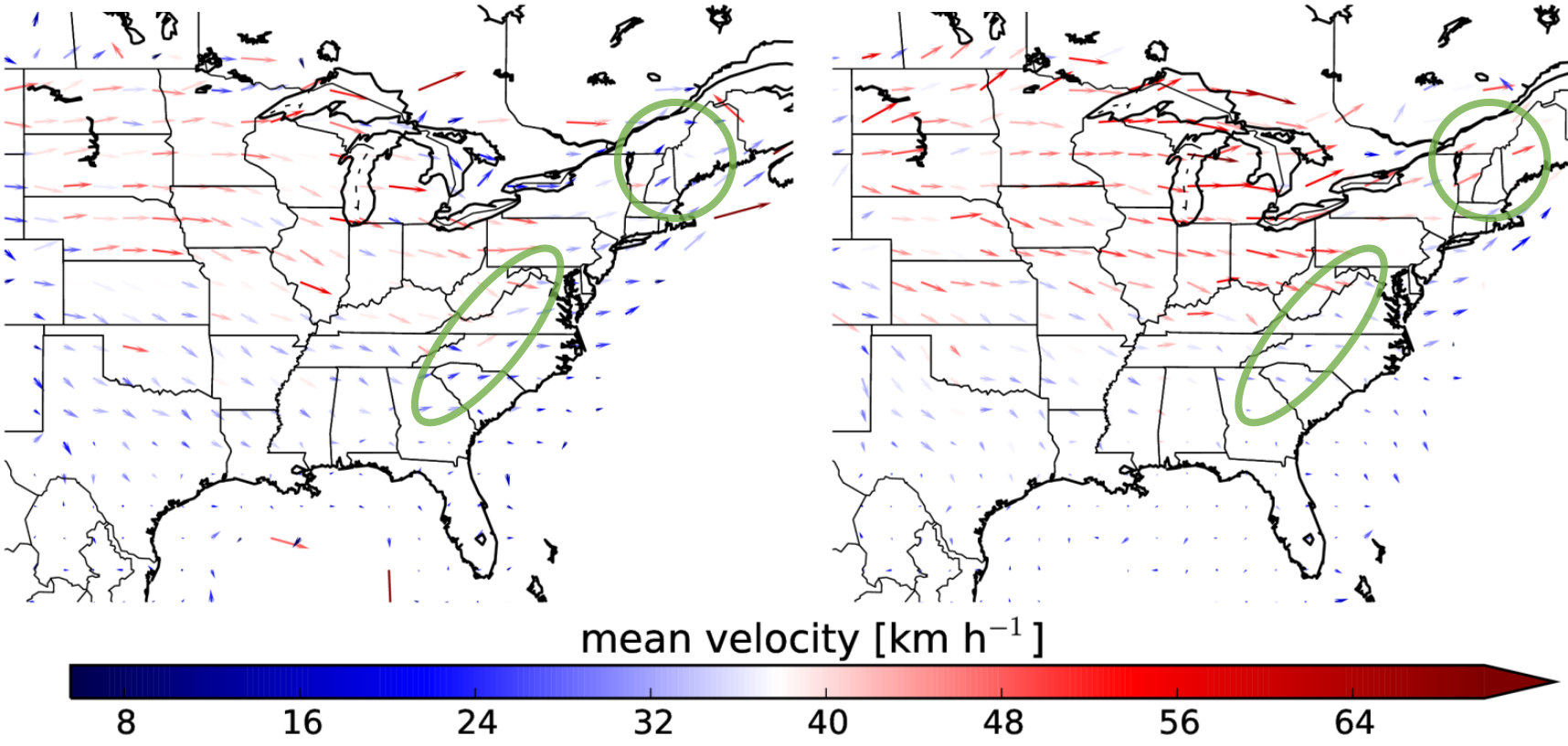
