NCAR
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Modeling future changes in Mesoscale Convective Systems

Why end-of-century floods might be more severe than expected

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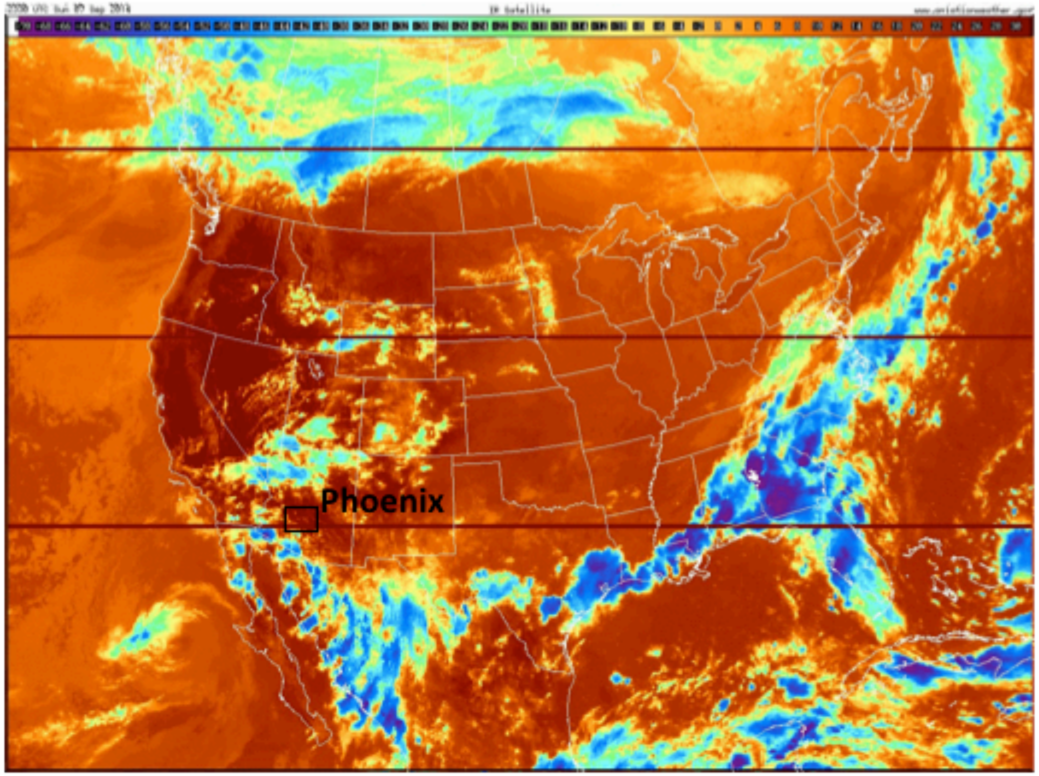
8TH GEWEX OPEN SCIENCE CONFERENCE: EXTREMES AND WATER ON THE EDGE

MAY 6 - 11, 2018 | CANMORE, ALBERTA, CANADA

Why are MCSs important?

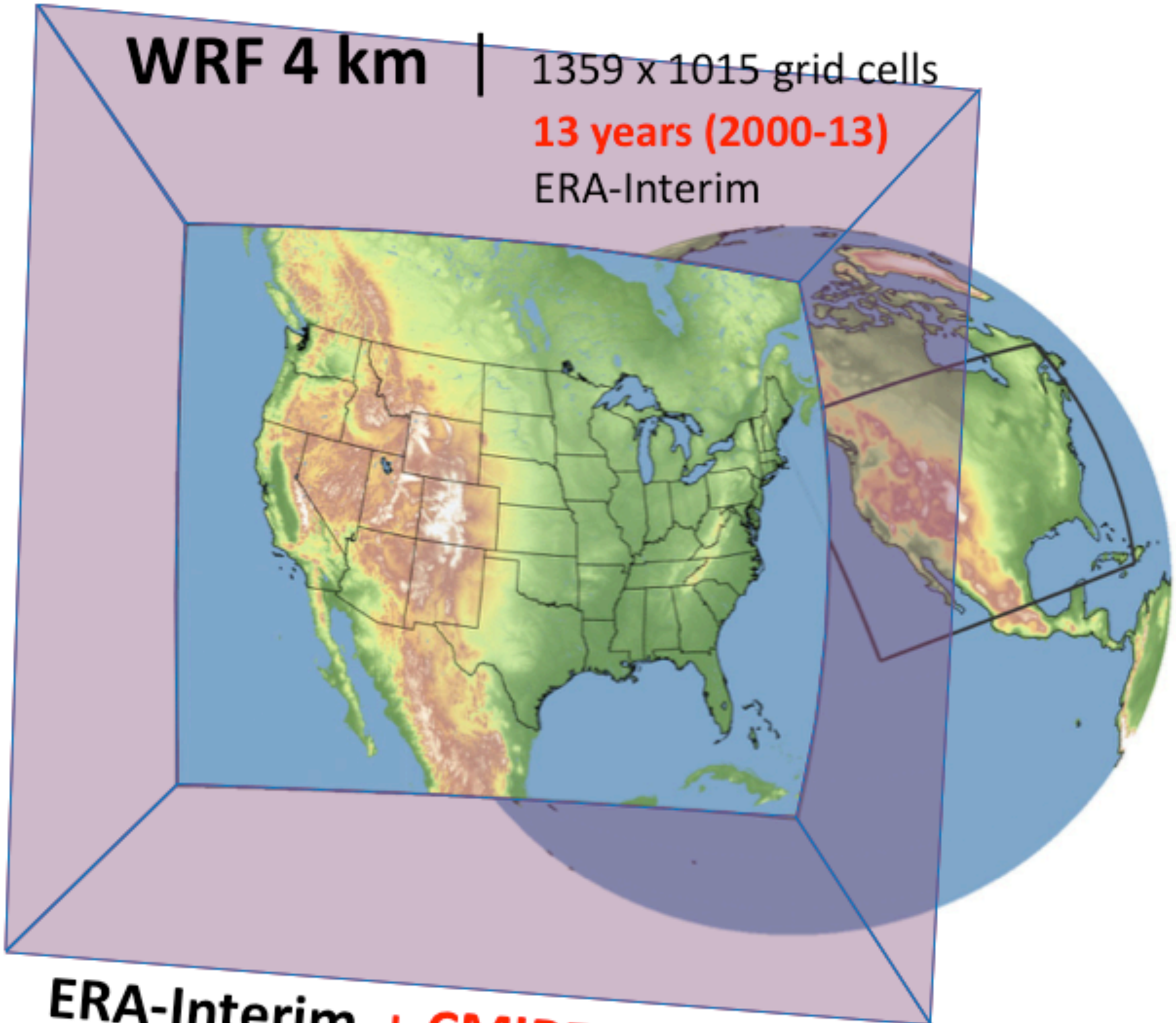
Most major flooding events during the warm season are caused by MCSs

- West Virginia 2016
- Louisiana 2016
- Phoenix AZ 2014



Climate Change and MCS precipitation

Simulation Domain and Setup



ERA-Interim 6-hourly **+ CMIP5** Monthly RCP8.5 19 model average

Liu et al. 2016, Clim. Dyn.

