Separation of interannual signals into decadal and shorter time scales in dynamical ensembles for seasonal forecasting

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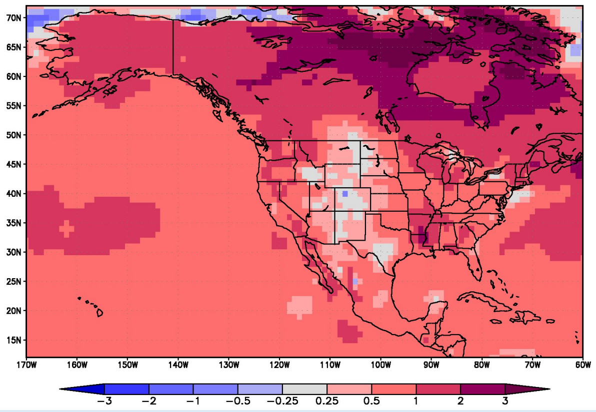
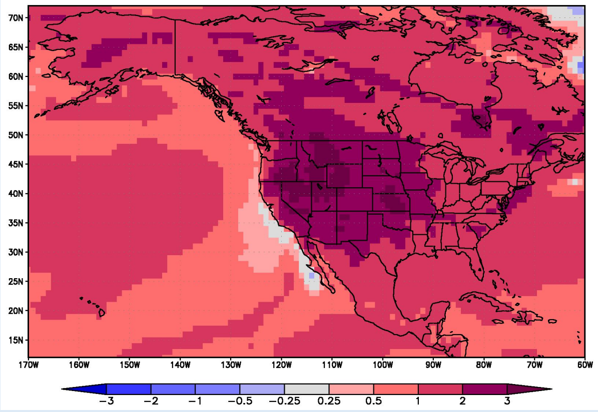
Background

- We analyze the skill and errors of ensemble model systems related to longer decadal timescales and shorter interannual timescales.
- Much of the skill of seasonal forecasts can be attributed to decadal timescale temperature trends.
- Ensemble models have probabilistic skill that is independent of decadal timescale variability.
- This provides a potential diagnostic of model errors and seasonal forecasting tool.



CFSv2



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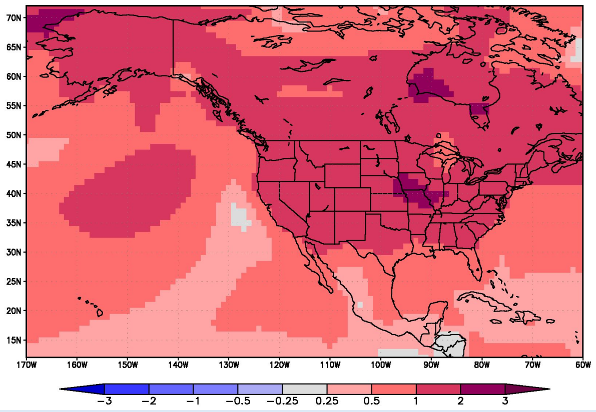

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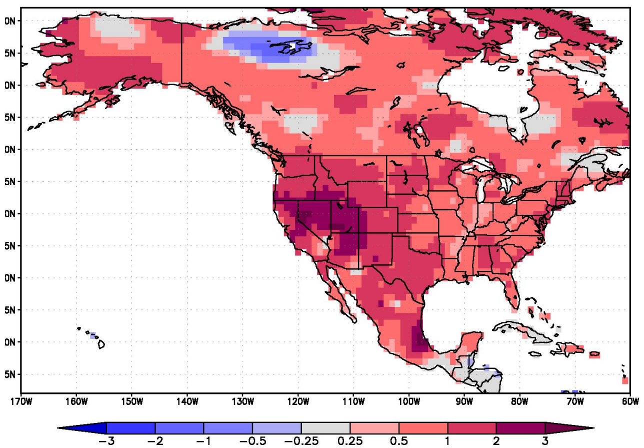
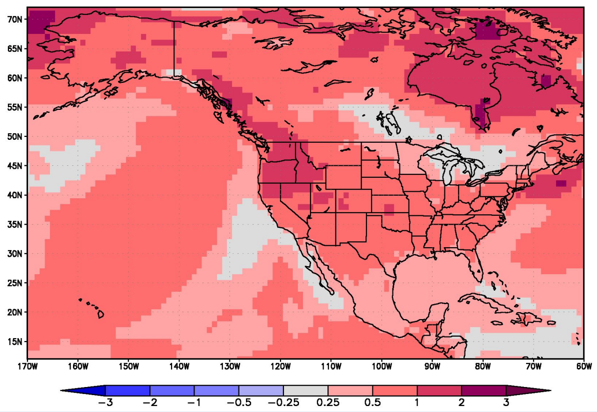
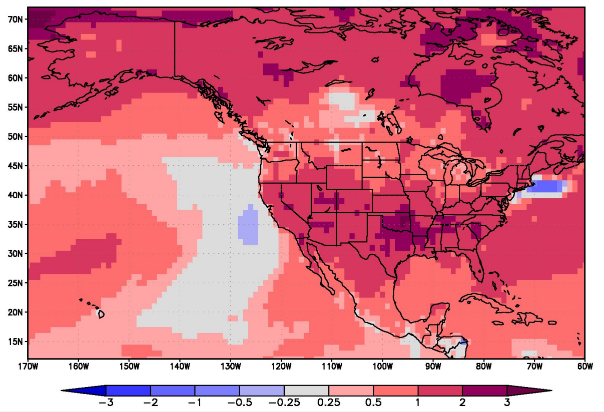


Observed JJA trends



GEM5 NEMO



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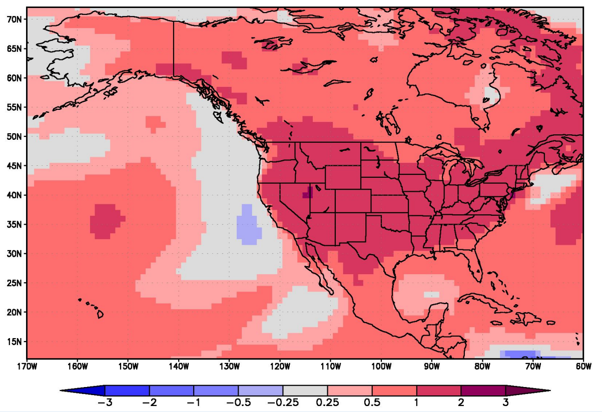
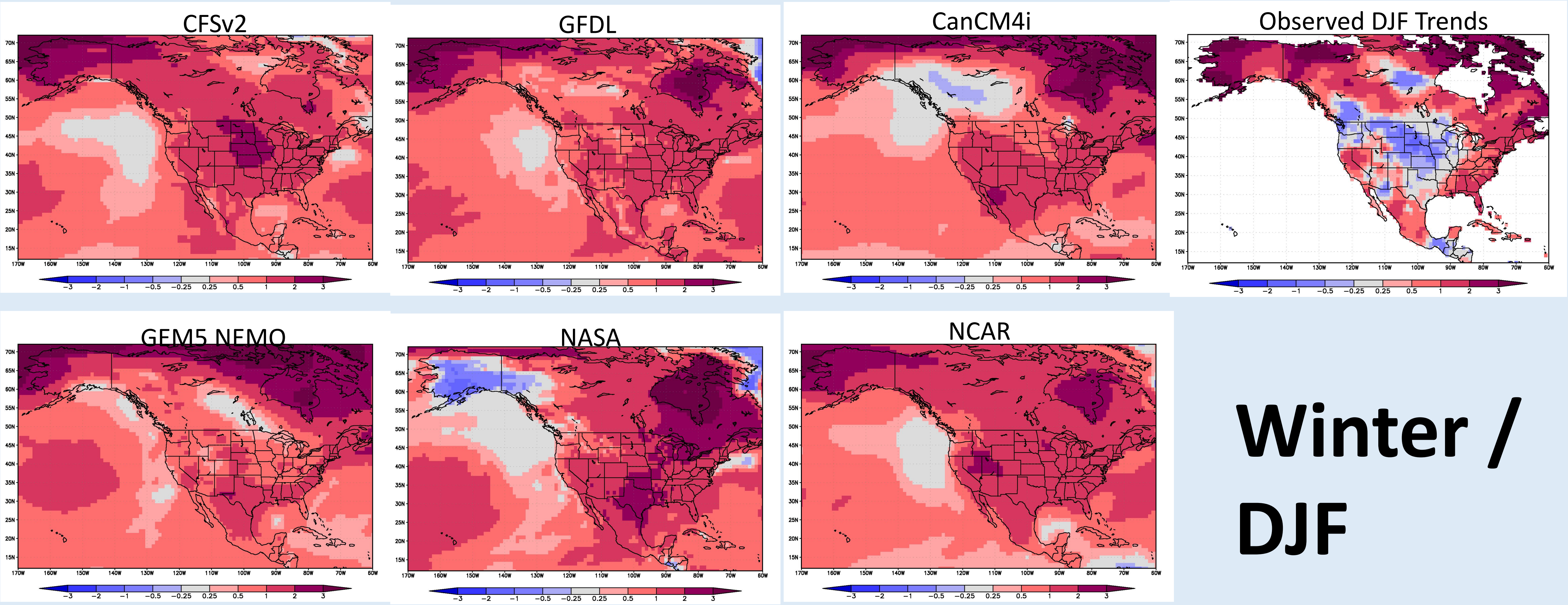


