Fixing Biases For Good

The Long, Difficult, and Rewarding Task of Improving km-Scale Climate Models

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National Center for Atmospheric Research (NCAR)

37th Session of the Working Group on Numerical Experimentation (WGNE)
Nov 10, 2022 | Boulder Colorado

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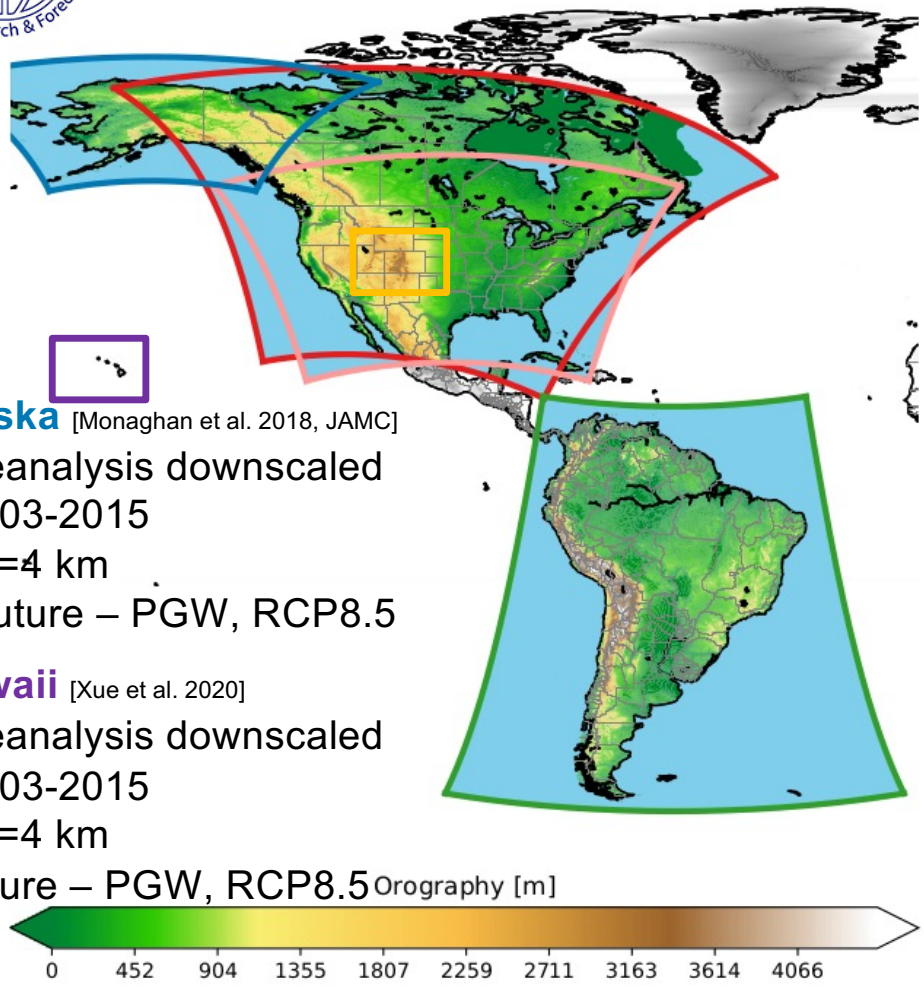
WRF K-scale Simulations



Alaska [Monaghan et al. 2018, JAMC]
- Reanalysis downscaled
- 2003-2015
- dx=4 km
- future – PGW, RCP8.5

Hawaii [Xue et al. 2020]
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Orography [m]

0 452 904 1355 1807 2259 2711 3163 3614 4066

NCAR/RAL Kilometer-Scale Climate Simulations

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South America [finished]
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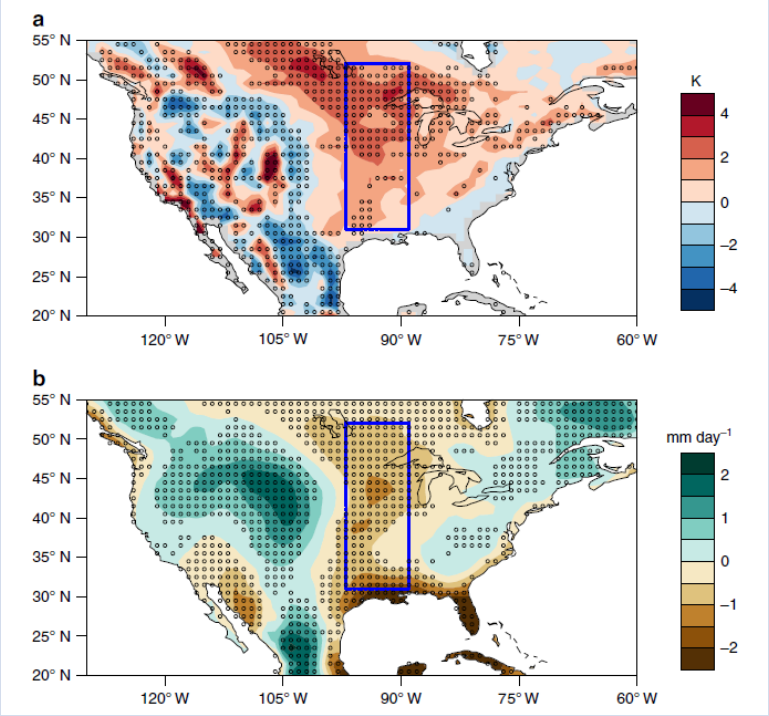
Precipitation and Temperature Biases in North America

(CAUSES) project
Clouds Above the United States and Errors at the Surface
[Lin et al. 2017, Nat. Com.]

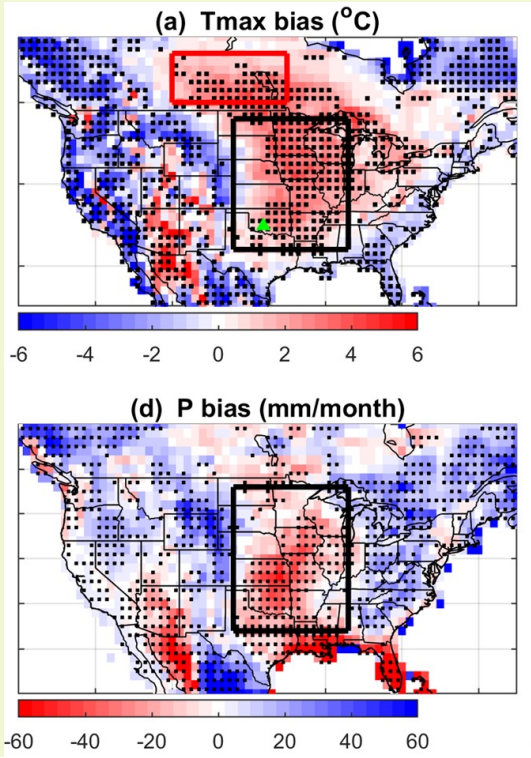
CMIP5



"The precipitation deficit is associated with the widespread **failure of models in capturing strong rainfall events** in summer over the central U.S."

