Attribution of Seasonal Climate Anomalies
February-March-April 2023

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

Summary of Observed Conditions and Outlooks

- The central equatorial Pacific SST anomalies were near normal and were located in between above normal SSTs to the east near the coastal regions of South America and to the west near the Maritime continent. The east-west SST gradient may be the reason for the below normal rainfall near the dateline. Over the other ocean basins, e.g., North Pacific, western Pacific, South Pacific and Atlantic ocean, SST anomalies were above normal (slide 4). The CFSv2 predicted the SST anomalies colder than the observation over the central equatorial Pacific and missed the observed warm anomalies over the far eastern Pacific along the South American coastal area (slide 10);

- The precipitation anomalies in tropical latitudes in the observation, the AMIP simulations and initialized CFSv2, and other MME forecasts continued in the spatial pattern consistent with responses to La Niña conditions, including above normal anomalies in the equatorial eastern Indian Ocean, Maritime Continent and dry conditions in the equatorial western, central Pacific Ocean (slides 11, 37-39).

- Both AMIP and the initialized CFSv2 predicted the large-scale distribution of observed 200mb height anomalies in tropics, however, missed the negative anomalies over northwest of North America. The erroneous prediction of height anomalies led to failed prediction of the observed cold temperature anomalies over the regions of Alaska, California, and the southwest US (slides 12,13,15,16).

- The spatial pattern of forecast North America precipitation anomalies in the AMIP simulations and the initialized CFSv2 and NMME forecasts were consistent with the La Niña composite. The observed anomalies over the most of US regions, however, differed from the La Niña composite (slides 7, 14).

- April 2023 monthly mean forecasts from the shortest leads didn't show improvements for predicting North America temperature and precipitation (slides 34,35).
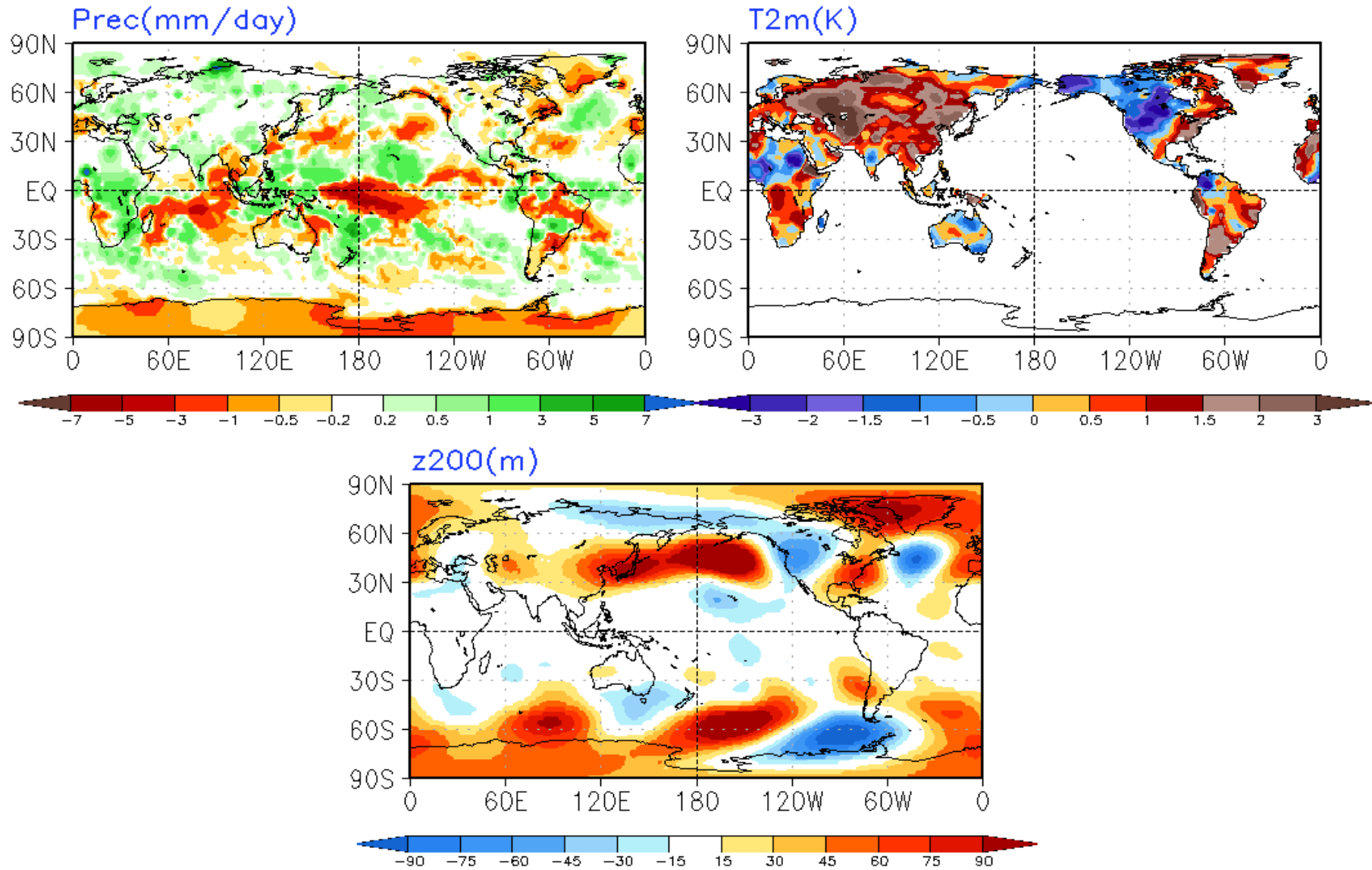
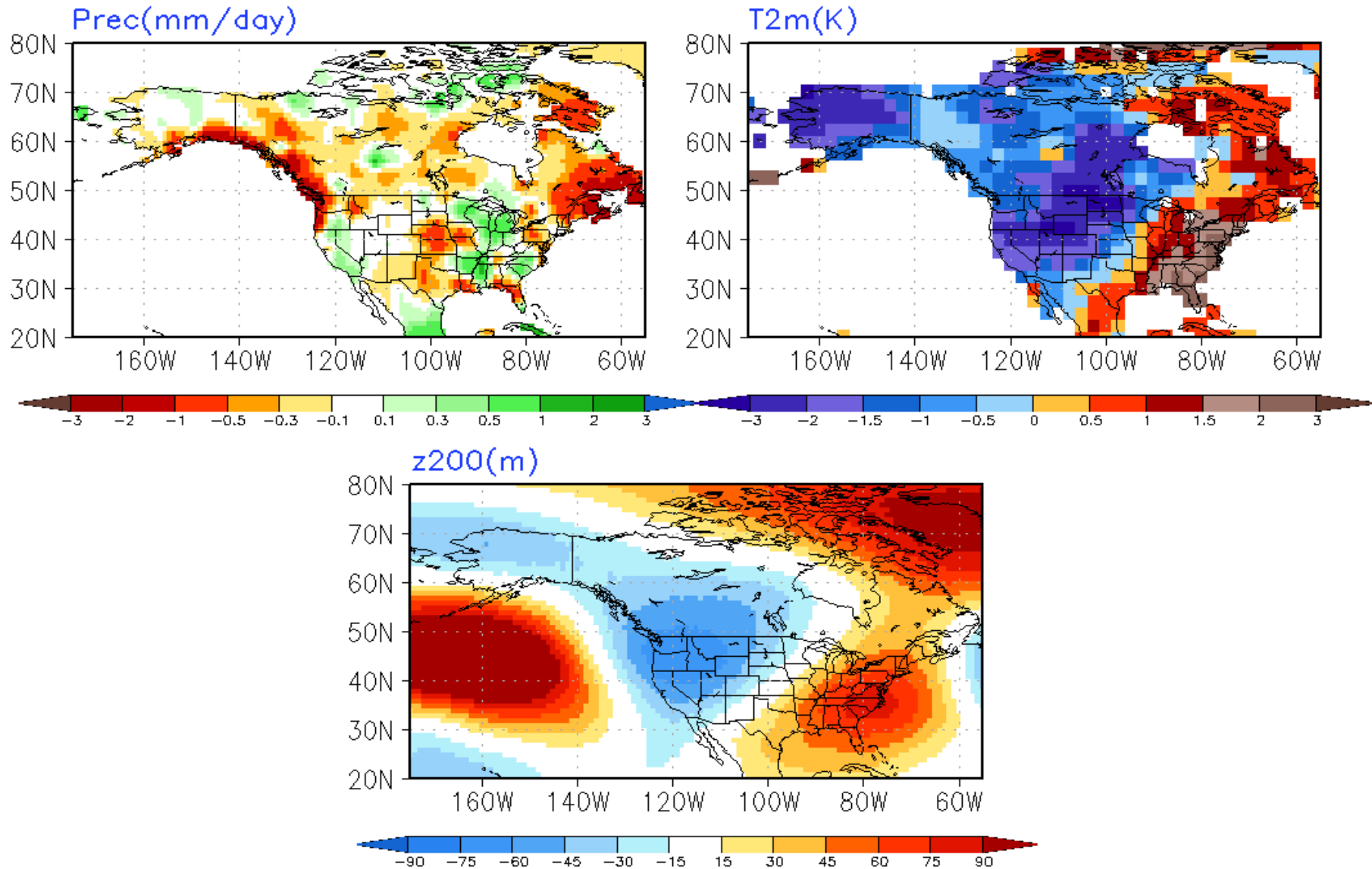Observed Seasonal Anomalies

Global and North America

Observed Anomaly FMA2023
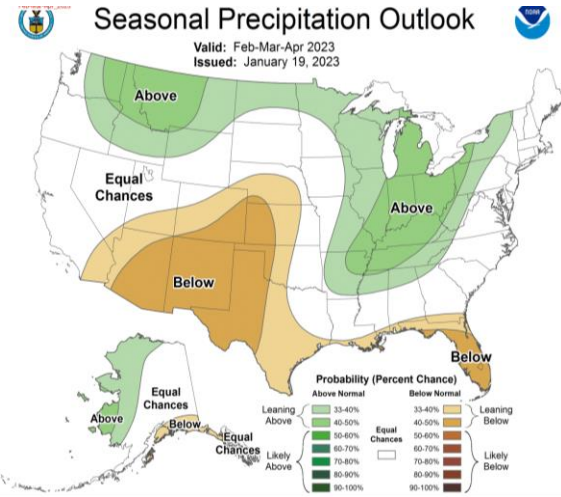

SST(K)

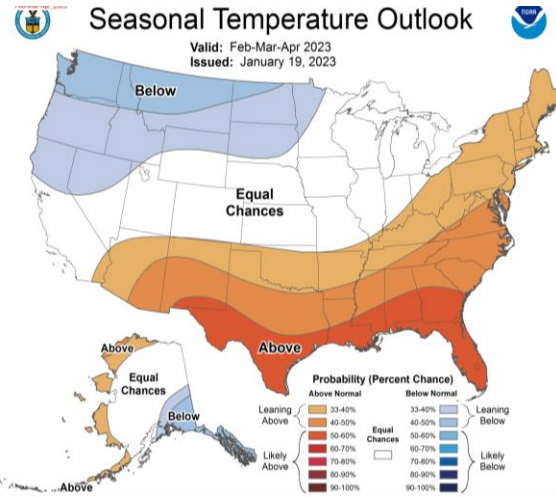# Observed Anomaly FMA2023

Prec(mm/day)

T2m(K)

z200(m)
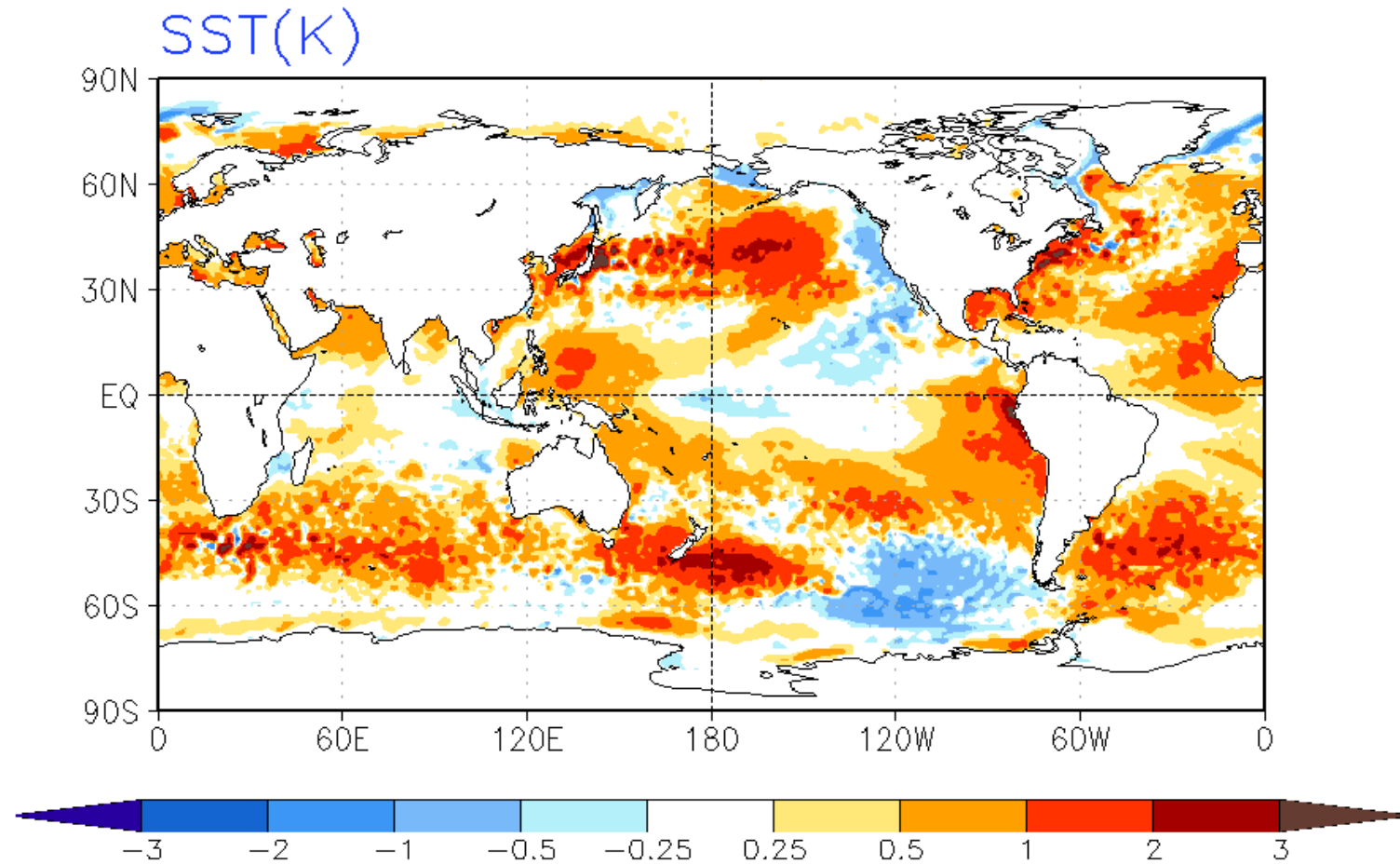
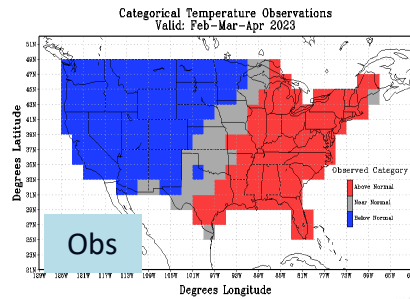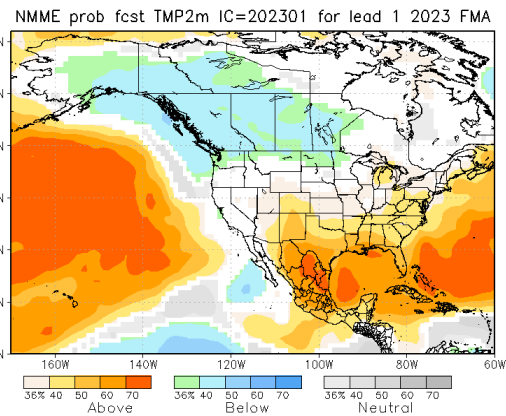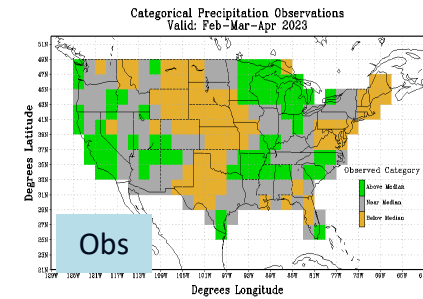# Observed Anomaly FMA2023