NCAR

Summer / JJA

Linear Trends based on **NMME model lead-1 JJA temperature forecasts** vs. observed trends:

Warm season trends are nearly uniformly positive but somewhat different between models and observations.

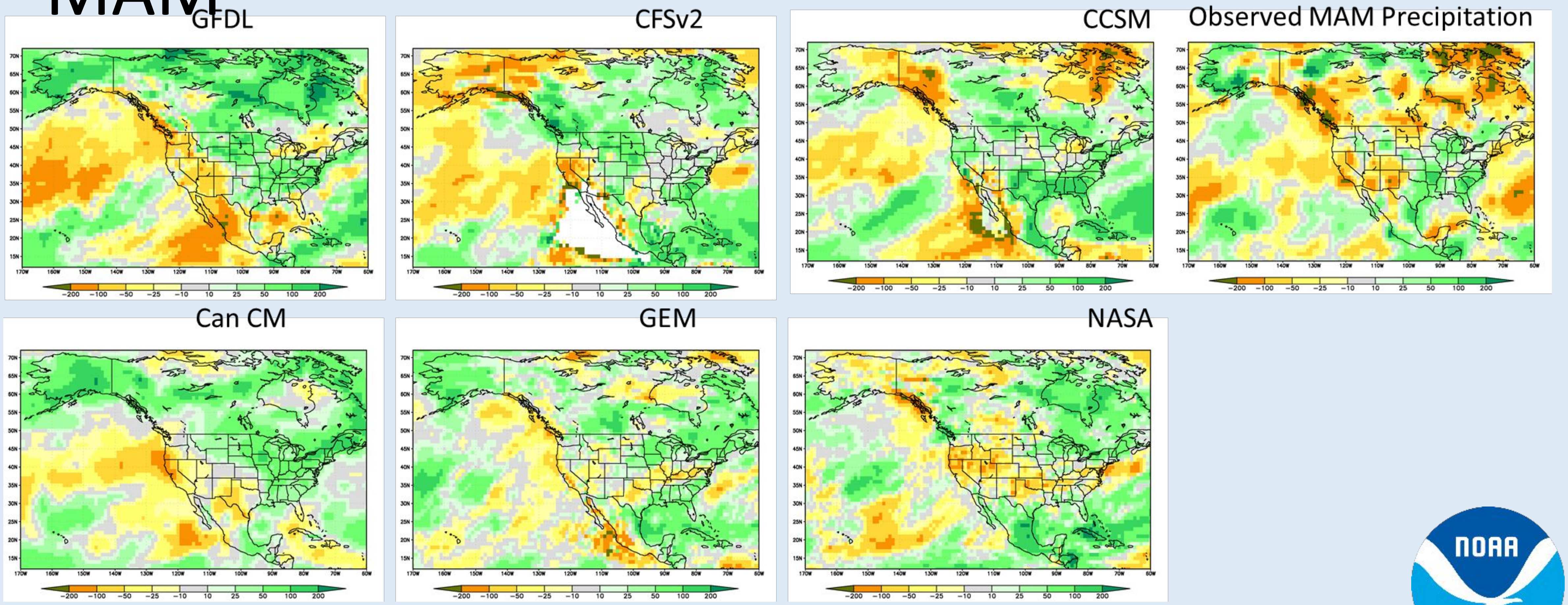


Winter / DJF

Linear Trends based on **NMME model lead-1 DJF temperature forecasts** vs. observed trends:

Dynamical model winter trends are more uniformly towards warmer conditions across the domain and greater than observed trends in many areas of North America.

Precipitation standardized linear trends: MAM



- ***Trend predictor***: Slowly varying representation of decadal variability / climate change
  - *CPC uses the Optimum Climate Normal (Huang, van den Dool, & Barnston 1996)*
  - *We also tested the linear variation of observed temperatures with time (Cross-validation is used to limit overfitting)*

Ensemble regression (ER) post-processing and calibration of dynamical models uses a standard linear regression model of the form:

