

Attribution of Seasonal Climate Anomalies March-April-May 2024

(<https://www.cpc.ncep.noaa.gov/products/people/mchen/AttributionAnalysis/>)

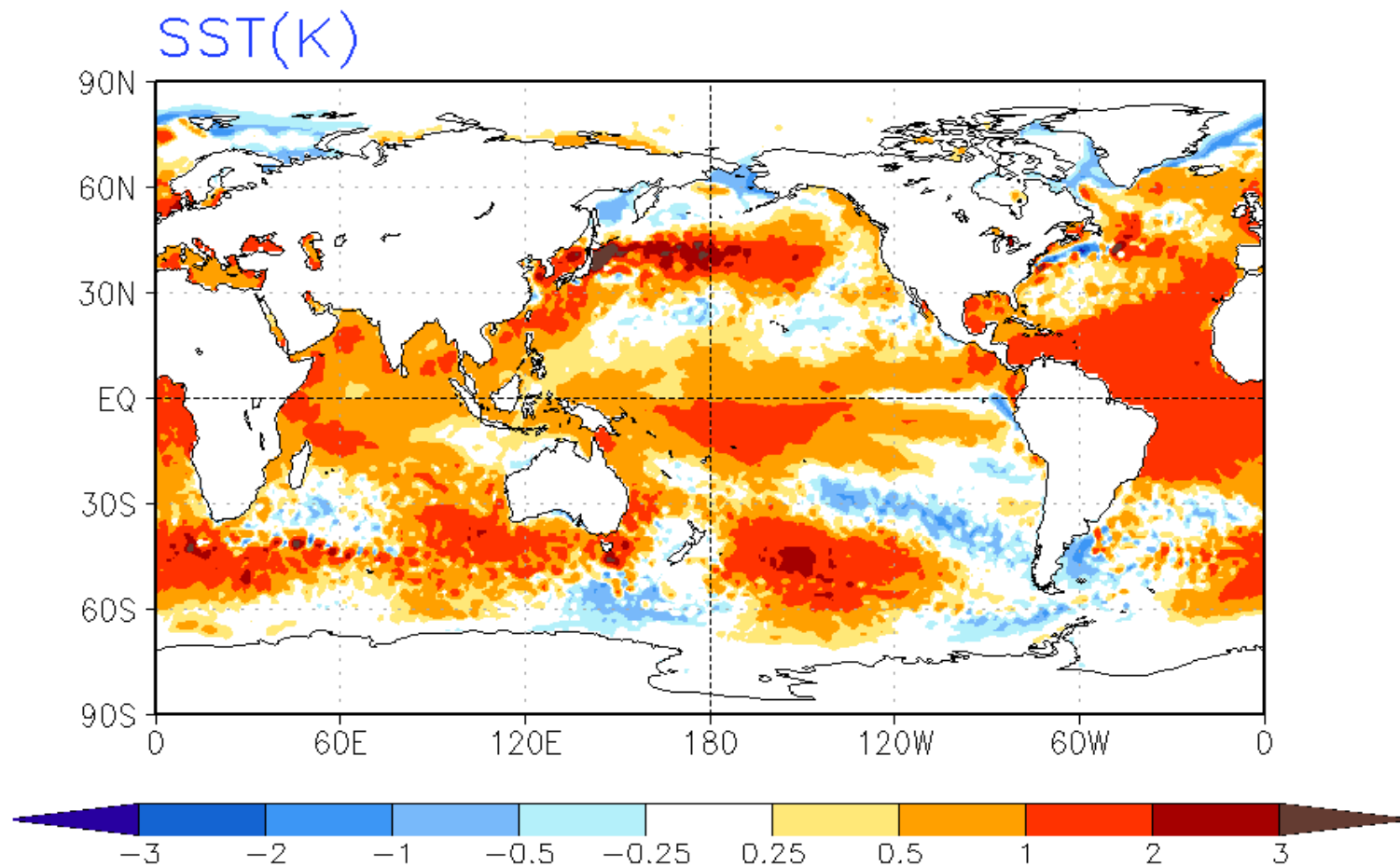
Summary of Observed Conditions and Outlooks

- In MAM2024, warm SST anomalies associated with El Niño declined further in the equatorial central Pacific and cold anomalies emerged in the far equatorial eastern Pacific along the coastal regions of South America. Most of other ocean basins, specifically, over the North Pacific, central southern Pacific, Atlantic, and Indian Ocean, the SST warm anomalies persisted (slide 4). Initialized with warm SST anomalies, CFSv2 maintained the large-scale structure of the warming over the global oceans (slide 10).
- Except for the initialized CFSv2 forecasts, the AMIP simulations and other MME forecasts show a spatial pattern of rainfall anomalies of canonical El Niño response with positive rainfall anomalies over the equatorial central Pacific, which is opposite to the observations. However, CFSv2 initialized forecasts still missed the observed negative precipitation anomalies over the equatorial eastern and southern Indian Ocean (slides 11, 37-39). It may be related to the SST warming biases over the eastern Indian Ocean in CFSv2 forecasts (slide 10).
- The tendency for above normal 200-mb heights and above normal land surface temperature anomalies continued to dominate almost throughout the globe both in observations and model predictions and simulations due to the warming SST globally (slide 10, 12, 13).
- The initialized CFSv2 forecasts, in general, predicted well the tendency for above normal 200-mb height and land surface temperature over North America (slide 15, 16).
- May 2024 monthly forecast skill for 200-mb height, T2m, and rainfall over North America was better for the shortest leads (slide 33-35).

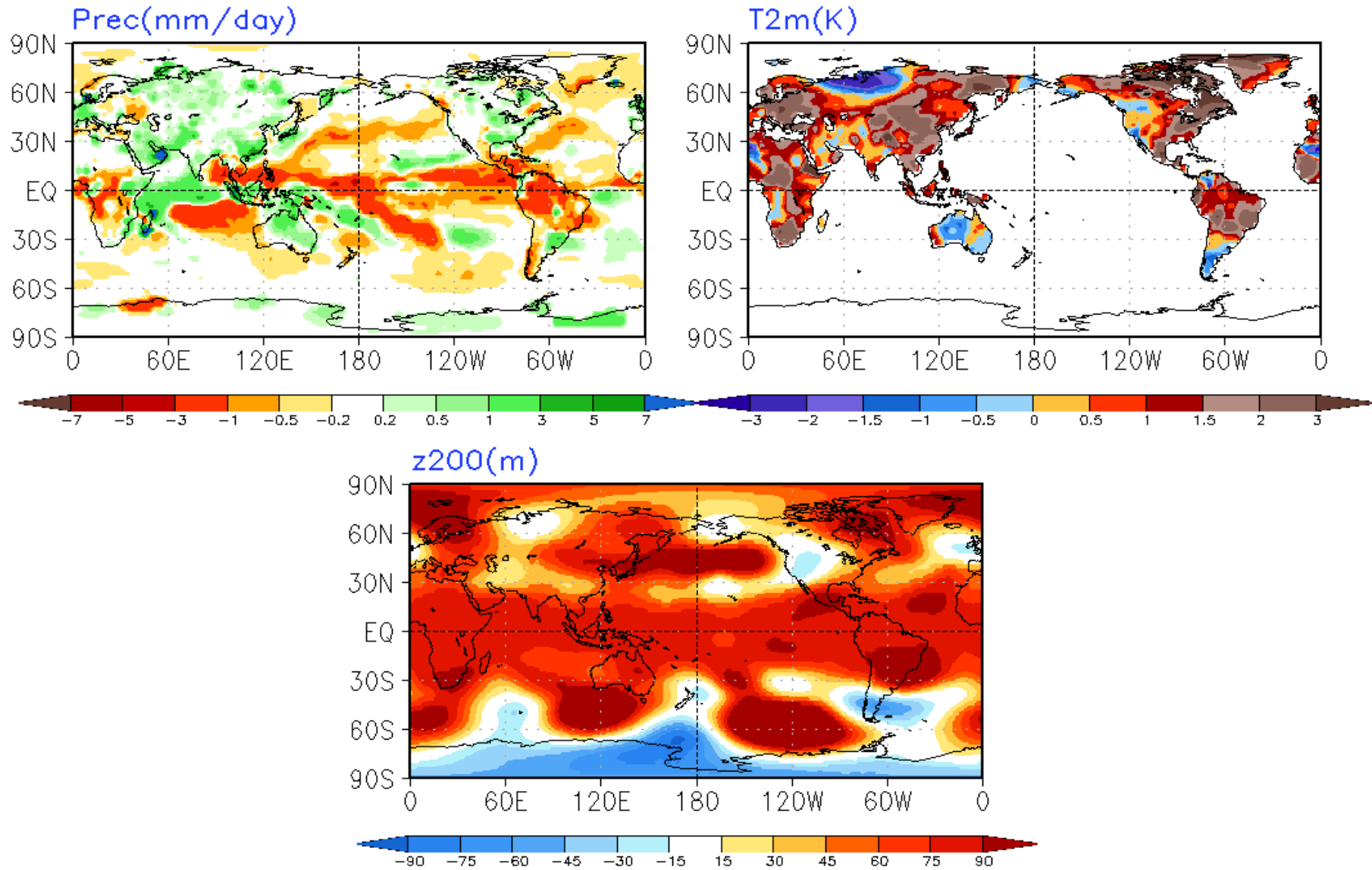
Observed Seasonal Anomalies

Global and North America

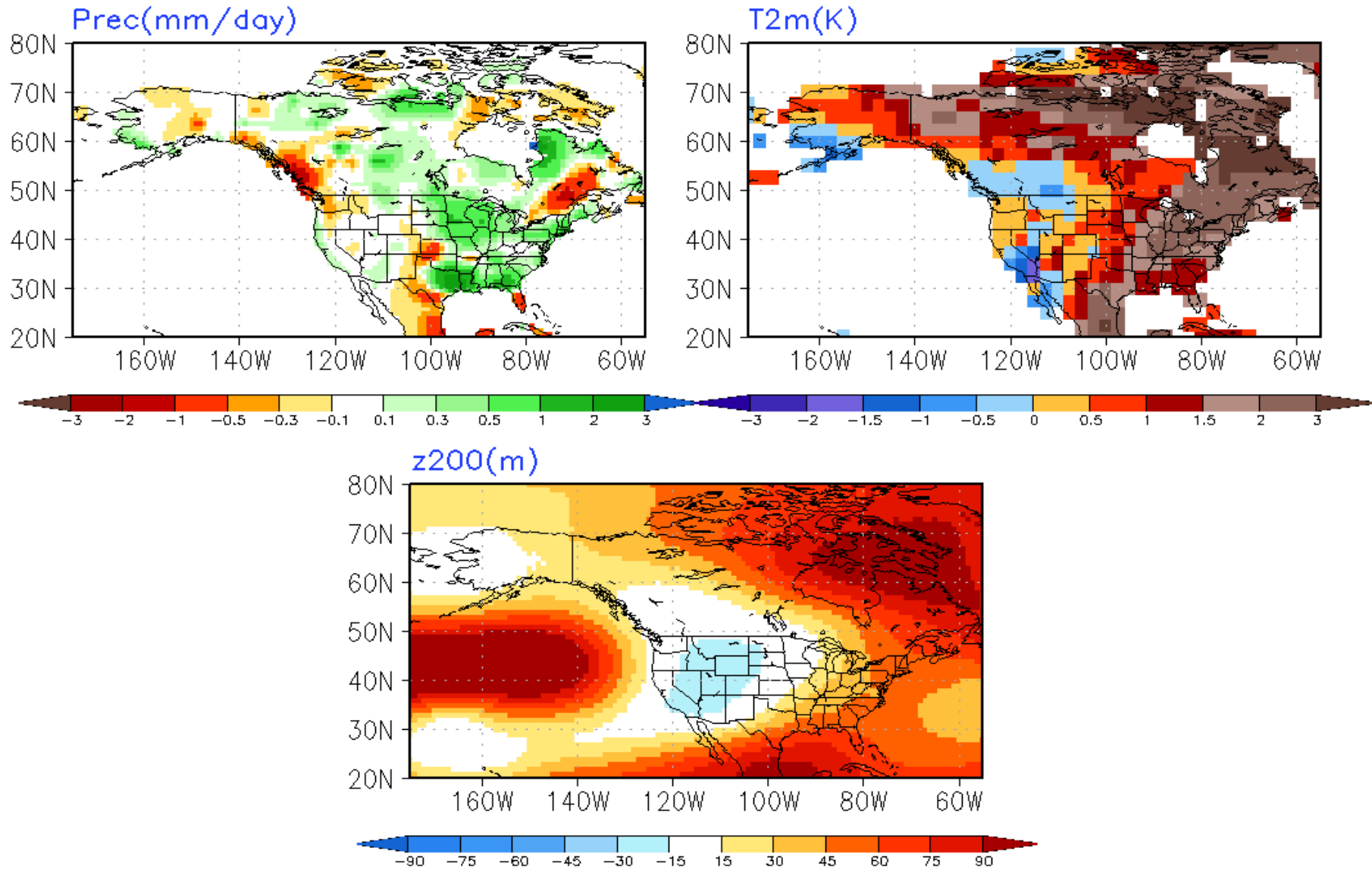
Observed Anomaly MAM2024



Observed Anomaly MAM2024



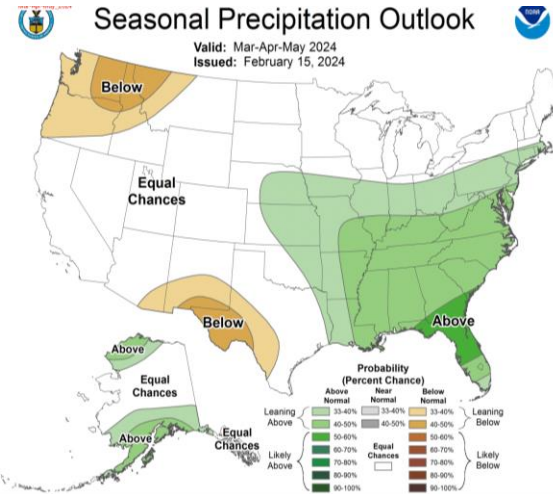
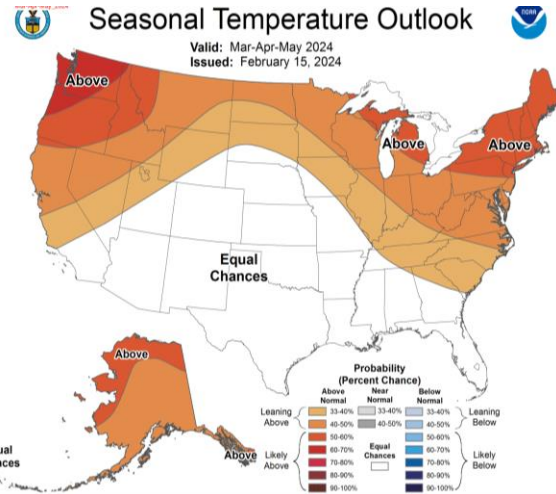
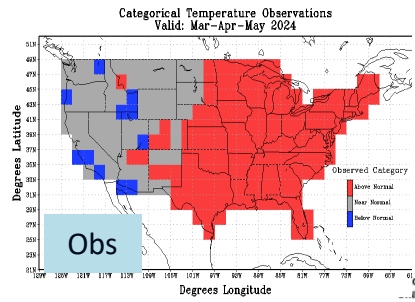
Observed Anomaly MAM2024



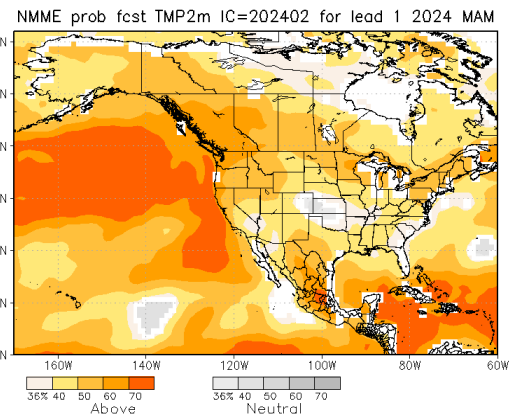
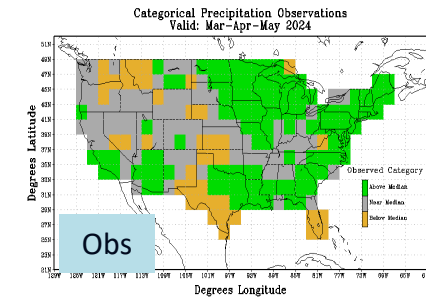
CPC Seasonal Outlooks and NMME Forecasts