CPC Seasonal Outlooks and NMME Forecasts
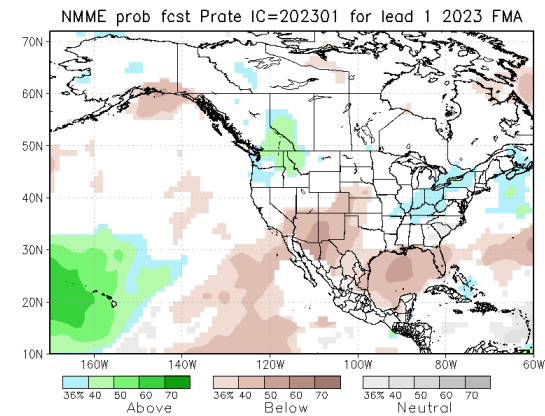
CPC

Temp nonEC
HSS=69

Prec nonEC
HSS=14

NMME

For the rationale behind CPC outlooks see: https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2023/202301_PMD90D
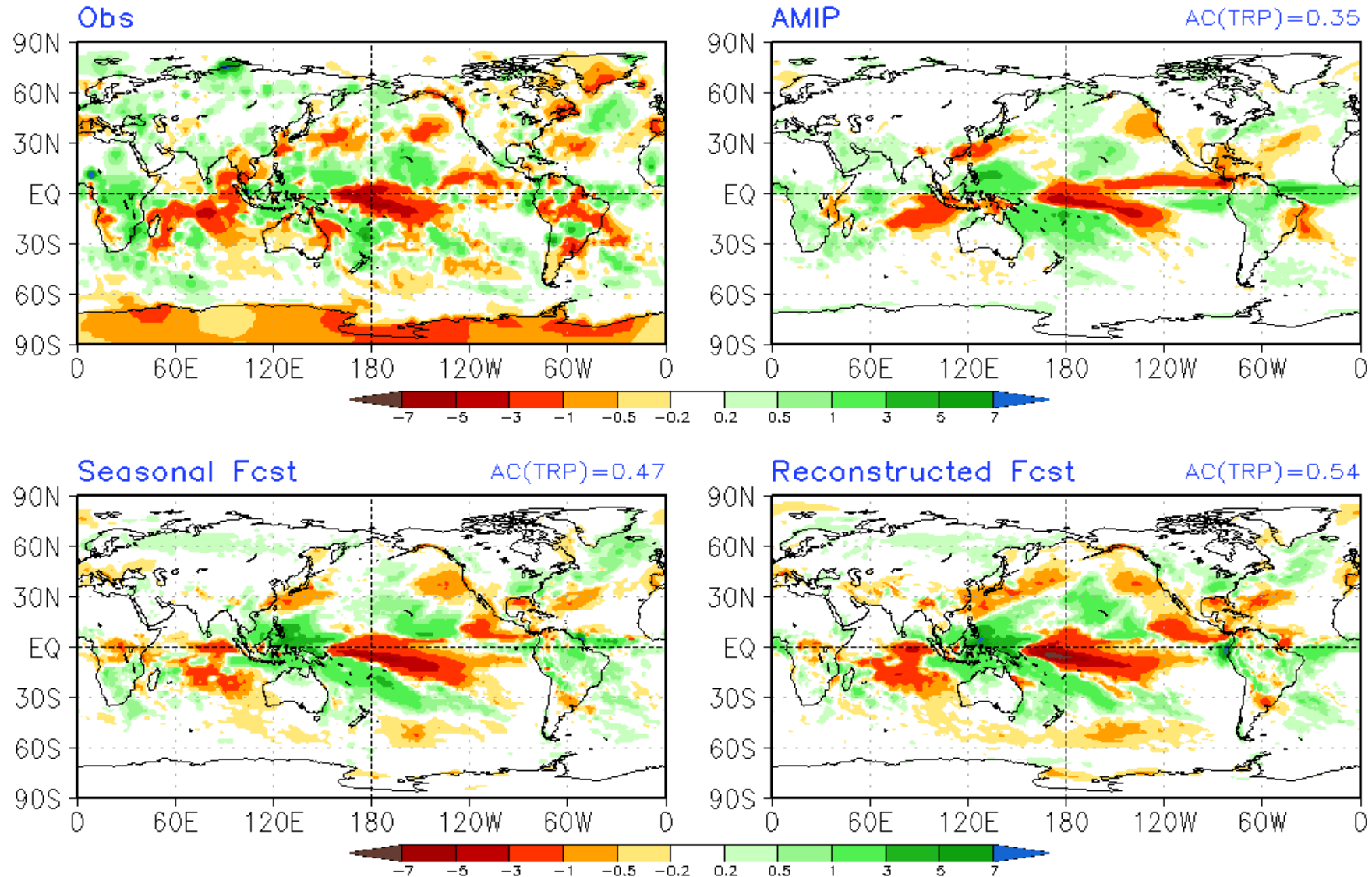
Model Simulated/Forecast Ensemble Mean Anomalies

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 fr 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.

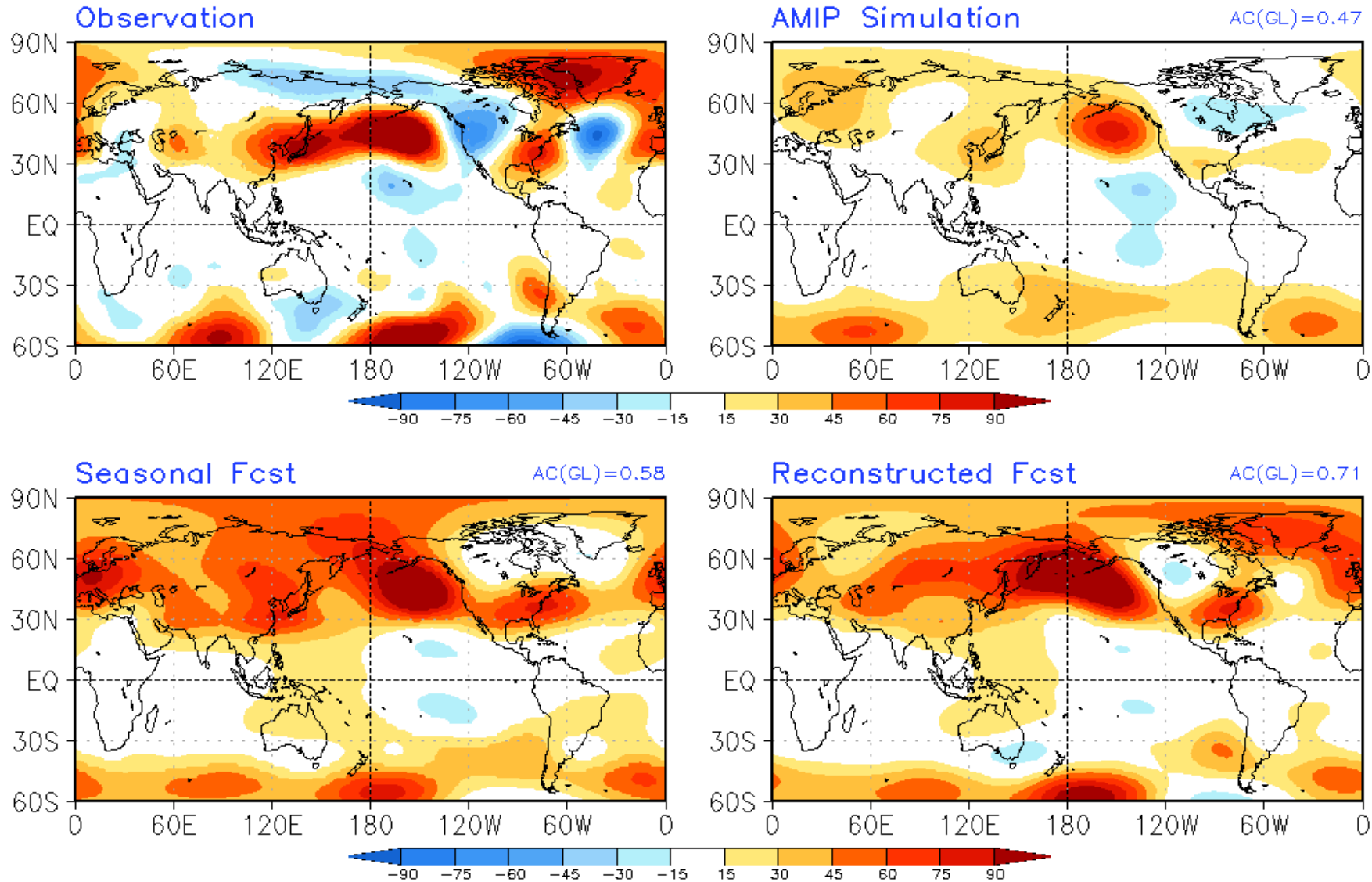- Numbers at the panels indicate the spatial anomaly correlation (AC).

