

# Attribution of Seasonal Climate Anomalies January-February-March 2024

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

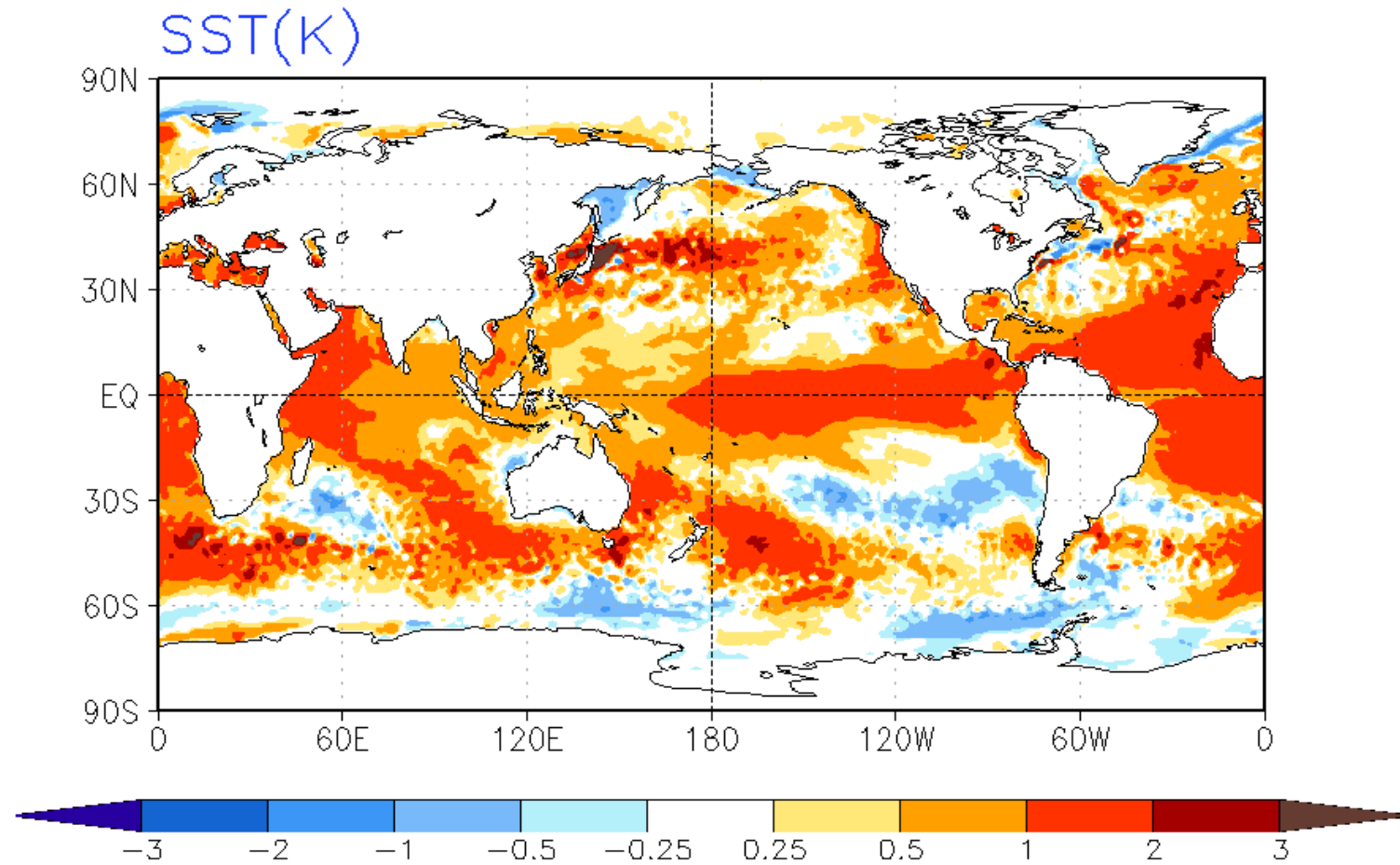
# Summary of Observed Conditions and Outlooks