CPC

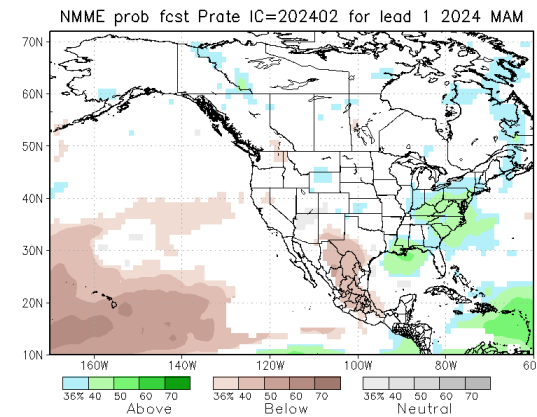
Temp nonEC
HSS=32



Prec nonEC
HSS=35



NMME



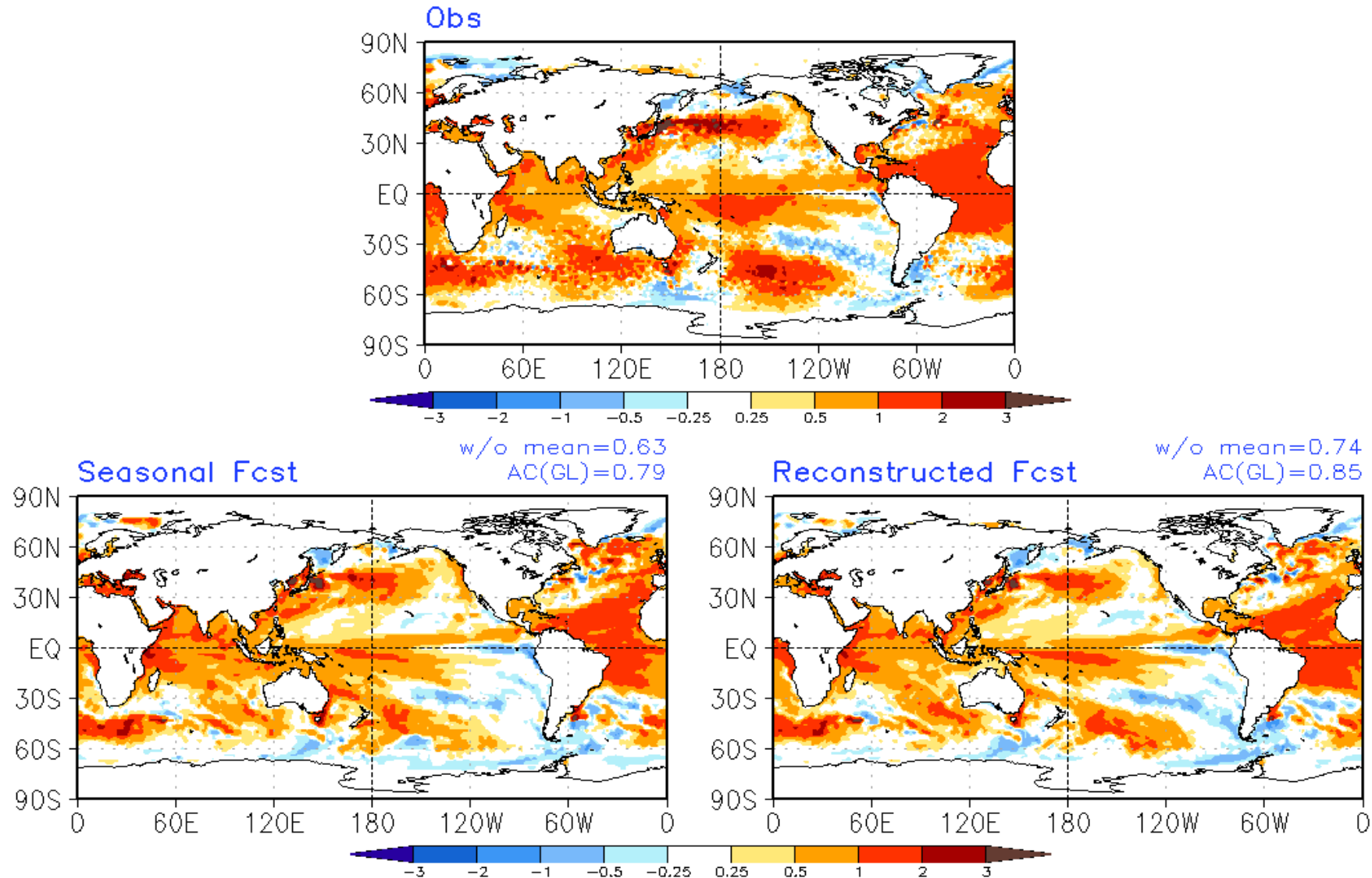
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2024/202402_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

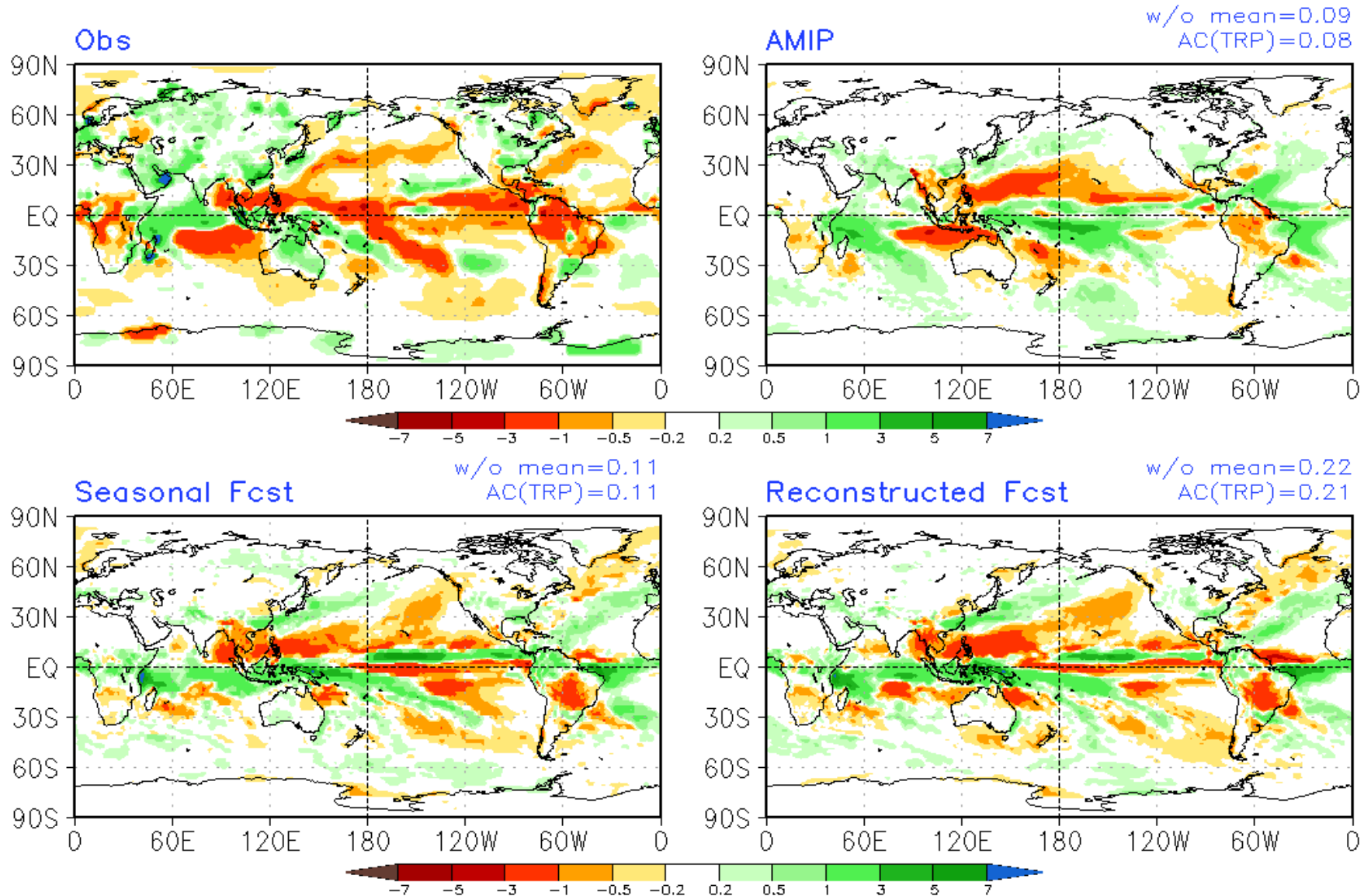
Model Simulated/Forecast Ensemble Average Anomalies

- **AMIP simulations** forced with observed sea surface temperatures (100 members ensemble)
- CFSv2 real time operational forecasts
 - **Seasonal forecast**: the seasonal mean forecasts based on 40 members from the latest 10 days before the target season (0-month-lead). For example, 2016AMJ seasonal mean forecasts are 40 members from 22-31 March2016 initial conditions.
 - **Reconstructed forecast**: the seasonal mean forecasts constructed from 3 individual monthly forecasts with the latest 10 days initial conditions for each individual monthly forecasts. This approach for constructing seasonal mean anomalies has more influence from the initial conditions (Kumar et al. 2013). For example, the constructed 2016AMJ seasonal mean forecasts are the average of April2016 forecasts from 22-31 March2016 initial conditions, May2016 forecasts from 21-30 April2016 initial conditions, and June2016 forecasts from 22-31 May2016 initial conditions.
- Numbers at the panels indicate the spatial anomaly correlation (AC). “w/o mean” is AC with area mean removed.

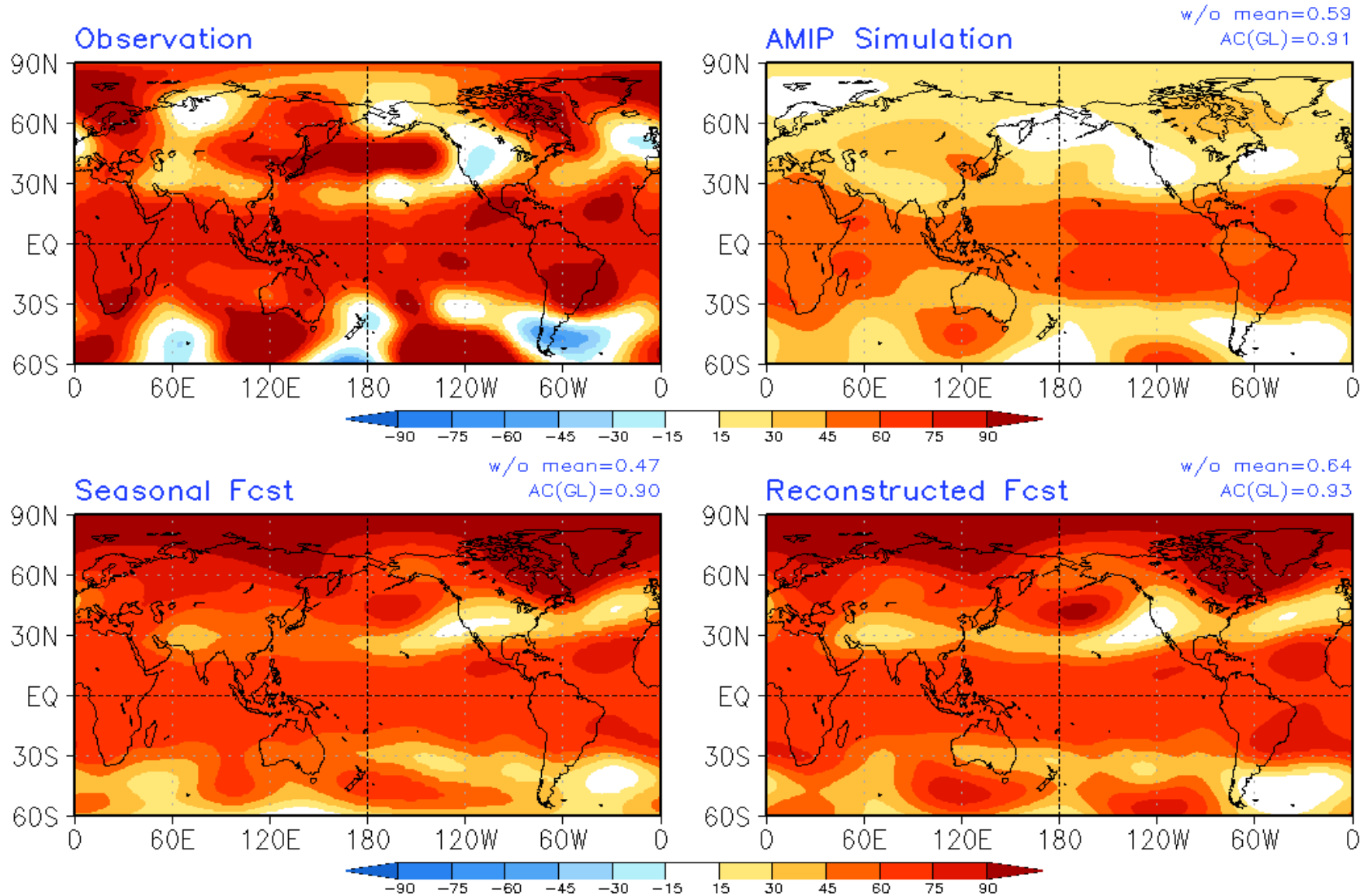
MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



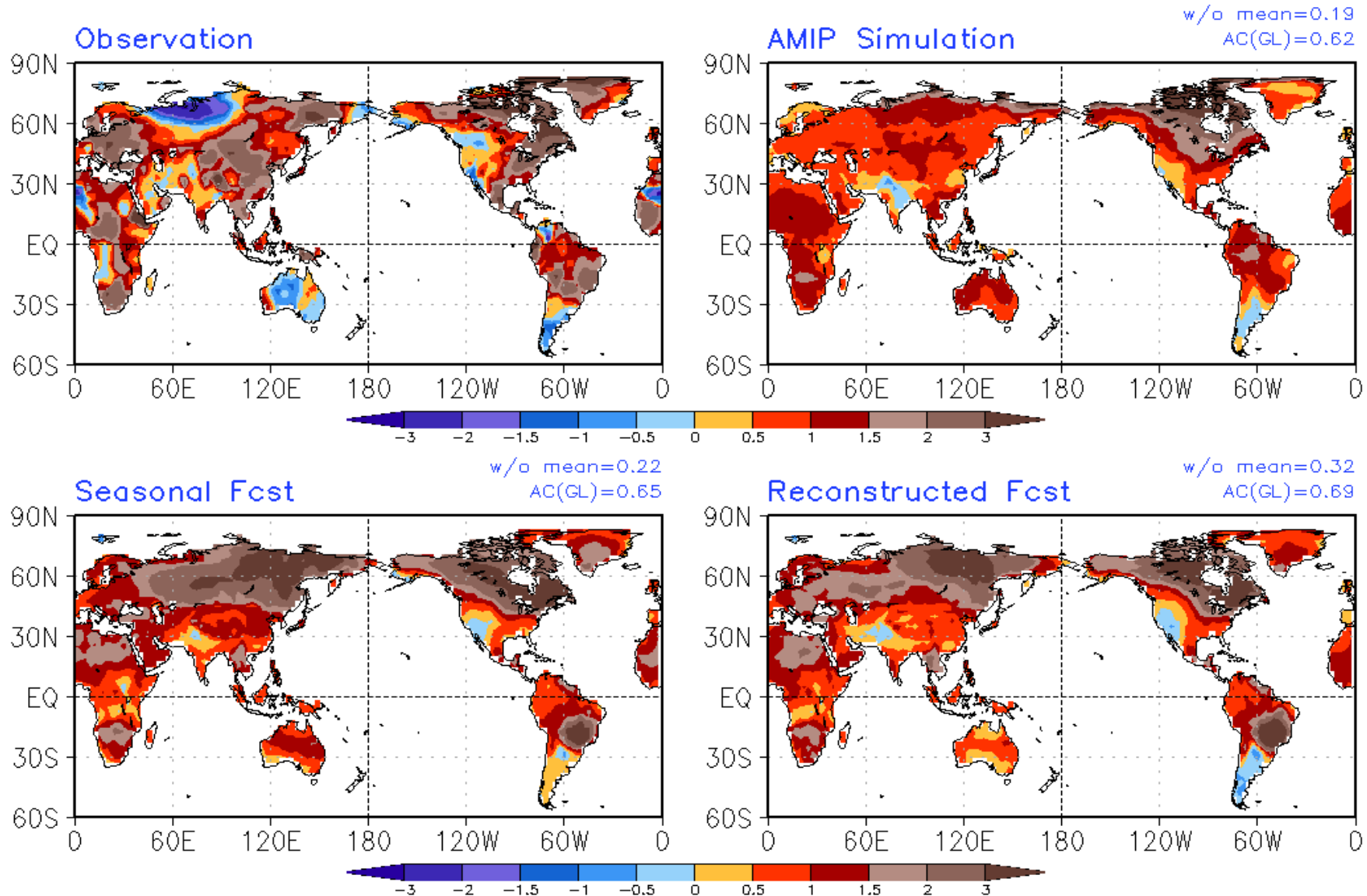
MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