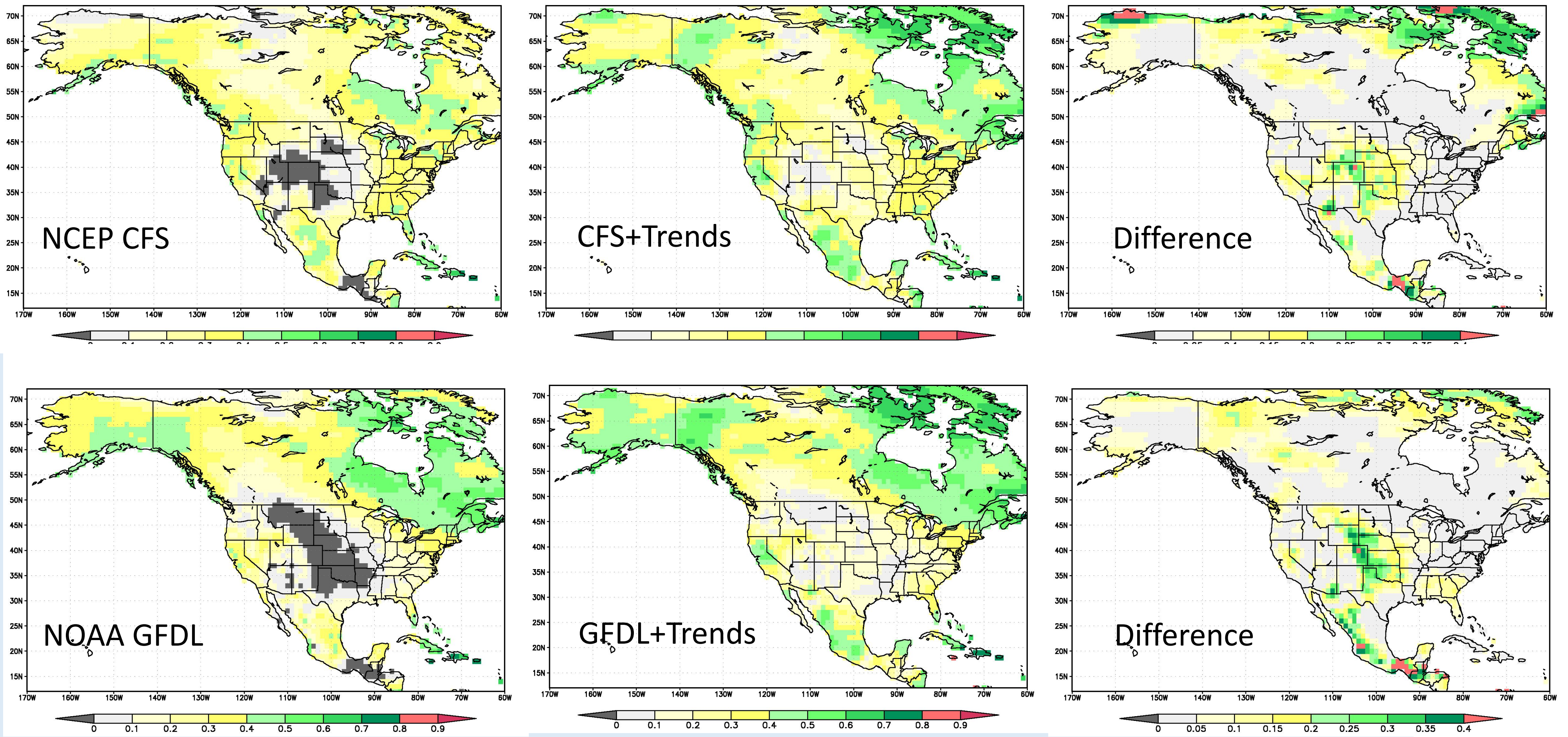
$$F^* = a + bF$$

F = model forecast

F^* = corrected model forecast

We propose to use a decadal trend predictor T, in addition to model forecasts F (Krakauer, 2019):

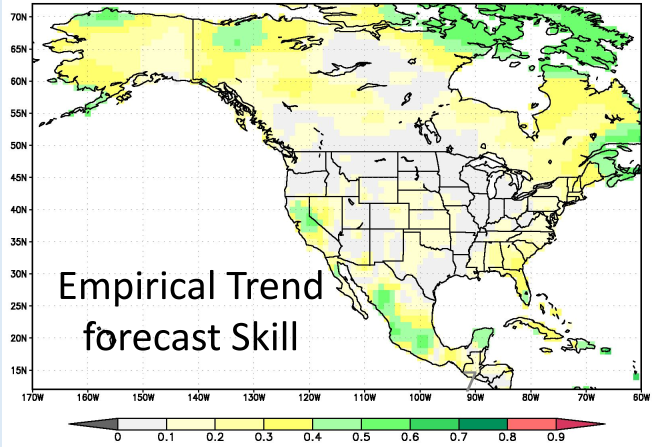
$$F^* = c + dF + eT$$



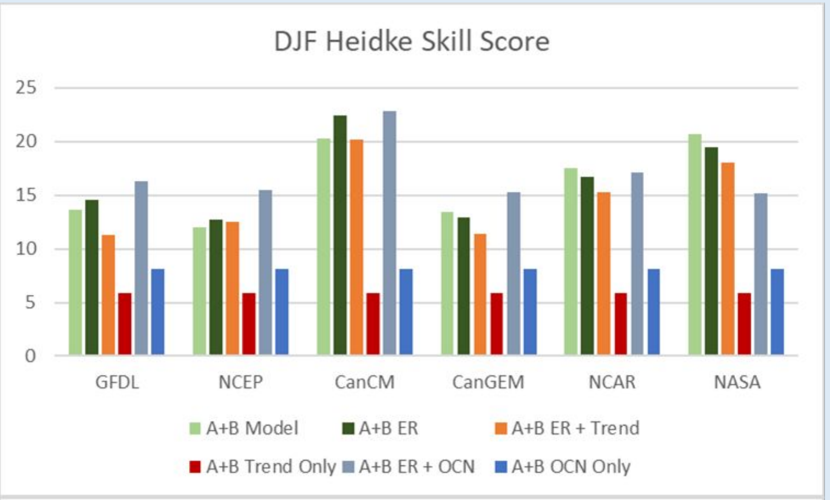
Addition of the decadal trend predictor uniformly increases the apparent **signal**.

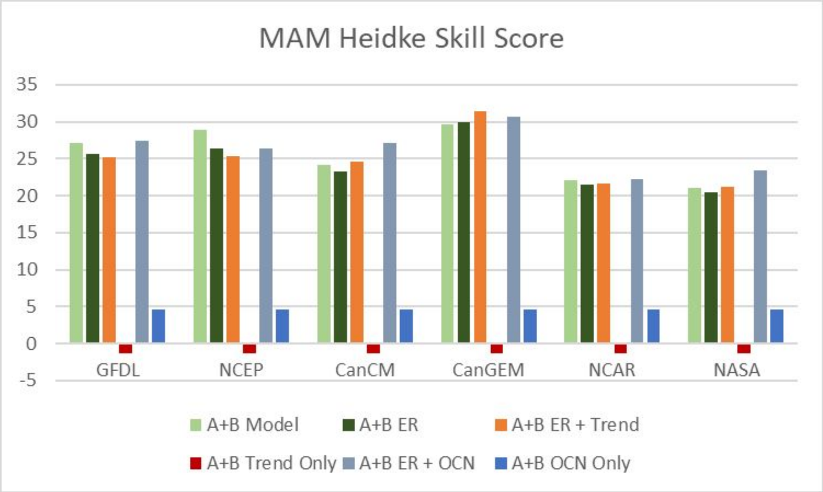
No change to signal where dynamical model predicts trend or trends are small.

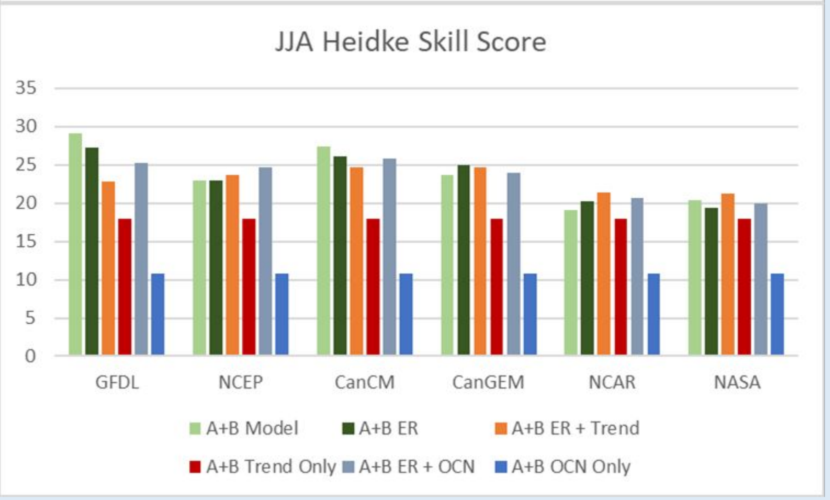
<u>**Correlation Signal from Calibrated Model + Decadal Trends**</u>:
Anomaly Correlations for **lead-1 DJF Temperature**

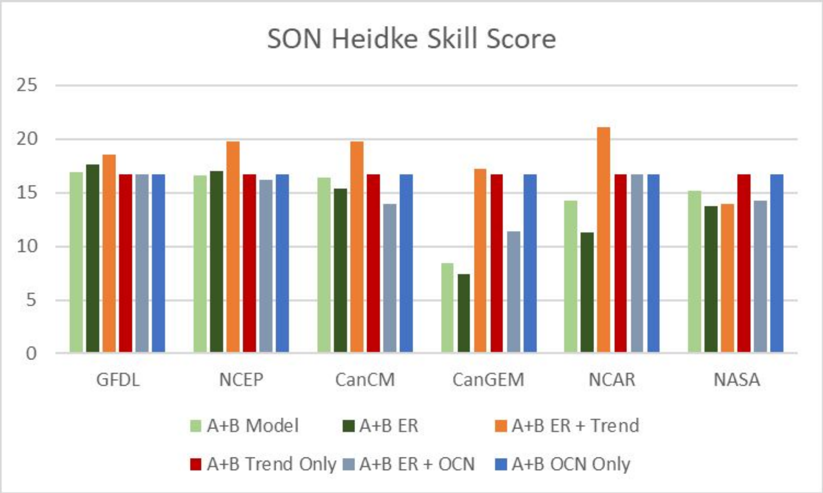


OCN predictor improves **Heidke Skill Score** (HSS) for **DJF Temperatures** while Linear Trend predictor improves skill in SON, when trends are greatest







