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Challenges of Representing Temperature and Precipitation Extremes with Fine-Scale Regional Climate Modeling

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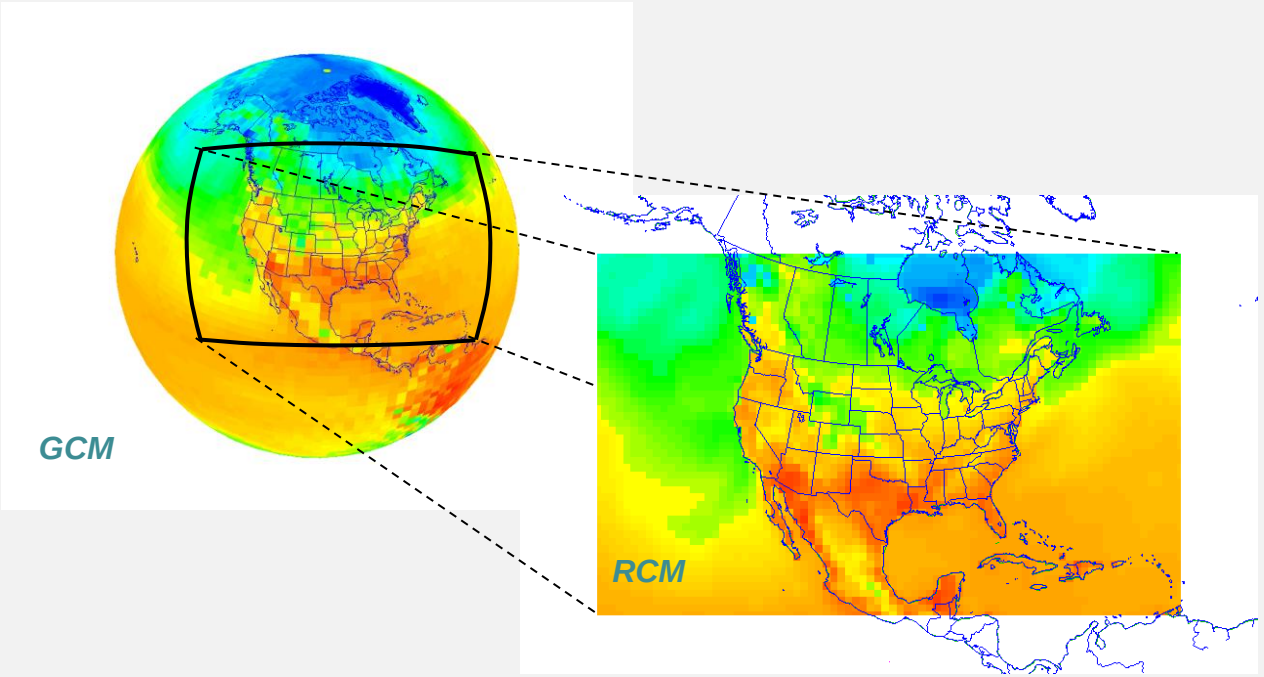

- Dynamical downscaling uses global climate model (GCM) output to drive a finer-scale limited-area regional climate model (RCM), which adds value through:
  - Improved representation of finer-scale processes & features (e.g., topography) due to finer grid resolution
  - Scale-appropriate physics
  - Increased temporal resolution

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- Dynamical downscaling is physics-based approach, unlike statistical downscaling.
- While statistical projections are available, they do not contain needed information to support AQ modeling applications.

- Previous RCM work done with **36-km** *(e.g., Nolte et al. ACP 2018; Nolte et al. JAWMA, 2021)* and **12-km grid spacing** *(e.g., Mallard & Spero, JGR-A, 2019).*
- Short-duration extreme precipitation events captured better in 12-km runs than in 36-km (*Jalowska & Spero, JGR-A, 2019).*