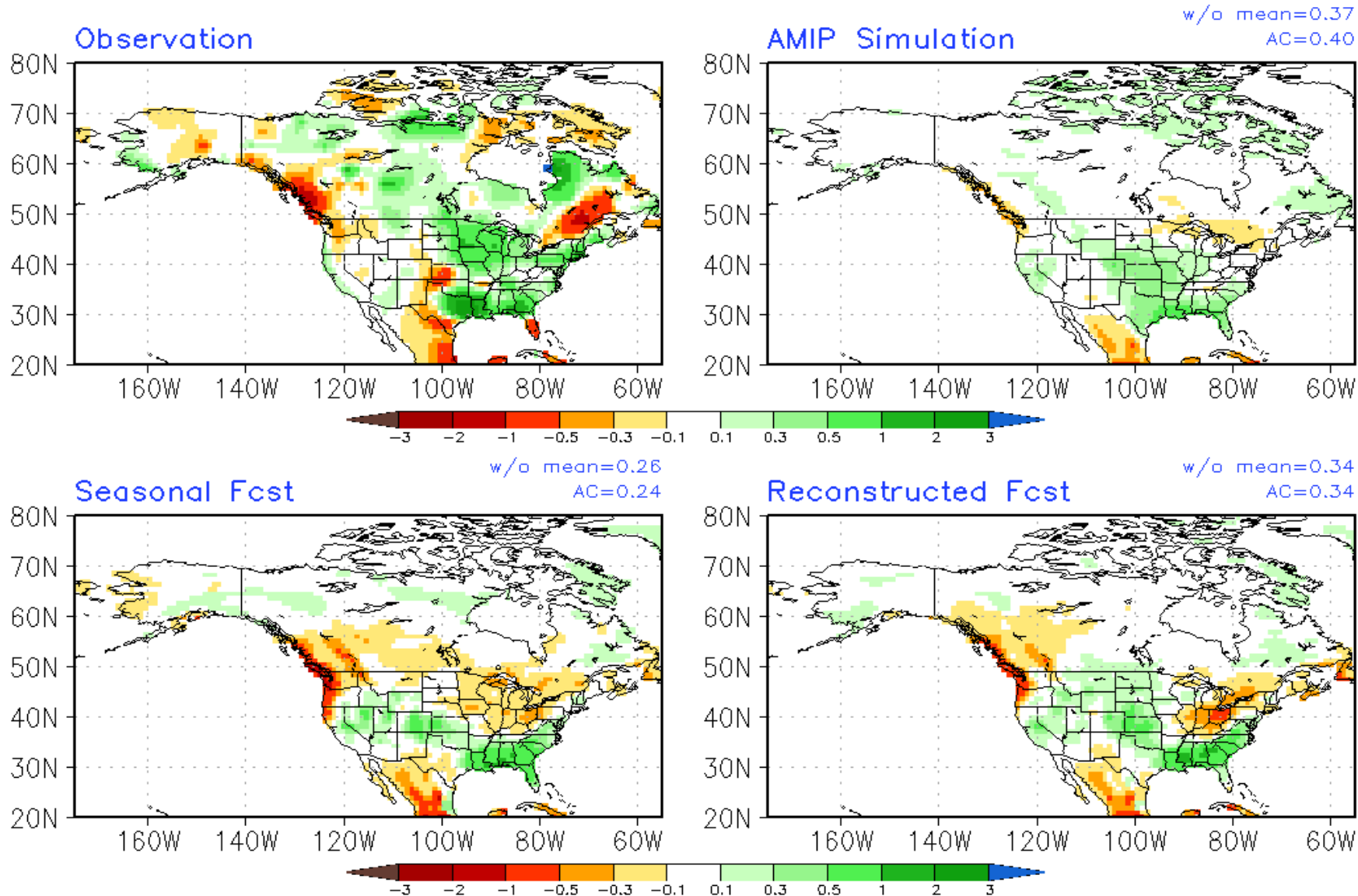
MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



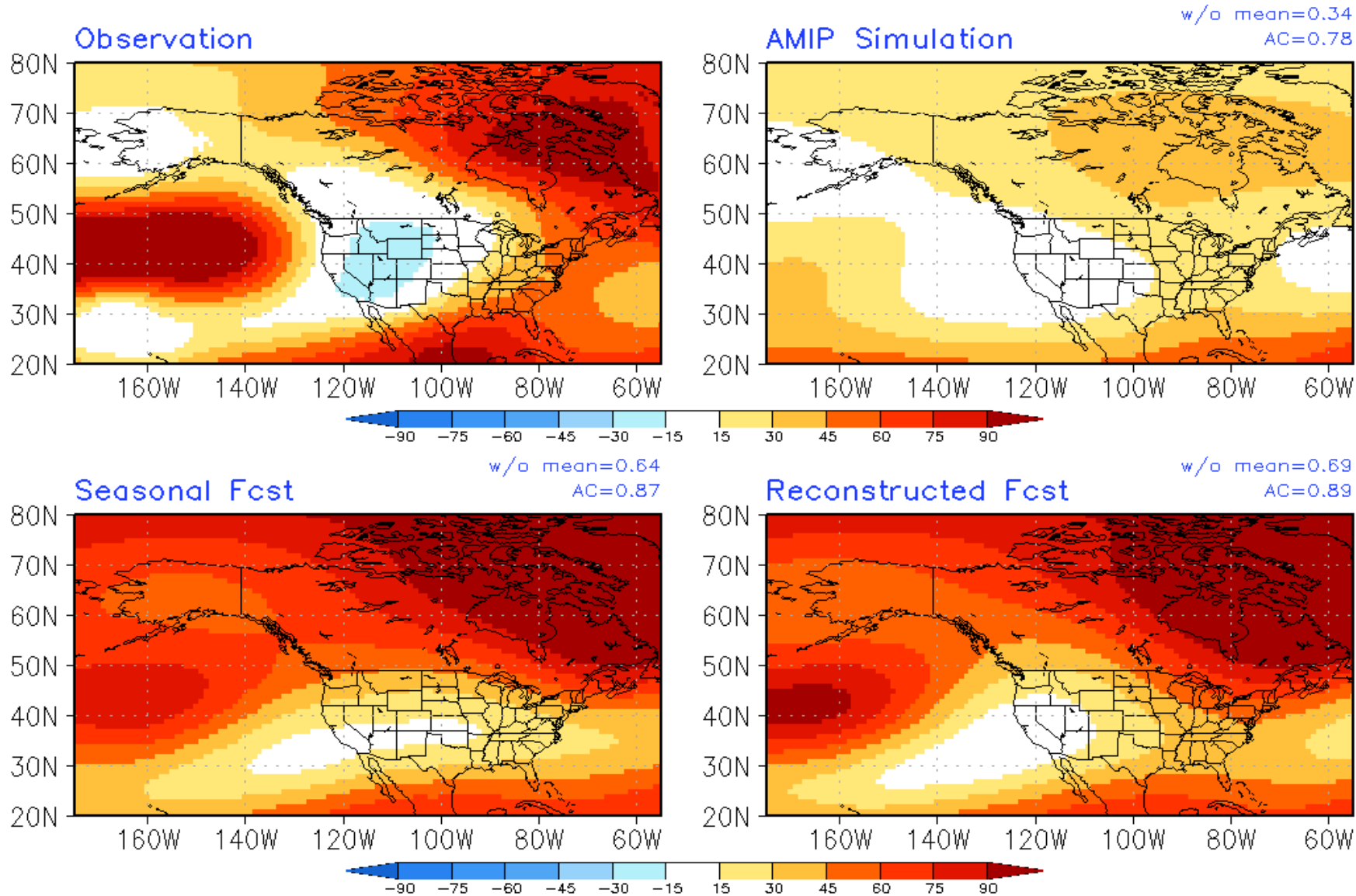
MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



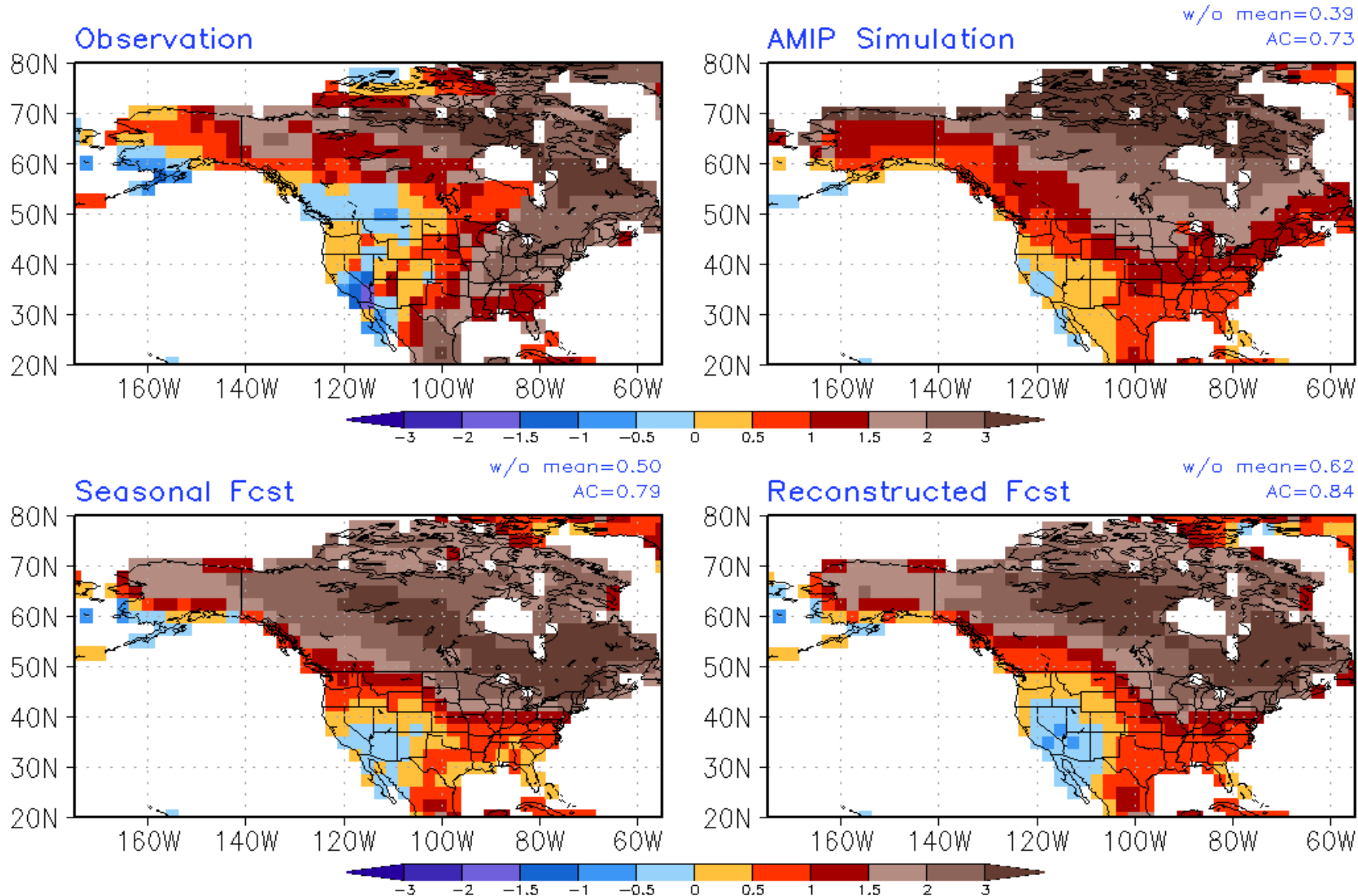
MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