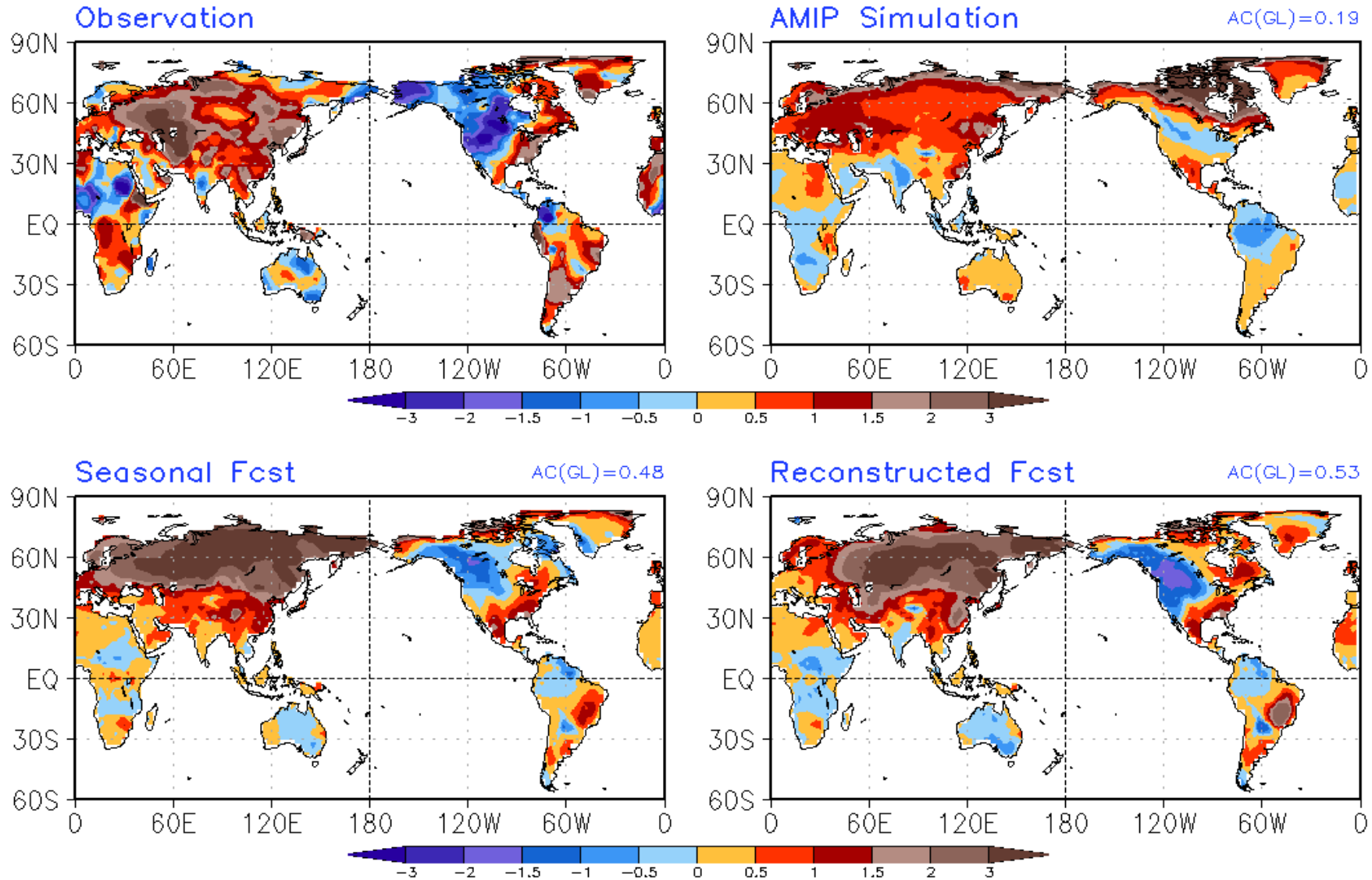# FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)
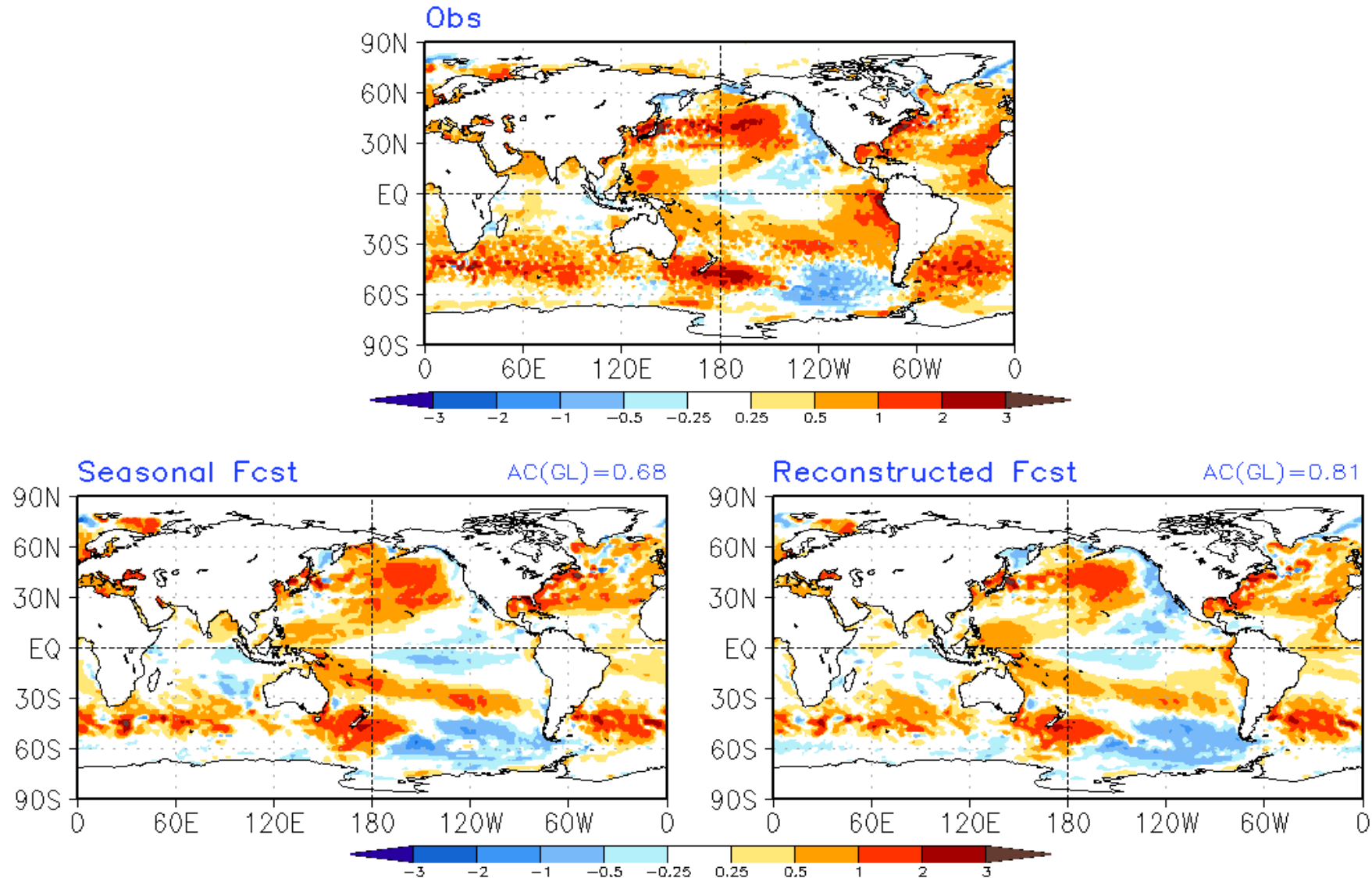
FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)
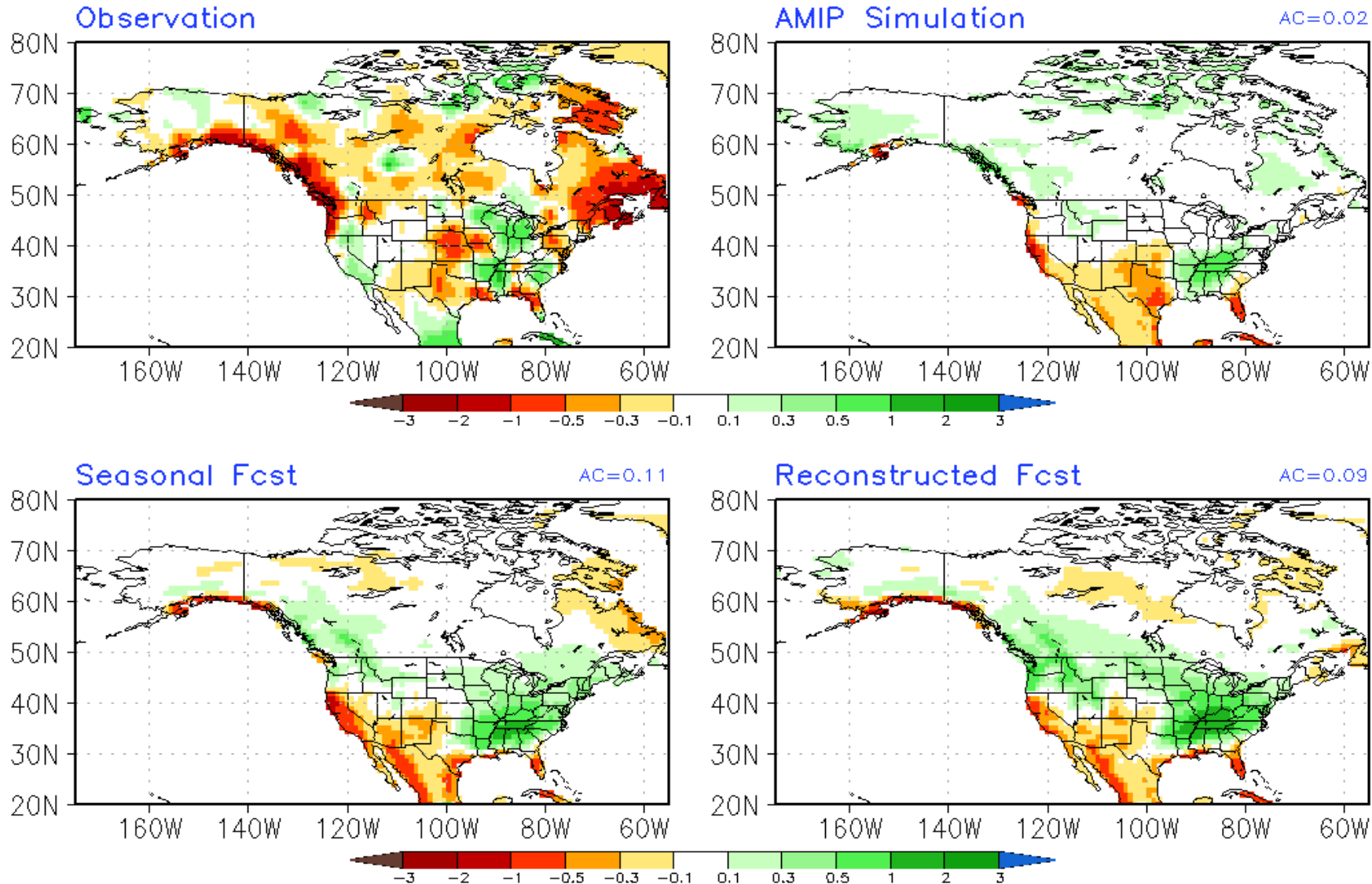
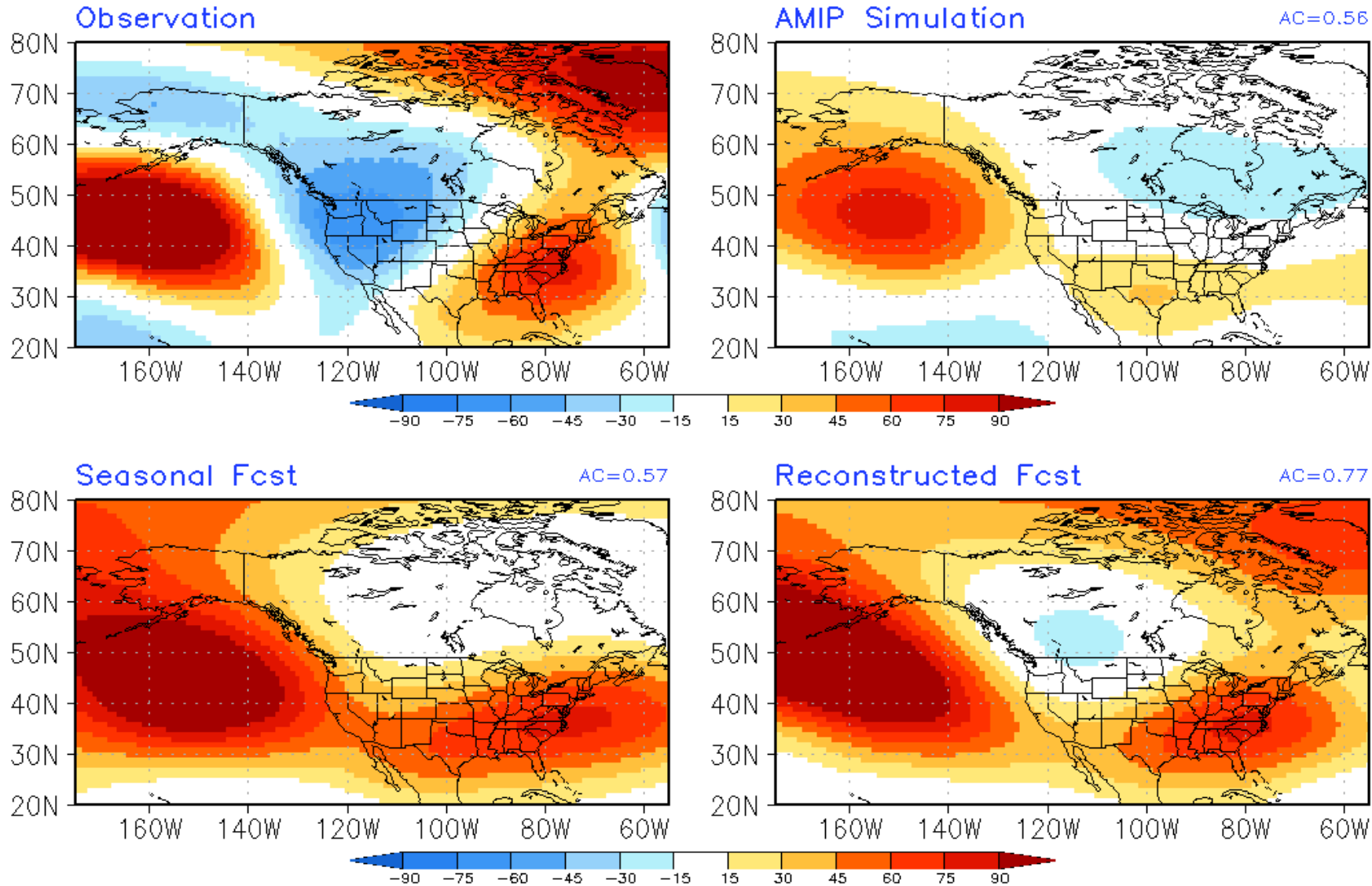FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)

FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)
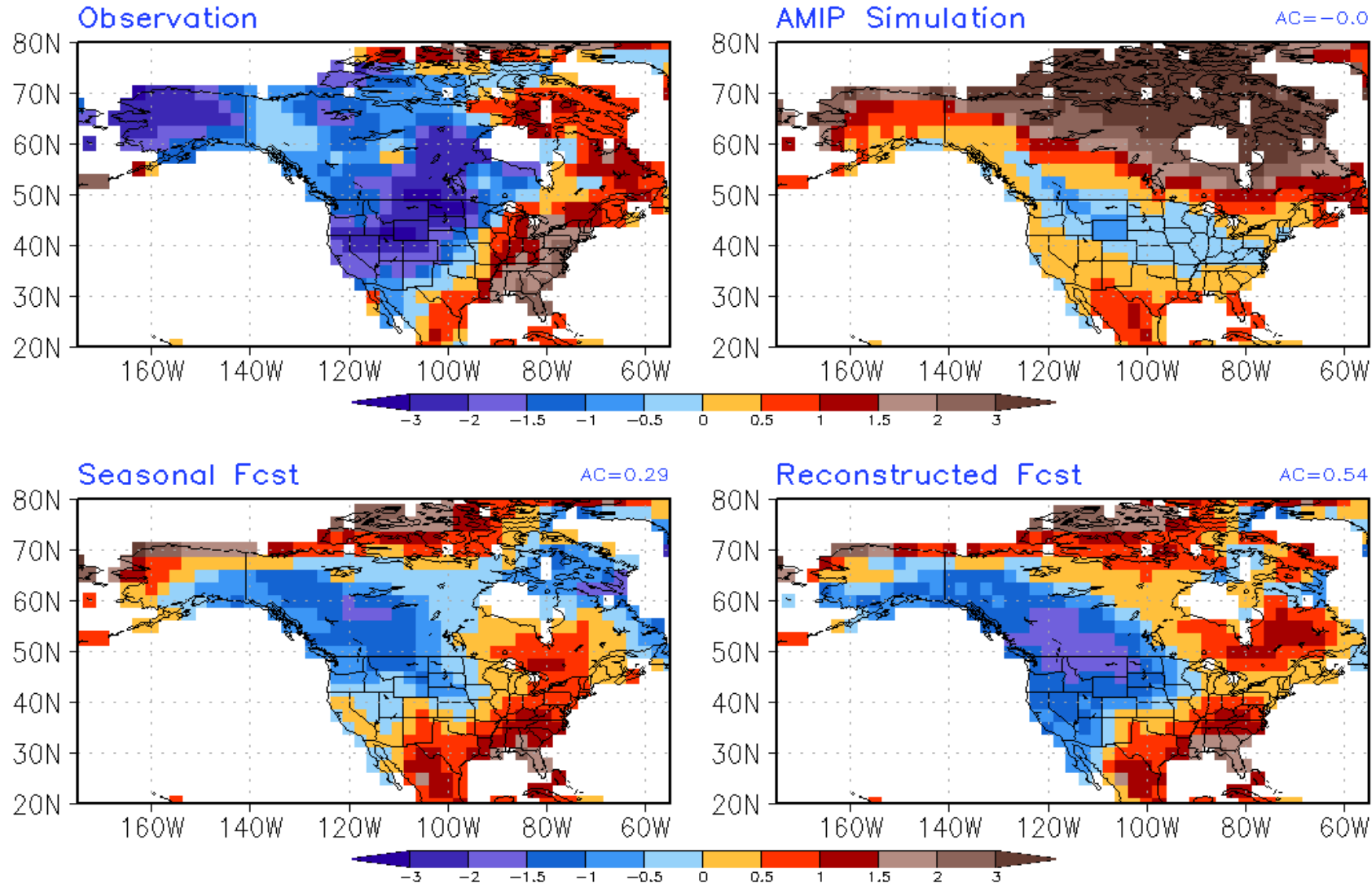
FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)

FMA2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)

FMA2023 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.