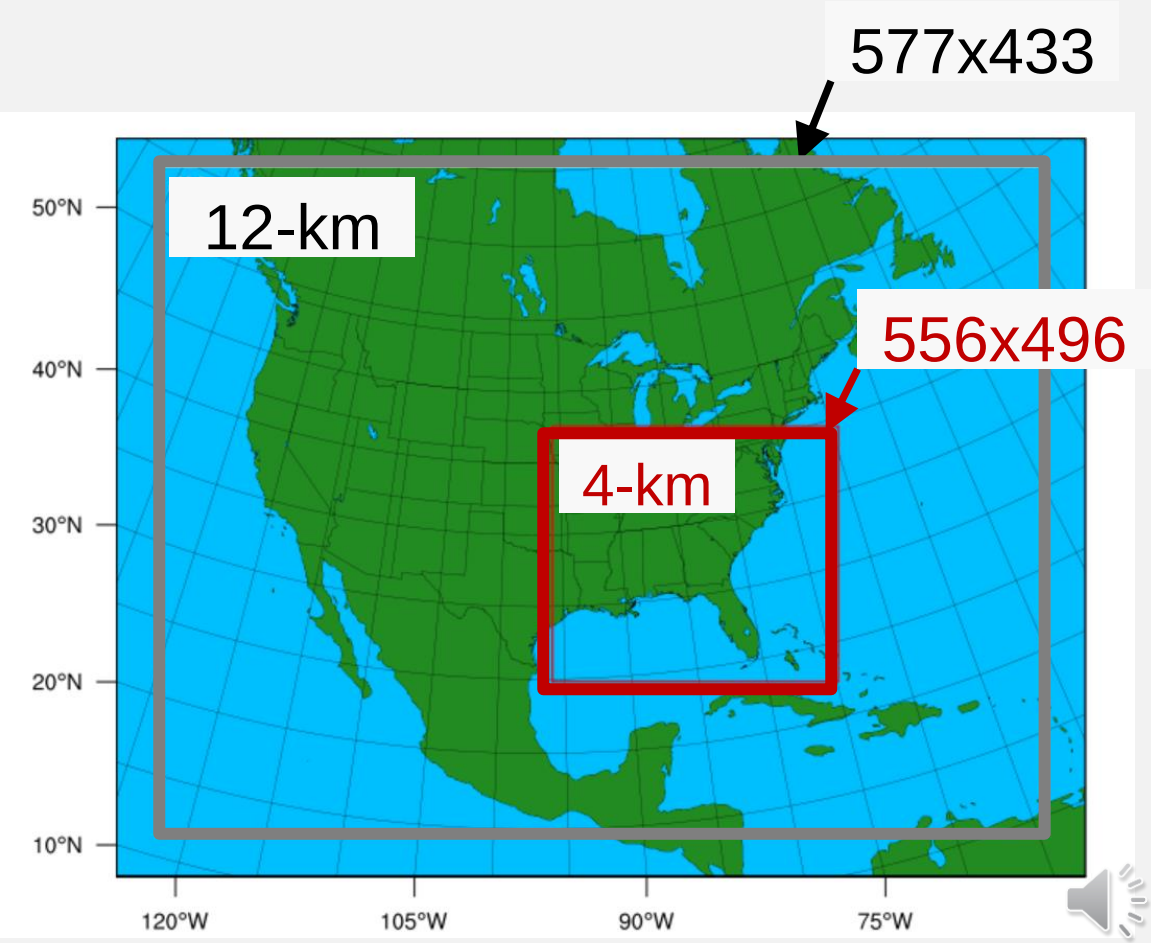
Use of Finer Resolution

- Current work explores use of **4-km** resolution
  - Finer resolution projected changes in extremes that impact *communities,* especially those challenged by resilience and issues of environmental justice

- Will potentially improved results justify computational expense?
  - Planned comparison of 12-km vs 4-km results

Domains & Set-Up

- Weather Research & Forecasting (WRF) model version 4.2.1
- Time period: 1 Oct 2014 – 1 Jan 2018 (3 month spin-up)
- 12-km CONUS parent domain
- 4-km southeast domain
  - 2.5 TB per year of output
  - 512 processors over 4 days to simulate 1 year