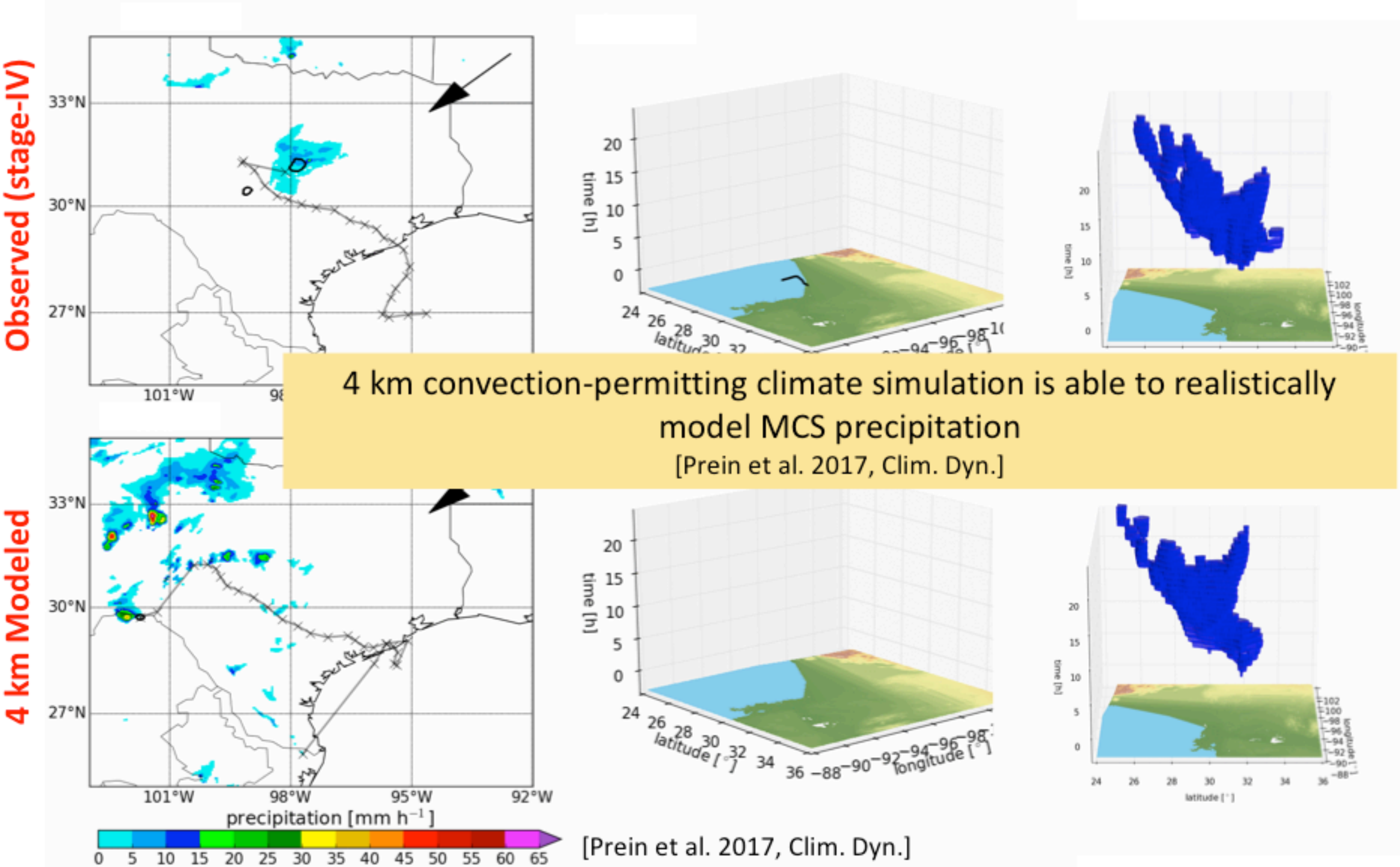
Pseudo Global Warming (PGW) [Rasmussen et al. 2011: JOC]

- Monthly averaged climate change perturbations from **19 CMIP5 GCMs**
- Delta 2071 to 2100 – 1976 to 2005 → RCP8.5

NOAH-MP

- Thermodynamic response of climate change
- No changes in weather patterns / moisture convergence
- No issues with internal variability

MCS in Texas during March 2007

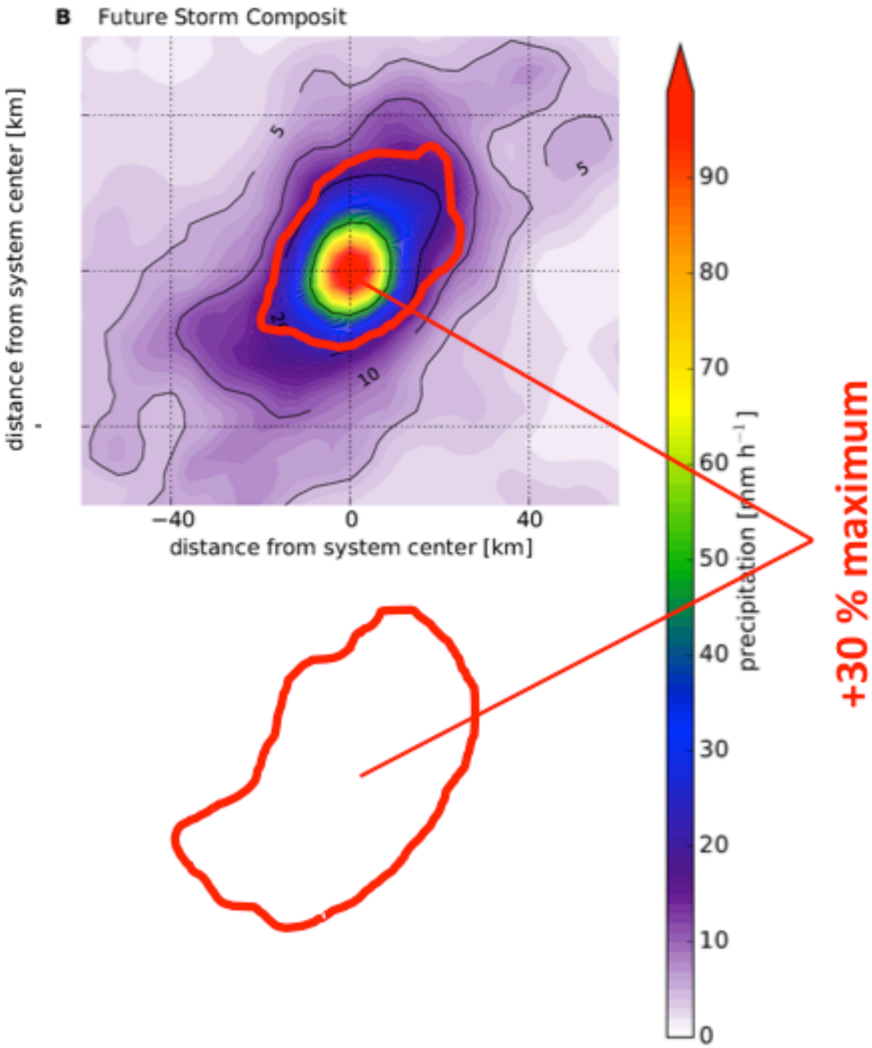


4 km convection-permitting climate simulation is able to realistically model MCS precipitation

[Prein et al. 2017, Clim. Dyn.]

[Prein et al. 2017, Clim. Dyn.]

