Attribution of Seasonal Climate Anomalies December-January-February 2023-24

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

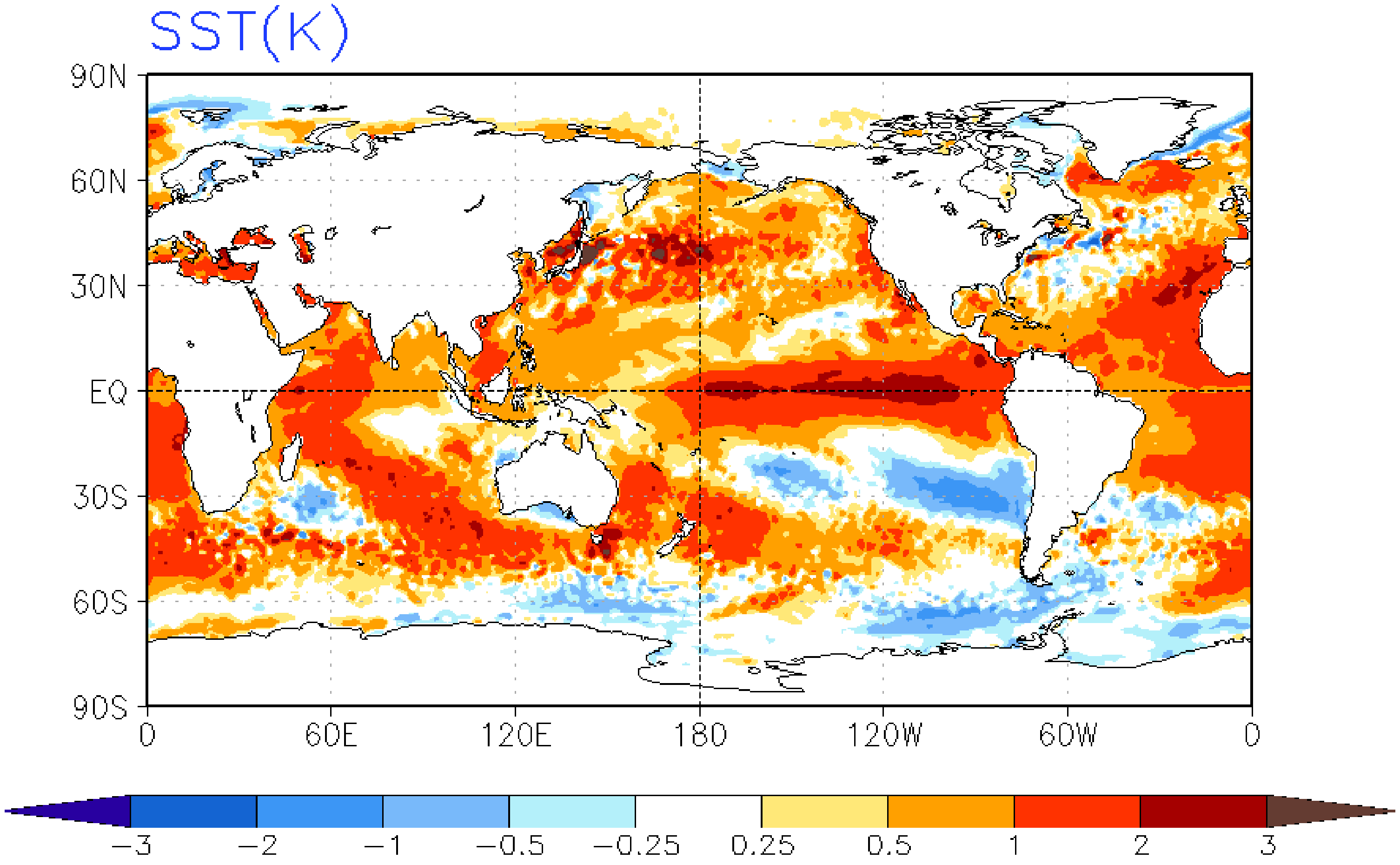
Summary of Observed Conditions and Outlooks

- In DJF 2023/24, warm SST anomalies associated with El Niño continued in the equatorial eastern Pacific with a further reduction in warming anomalies along the coastal regions of South America. Almost over all ocean basins, specifically, over the North Pacific, central southern Pacific, Atlantic, and western and southern 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).
- The AMIP simulations, the initialized forecasts, and other MME forecasts all captured the large-scale distribution of observed precipitation anomalies in tropical latitudes – drier (wetter) conditions in the equatorial eastern and southern Indian Ocean and Maritime Continent (equatorial western Pacific) and wetter conditions stretching along a narrow equatorial band across the entire Pacific basin (slides 11, 37-39).
- A distinctive feature in rainfall was below normal anomalies in the equatorial eastern Indian Ocean associated with the positive phase of the Indian Ocean Dipole Mode and was well reproduced in model simulations and predictions (slide 11, 37-39).
- Consistent with the notion of SSTs constraining atmospheric variability, the tendency for above normal 200-mb heights and above normal land surface temperature anomalies continued almost throughout the globe both in observations and model predictions and simulations (slide 12, 13).
- The initialized CFSv2 forecasts predicted well the tendency for above normal 200-mb height and land surface temperature over North America in general, while the z200 positive center over the high latitude North America was shifted westward resulting in a missed forecast of the observed below normal anomalies over the east Alaska and the southwest areas (slide 15, 16).
- January 2024 monthly forecast skill for 200-mb height, T2m, and precipitation over North America improved from the shortest leads (slide 33-35).

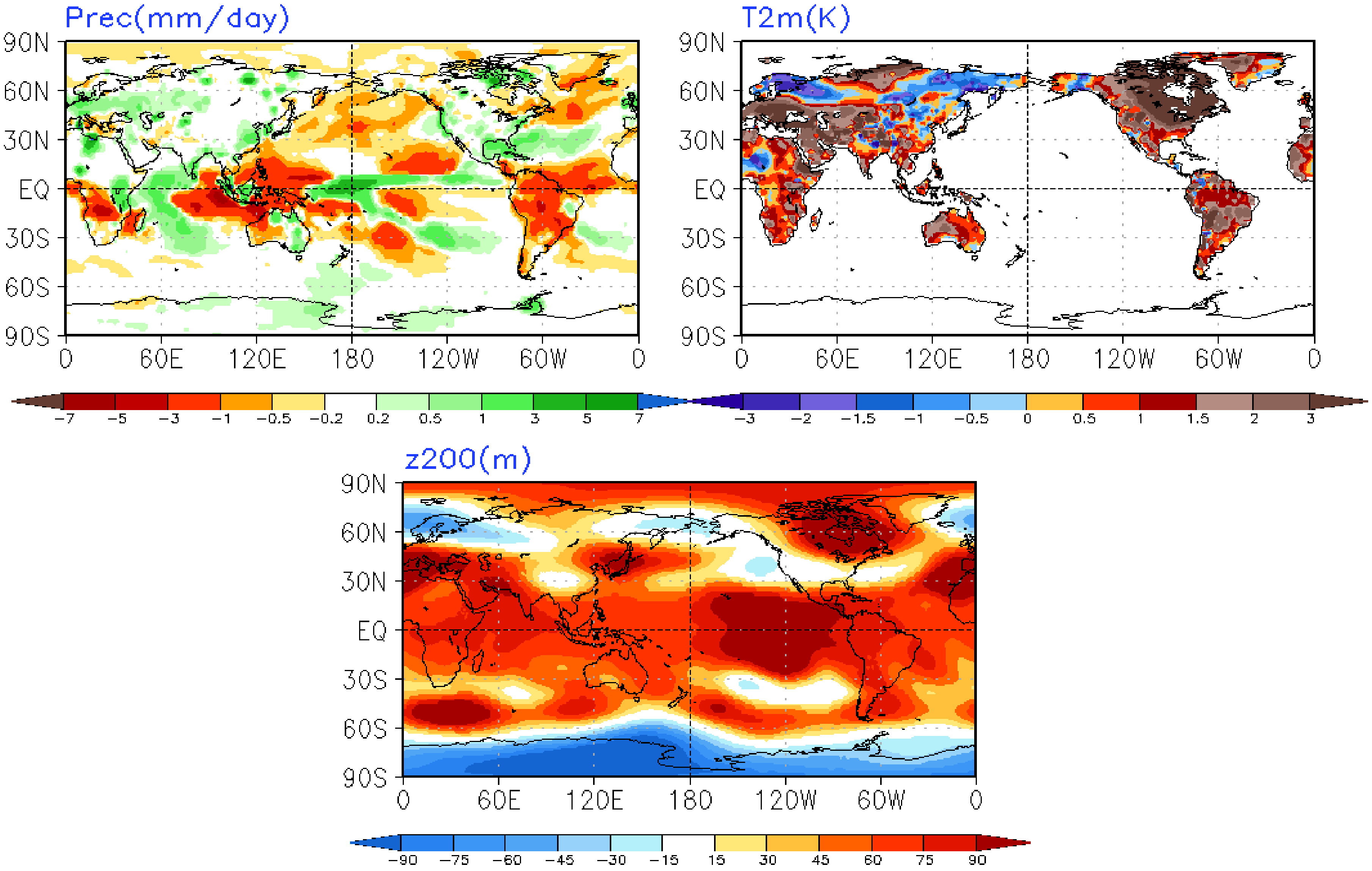
Observed Seasonal Anomalies

Global and North America

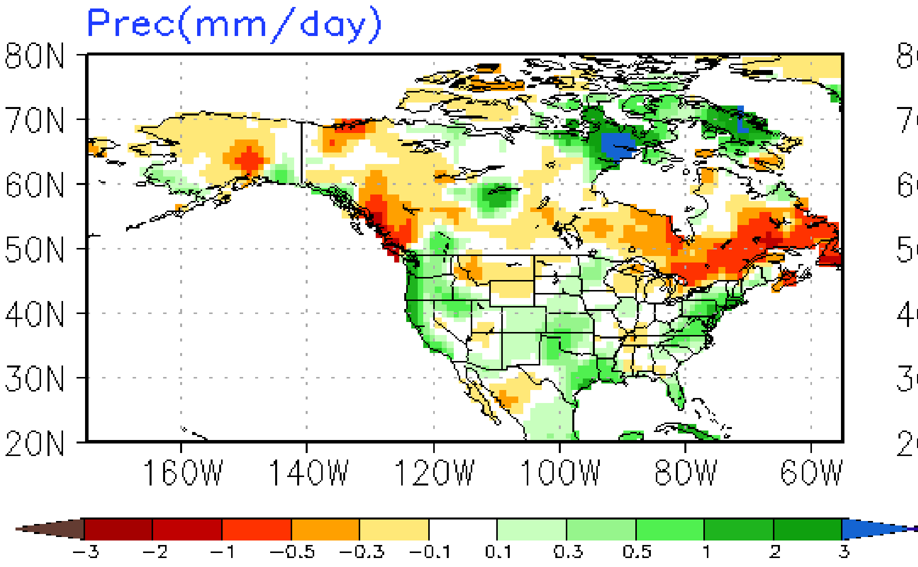
Observed Anomaly DJF2023/2024

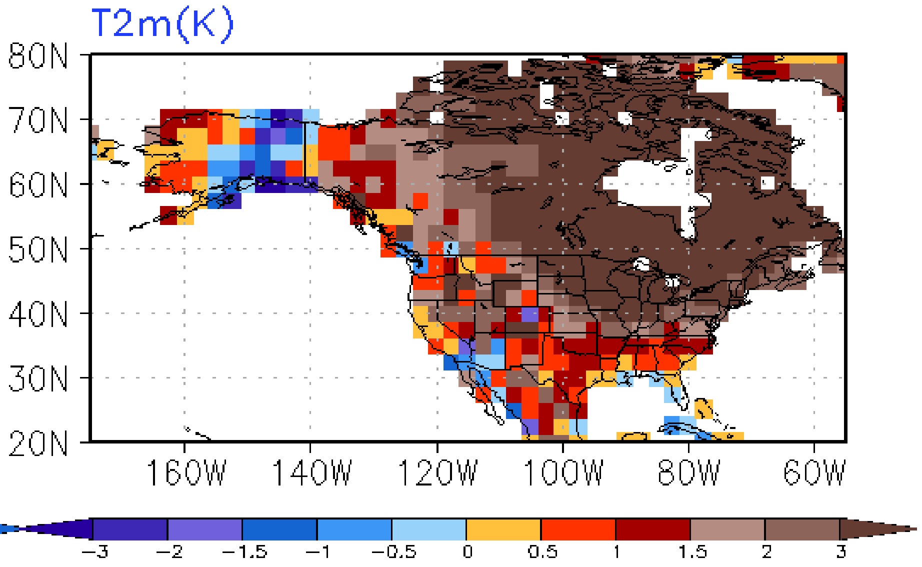


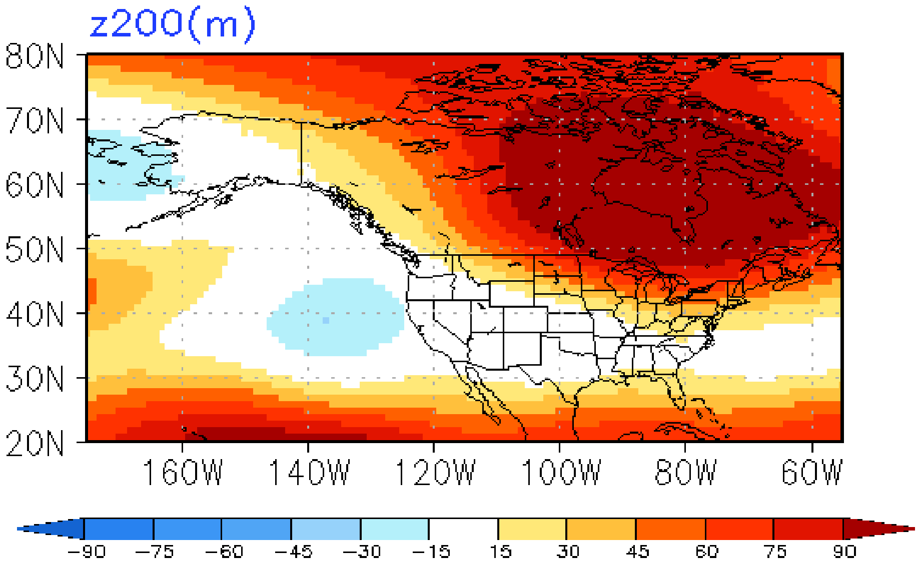
Observed Anomaly DJF2023/2024



Observed Anomaly DJF2023/2024



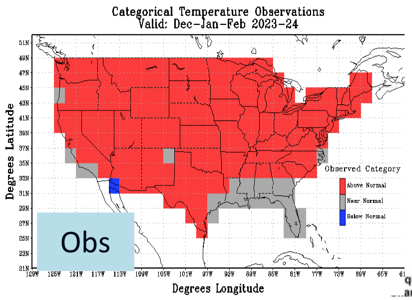


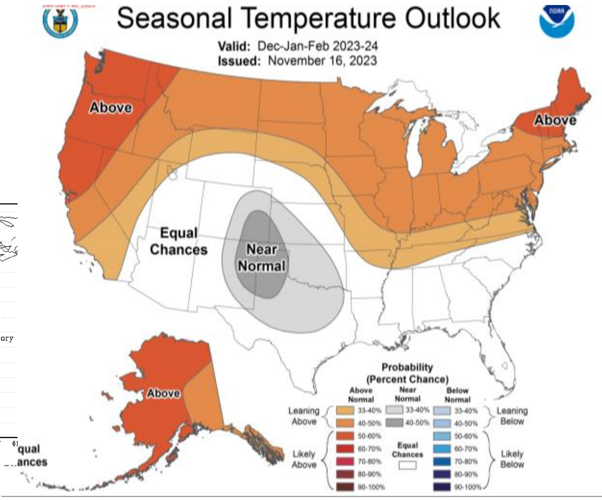


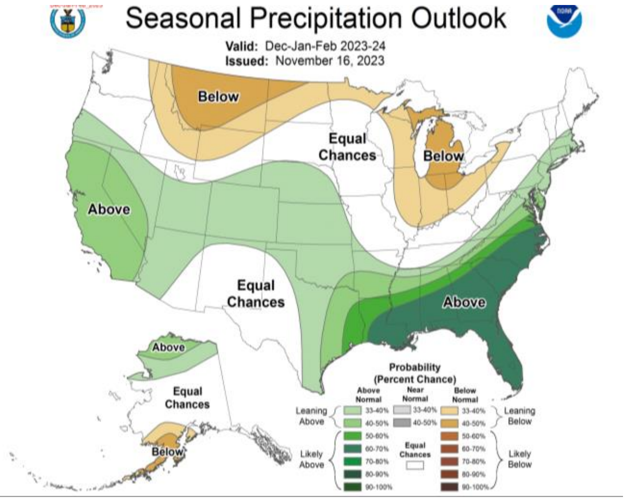
CPC Seasonal Outlooks and NMME Forecasts

