Using Weather Regimes to Improve S2S Forecasting

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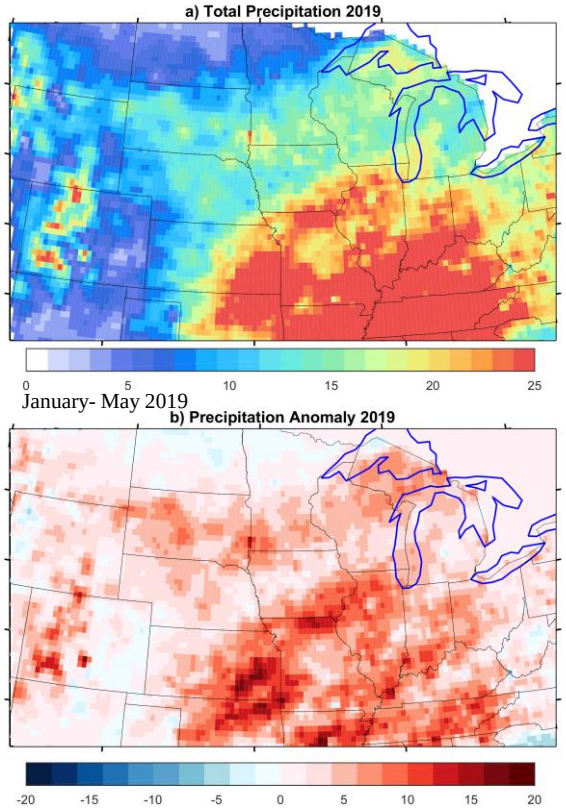
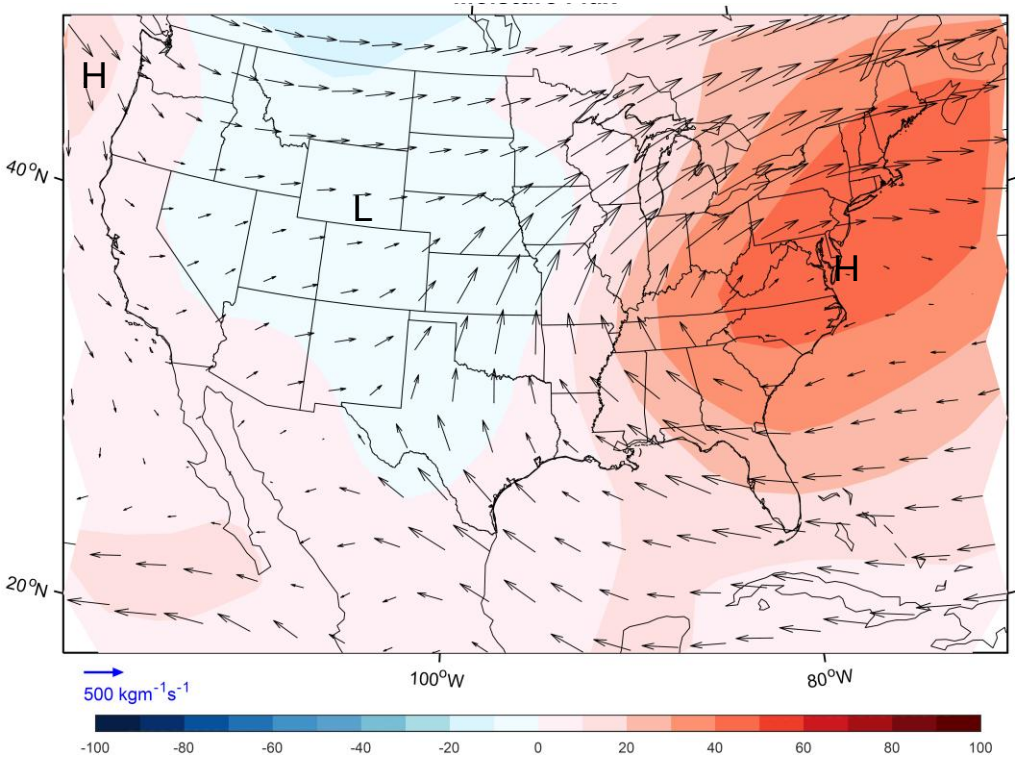
Weather Regimes: large-scale atmospheric circulation manifested as quasi-stationary, persistent, and recurrent large-scale flow patterns.

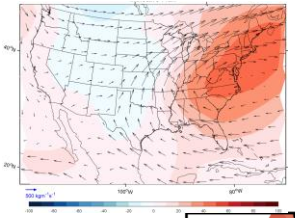


2019 Midwest Flooding



Data source: CPC daily precipitation

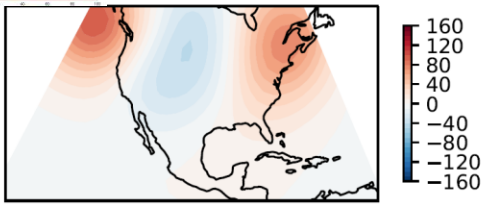
Five clusters or *weather regimes* are identified from daily 500-hPa geopotential height anomalies (more than 20,000 maps) by k-means clustering.



2019 Midwest Flooding

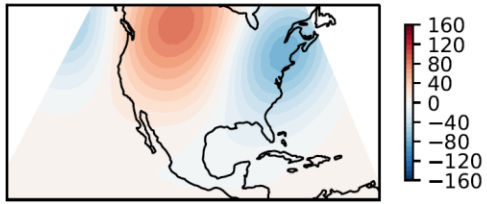
Midwest water hose

WT1, 21.3%



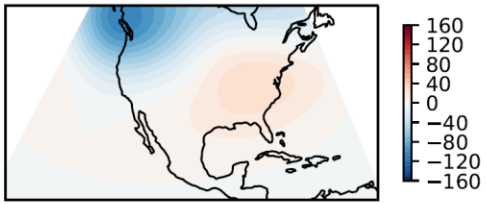
Pacific North America (PNA)

WT2, 22.6%

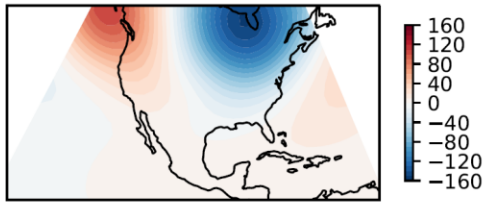


Western Trough

WT3, 22.4%

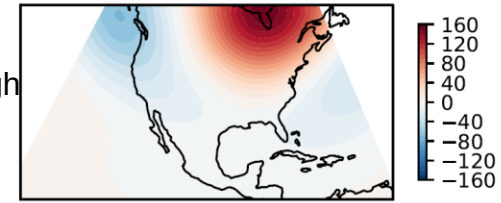


WT4, 15.9%



Deep South Trough

WT5, 17.8%



Western Ridge

Zhang et al. 2019; 2021; 2022; 2024

Questions to answer

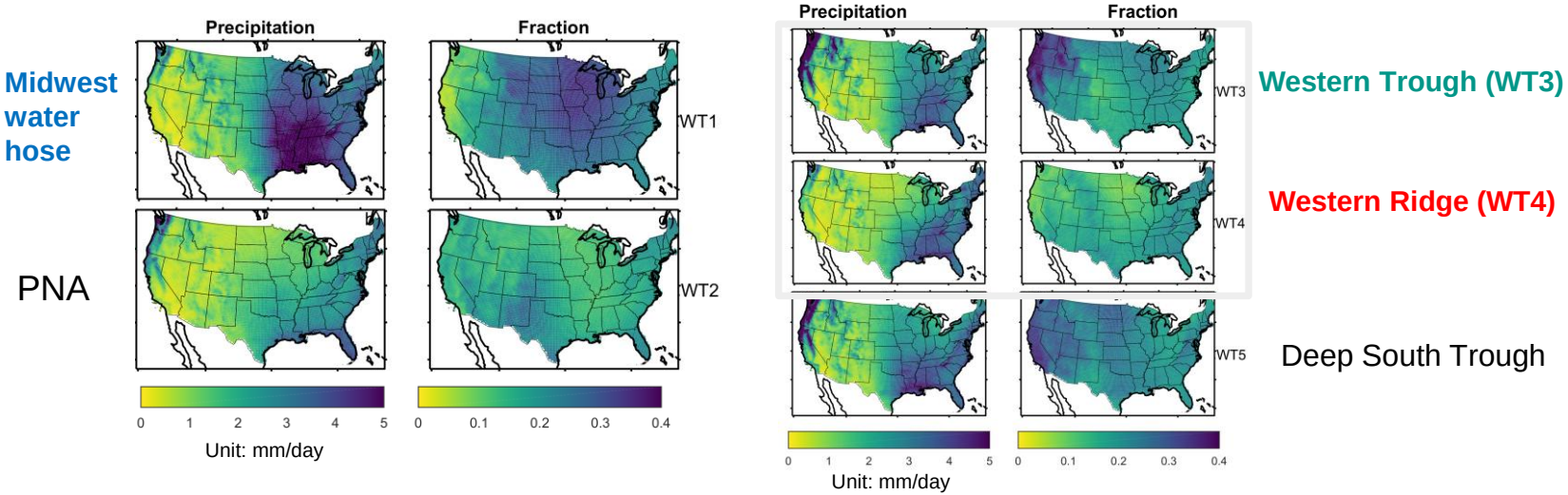
Can weather regimes be used to characterize precipitation?

