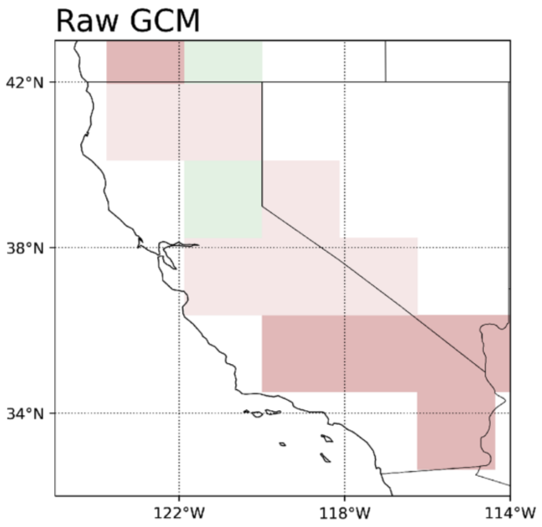
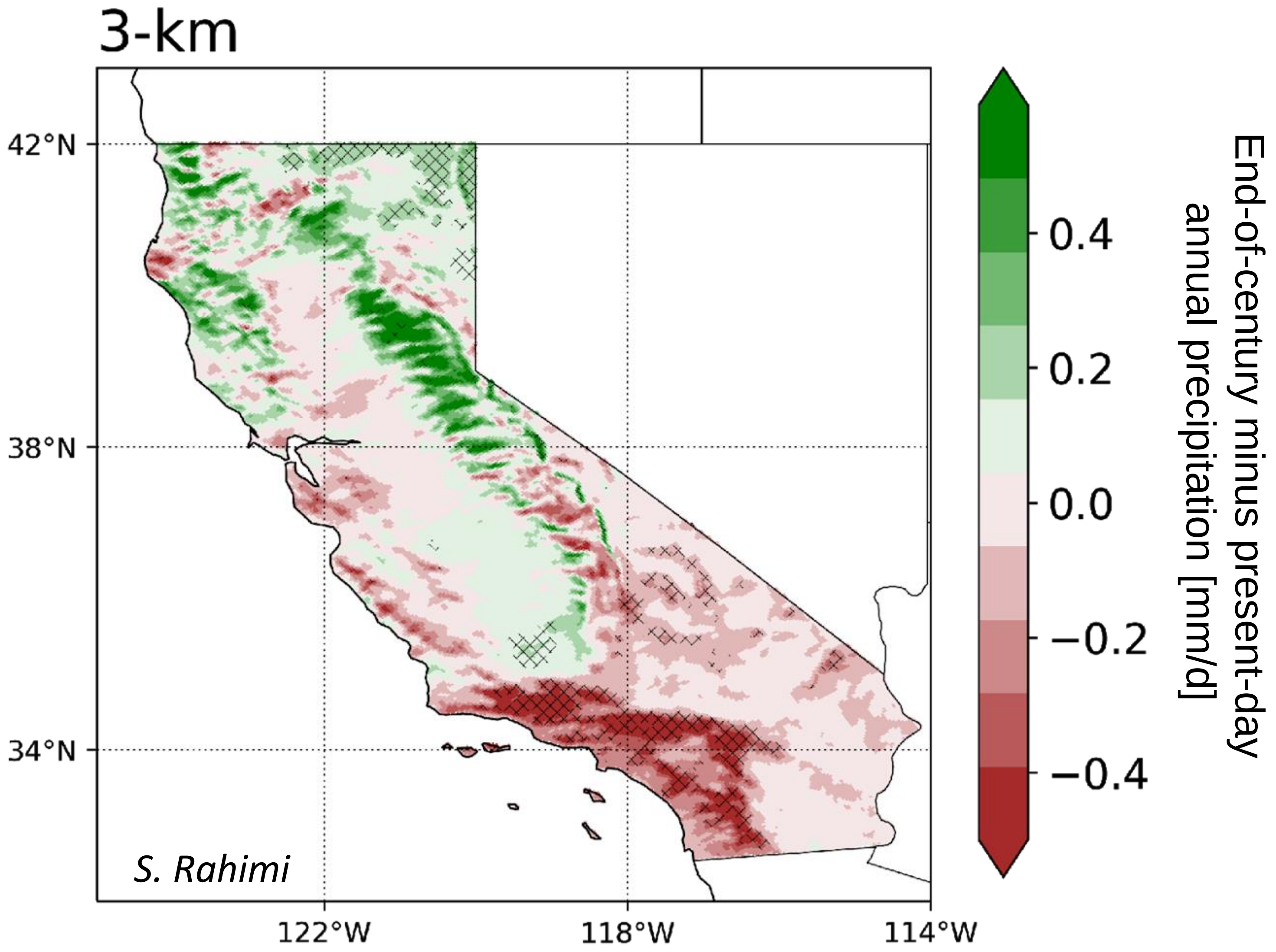
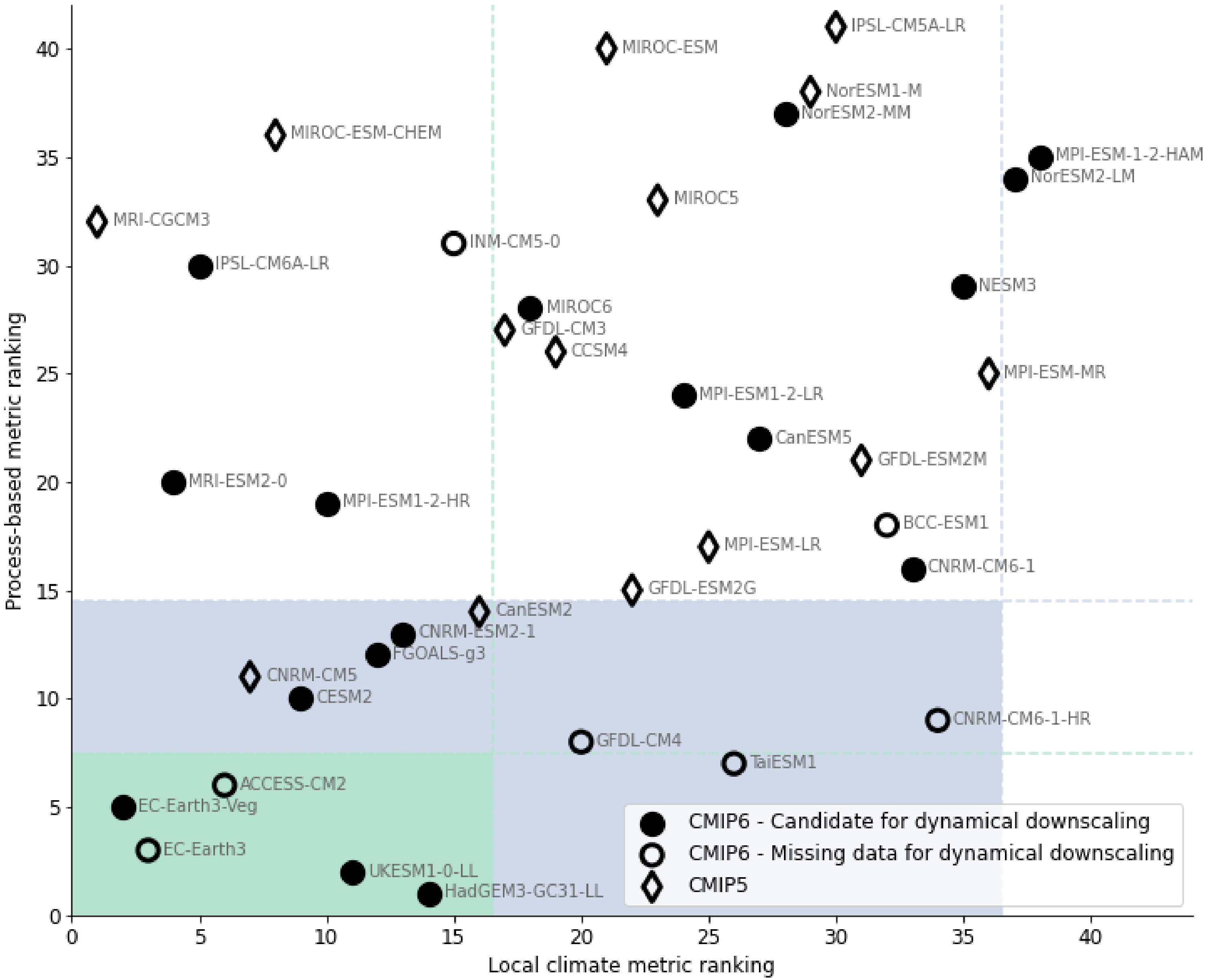
New CMIP6 Climate Projections for California