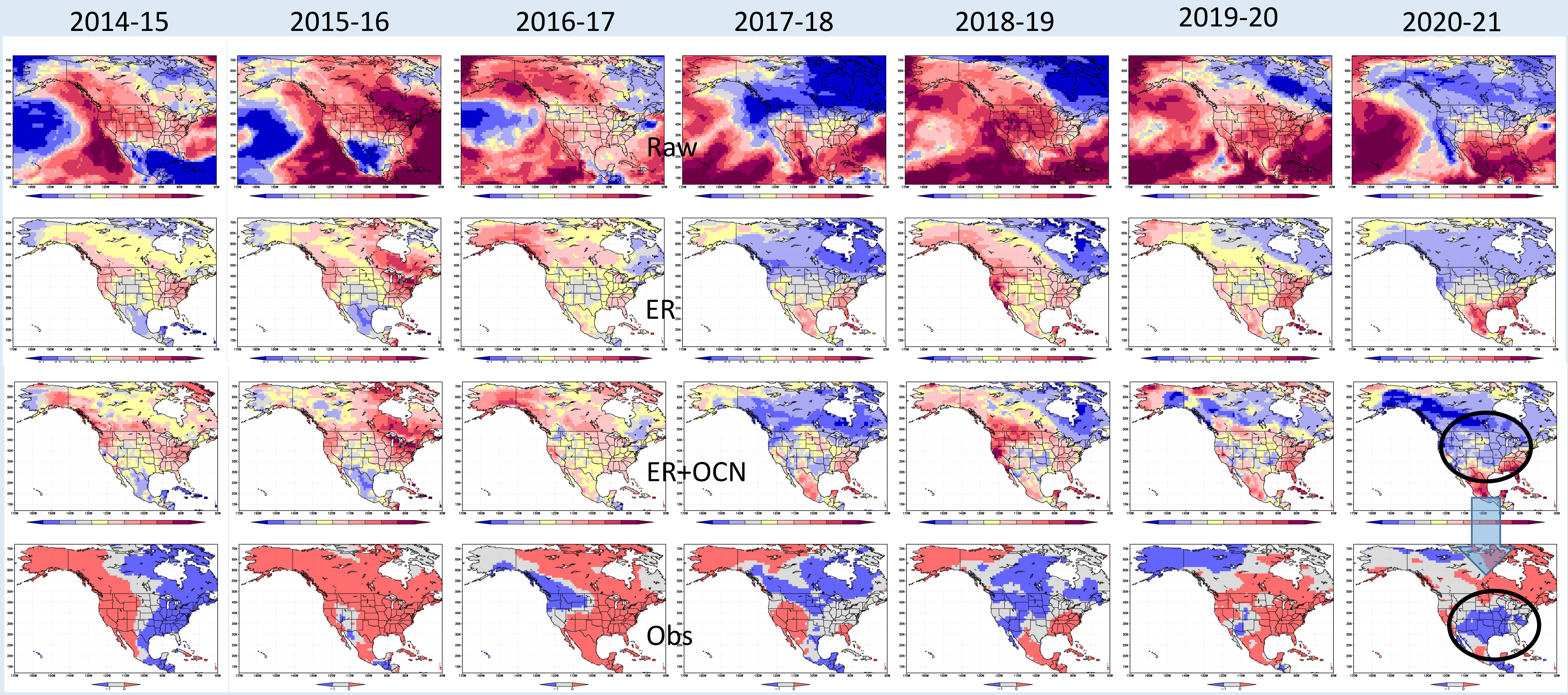


HSS, Temperature

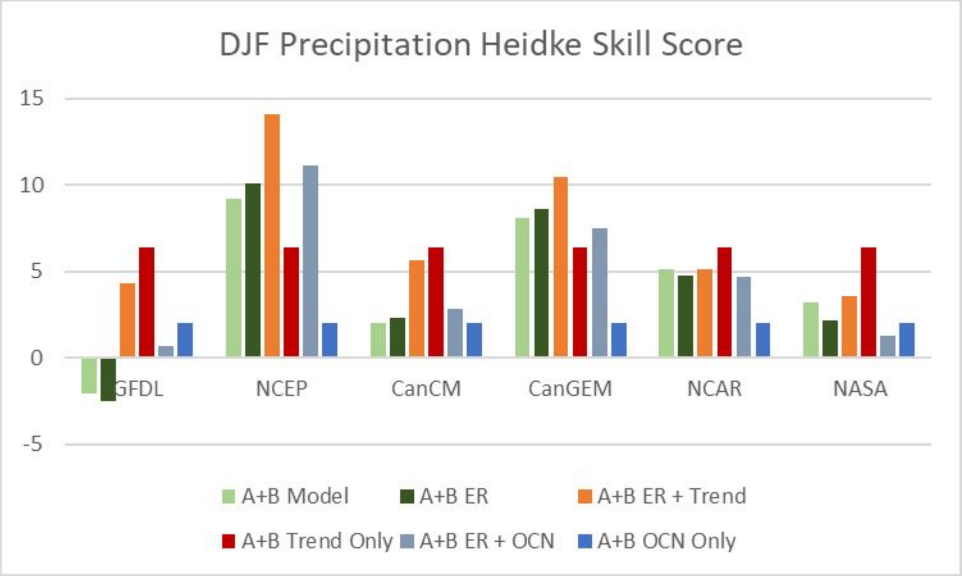
Non-EC, Above and Below Normal

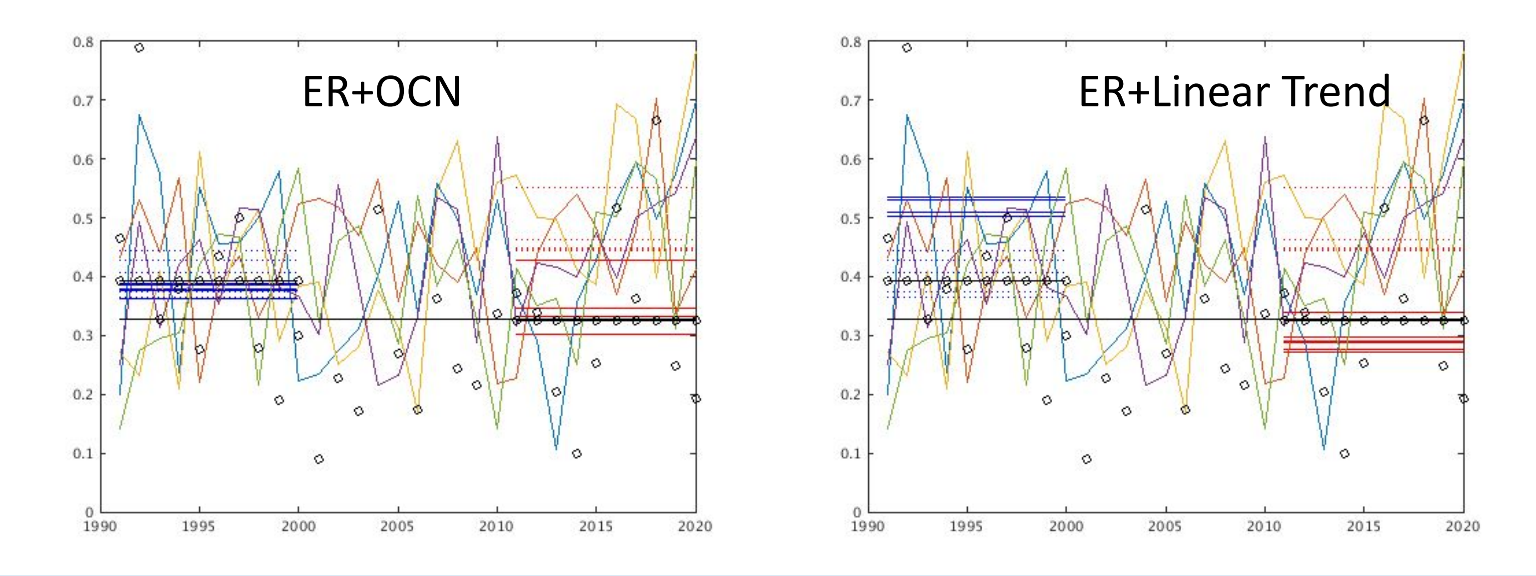
Post-processing using Ensemble Regression with OCN, gray bars, performs best overall

CFSv2 DJF forecasts: Raw, ER, OCN+ER, Obs.