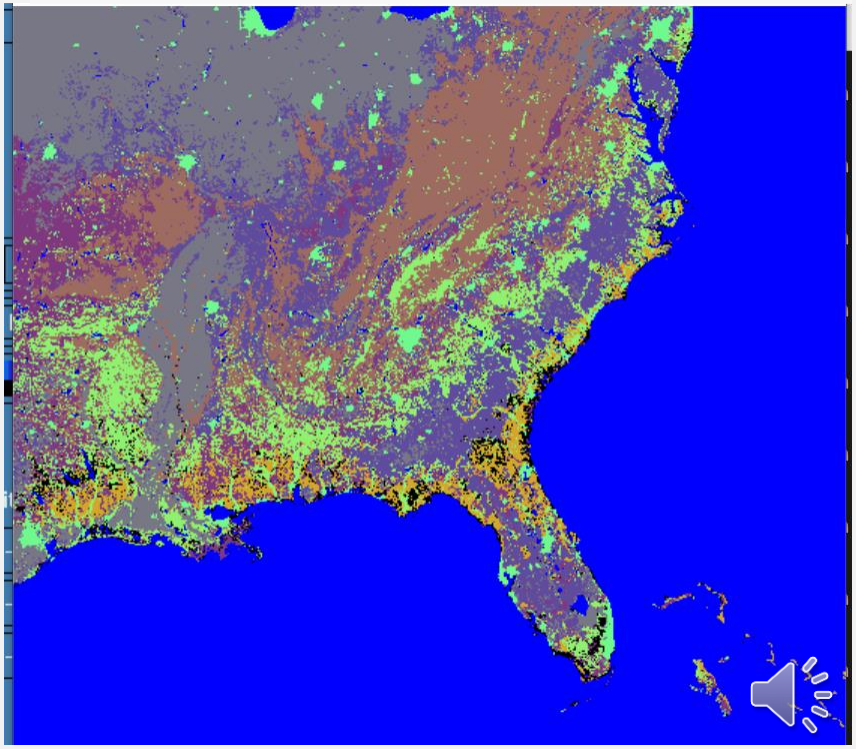


Physics Set-Up

- Driven by ERA-Interim global reanalysis (0.75º), which serves as a proxy for a similarly coarse GCM

Land Surface Model	Noah mosaic
Land Use	MODIS
PBL	YSU scheme
Shallow convection scheme	GRIMS from YSU group
Microphysics	WSM6
SW & LW Radiation	RRTMG
Convection	MSKF (12-4-km) & explicit (4-km)
Spectral nudging (above PBL) of horizontal wind components, potential temperature, geopotential, & moisture	

Dominant landuse on 4-km Southeast U.S. domain



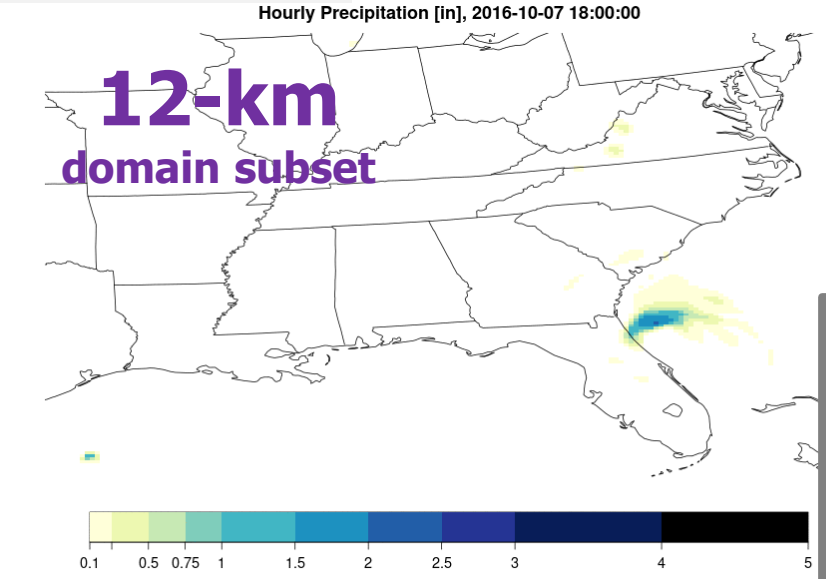
Development of Configuration

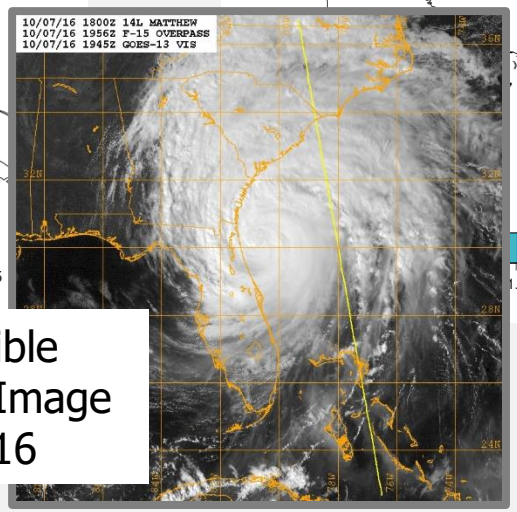
- Previous 12-km RCM studies tested use of:
  - analysis & spectral nudging *(Bullock et al., JAMC, 2014)*
  - use of lake model *(Mallard et al., JGR-A, 2014)*
  - mosaic representation of land use *(Mallard & Spero, JGR-A, 2019)*
- Additional 12-km runs: 20+ member ensemble testing various physics configurations, WRF versions, use of alternative sea & lake surface temperature data over multiple decades
- Here, 4-km sensitivity experiment performed testing choice of convective parameterization (CP)
  - WRF-CTL: MSKF
  - WRF-EXP: no CP, explicit convection only
  - Both 4-km runs driven by lateral boundary conditions from same 12-km parent