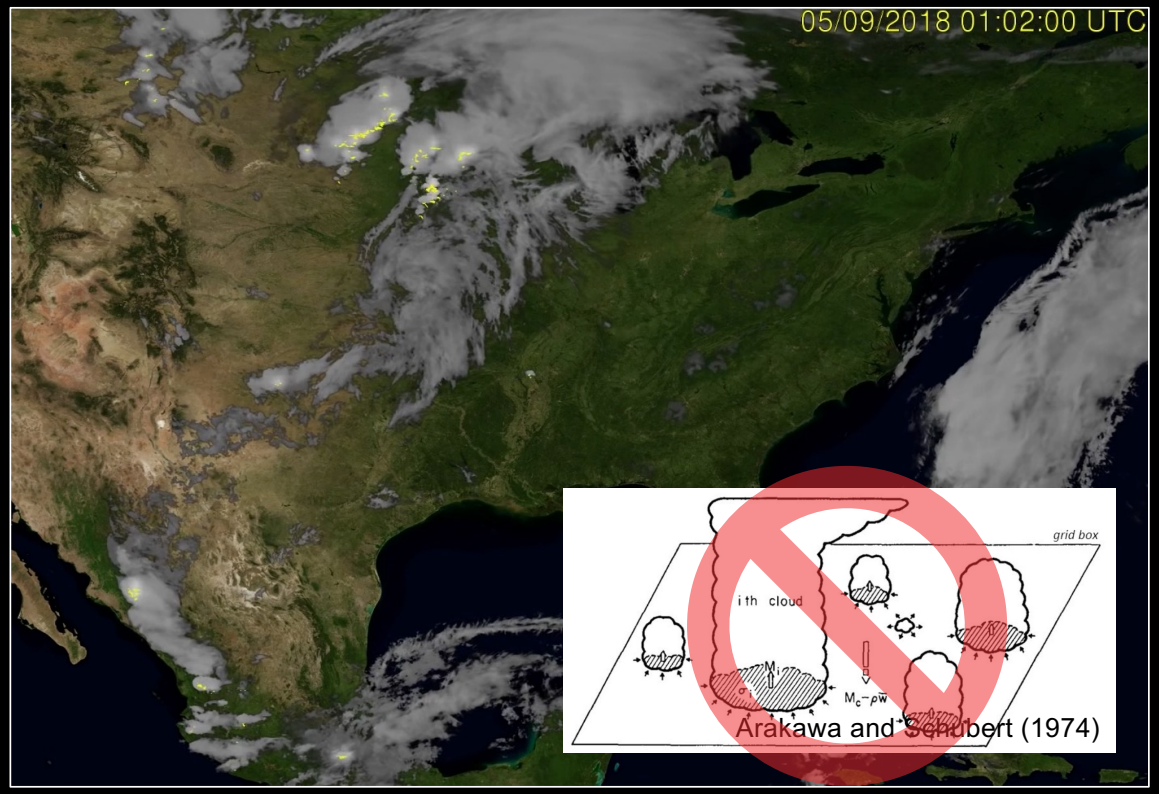
CMIP6

[Dong et al. 2022, Nat. Com.]



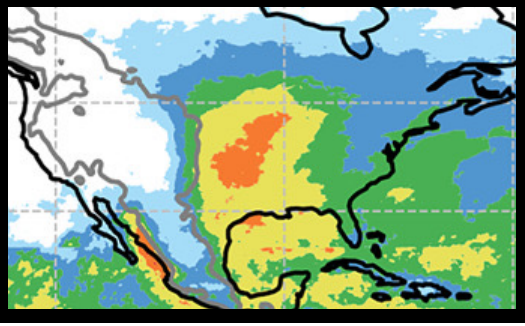
"CMIP6 ESMs do **not effectively use available rootzone soil moisture** for summertime transpiration and instead rely excessively on shallow soil and canopy-intercepted water storage to supply ET."

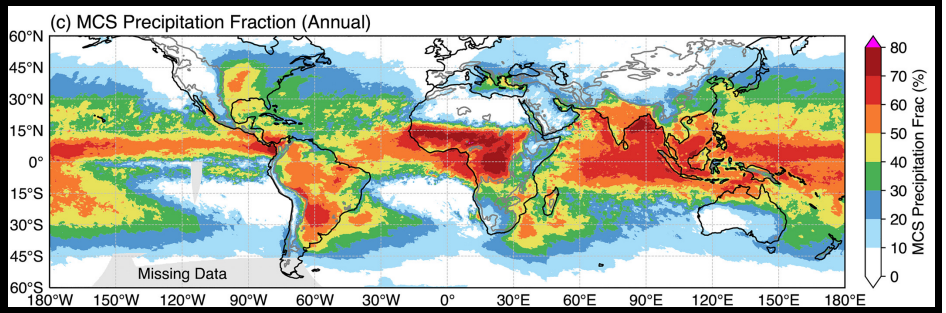
The Importance of Mesoscale Convective Systems in the Central U.S.



NOAA - https://www.youtube.com/watch?v=QFTrwqhEaKE

Fritsch et al. 1986:
"MCSs contribute between 30—70% to the warm season precipitation (April—September) in region between the Rocky mountains and the Mississippi River."





[Feng et al. 2021]

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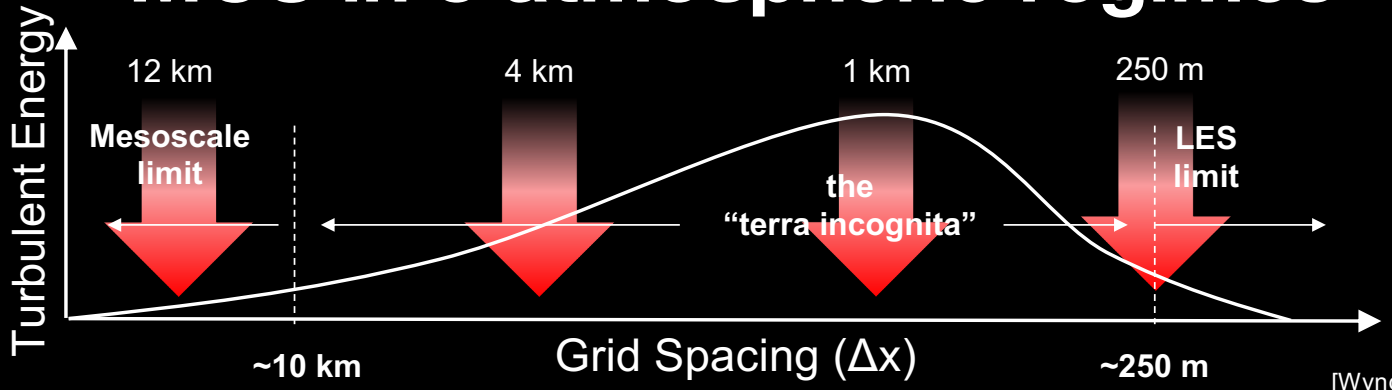
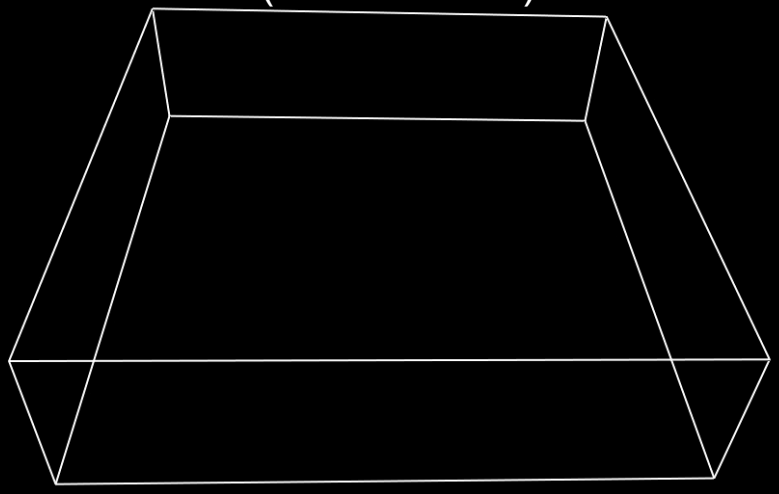
MCS in 3 atmospheric regimes

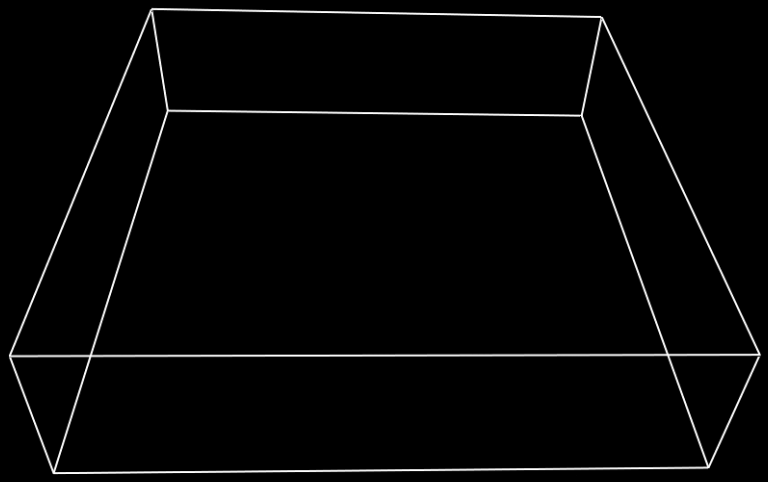


[Wyngaard 2004, JAS]

Δx = 12 km
(K-F scheme)