Dan Cayan, David Pierce, Stefan Rahimi, Ben Bass, Lu Su, Dennis Lettenmaier, Josh Mumford





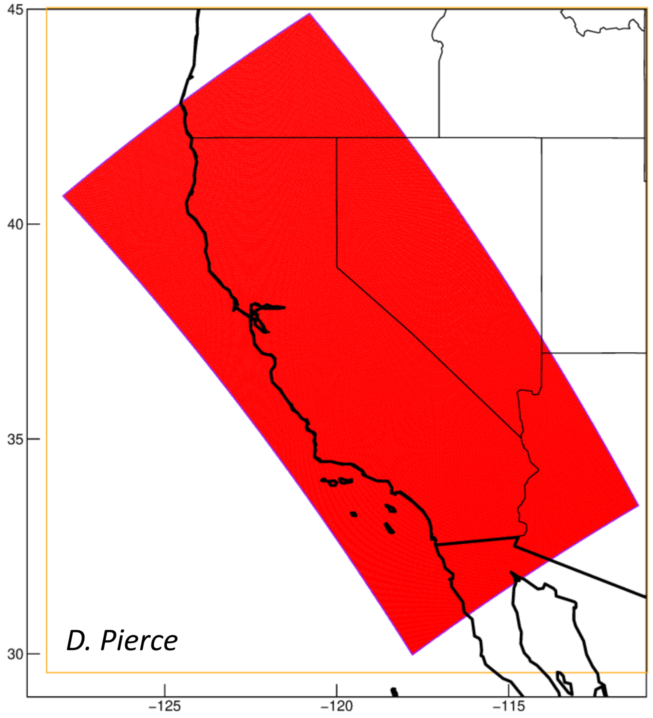
Evaluation of Global Climate Models for California



W. Krantz, D. Peirce

Types of Downscaled Data

3 km CA Domain



Dynamically Downscaled Data

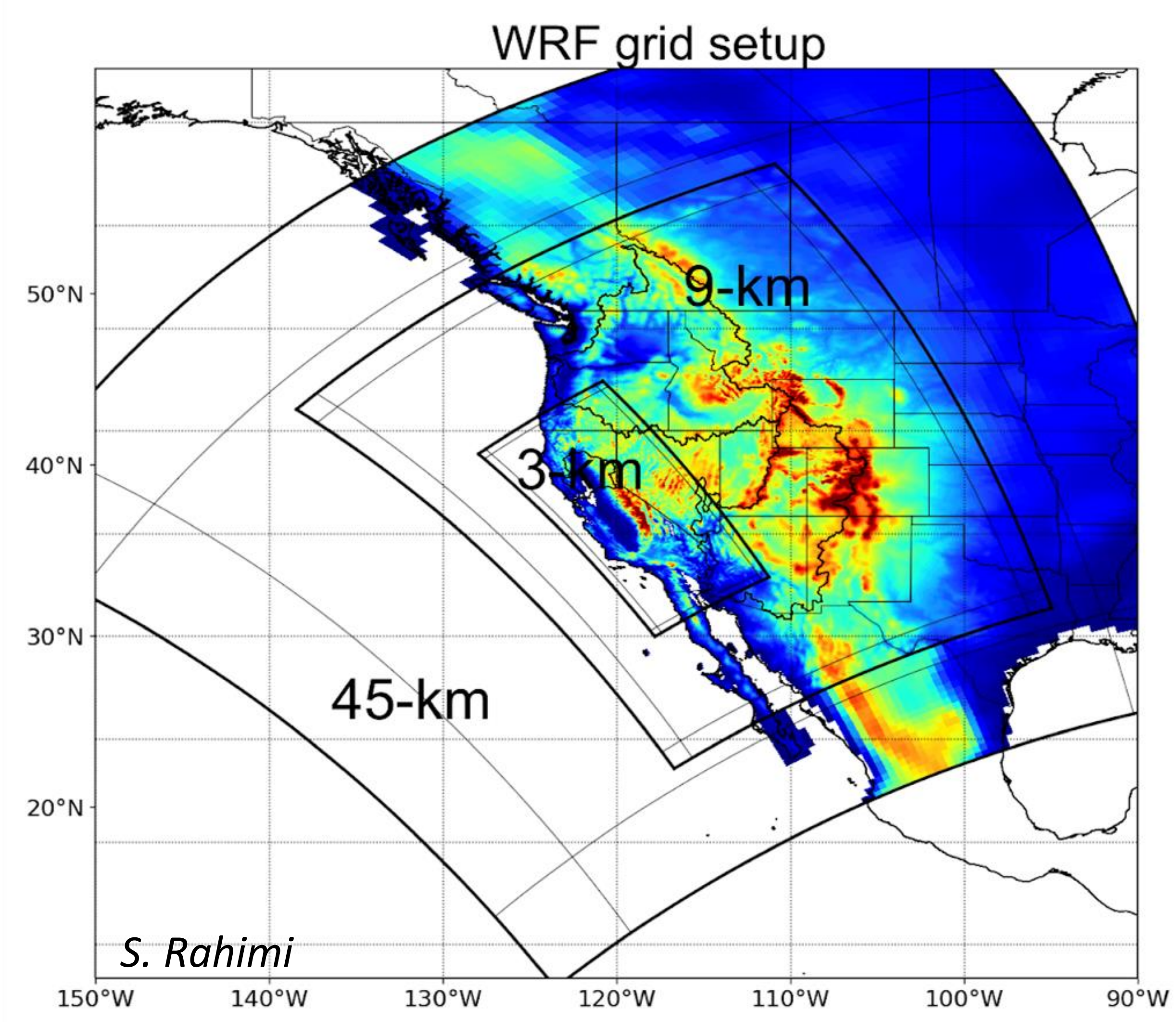
- Downscaled with WRF
- SSP 370
- Hourly data for 37 variables
- Dynamically consistent
- Non-biased corrected
- 1980-2100
- 4 models
- ~500 years of model data