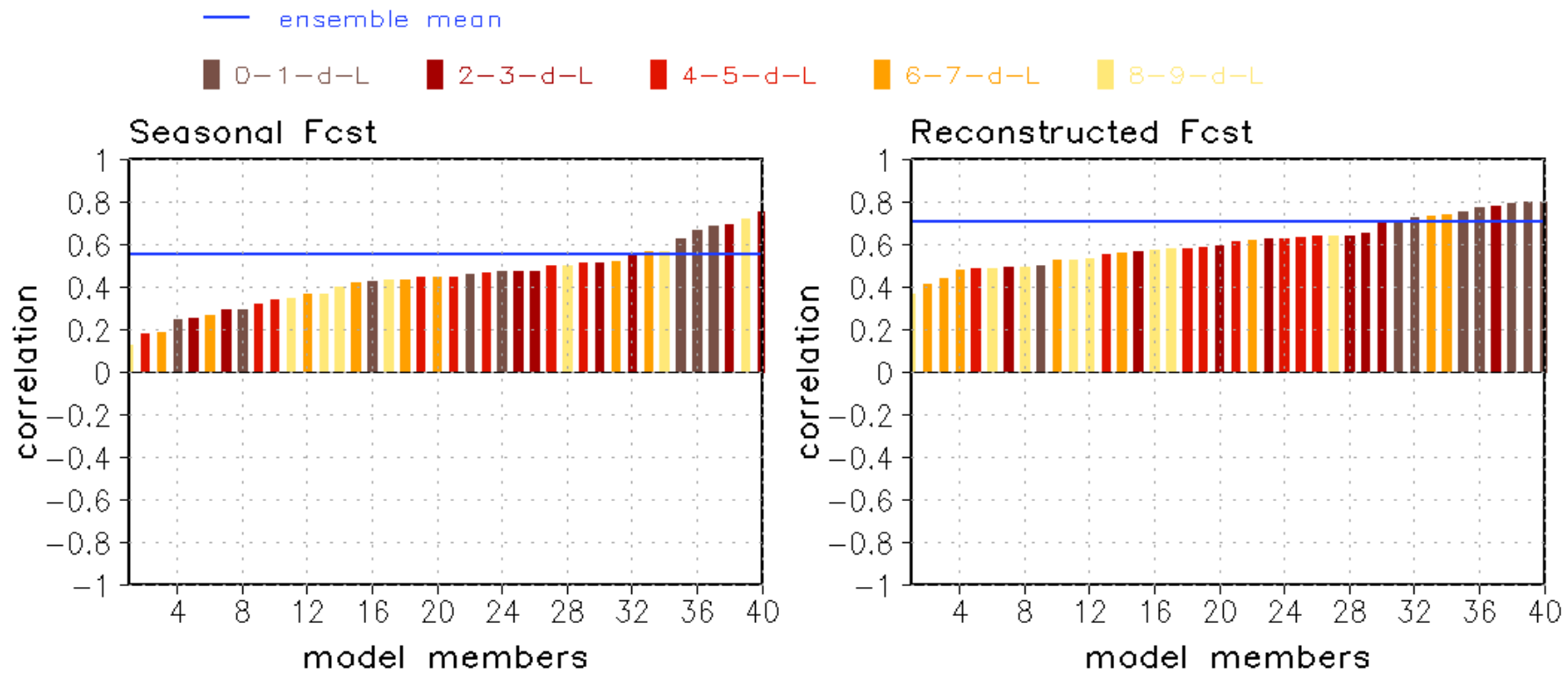FMA2023 Anomaly Correlation for Individual AMIP Simulation with Observation —— z200(20N—90N)
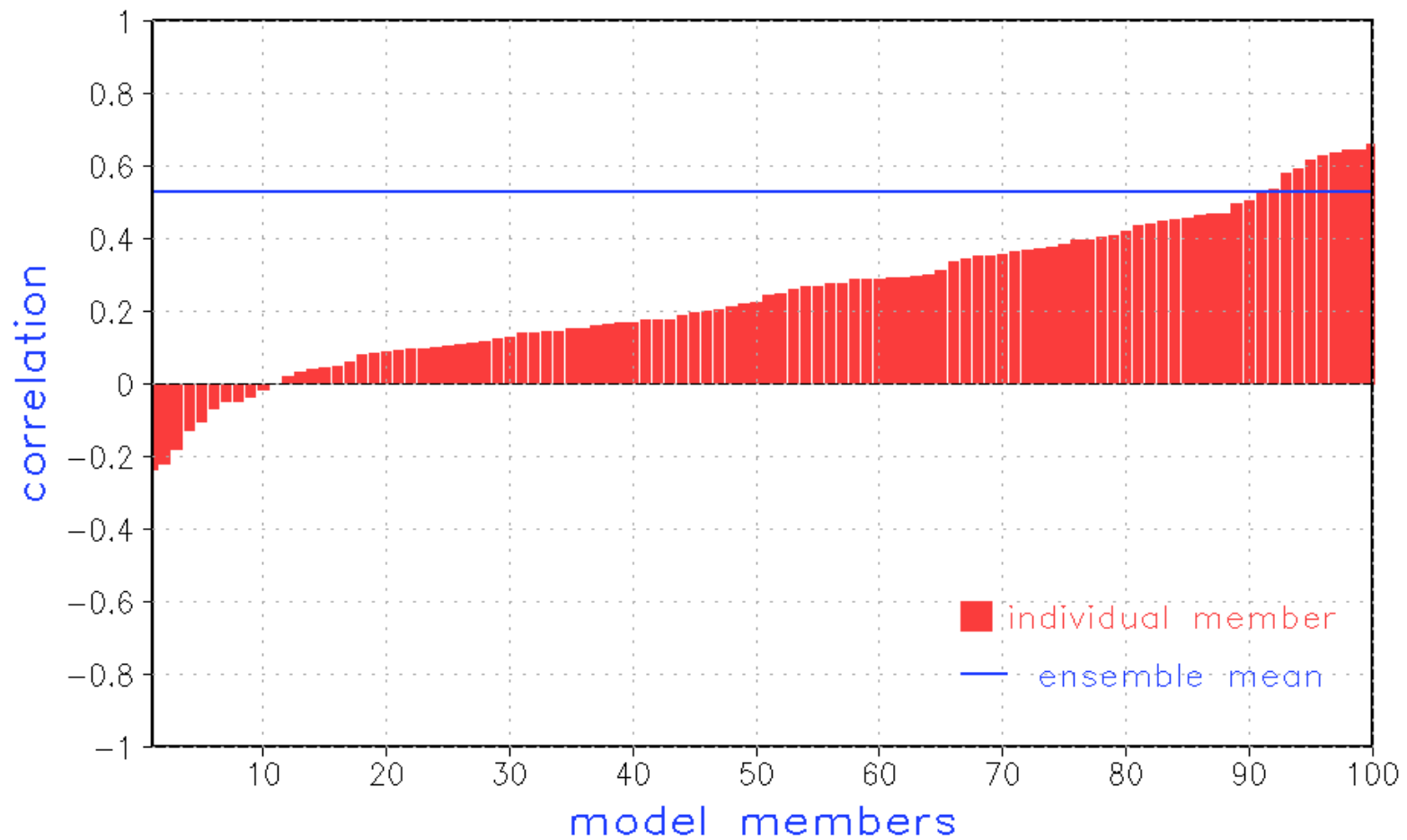
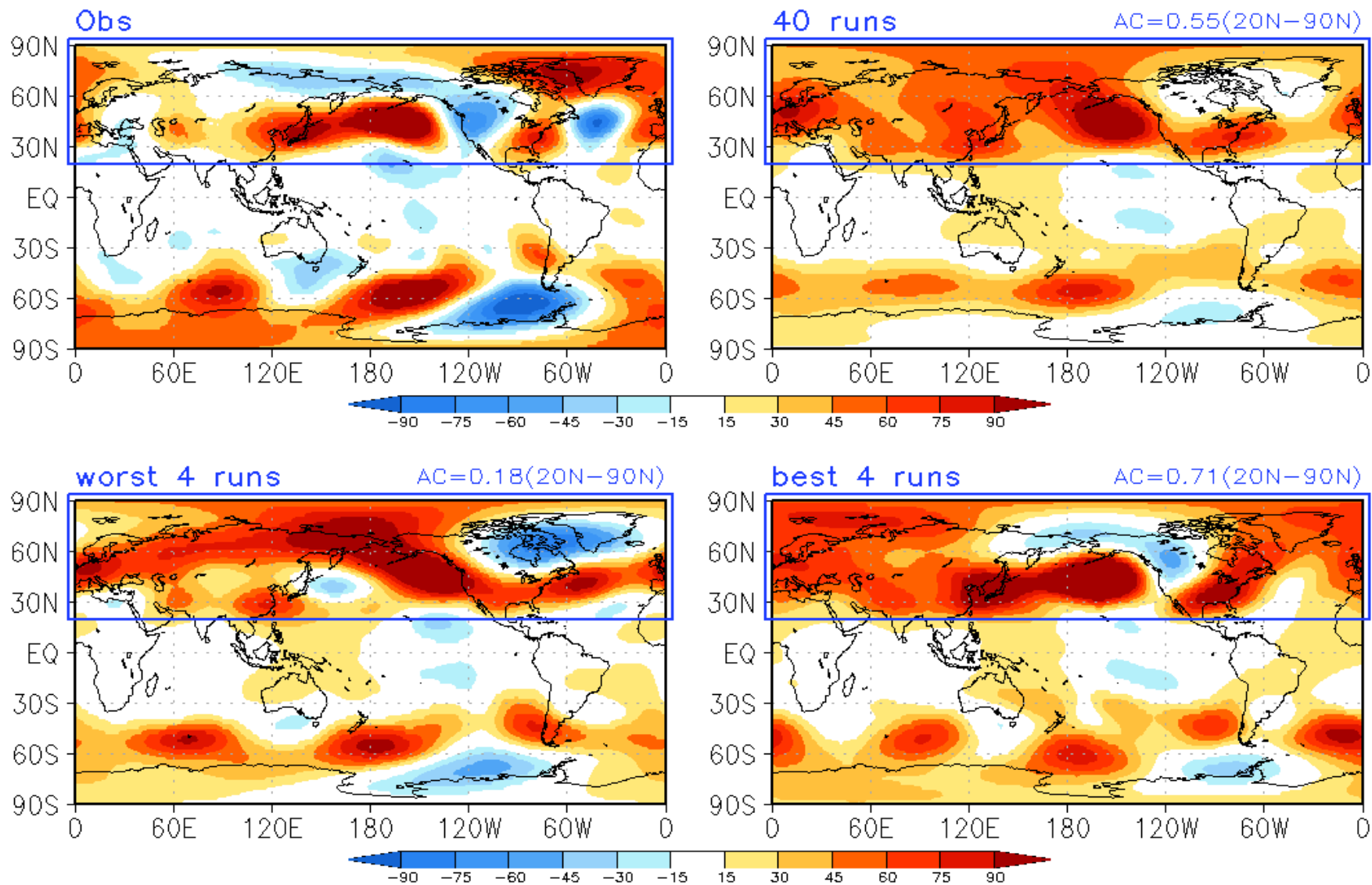# Observed & AMIP Ensemble Mean Anomalies
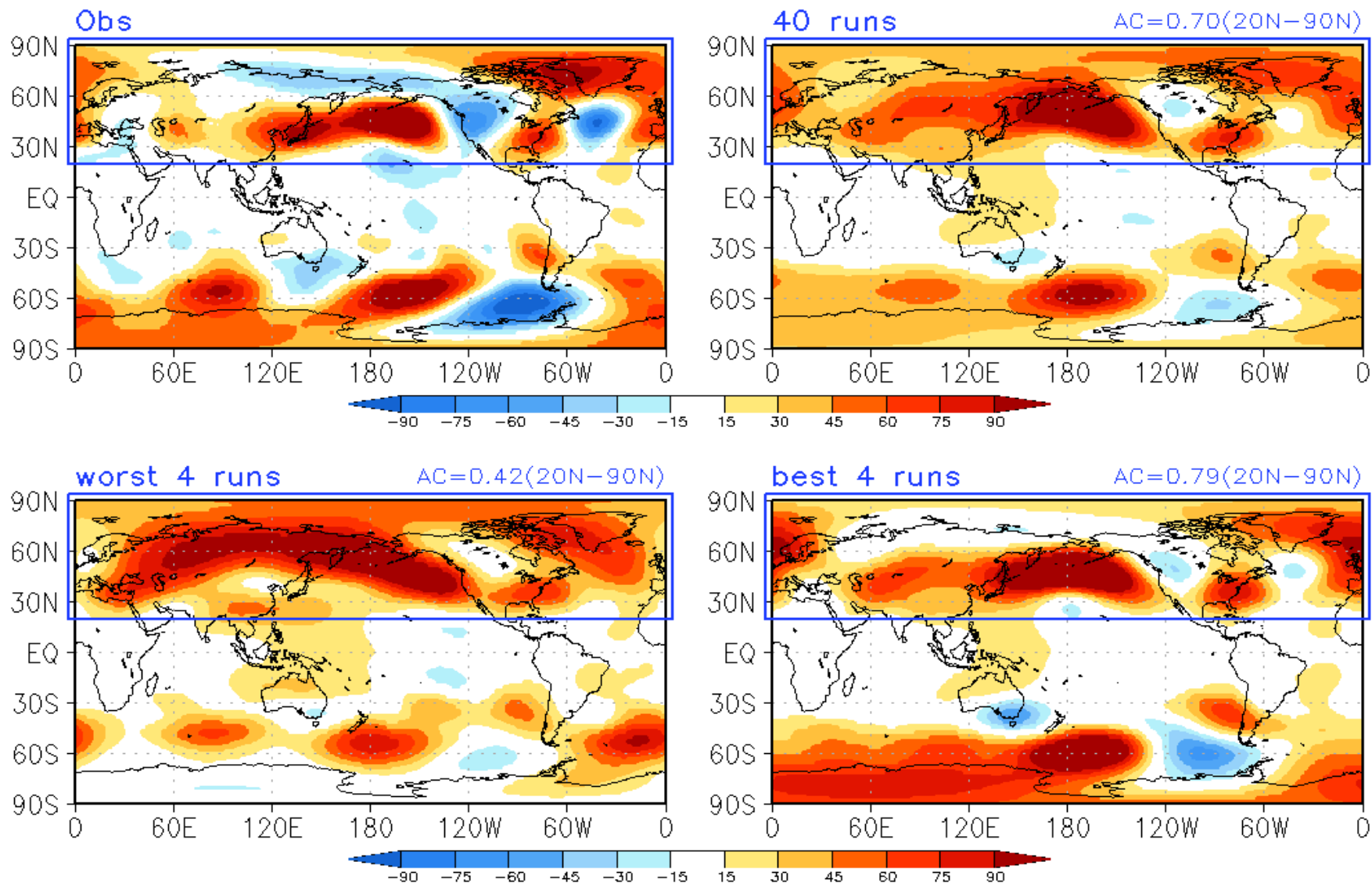## FMA2023 z200(m) 100 runs/worst 4 runs/best 4 runs
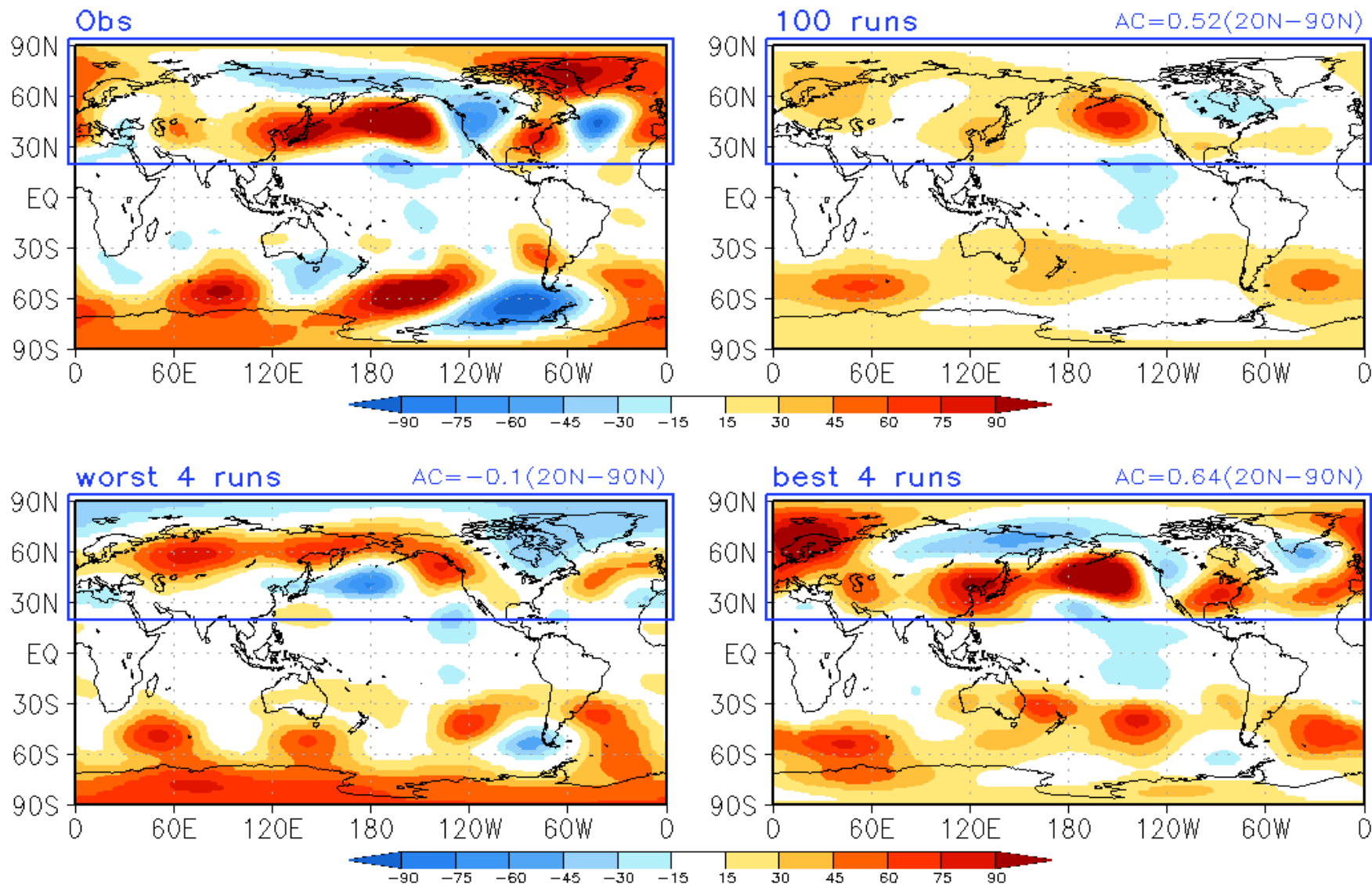
FMA2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation –– z200 (20N–90N)
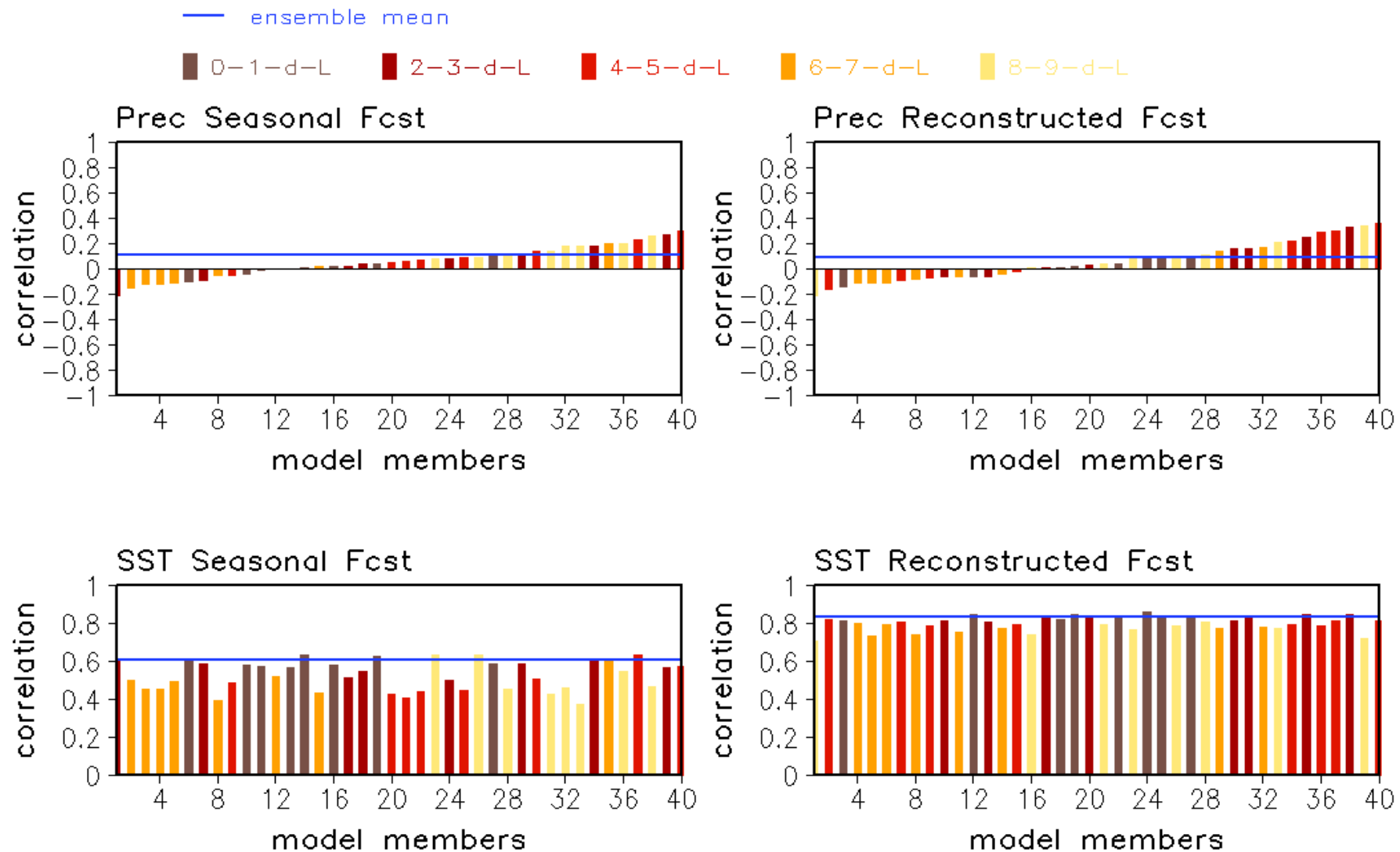
Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2023 z200(m) 40 runs/worst 4 runs/best 4 runs
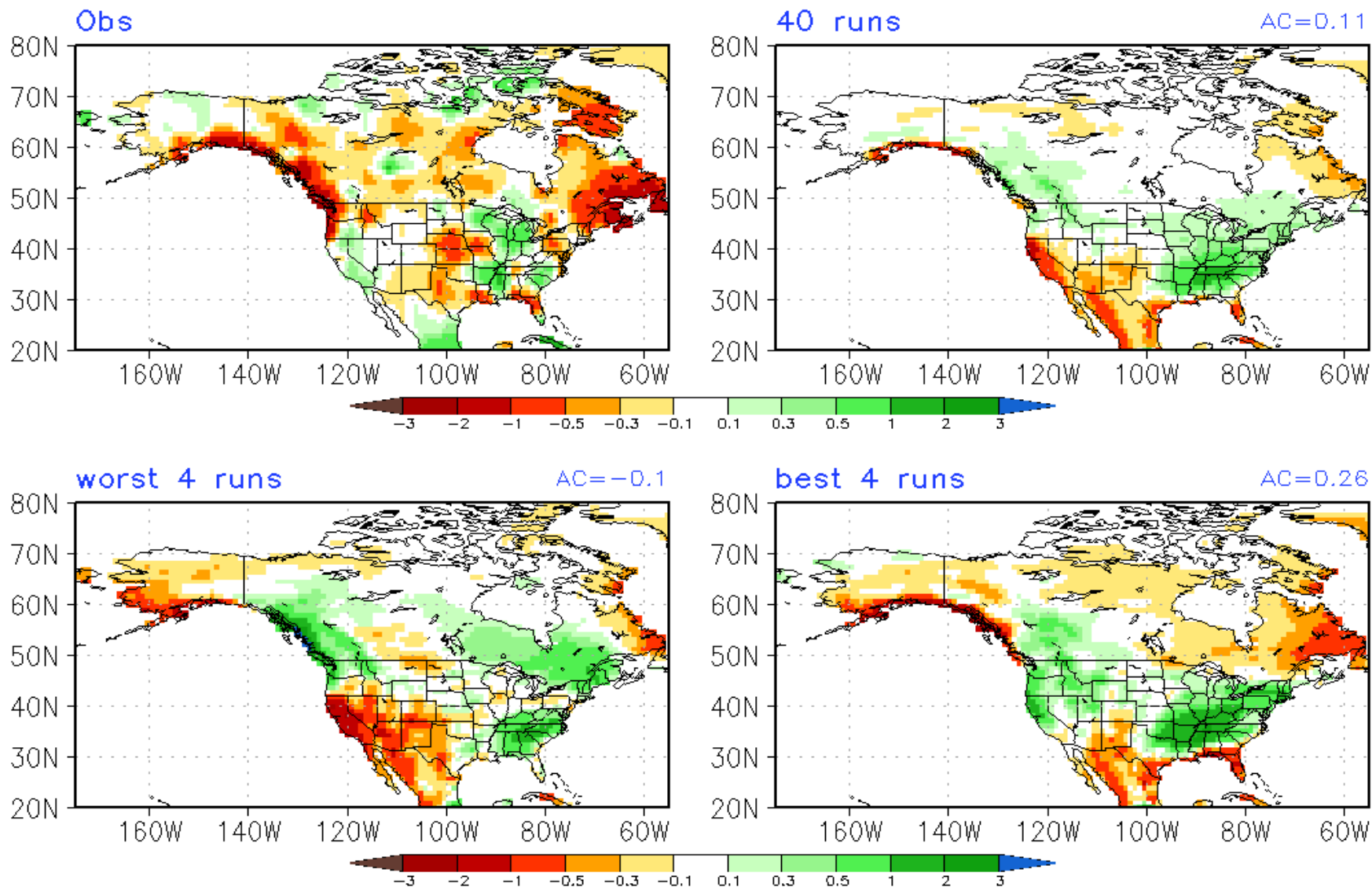Seasonal Forecast

Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2023 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

FMA2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation —— Prec(NA)/SST(30S−30N)

Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2023 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

Observed & CFSv2 Forecast Ensemble Average Anomalies
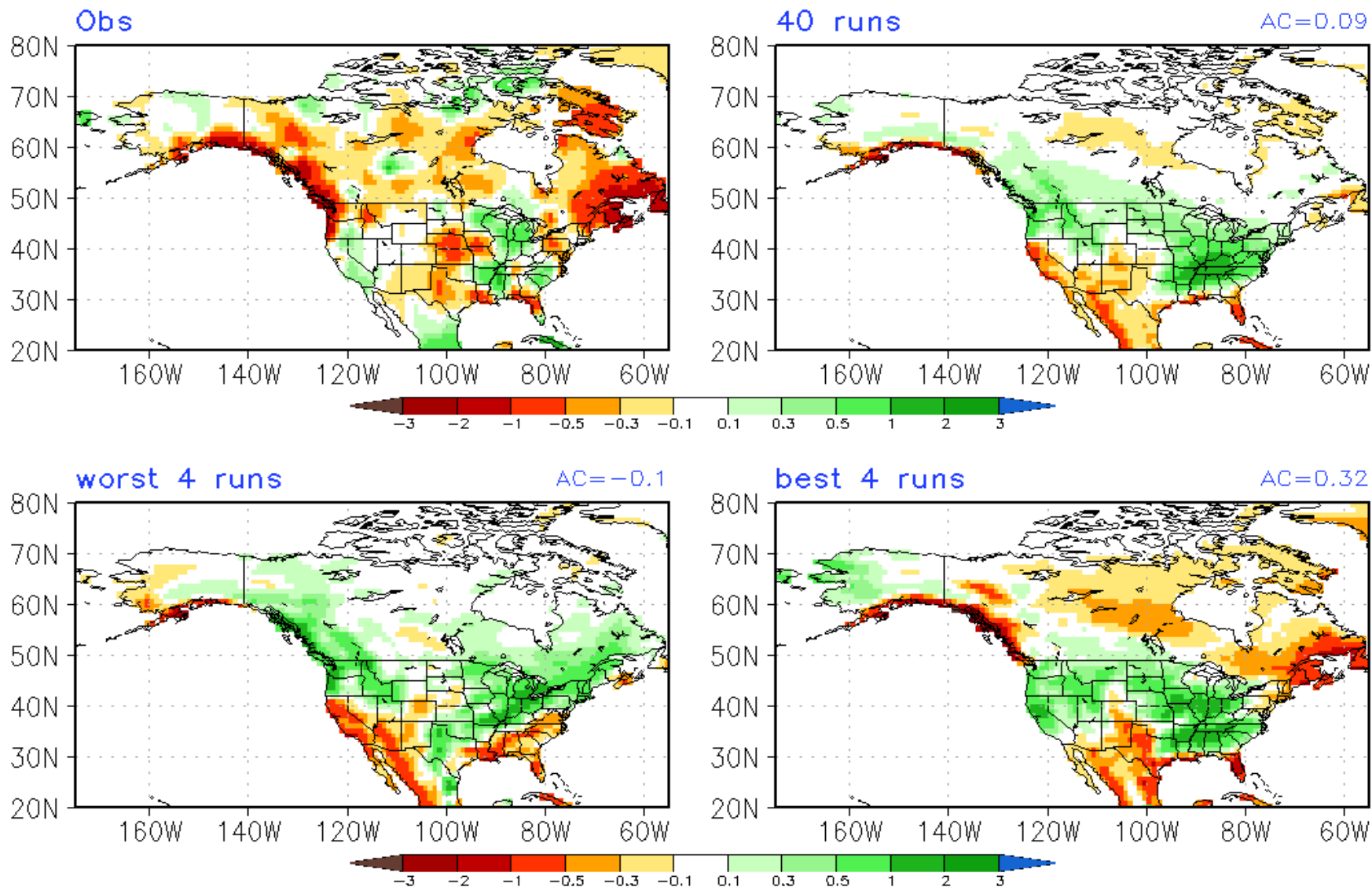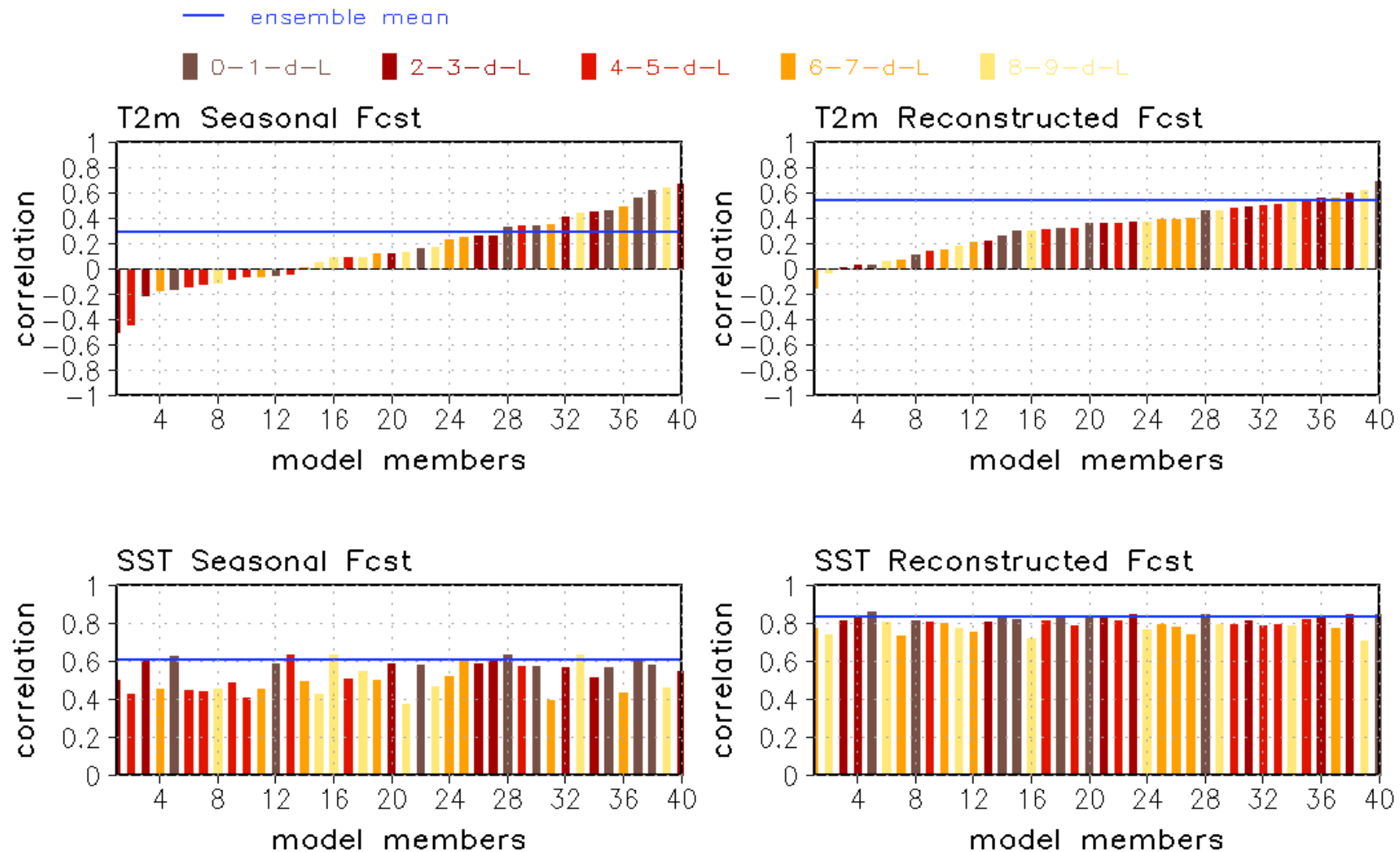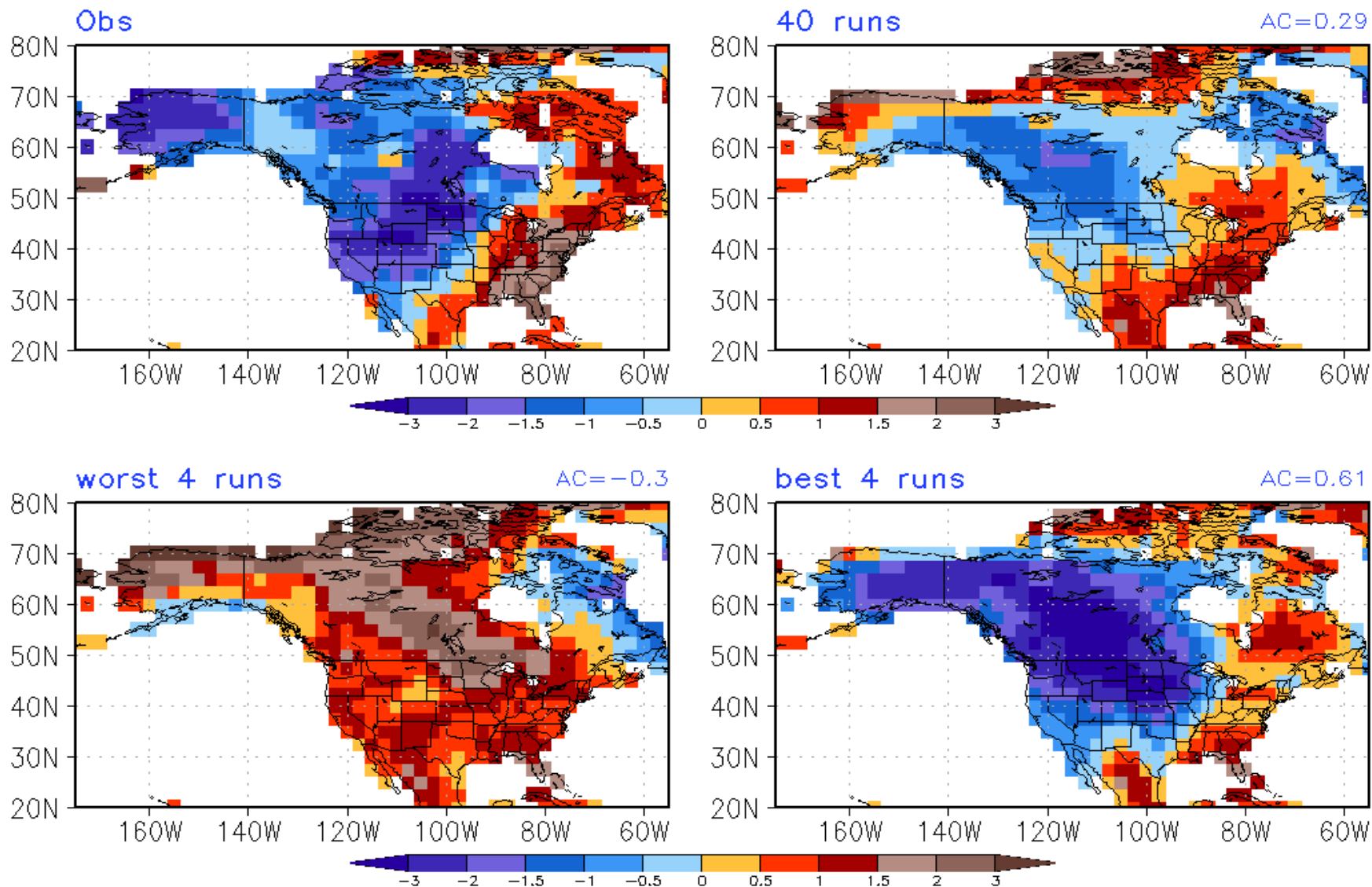## FMA2023 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
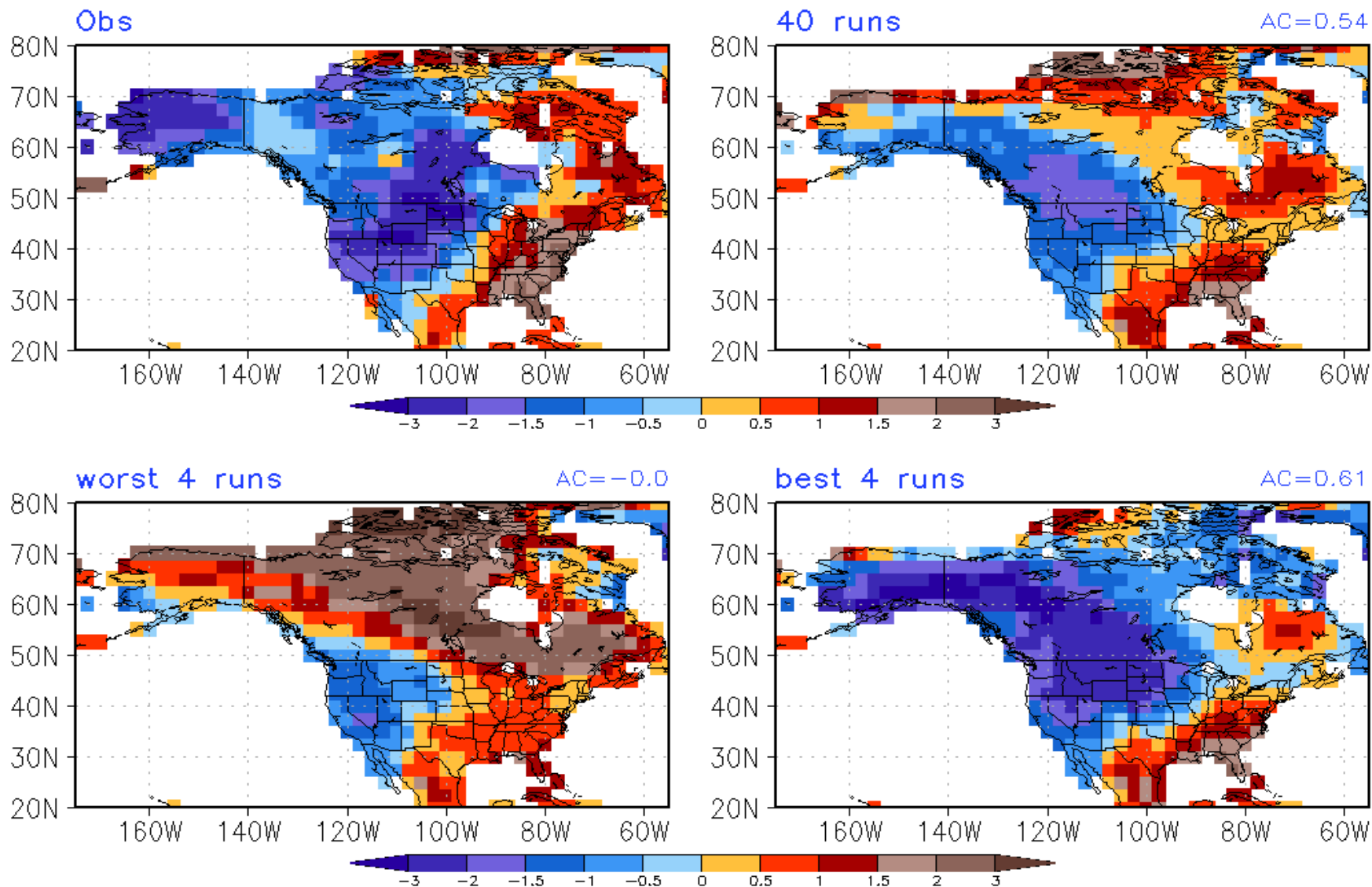### Reconstructed Forecast