DJF Precipitation HSS for CONUS + AK



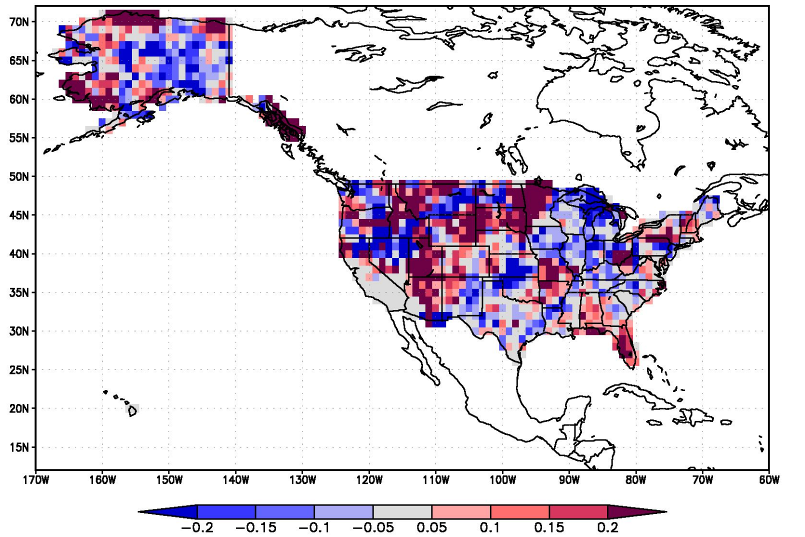


- ER + Linear Trend (orange bars) most skillful in winter (with an overall drying trend)
- However, frequency of above normal (horizontal lines) is less than observed (circles) in recent decade

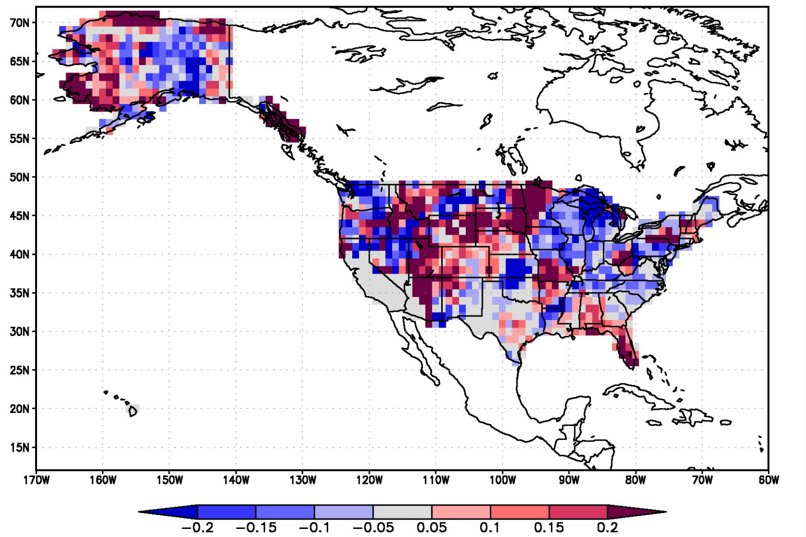
Δ HSS for CFSv2 Precipitation

SON

Trend+ER Forecast - Raw



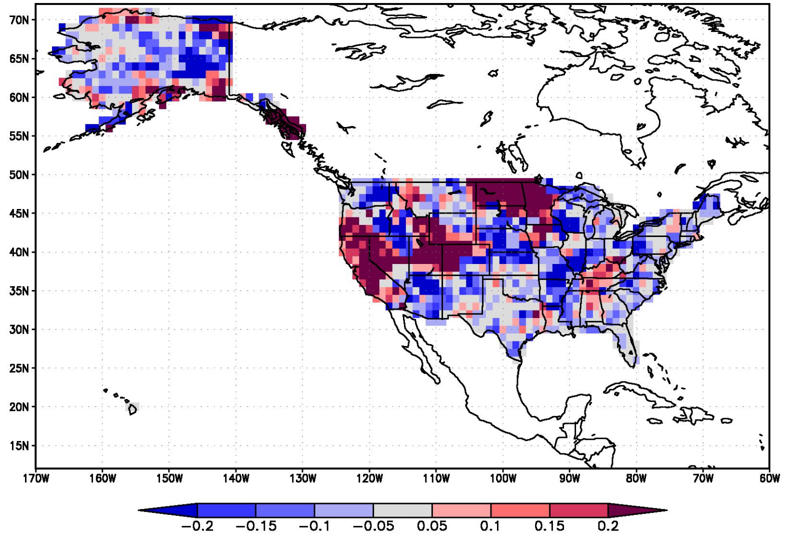
Trend+ER Forecast - ER



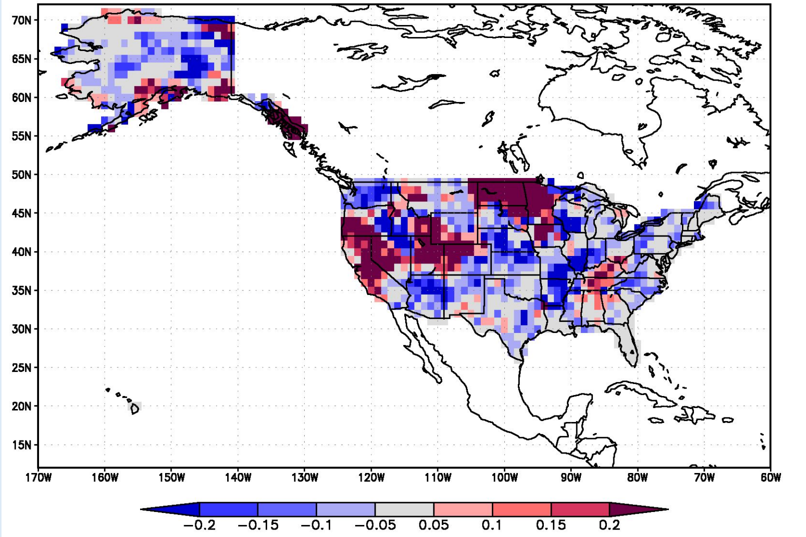
- Red areas show improvement of Heidke skill score using trend-aware post-processed forecasts over both simple post-processed and raw model forecasts