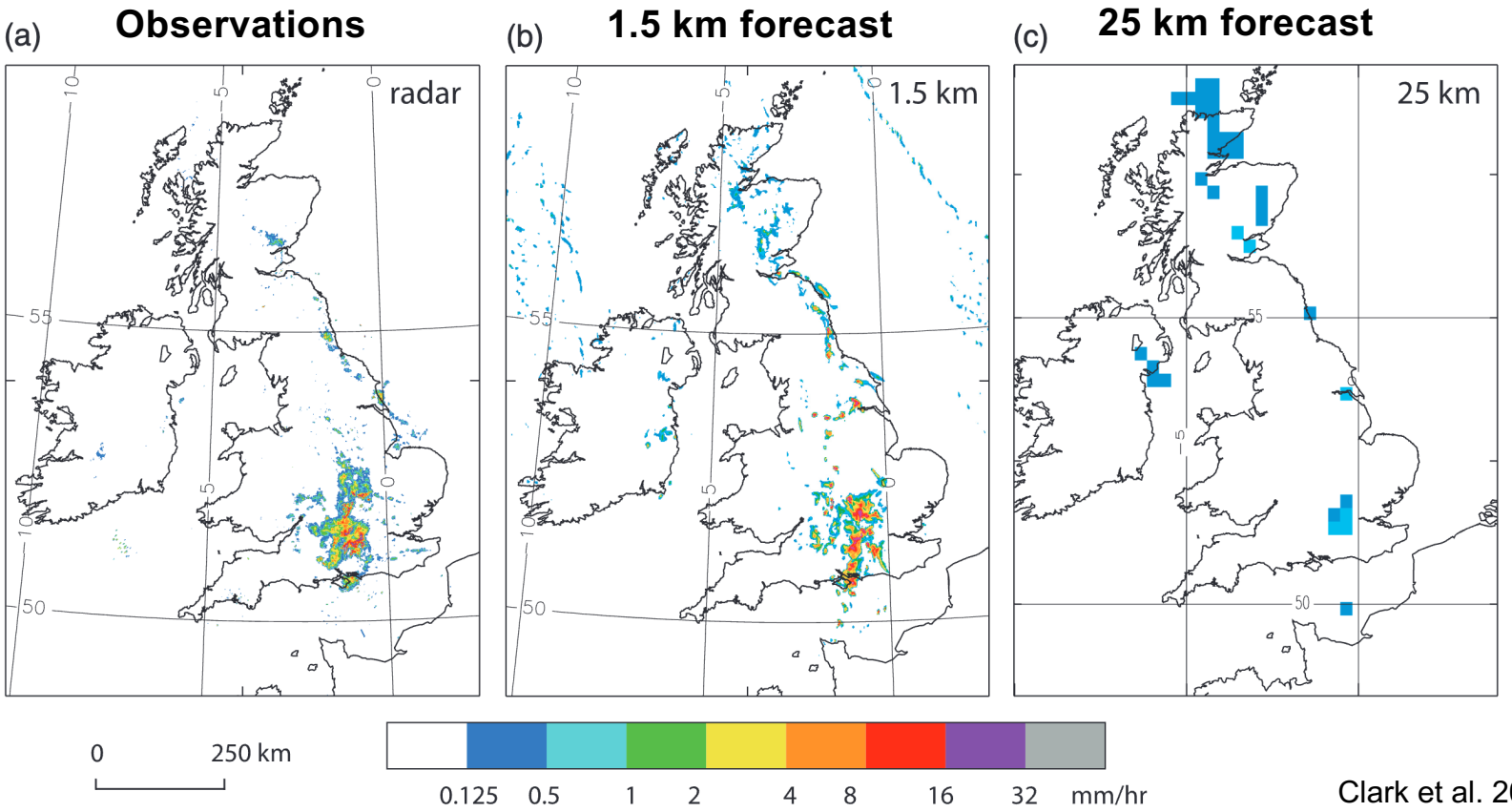


Δx = 4 km



Prein et al. 2021

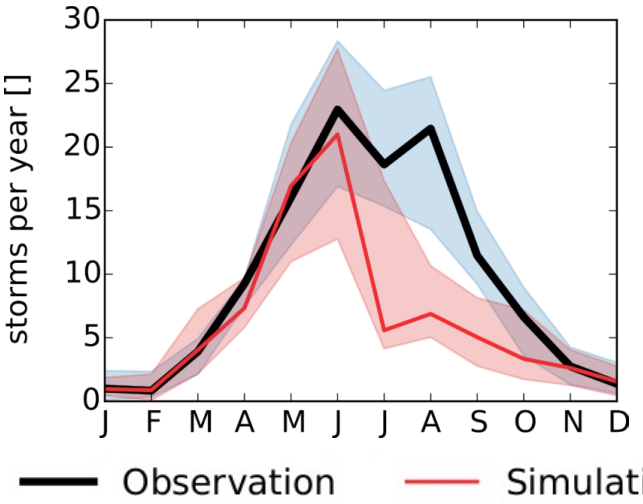
Mesoscale convective system (MCS) over the UK



Clark et al. 2016

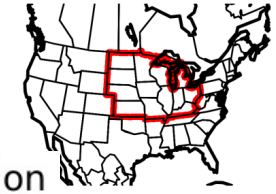
Annual Cycle of Mesoscale Convective Systems

MCSs per Year

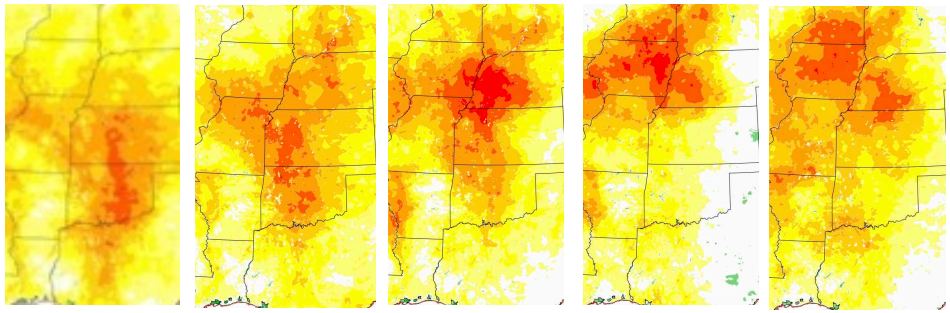


4 km Hindcast

Liu et al. (2017)
Prein et al. (2017)



Temperature Bias in Central U.S.

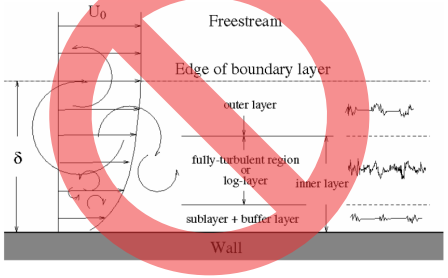


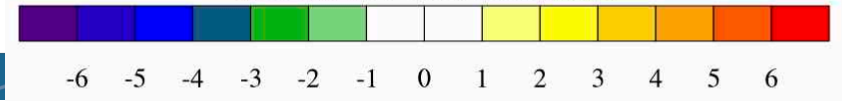
[Barlage et al. 2021]