FMA2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation —— T2m(NA)/SST(30S–30N)

Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2023 T2m(K) 40 runs/worst 4 runs/best 4 runs
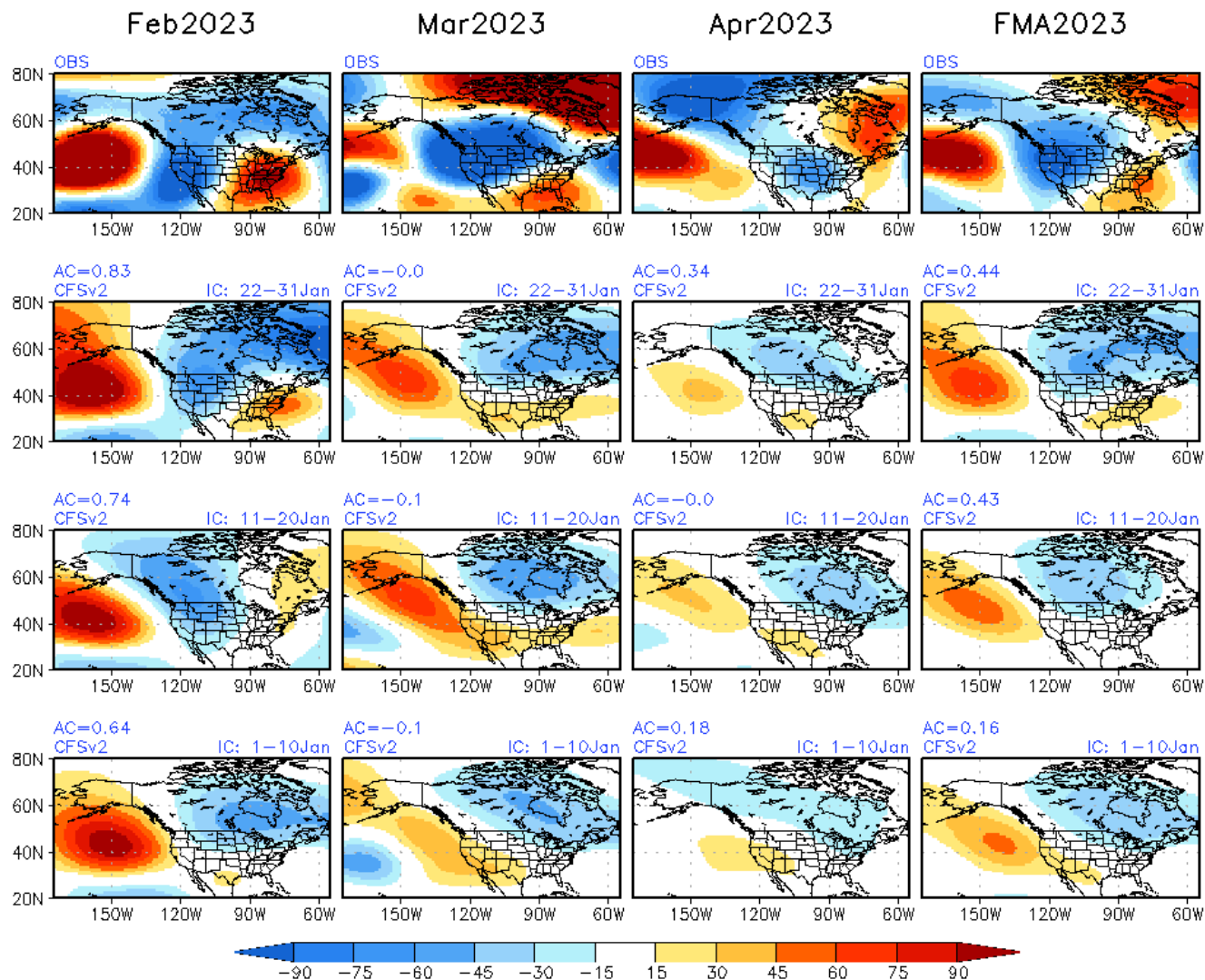Seasonal Forecast

Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2023 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) FMA2023 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) FMA2023 T2m(K) & Obs
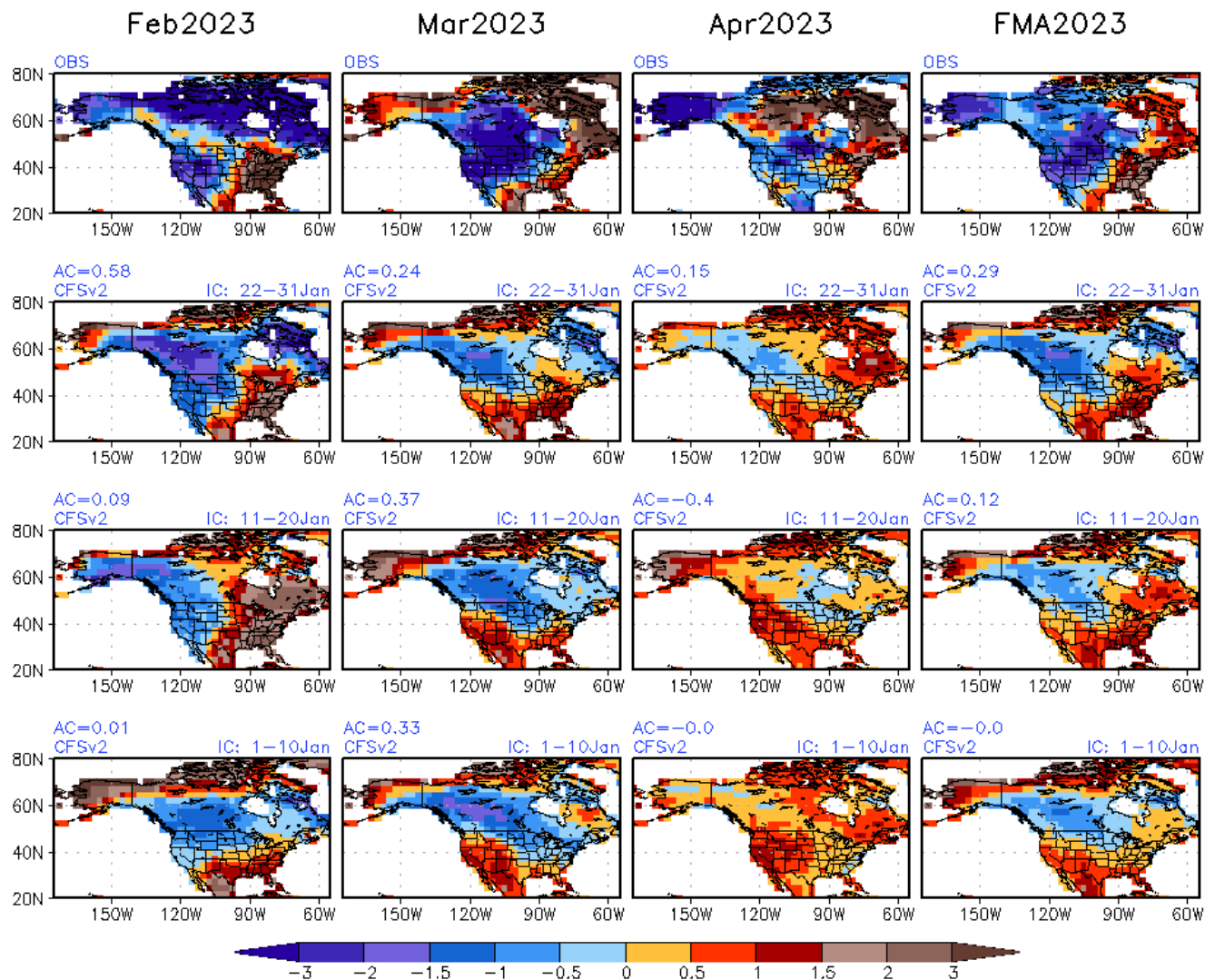
Top row: Observed anomaly.

CFSv2 seasonal forecasts from different initial conditions in the month prior to the target season:
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- 3rd row: 11th - 20th of the prior month.
- 4th row: 1st - 10th of the prior month.