- In JFM2024, warm SST anomalies associated with El Niño continued with a further reduction in warming anomalies over the equatorial eastern Pacific and along the coastal regions of South America. Almost over all 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).
- For AMIP simulations, initialized CFSv2, and other MME forecasts, the spatial pattern of rainfall differed from the observed pattern over the central Pacific in that the model anomalies indicated a more canonical El Niño response. All models (except CFSv2) captured the observed negative precipitation anomalies over the equatorial eastern and southern Indian Ocean (slides 11, 37-39). The errors in the CFSv2 forecast precipitation may be related to the SST warming biases over the eastern Indian Ocean (slide 10).
- Consistent with the notion of SSTs constraining atmospheric variability, the tendency for above normal 200-mb heights and above normal land surface temperature anomalies dominated almost throughout the globe both in observations and model predictions and simulations (slide 12, 13).
- The initialized CFSv2 forecasts, in general, predicted the tendency for above normal 200-mb height and land surface temperature over North America, although the z200 positive center over the eastern North America was shifted westward and the negative anomalies over the west coast of North America was not captured resulting in a missed forecast of below normal temperature over the western parts of North America (slide 15, 16).
- March 2024 monthly forecast skill for 200-mb height, T2m, and precipitation over North America improved from the shortest leads (slide 33-35).