Aerosols

Shallow Convection

Boundary Layer Scheme



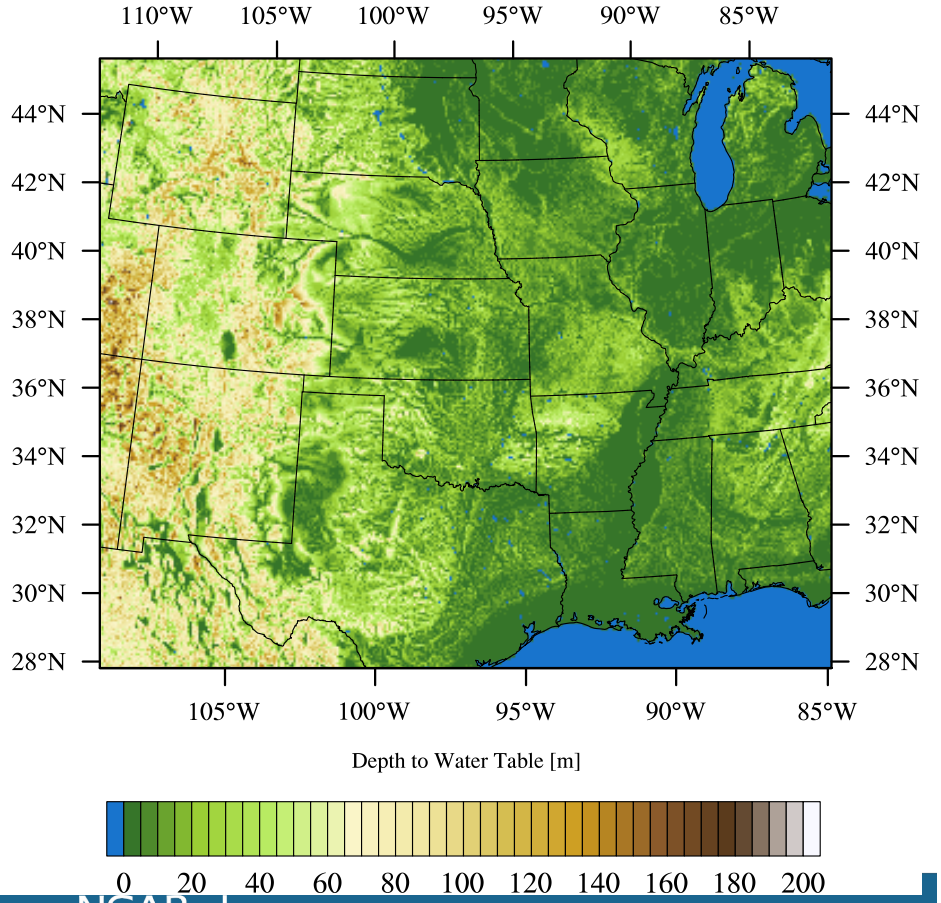


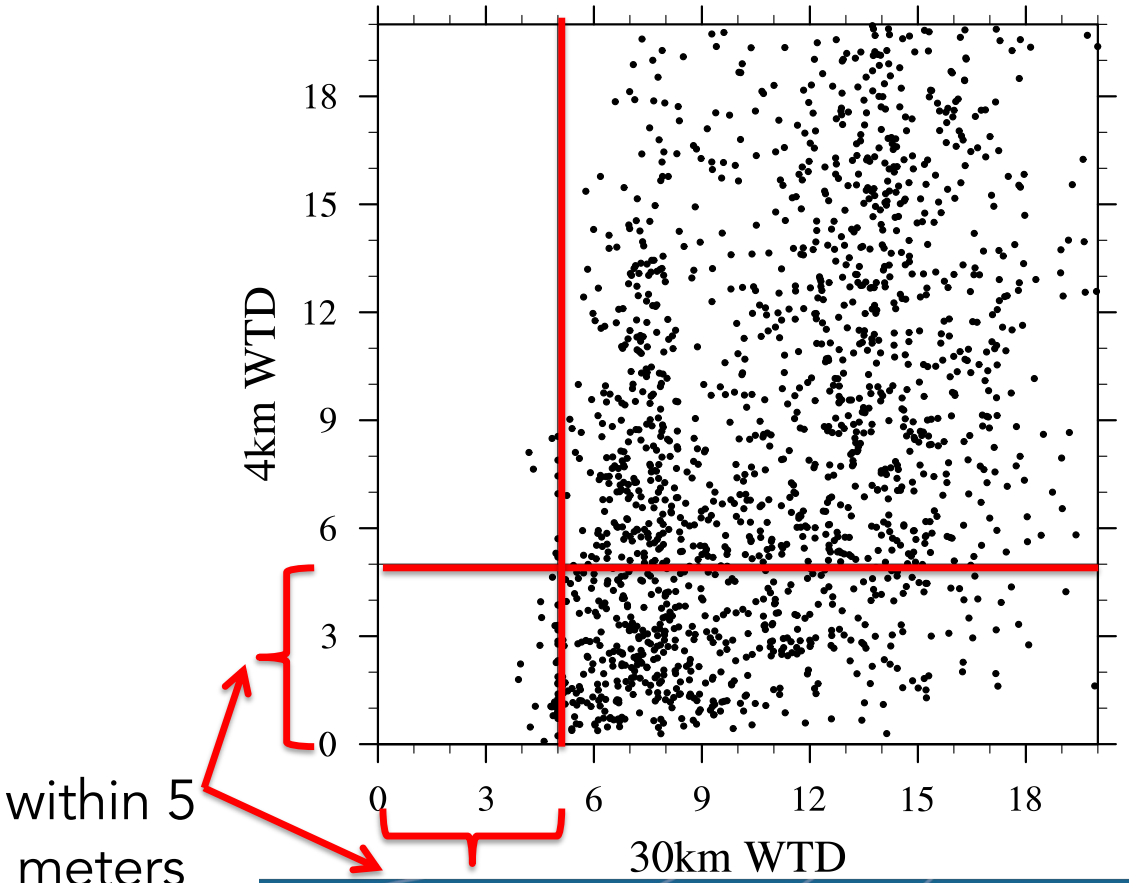
Temperature bias relative to PRISM

Scale Dependencies of the Water Table Depth

Significant sub-grid variability is missed when using coarse resolution

[Barlage et al. 2021]





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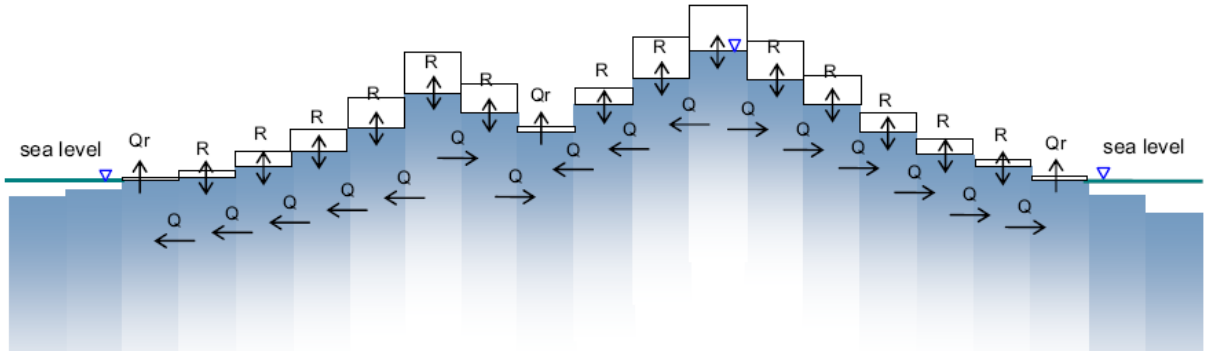
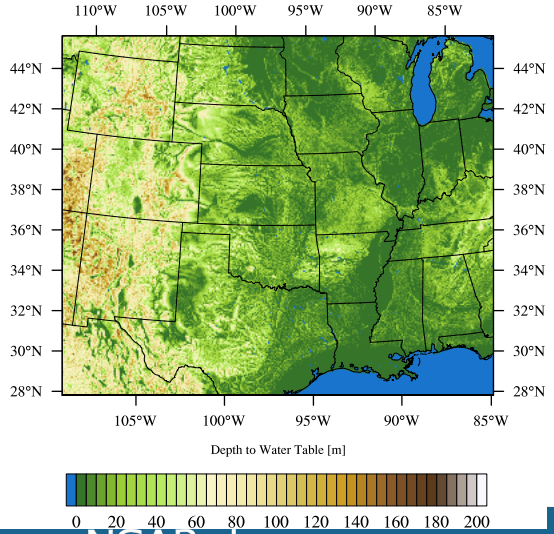
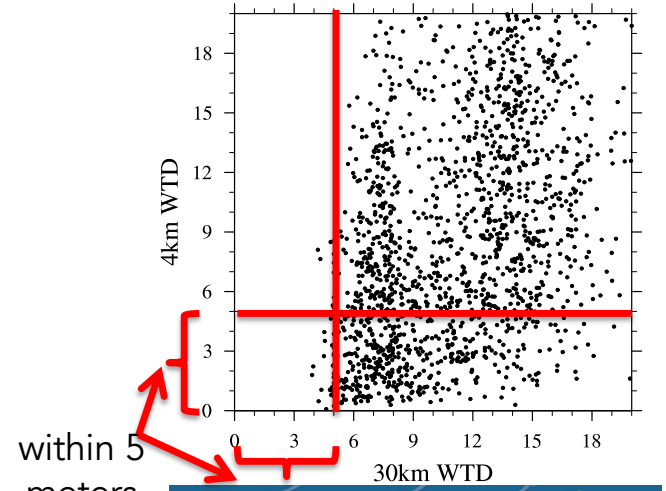


Fan et al, JGR 2007
Miguez-Macho et al., JGR 2007





[Barlage et al. 2021]