DJF

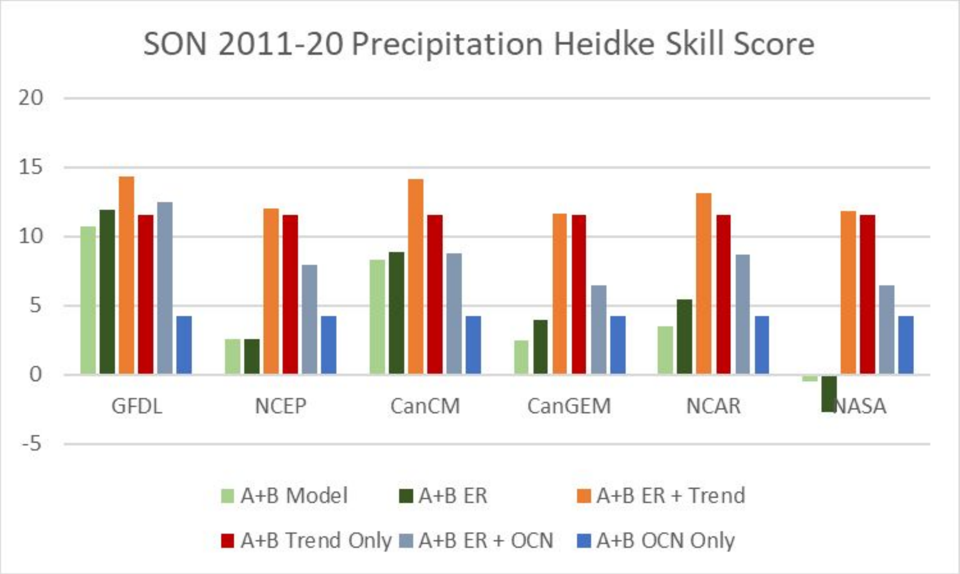
Trend+ER Forecast - Raw

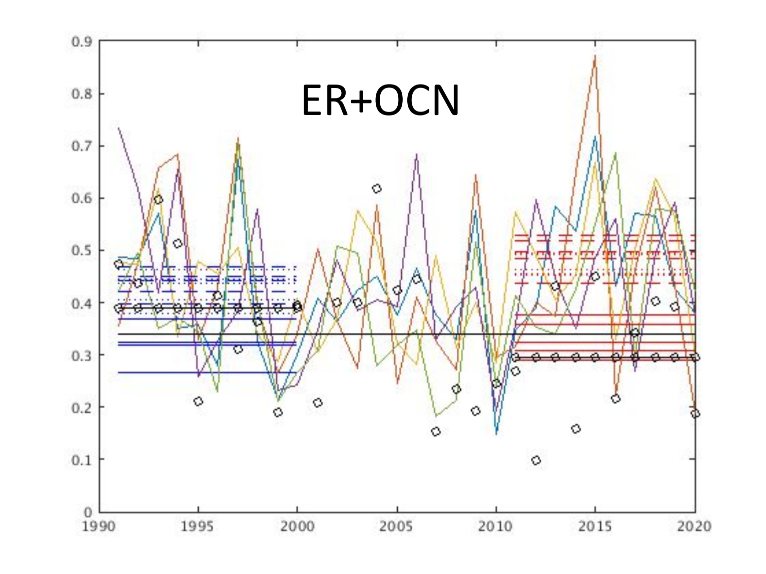


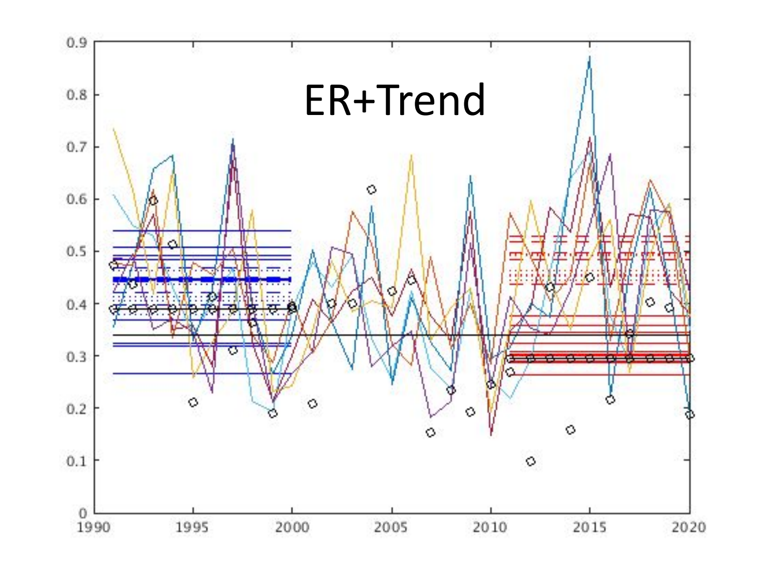
Trend+ER Forecast - ER



SON Precipitation HSS for CONUS + AK





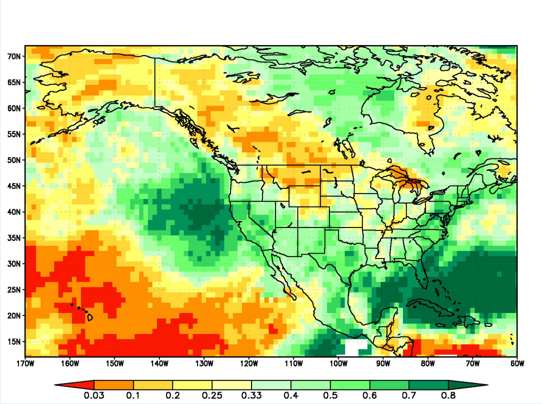


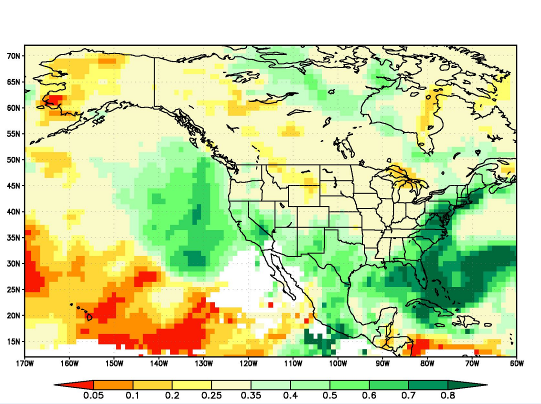
- Drying trend;
- ER+OCN improves skill, while ER + linear trend improvement is greater

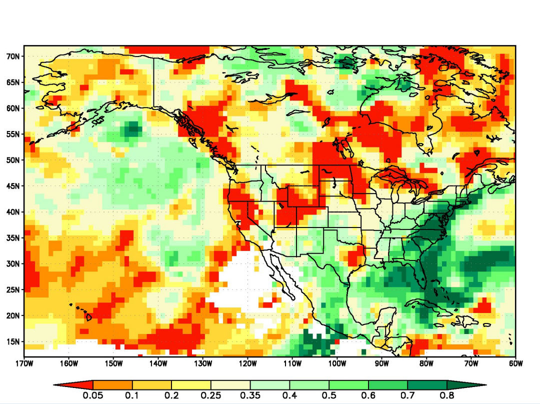
Winter (DJF) 2015-16 Precipitation forecasts:

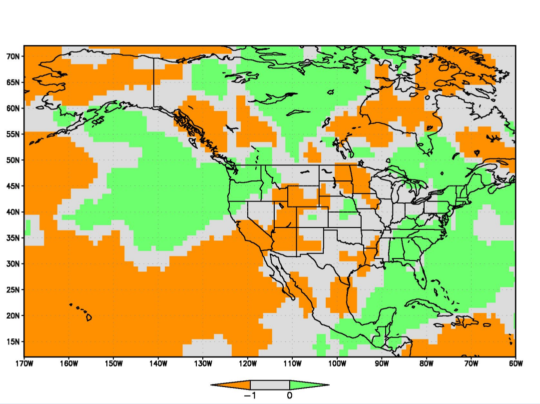
Raw, ER, ER w/Trends, Obs.

