Seasonal Variations in Forecast Skill of NOAA CFSv2 Operational and CWRF downscaled Predictions over the CONUS

Aditya Kumar Dubey, Sanghoon Shin, Guangwei Li, Chao Sun and Xin-Zhong Liang

Earth System Science Interdisciplinary Center, University of Maryland, College Park, USA

Introduction

- In the current scenario, there is an increase in extreme weather events, which poses a greater risk to food security.
- Seasonal forecasts can help in reducing these risks by proper utilizing the beforehand information for proper management and decisions.
- To obtain more reliable information at a regional scale for impact-based studies, fine-grid datasets with detailed regional information are required.
- To achieve this, we have downscaled the NCEP Coupled Forecast System model version 2 (CFSv2) predictions (referred as NOAA) to a horizontal resolution of ~30 km using the regional Climate-Weather Research and Forecasting (CWRF) model over the North American domain.
- CWRF is an extension of the Weather Research and Forecasting (WRF) model, with additional parameterizations and modules.
- The evaluation of the performance of CFSv2 and CWRF is necessary to produce robust forecasts and to further improve the CWRF model.
- The main goal of the downscaled product is to use it in crop models to provide farmers with weather and crop-related information, thereby aiding them in making better decisions.

Data and Methods

- ❖ 6-hourly NOAA operational seasonal predictions are downscaled using CWRF for spring (MAM), Summer (JJA), Fall (SON) and winter (DJF) seasons.
- ❖ CWRF ensemble members include initializations at each 5-day interval starting from January 1 with two physics CTL (ensemble cumulus parametrization) & Morrison (radiation scheme) at 00Z and CTL at 06Z for 2012-2023.
- ❖ The CFSv2 also have the same initialized ensemble members as CWRF.
- ❖ Selected variables: daily T2AVG (2m mean temperature), TMAX (2m maximum temperature), TMIN (2m minimum temperature), and PRAVG (daily mean precipitation)
- ❖ gridMet observations (Abatzoglou, 2013) at ~4 Km horizontal are upscaled to ~30 km using bilinear interpolation method for evaluation.
- ❖ The CFSv2 data is converted to daily mean, max and min data for PRAVG, T2MAX and T2MIN respectively and then averaged to get at monthly scale.
- ❖ CFSv2 downloaded at horizontal resolution of ~one degree which is downscaled to ~30 km using bi-linear interpolation method.
- ❖ The details about CWRF regional model can be obtained from Liang et al. (2012).

The following metrics are used for evaluation:

- ❖ **Mean Bias:** Period mean (prediction) – Period mean (observation)
- ❖ **Inter Annual Anomaly correlation (IAC):** The person correlation coefficient between anomaly of prediction and observation.
- ❖ The anomaly is calculated by subtracting the monthly climatology from the data.
- ❖ **Root mean square error (RMSE):** $\sqrt{1/n \sum_{i=1}^{n}(y_i - x_i)^2}$

Where, y is the prediction and x is the observation

- ❖ **Equitable threat score (ETS):** $ETS = \frac{Hits - E}{Hits + Misses + False\ Alarms - E}$
- ❖ **Where,** $E = \frac{Forecast\ points\ x\ observed\ points}{Total\ points}$

Results

Precipitation Equitable Threat Score

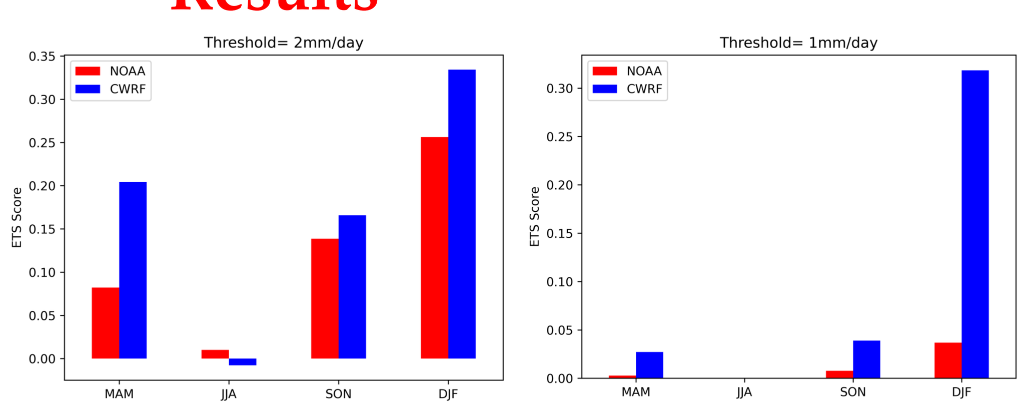

Fig.1: Precipitation ETS score for 2012-2023 for corn belt region.