MAM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

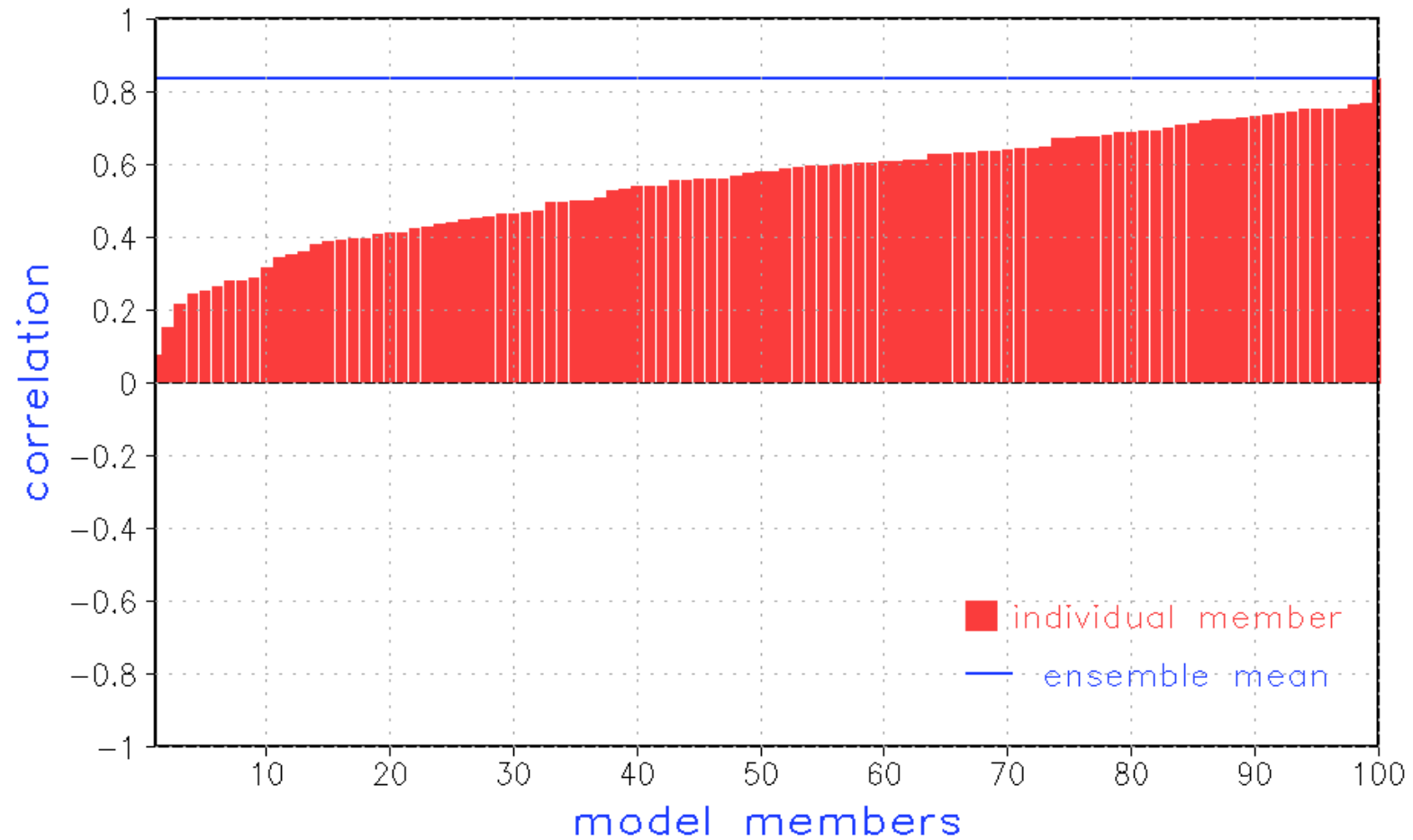


Model Simulated/Forecast Anomalies: Individual Runs

Model Simulated/Forecast Anomalies: Individual Runs

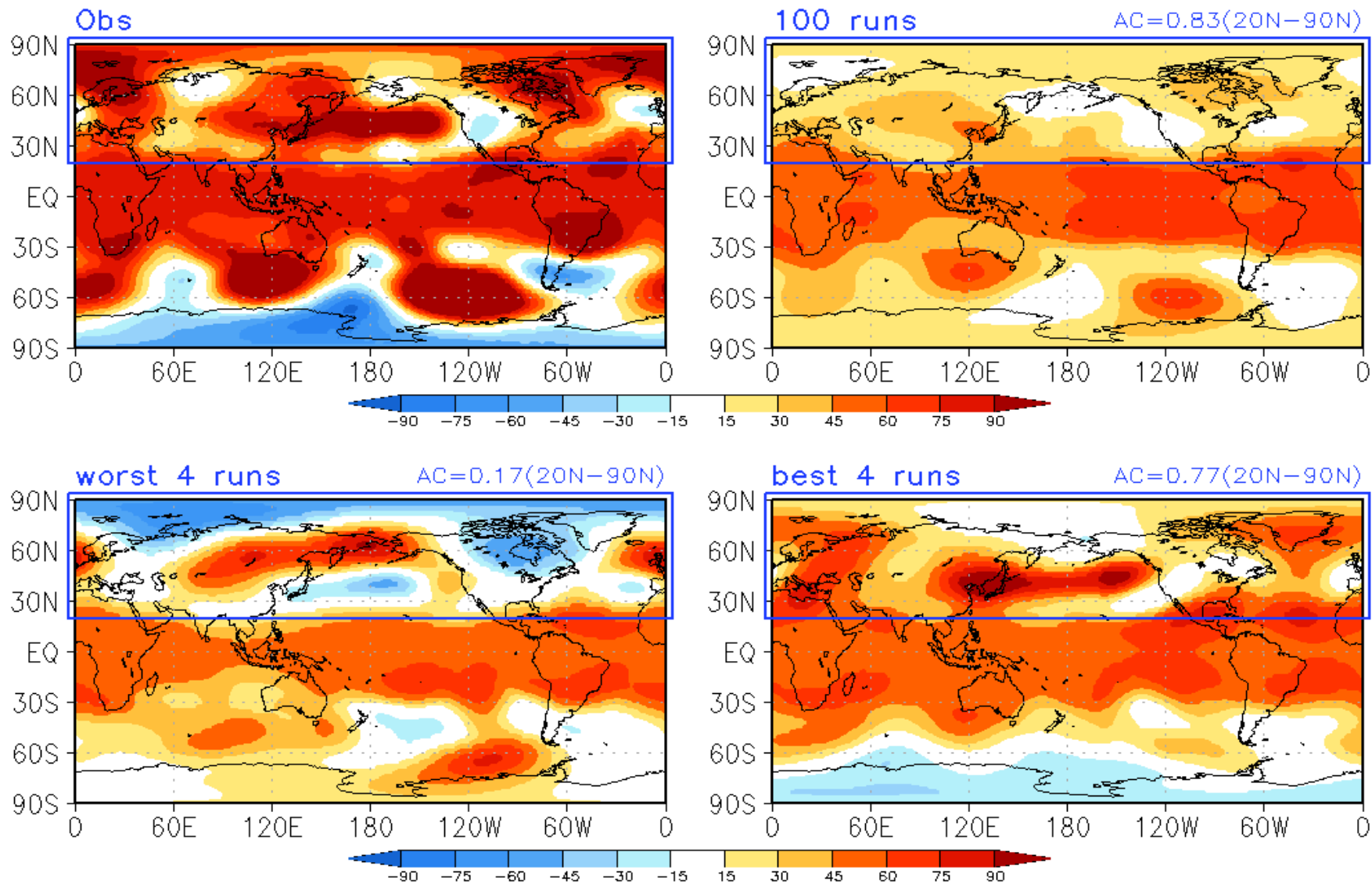
- In this analysis, anomalies from individual model runs are compared against the observed seasonal mean anomalies. The spatial resemblance between them is quantified based on anomaly correlation (AC).
- The distribution of AC across all model simulations is indicative of probability of observed anomalies to have a predictable (or attributable) component.
- One can also look at best and worst match between model simulated/forecast anomalies to assess the range of possible seasonal mean outcomes.
- For further details see: Kumar, A., M. Chen, M. Hoerling, and J. Eischeid (2013), Do extreme climate events require extreme forcings? *Geophys. Res. Lett.*, 40, 3440-3445. [doi:10.1002/grl.50657](https://doi.org/10.1002/grl.50657).

MAM2024 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)

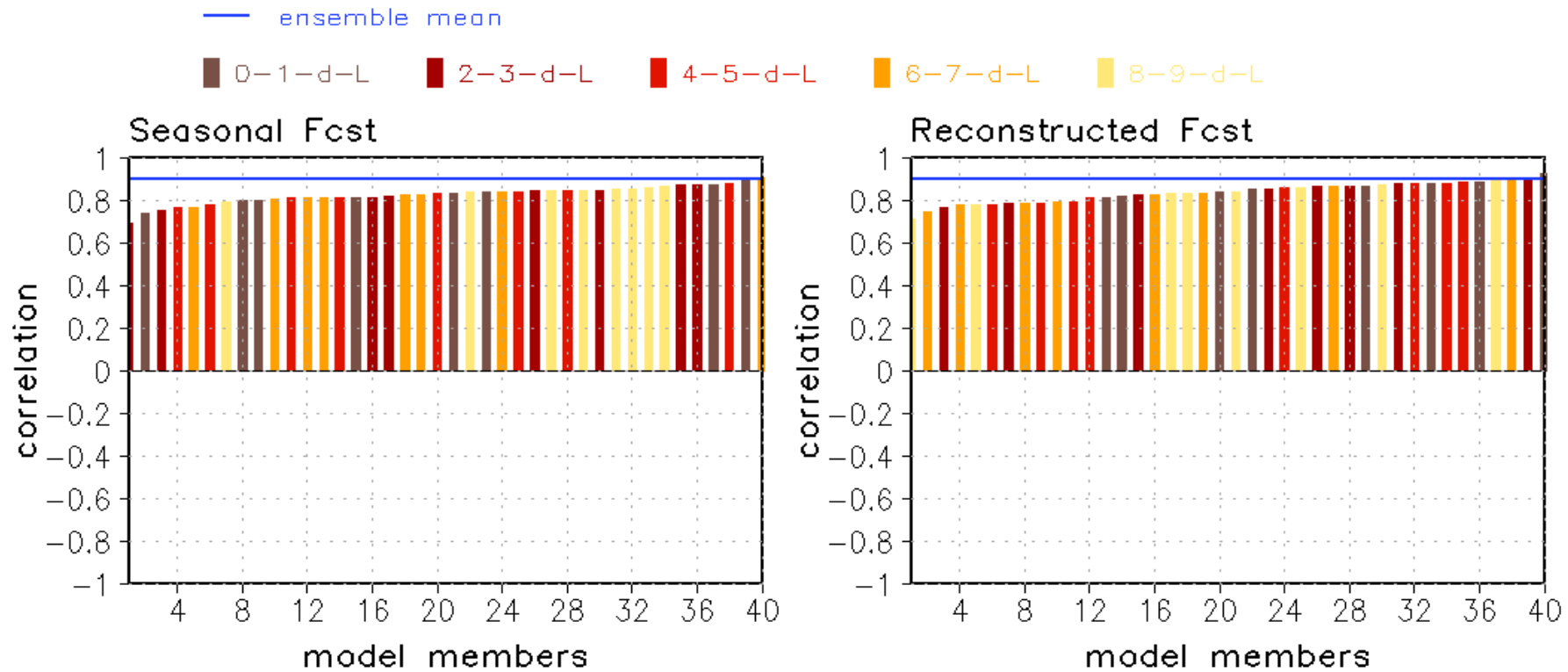


Observed & AMIP Ensemble Mean Anomalies

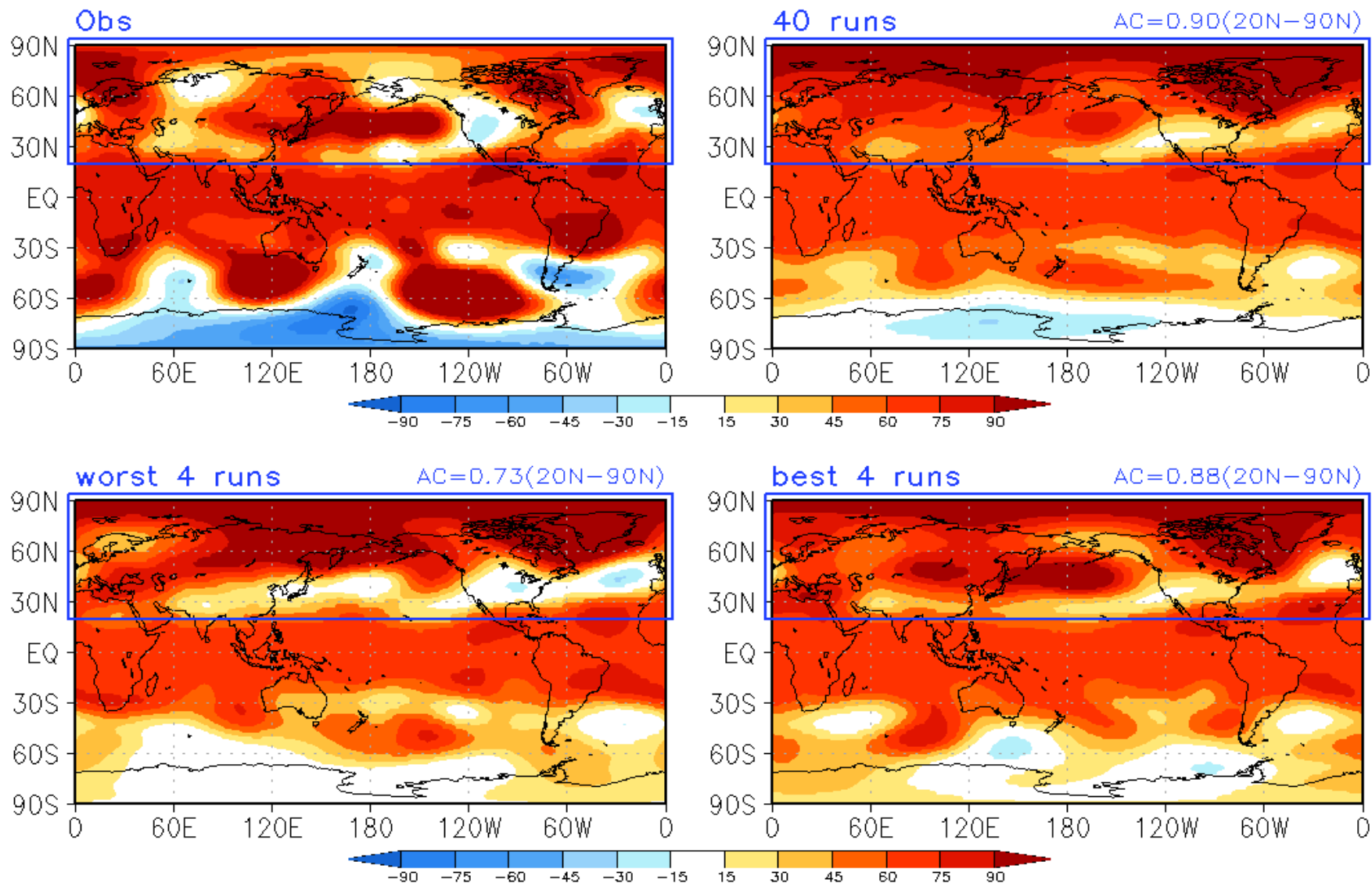
MAM2024 z200(m) 100 runs/worst 4 runs/best 4 runs



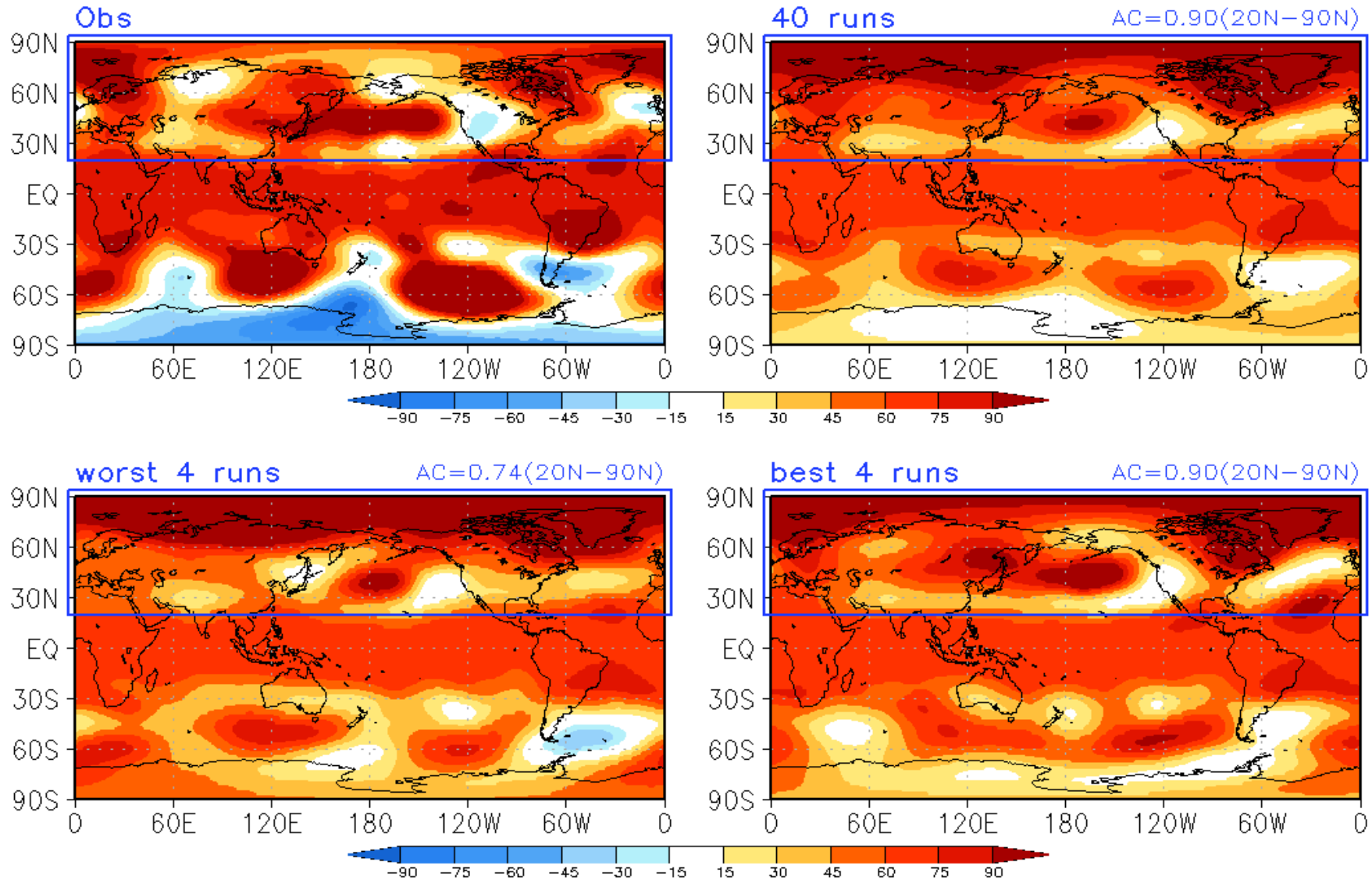
MAM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



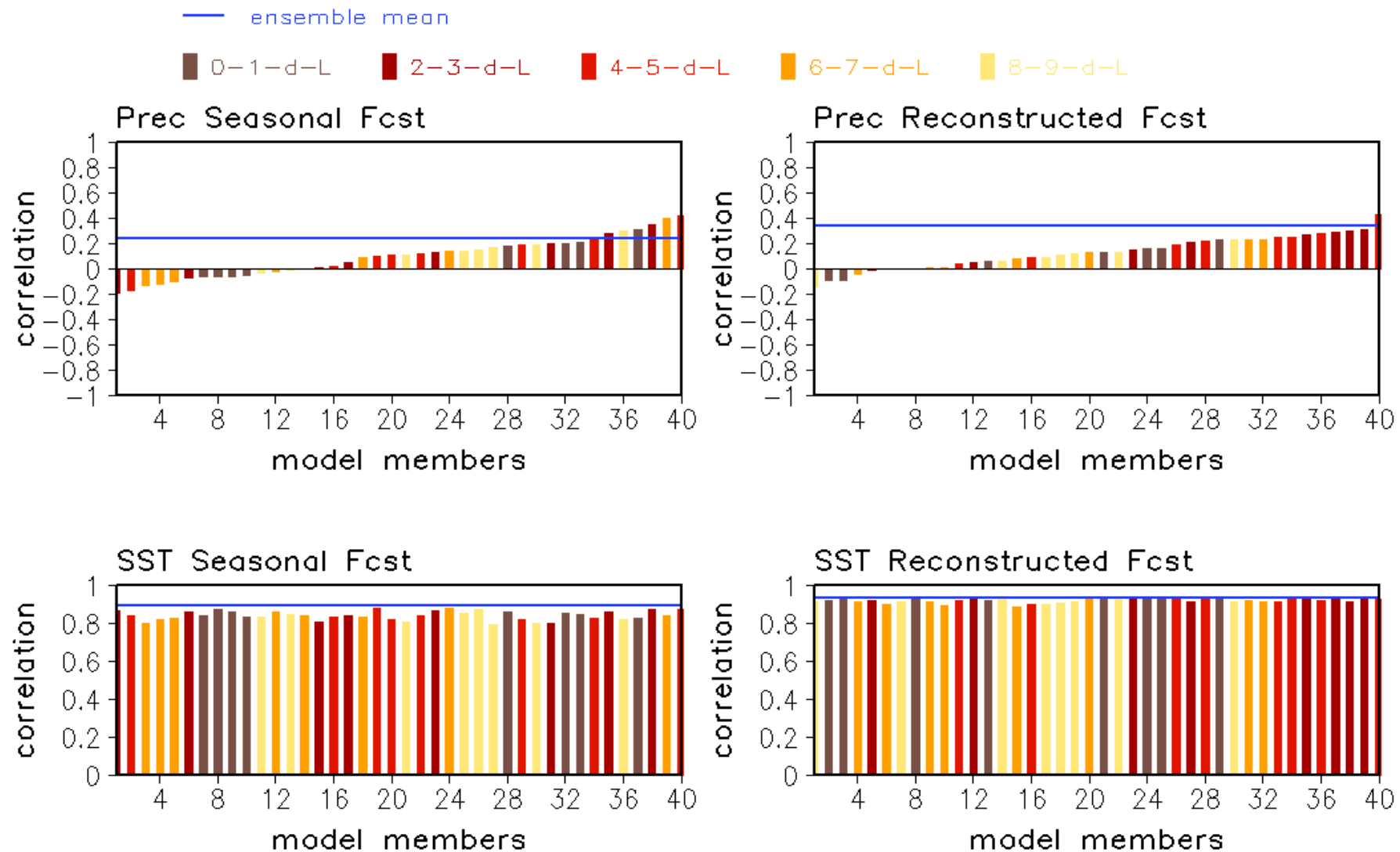
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