Can weather regimes be forecasted by climate models?

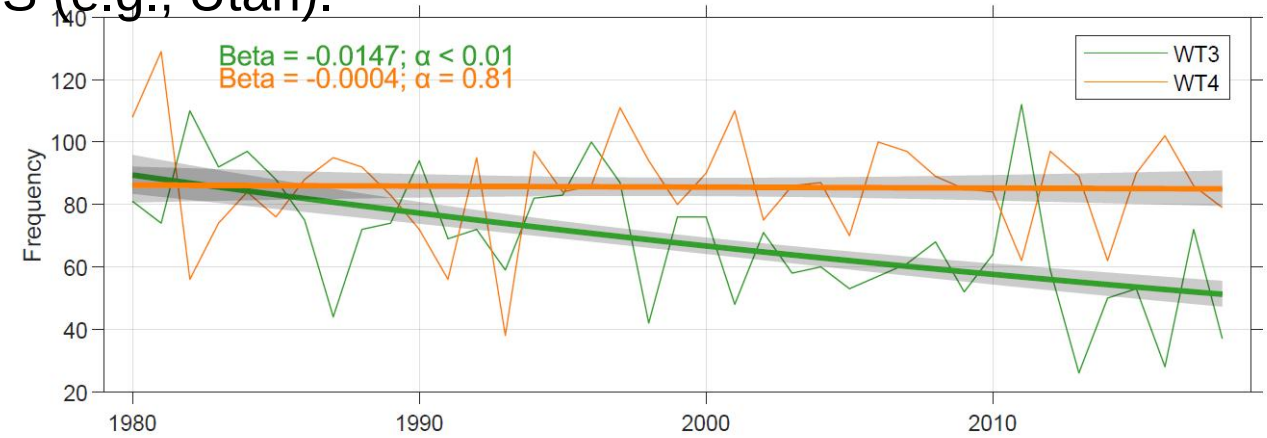
If yes, can forecasted weather regimes help improve precipitation forecasts?

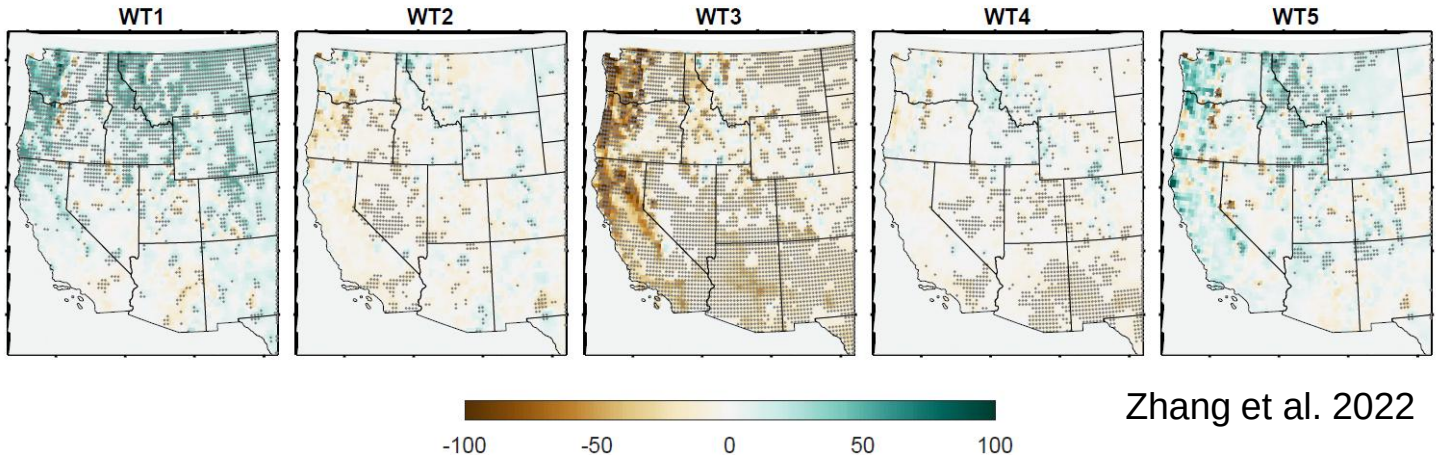
Q1: Can weather regimes characterize precipitation?

WT3 makes the largest contribution to annual precipitation in the western Untied States in the five WTs.



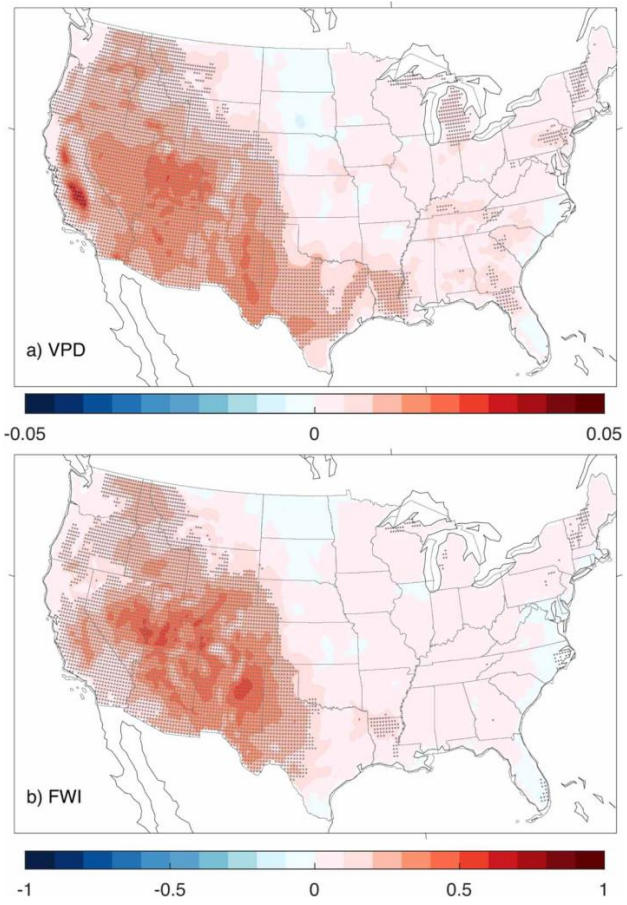
Dry patterns (WT4) are not increasing, but wet patterns (WT3) are decreasing. It is the decreasing wet patterns that are responsible for the drying trend in the western US (e.g., Utah).