MCS total precipitation – Mid Atlantic



40 most intense MCSs in Mid Atlantic Region

Maximum rain rate

- **+30 %**

approximately Clausius–Clapeyron relation

Size of > 10 mm/h Area

- **+88 %**

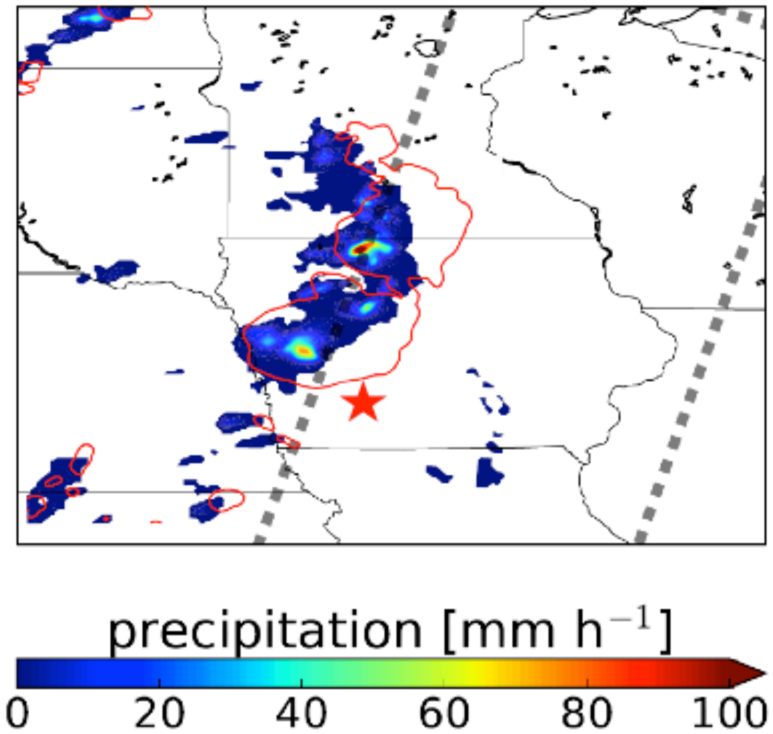
Volume within > 10 mm/h Area

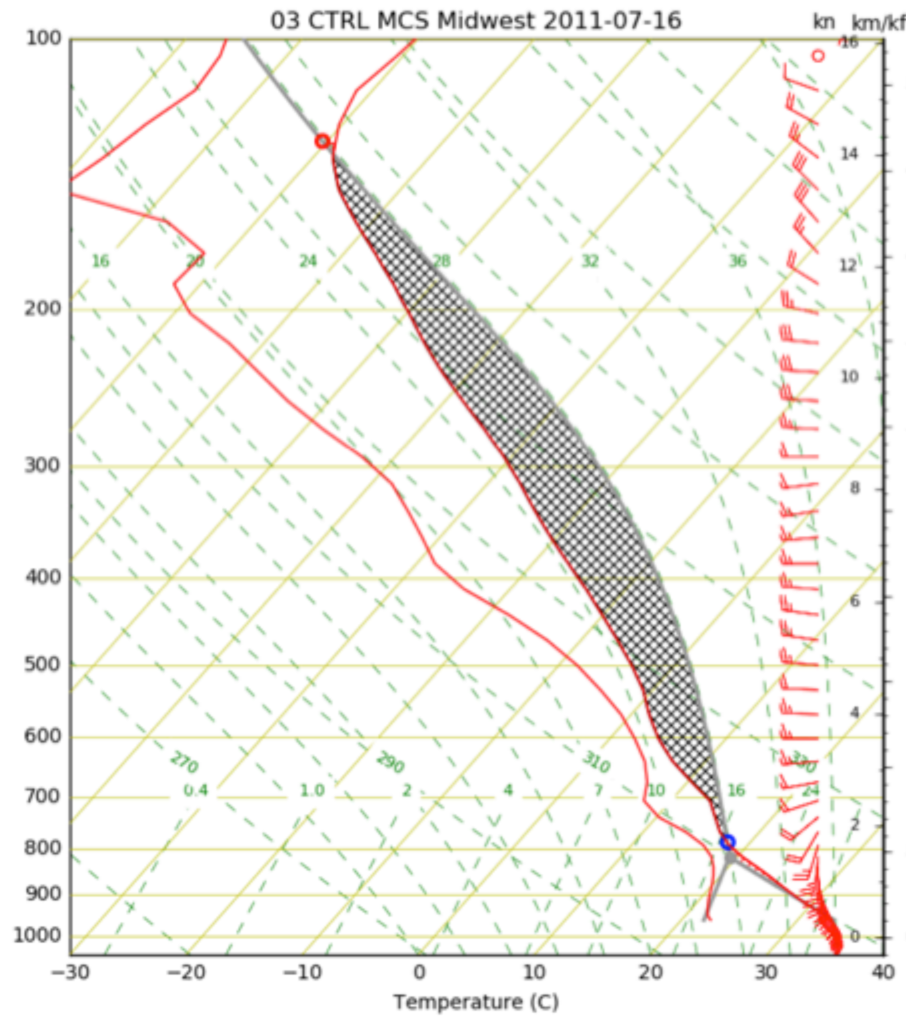
- **+105 %**

[Prein et al. 2017, Nat. Clim. Change]

MCS precipitation and its sensitivity to grid spacing

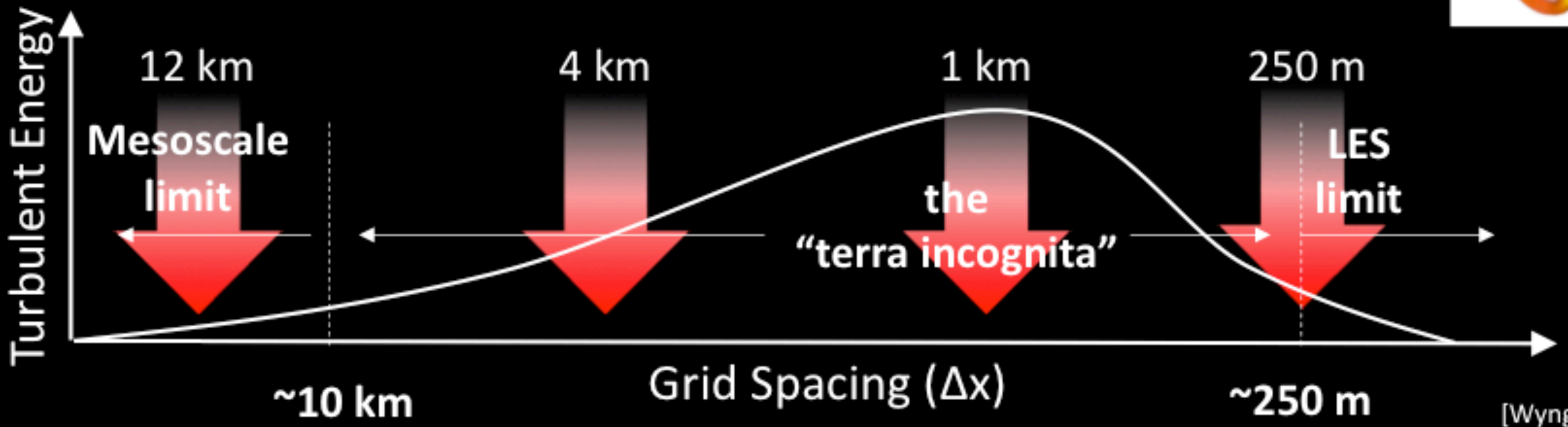
Idealized WRF simulations





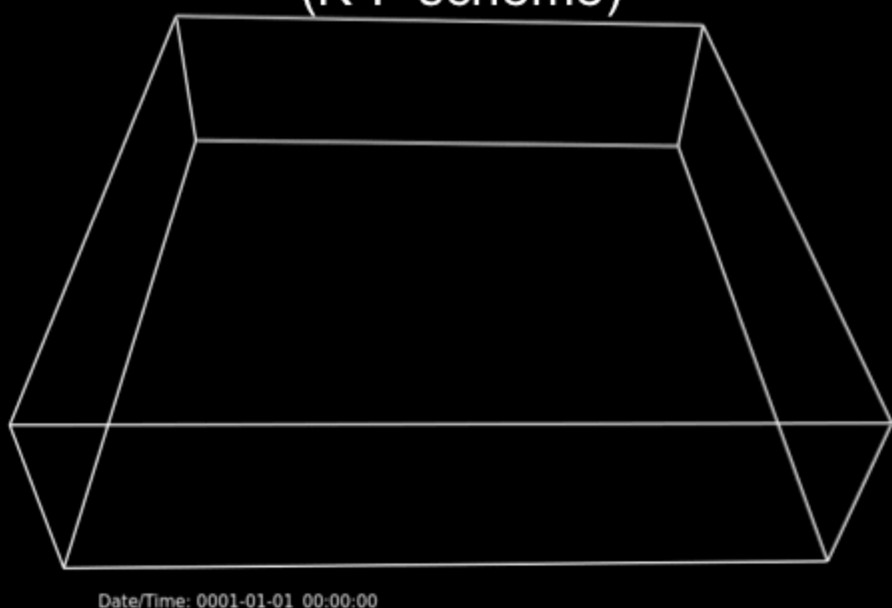
WRF model with 500x500 km domain, 94 vertical levels, open boundaries, no radiation, no surface fluxes, 6 hour long integration