Hurricane Matthew (2016) on 4-km Domain

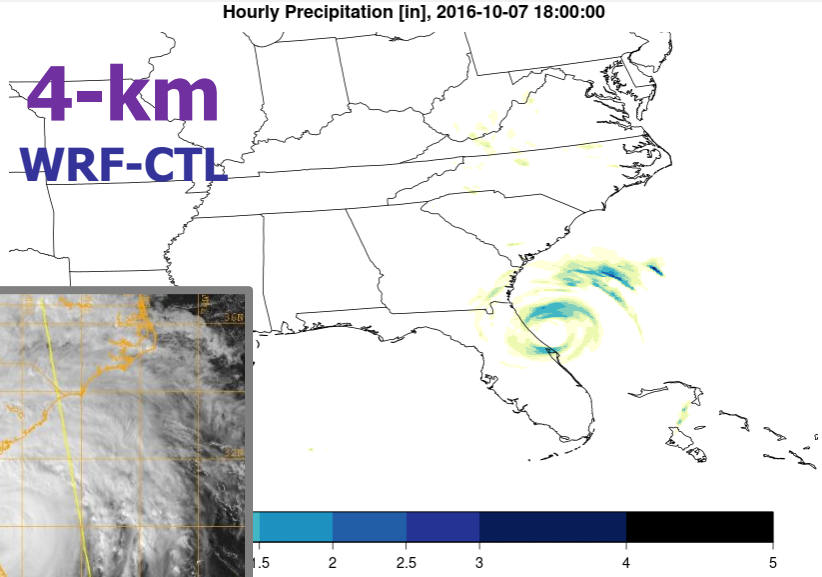
- On 4-km grid, initial “spot checking” of specific extreme events is promising!

Simulated Hourly Precipitation [mm]