- The precipitation ETS over corn-belt region shows higher scores for CWRF compared to NOAA in all seasons except summer (Fig.1).
- CWRF has better capability in capturing precipitation days.

Mean Bias

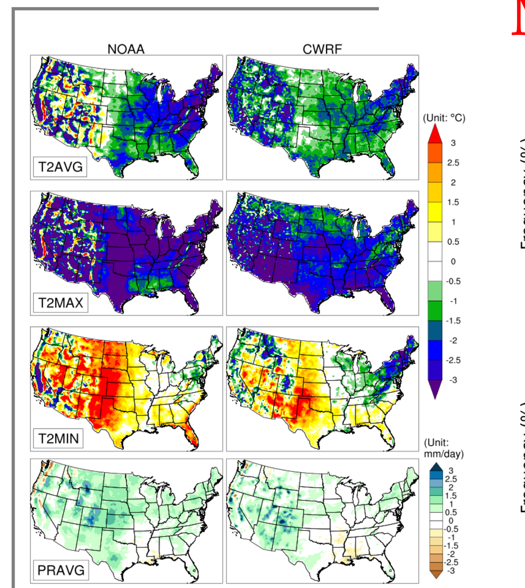

Fig.2: Spring mean bias between NOAA and CWRF with observation.

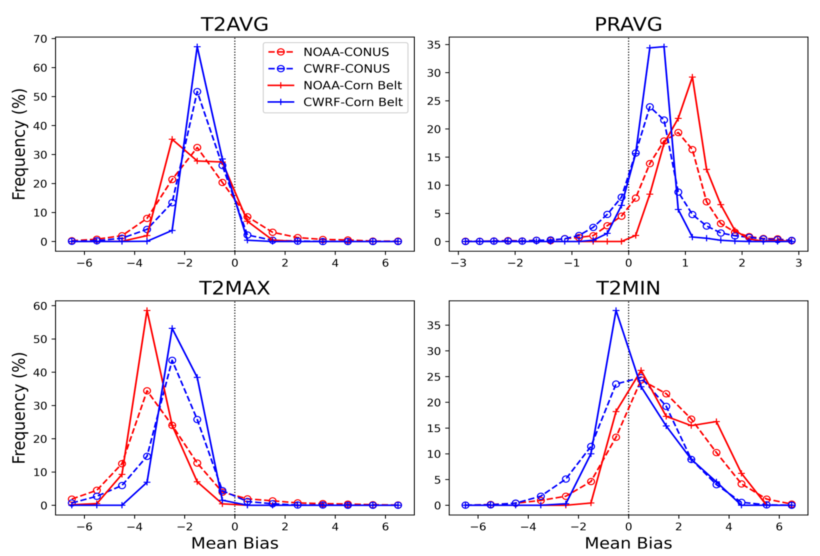

Fig.3: Spring frequency distribution of the associated maps in Fig.1 for CONUS and corn belt regions.

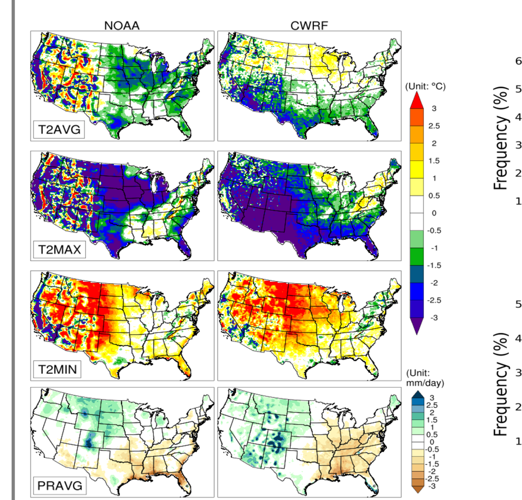

Fig.4: Same as Fig.1 but for summer season.