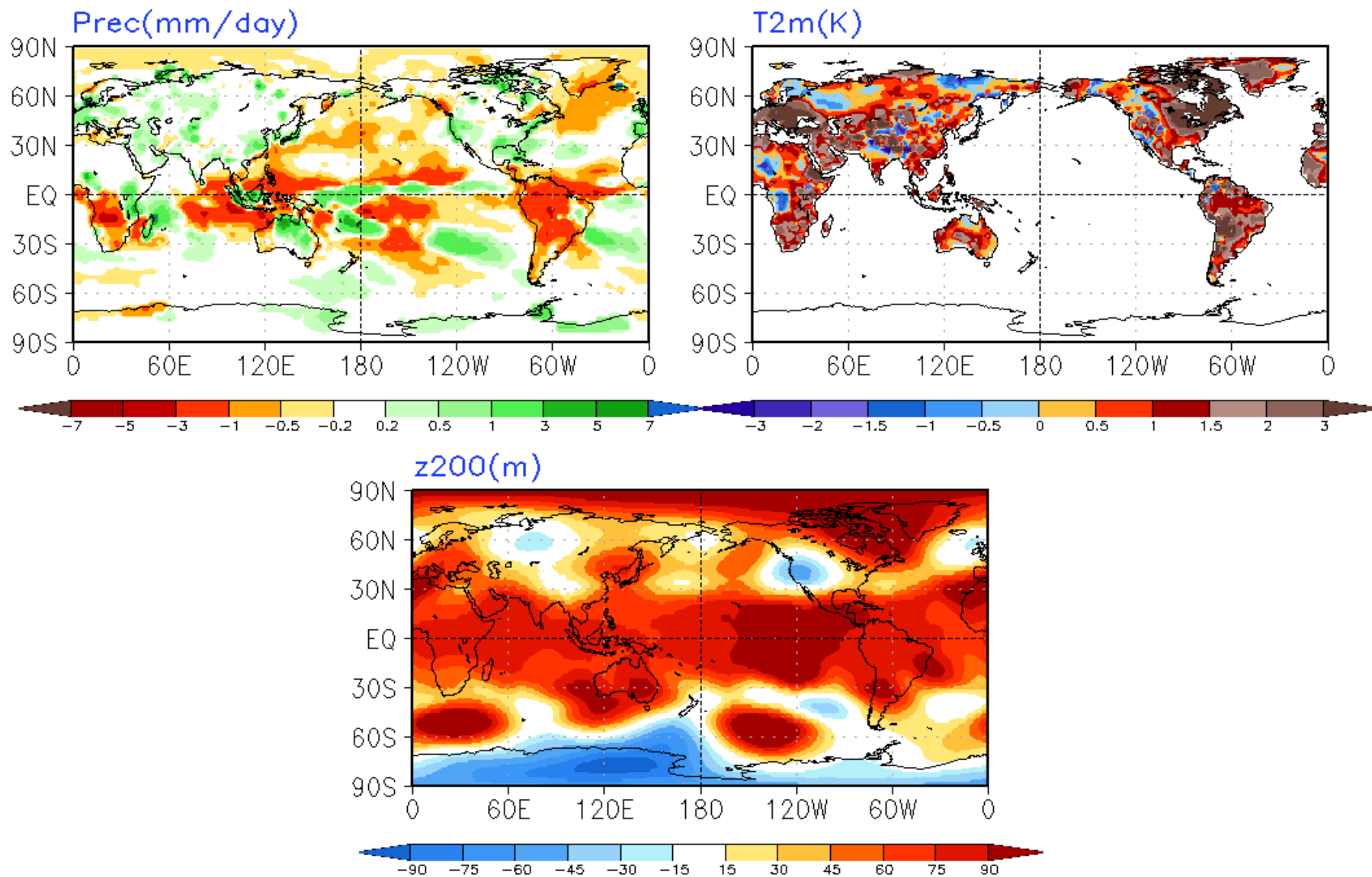
# Observed Seasonal Anomalies

## Global and North America

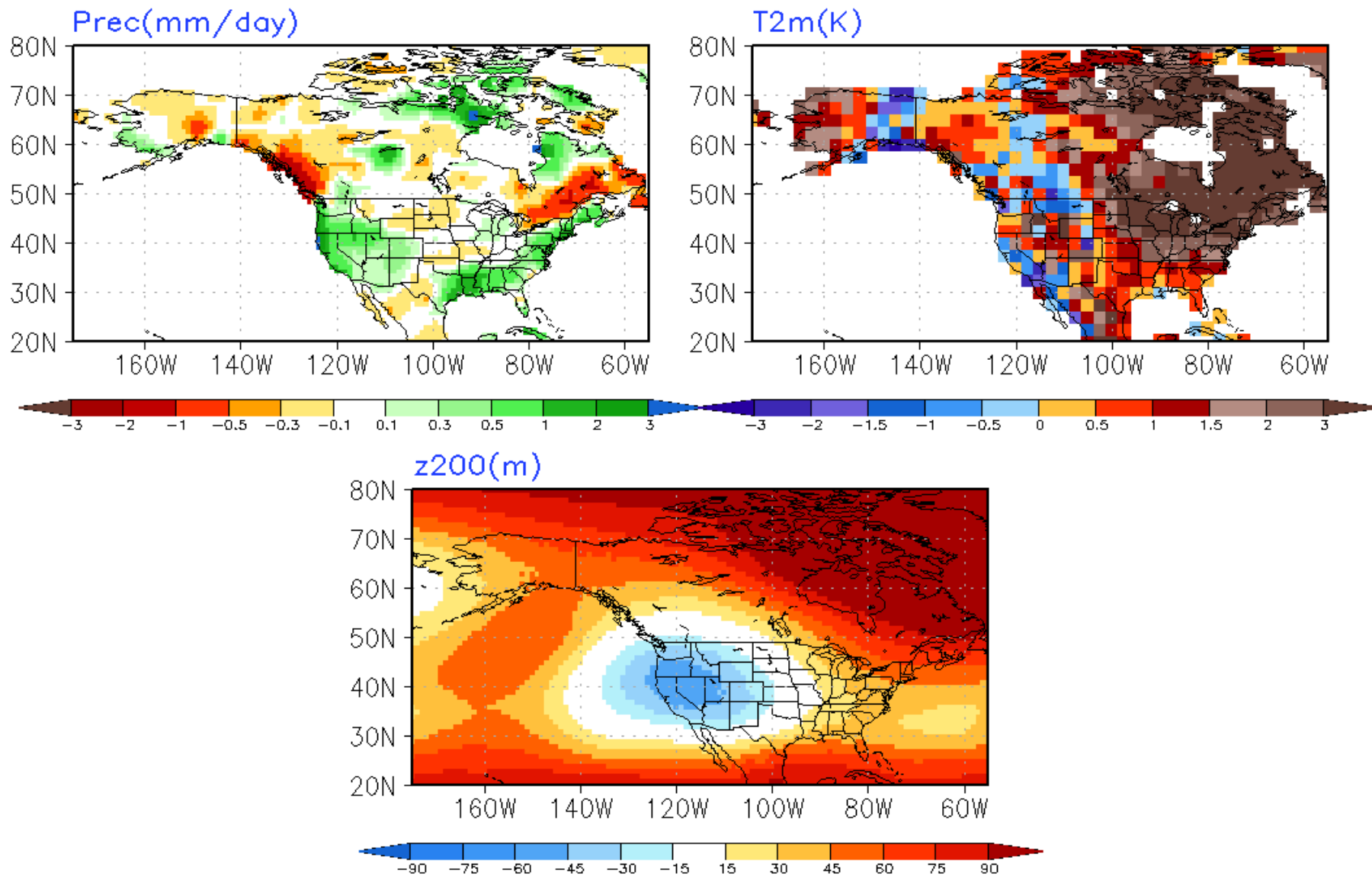
# Observed Anomaly JFM2024



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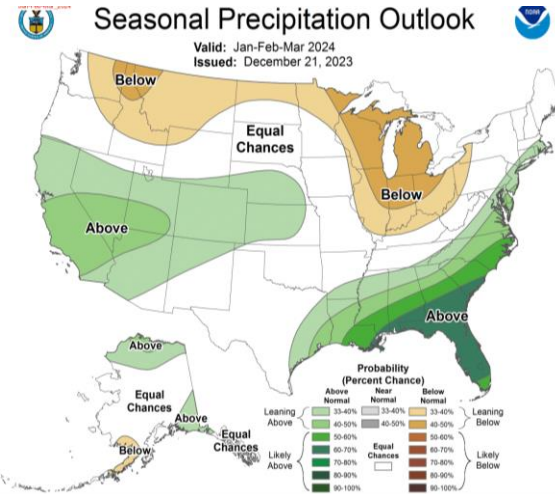
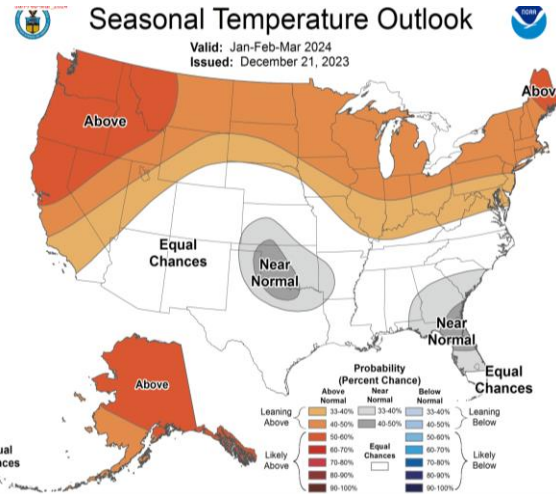
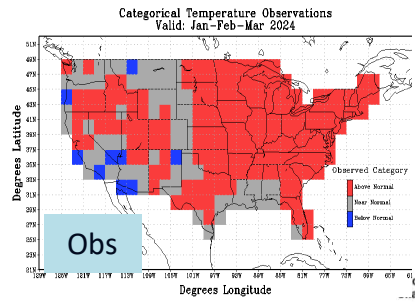
# Observed Anomaly JFM2024



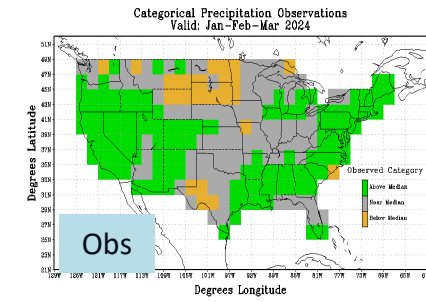
# CPC Seasonal Outlooks and NMME Forecasts

CPC