MCS in 3 atmospheric regimes

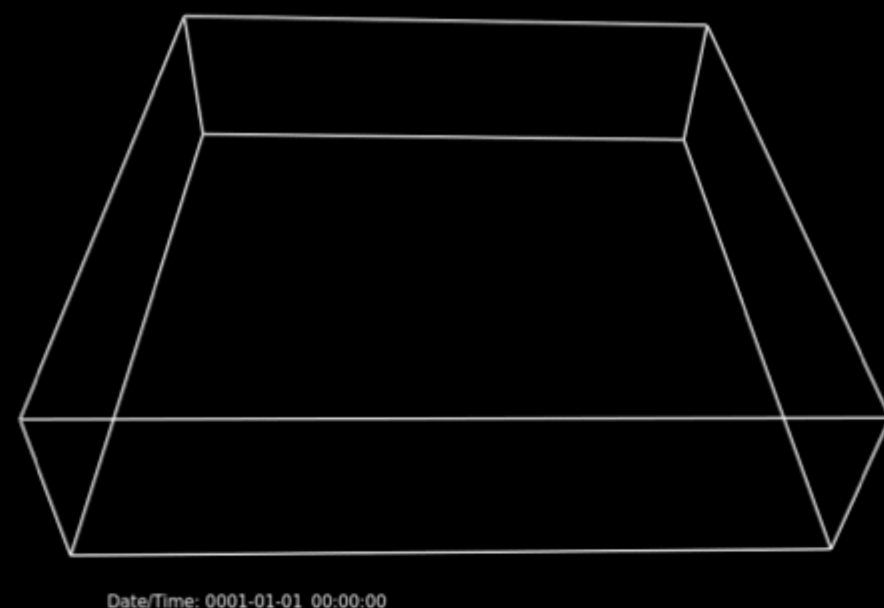


[Wyngaard 2004, JAS]

Δx = 12 km
(K-F scheme)