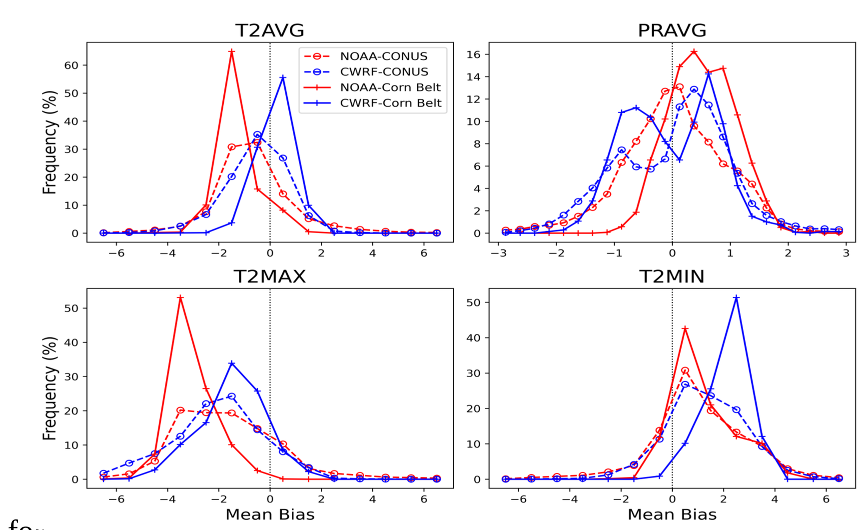

Fig.5: Same as Fig.2 but for associated maps in Fig.4.

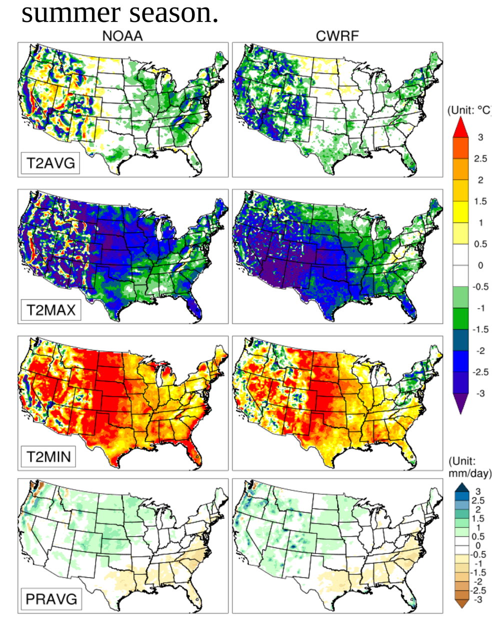

Fig.6: Same as Fig.1 but for Fall season.

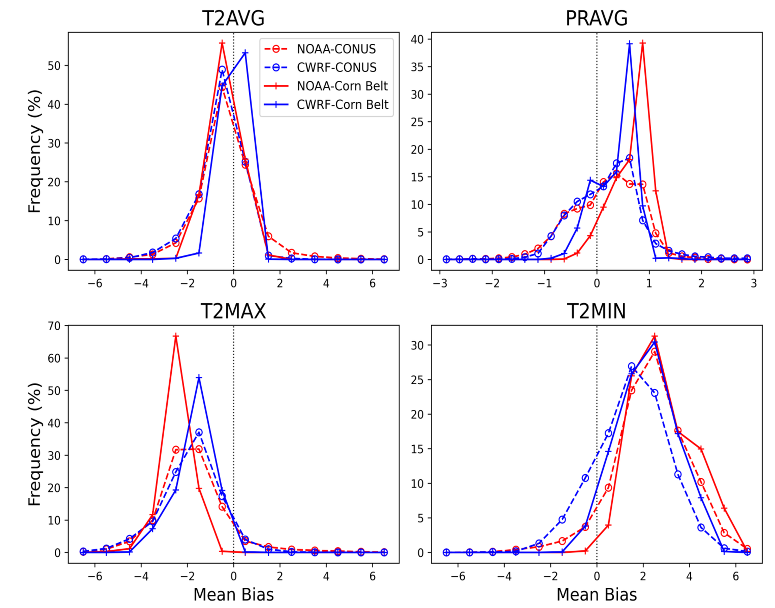

Fig.7: Same as Fig.2 but for associated maps in Fig.6.