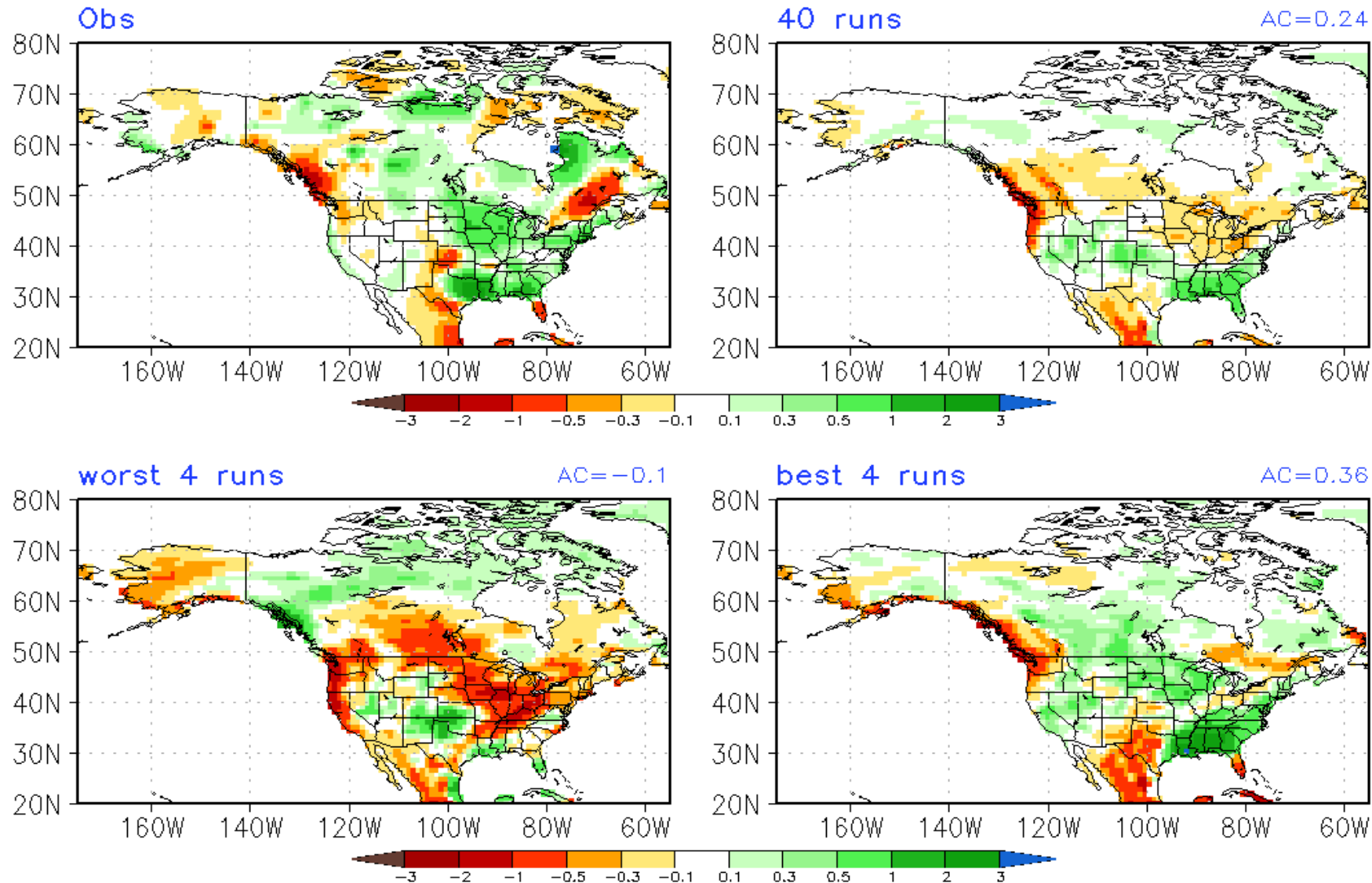
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



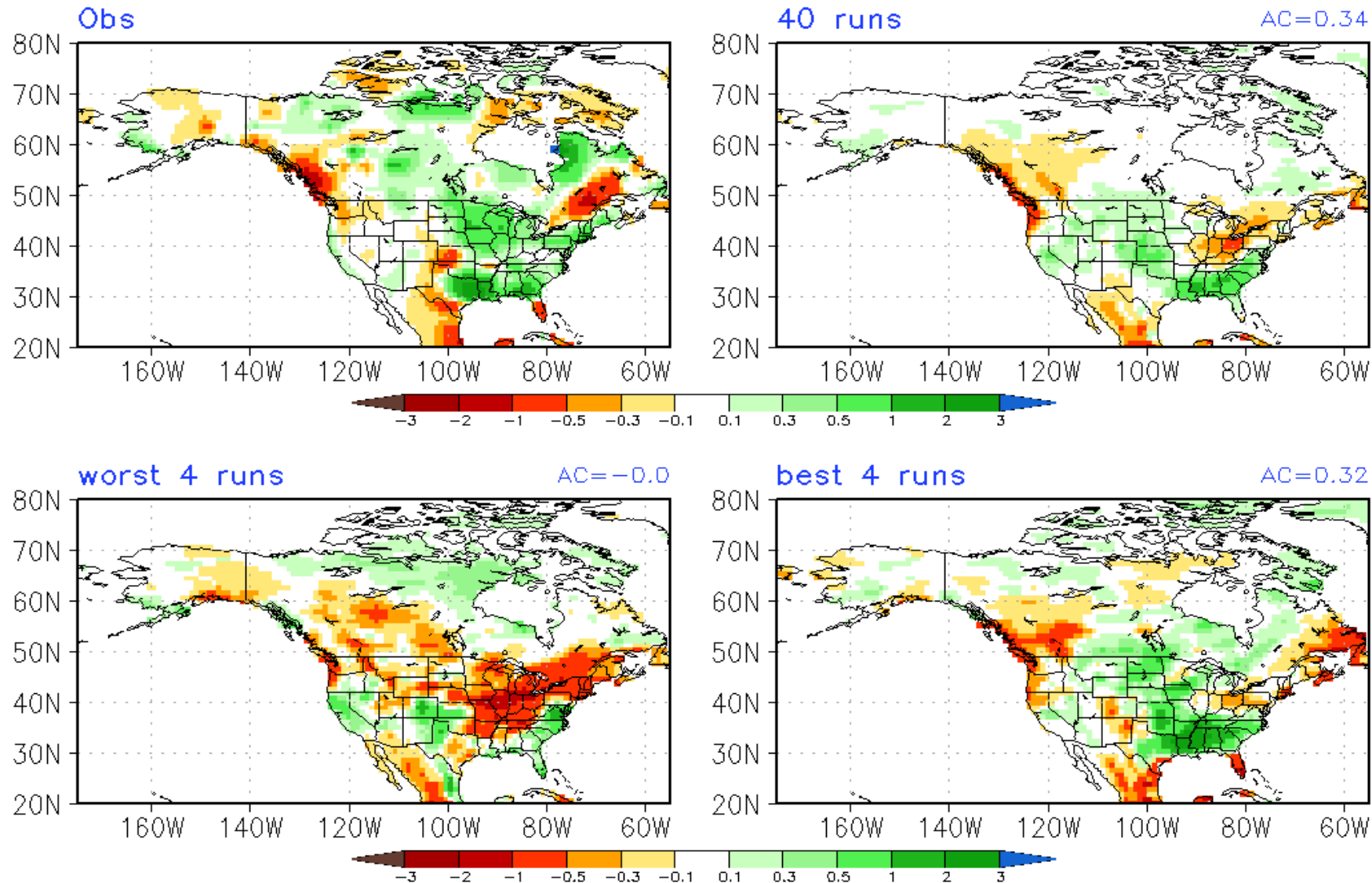
MAM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



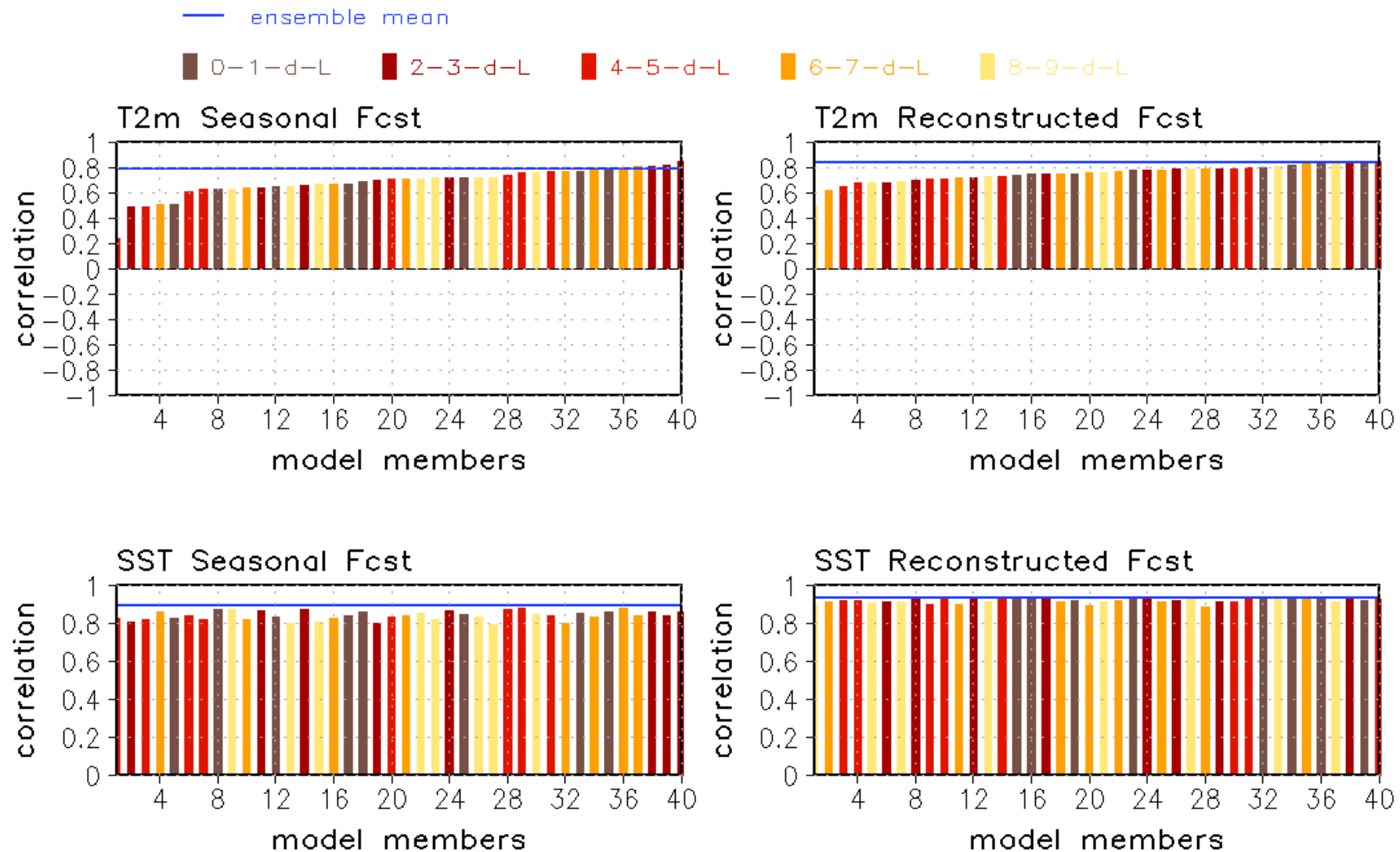
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



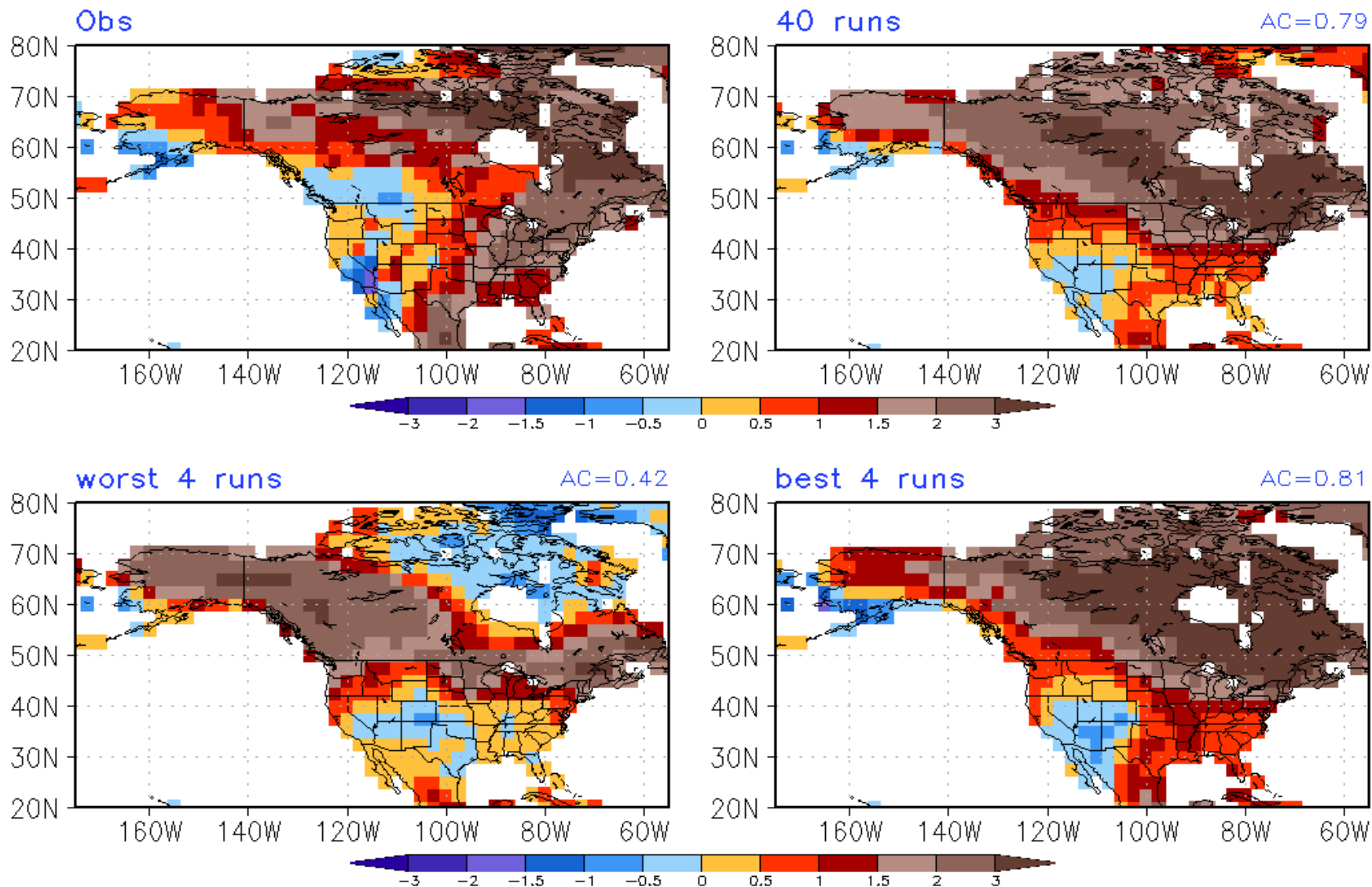
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