CPC

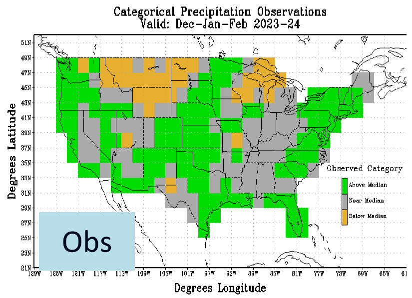
Temp nonEC
HSS=75

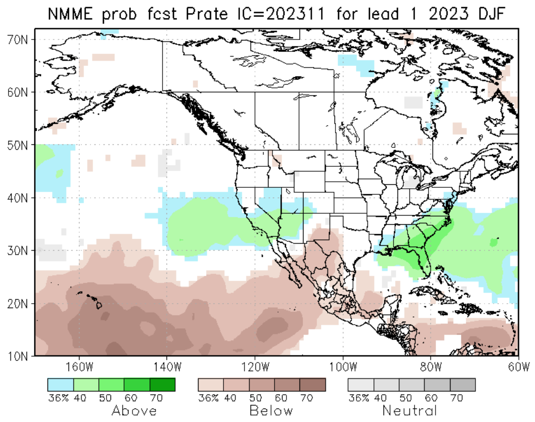




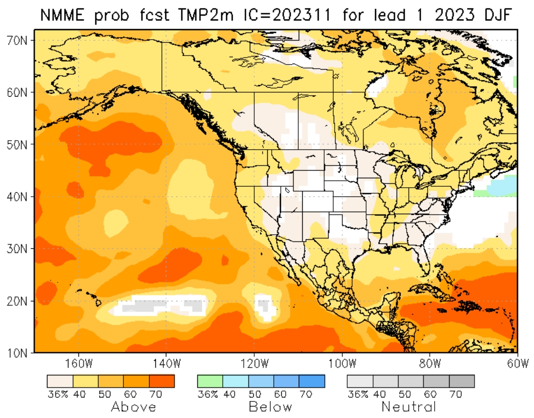


Prec nonEC
HSS=40





NMME



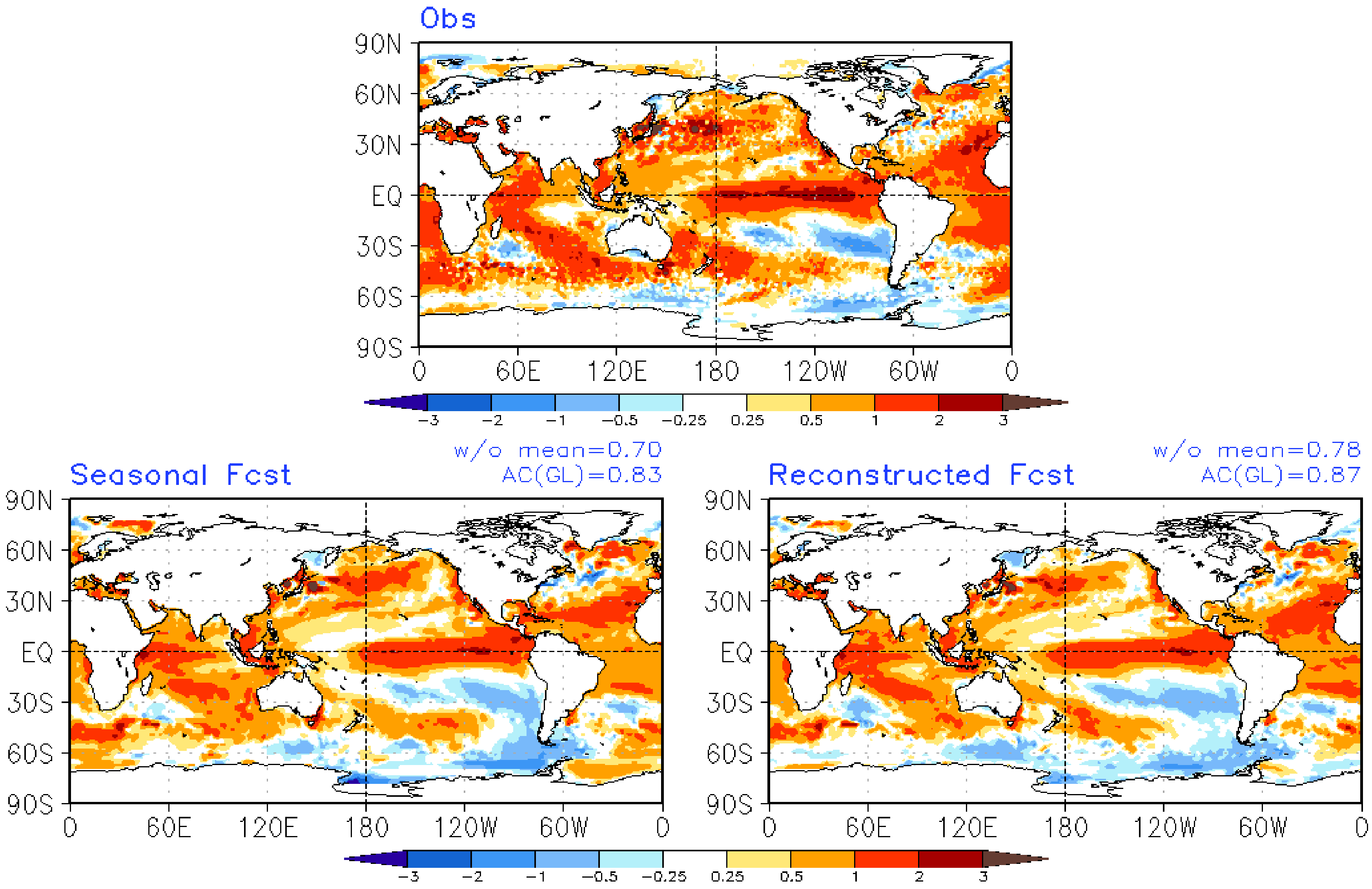
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2023/202311_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

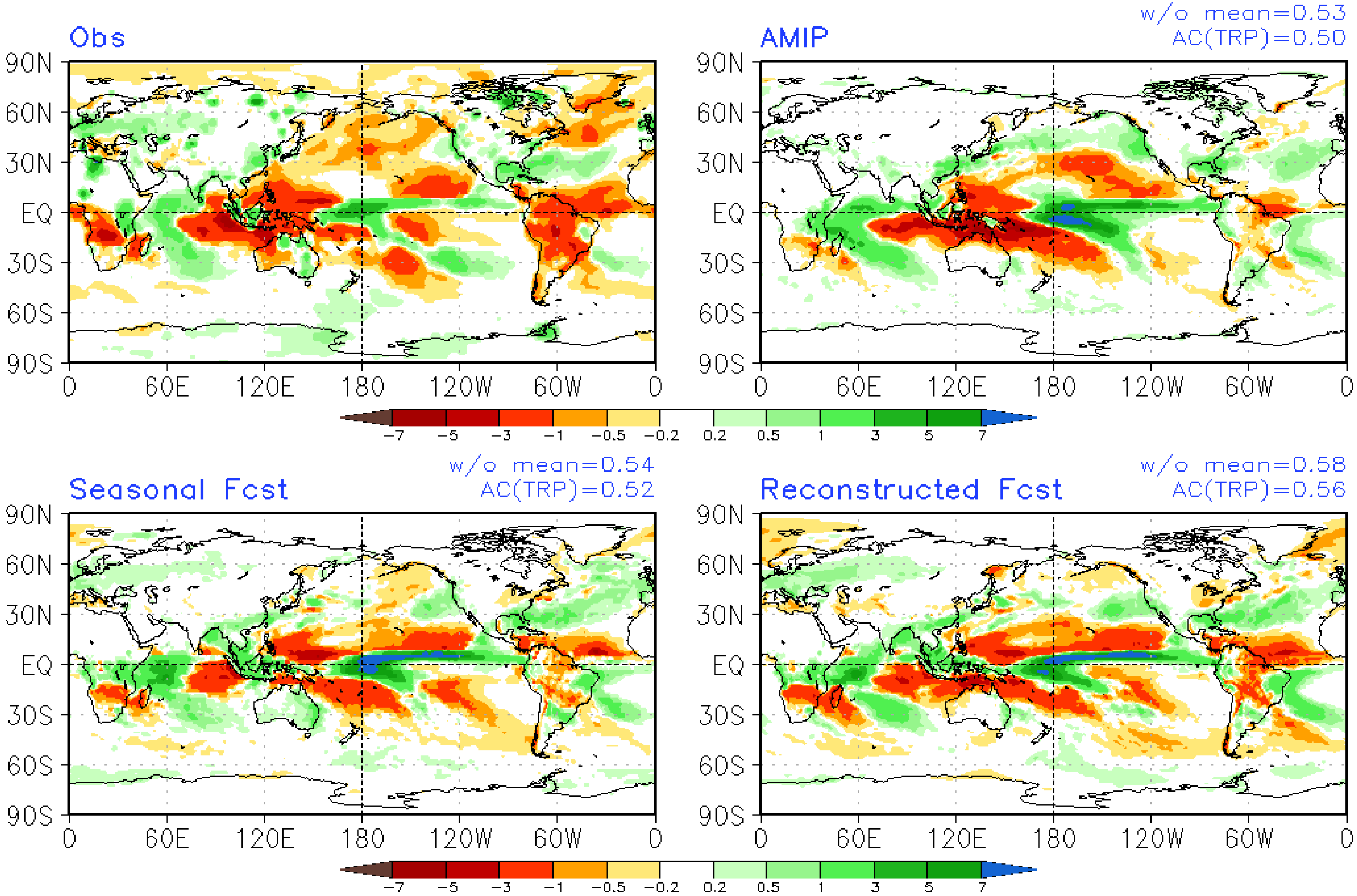
Model Simulated/Forecast Ensemble Average Anomalies

- 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). “w/o mean” is AC with area mean removed.

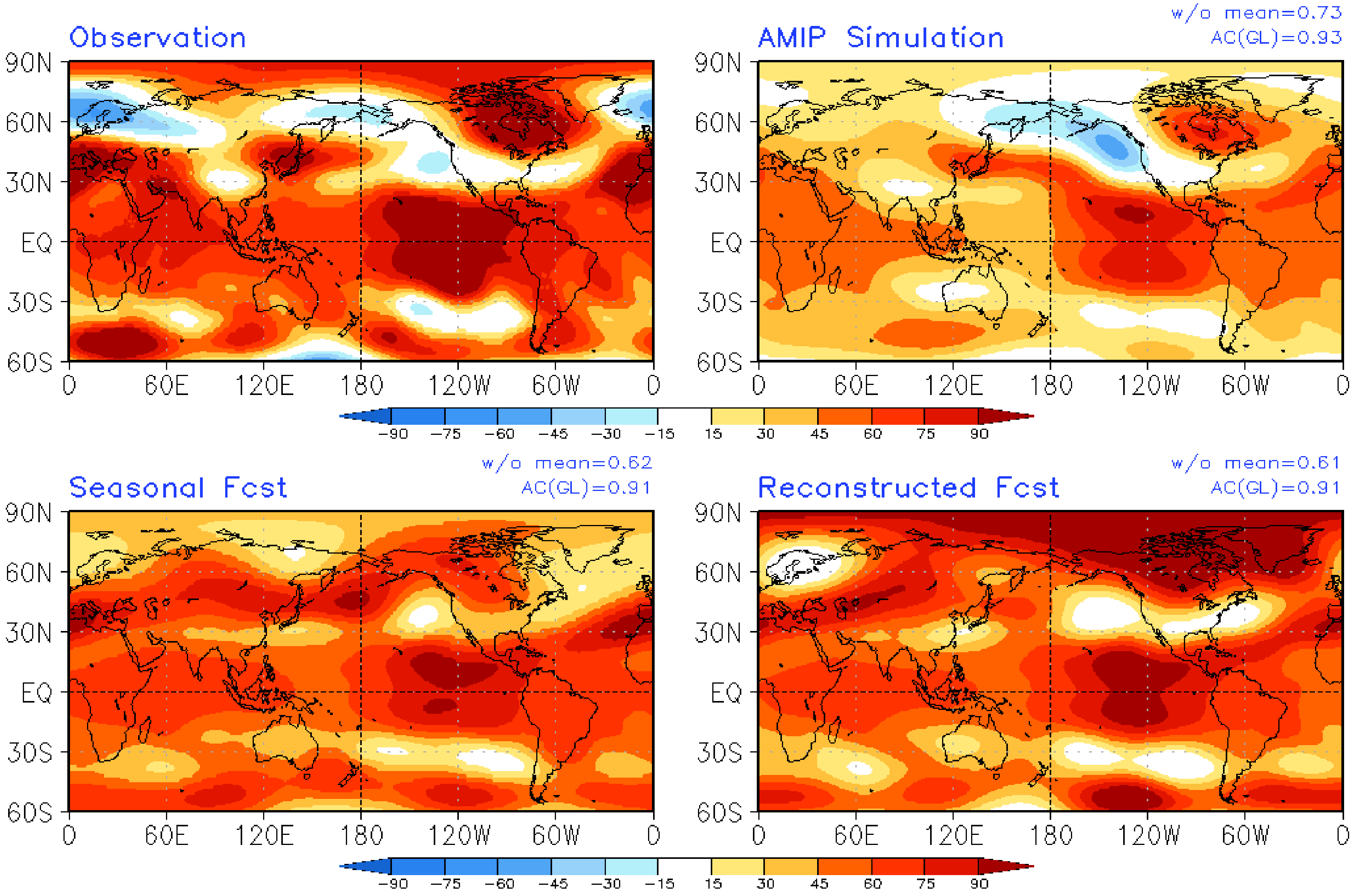
DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



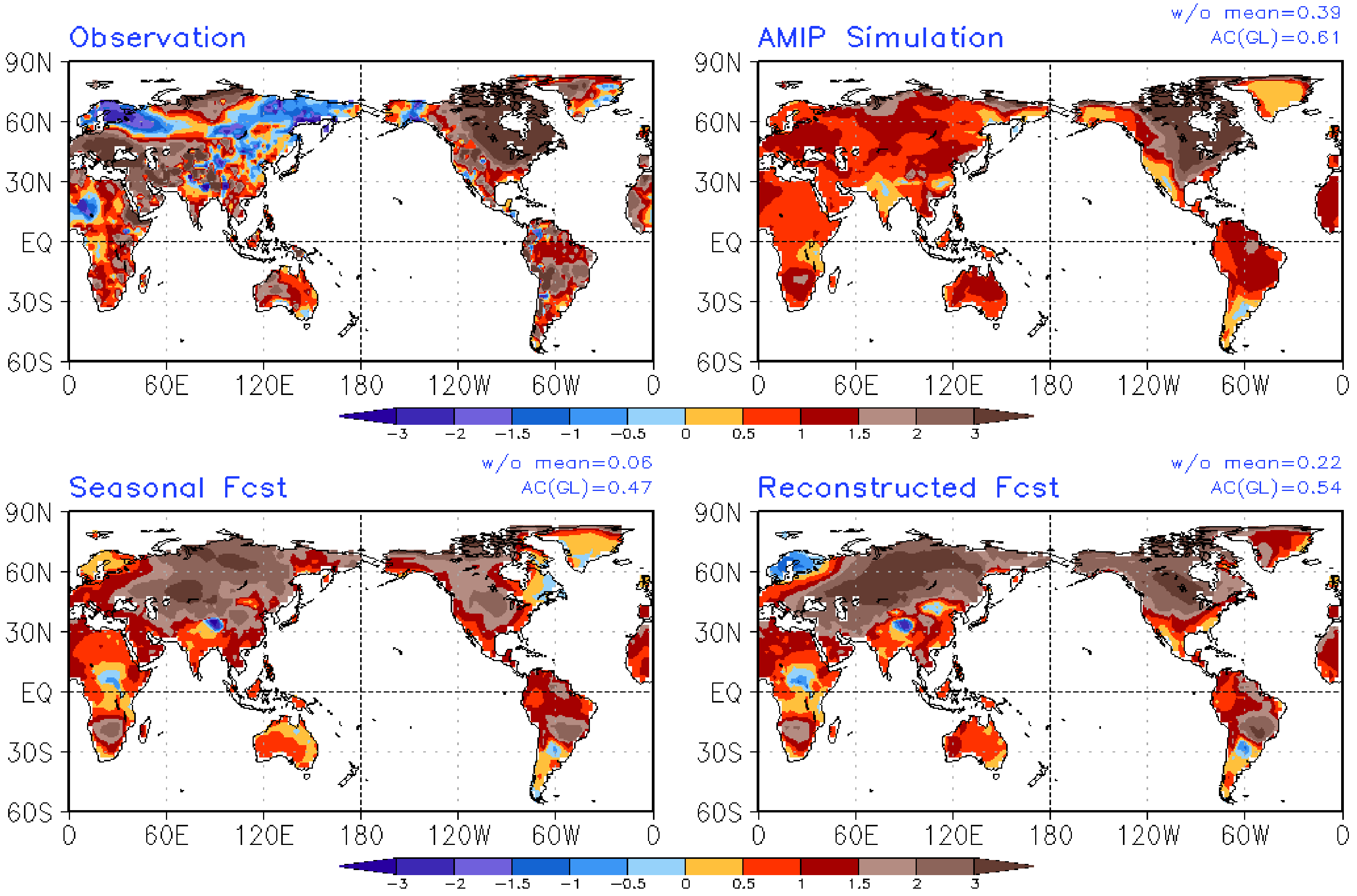
DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