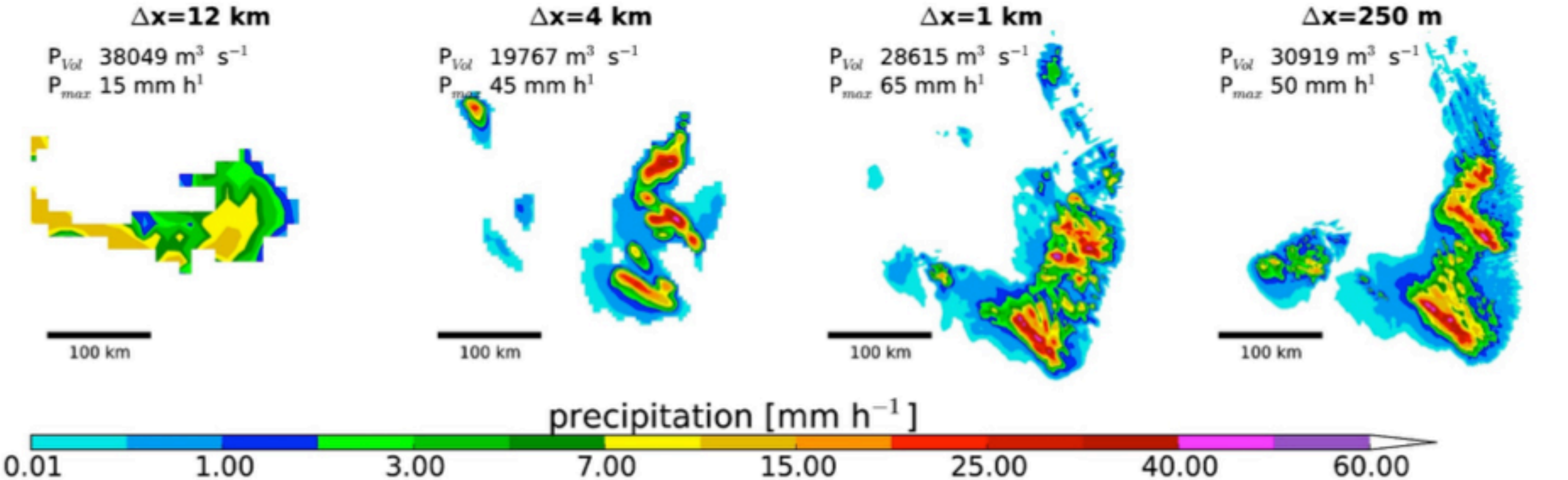
Δx = 4 km



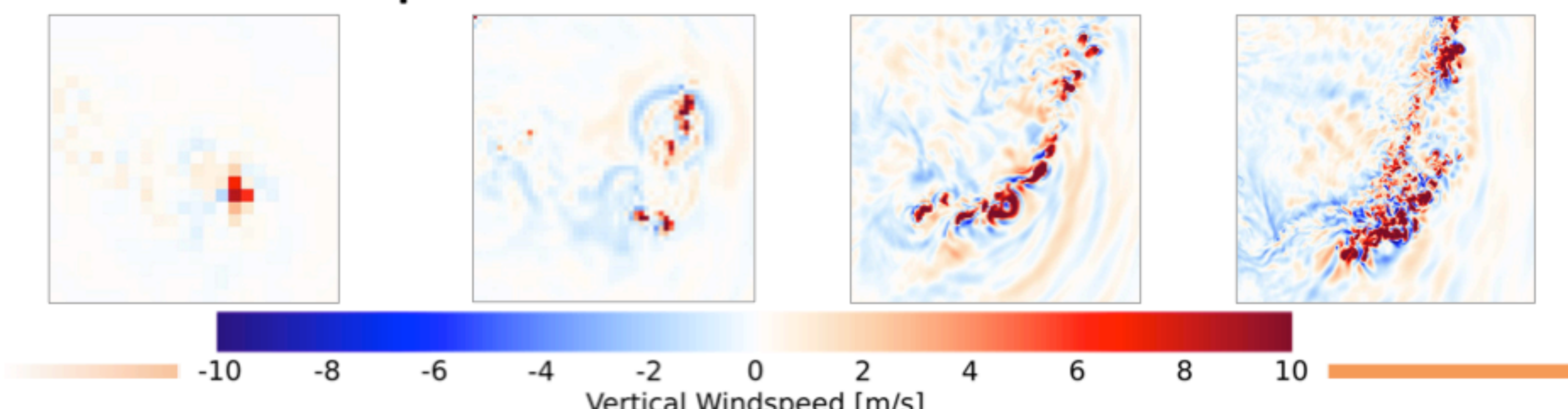
Precipitation Patterns

Hourly precipitation accumulation

hour 4-5 after simulation start



Vertical Wind Speed at 6 km –and 4:30 h

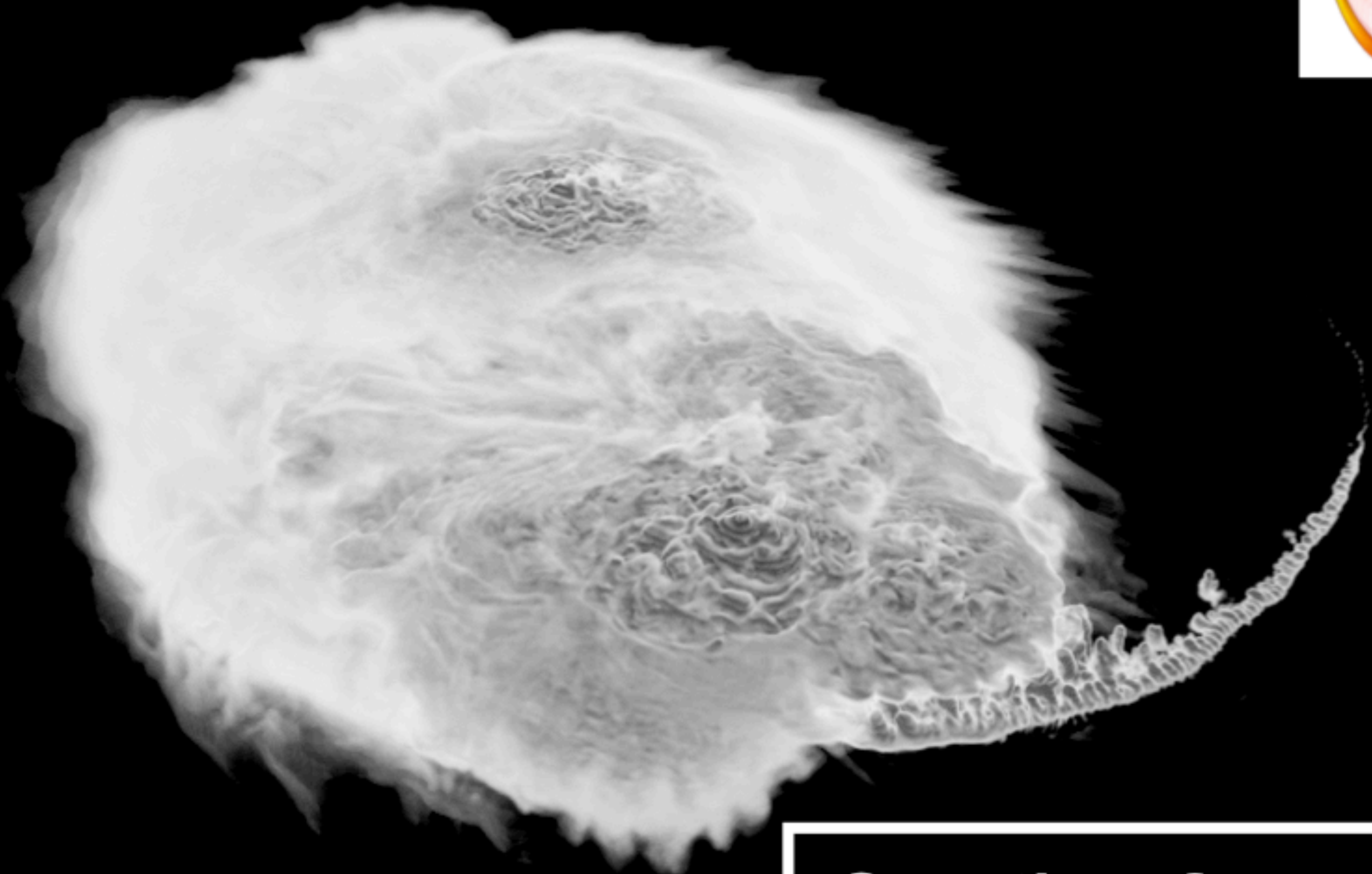


Conclusion and Outlook

- MCS precipitation volume is likely to increase much faster than peak rainfall intensity

- Caused by changes in thermodynamics and microphysics [Prein et al. 2017, Nat. Clim. Change]

- Additional idealized MCS simulations will allow to assess the effect of model resolution

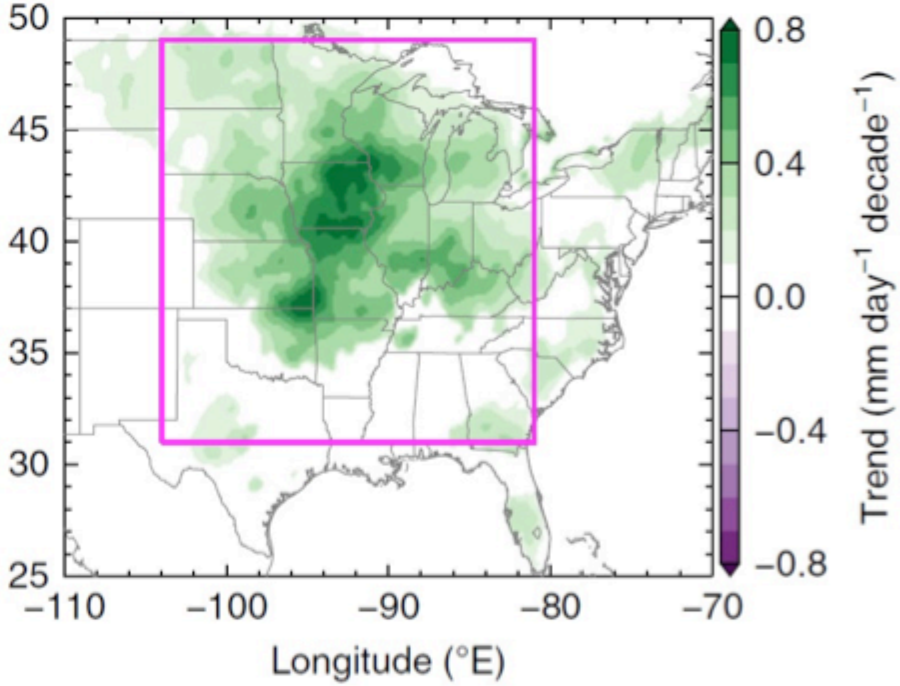


Questions?

Observed changes in US MCSs

Springtime mesoscale convective systems rainfall climatology and trends 1979 to 2014

[Feng et al. 2016, Nature Com.]



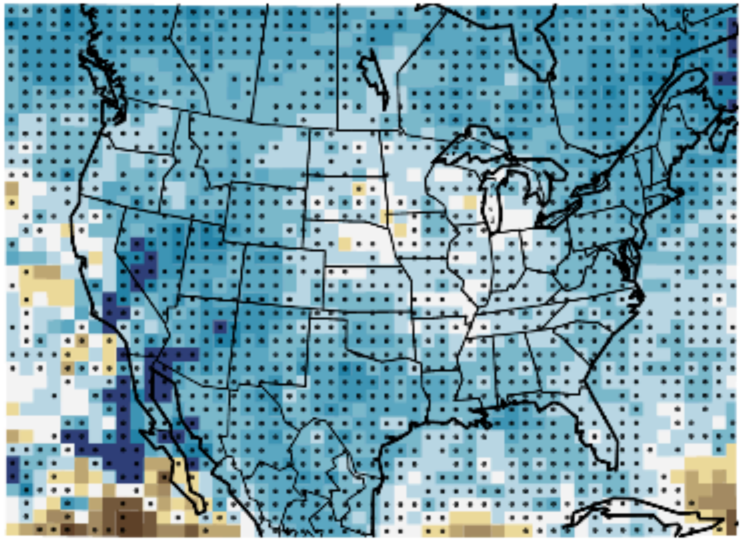
[Feng et al. 2016, Nature Com.]

Future extreme precipitation might increase by

7 % per degree warming

(Clausius–Clapeyron)

[e.g., Trenberth et al. 2003, BAMS; Cendon et al. 2014, Nat. Clim. Change; Ban et al. 2015 GRL, Prein et al. 2017, Nat. Clim. Change]