Annual Cycle of Mesoscale Convective Systems

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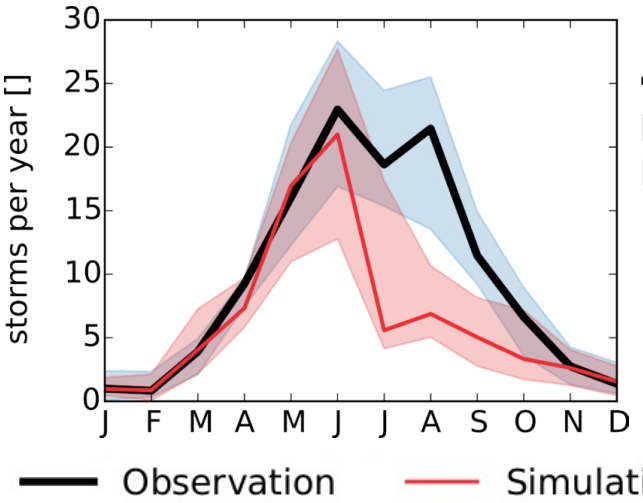
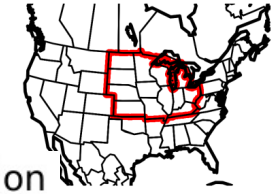
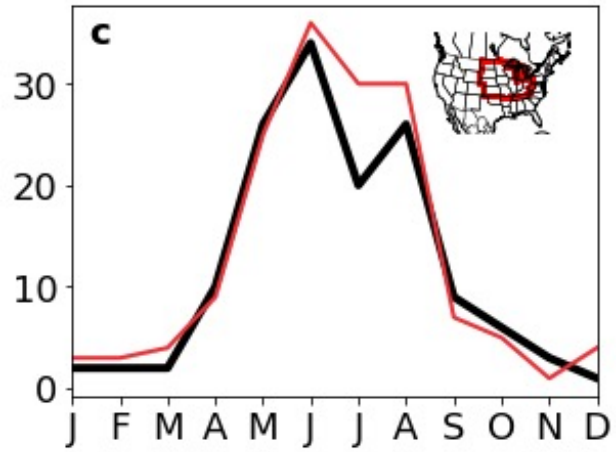


4 km Hindcast

Liu et al. (2017)

Prein et al. (2017)

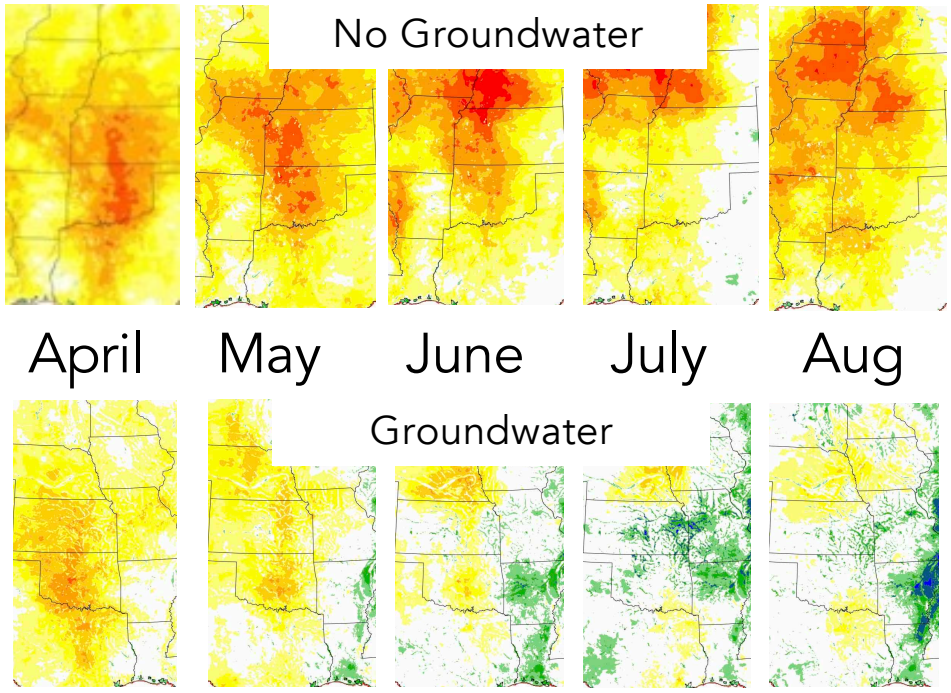




4 km Hindcast

with groundwater

Temperature Bias in Central U.S.



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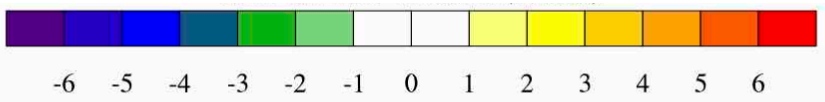


What I want you to remember from this talk

Do not expect that everything gets immediately better at high-resolution. Key processes might be missing.

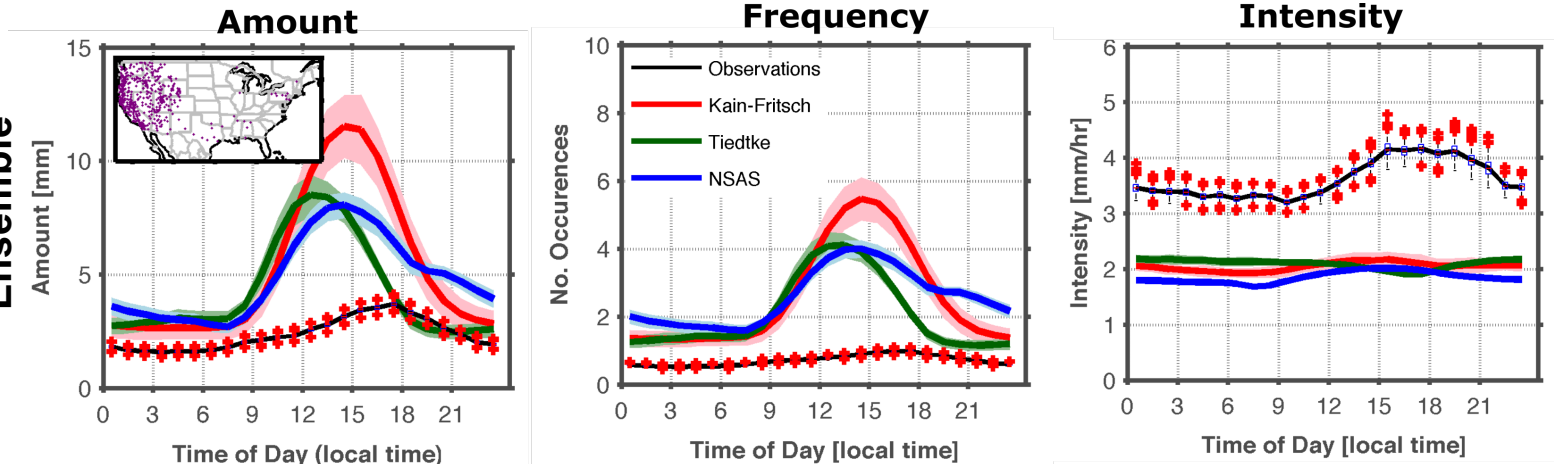
The coupling strength between earth system components is grid spacing depended. You need experts from different disciplins to fix model errors.

There is a serious lack of communication and collaboration between modeling communities.