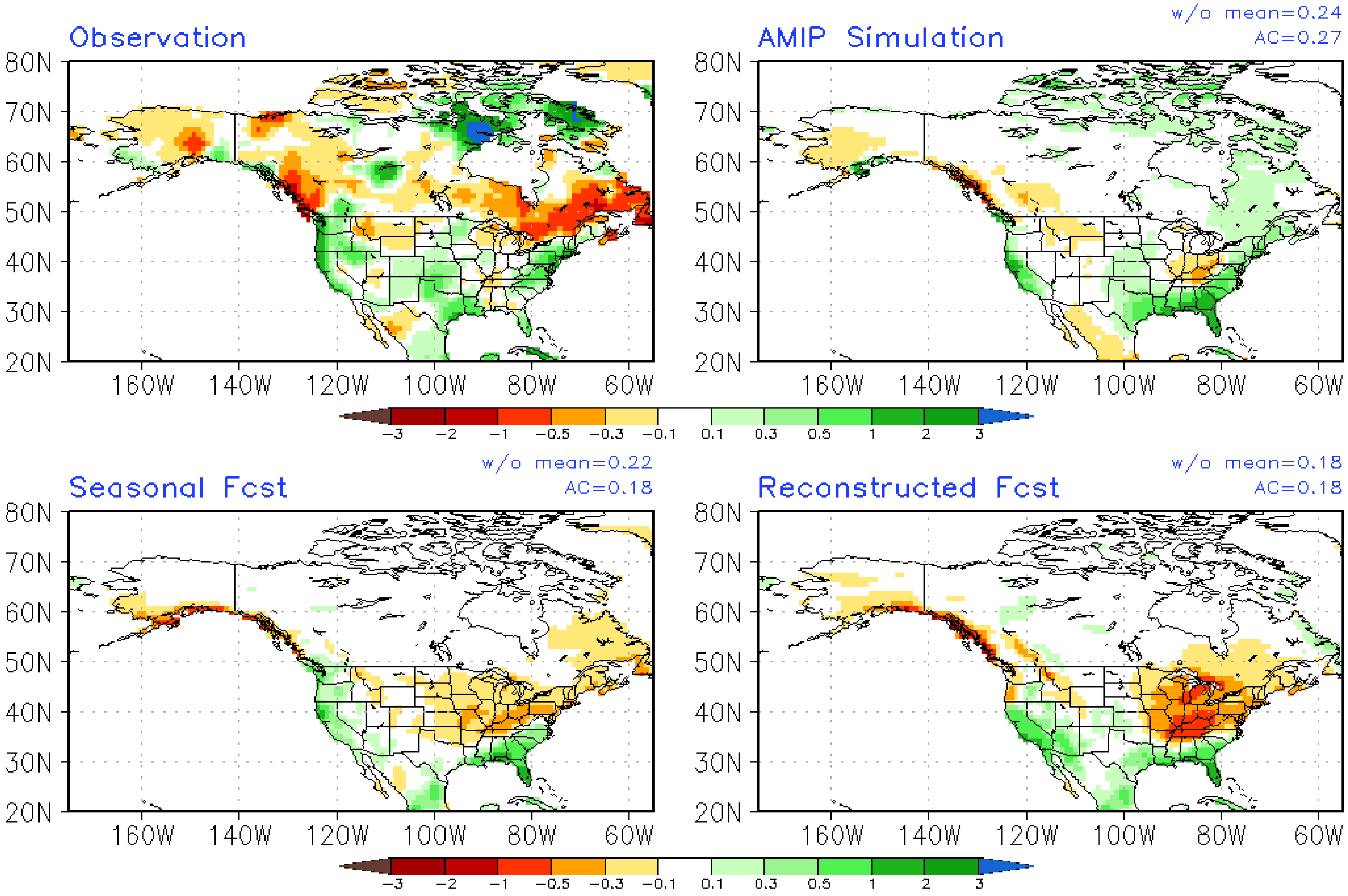
DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



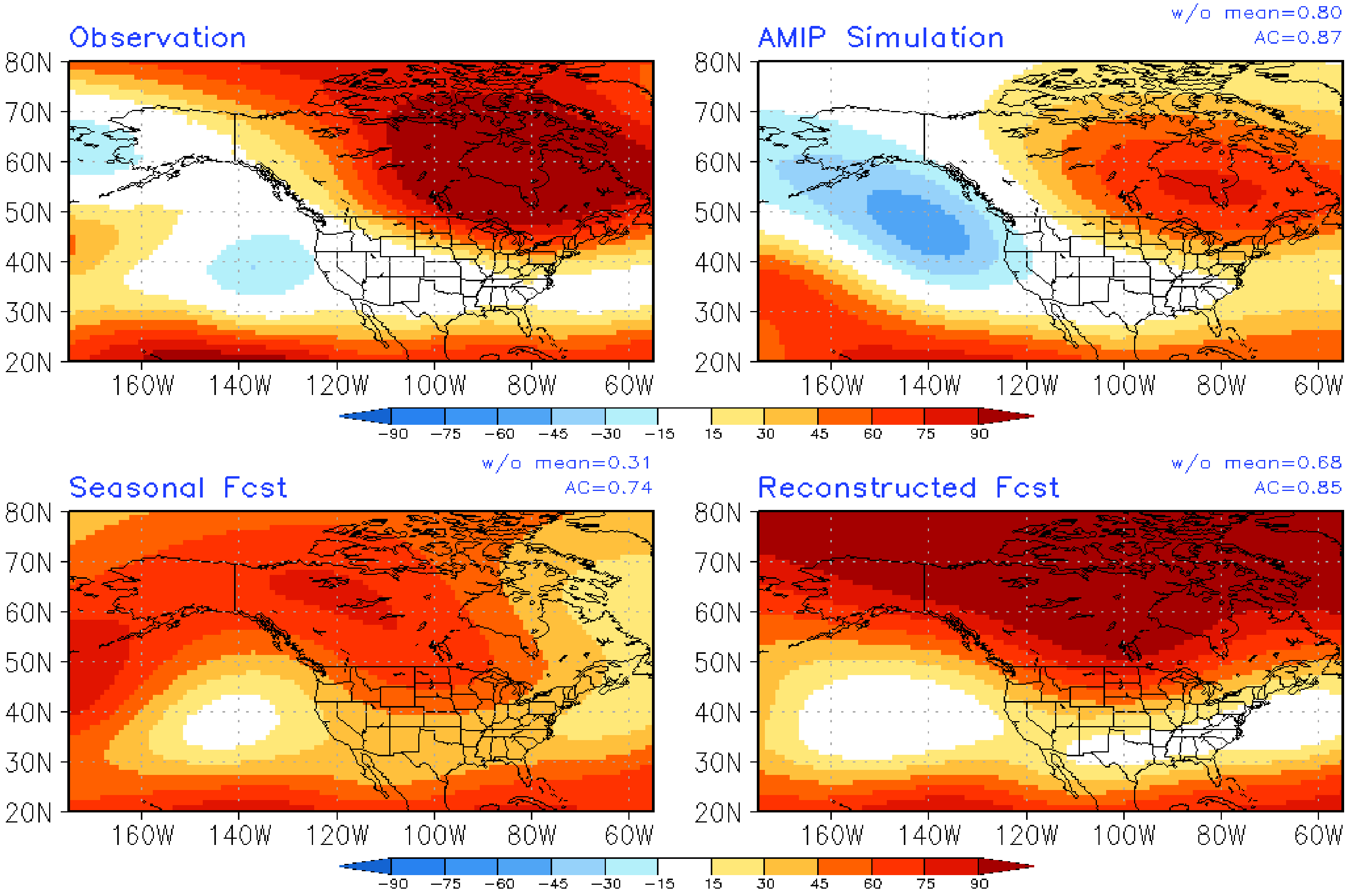
DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



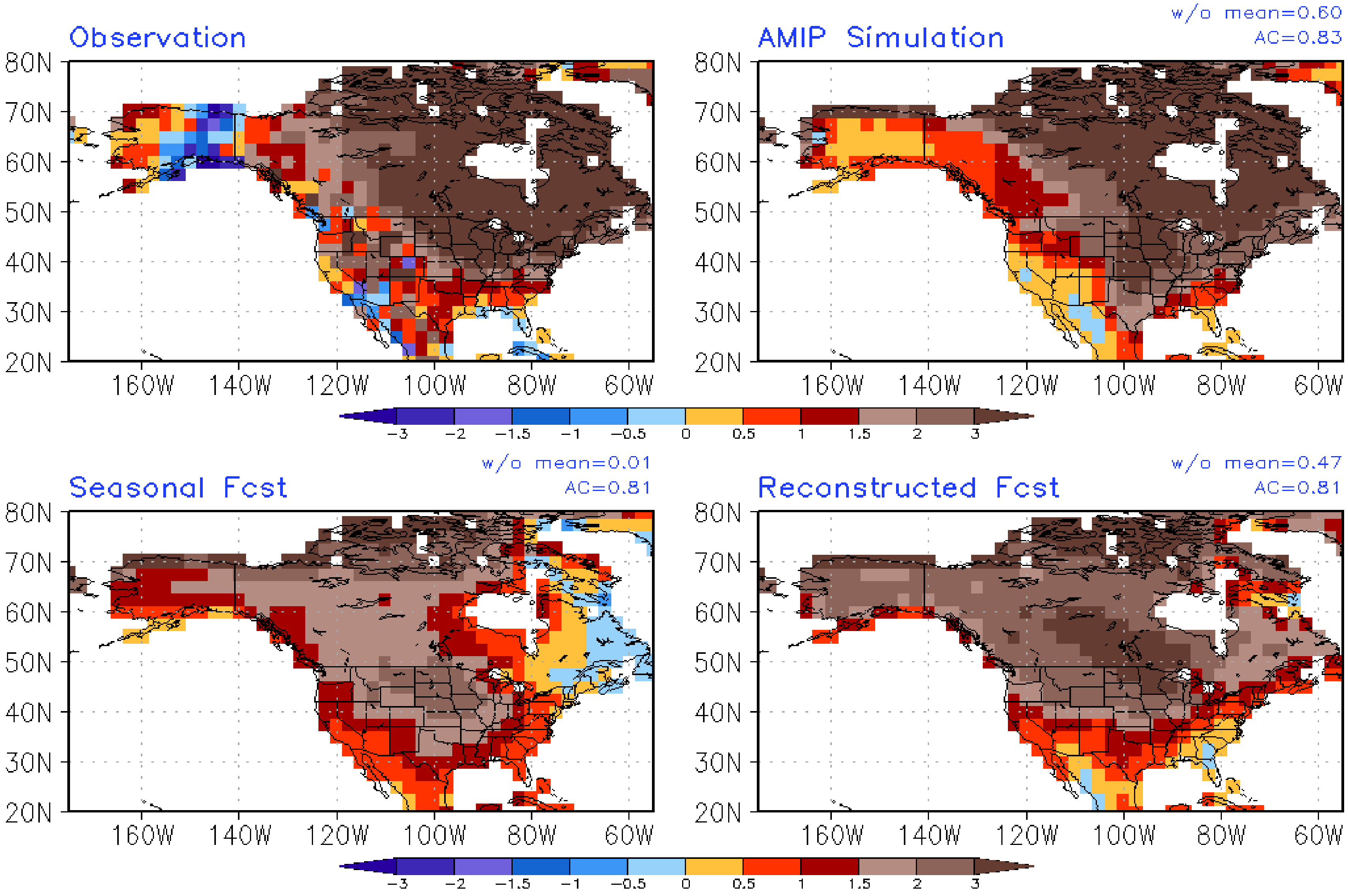
DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