Statistically Downscaled Data

- Downscaled with LOCA2
- SSP 245, 370, & 585
- Daily data for 8 variables**
- Hourly temperature at stations
- Biased corrected to observations
- 1950-2100
- 15 models, 199 runs
- ~10,000 years of model data

*Variables: Tmin, Tmax, precipitation, diurnal temperature range, RH min, RH max, specific humidity, surface downward shortwave, vector winds

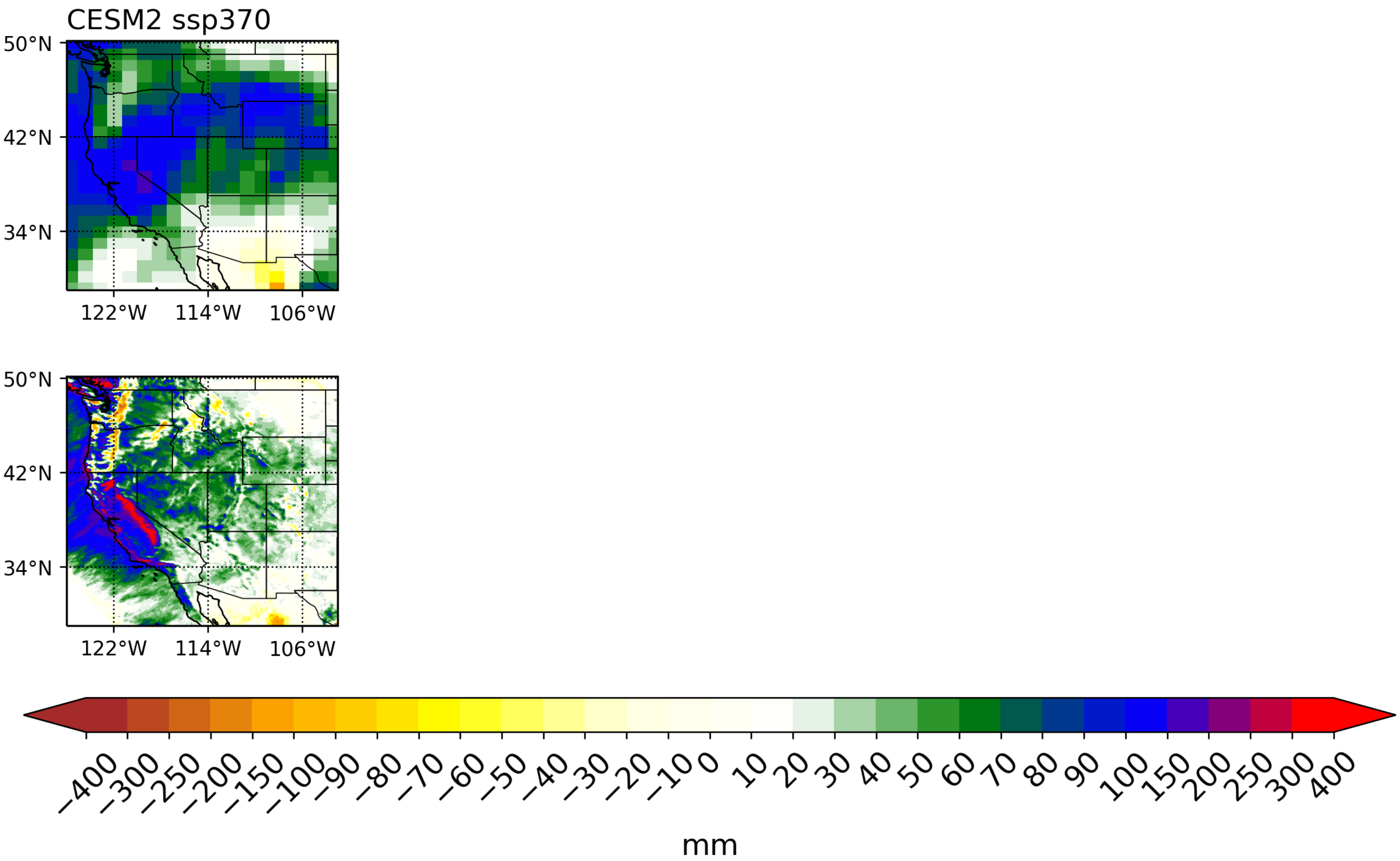
WRF Dynamical Downscaled Data



Hourly Variable

Name	Units
1. 2-m temperature	[K]
2. 2-m specific humidity	[kg kg-1]
3. Surface pressure	[Pa]
4. 10-m u-component of the wind (grid relative)	[m s-1]
5. 10-m v-component of the wind (grid relative)	[m s-1]
6. Snow water equivalent	[mm]
7. Skin temperature	[K]
8. Non-convective precipitation (cumulative)	[mm]
9. Convective precipitation (cumulative)	[mm]
10. Cumulative snowfall equivalent	[mm]
11. Diffuse downwelled solar radiation	[W m-2]
12. Surface upwelled solar radiation (all sky)	[W m-2]
13. Surface upwelled solar radiation (clear sky)	[W m-2]
14. Surface downwelled solar radiation (all sky)	[W m-2]
15. Surface downwelled solar radiation (clear sky)	[W m-2]
16. Surface upwelled longwave radiation (all sky)	[W m-2]
17. Surface upwelled longwave radiation (clear sky)	[W m-2]
18. Surface downwelled longwave radiation (all sky)	[W m-2]
19. Surface downwelled longwave radiation (clear sky)	[W m-2]
20. Surface runoff	[mm s-1]
21. Sub-surface runoff	[mm s-1]