Prec(mm/day) Monthly Means from Seasonal Forecast

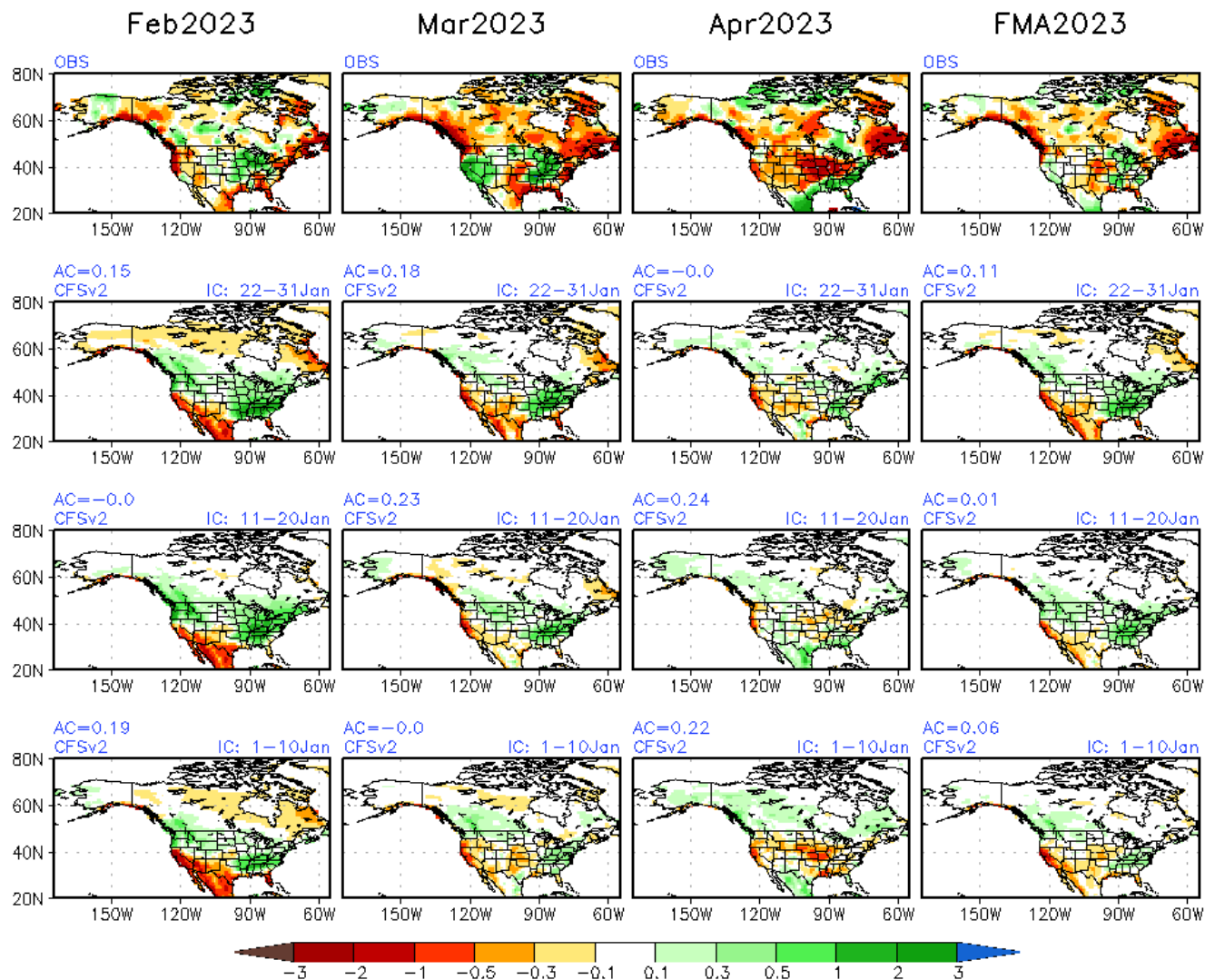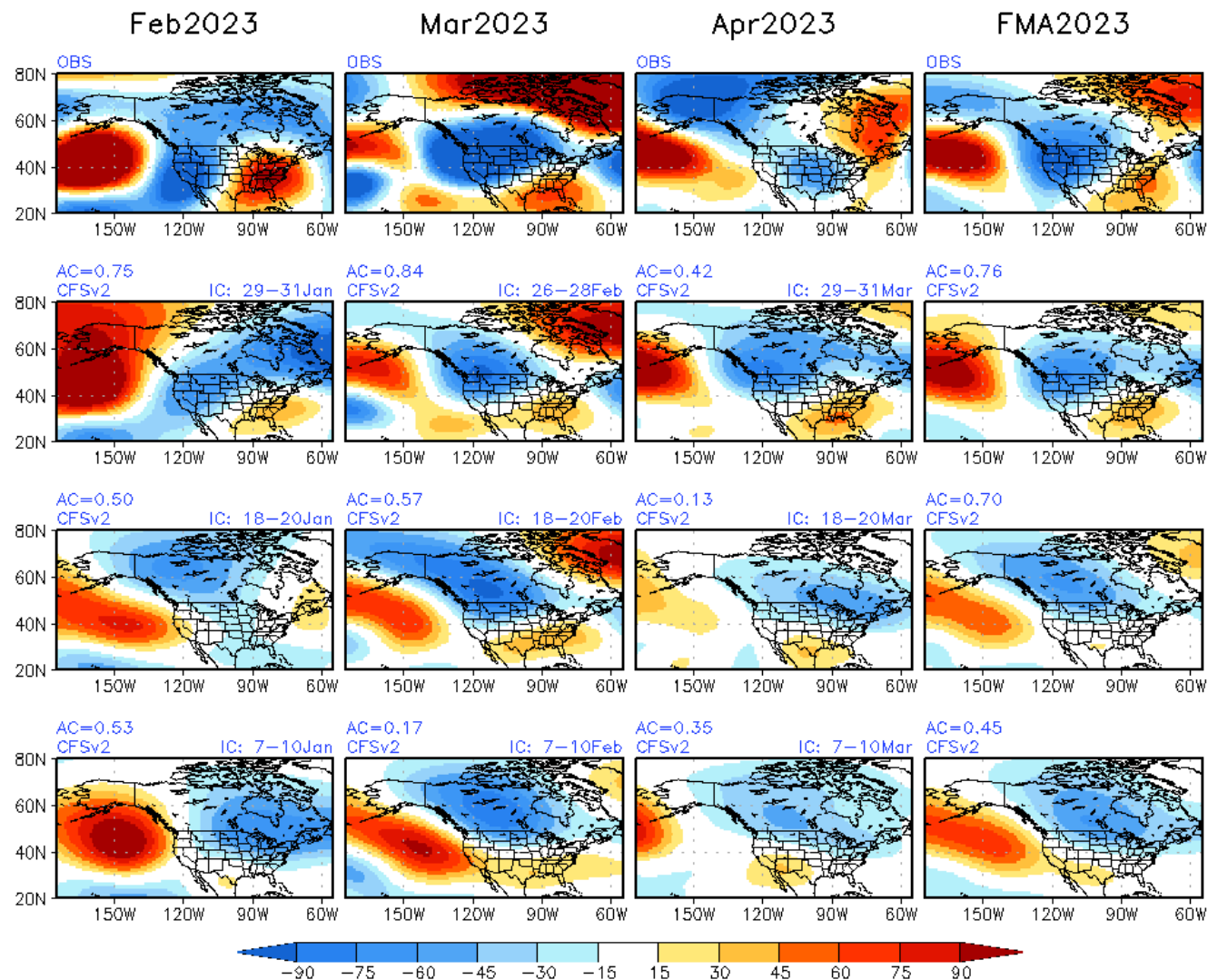Monthly Means from Seasonal Fcst (40ensm) FMA2023 Prec(mm/day) & Obs

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.

Monthly Means from Monthly Fcst FMA2023 z200(m) eddy & Obs

Top row: Observed anomaly.

CFSv2 monthly forecasts from different initial conditions in the <u>month prior</u> to the <u>target month</u>:
- 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.

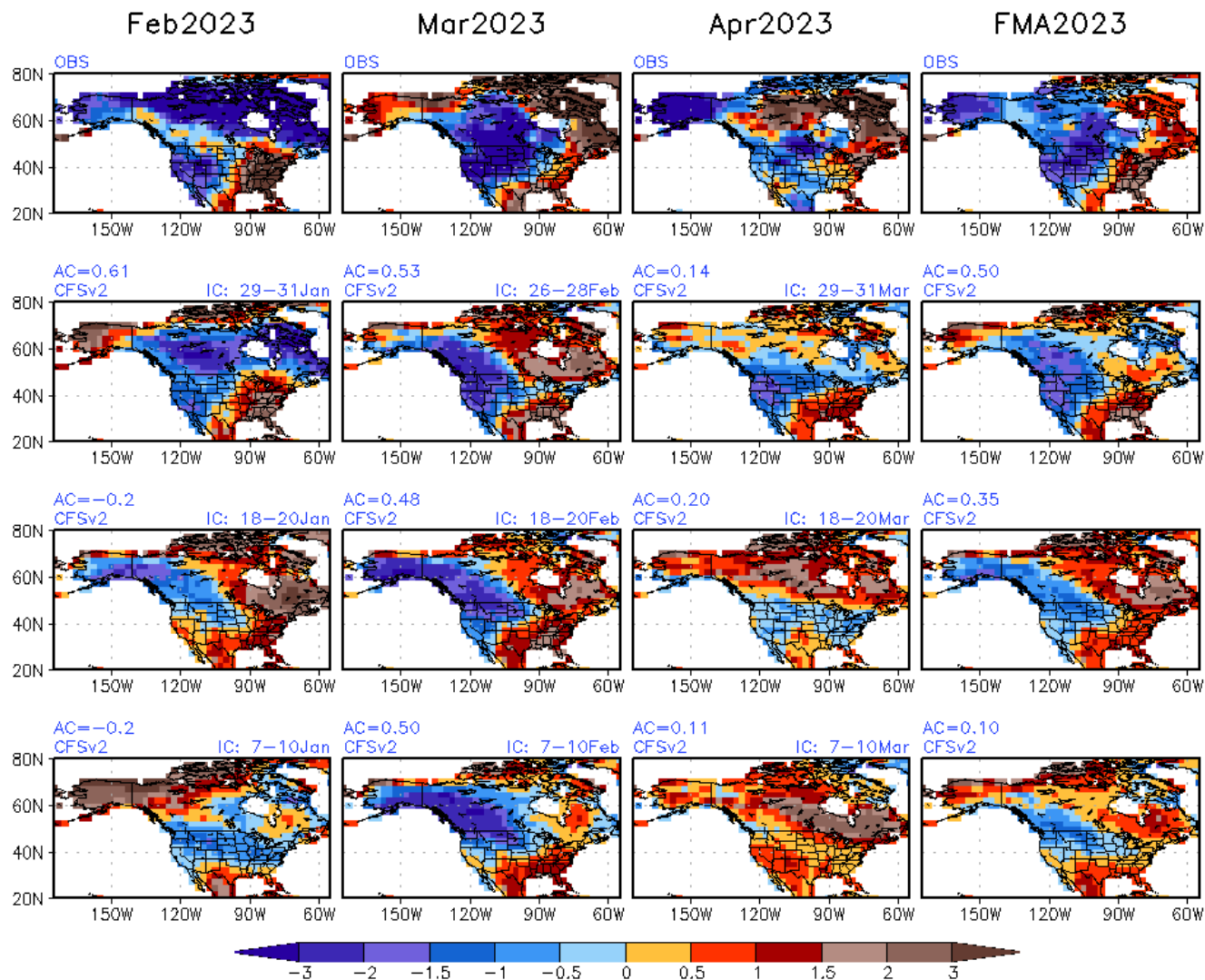Monthly Means from Monthly Fcst FMA2023 T2m(K) & Obs

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

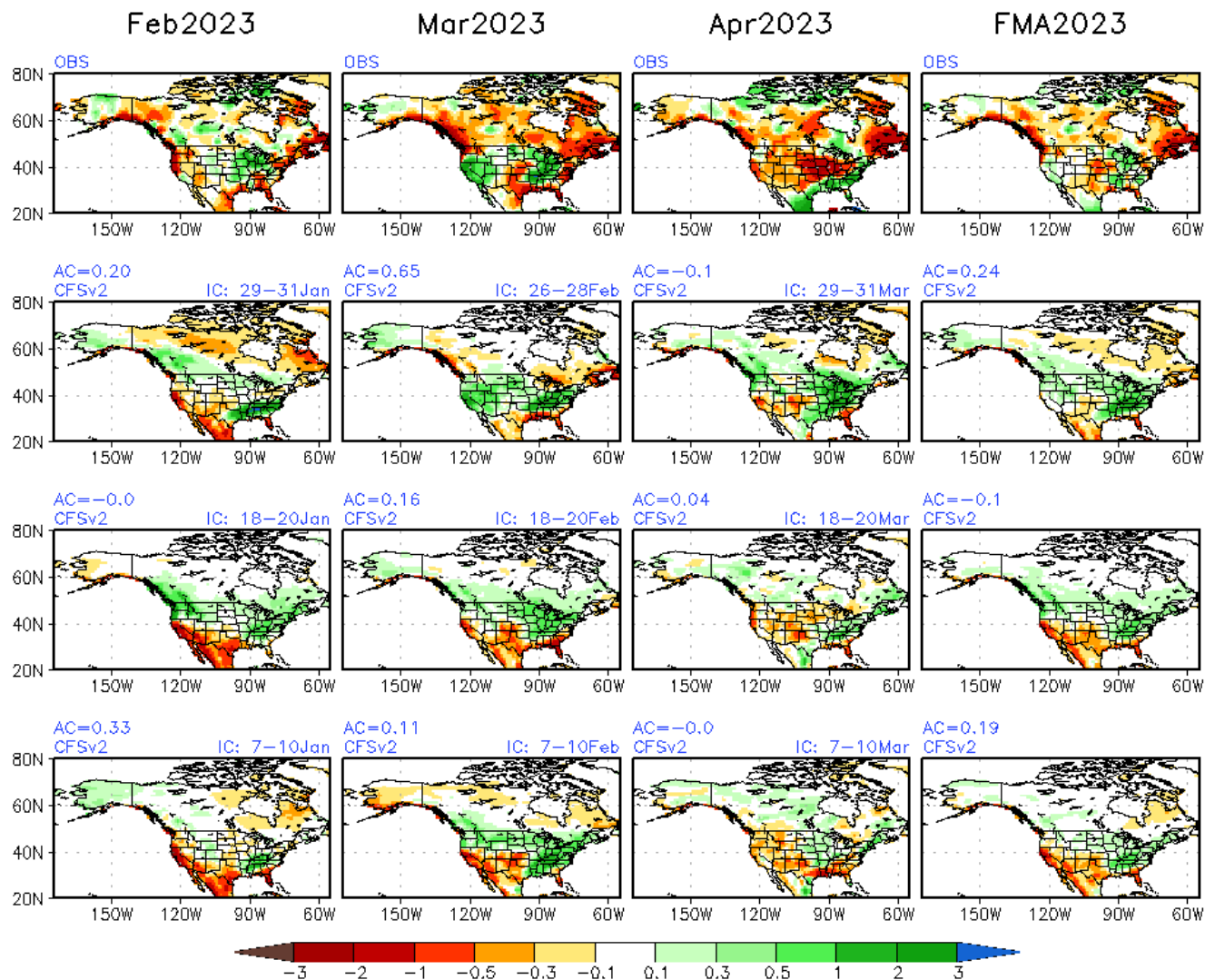Monthly Means from Monthly Fcst FMA2023 Prec(mm/day) & Obs

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/

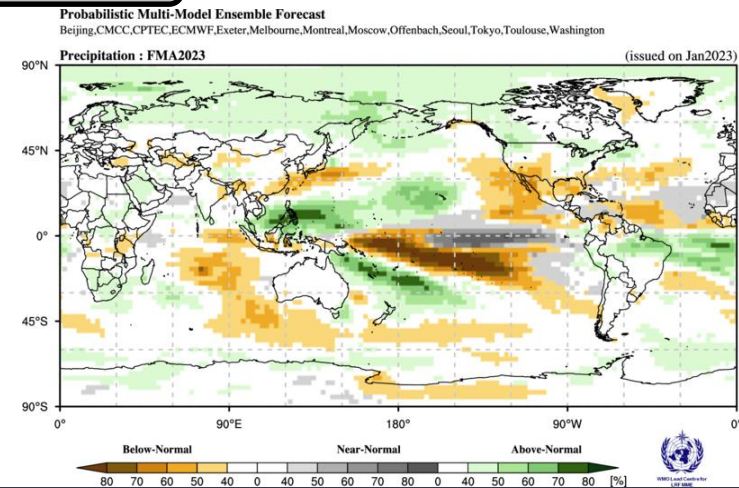- North American Multi-Model Ensemble (NMME) seasonal forecasts. https://www.cpc.ncep.noaa.gov/products/NMME/

LC-LRFMM Seasonal Forecasts
(https://www.wmolc.org/)