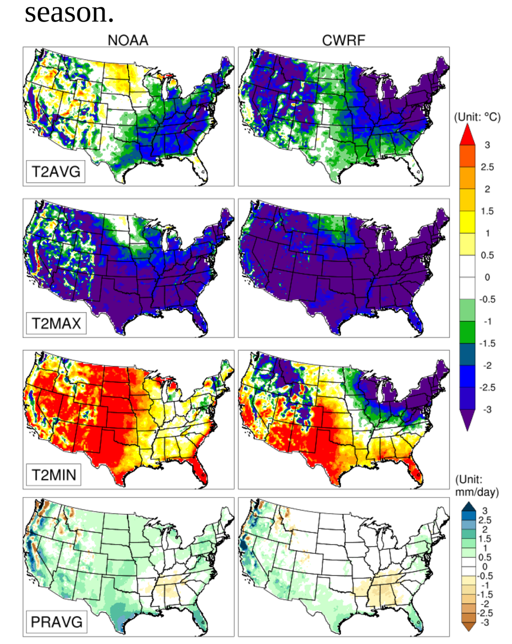

Fig.8: Same as Fig.1 but for Fall season.

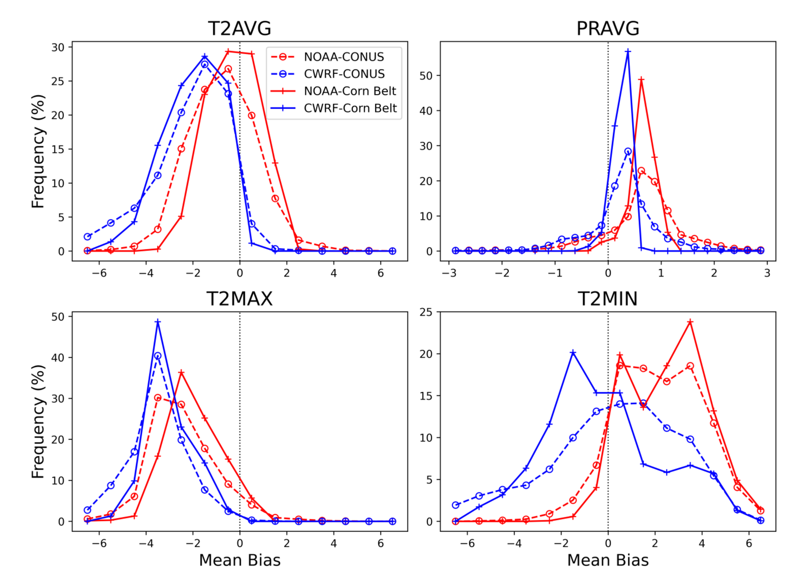

Fig.9: Same as Fig.2 but for associated maps in Fig.8.

- Both NOAA and CWRF ensembles show systematic cold bias in T2MAX and warm bias in T2MIN along with wet bias in precipitation (dry over southeastern states) specially over corn-belt region (Fig.2-Fig.9).
- The CWRF reduces the cold bias in TMAX by 1-3°C, and the warm bias in TMIN by 0.5-1°C. The CWRF reduces the wet bias but enhances the dry bias, especially in summer.

Inter Annual Anomaly Correlation

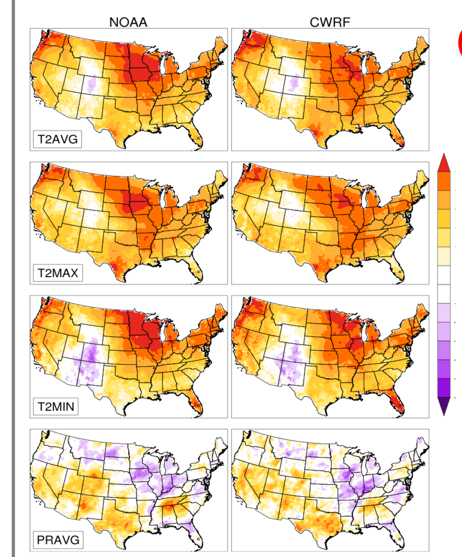

Fig.10: IAC between NOAA and CWRF with observation.