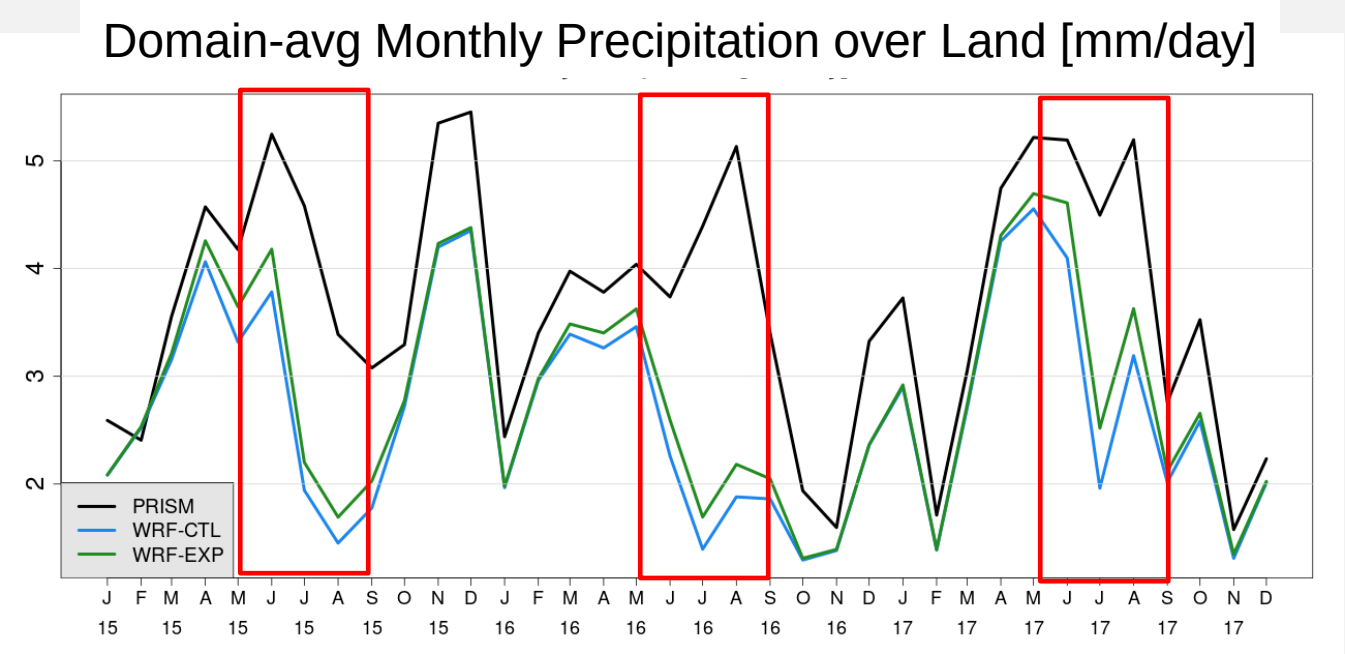
SSMI Visible Satellite Image 7 Oct 2016



Satellite image: http://www.nrlmry.navy.mil/TC.html

4-km CP Sensitivity Results

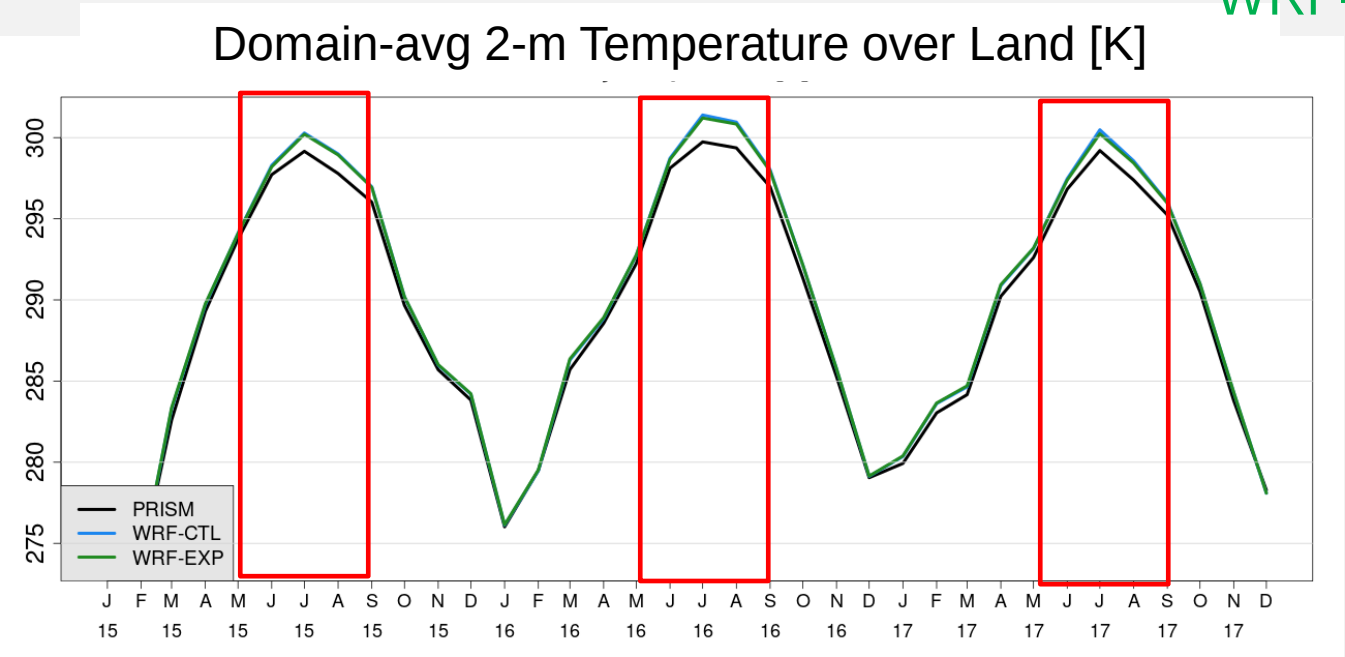
- Consistent negative bias in precipitation
  - Normalized mean biases are slightly better in WRF-EXP (-0.23) than in WRF-CTL (-0.27)
- Across the ensemble, precipitation results are notably worse during summer months (in red below), with largest biases occuring during summer 2015 & 2016



4-km CP Sensitivity Results

- 2-m temperature is positively biased, especially during summer.
  - WRF-EXP simulation is most skillful