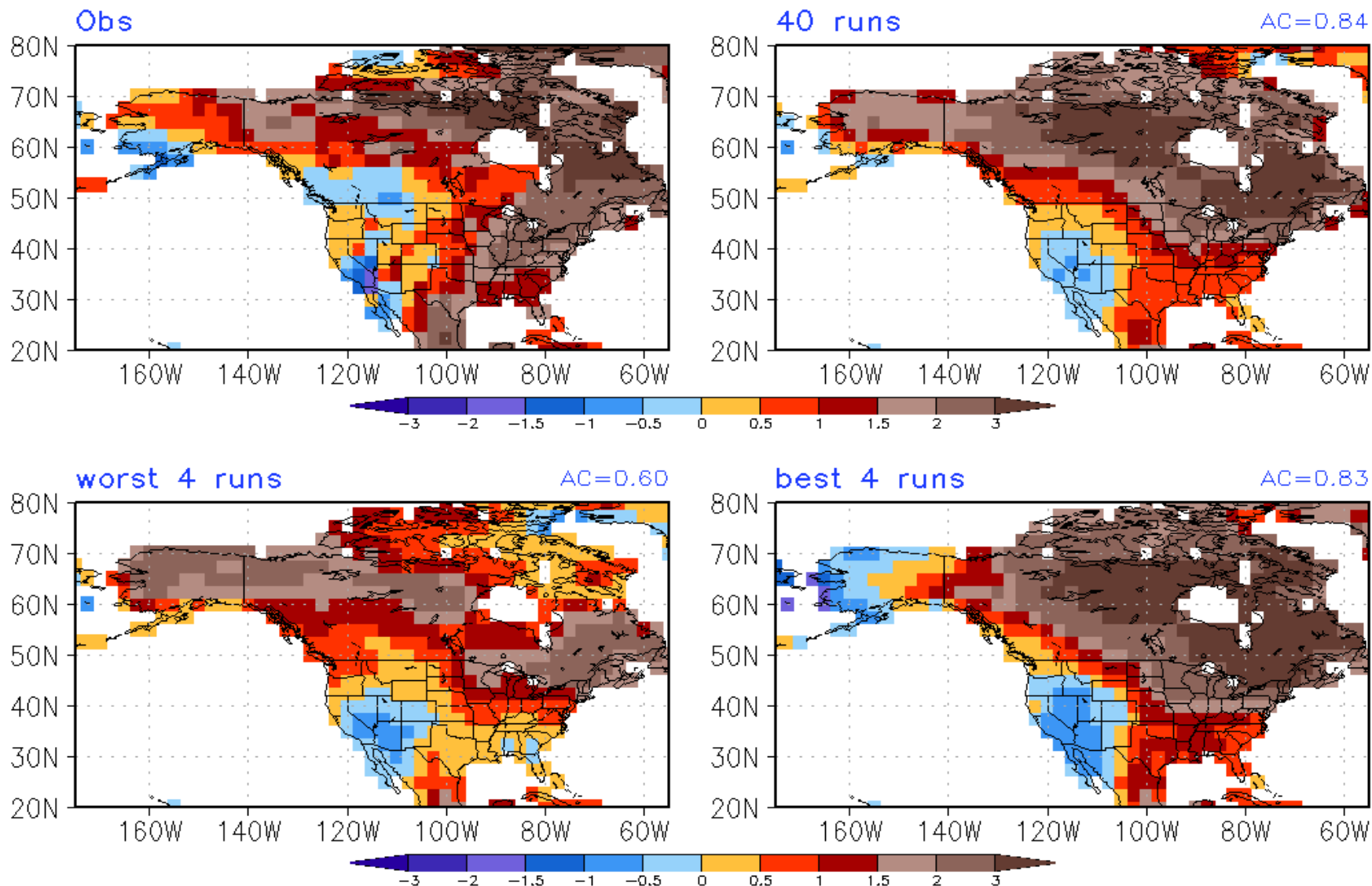
MAM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

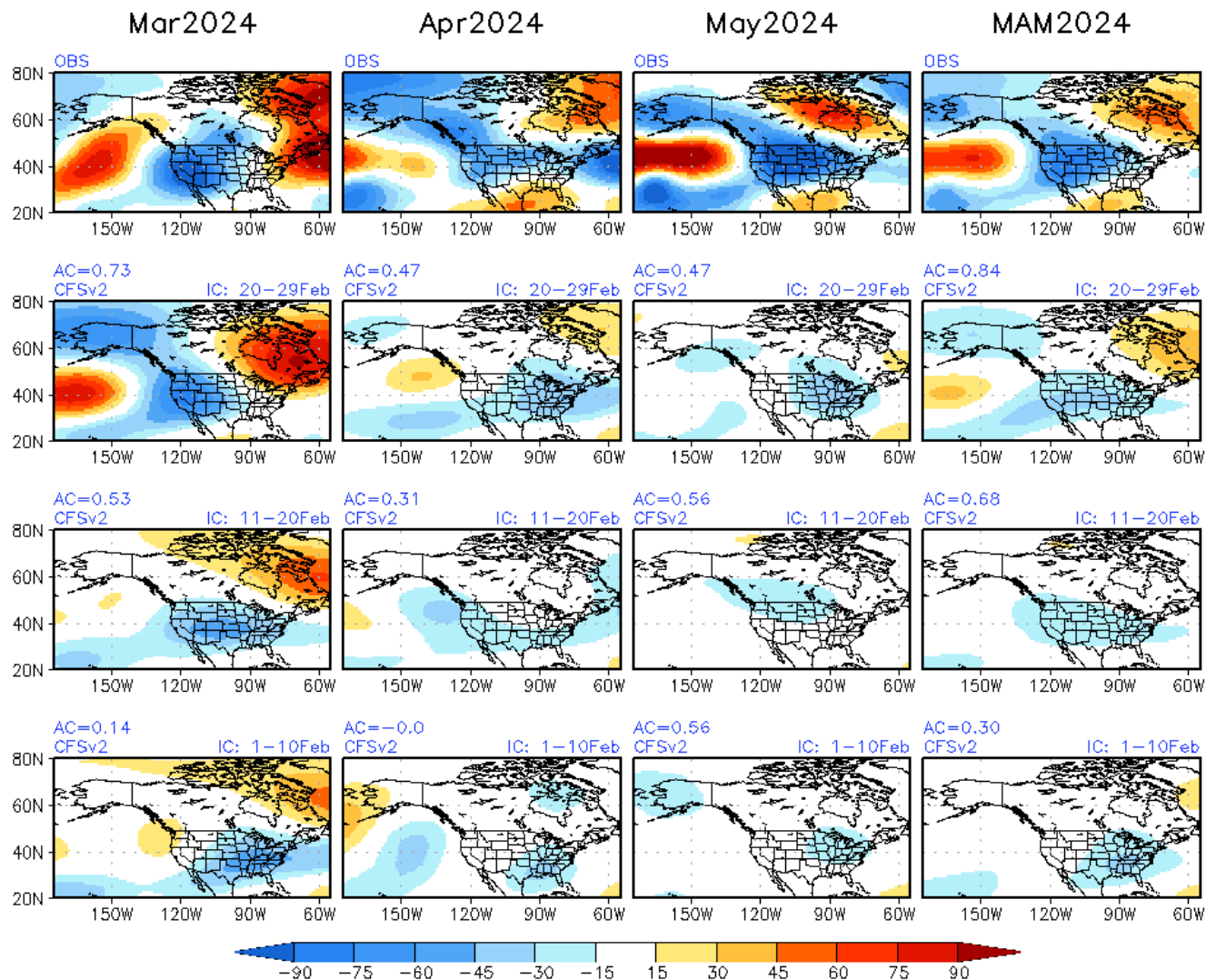


Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) MAM2024 z200(m) eddy & Obs



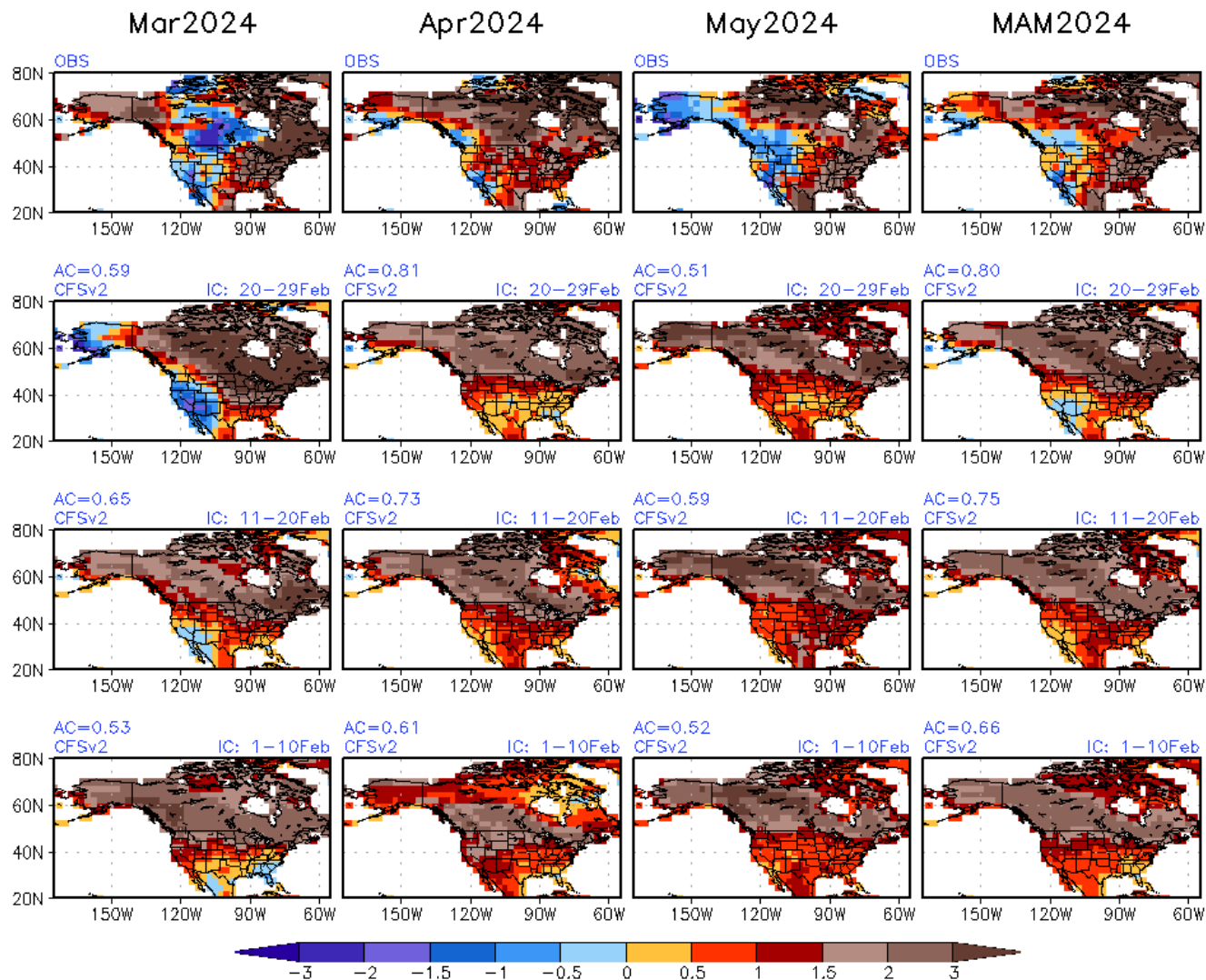
Top row: Observed anomaly.

CFSv2 seasonal forecasts from different initial conditions in the month prior to the target season:

- 2nd row: last 10 days of the prior month.
- 3rd row: 11th - 20th of the prior month.
- 4th row: 1st - 10th of the prior month.

T2m(k) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) MAM2024 T2m(K) & Obs



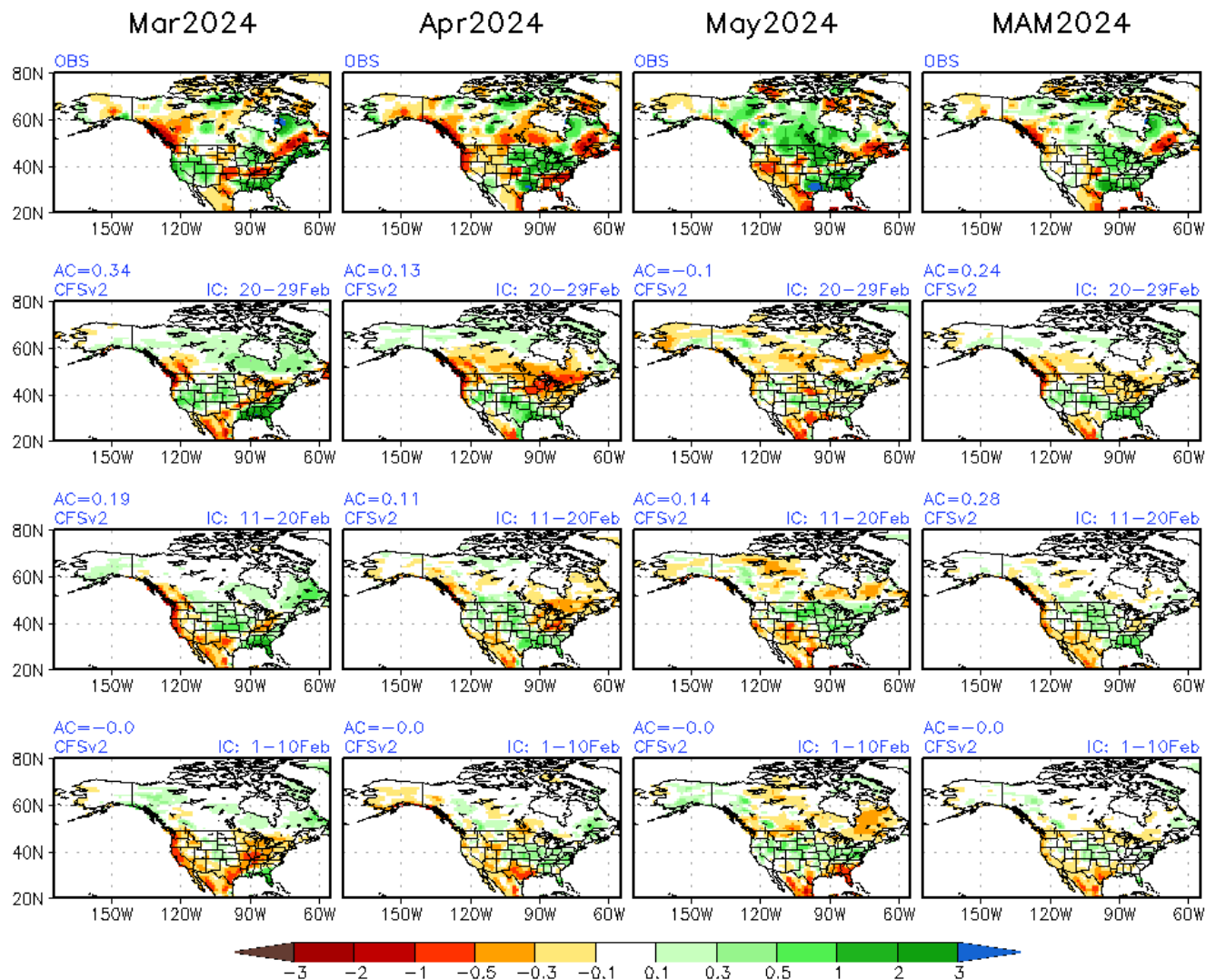
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Prec(mm/day) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) MAM2024 Prec(mm/day) & Obs



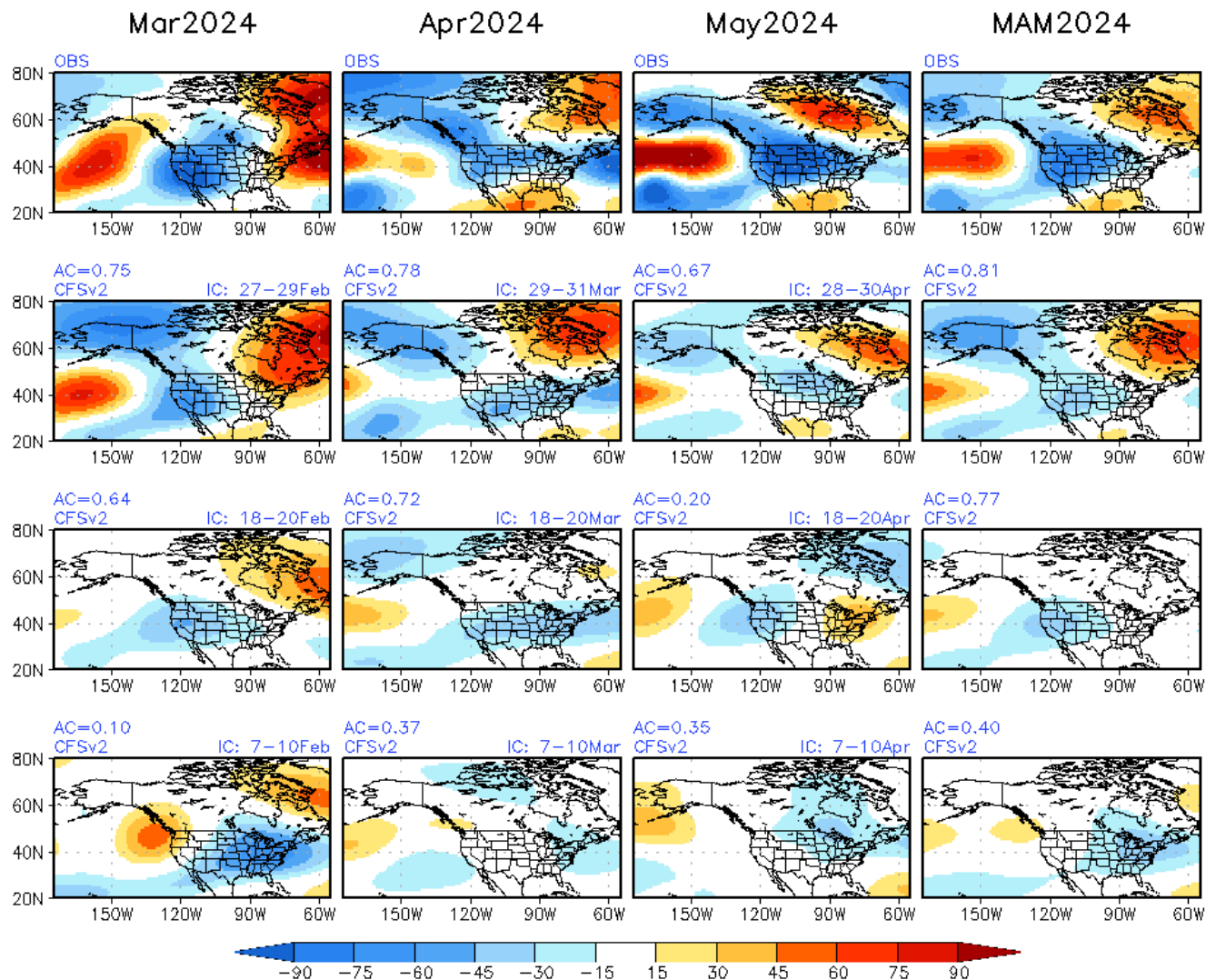
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z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst MAM2024 z200(m) eddy & Obs