WRF Dynamical Downscaled Results

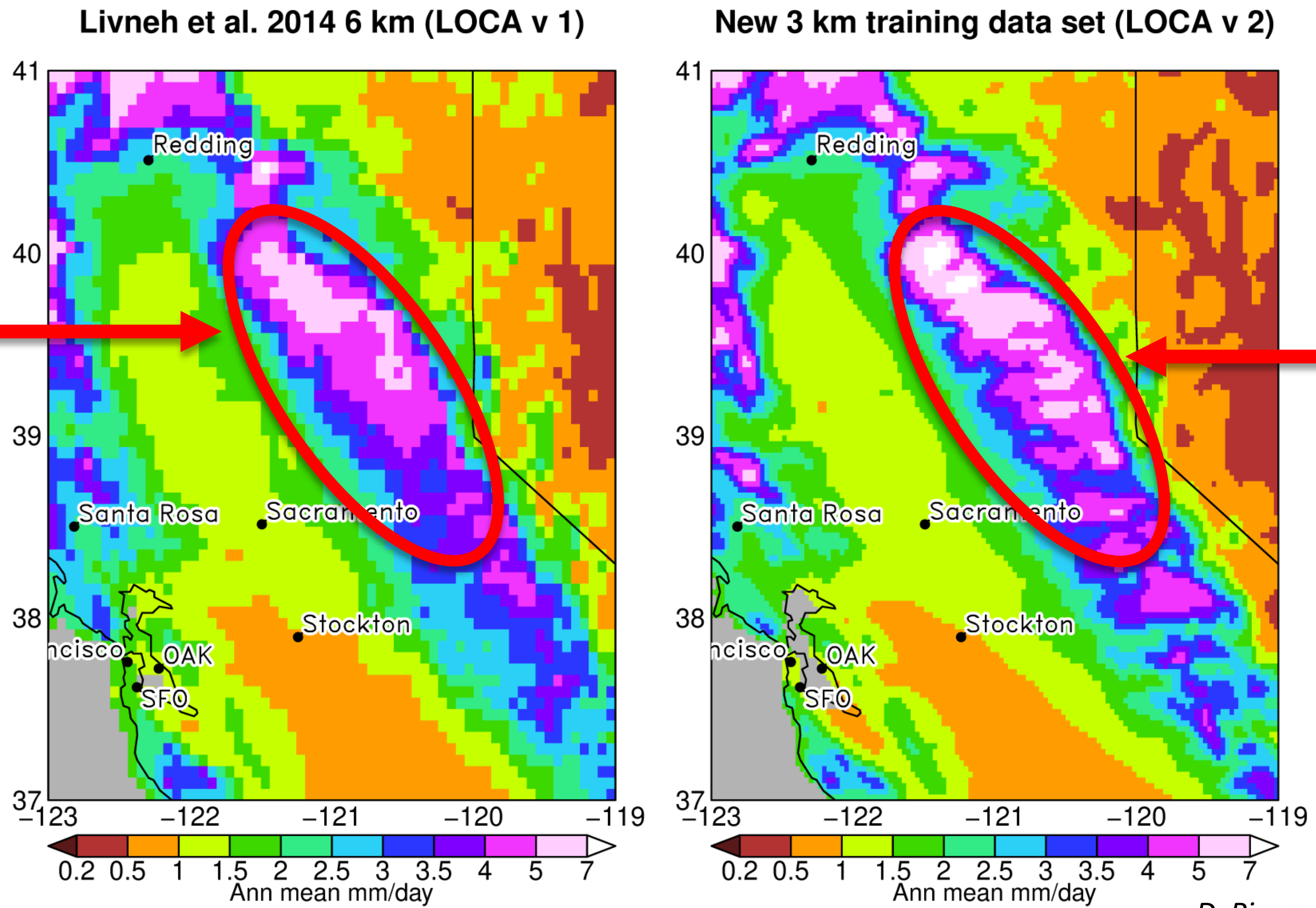


Future (2070-2100 mean) minus present-day (1980-2010 mean) differences in cumulative annual water year precipitation in [mm] for the four WRF-downscaled GCMs

S. Rahimi

New, higher resolution training data uses WRF to interpolate between stations for more realistic precipitation

Poor station coverage and simple interpolation smears out topographic effects of Sierra Nevada peaks

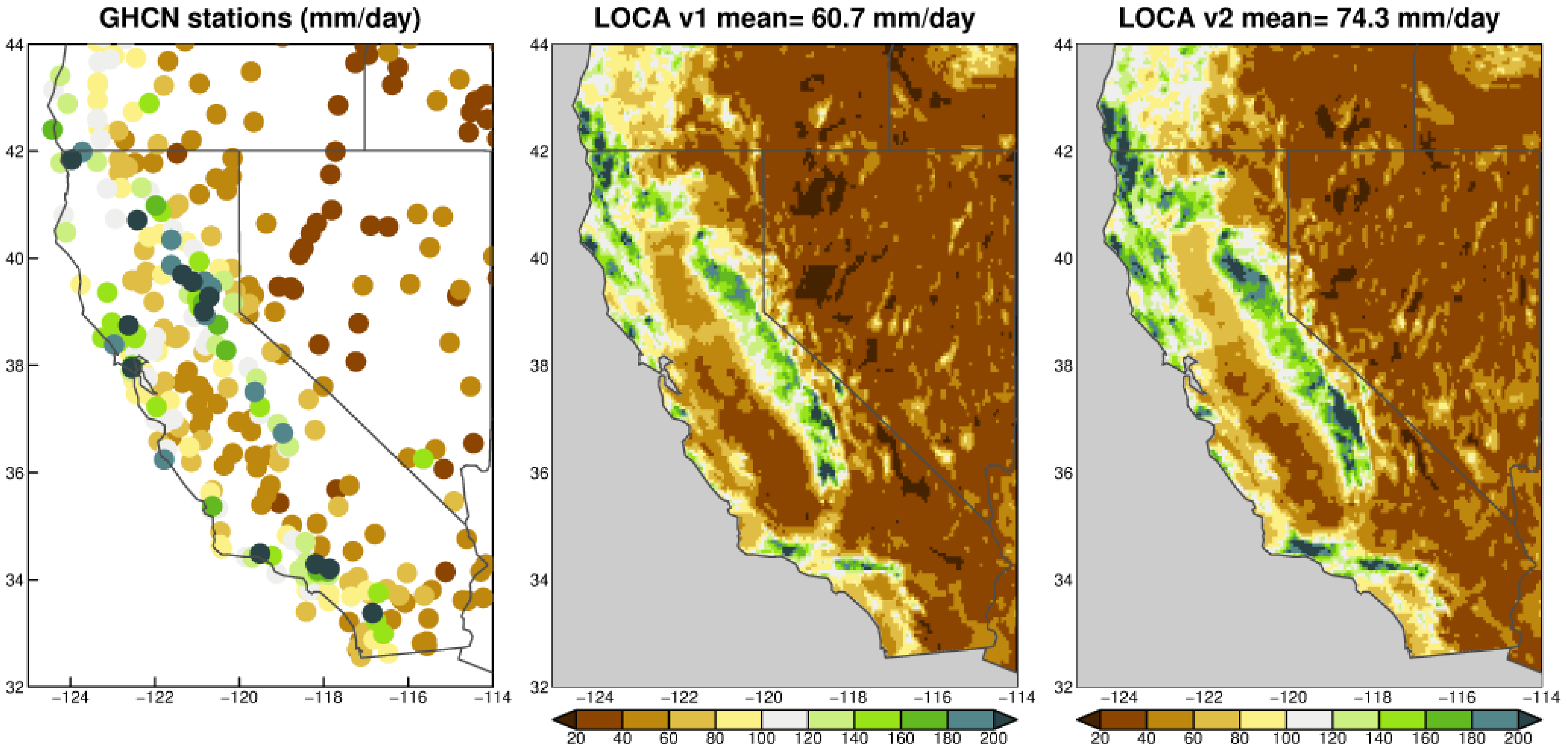


Same stations, but using WRF to interpolate between stations improves realism

D. Pierce

New ensemble bias correction scheme better represents extreme precipitation events