DJF2023/2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

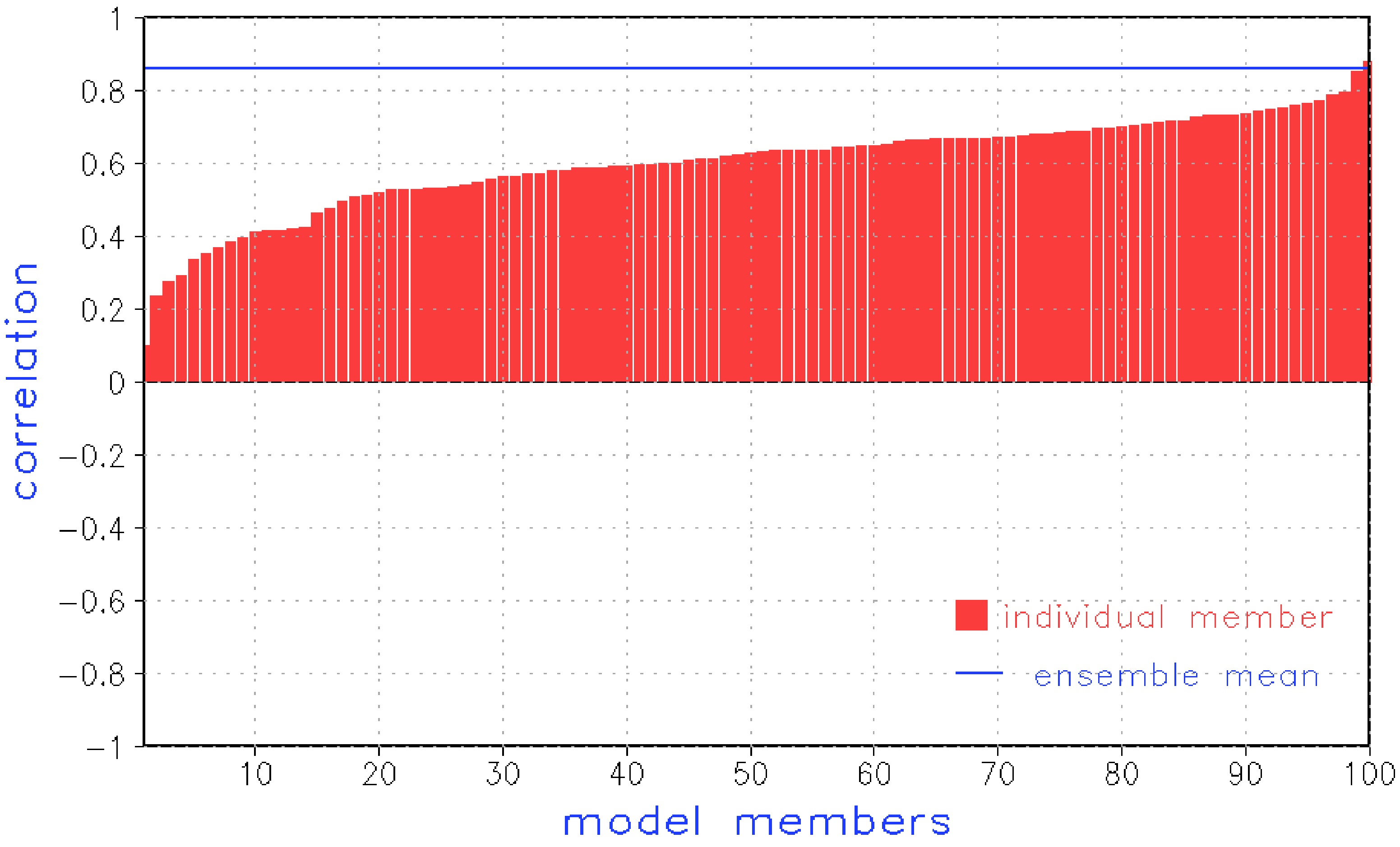


Model Simulated/Forecast Anomalies: Individual Runs

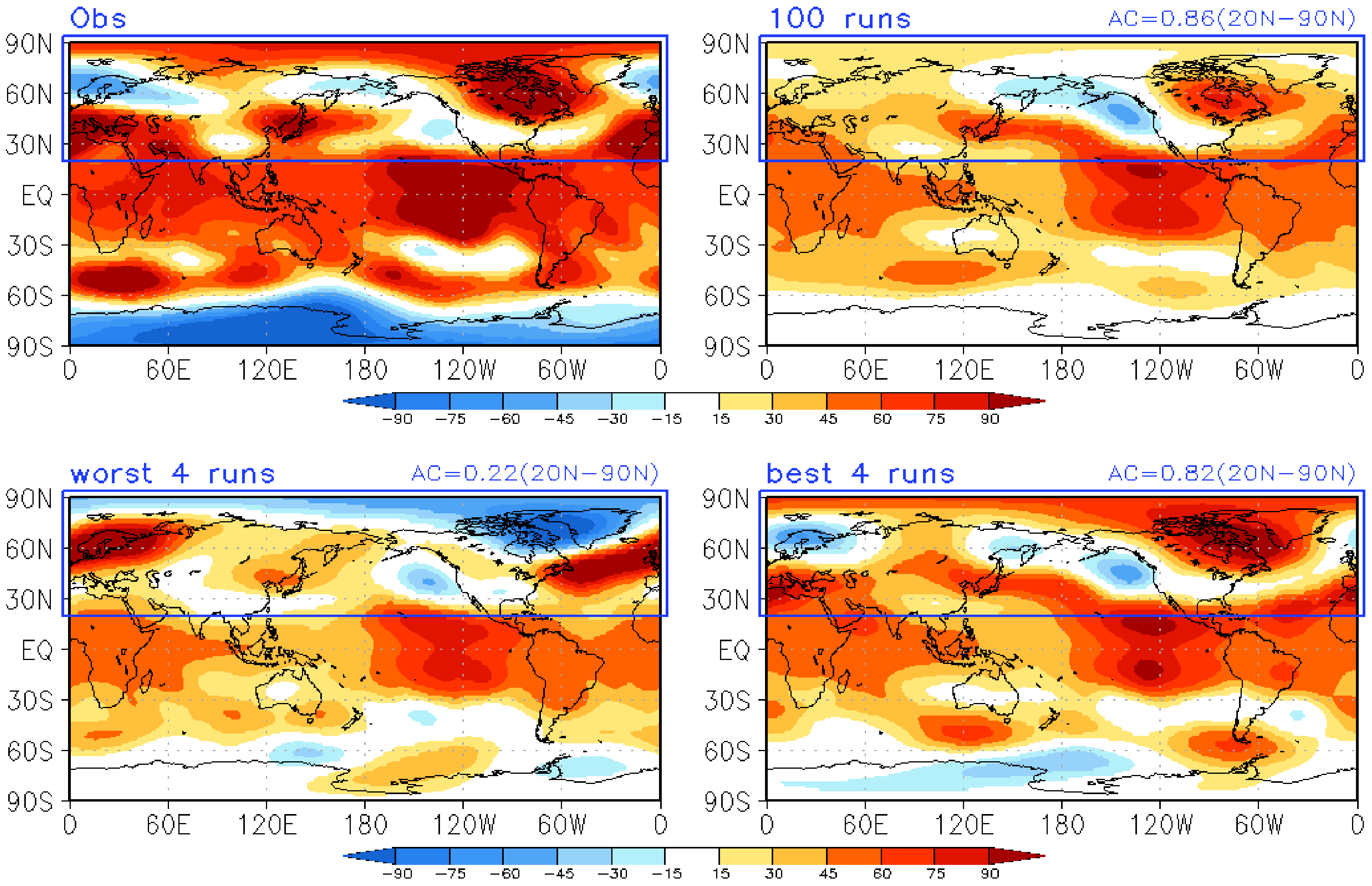
Model Simulated/Forecast Anomalies: Individual Runs

- 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.

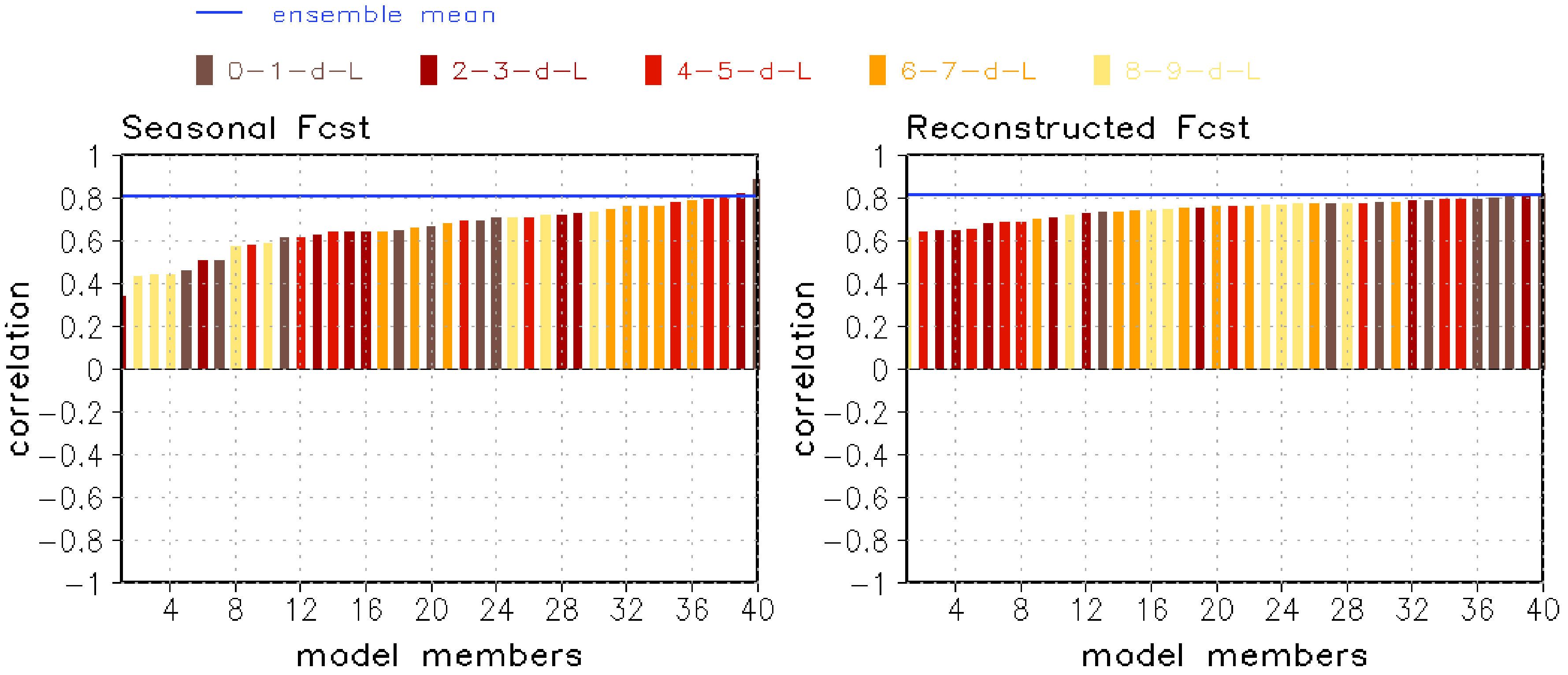
DJF2023/2024 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)



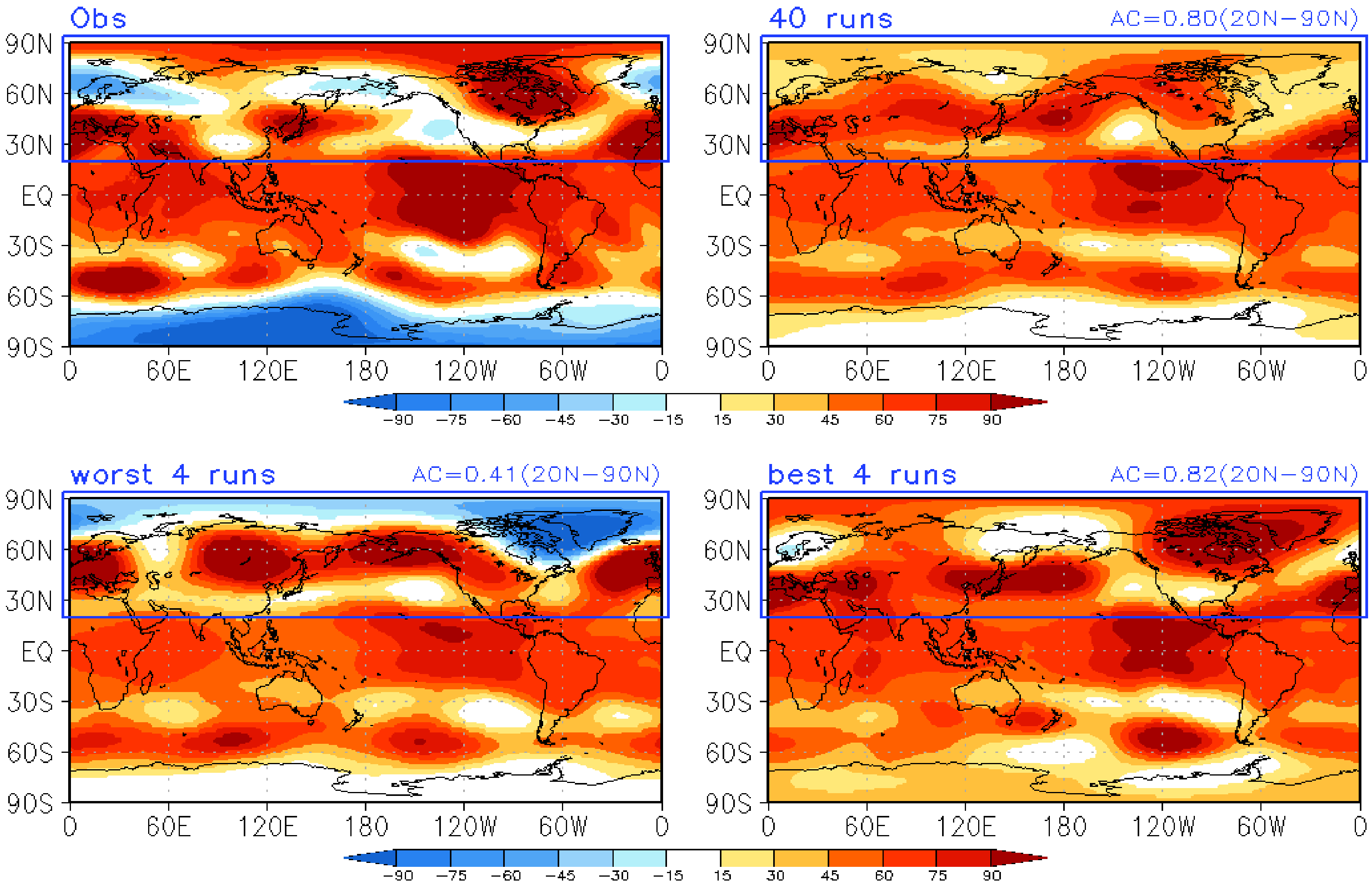
Observed & AMIP Ensemble Mean Anomalies
DJF2023/2024 z200(m) 100 runs/worst 4 runs/best 4 runs



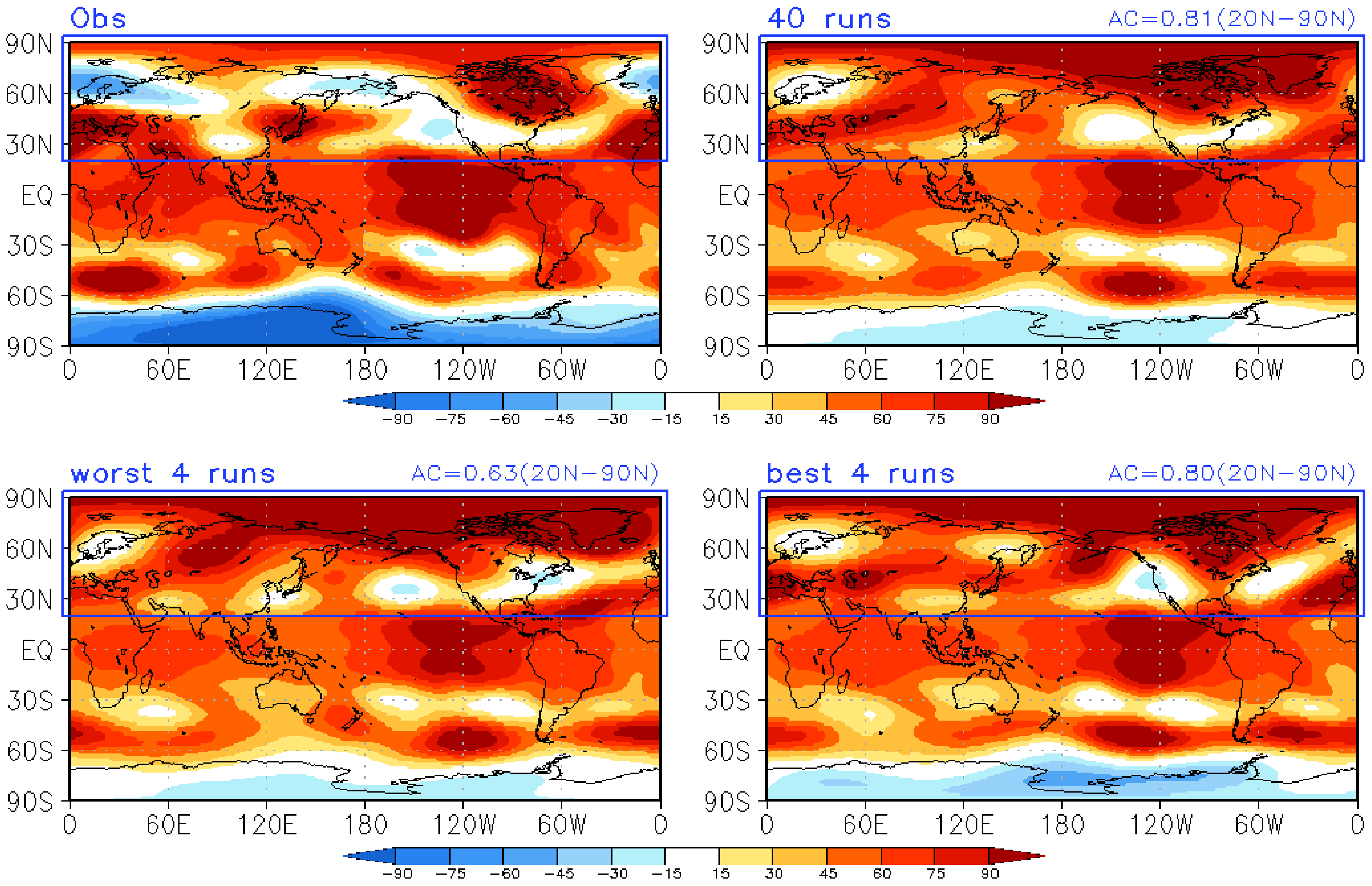
DJF2023/2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