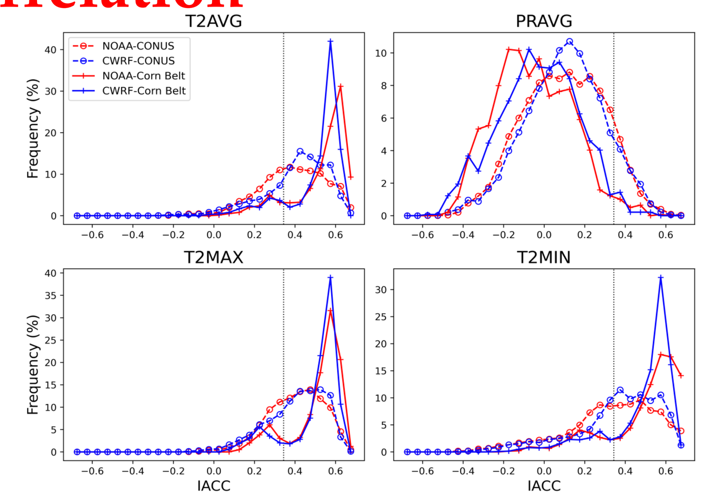

Fig.11: Spring frequency distribution of the associated maps in Fig.10 for CONUS and corn belt .

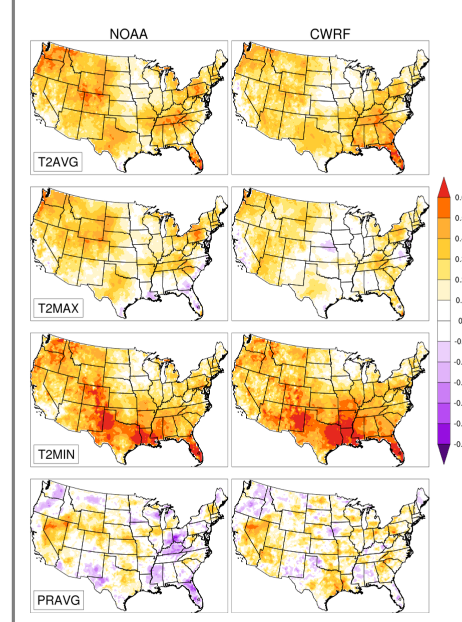

Fig.12: Same as Fig.10 but for summer.

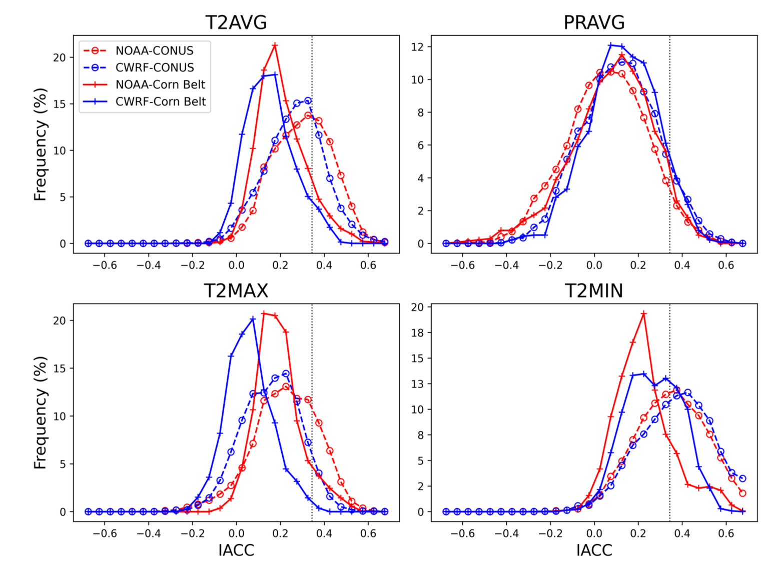

Fig.13: Same as Fig.11 but for associated maps in Fig.12.