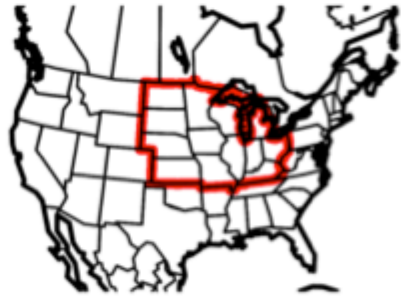


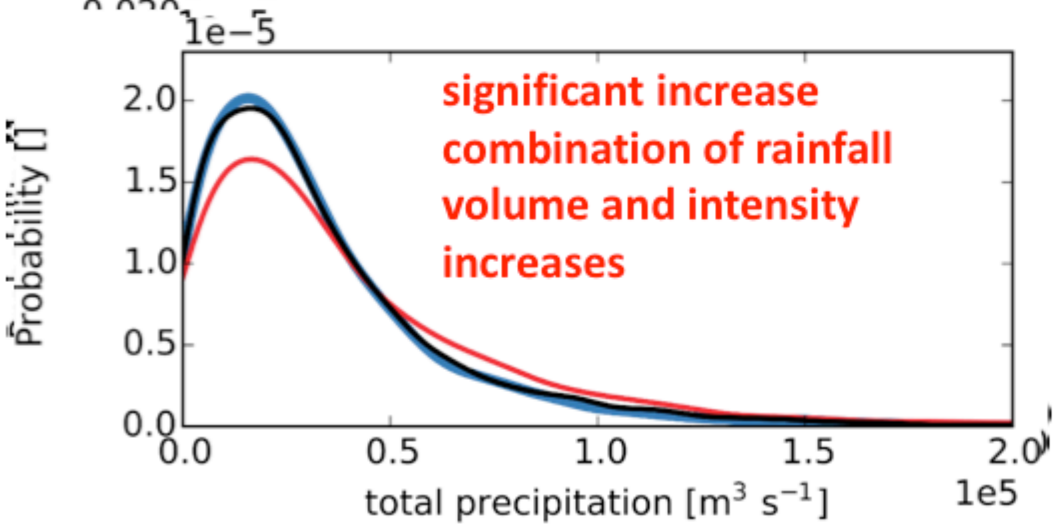
Median: 26.8 (%) SR: 5.8 (% °C^{-1})

[Prein et al. 2017, Nat. Clim. Change]

MCS characteristics – JJA Central U.S.

Observation
Model current
Model future

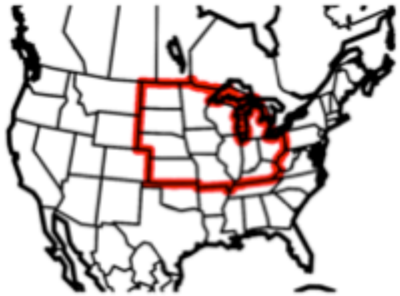




MCS attributes – JJA Central U.S.

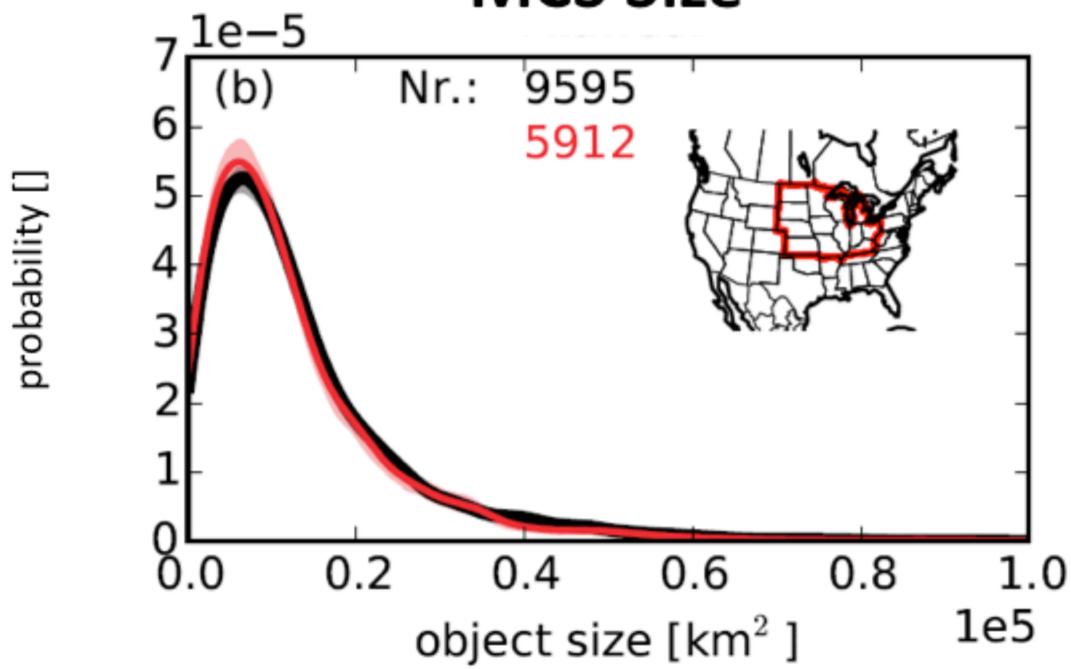
Observation

Model

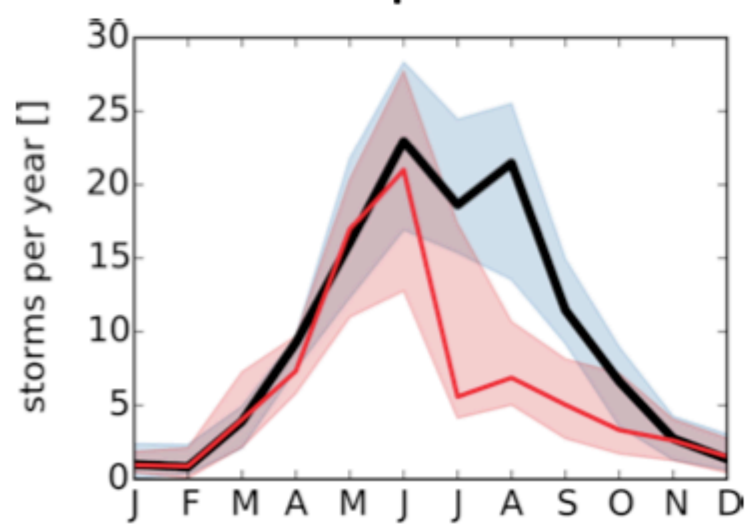


- Superior representation of MCS attributes
- But underestimation of MCS frequency

MCS Size



MCSs per Year



Future MCSs

[Prein et al. 2017, Nat. Clim. Change]

Pseudo Global Warming (PGW) [Schär et al. 1996]