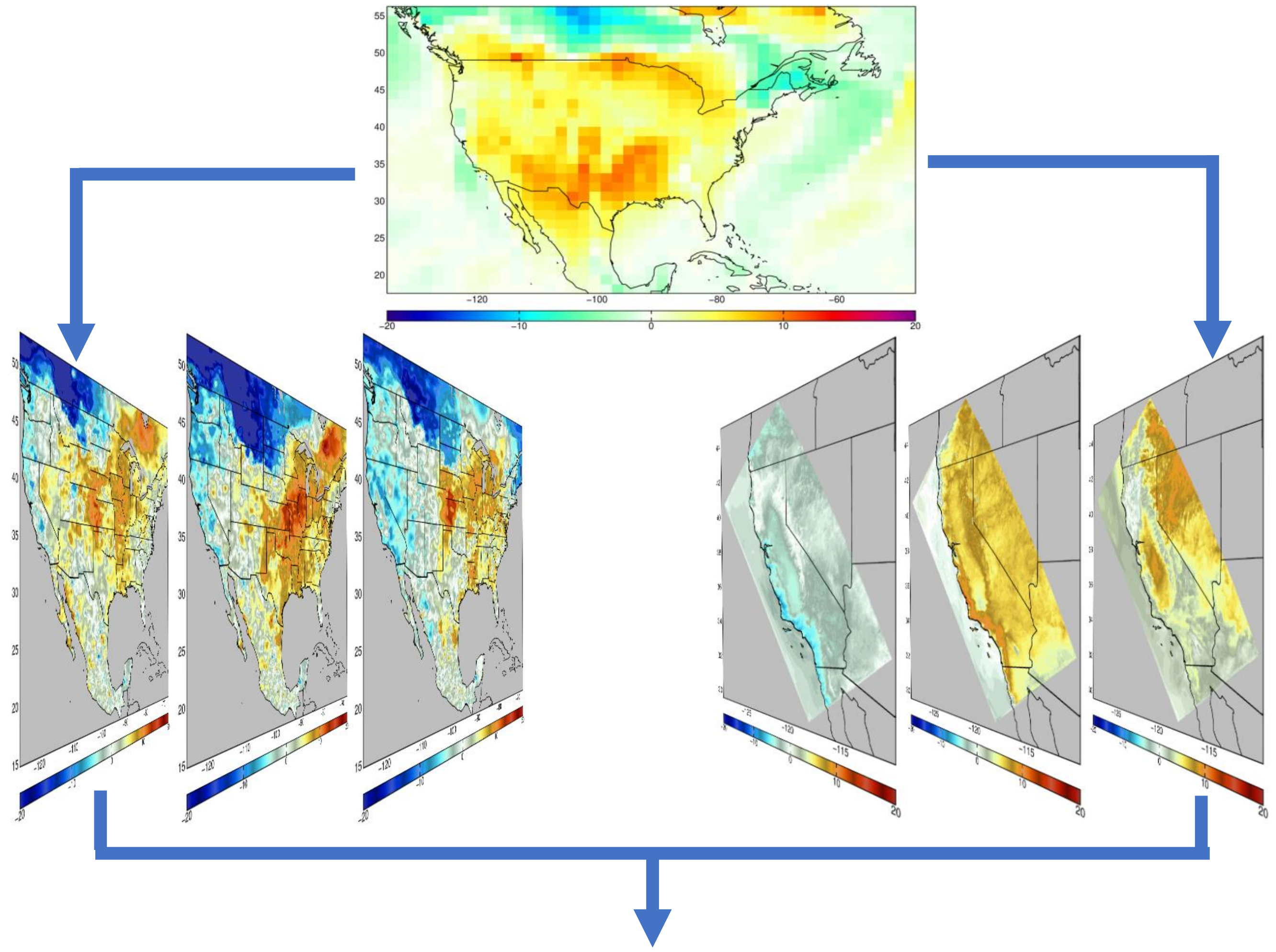
20-year return value of daily precipitation



Pierce et al., 2023; https://doi.org/10.1175/JHM-D-22-0194.1

New hybrid downscaling scheme uses WRF-projected future weather patterns at the end of the century

Original GCM day to downscale (end of century)



LOCA version 1: Weather pattern library from historical observations

LOCA version 2: Weather pattern library from end of century WRF simulations

Downscaled result

New method limits the stationarity assumption

More data available to address stakeholder needs

1. More variables to answer stakeholder questions
    - LOCA 1: Tmin, Tmax, P, 10-meter windspeed, daily min and max of relative humidity; downward solar radiation
    - LOCA 2: Tmin, Tmax, P, 10-meter windspeed; daily min and max of relative humidity; downward solar radiation, <u>*10-meter U, V wind components (vector wind), specific humidity*</u>

2. More emissions scenarios to explore possible futures
    - LOCA 1: 2 RCPs: 4.5, 8.5 ("medium-low" and "high")
    - LOCA 2: 3 SSPs: 245, 370, 585 ("medium-low", "medium", and "high". Earth currently close to SSP 370)

3. More ensemble members available for stakeholders who need to evaluate natural variability
    - LOCA 1: Only one ensemble member available
    - LOCA 2: Up to 10 ensemble members (determined by what the original GCMs made available)

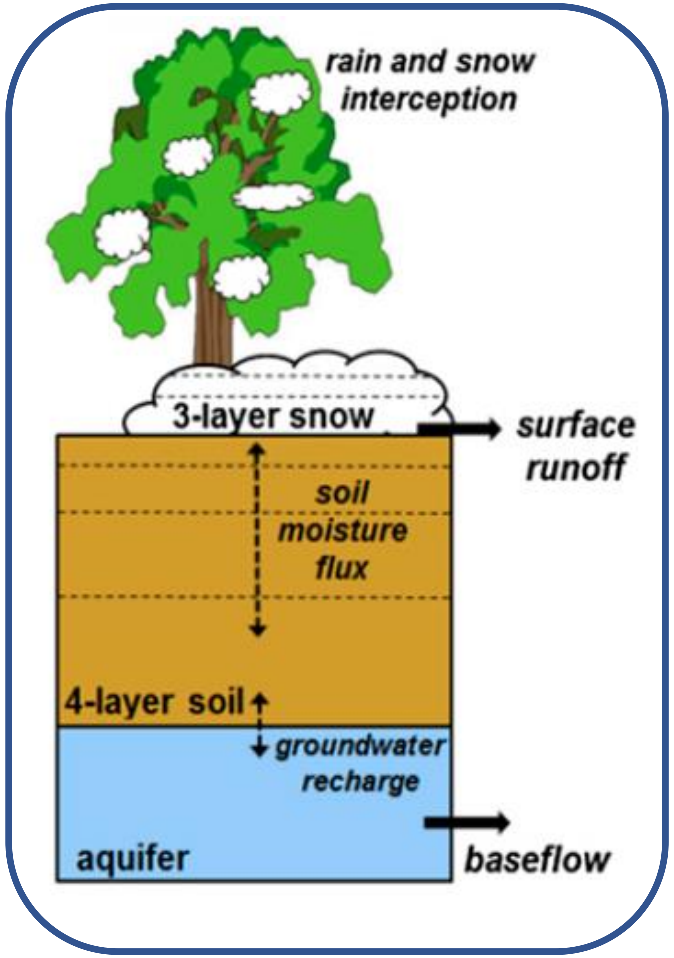
4. Potentially more hourly data available
    - LOCA 1: Hourly temperature data at 32 stations
    - LOCA 2: Hourly temperature data at 32 stations, potentially other variables and stations if stakeholders have access to observed data they can share with us for training the model