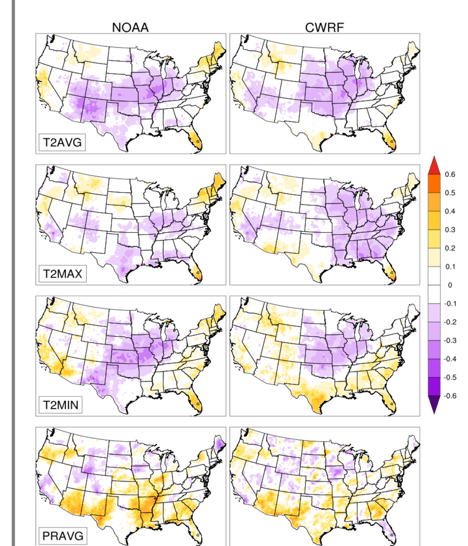

Fig.14: Same as Fig.10 but for Fall.

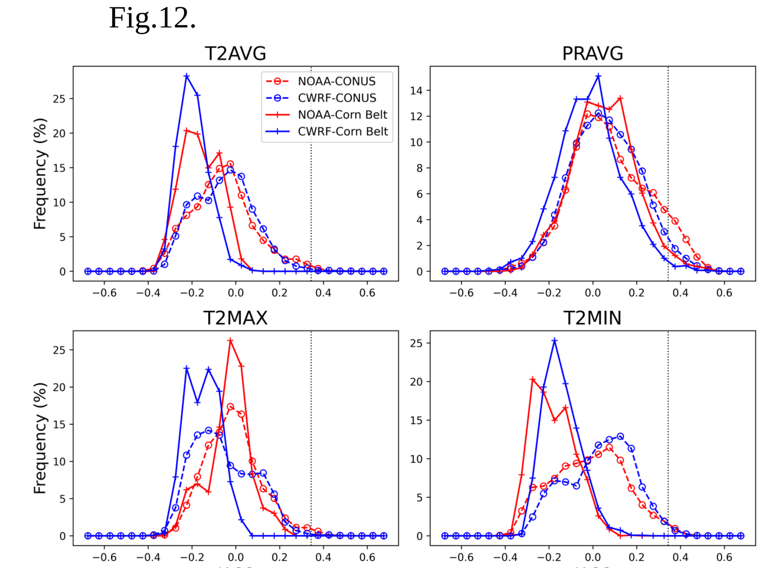

Fig.15: Same as Fig.11 but for associated maps in Fig.14.

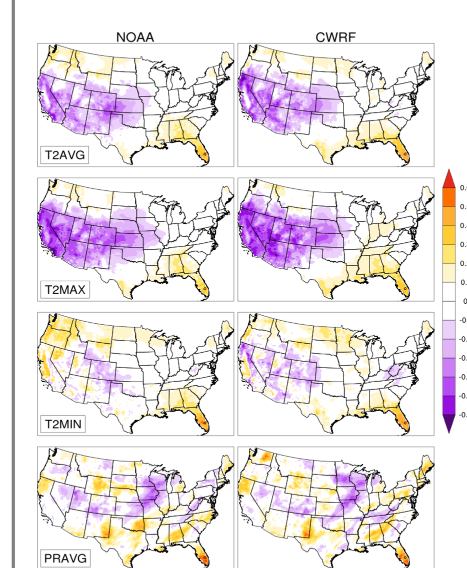

Fig.16: Same as Fig.10 but for winter.

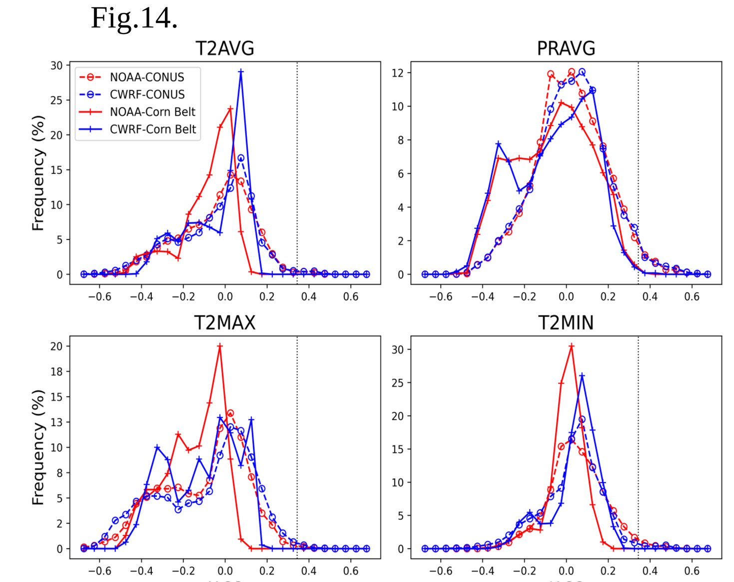

Fig.17: Same as Fig.11 but for associated maps in Fig.16.