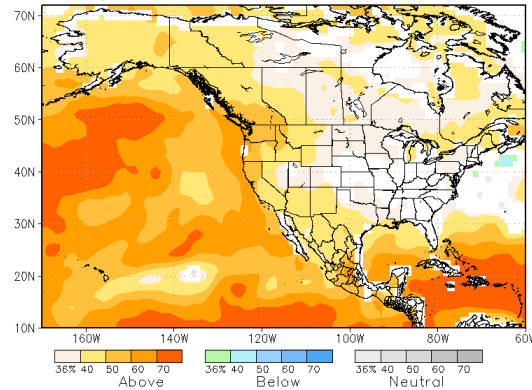
Temp nonEC  
HSS=44



Prec nonEC  
HSS=31

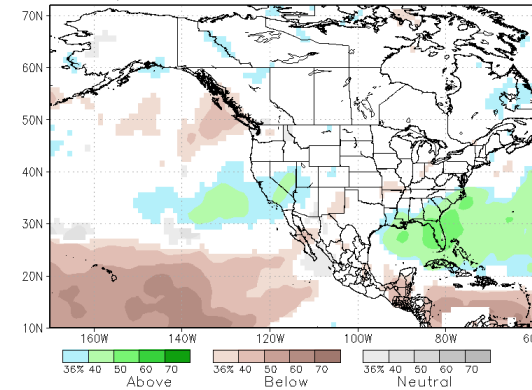


NMME prob fcst TMP2m IC=202312 for lead 1 2024 JFM



NMME

NMME prob fcst Prate IC=202312 for lead 1 2024 JFM



For the rationale behind CPC outlooks see [https://www.cpc.ncep.noaa.gov/products/archives/long\\_lead/PMD/2024/202412\\_PMD90D](https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2024/202412_PMD90D)