Thank you
7th Workshop
Bergen, Norway
Aug. 29-31, 2023
ral-cpcm@ucar.edu
prein@ucar.edu

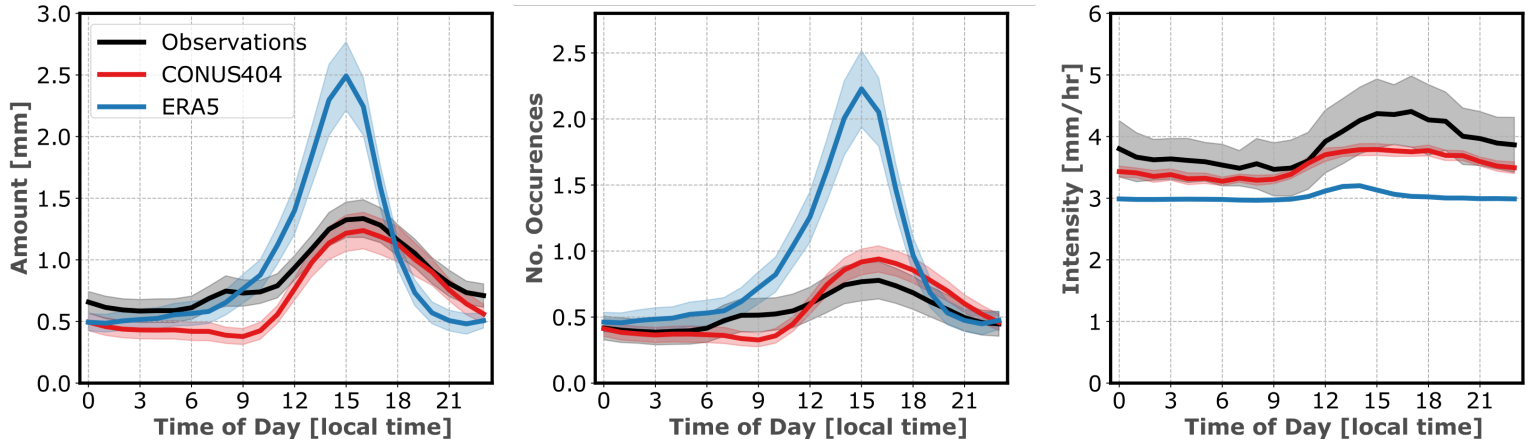
Easter U.S. Cold and Wet Biases

36 km WRF Multi-Physics Ensemble



Mooney et al. (2017)

4 km WRF & ERA5



Km-Scale models largely improve the wet bias and precipitation characteristics in the Western U.S. during summer

Rasmussen et al. (submitted)

SAAG
South American Affinity Group

NCAR
GEWEX
University of Saskatchewan
Colorado State University
CONICET
Universidade Federal de Santa Maria
Hong Kong Baptist University
U. of Illinois
Maine's Public Universities
Met Office
Oxford University
Pacific Northwest National Laboratory
Senamhi
State Univ. of New York at Albany
Universidad de Antioquia
University of Machester
University of Manchester
Universidade de São Paulo
University of Arizona
UC Santa Barbara
UC Los Angeles
UFSM Universidade Federal de Santa Maria
Universidad de Buenos Aires
Universidad Nacional de Colombia
Universidad de la Frontera
University of Oklahoma
University of Richmond
University of Saskatchewan
University of Utah
Universidad de Santiago de Compostela
University Grenoble Alpes
Instituto de Astronomia, Geofisica e Ciências Atmosféricas
Center for Climate and Resilience Research
Universidad de Chile

Thank You

Andreas F. Prein (prein@ucar.edu)

South America Simulations

4 km WRF
2000 – 2021 present day
20-years of future climate

Courtesy of David Bock – University of Illinois

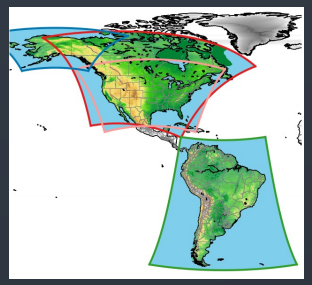
How to Move Foreword?

Define community activities that help to test and improve **processes** in km-scale coupled modeling systems

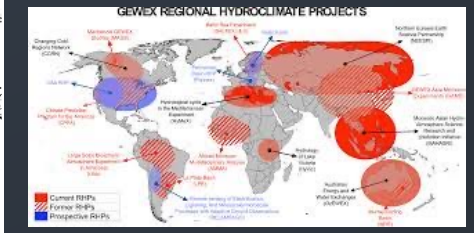
WCRP Digital Earths LHA could play a **coordinating role** and help to set **research priorities**