Summary: LOCA version 2 improvements

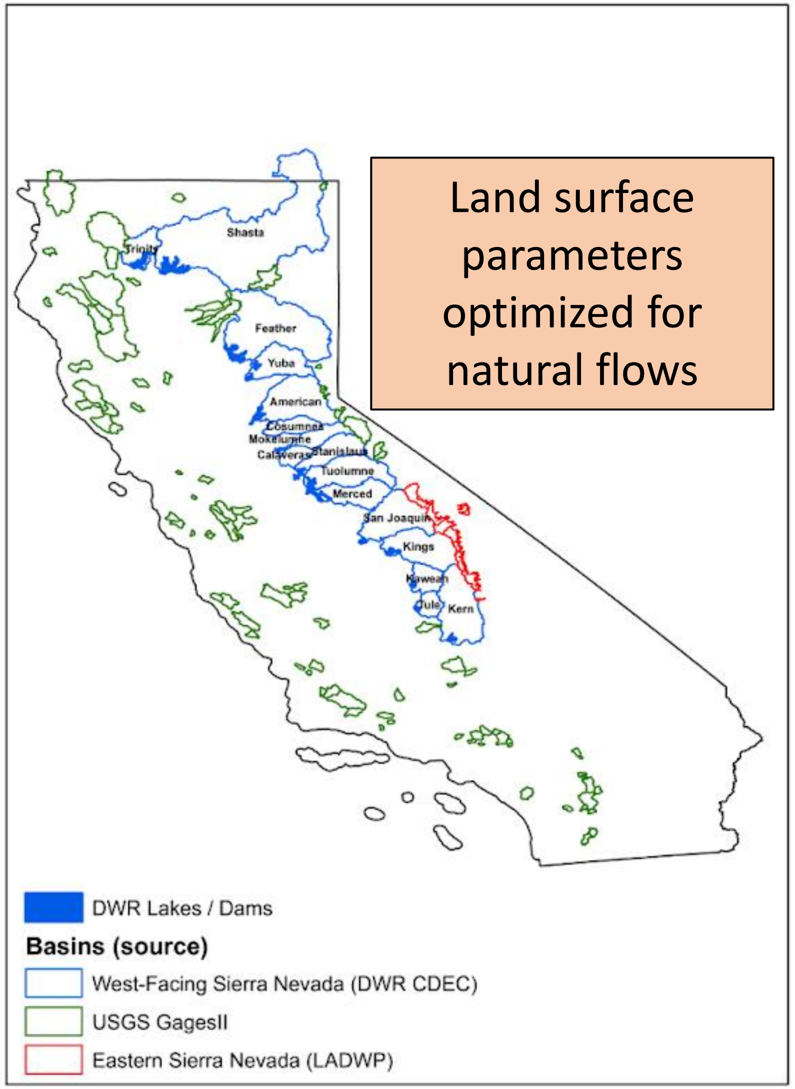
- Improved, higher resolution training data set
  - New approach better depicts effects of California’s topography; 3 km vs. 6 km in version 1
- Improved representation of precipitation extremes
  - Critical for flooding and water management
- Hybrid downscaling scheme
  - More realistic projections for coming decades
  - Limits stationarity assumption
- More variables
  - Supports a wider range of stakeholder applications
- More runs, multiple ensemble members
  - Allows better understanding of uncertainty, natural variability, and extremes
- More emissions scenarios
  - Better understanding of possible future human/societal/policy choices