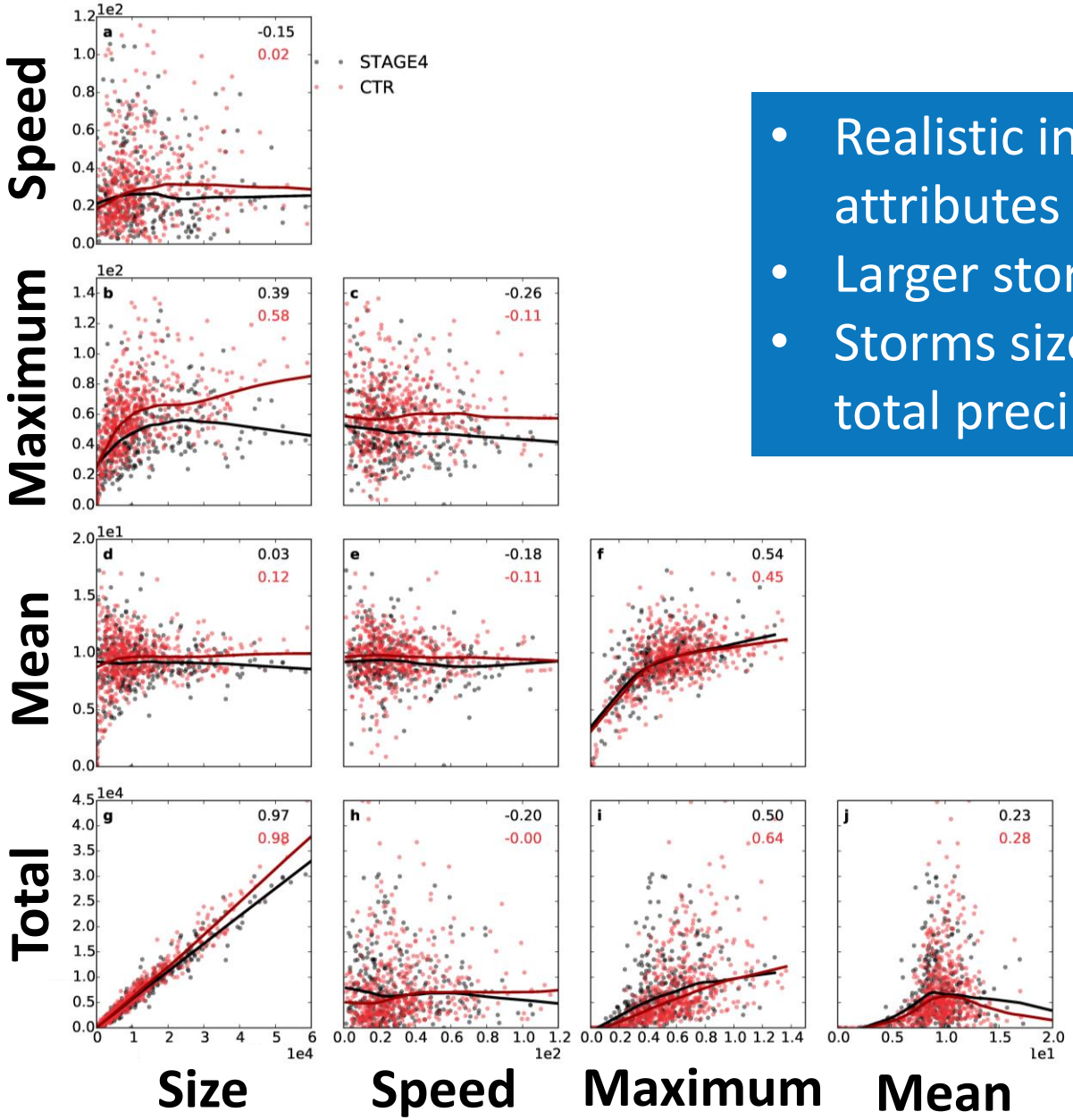
Observed