Ensemble means
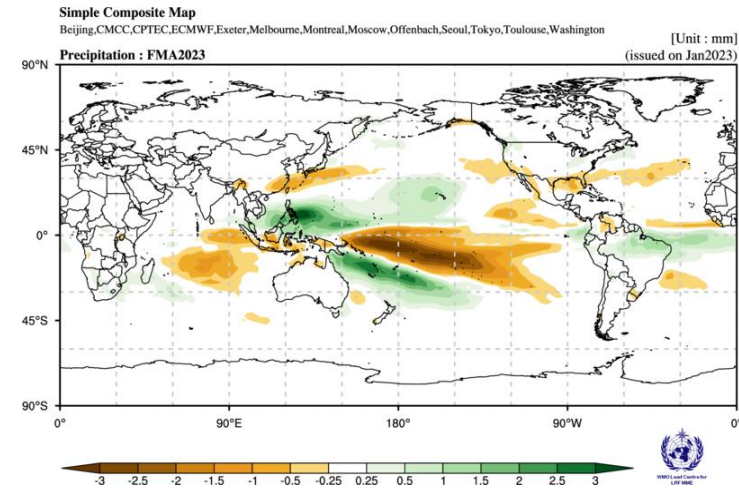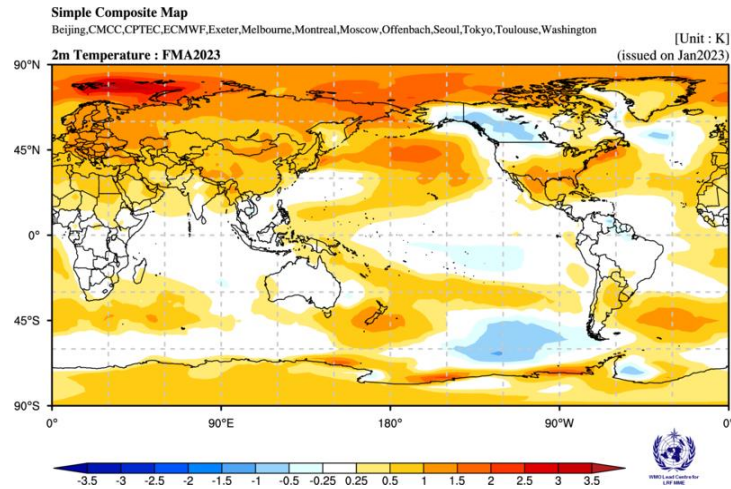
Probabilities
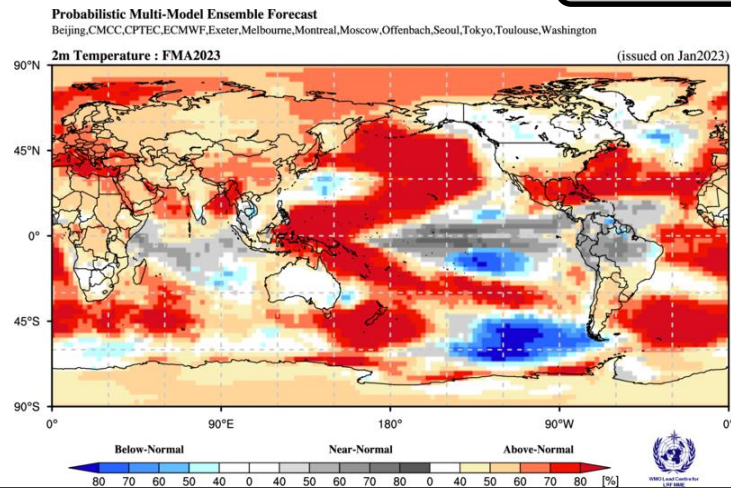
C3S Seasonal Forecast
(https://climate.copernicus.eu/charts/c3s_seasonal/)
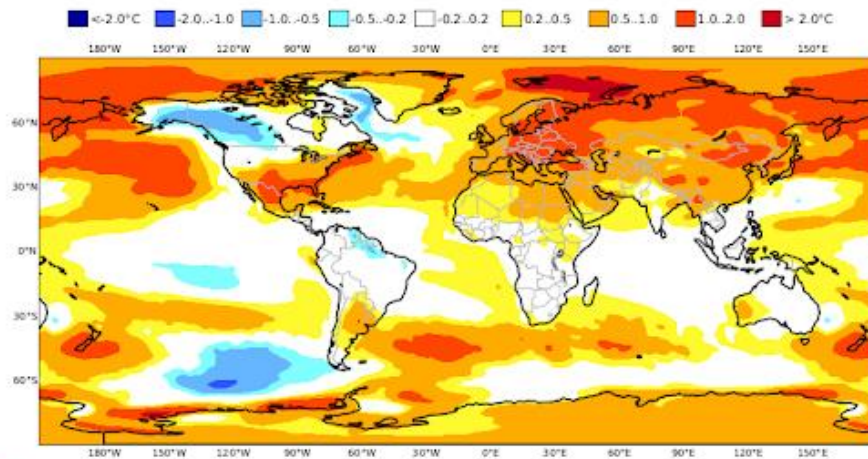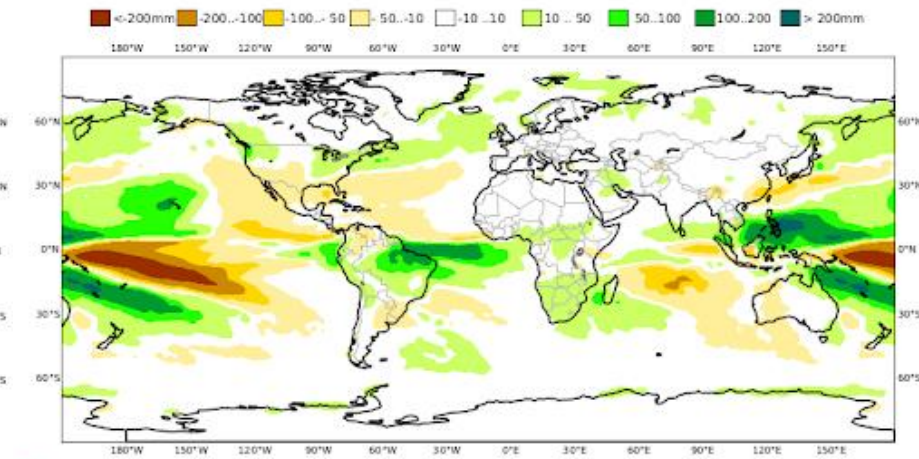
North American Multi-Model Ensemble Seasonal Forecast
(https://www.cpc.ncep.noaa.gov/products/NMME/)
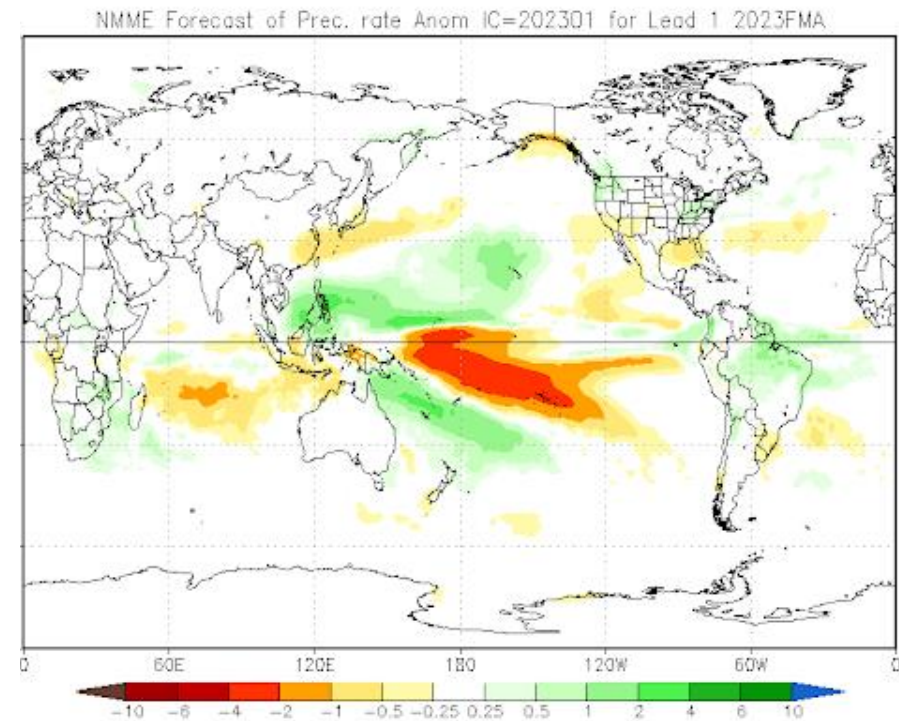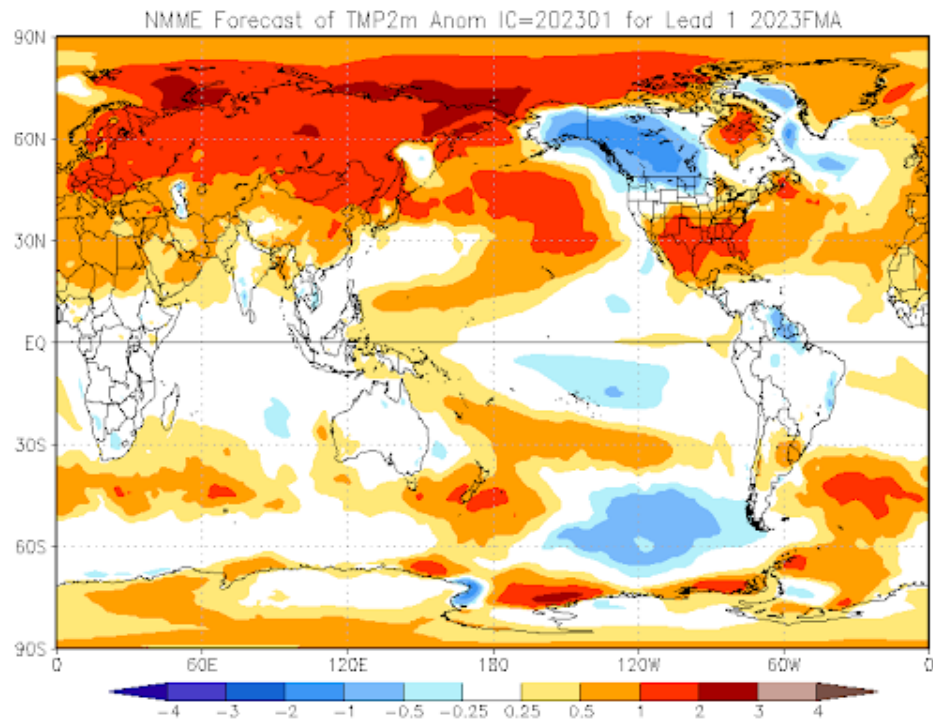
FMA2023 200mb Eddy HGT(m)
OBS vs. Linear Model Response to Tropical Heating
Heating is converted from Prate in 15S–15N
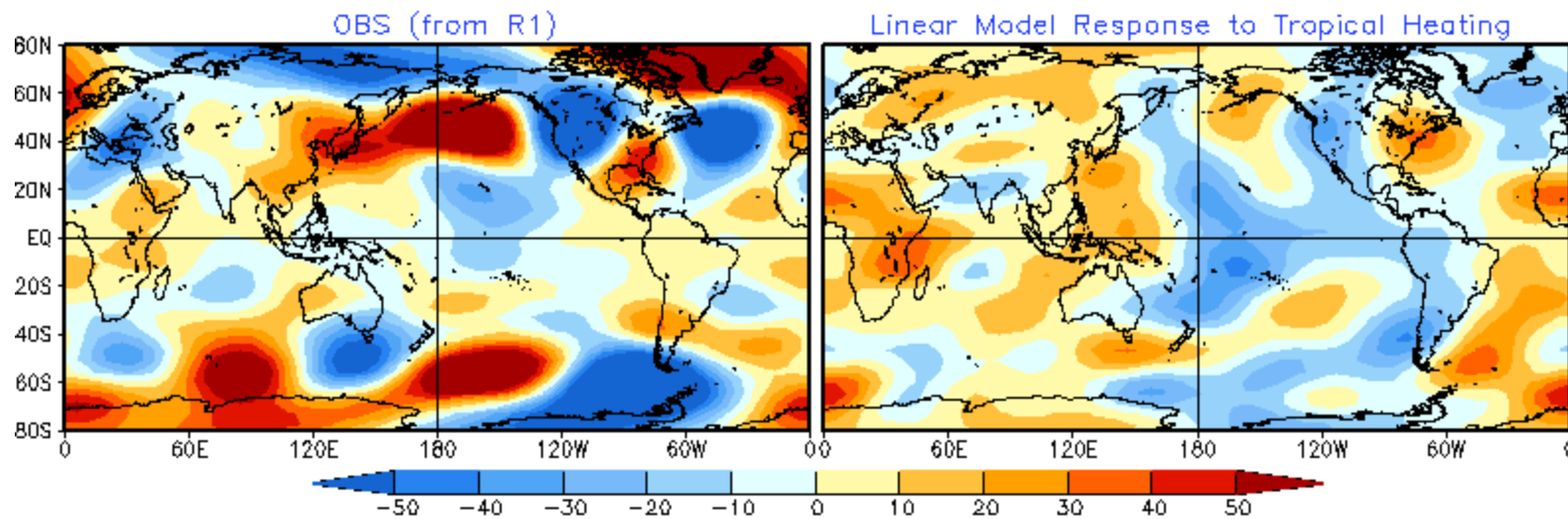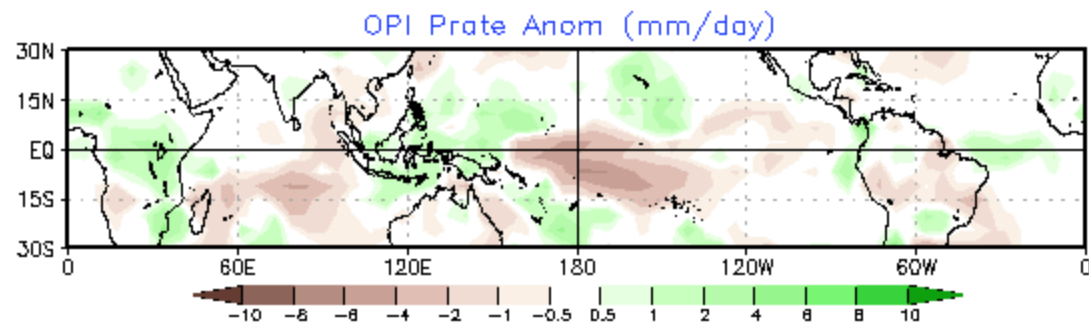
Pattern COR: global=0.10, tropics(30S–30N)=0.30

Seasonal Forecasts from the Constructed Analog Model

CA HGT200 Prd for FMA2023, ICs through Apr2023(m), Lead −3
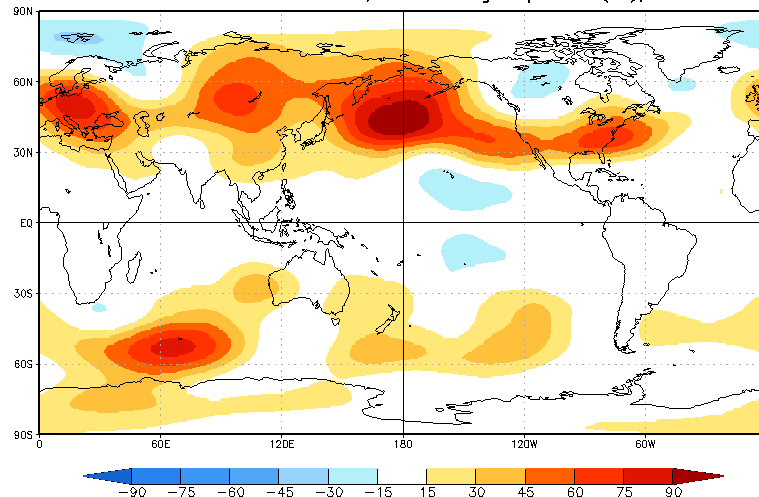
CA T2m Prd for FMA2023, ICs through Apr2023(K), Lead −3
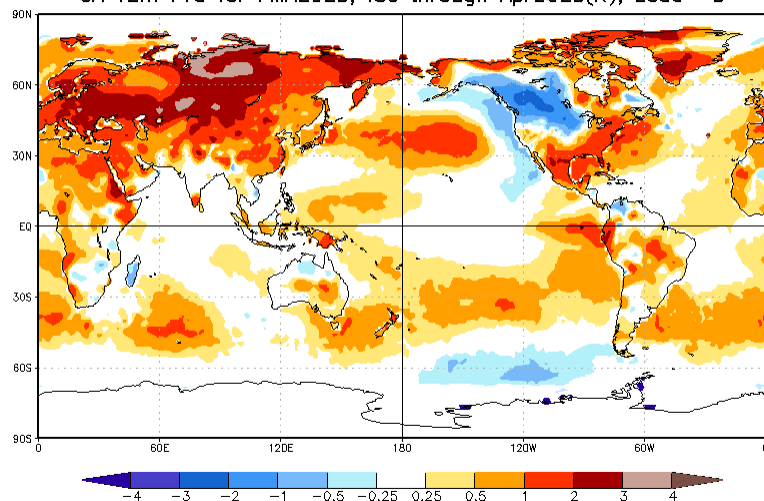
CA Prec Prd for FMA2023, ICs through Apr2023(mm/day), Lead −3
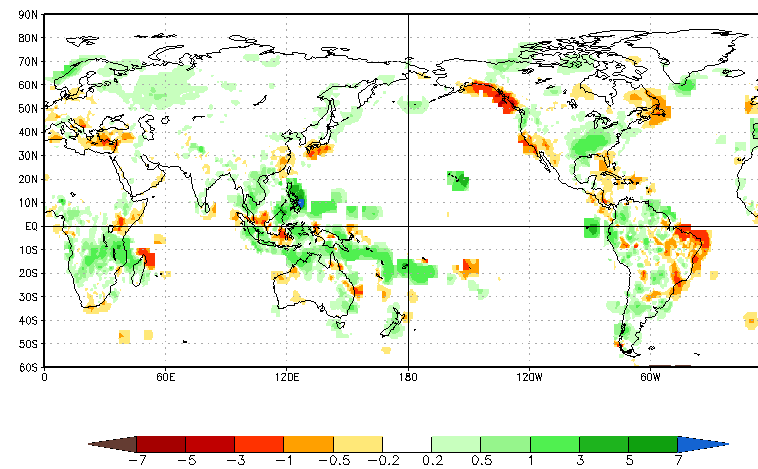
Background & Methodology

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.

- 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 (provided by Dr. Peitao Peng/CPC)
- Seasonal mean anomalies of z200, T2m, and Prec forecasted from the Constructed Analog Model (provided by Dr. Peitao Peng/CPC)