Zhang et al. 2022

Trend in Fire Weather Indices

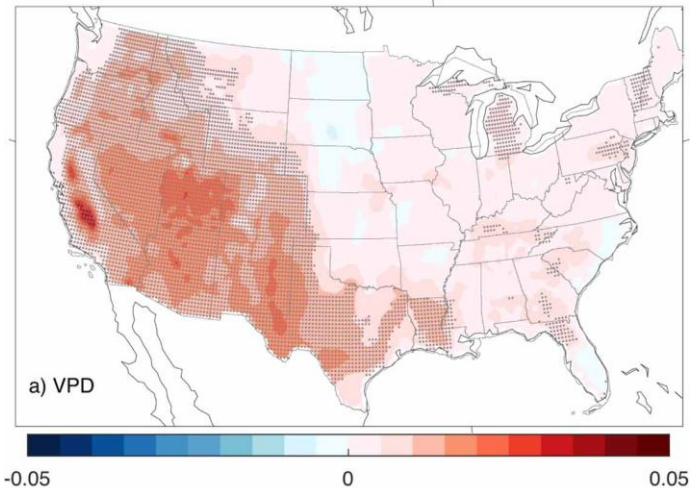


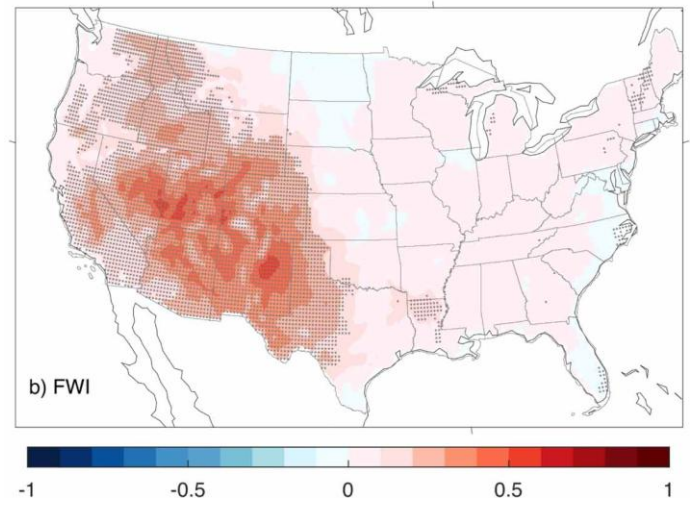
Zhang et al. 2024

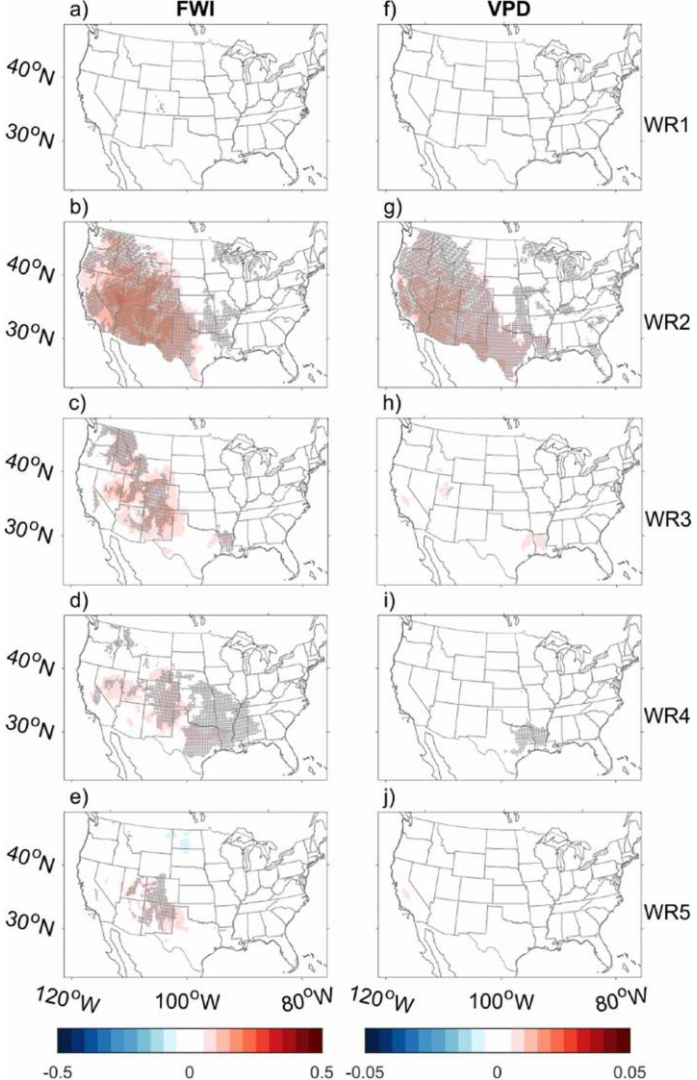
Wildfires raging in the West | CNN

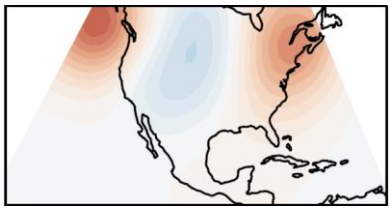
VPD: Vapor Pressure Deficit (RH and Temp)
FWI: Canadian Forest Fire Weather Index
(RH, temp, wind, precipitation)

Trend in Fire Weather Indices





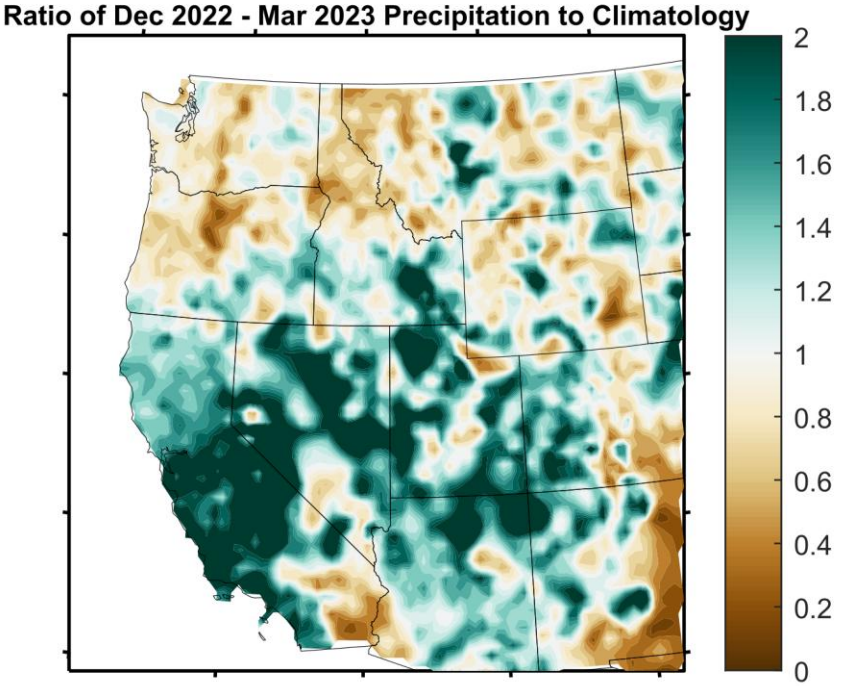


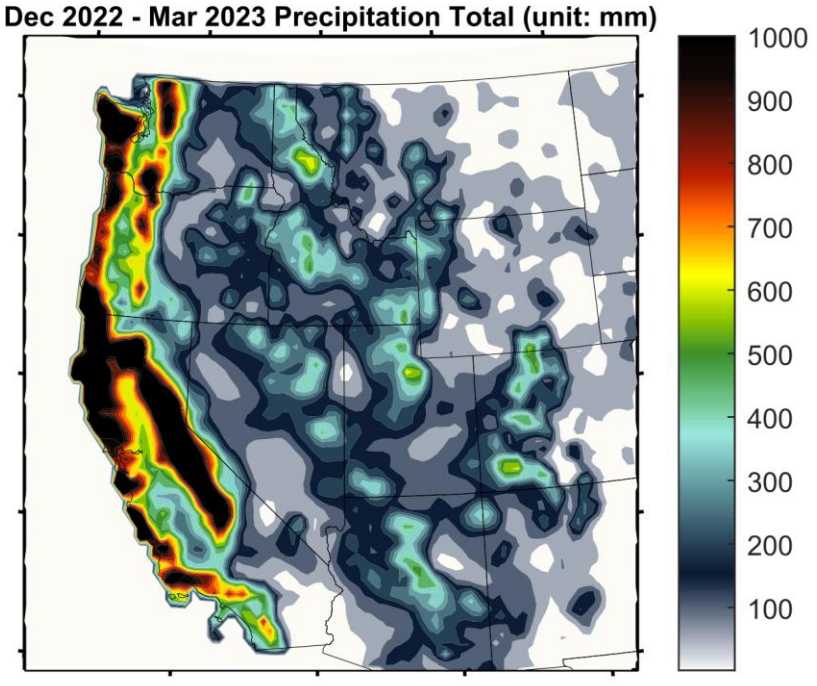


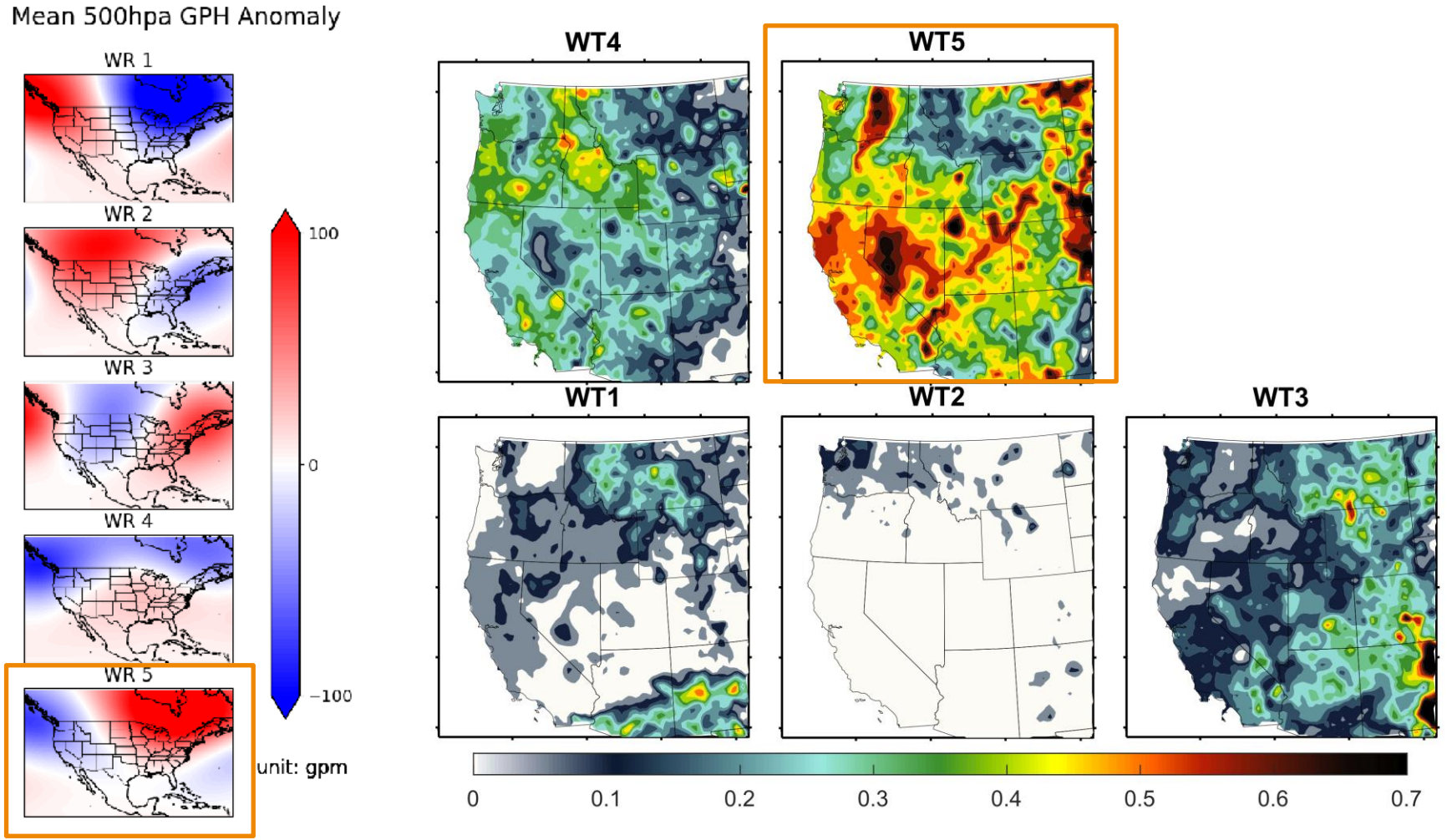
[A Weather Pattern Responsible for Increasing Wildfires in the Western United States]