Mean Abs Error
WRF-CTL 0.94
WRF-EXP 0.93

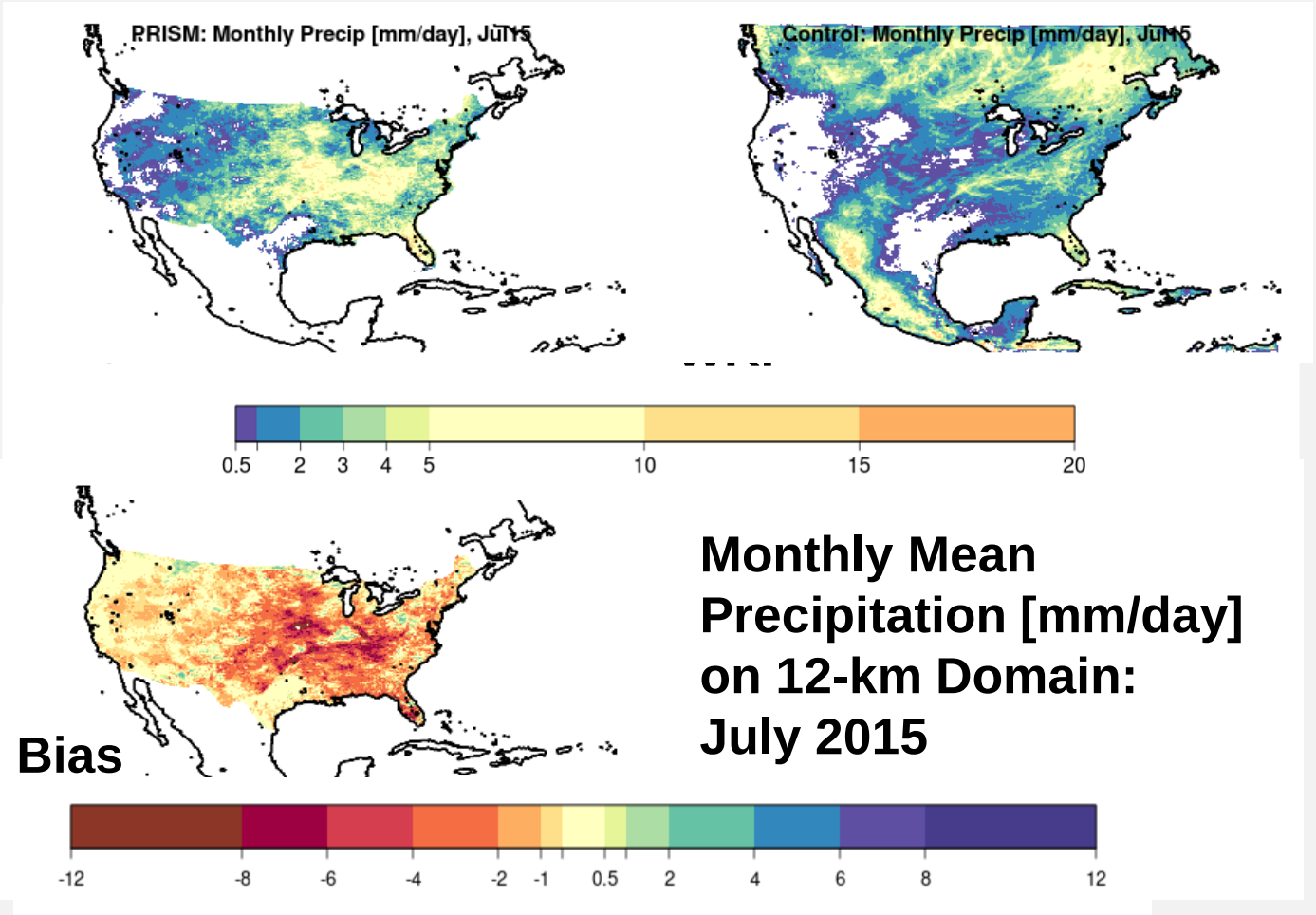


4km Results

- Runs show large negative bias in precipitation, which is somewhat alleviated by use of explicit convection.
- The largest biases occur during the summer months, when the CP scheme should be most active.
- Work is underway to revise the “control” configuration before continuing analysis of CP sensitivity.
- Are similar biases found in 12-km run?