CFSv2









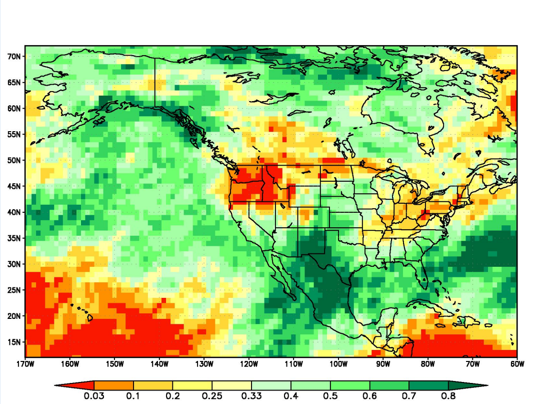
Raw

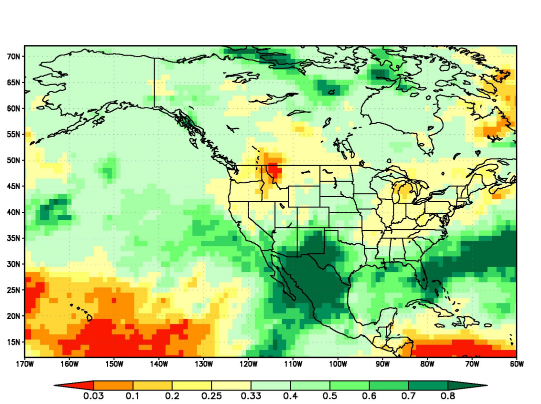
ER

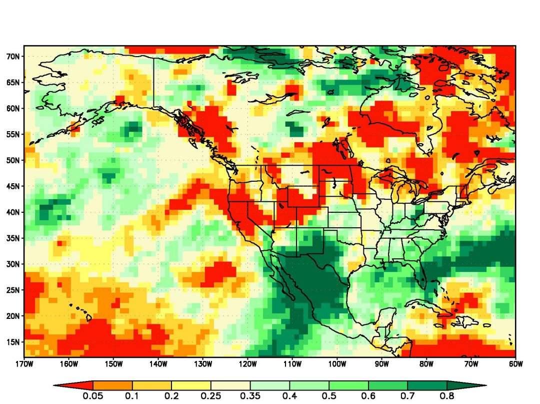
ER+Trend

Observed Tercile

GFDL



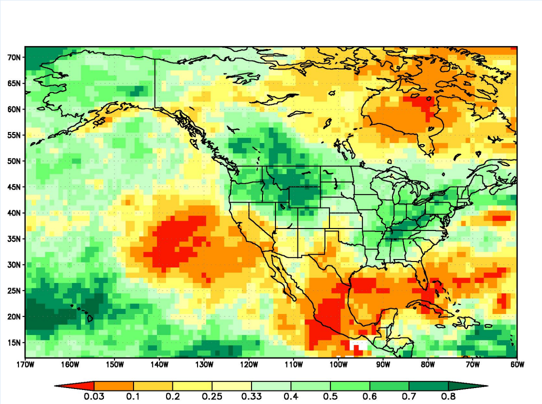




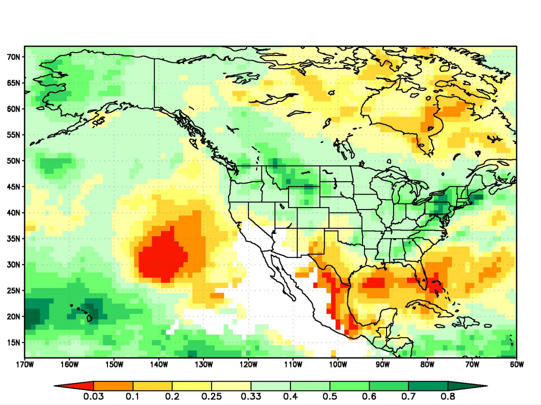
Winter (DJF) 2020-21 Precipitation forecasts:

Raw, ER, ER w/Trends, Observed

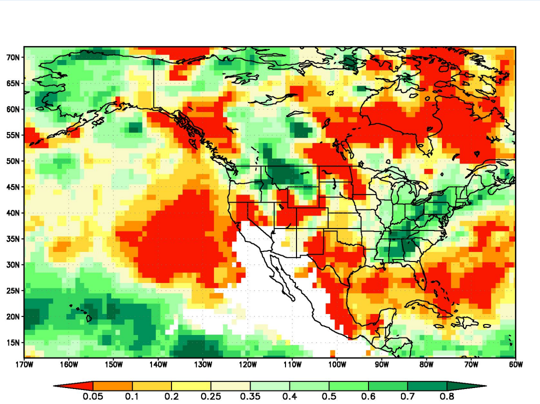
CFSv2



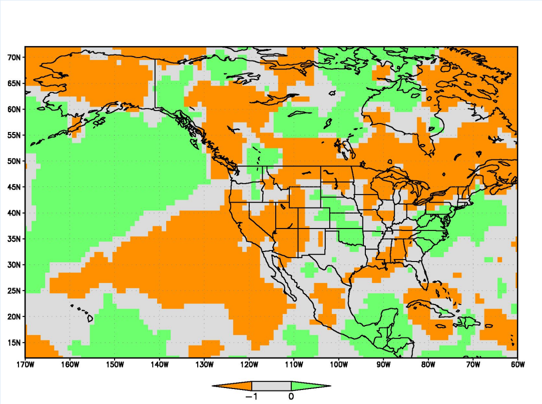
Raw



ER

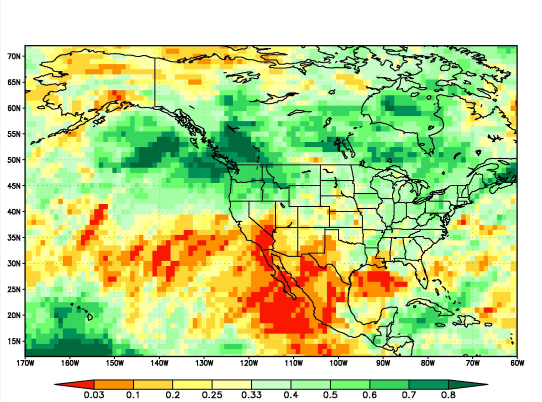


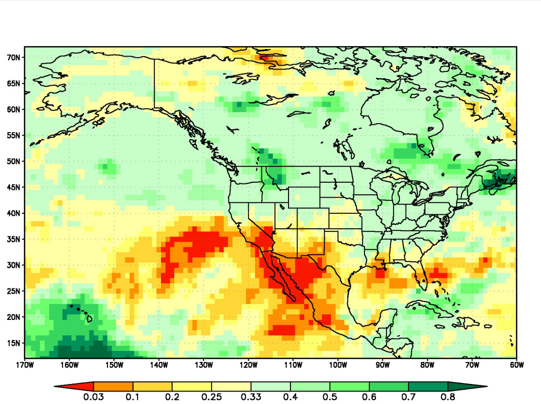
ER+Trend

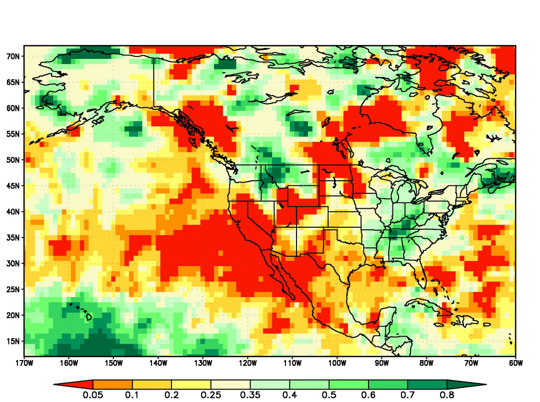


Observed Tercile

GFDL







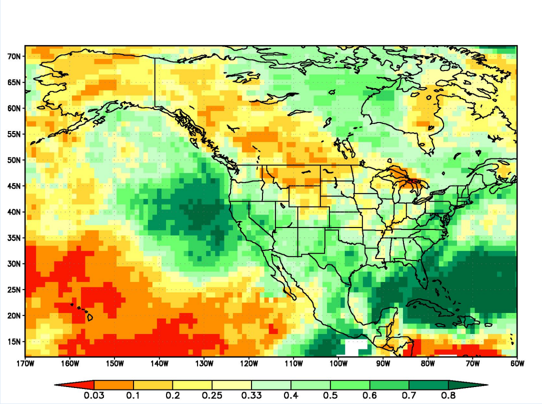
Summary

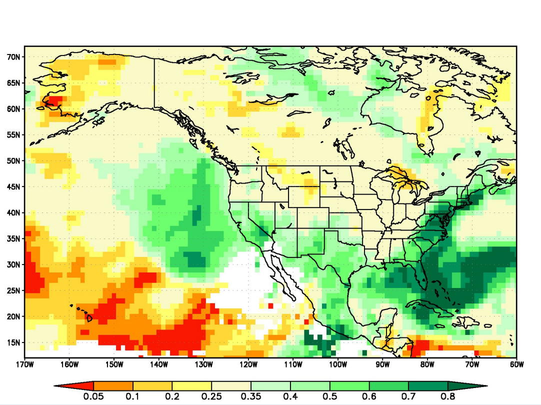
- Biases in dynamical models are separated into decadal and shorter timescale variability
- Models appear to have biases associated specifically with longer timescales, varying by season and location
- Correction or removal of longer/decadal timescale errors increases skill
- Separation of model error by timescale is a potential diagnostic that may help determine sources of model error