Zhang et al. 2024

Observations unfolded a wetter-than-normal condition for the southwestern US. What drove the extremely wet 22/23 winter?

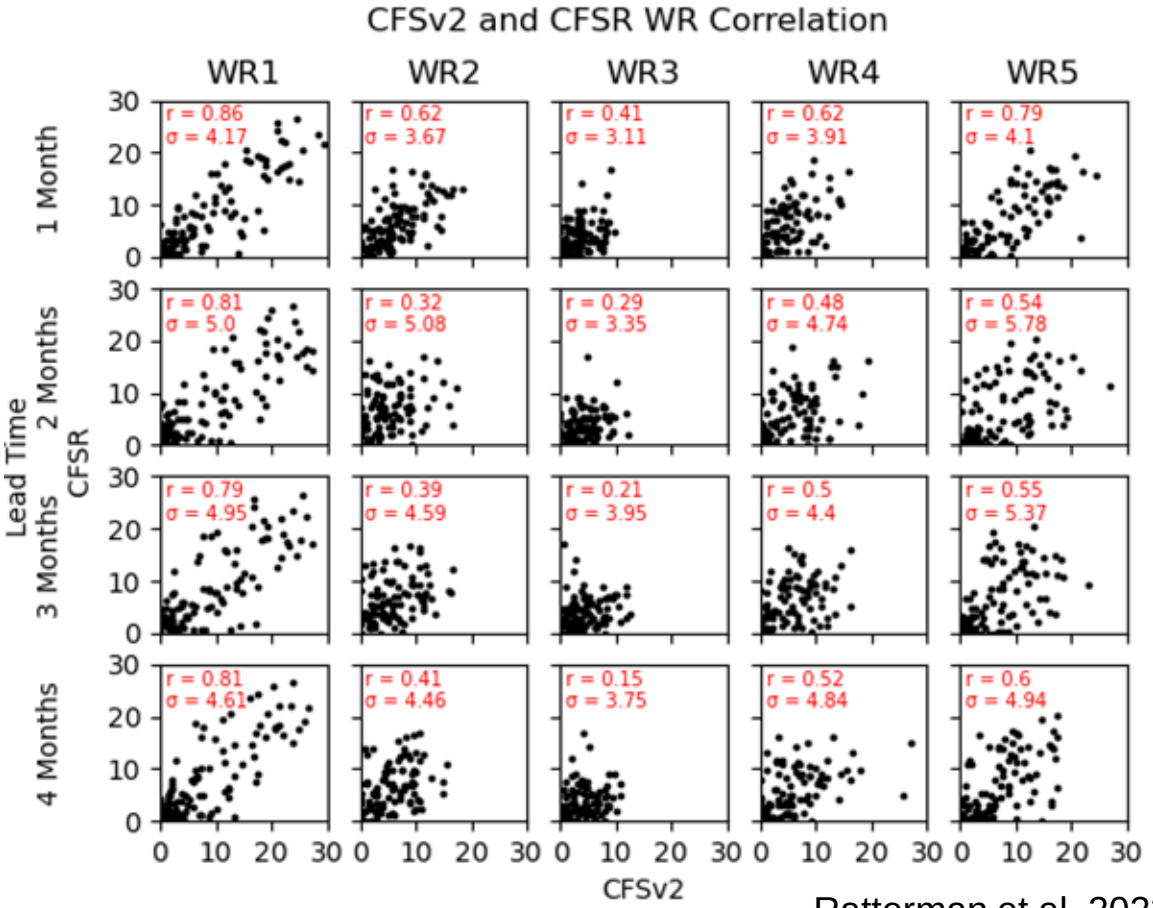





Mean 500hpa GPH Anomaly
WR 1
WR 2
WR 3
WR 4
WR 5
100
0
−100
unit: gpm
WT4
WT5
WT1
WT2
WT3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Q2: Can dynamical model(s) forecast weather regimes?

Can the frequency of weather regimes be forecasted? Yes, much better than precipitation.



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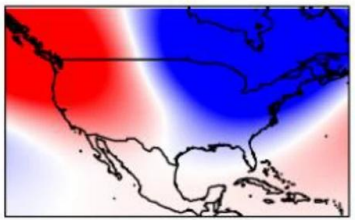
Weather Regimes - Gaussian Mixture Models: Deterministic or Probabilistic?

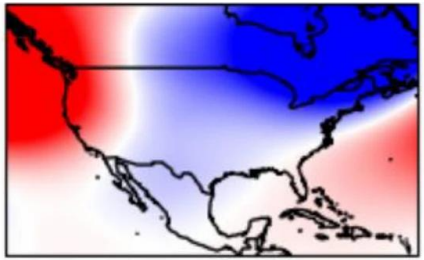
Observations

WT4



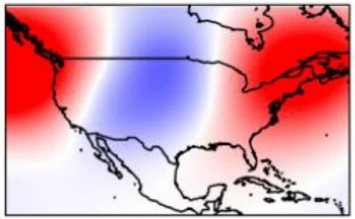
Forecast

WT4 or WT1?