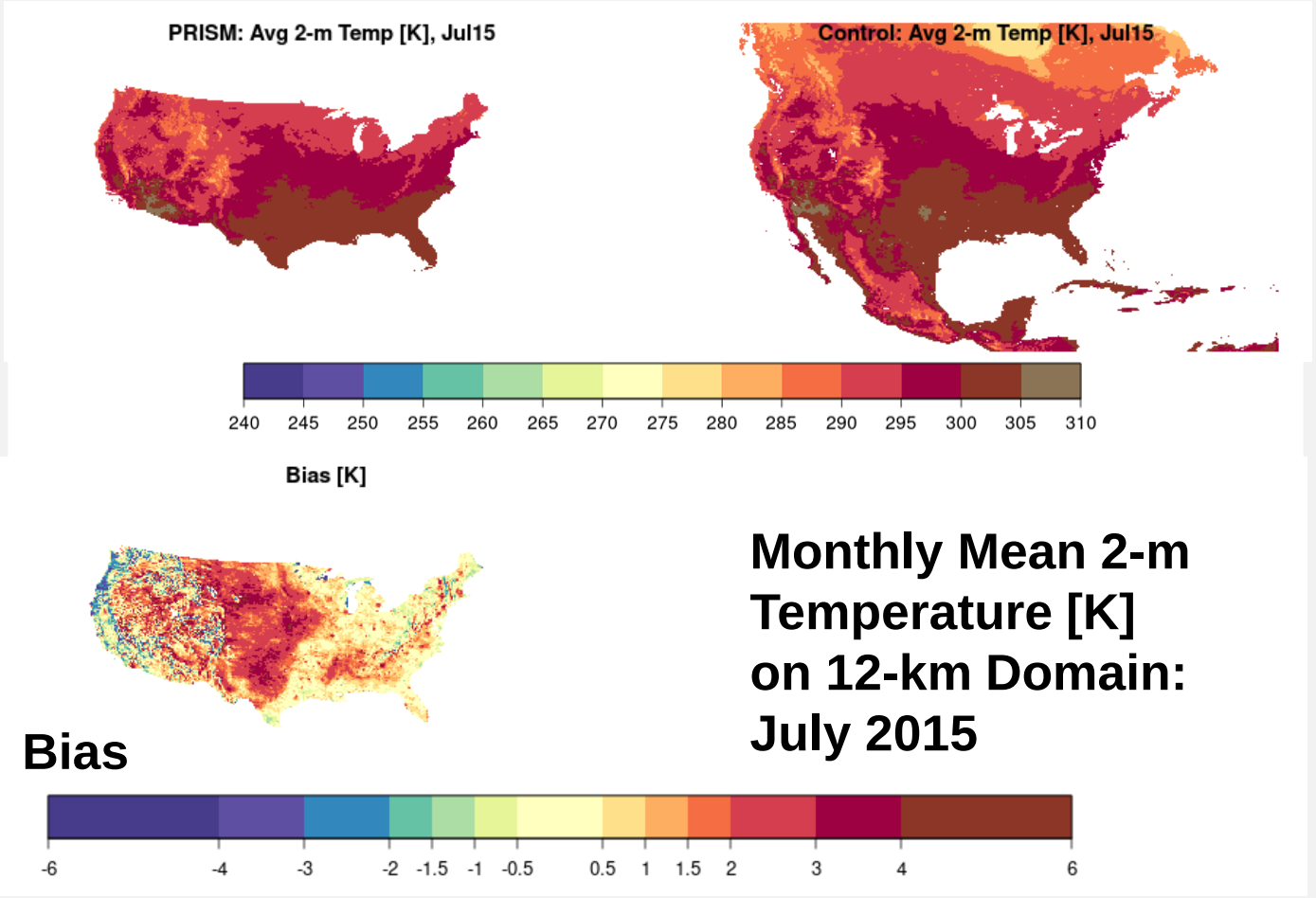
12-km Results

- Summertime precipitation on 12-km domain also shows negative bias in precipitation throughout eastern CONUS