- Spring and Summer shows positive IAC over most CONUS for temperatures but precipitation showed mixed patterns for both NOAA and CWRF. Fall and winter have negative IAC over west and positive over east.
- Both NOAA and CWRF have similar magnitudes during all seasons.

Root Mean Square Error

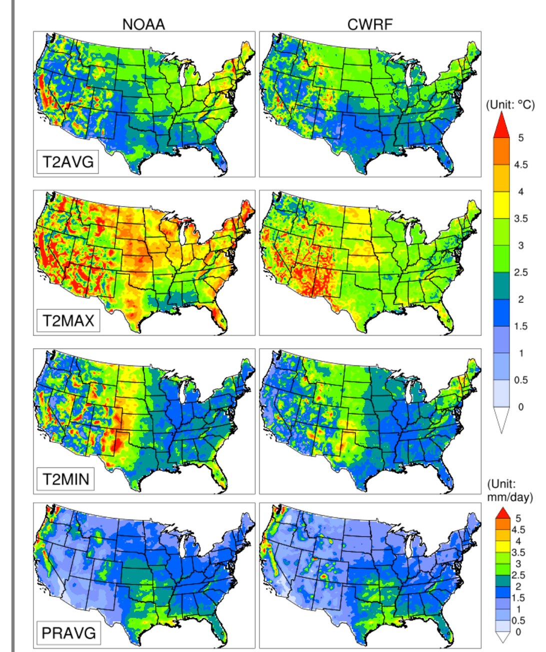

Fig.18: Spring RMSE for NOAA and CWRF

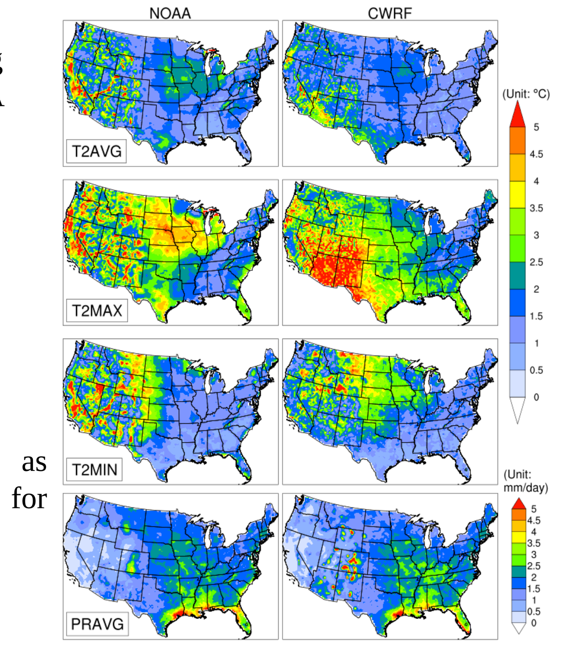

Fig.19: Same as Fig.18 but for summer season.