Modeled



- Fast storms in the north, slow storms in the south
- Local differences between WRF and STAGE IV

Object properties intercorrelations



- Realistic intercorrelation of storm attributes
- Larger storms are more intense
- Storms size correlates with storm total precipitation

Diurnal Cycle of storm densities

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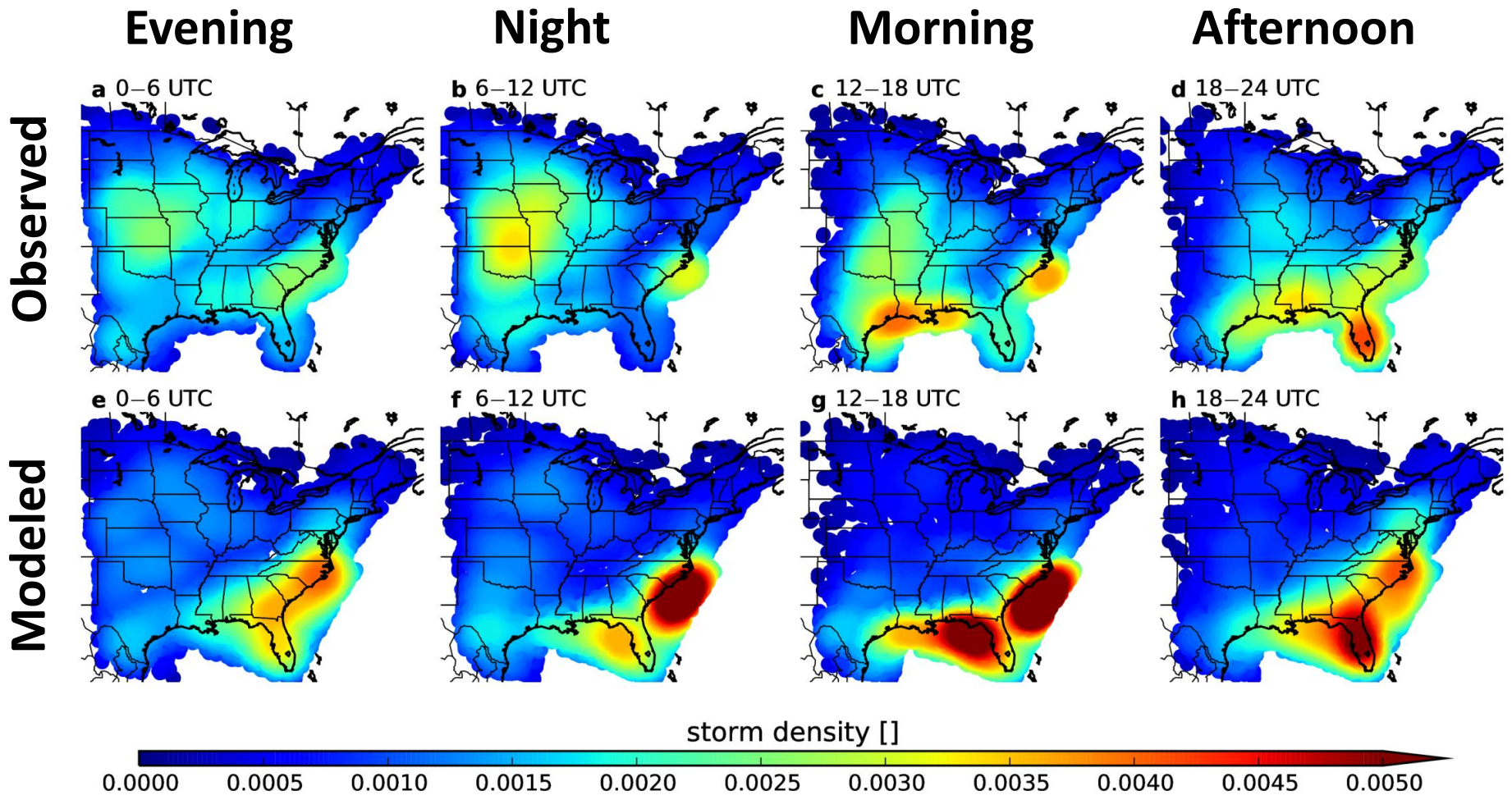
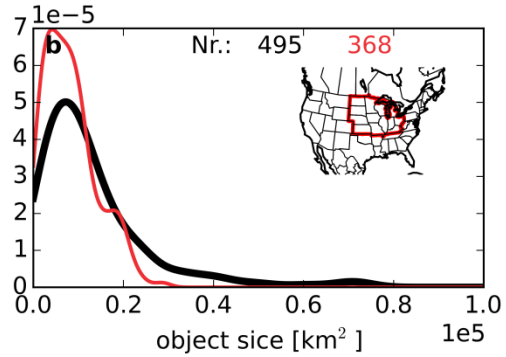
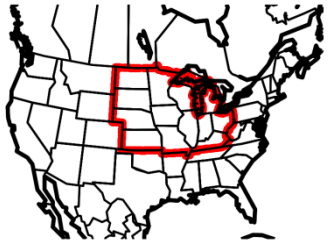