This will only work if we get broad **community engagement**

NCAR efforts in Americas



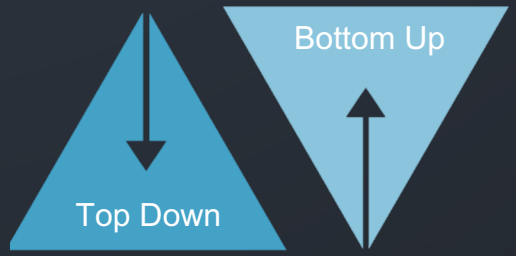
GEWEX RHPs



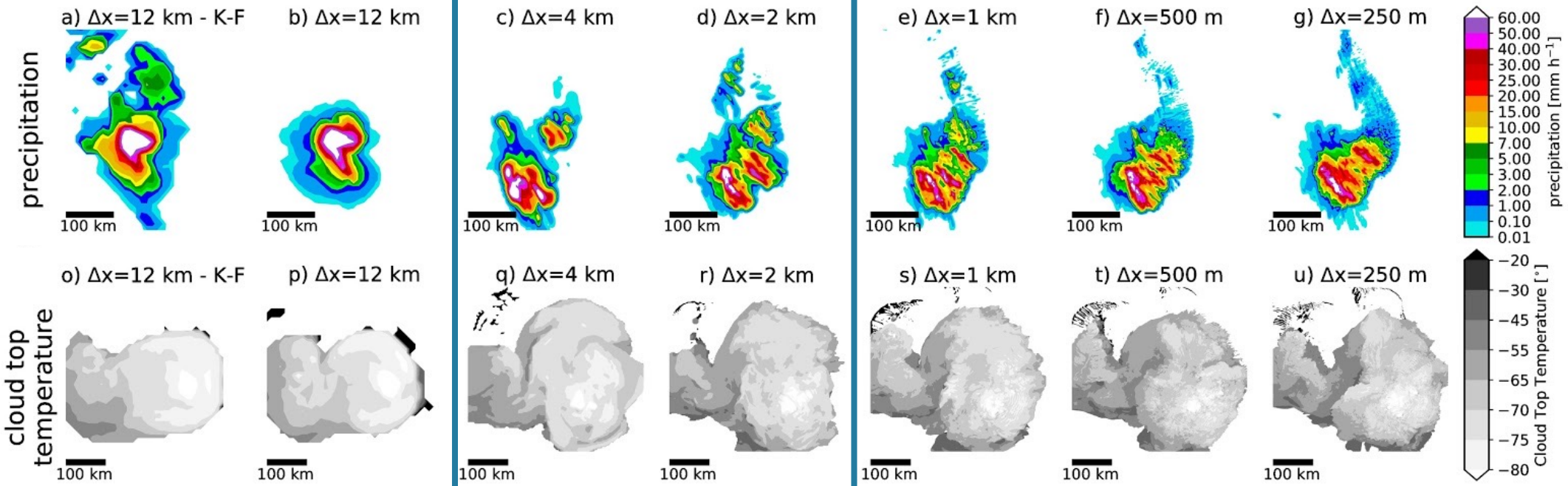
CORDEX FPSs

WCRP CORDEX
FLAGSHIP PILOT STUDIES

Digital Earths Lighthouse Activity
WCRP
World Climate Research Programme



Example MCSs Features

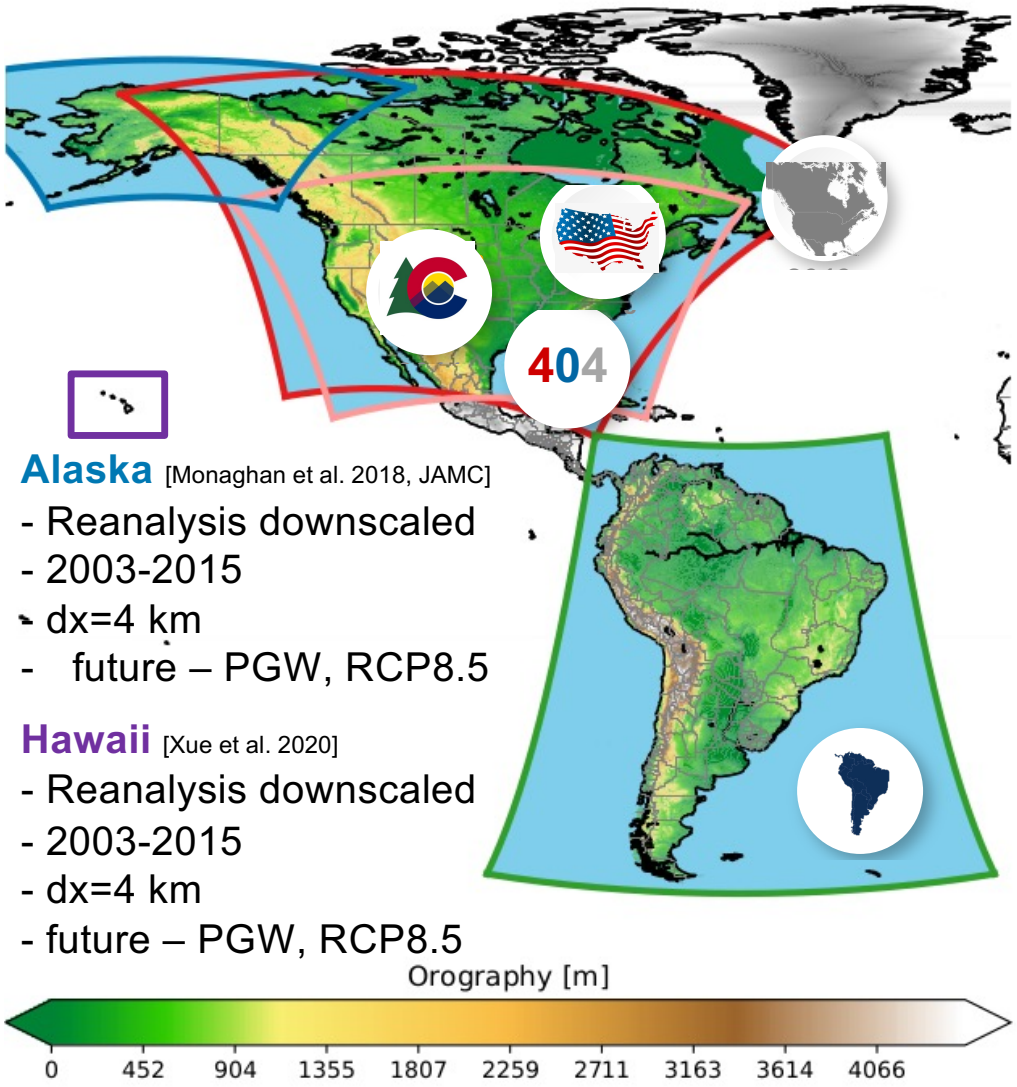


bulk convergence

step improvement
from Δx=12 km to Δx=4 km

further structural improvements from
Δx=4 km to Δx=1 km

[Prein et al. 2021]



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South America [in progress]
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- 20-years
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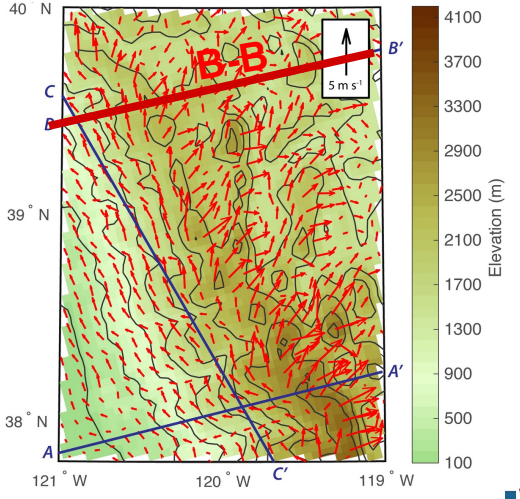
- future – PGW, RCP8.5

Flow Interaction with Topography

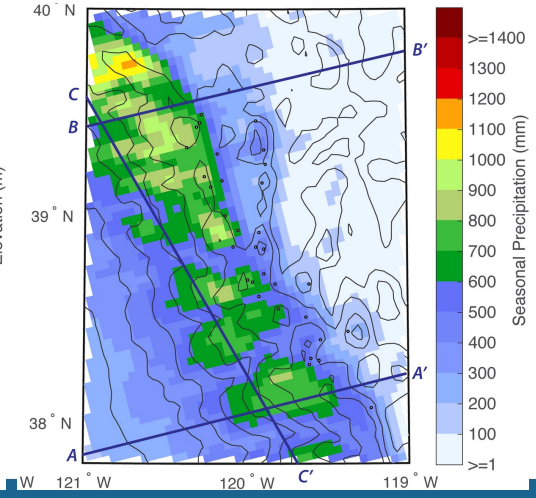
The Sierra Nevada Barrier Jet in CONUS1

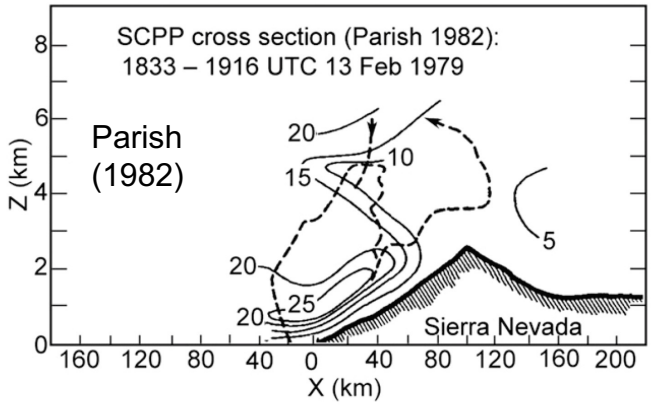
2014
CONUS1
ERA-Interim forcing

10 m DJF wind

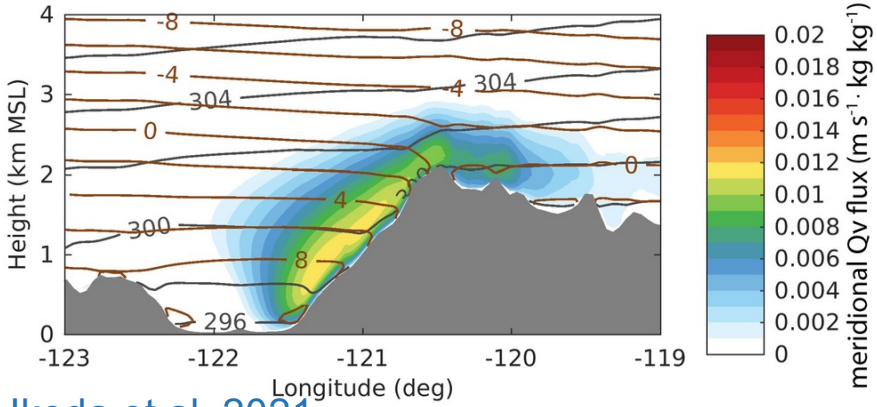


DJF precipitation





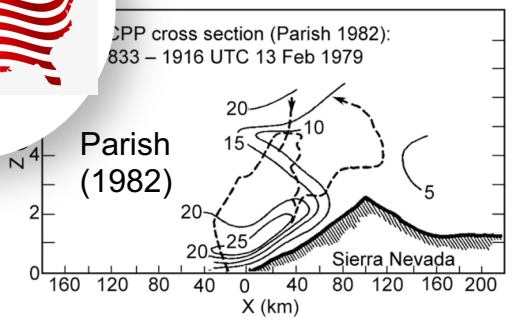
Meridional Qv flux (B-B)



Ikeda et al. 2021

2014 CONUS1 ERA-Interim forcing

Precipitation Shadowing Effect



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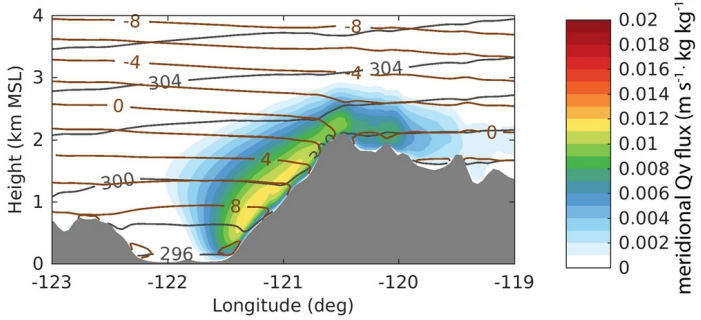
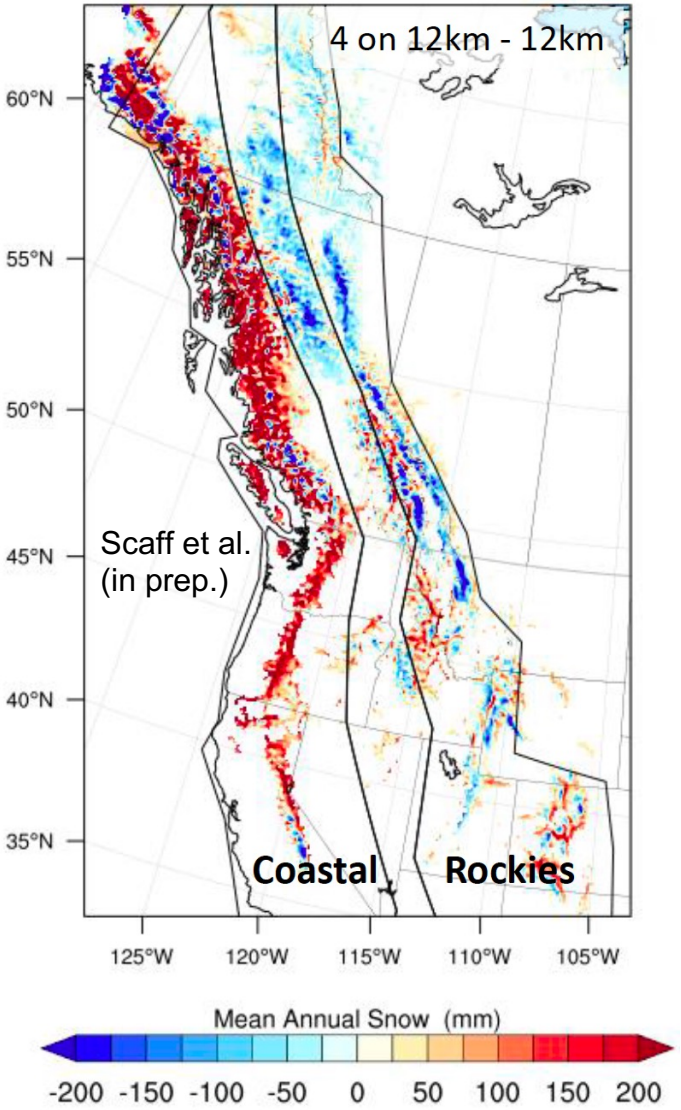