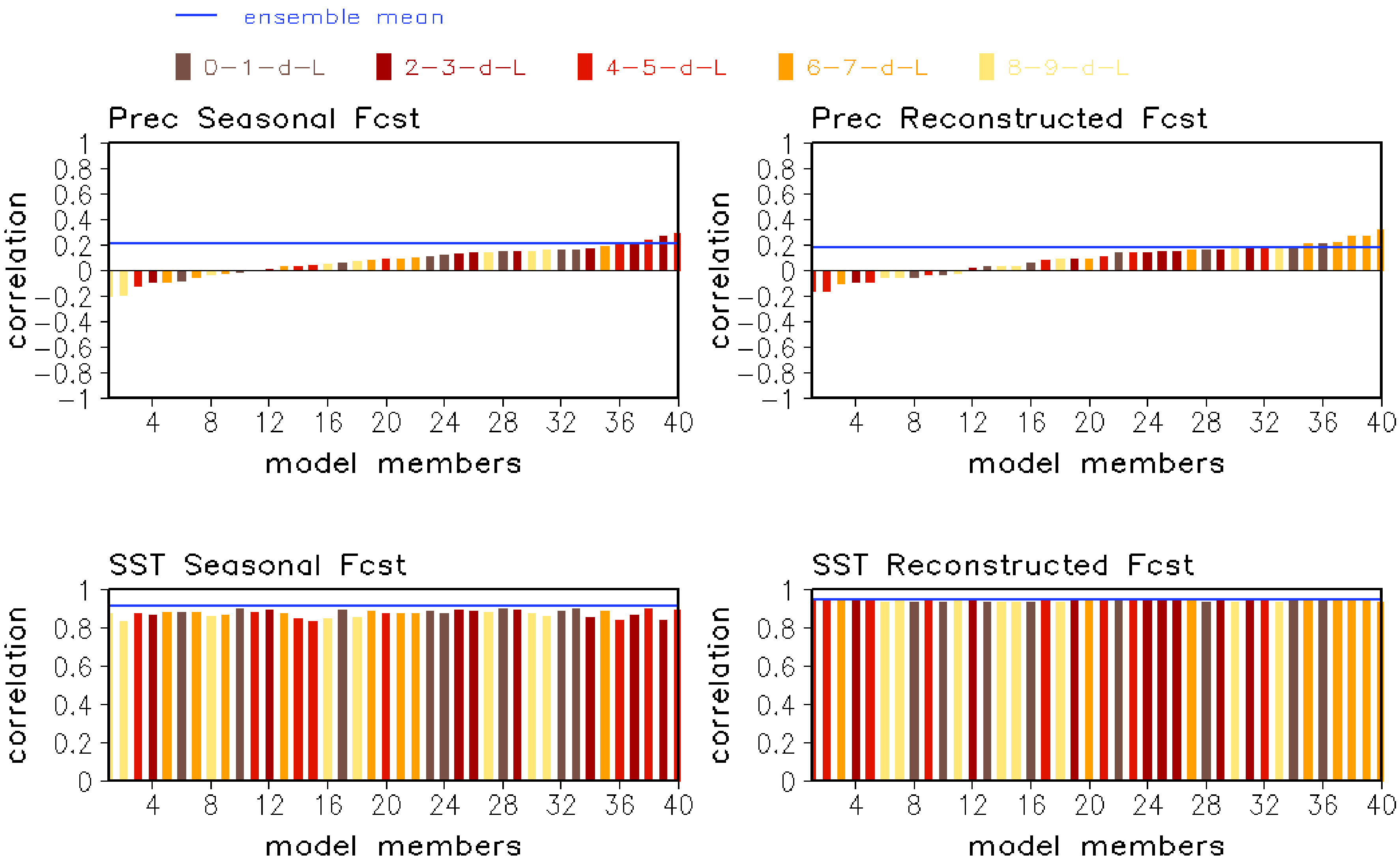
Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

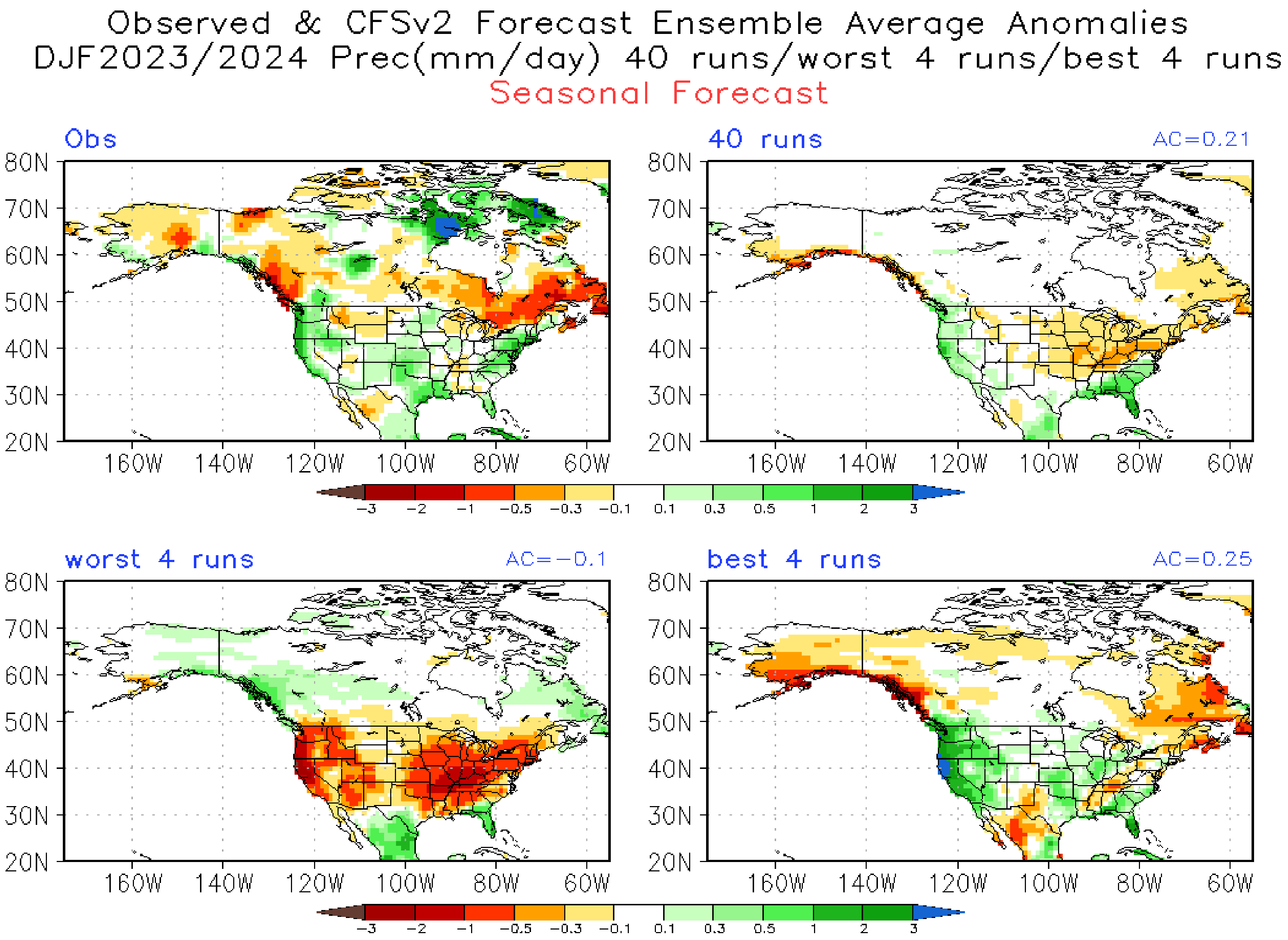


Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

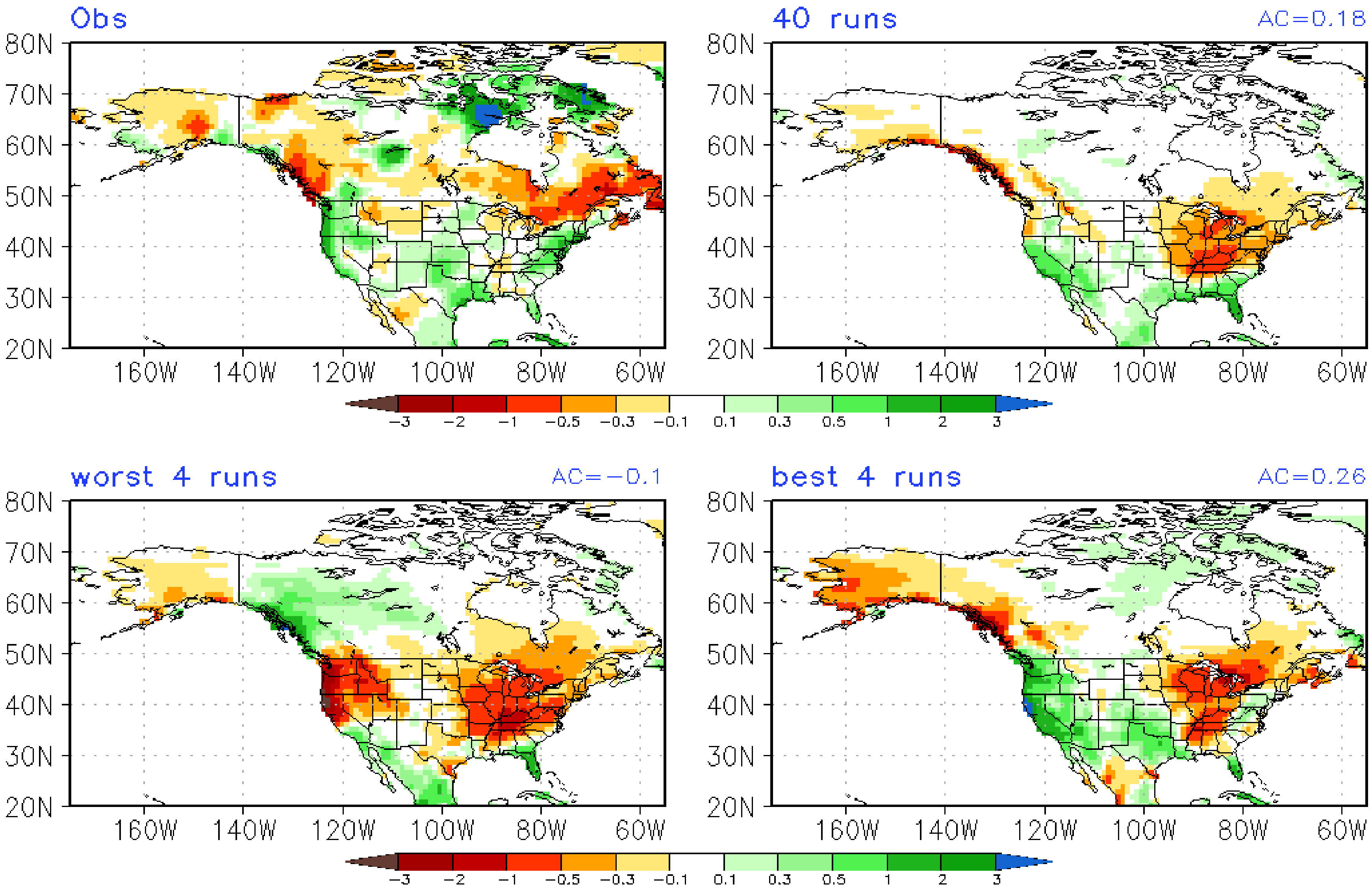


DJF2023/2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

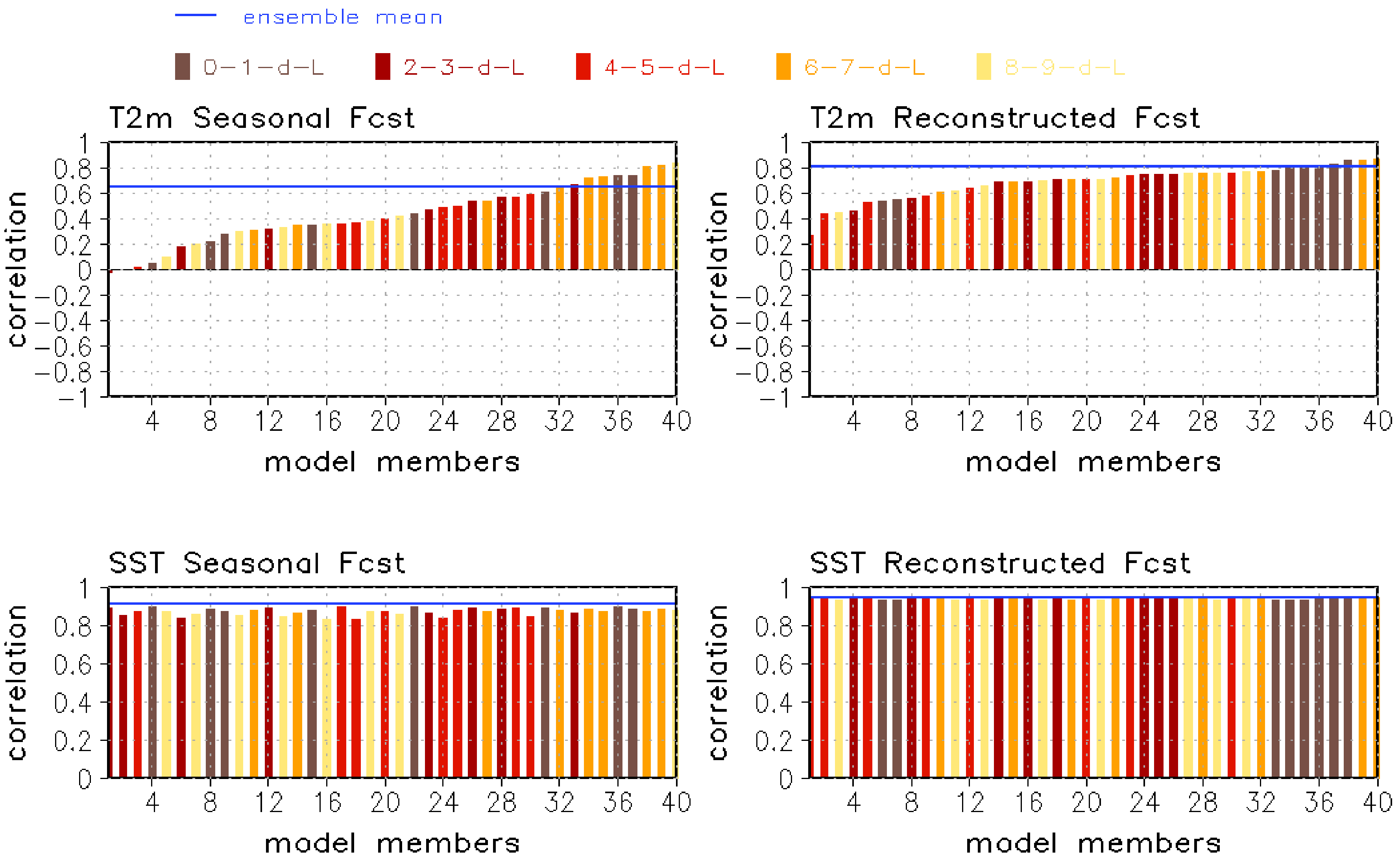



Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast
Obs
40 runs
AC=0.21
worst 4 runs
AC=−0.1
best 4 runs
AC=0.25
80N
70N
60N
50N
40N
30N
20N
160W
140W
120W
100W
80W
60W
−3 −2 −1 −0.5 −0.3 −0.1 0.1 0.3 0.5 1 2 3

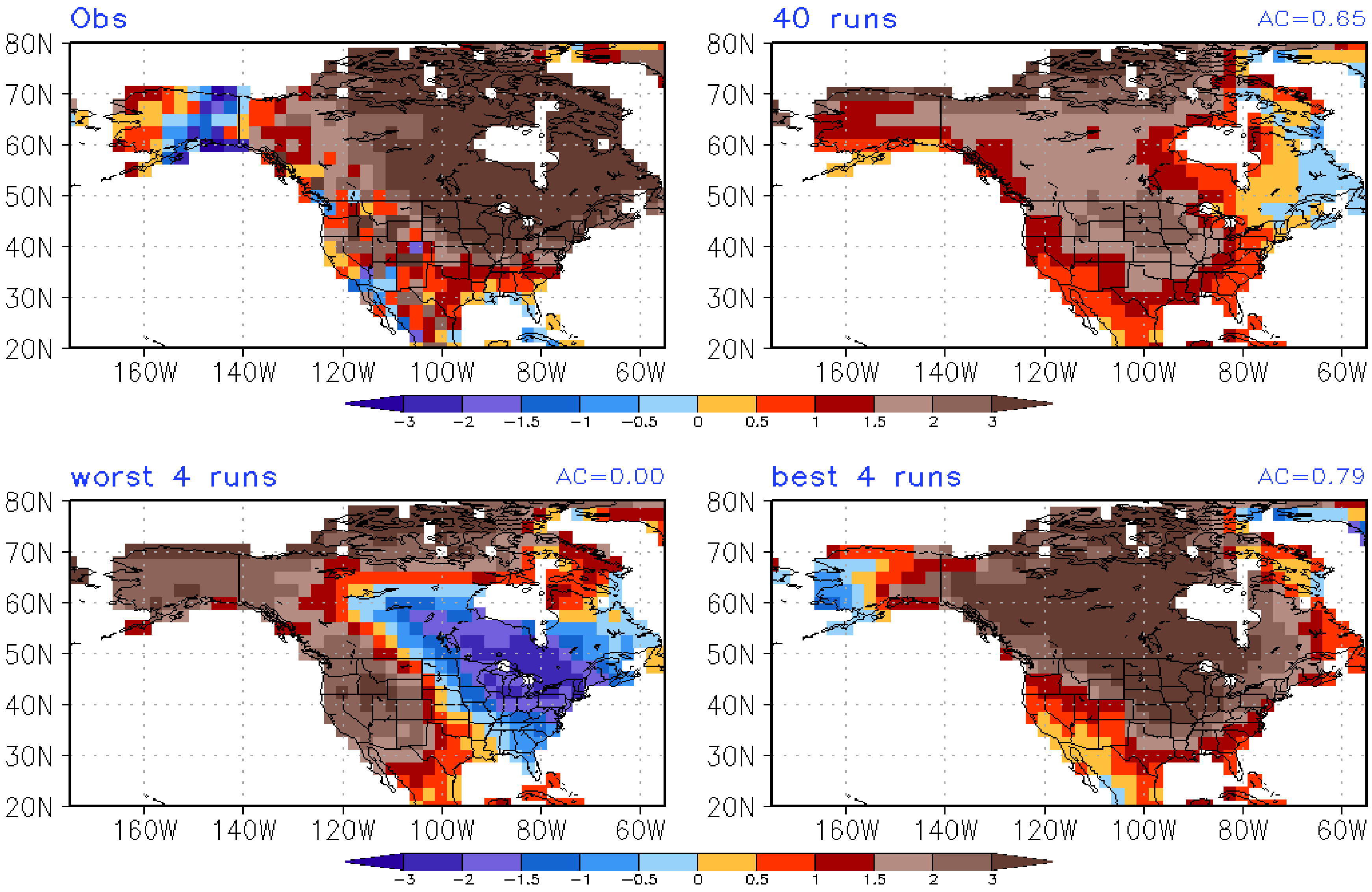
Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