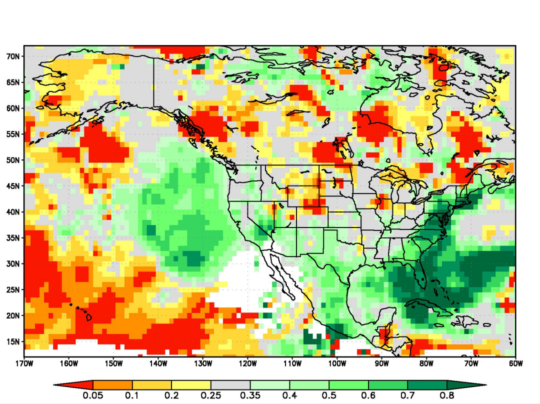
Winter (DJF) 2015-16 Precipitation forecasts:

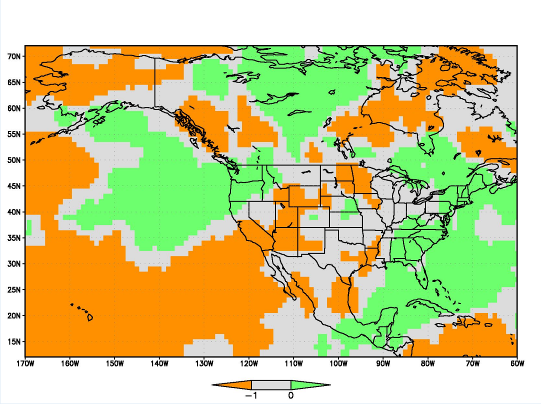
Raw, ER, ER w/Trends, Obs.

CFSv2









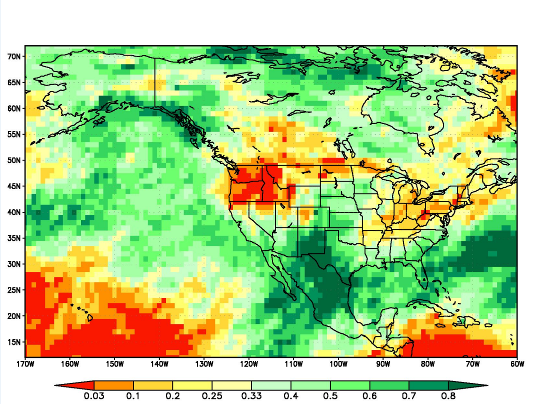
Raw

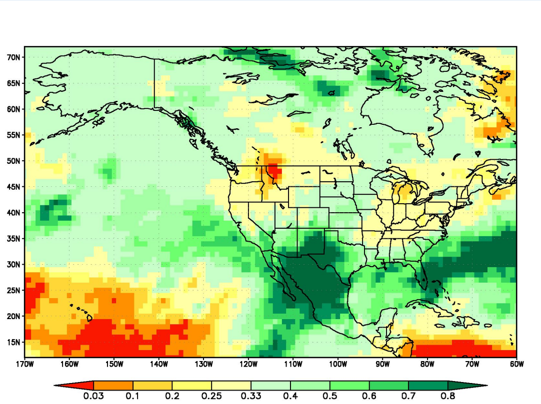
ER

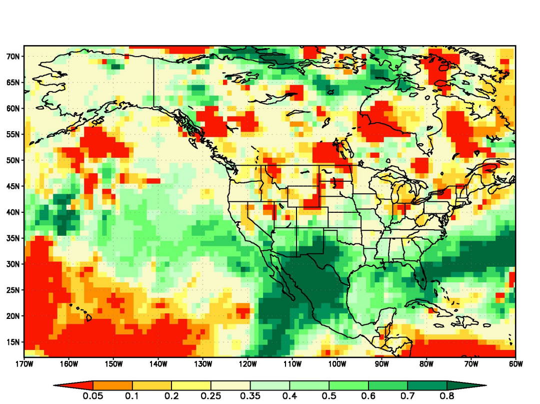
ER+OCN

Observed Tercile

GFDL



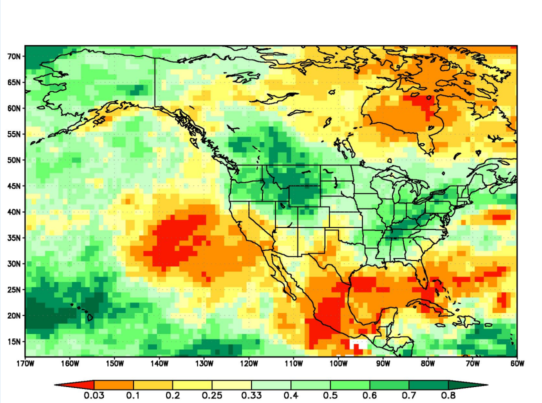




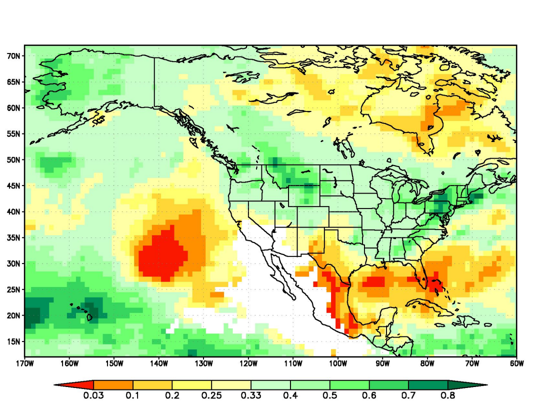
Winter (DJF) 2020-21 Precipitation forecasts:

Raw, ER, ER w/Trends, Observed

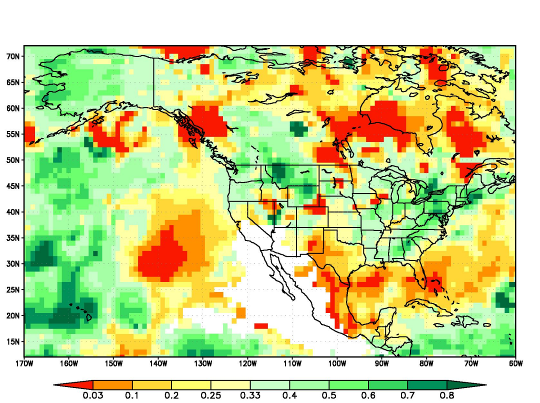
CFSv2



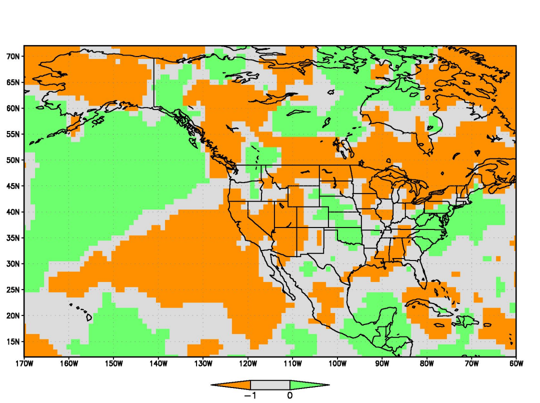
Raw



ER



ER+OCN



Observed Tercile

GFDL