Ikeda et al. 2021

Snow accumulation in 12 km vs 4 km simulation

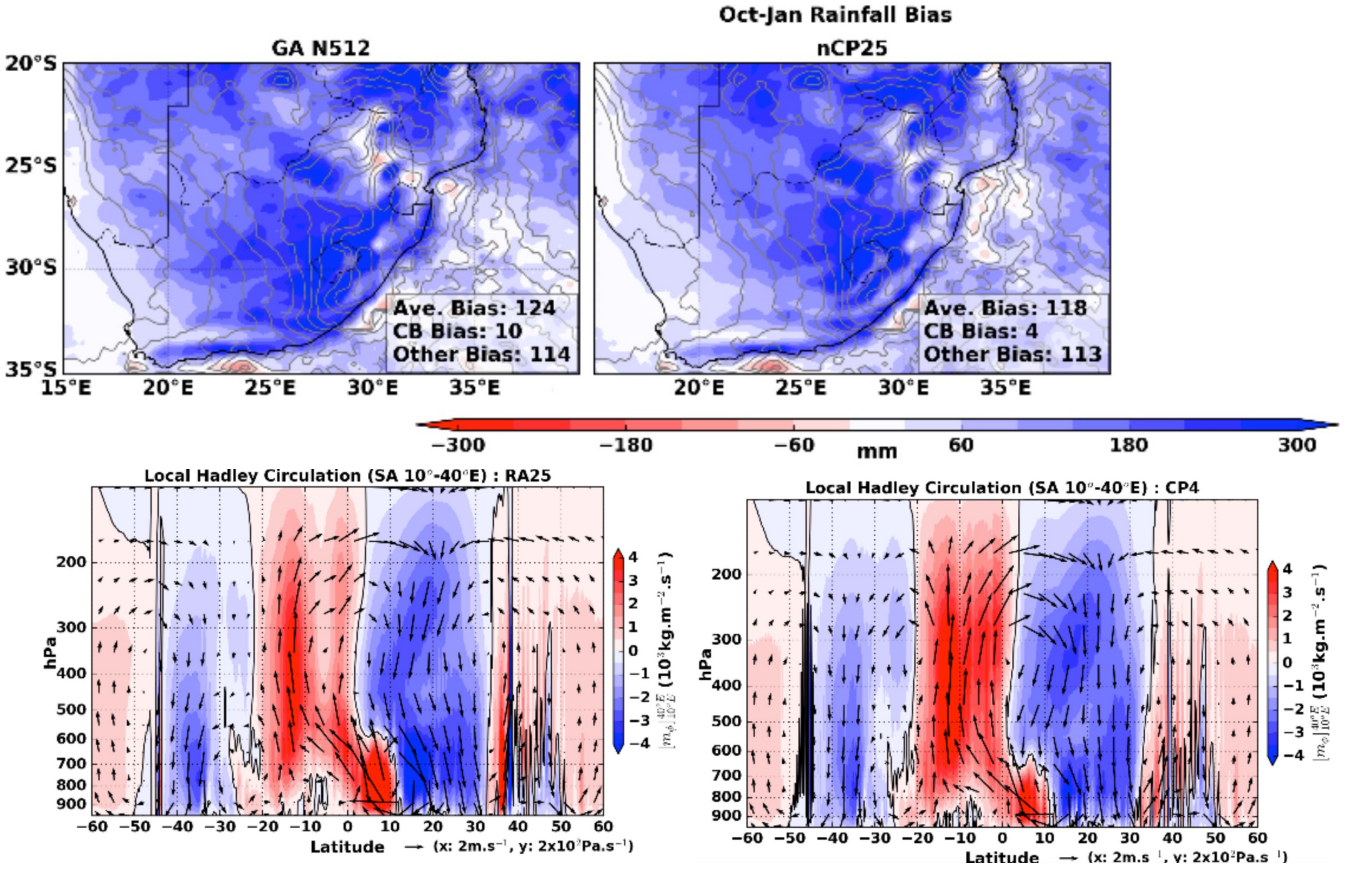
12 km model underestimates snowfall in the coastal mountains but overestimates it along the Continental Divide compared to a 4 km counterpart



Upscaling Effects

Global Model

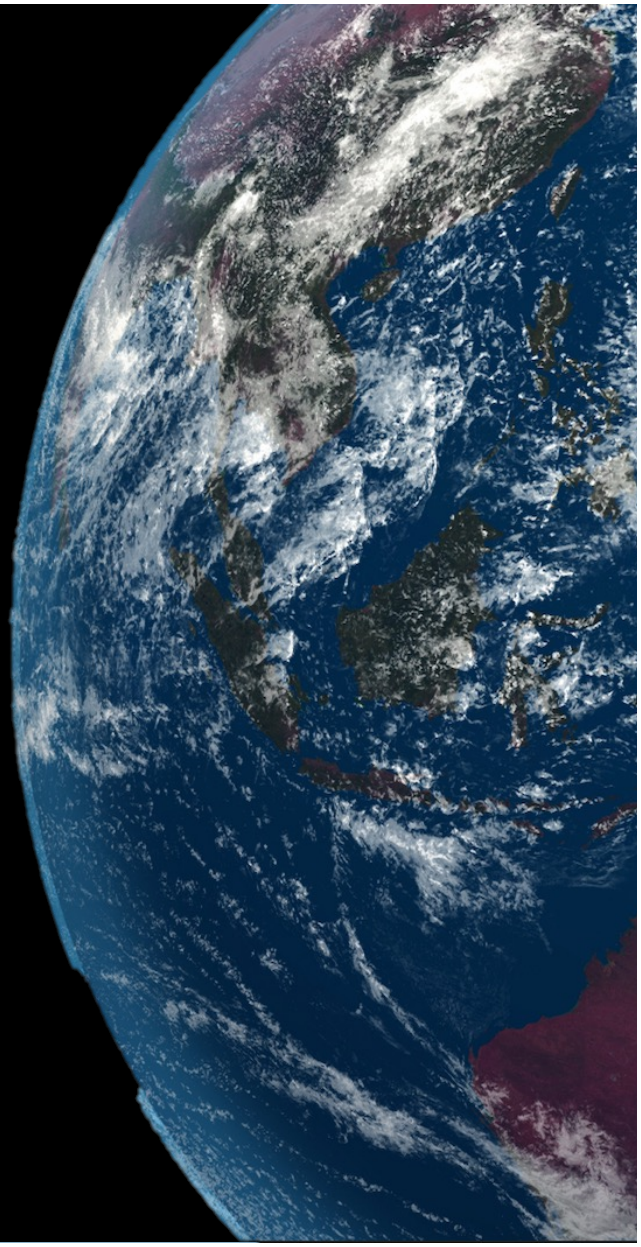
25 km Model



Hart et al. 2018; GRL

4 km has more realistic Hadley overturning circulation which halves the subtropical wet bias in

Thank You



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