Hydrologic Modeling

Hydrologic Models
WRF-Hydro (Noah-MP)
VIC
SUMA

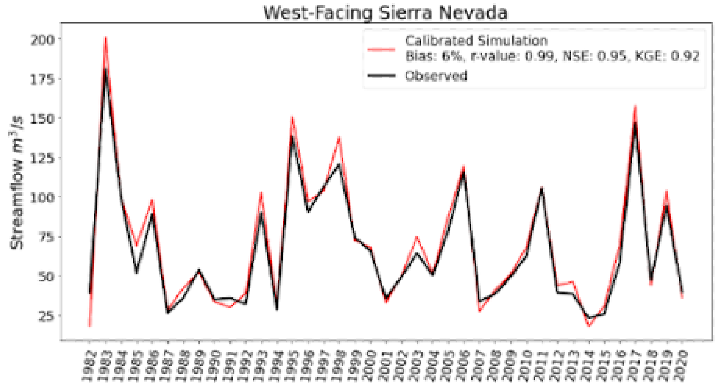


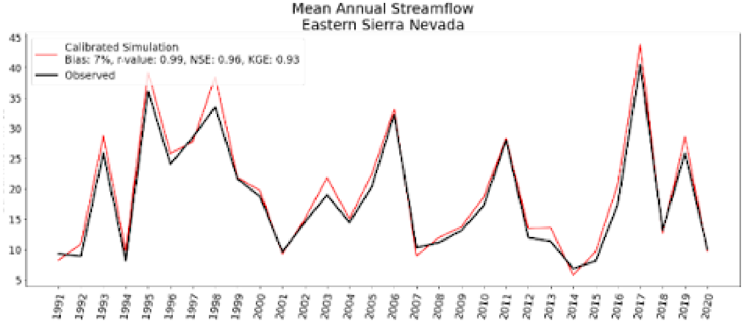
4 West-WRF models + 5 LOCA models

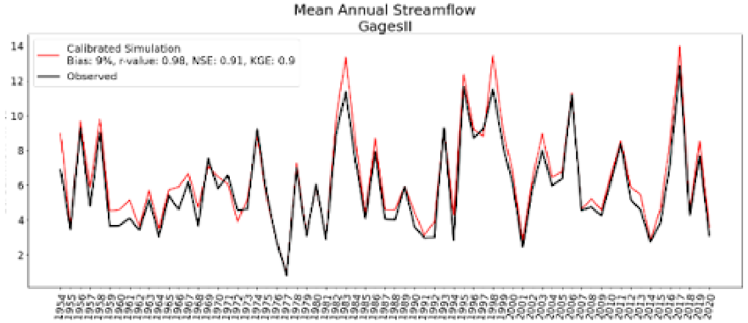


B. Bass

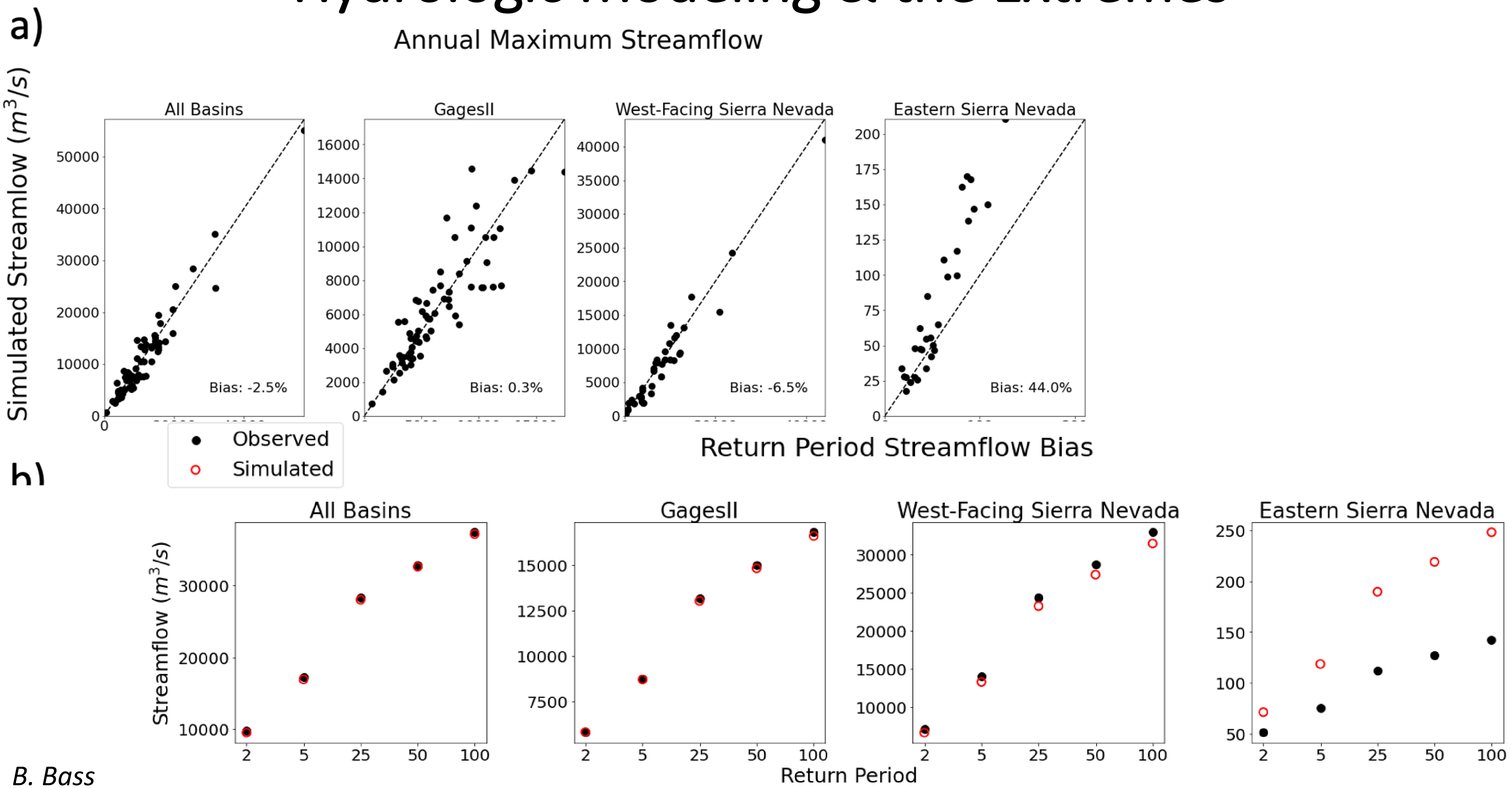
Mean Annual Stream Flow







Hydrologic Modeling & the Extremes



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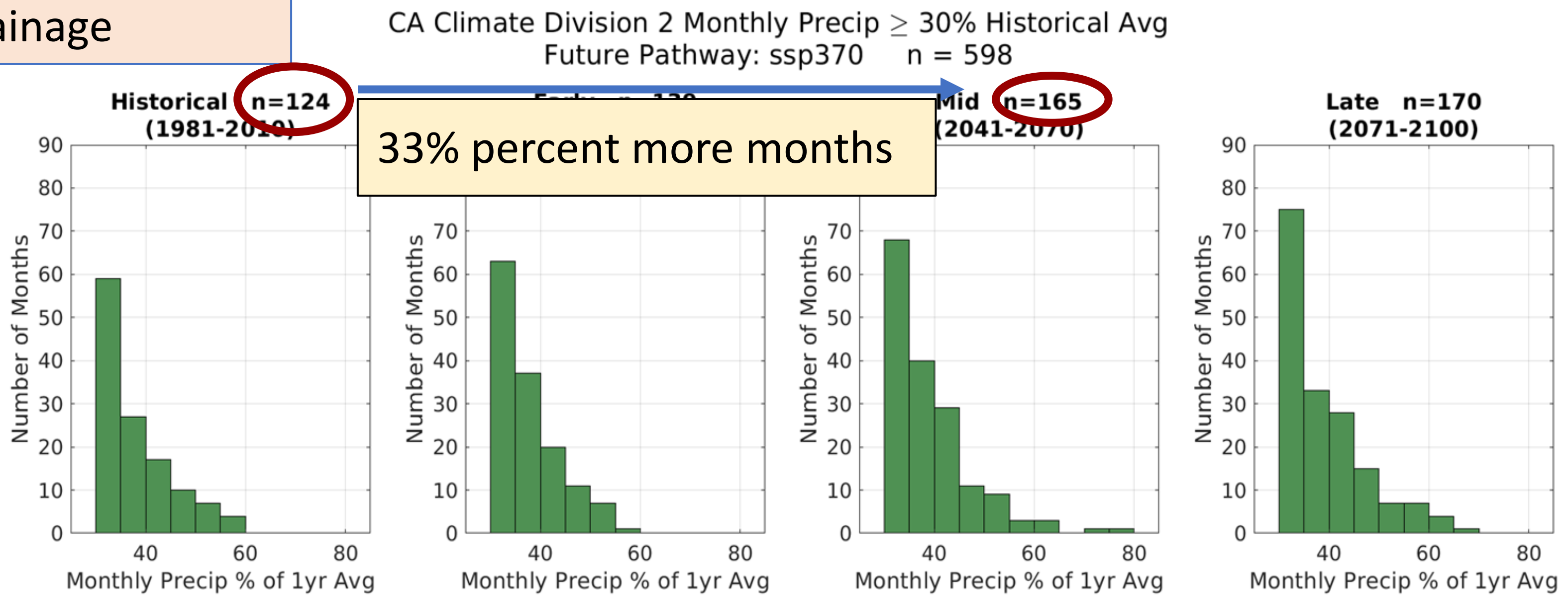
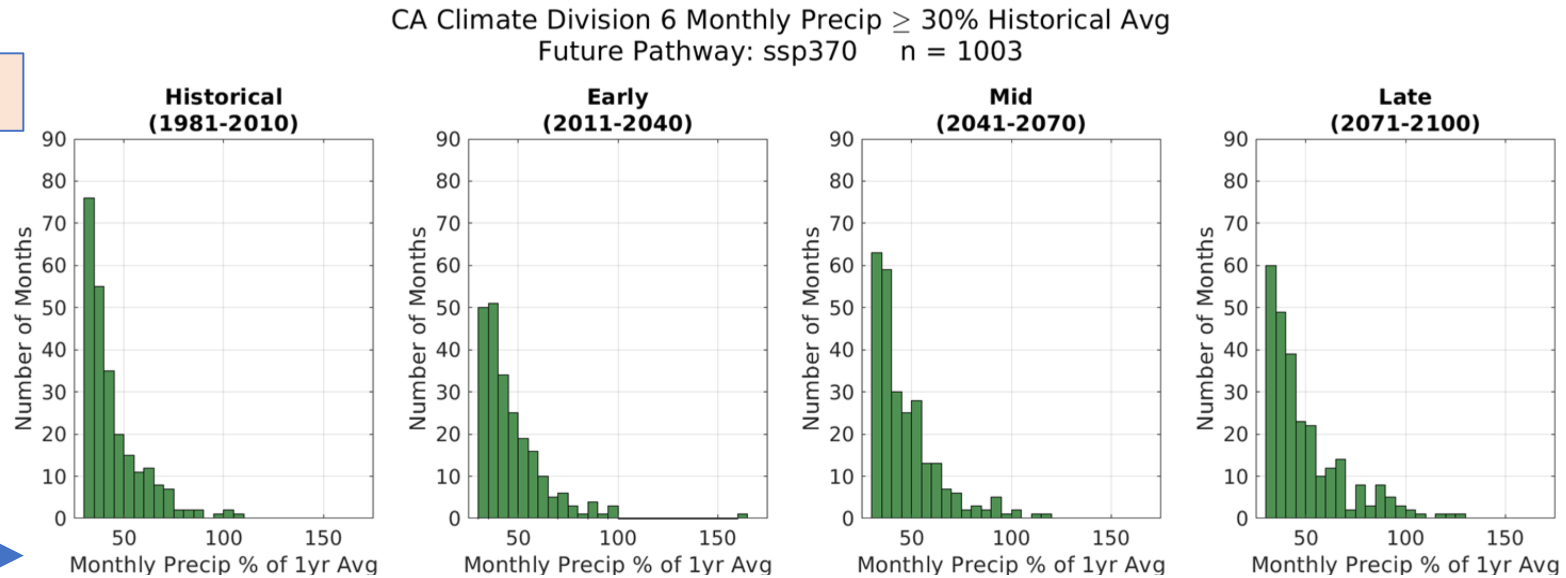
Monthly Precipitations Extremes in CMIP6