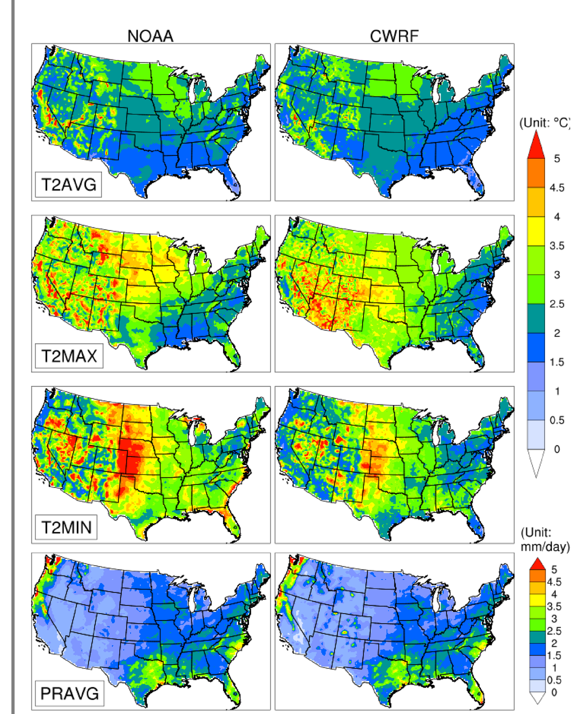

Fig.20: Same as Fig.18 but for fall season.

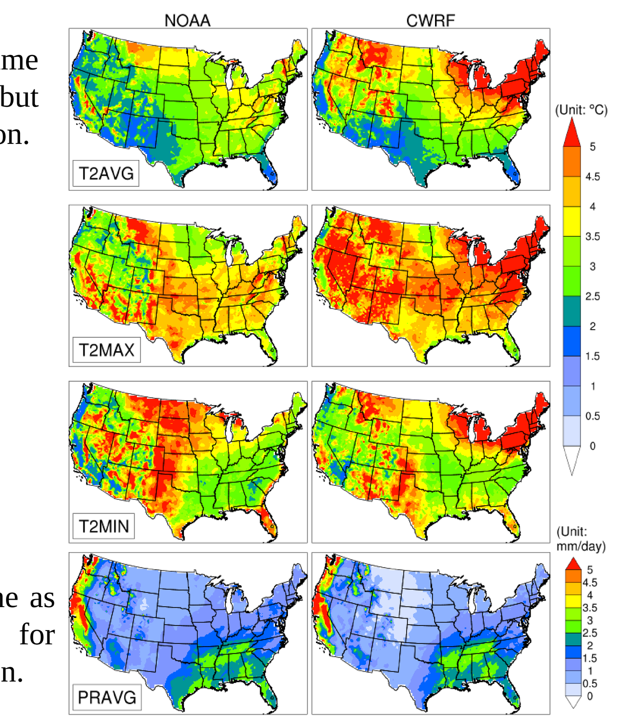

Fig.21: Same as Fig.18 but for winter season.

- TMAX has highest RMSE in spring for both NOAA and CWRF and precipitation have least RMSE.
- Summer has lowest RMSE for all variables and winter has highest RMSE for all variables.
- CWRF has reduced the RMSE in all spring and fall but enhanced in summer and winter.

Conclusion and Future Work

- ✓ The CFSv2 operational forecasts are downscaled using CWRF for all seasons for 2012-2023.
- ✓ TMAX have cold bias in all seasons and TMIN have warm bias for both NOAA and CWRF.
- ✓ CWRF reduced the cold bias in TMAX and warm bias in TMIN except for summer season.
- ✓ Spring and summer have positive IAC over all CONUS while fall and winter have mixed IAC for temperatures. Precipitation have mixed IAC for all seasons.
- ✓ RMSE in winter is higher than other seasons and CWRF reduced it in all seasons except winter.
- ✓ CWRF climate predictions will be used to drives standalone and coupled crop models for crop growth forecasts.
- ✓ We are working on designing better ensemble methods, more physics, and bias corrections method to further improved the predictions.

Acknowledgement

This is part of the Dashboard for Agricultural Water Use and Nutrient Management (DAWN) funded by the U.S. Department of Agriculture National Institute of Food and Agriculture, Grant 2020-68012-31674.

References

- Abatzoglou JT (2013), Development of gridded surface meteorological data for ecological applications and modelling. Int. J. Climatol., 33: 121–131.
- Liang X-Z, Xu M, Yuan X, Ling T, Choi HI, Zhang F, Chen L, Liu S, Su S, Qiao F, He Y, Wang JXL, Kunkel KE, Gao W, Joseph E, Morris V, Yu TW, Dudhia J, Michalakes J (2012) Regional climate-weather research and forecasting model. Bull Am Meteor Soc 93(9):1363–1387. https://doi.org/10.1175/BAMS-D-11-00180.1

Correspondence: adubey14@umd.edu