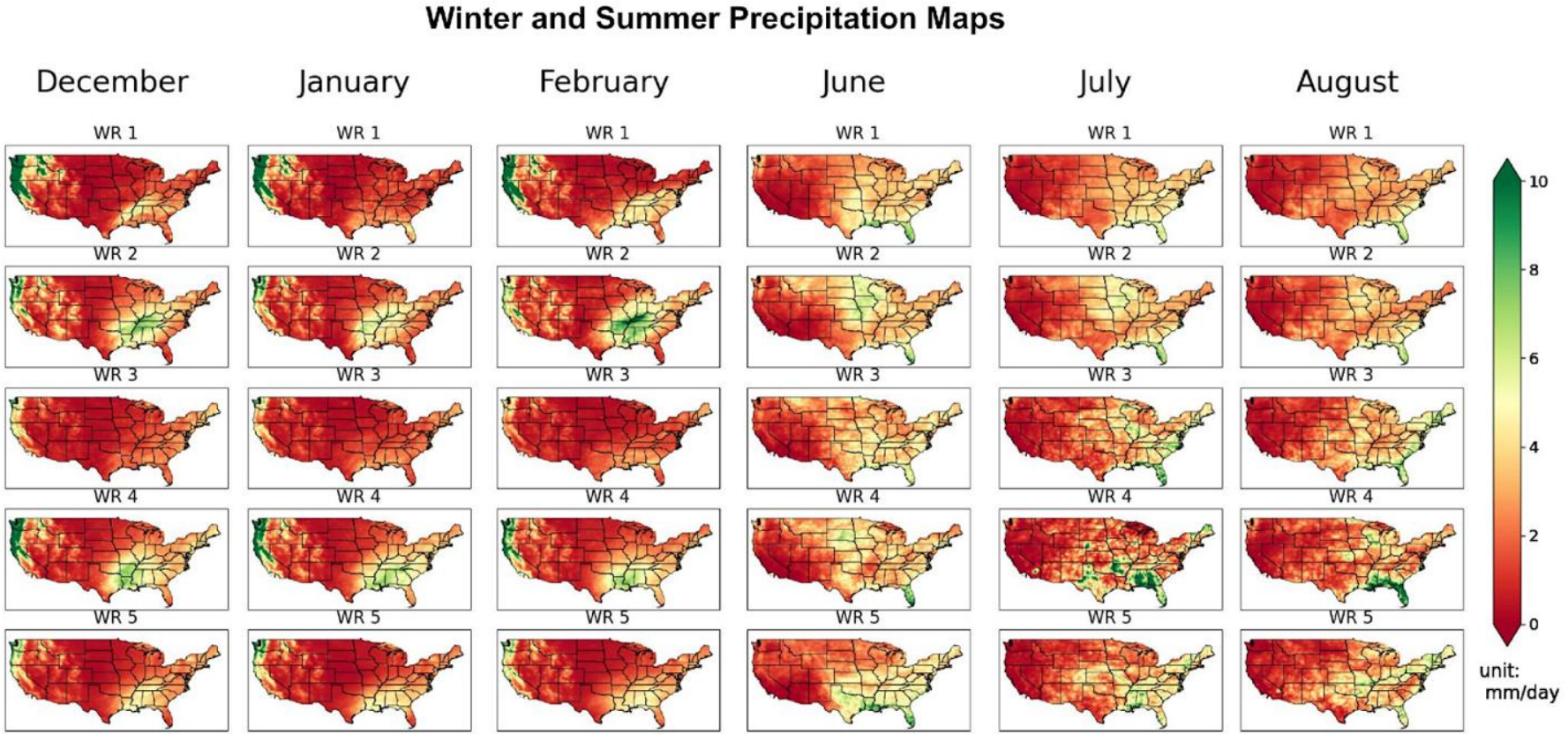
Observations

WT1



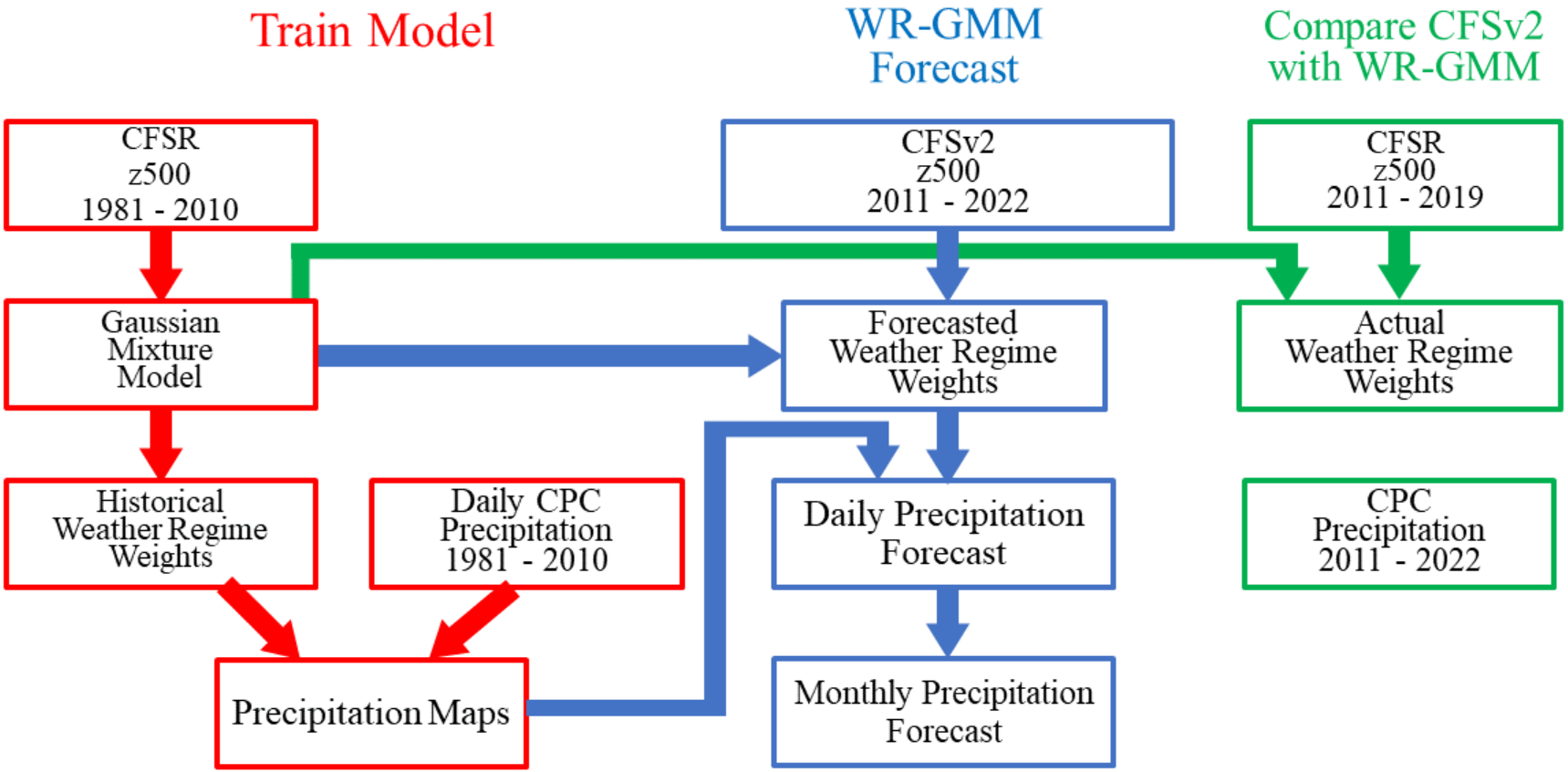
0.6*WT4 + 0.4*WT1

Precipitation maps for each weather regime are used to build precipitation forecasts.



Q3: Can we use forecasted weather regimes to forecast precipitation?

Weather Regime Gaussian Mixture Model (WR-GMM) Framework



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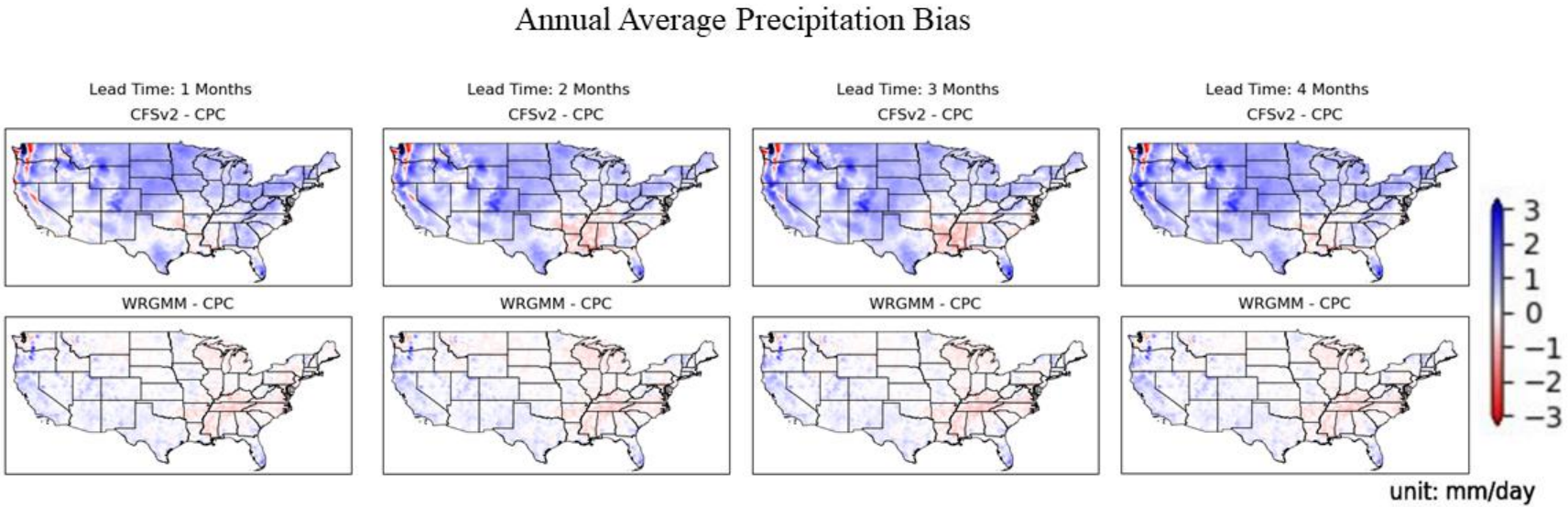
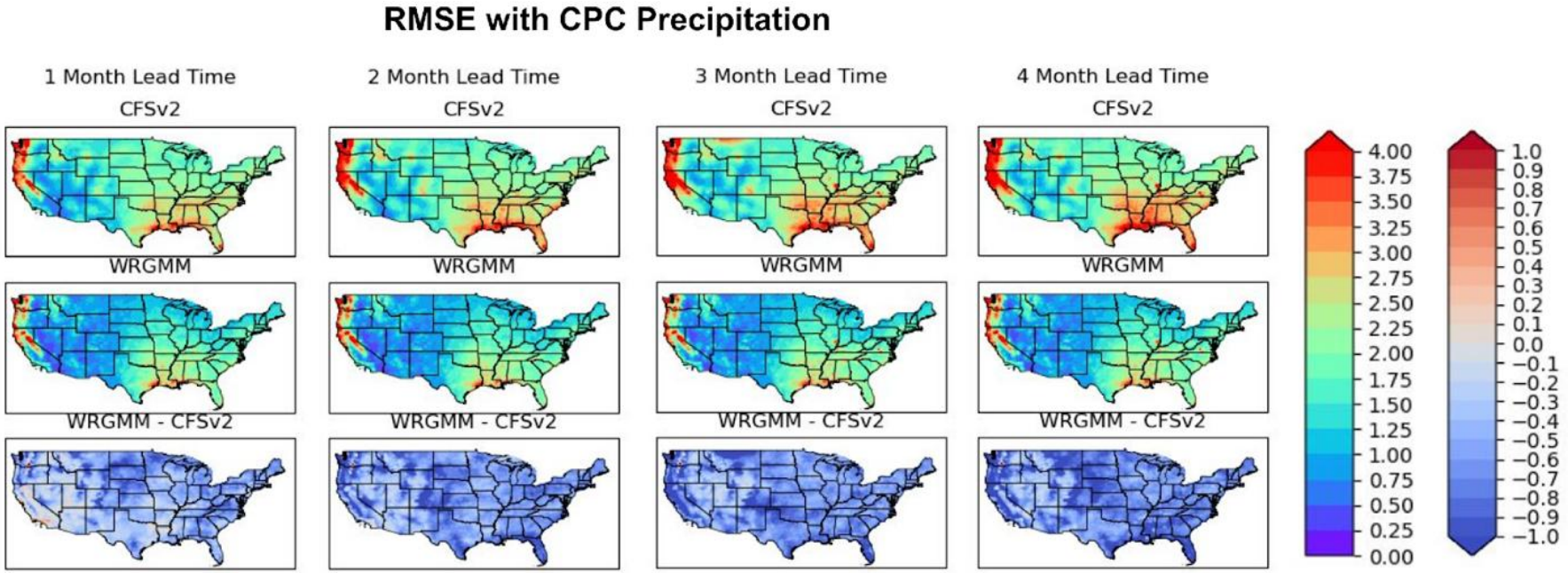
WR-GMM forecasts outperform CFSv2 forecasts in terms of mean precipitation bias.