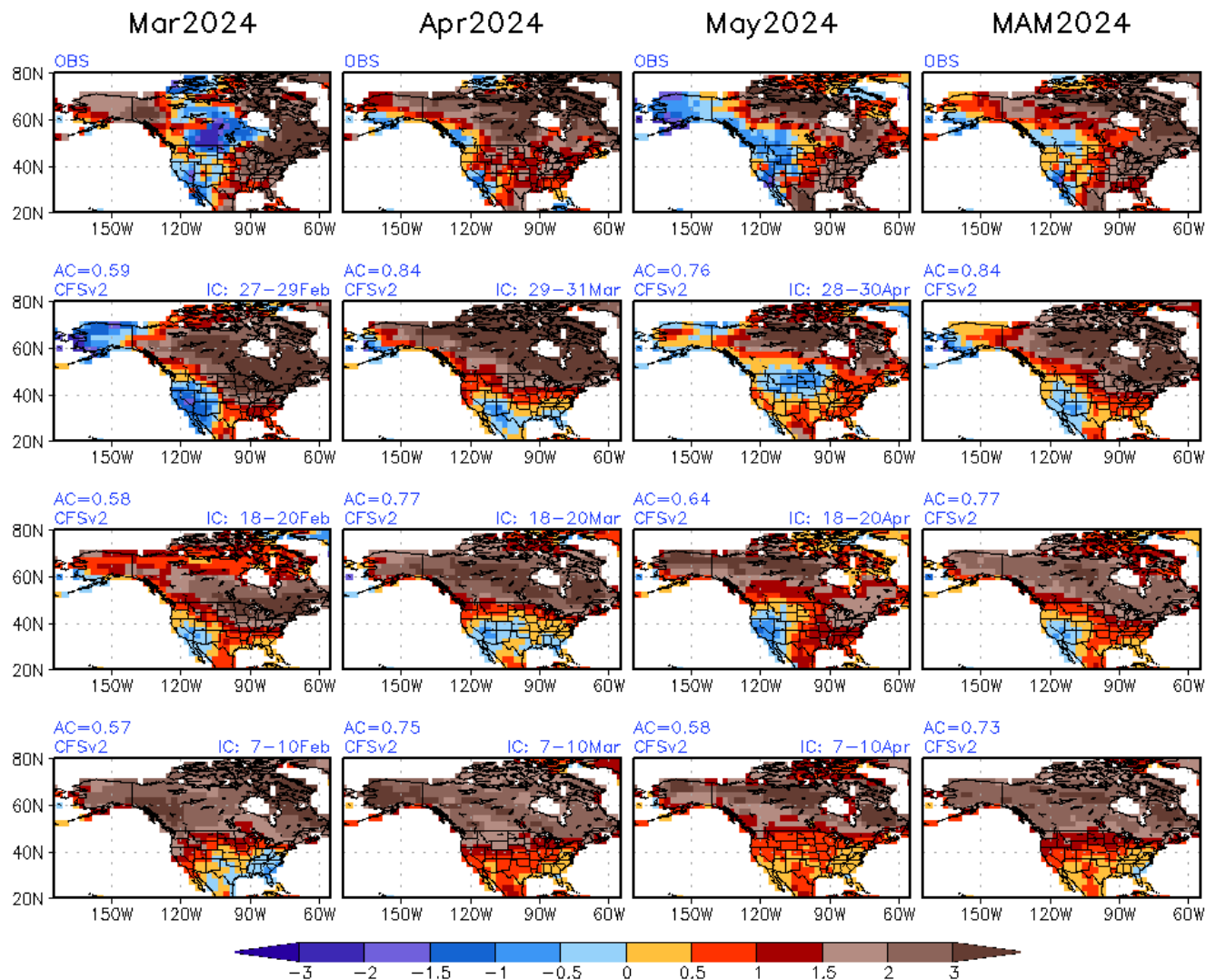
Top row: Observed anomaly.

CFSv2 monthly forecasts from different initial conditions in the month prior to the target month:

- 2nd row: last 3 days of the prior month.
- 3rd row: 18th – 20th of the prior month.
- 4th row: 7th – 10th of the prior month.

T2m(k) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst MAM2024 T2m(K) & Obs



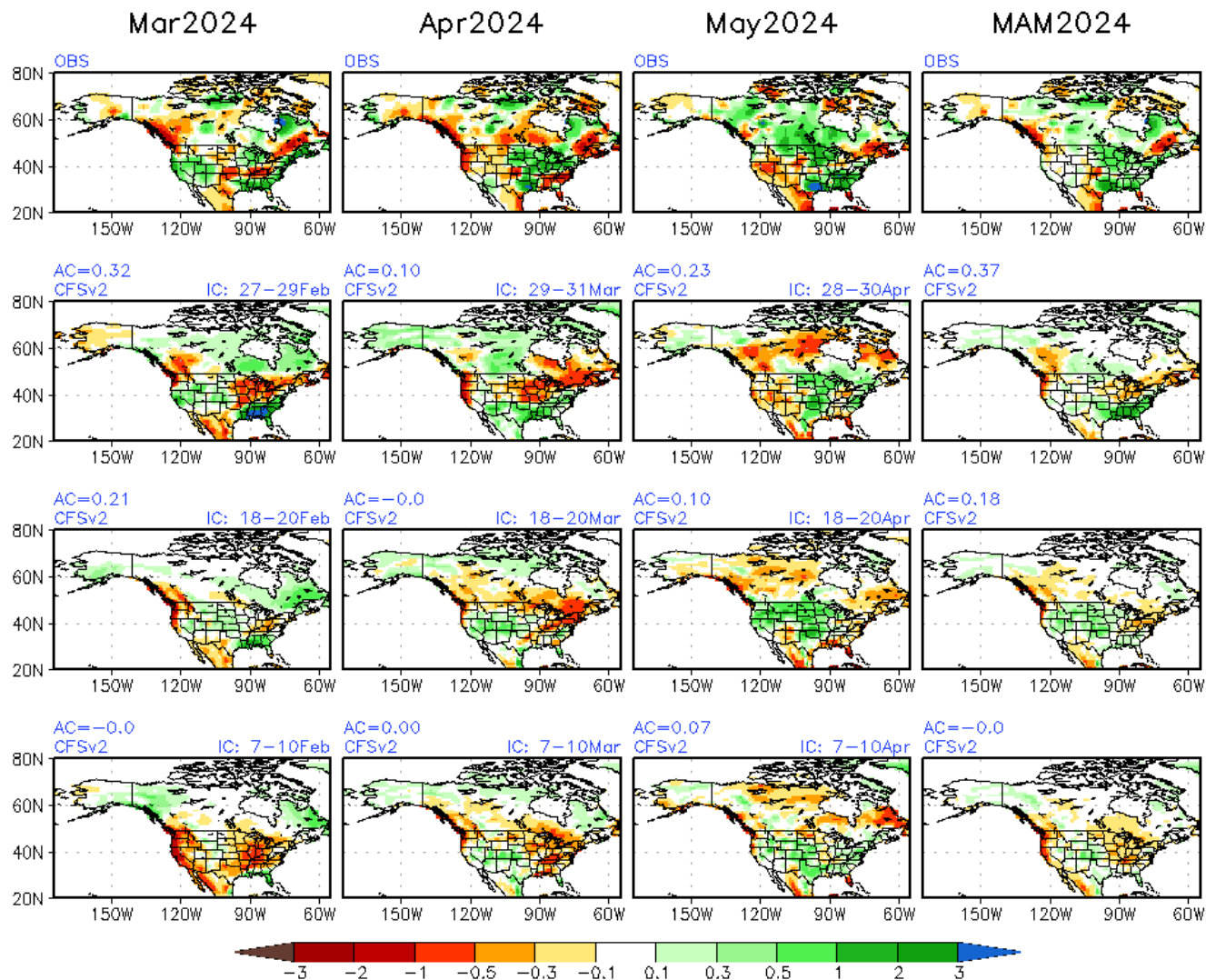
Top row: Observed anomaly.

CFSv2 monthly forecasts from different initial conditions in the month prior to the target month:

- 2nd row: last 3 days of the prior month.
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- 4th row: 7th – 10th of the prior month.

Prec(/mm/day) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst MAM2024 Prec(mm/day) & Obs



Top row: Observed anomaly.

CFSv2 monthly forecasts from different initial conditions in the month prior to the target month:

- 2nd row: last 3 days of the prior month.
- 3rd row: 18th – 20th of the prior month.
- 4th row: 7th – 10th of the prior month.

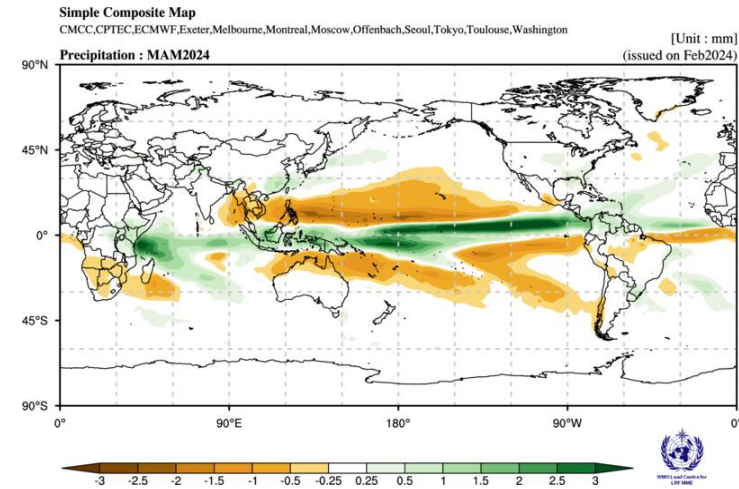
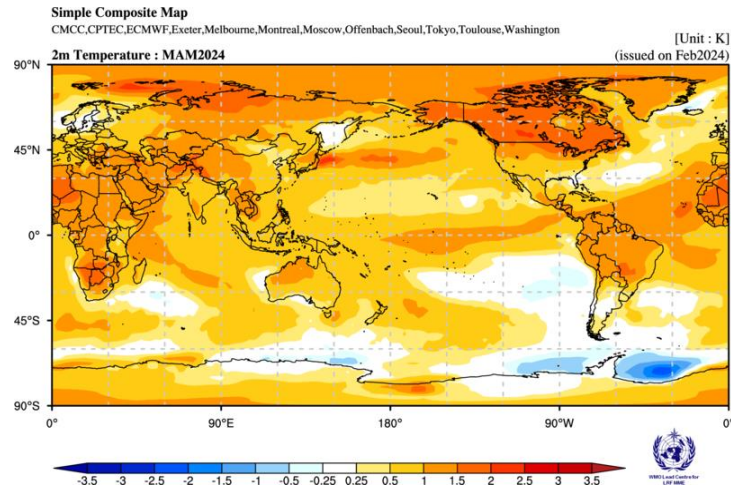
Seasonal Forecasts from Multi-Model Ensemble Systems

- WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME).
<https://www.wmolc.org/>
- Copernicus Climate Change Service (C3S) Multi-model seasonal forecasts.
https://climate.copernicus.eu/charts/c3s_seasonal/
- North American Multi-Model Ensemble (NMME) seasonal forecasts.
<https://www.cpc.ncep.noaa.gov/products/NMME/>

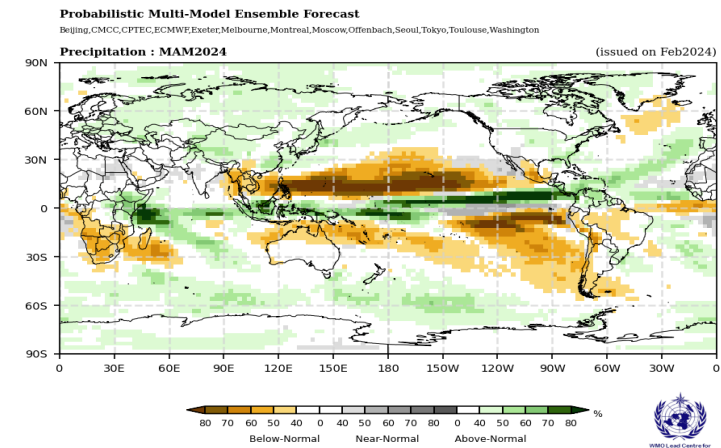
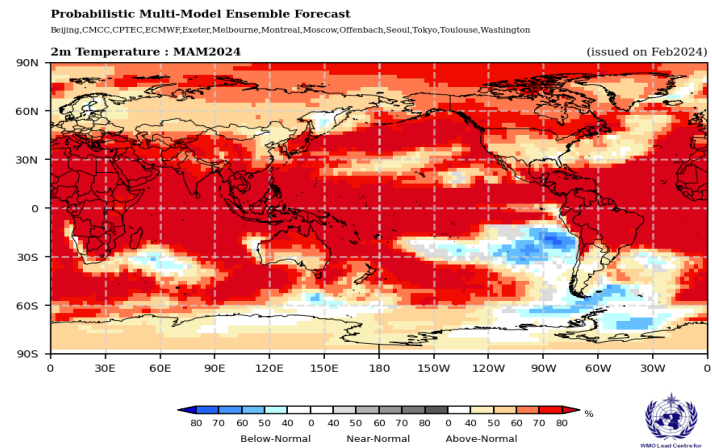
LC-LRFMM Seasonal Forecasts

(<https://www.wmolc.org/>)

Ensemble means



Probabilities

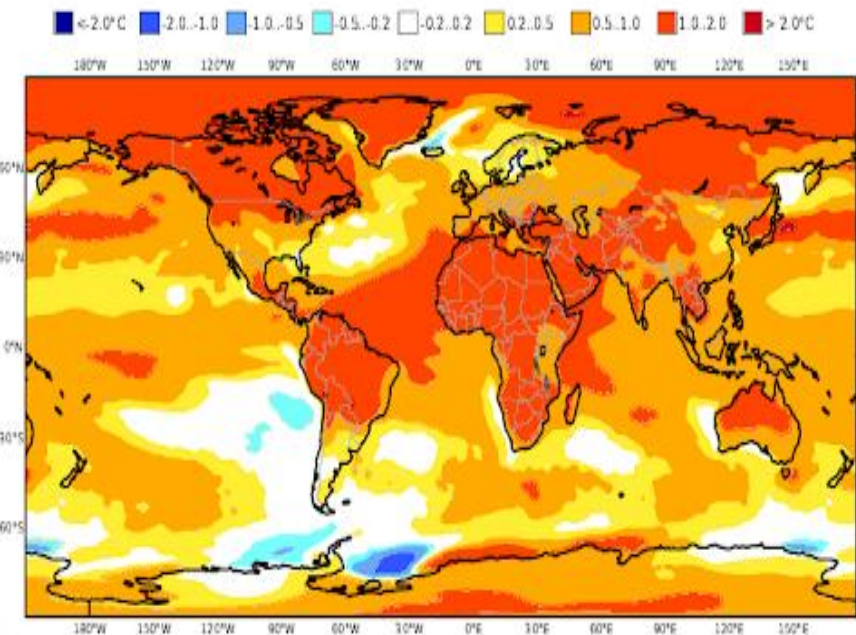


C3S Seasonal Forecast

(https://climate.copernicus.eu/charts/c3s_seasonal/)