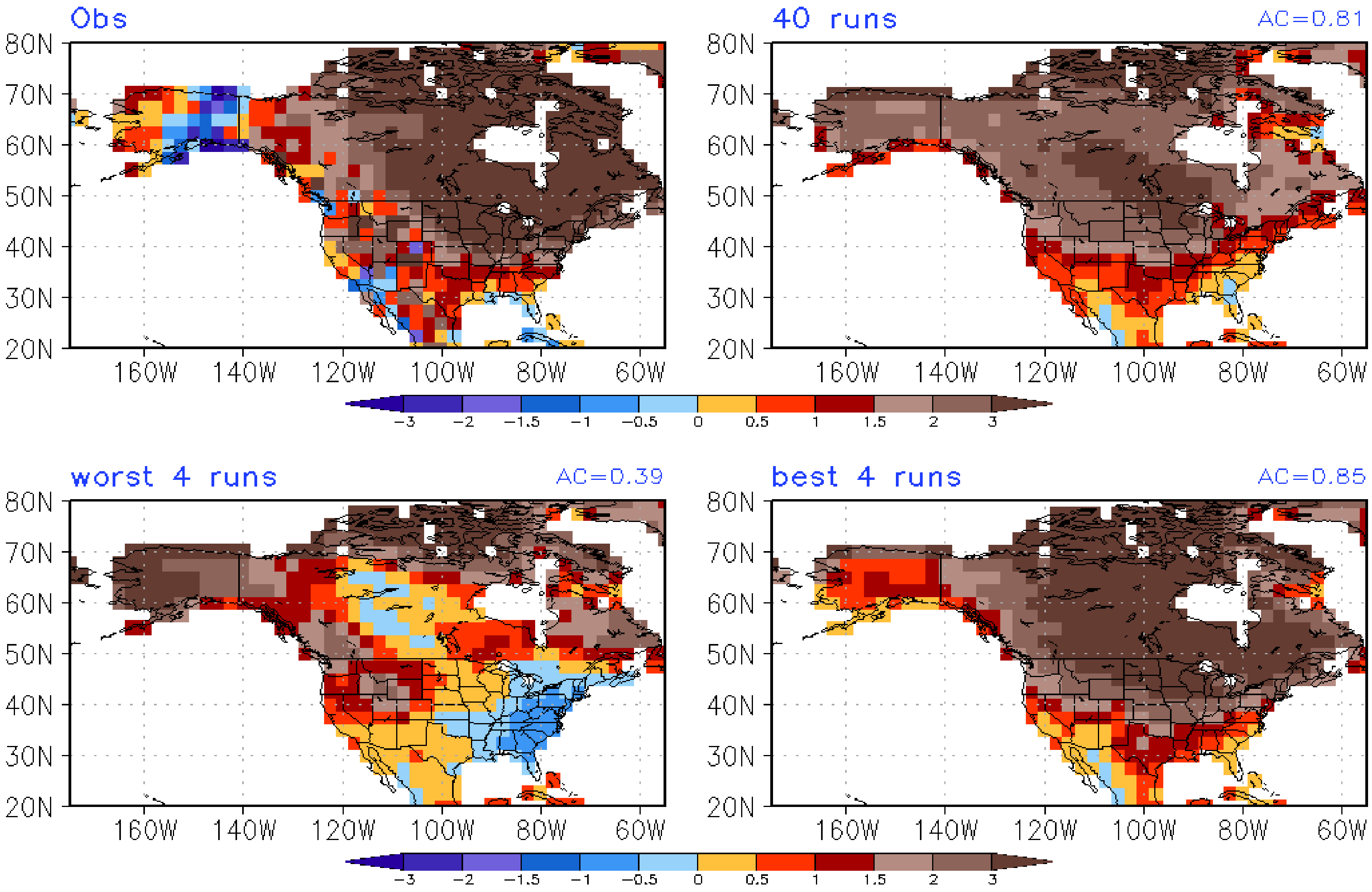
DJF2023/2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



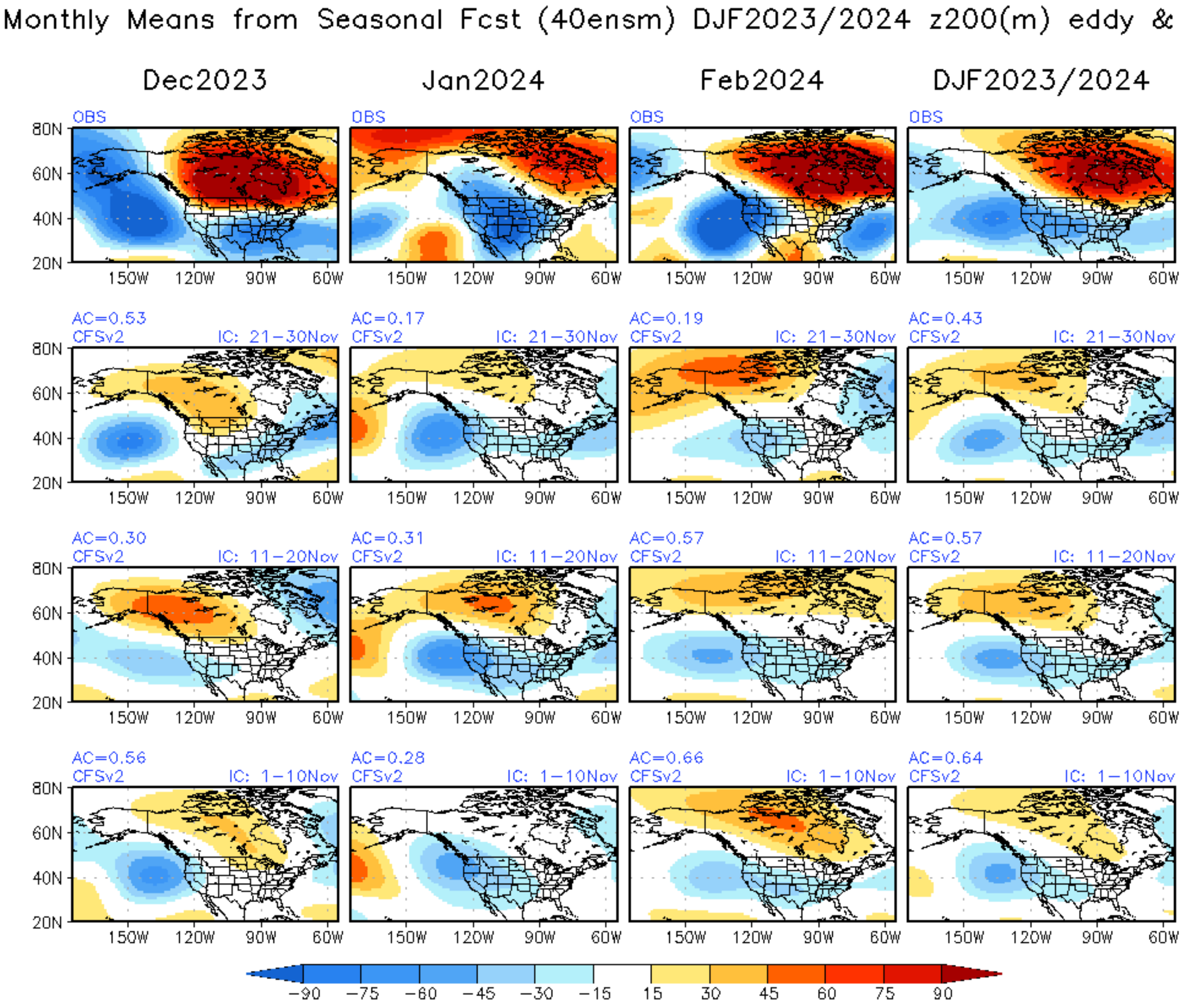
Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2023/2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

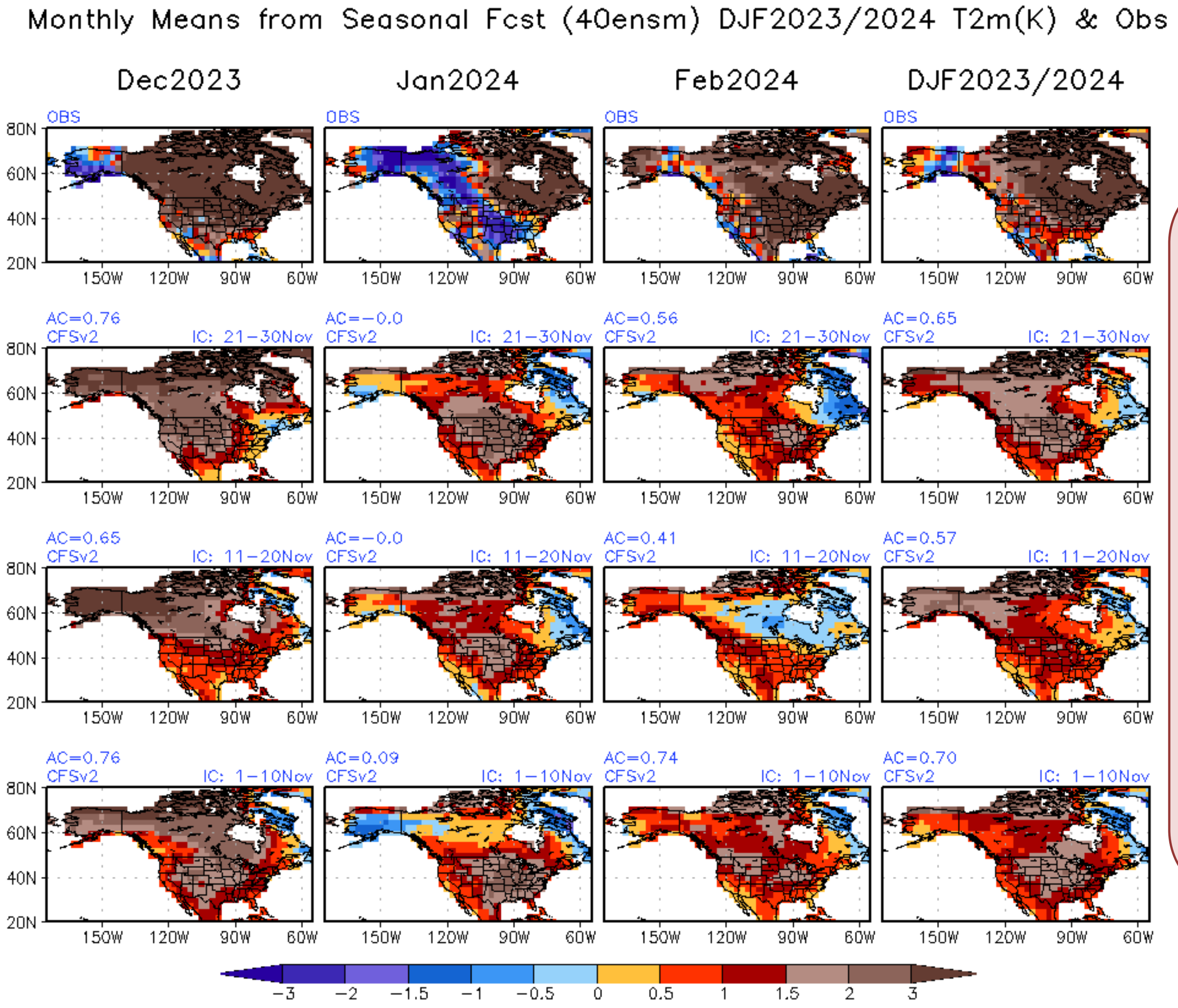


Top row: Observed anomaly.

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 <u>Seasonal Forecast</u>

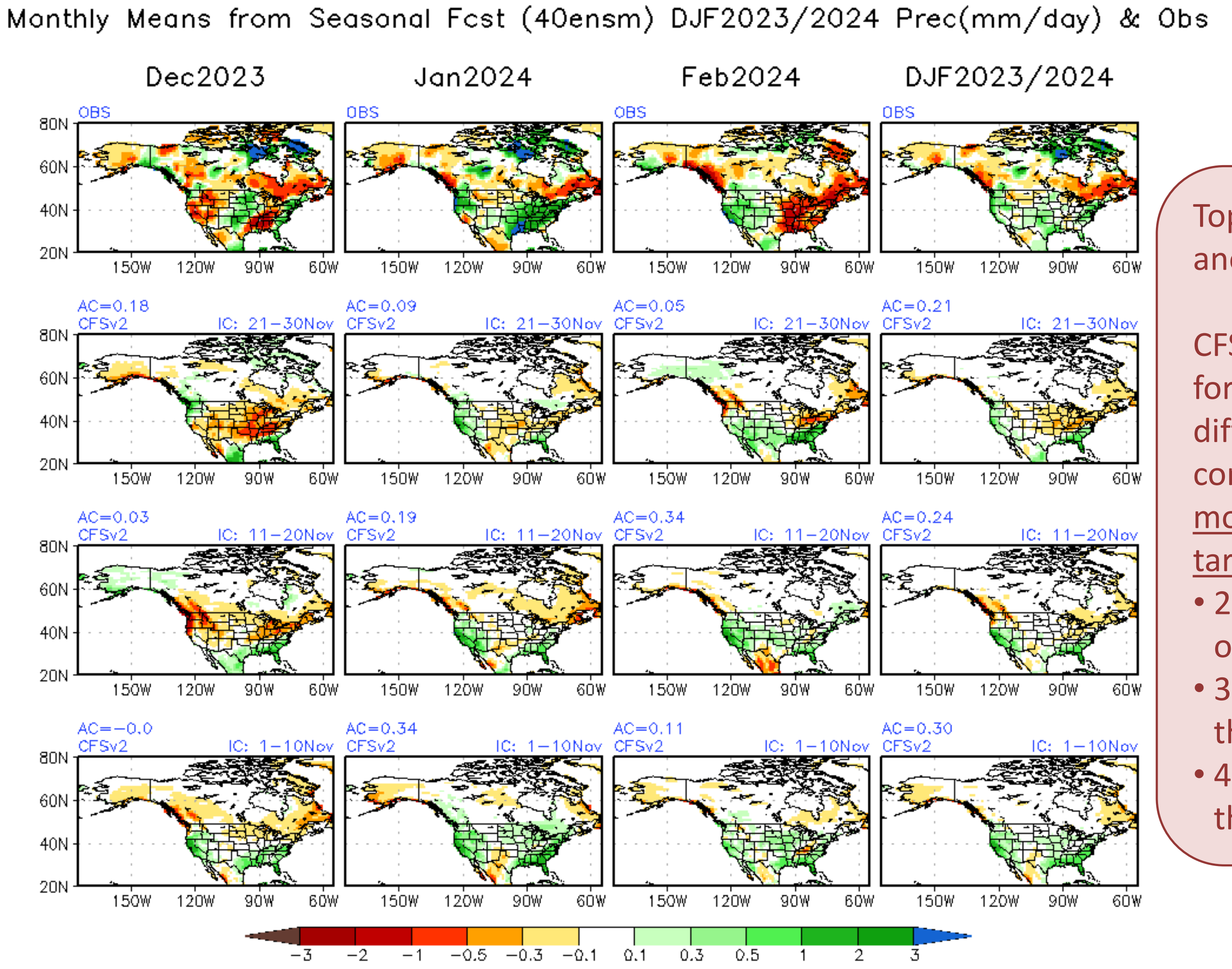


Top row: Observed anomaly.