The WR-GMM forecasts outperform CFSv2 forecasts in terms of RMSE.



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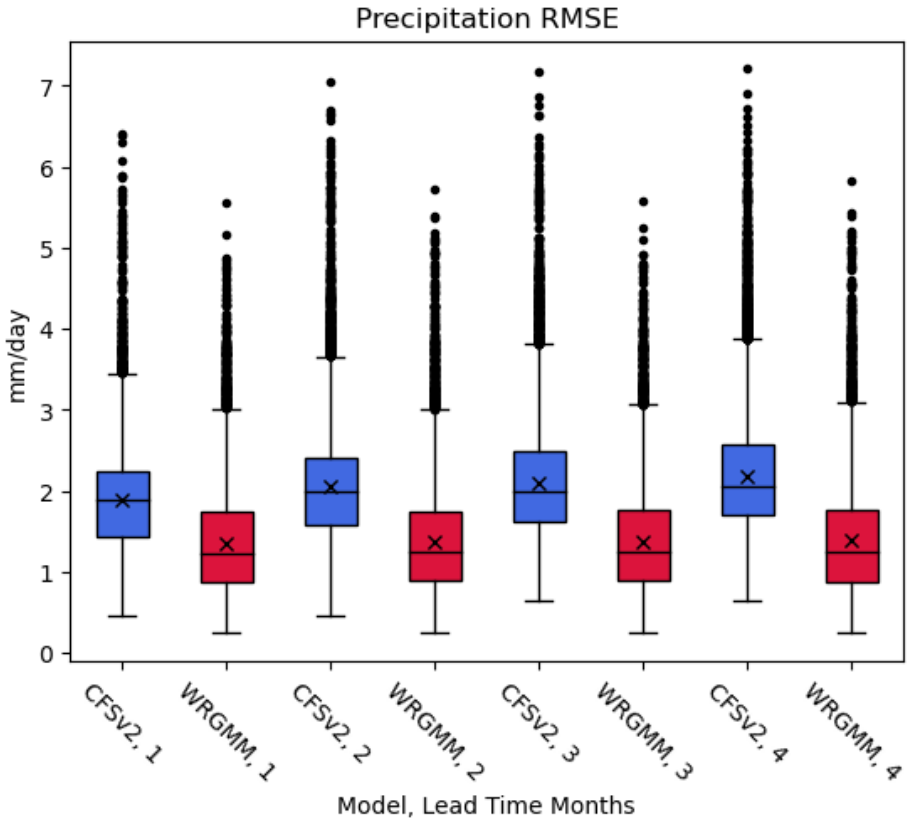
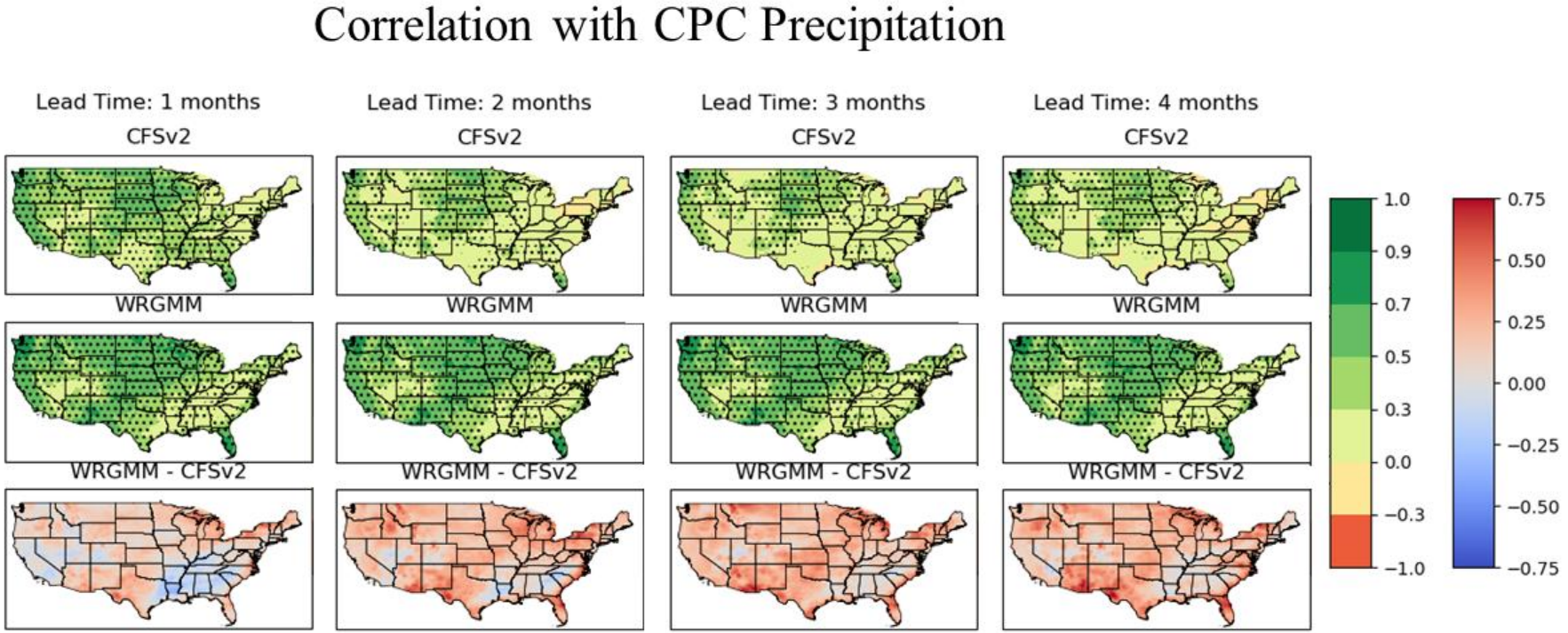
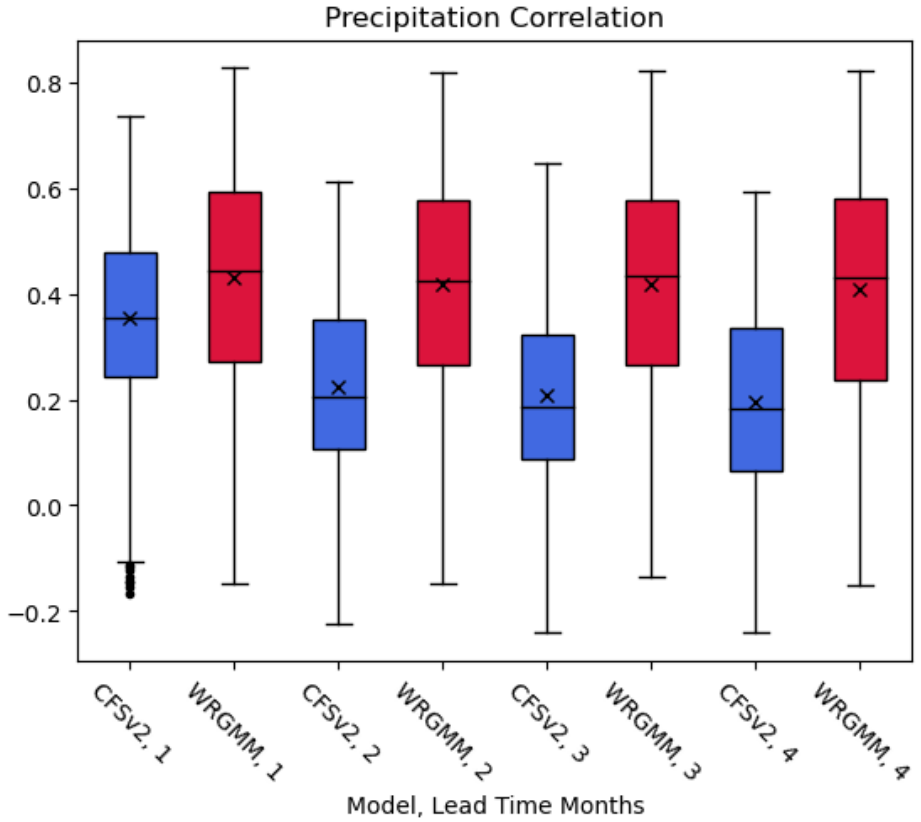


The WR-GMM forecasts outperform CFSv2 forecasts in terms of correlation.