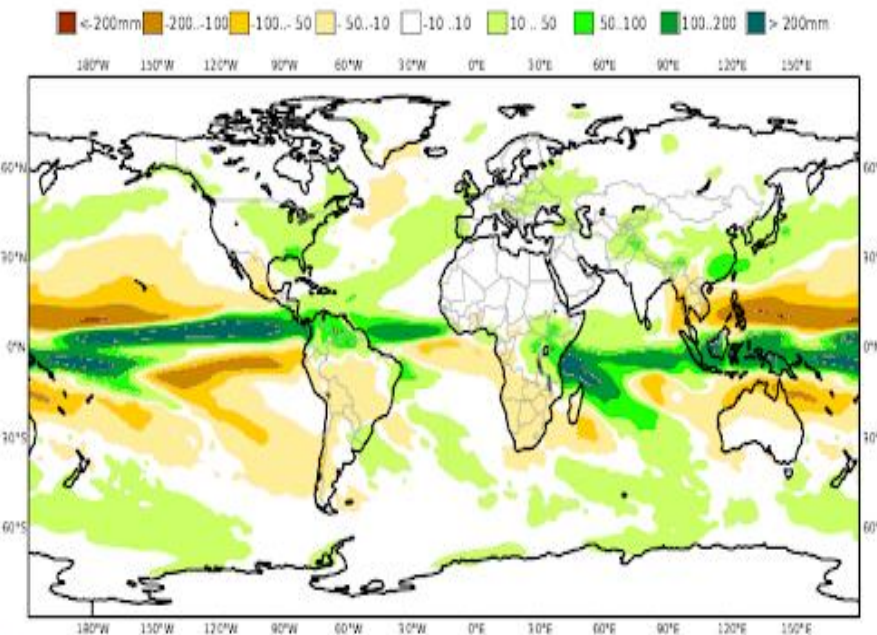
C3S multi-system seasonal forecast
Mean 2m temperature anomaly
MAM 2024

Nominal forecast start: 01/02/24
Variance-standardized mean



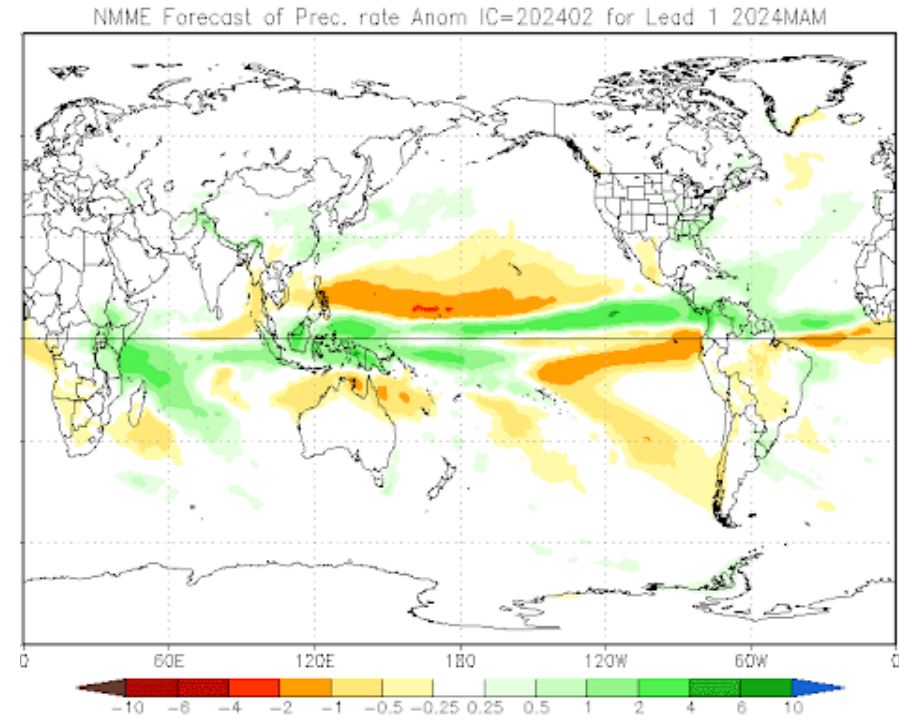
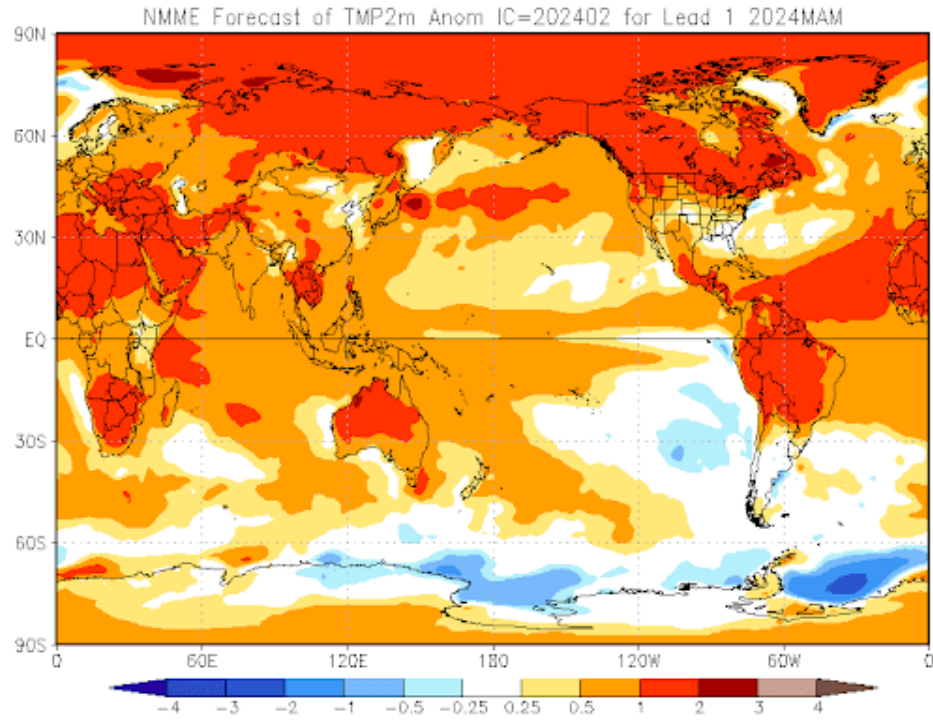
C3S multi-system seasonal forecast
Mean precipitation anomaly
MAM 2024

Nominal forecast start: 01/02/24
Variance-standardized mean



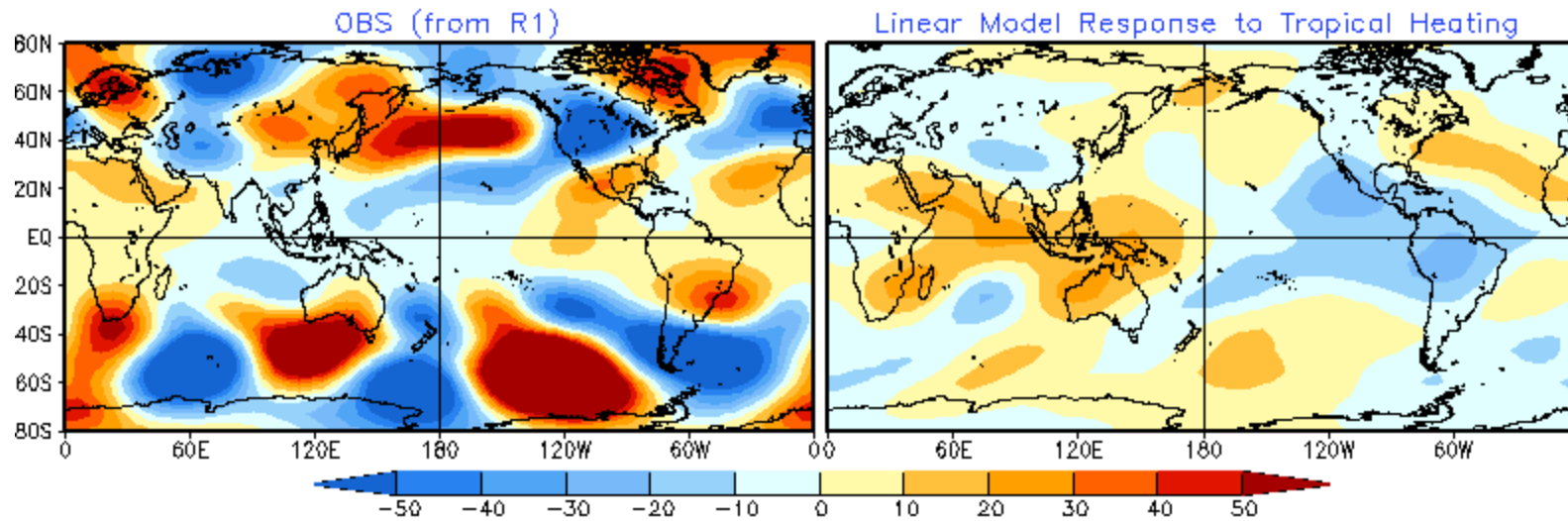
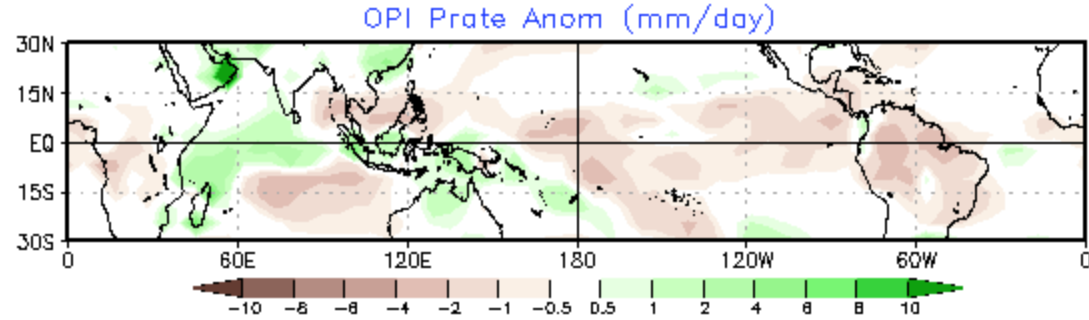
North American Multi-Model Ensemble Seasonal Forecast

(<https://www.cpc.ncep.noaa.gov/products/NMME/>)



200mb Height from Linear Model

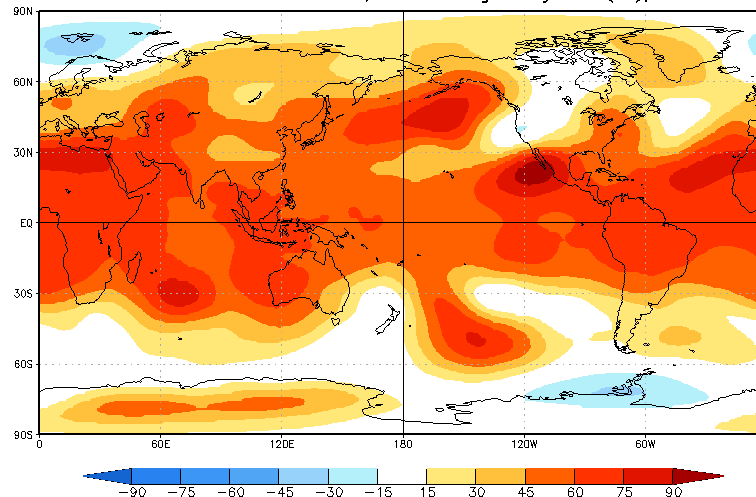
MAM2024 200mb Eddy HGT(m)
OBS vs. Linear Model Response to Tropical Heating
Heating is converted from Prate in 15S-15N



Pattern COR: global=0.06, tropics(30S-30N)=-0.10

Seasonal Forecasts from the Constructed Analog Model

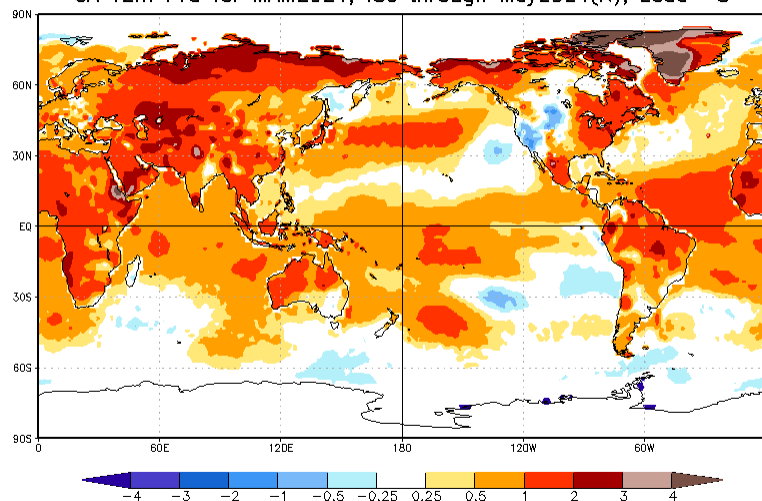
CA HGT200 Prd for MAM2024, ICs through May2024(m), Lead -3



Peitao Peng CPC/NCEP/NWS/NOAA

Base Period 1991-2020

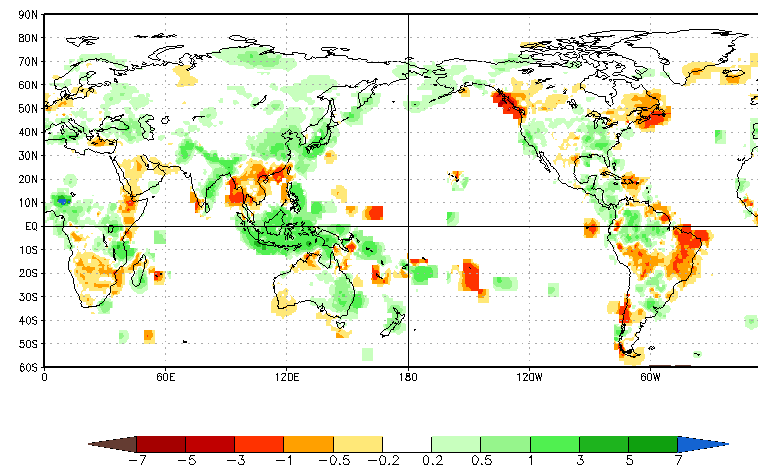
CA T2m Prd for MAM2024, ICs through May2024(K), Lead -3



Peitao Peng CPC/NCEP/NWS/NOAA

Base Period 1991-2020

CA Prec Prd for MAM2024, ICs through May2024(mm/day), Lead -3



Peitao Peng CPC/NCEP/NWS/NOAA

Base Period 1991-2020

Background & Methodology

Attribution of Seasonal Climate Anomalies

- Goal
 - In the context of prediction of seasonal climate variability, utilize seasonal climate forecasts and atmospheric general circulation model (AGCM) simulations to attribute possible causes for the observed seasonal climate anomalies.
 - The analysis can also be considered as an analysis of predictability of the observed seasonal climate anomalies.

Methodology - 1

- Compare observed seasonal mean anomalies with those from model simulations and forecasts.
- Ensemble averaged model simulated/predicted seasonal mean anomalies are an indication of the predictable (or attributable) component of the corresponding observed anomalies.
- For seasonal mean atmospheric anomalies, predictability could be due to
 - Anomalous boundary forcings [e.g., sea surface temperature (SSTs); soil moisture etc.];
 - Atmospheric initial conditions.
- The influence of anomalous boundary forcings (particularly due to SSTs, can be inferred from the ensemble mean of AGCM simulations forced by observed SSTs, the so called AMIP simulations). This component of predictability (or attributability) is more relevant for longer lead seasonal forecasts.

Methodology - 2

- The influence of the atmospheric initial state can be inferred from initialized predictions. This component is more relevant for short lead seasonal forecasts.
- The influence of unpredictable component in the atmospheric variability can be assessed from the analysis of individual model simulations, and the extent anomalies in individual runs deviate from the ensemble mean anomalies.
- The relative amplitude of ensemble averaged seasonal mean anomalies to the deviations of seasonal mean anomalies in the individual model runs from the ensemble average is a measure of seasonal predictability (or the extent observed anomalies are attributable).
- Observed anomalies are equivalent to a realization of a single model run, and therefore, analysis of individual model runs also gives an appreciation of how much observed anomalies can deviate from the component that is attributable (Kumar et al. 2013).

Data

- Observations
 - SST: OI version 2 analysis (Reynolds et al., 2007)
 - Prec: CMAP monthly analysis (Xie and Arkin, 1997)
 - T2m: GHCN-CAMS land surface temperature monthly analysis (Fan and van den Dool, 2008)
 - 200mb height (z200): CFSR (Saha et al., 2010)
- 0-month-lead seasonal mean forecasts from CFSv2 (Saha et al. 2014)
 - Seasonal forecast: the seasonal mean forecasts based on 40 members from the latest 10 days before the target season (0-month-lead);
 - Reconstructed forecast: the seasonal mean forecasts constructed from 3 individual monthly forecasts with the latest 10 days initial conditions for each individual monthly forecasts. This approach for constructing seasonal mean anomalies has more influence from the initial conditions (Kumar et al. 2013);
- Seasonal mean AMIP simulation based on GFS_FV3 (provided by Dr. Tao Zhang/CPC)
 - 100 members
- All above seasonal mean anomalies are based on 1991-2020 climatology.
- z200 responses to tropical heating in linear model.
- Seasonal mean anomalies of z200, T2m, and Prec forecasted from the Constructed Analog Model.