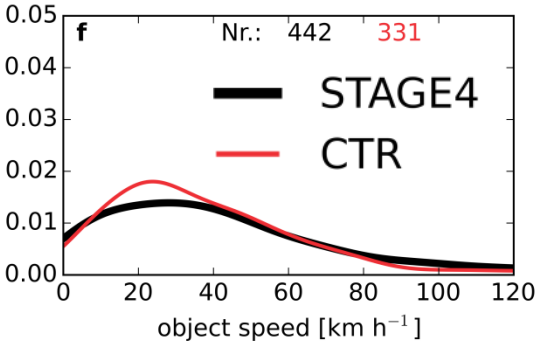
- Largest difference during nighttime in Central U.S.
- Overestimation at Golf and Atlantic Coast?

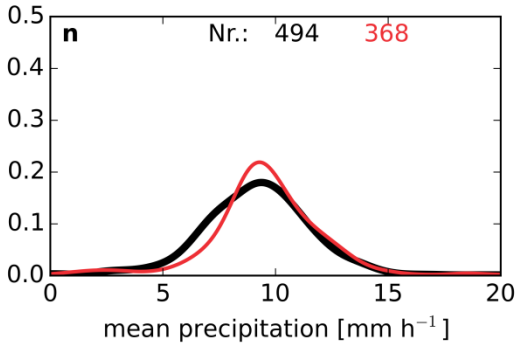
Storm attributes – Midwest region

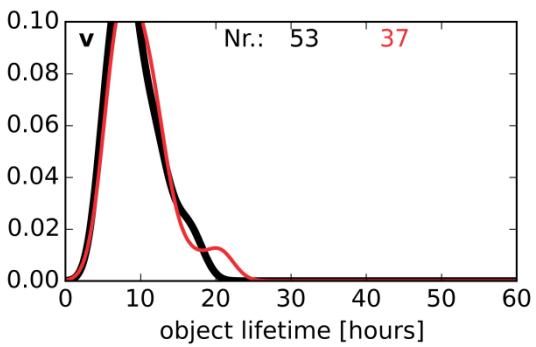


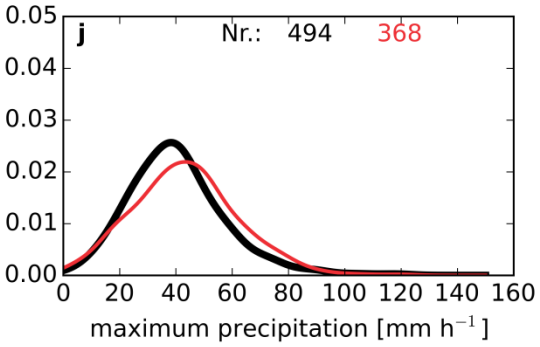


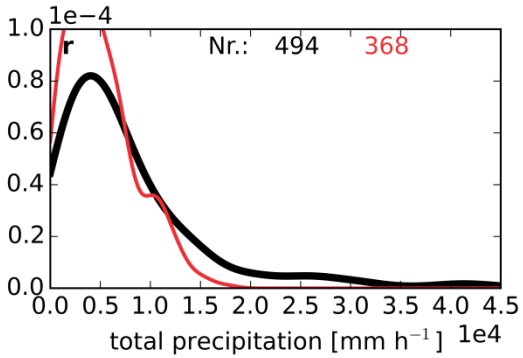
- Superior representation of storm attributes
- But underestimation of total storms