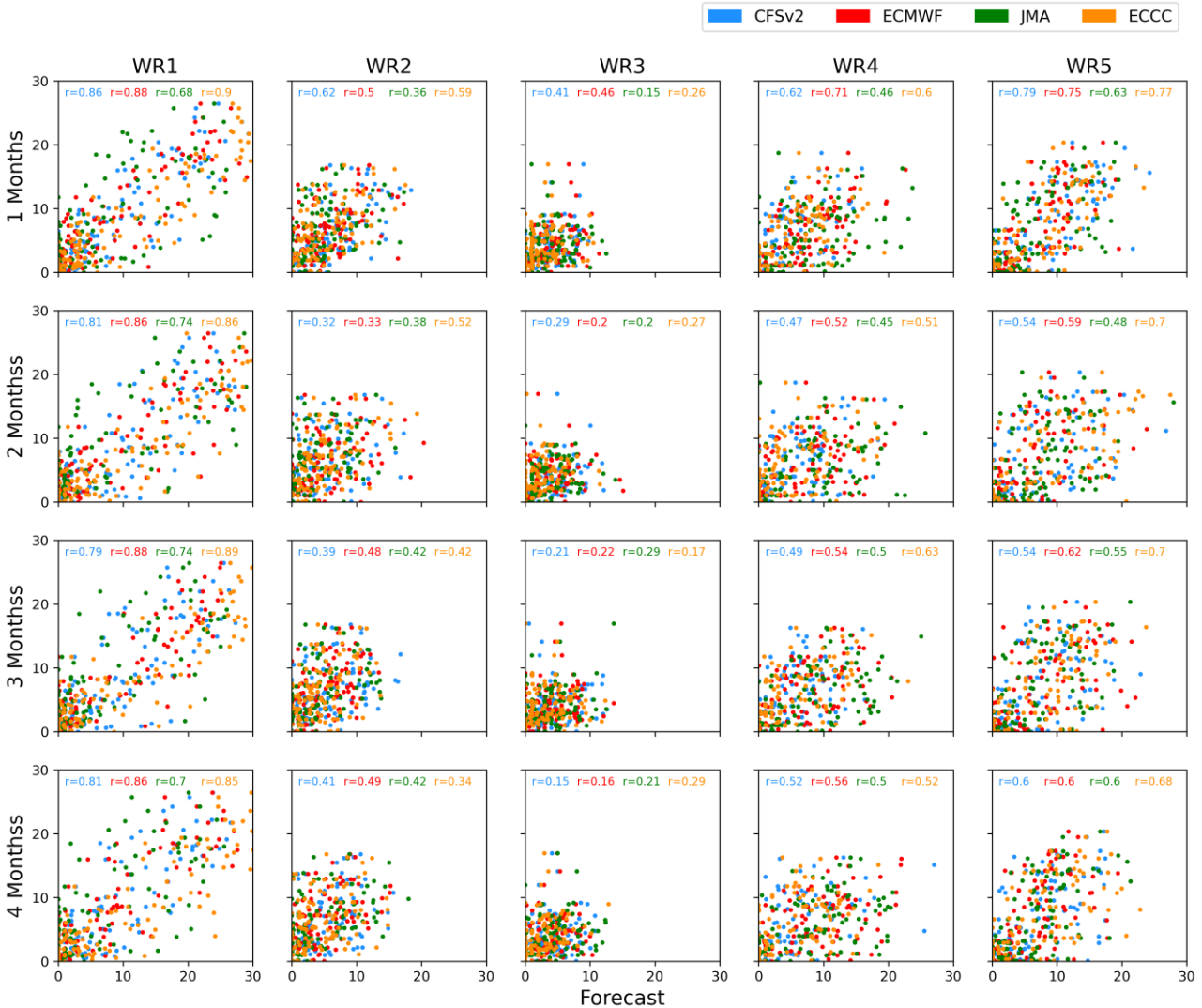
The WR-GMM forecasts outperform CFSv2 forecasts in terms of correlation.



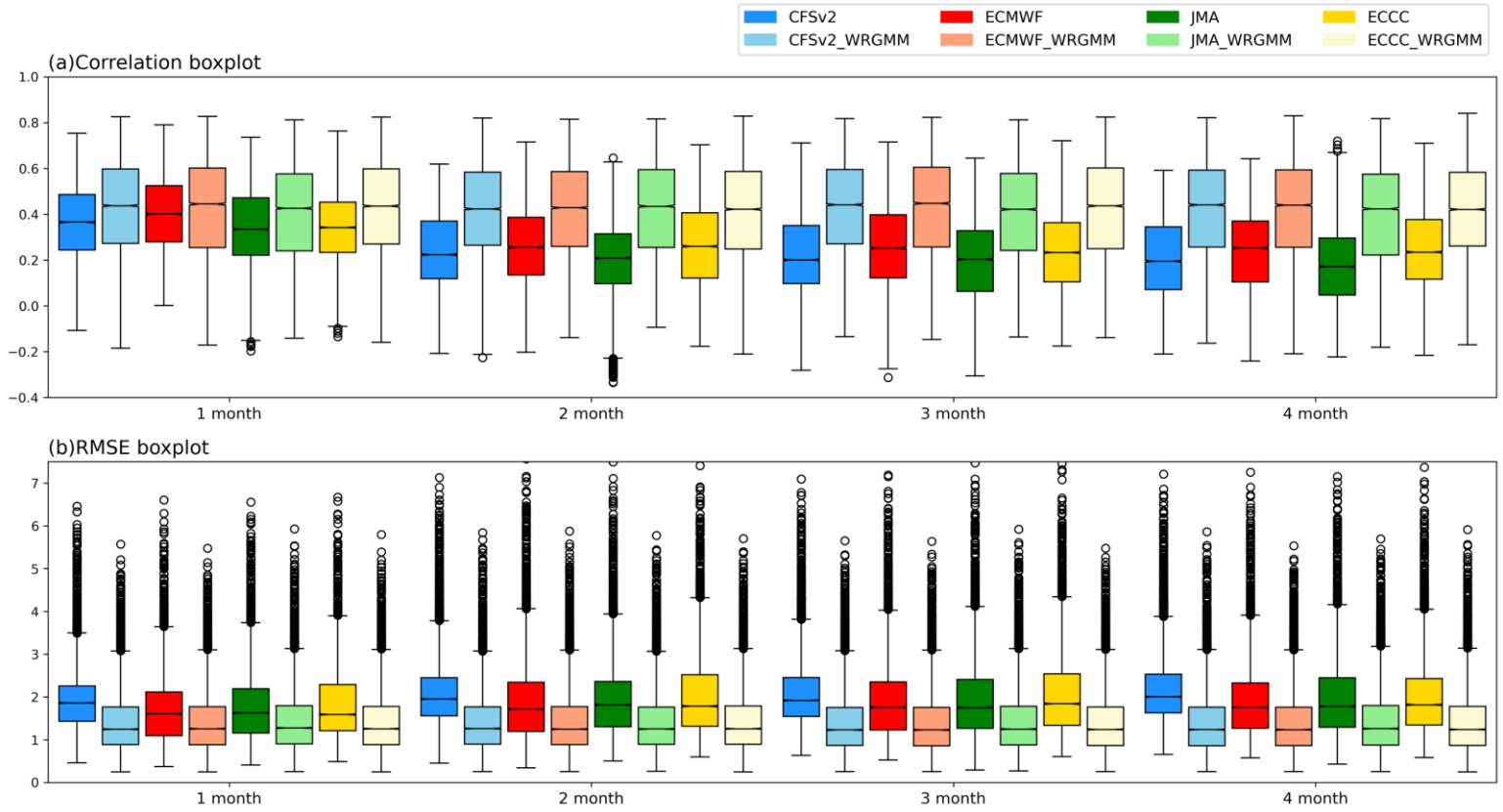
Not all WRs are predicted equal.