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- Thermodynamic response of climate change
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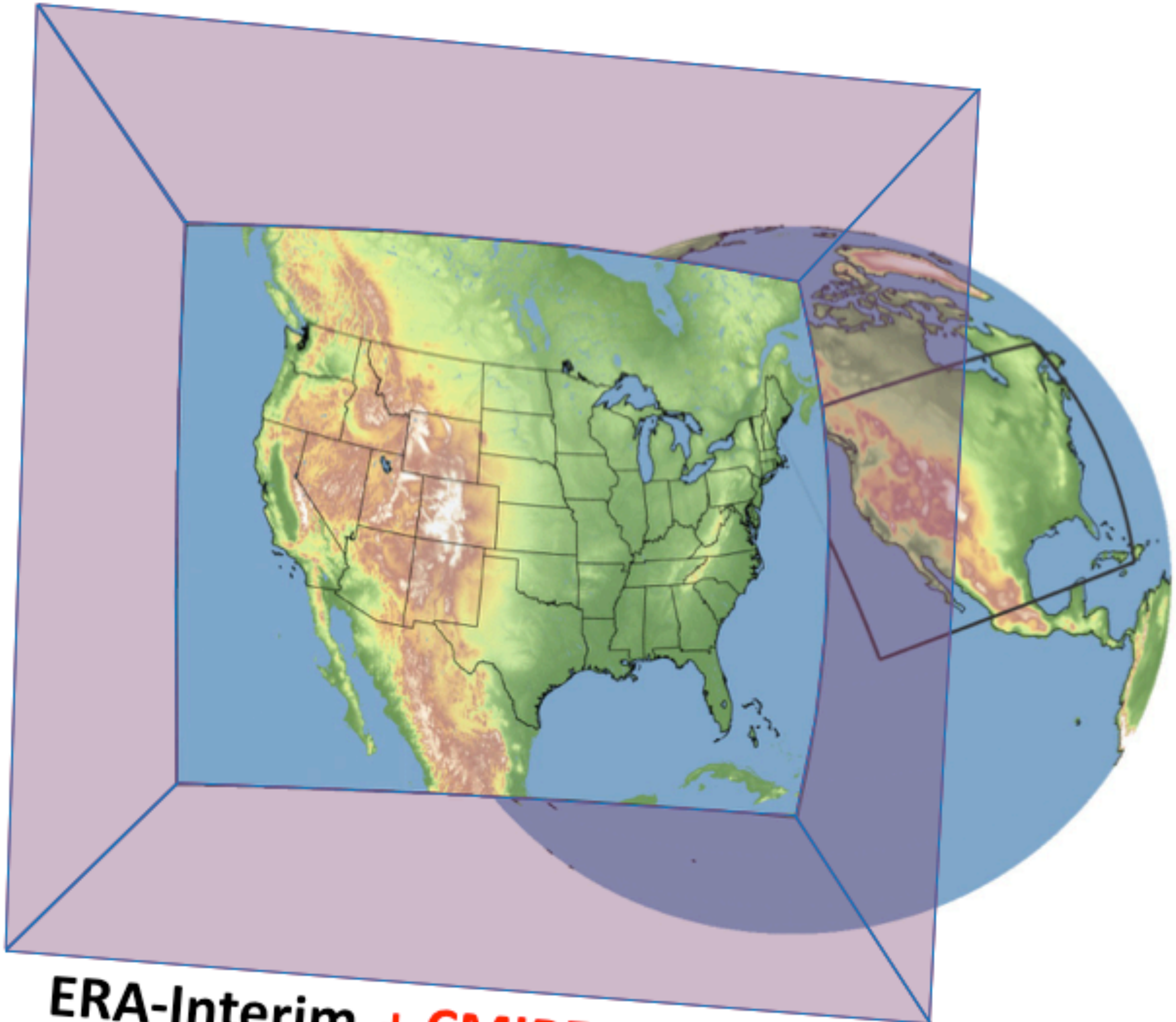
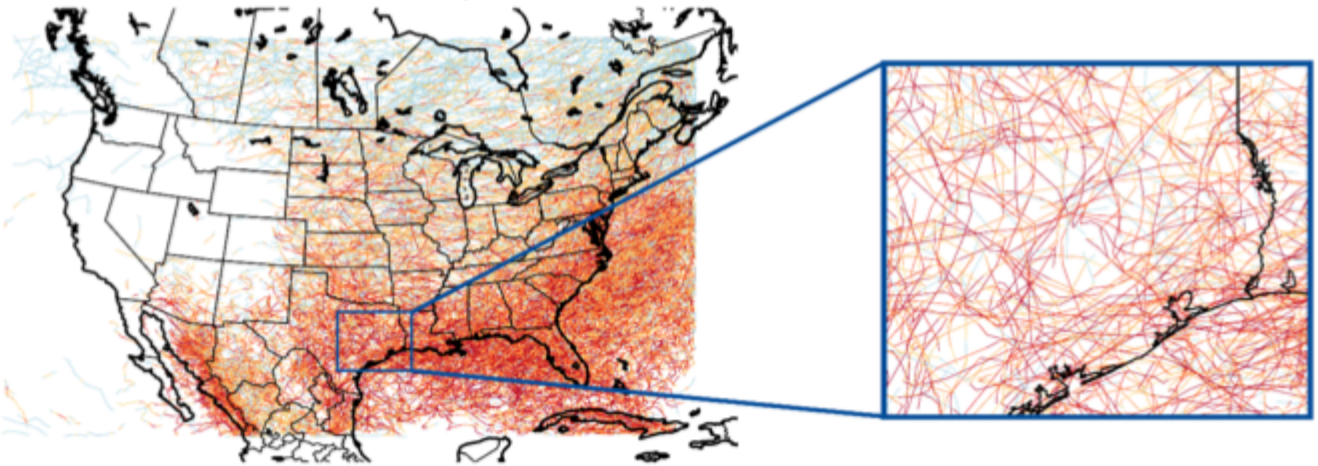


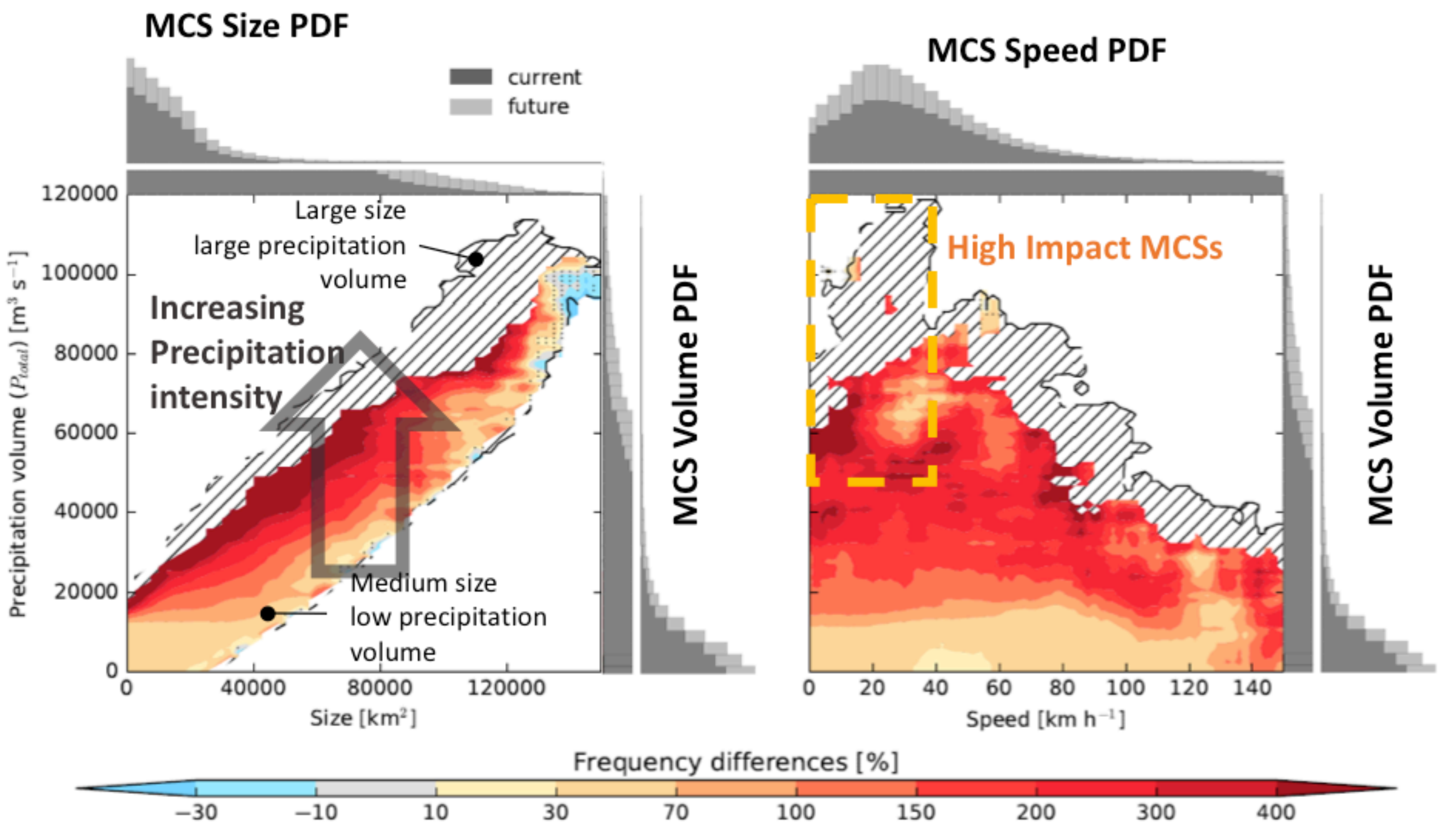
MCS Tracks & Intensities

End of century



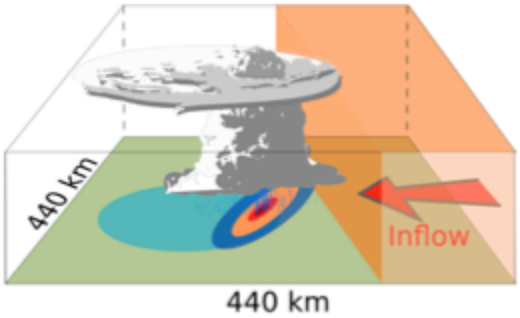
At least
4-times more
extreme
(>90 mm/h max. rainfall)
MCSs in North America