Sacramento Drainage



South Coast



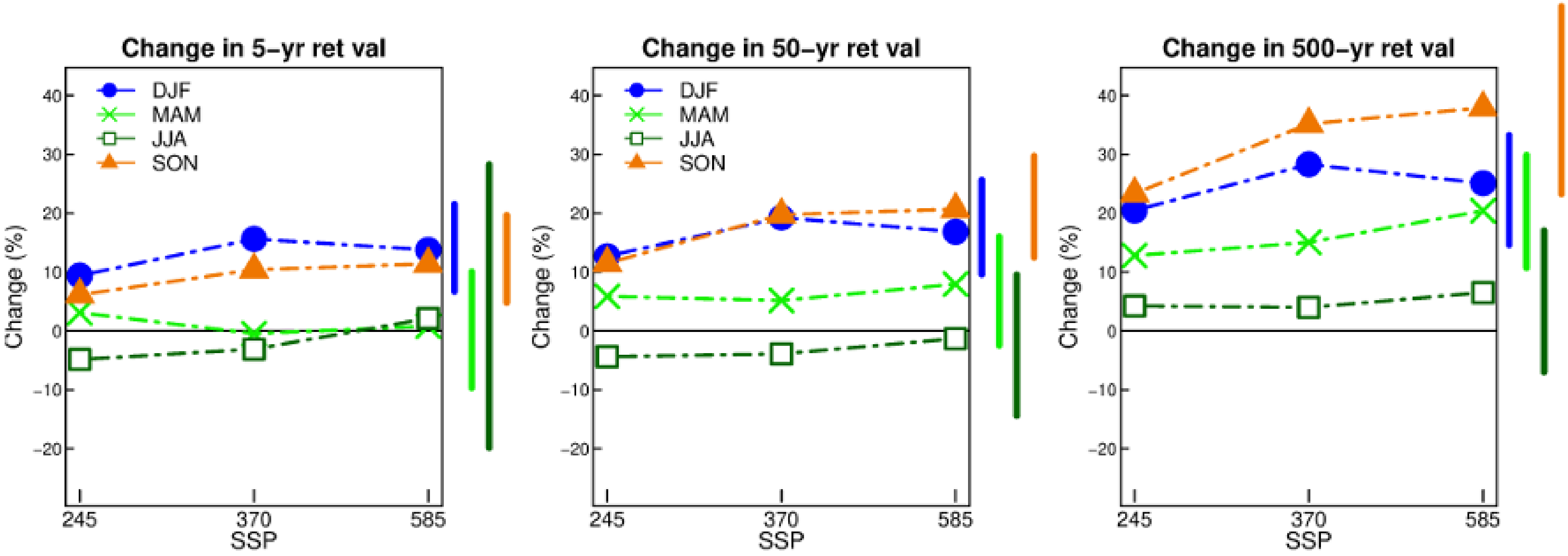
Up to 100%+ of 1 yr Aver

- NoCal simulations exhibit **greater** increase than SoCal
- *BUT* SoCal exhibits strong **increase in magnitude** of >30% historical mean annual months

D. Cayan, J. Mumford, D. Pierce

Extremes Precipitation Projections in CMIP6

Most extreme **precipitation will become** ***more extreme***

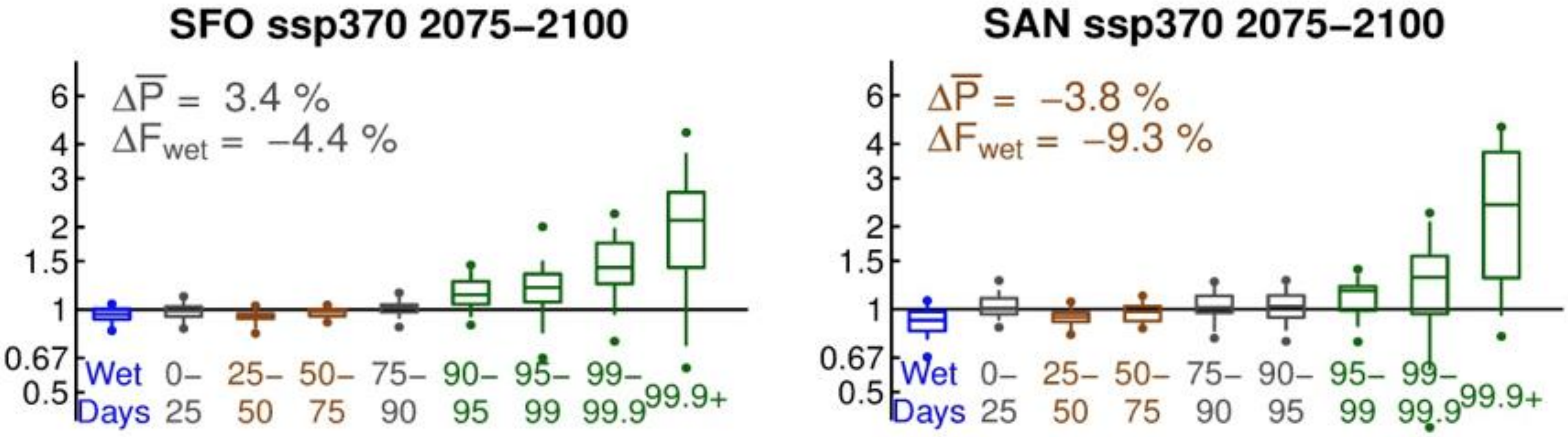


Change in 5yr, 50yr and 500yr daily precipitation return value for each season, for 3 SSPs, aggregate over California
2075 – 2100 relative to historical
27 GCMs used in analysis

D. Pierce

Extremes Precipitation Projections in CMIP6

Most extreme precipitation will become ***more frequent***



ΔP = change in annual precipitation

ΔF_{wet} = change in number of wet days

D. Pierce

Concluding Remarks

- Wealth of high resolution data to examine climate change impacts in California.
  - Dynamically downscaled data provide opportunities to look at more hourly data and dynamically consistent events
  - LOCA data provide ability to understand projections across a range of scenarios and natural variability

- LOCA Hybrid downscaling has improved to captured extreme precipitation better

- Hydrologic modeling has expanded significantly since CA 4th Climate Assessment Data
  - VIC, NOAH-MP (WRF-Hydro), SUMA
  - Captures stream flows well

- Extreme precipitation projections in CMIP6 are similar to CMIP5 projections in that the most extreme events will become more extreme and more frequent
  - Difference between Norther and Southern CA in frequency versus magnitude of extremes