CFSv2 seasonal forecasts from different initial conditions in the <u>month prior</u> to the <u>target season</u>:

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

Prec(mm/day) Monthly Means from Seasonal Forecast

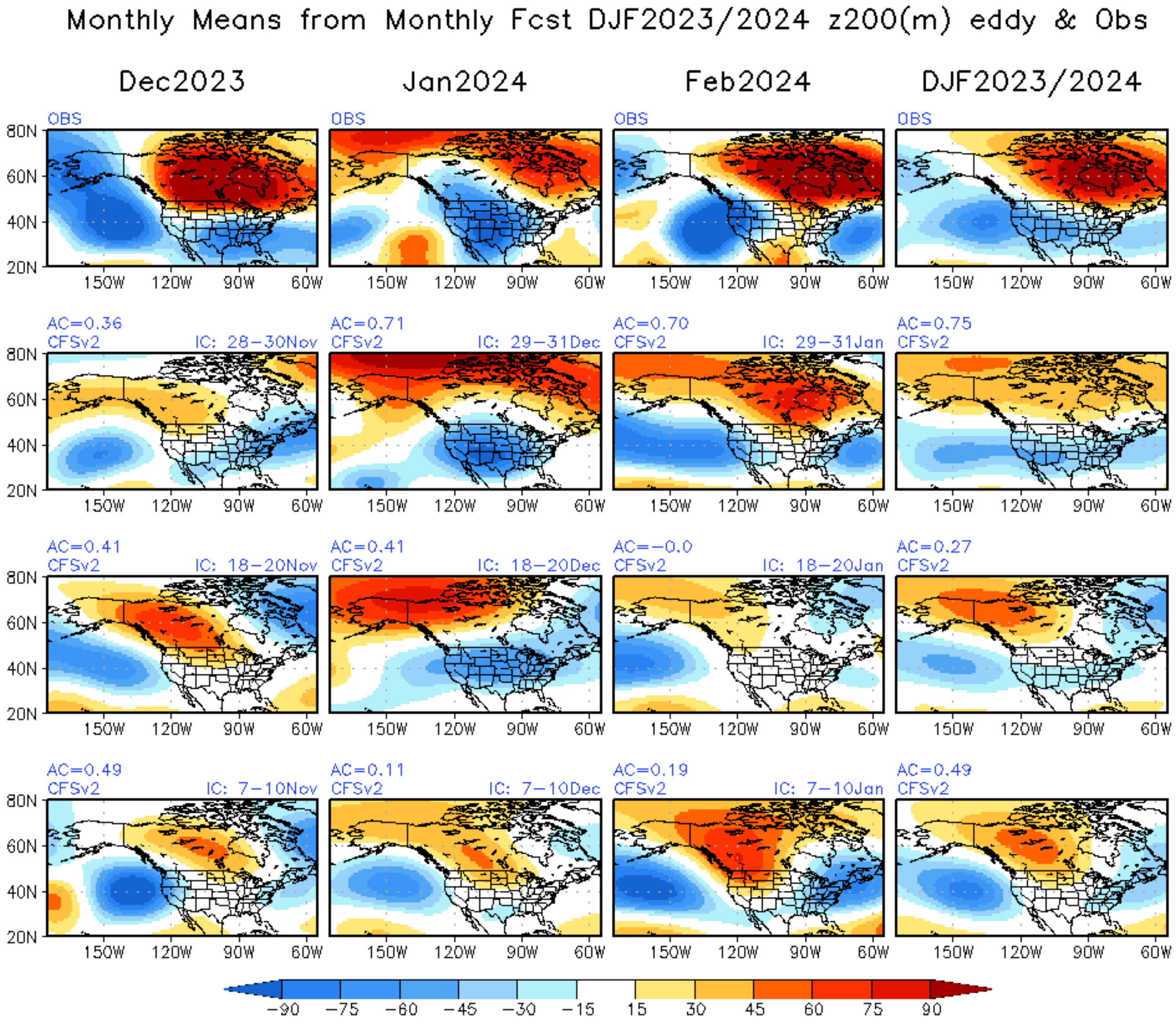


Top row: Observed anomaly.

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.

z200(m) Monthly Means from Monthly Forecast

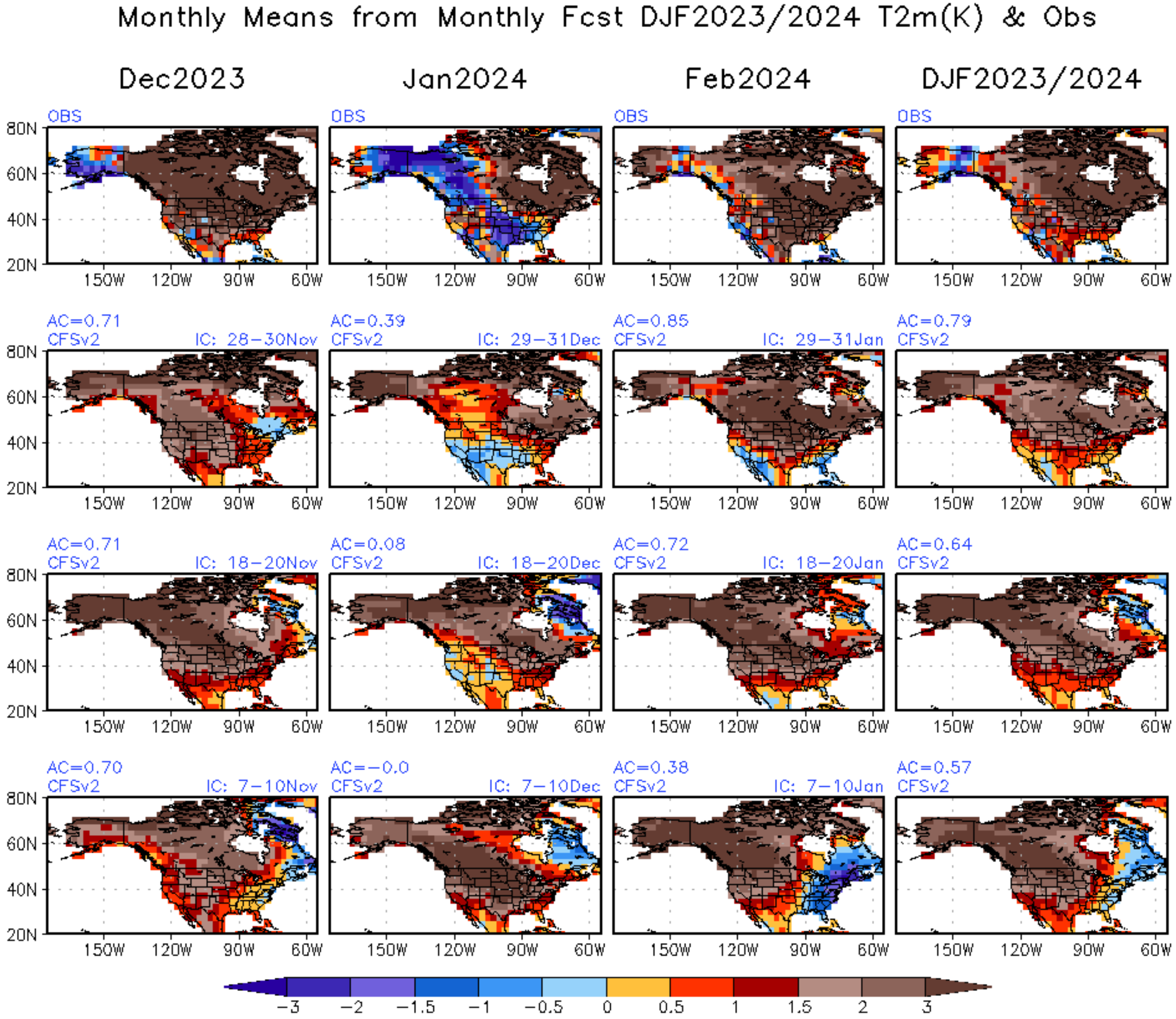


Top row: Observed anomaly.

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



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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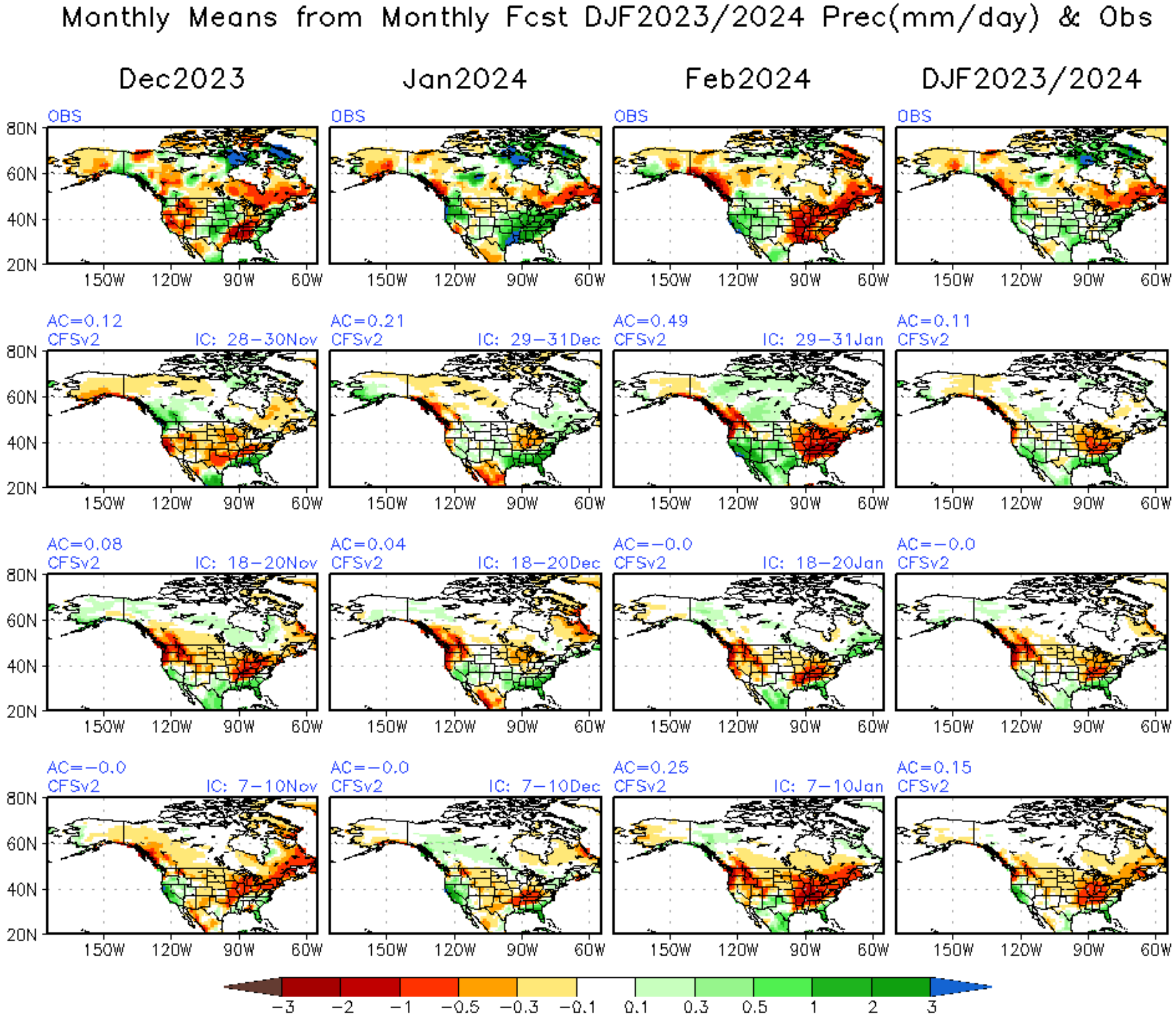
- 4th row: 7th – 10th of the prior month.

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



Top row: Observed anomaly.

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

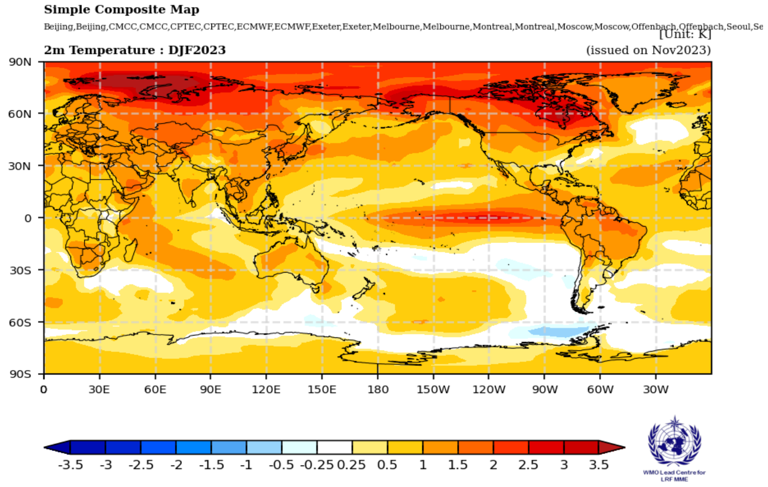
- 2^{nd} row: last 3 days of the prior month.
- 3^{rd} row: 18^{th} – 20^{th} of the prior month.
- 4^{th} row: 7^{th} – 10^{th} of the prior month.

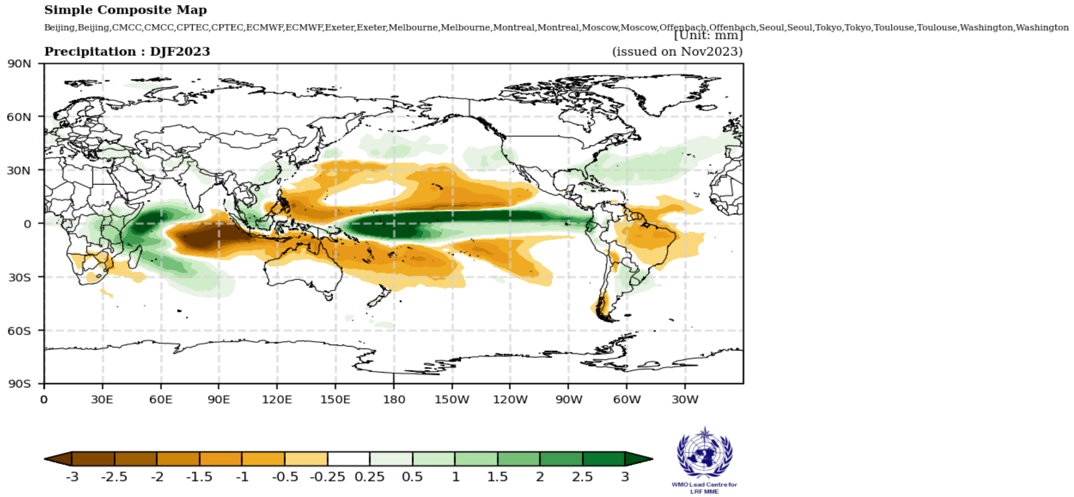
Seasonal Forecasts from Multi-Model Ensemble Systems

- 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/

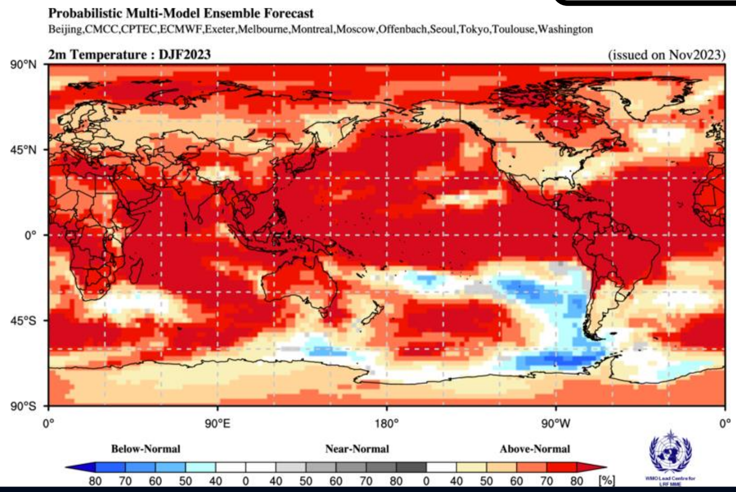
LC-LRFMM Seasonal Forecasts
(https://www.wmolc.org/)

