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

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Motivation

The largest potential for added value in convection-permitting climate simulations can be found on small spatial and temporal scales…
Simulating on the Storm-scale

Convective outbreak in May 2010

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

Observation

WRF 4 km
Method for Object-based Diagnostic Evaluation (MODE) Time Domain (MODE-TD)

Gridded precipitation

“Smoothed”

Masked with threshold

Original data gets filtered by mask → objects

[Davis et al. 2005]

http://www.dtcenter.org/met/users/
Evaluation of WRF 4 km CONUS climate simulation
Simulation Domain and Setup

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

[Map images showing observed and modeled precipitation patterns with a color scale indicating precipitation in mm h⁻¹.]

[3D plot with latitude and longitude axes showing a weather pattern evolution over time with a color gradient indicating precipitation.]
MCS in Texas during March 2007

4 km WRF model is able to simulate the precipitation form MCSs realistically
June, July, and August Storm tracks

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

Observation
Model

U.S. Midwest

Underestimation in storm frequency in July and August causes dry bias
Storm Environments in Midwest

Hit Events
Storms in Obs. and in Mod.

Missed Events
Storms in Obs. but not in Mod.

WRF is not able to trigger storms in weakly forced conditions

700 hPa geopotential height anomaly

-225 -175 -125 -75 -25 25 75 125 175 225
Storm attributes – Midwest region

- Observation
- Model

Superior representation of storm
- Speed
- Maximum Precipitation
- Lifetime
- Track length

Graph showing:
- Observation vs. Model
- Probability of different object sizes
- Probability of maximum precipitation

Legend:
- Observation
- Model
Storm development – Midwest region
Storms between 10 to 20 hours Lifetime

- 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
Thank you
• Underestimation of storm geneses in central U.S.
• Overestimation along the Golf and Atlantic coast
MODE Time Domain (MTD)

Extension of the MODE tool to the time dimension

[Randy Bullock, NCAR]
Storm Environments in Midwest

May
Hit Events
37%
Storms in Obs. and in Mod.

Missed Events
14%
Storms in Obs. but not in Mod.

No Events
40%
No storms in Obs. and in Mod.

July
27%
700 hPa geopotential height anomaly

32%
WRF is not able to trigger storms in weakly forced conditions

30%
Method for Object-based Diagnostic Evaluation (MODE) Time Domain (MODE-TD)

- **Smoothing Radius:** 8, 16, and 32 km

- **Threshold:** 2.5 and 5 mm/h

[adapted form Randy Bullock]
Storm Movement

- 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

○ 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
Future changes storm attributes