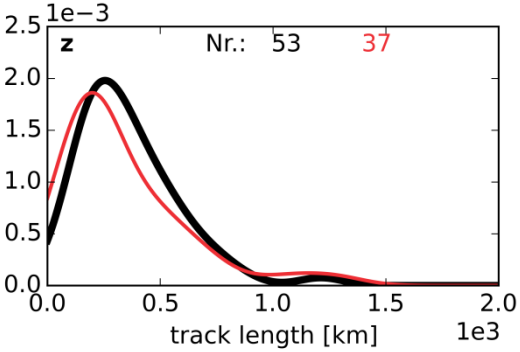




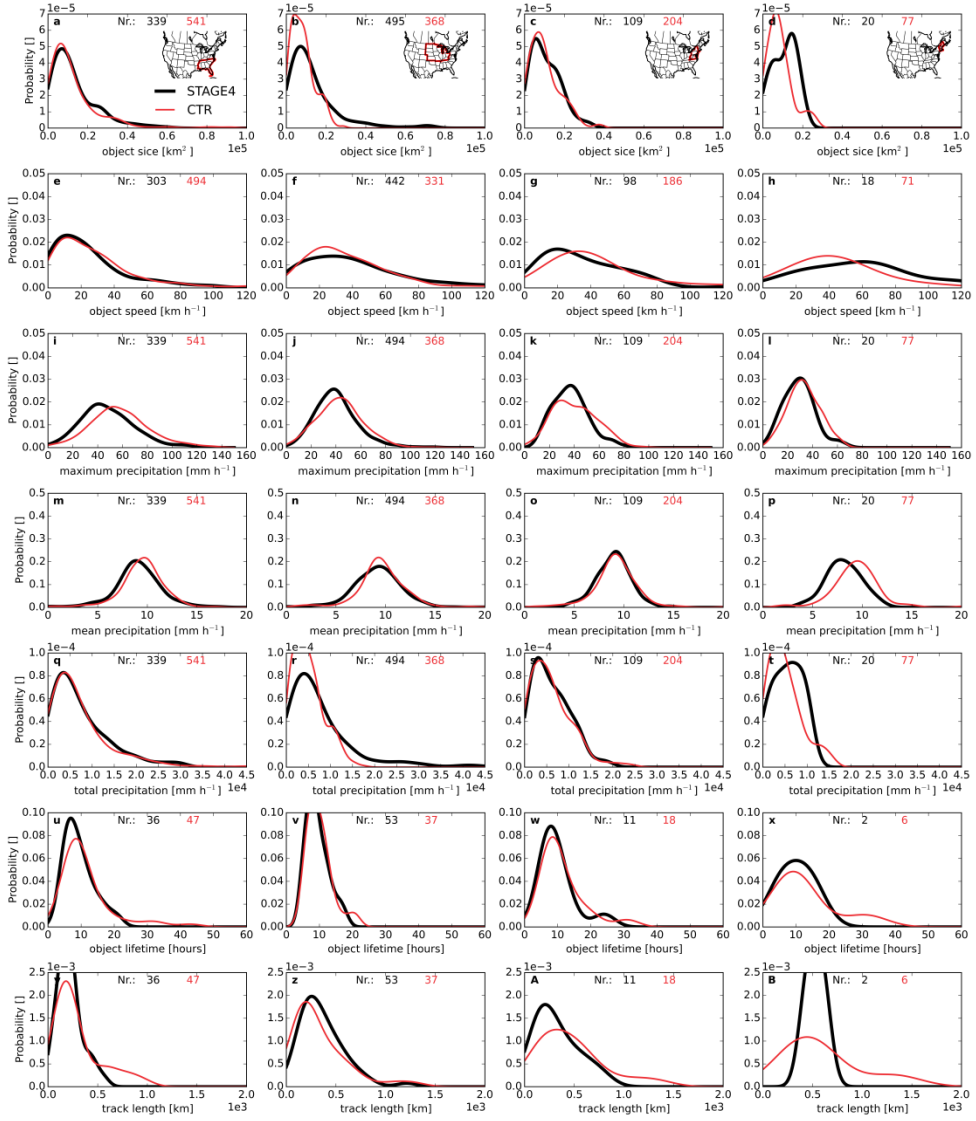








Object Properties



Future changes storm attributes