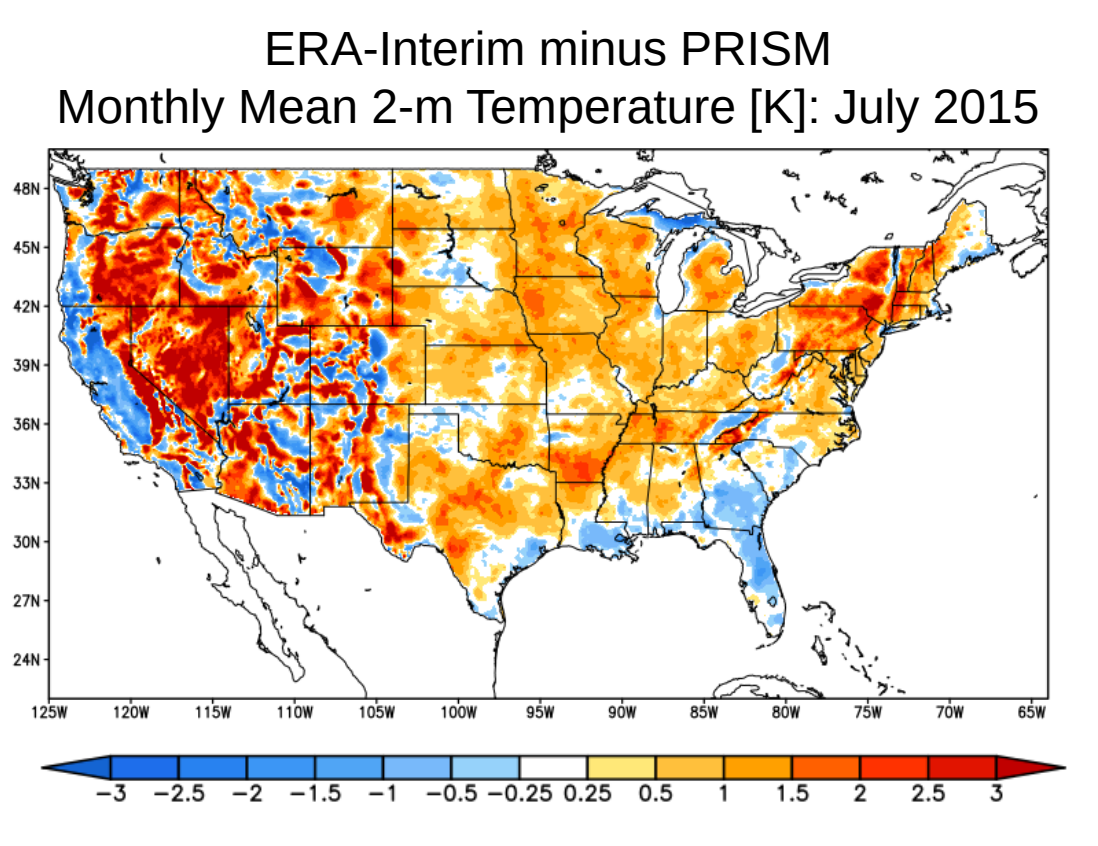
12-km Results

- 2-m temperature biases are heavily concentrated in central CONUS, with reduced warm biases present in southeast



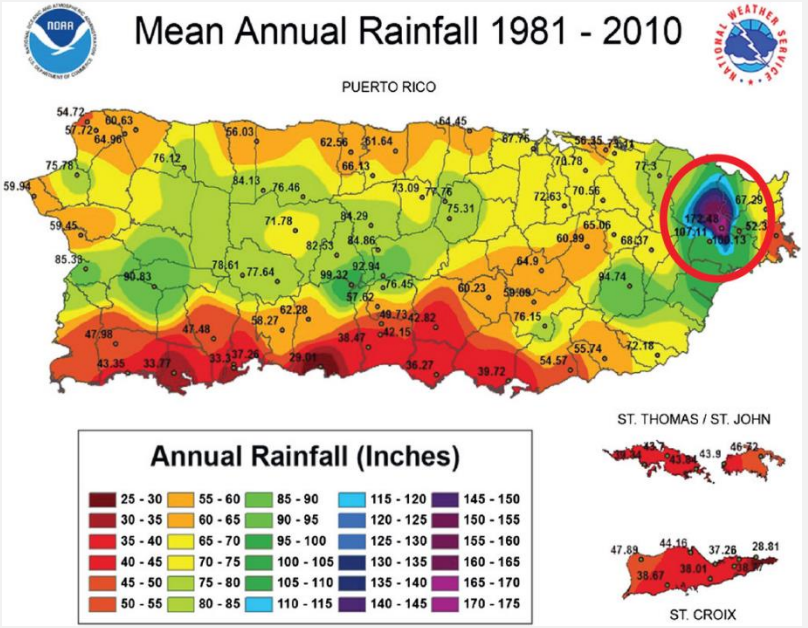
ERA-Interim Comparison

- ERA-I temperatures are generally 1-1.5 K warmer than PRISM throughout central CONUS.
- Monthly biases in WRF runs are generally larger, therefore, warm/dry conditions in driving data are amplified in WRF runs.



Summary

- Regional climate modeling is not “plug-and-play”
- Use of finer resolution, *even convective-permitting scales*, does not guarantee improved results and can amplify biases in driving data (here, a parent nest)
- Wooten et al. (JAMC, 2019): 2-km dynamical downscaling over Puerto Rico
  - Even with fine resolution, use of CP improved results
- Highlights need for further understanding of CP sensitivity in fine-resolution RCMs



Taken from Wooten et al. (2019)

Climatological precipitation for Puerto Rico and the U.S. Virgin Islands. El Yunque National Rainforest is circled in red. The figure is provided through the courtesy of the San Juan, Puerto Rico, Office of the National Weather Service.

- RCM projections on finer scales can have value for local stakeholders and communities
  - Complex topography and other influences on extremes at local scale

- Future Work:
  - Continued refining 12-km CONUS-wide model configuration
    - Prior WRF versions, alternative CP, landuse data
  - Additional dataset for model validation, so results are not solely reliant on PRISM

References

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