COR(CFSR WR, Forecasted WR)

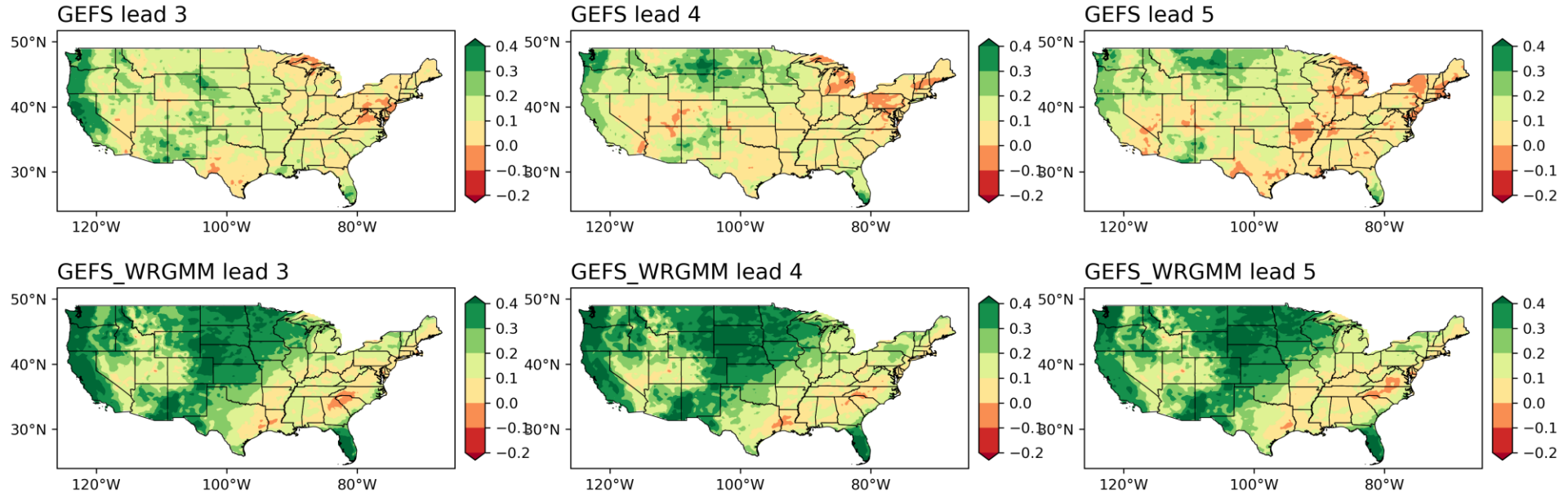
Supported by NOAA WPO



The WR-GMM forecasts outperform numerical forecasts in all four models in terms of correlation.

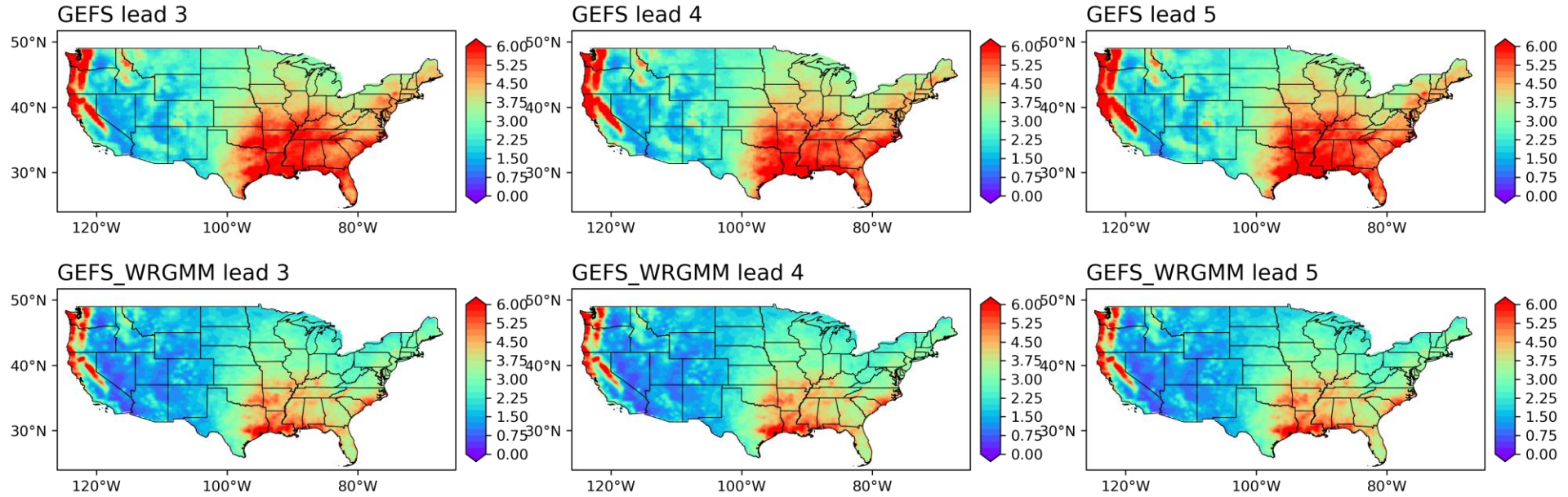


GEFSv12 (3-5 Week Lead)

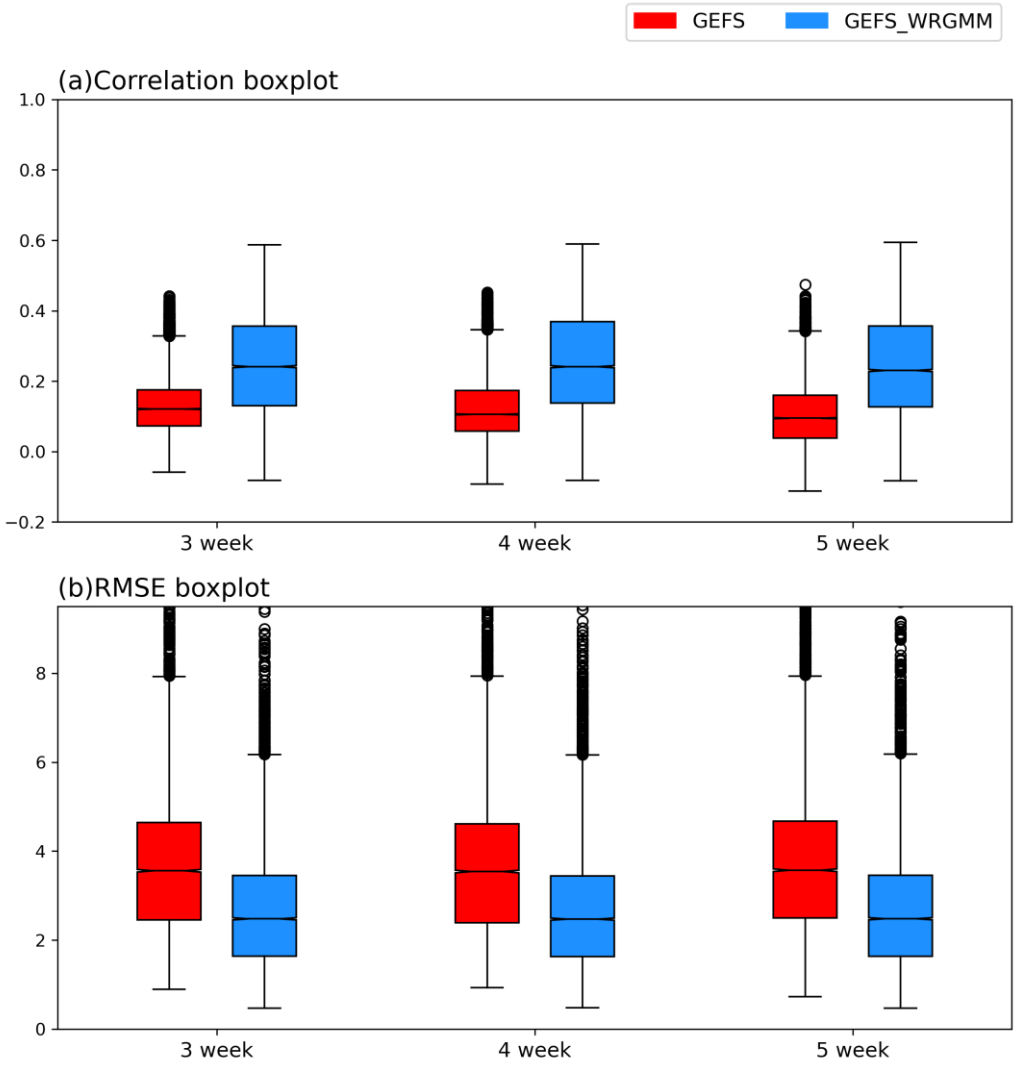


WR-GMM enhances sub-seasonal forecasting precipitation skill.

WR-GMM enhances sub-seasonal forecasting skill in terms of RMSE.



WR-GMM improves sub-seasonal forecasting skill of GEFS.



Summary

- Weather Regimes (WRs) can well characterize precipitation in the US, including Midwestern floods and western US droughts.
- K-means clustering has been used to classify daily synoptic patterns into individual WRs, but the new Gaussian Mixture Model approach allows multiple WRs to be represented for the same day.
- The WR-GMM method outperforms the dynamically forecasted ensemble precipitation in terms of root mean square error and Pearson correlation coefficient for lead months 1 through 4.
- WR-GMM model exhibits potential to improve precipitation forecasts across the continental United States at 3-5 week lead time.

Thanks!
Q & A

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References:

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Zhang, W., Hari, V., S-Y Wang, S., LaPlante, M. D., Garfin, G., Affram, G., & Kumar, R., 2022, Fewer troughs, not more ridges, have led to a drying trend in the western United States. Geophysical Research Letters, 49, e2021GL097089.

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