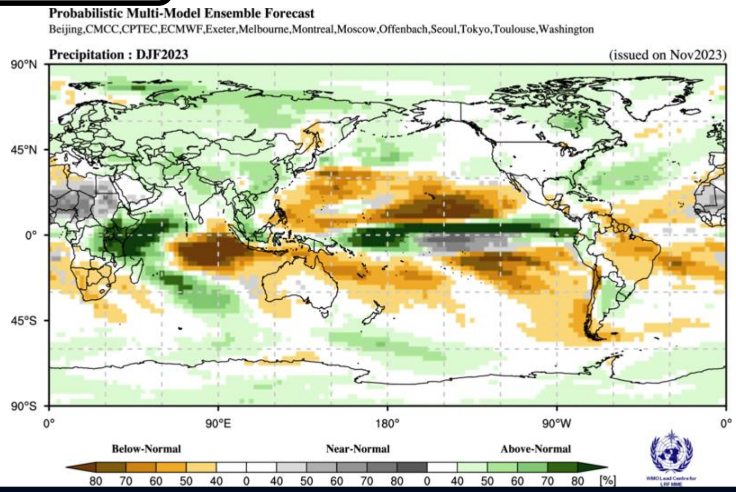
Ensemble means





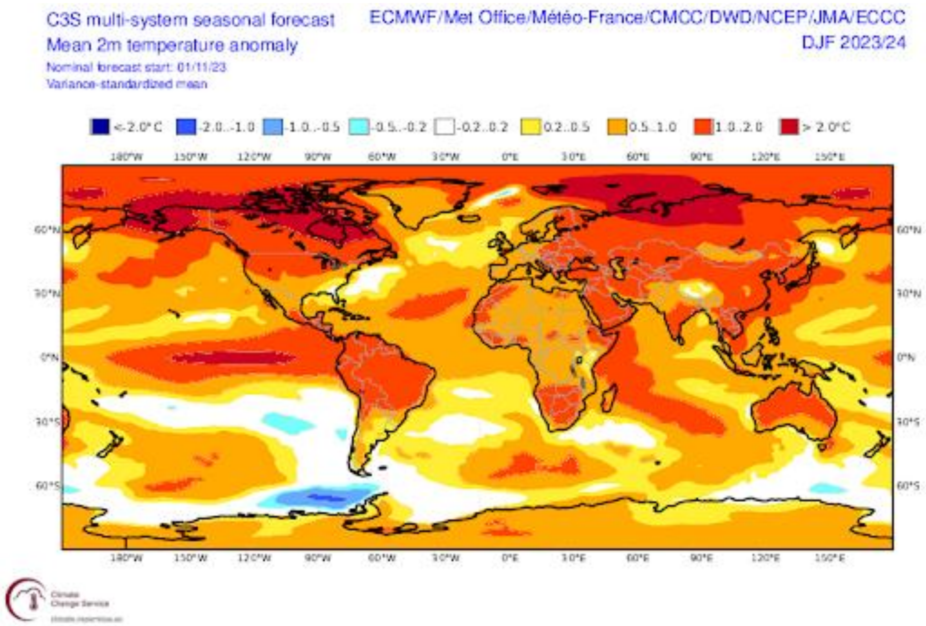
Probabilities

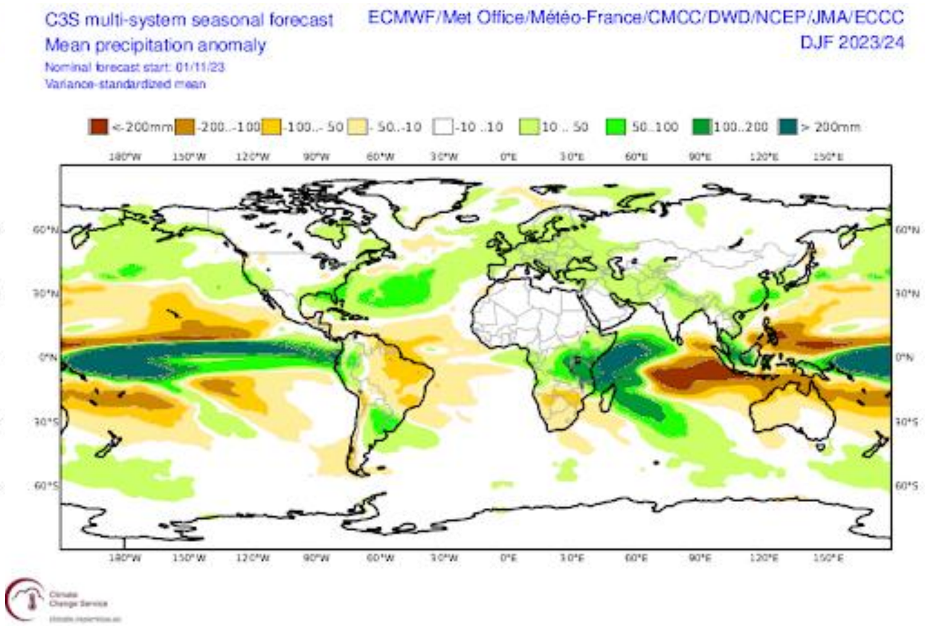




C3S Seasonal Forecast

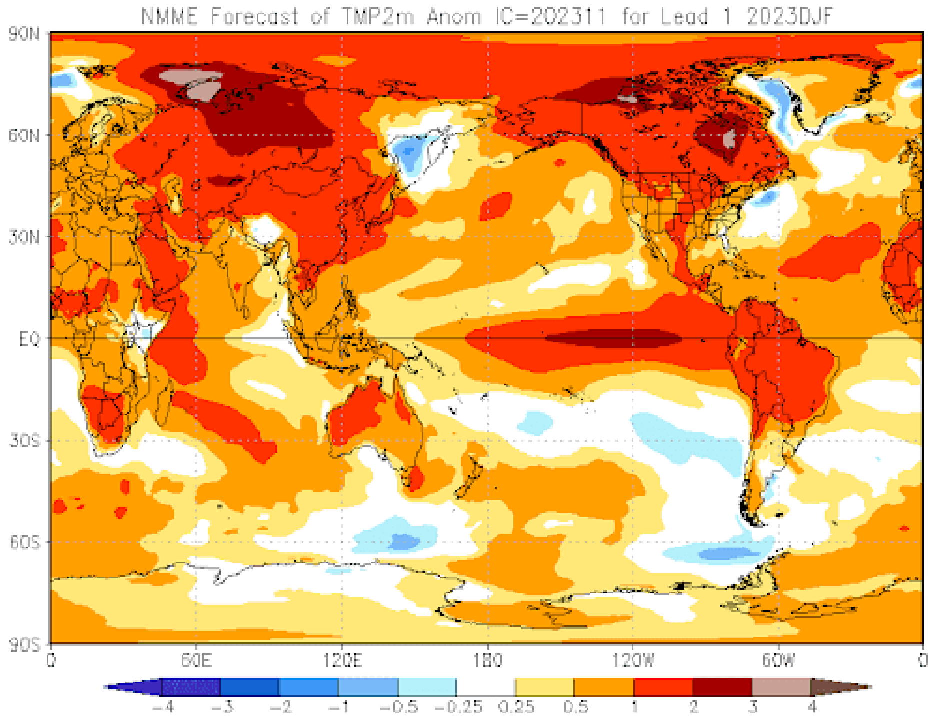
(https://climate.copernicus.eu/charts/c3s_seasonal/)

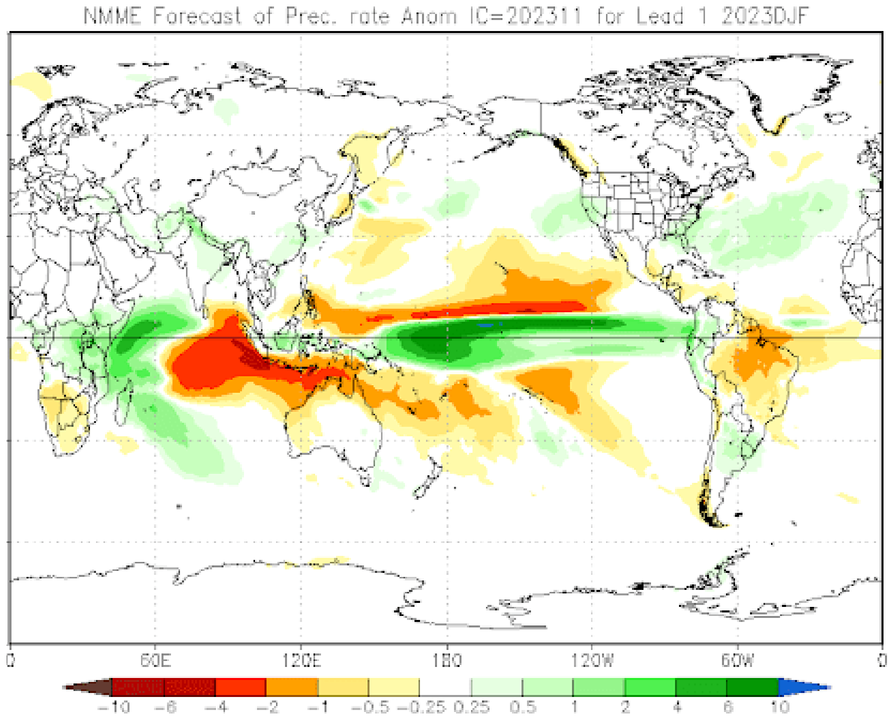




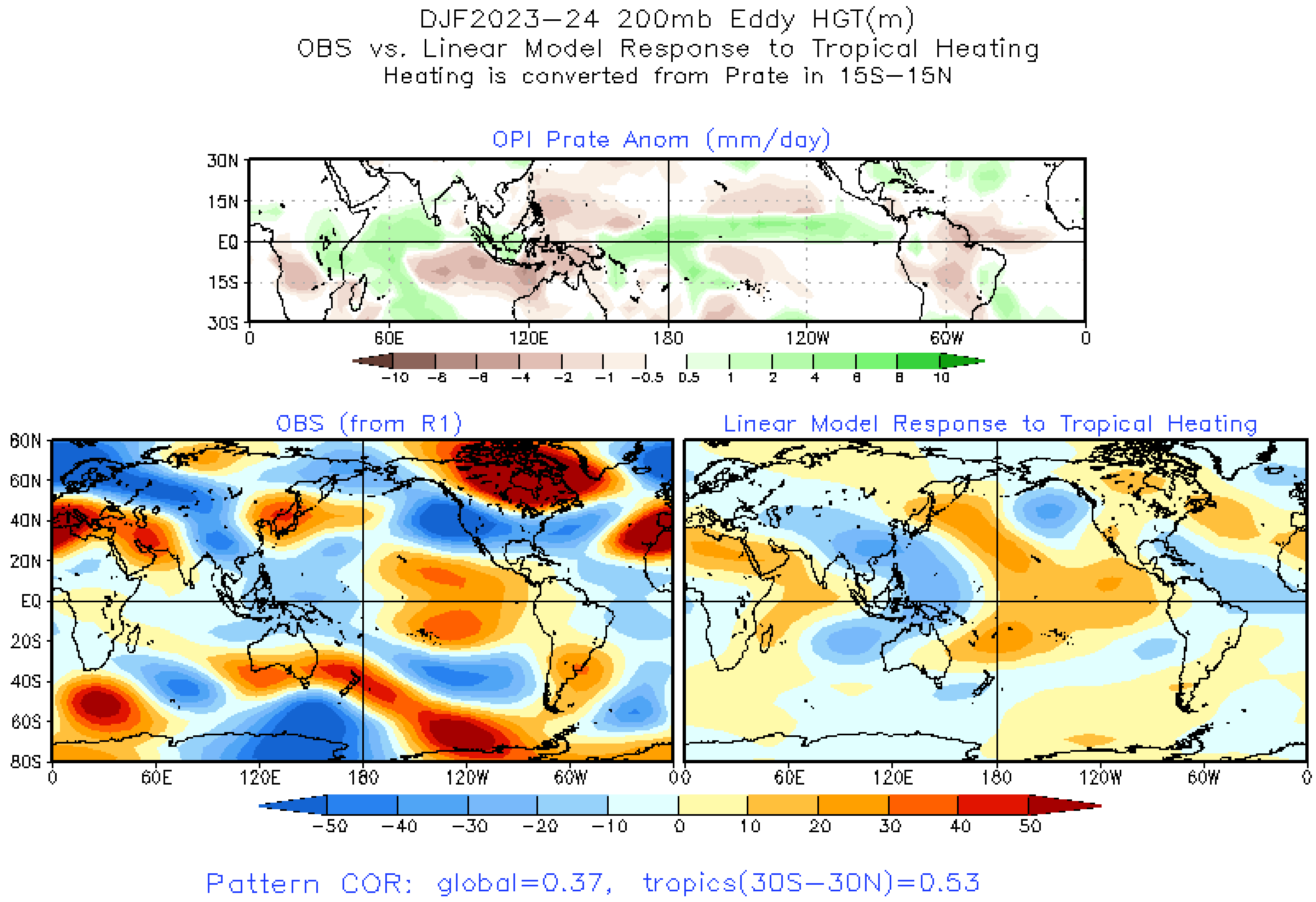
North American Multi-Model Ensemble Seasonal Forecast

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

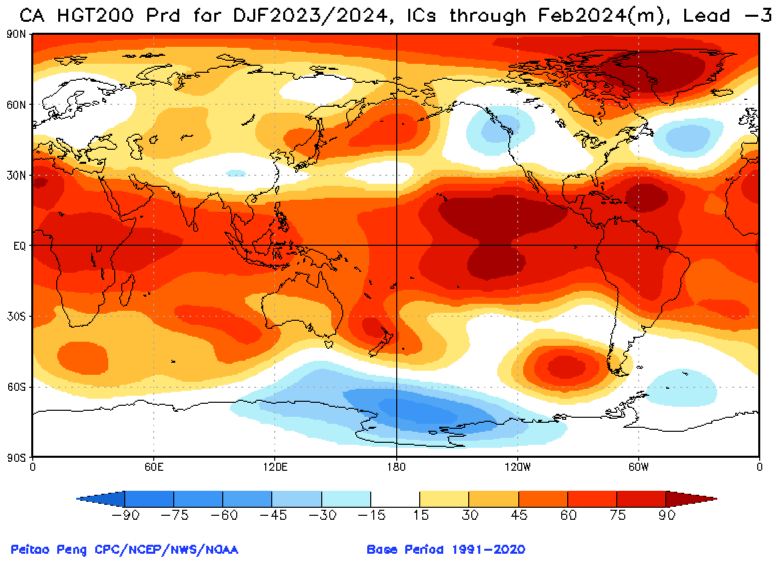


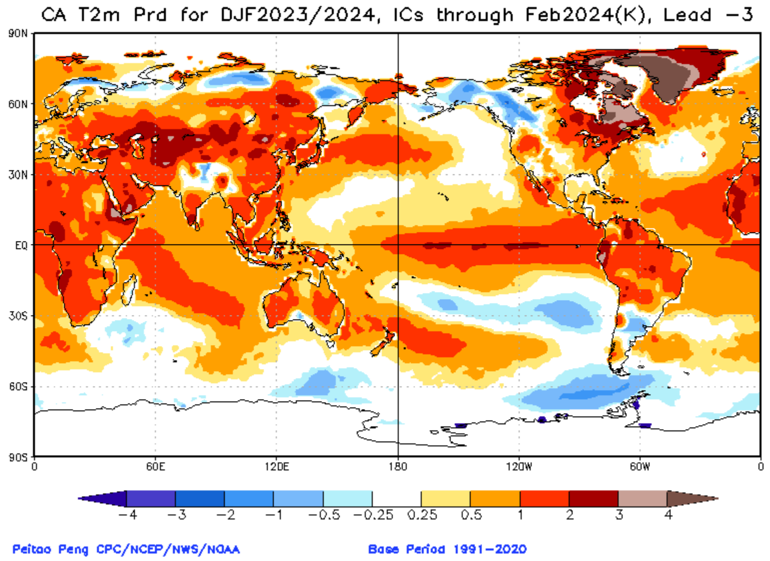


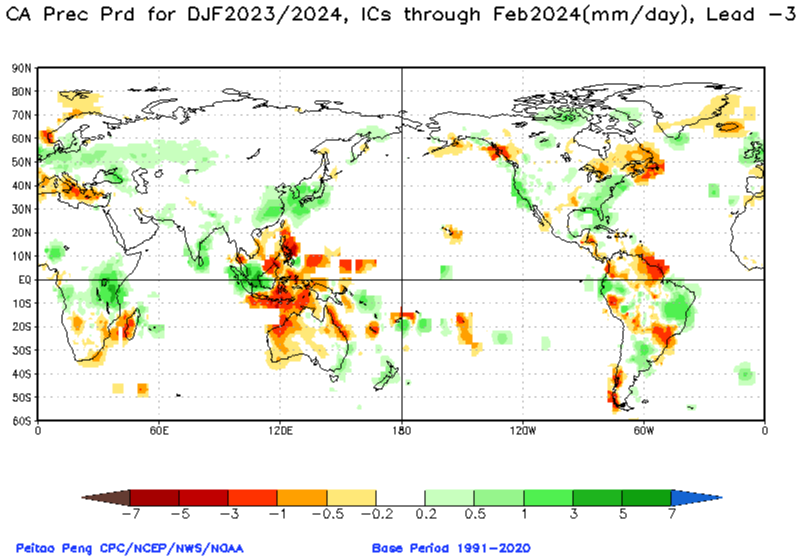
200mb Height from Linear Model



Seasonal Forecasts from the Constructed Analog Model







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.