Changes in MCS characteristics

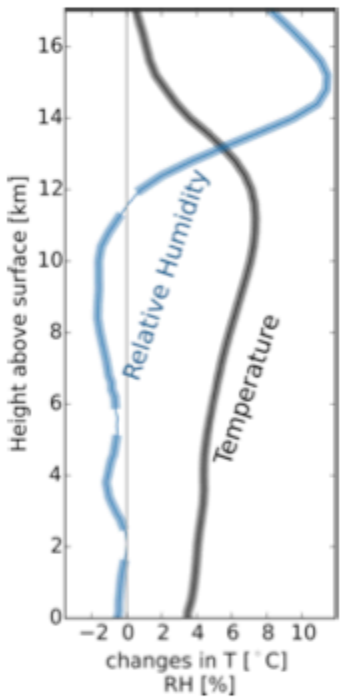


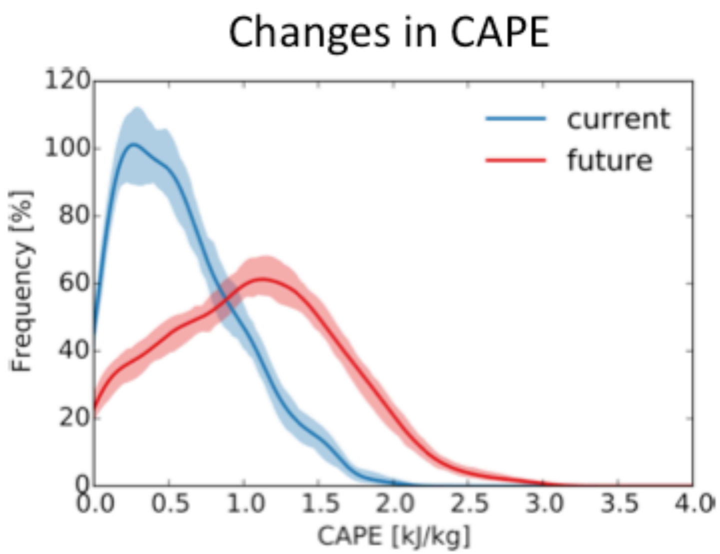
Changes in MCS Dynamics and Thermodynamics – Mid Atlantic

Rotated MCS environments



Changes in the Inflow





More Favorable

\+ Increased CAPE

Less Favorable

- Increasing stability
- Less Rel. Humidity

Changes in MCS Dynamics and Thermodynamics – Mid Atlantic

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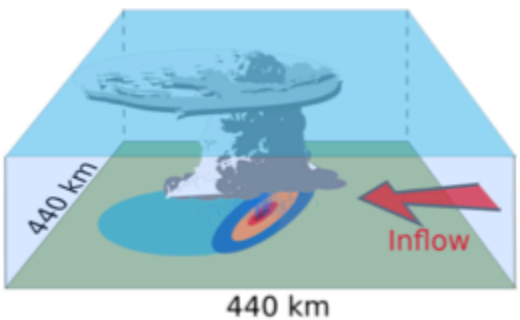
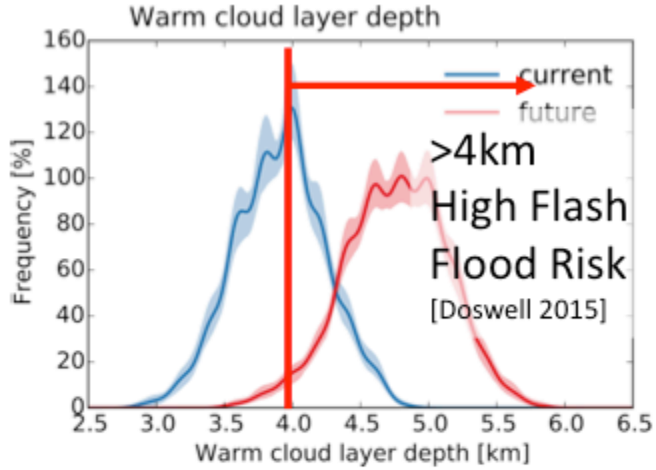
Rotated MCS environments





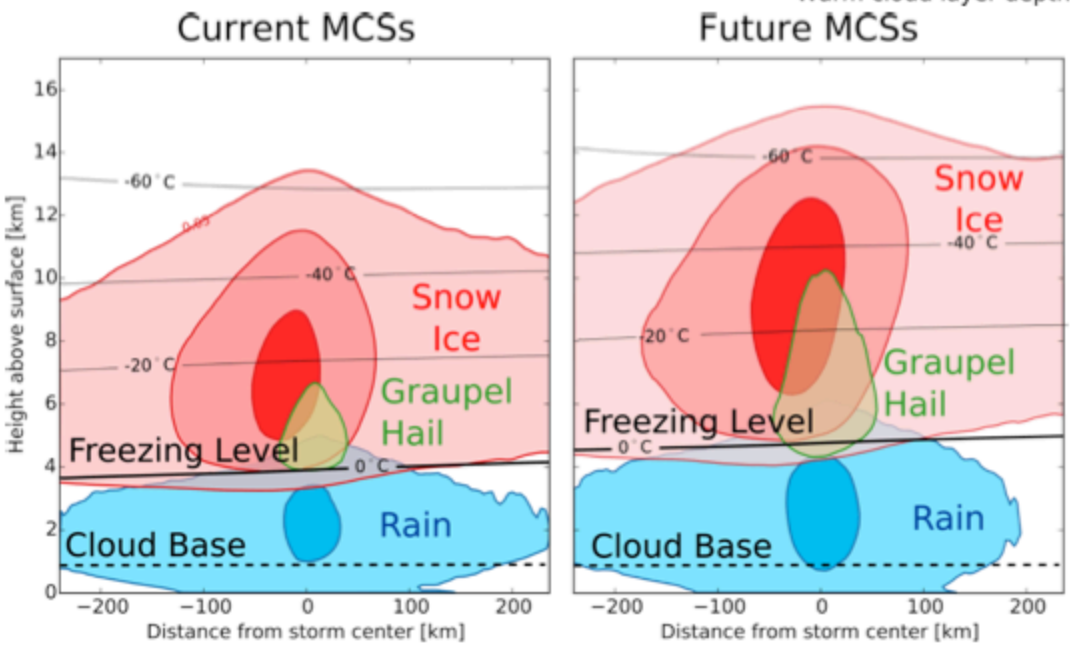
More Favorable

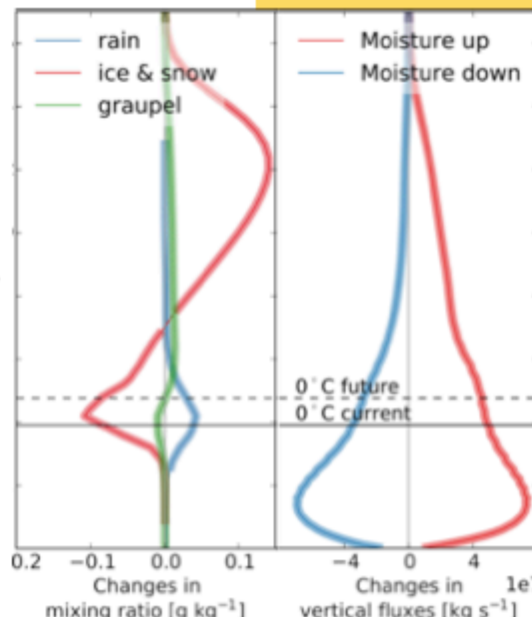
- \+ Increased CAPE
- \+ Higher cloud top
- \+ Increased vertical moisture transport
- \+ Deeper warm cloud layer

le

g stability

Humidity





Conclusion