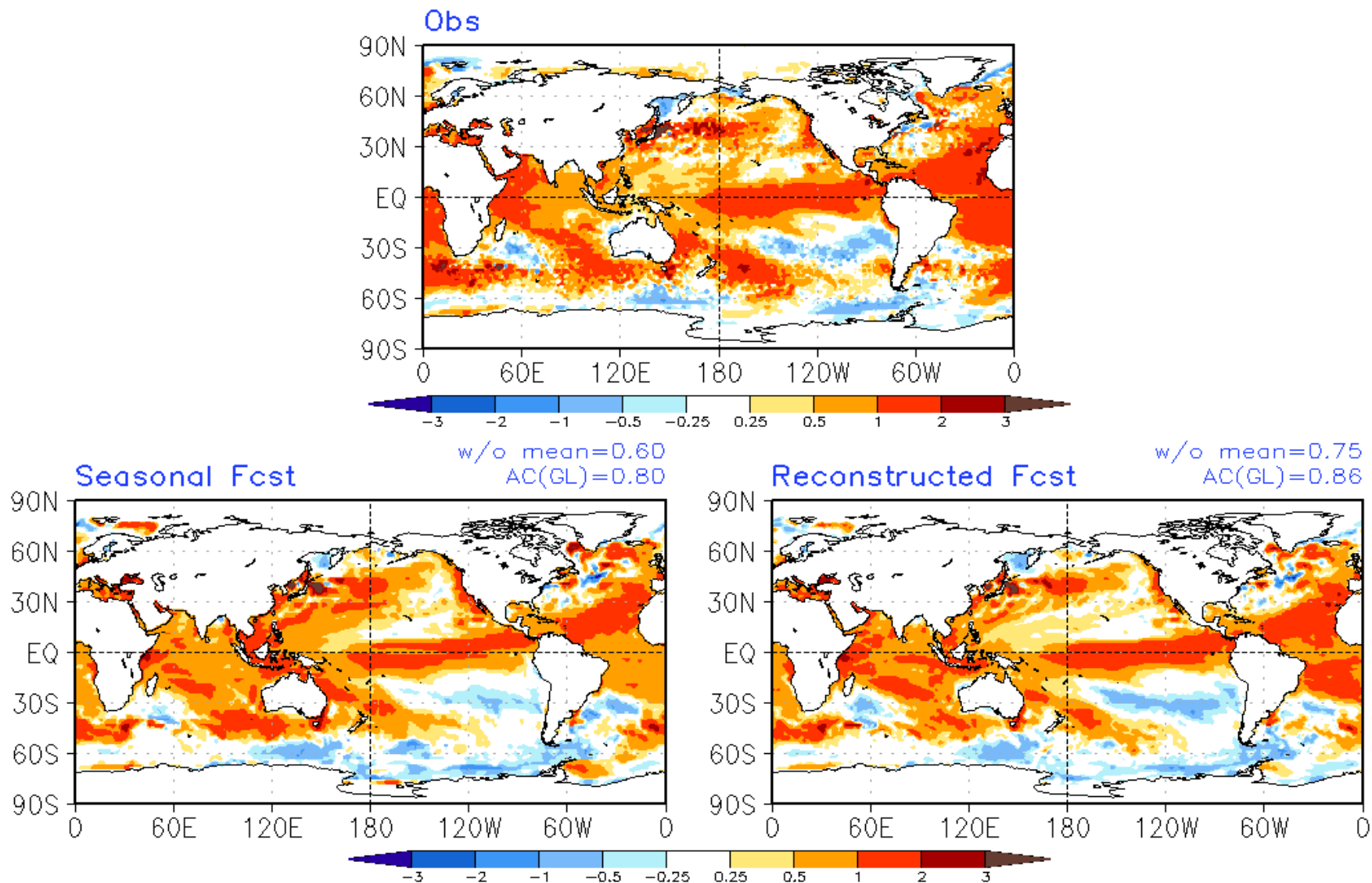
## Model Simulated/Forecast Ensemble Mean Anomalies



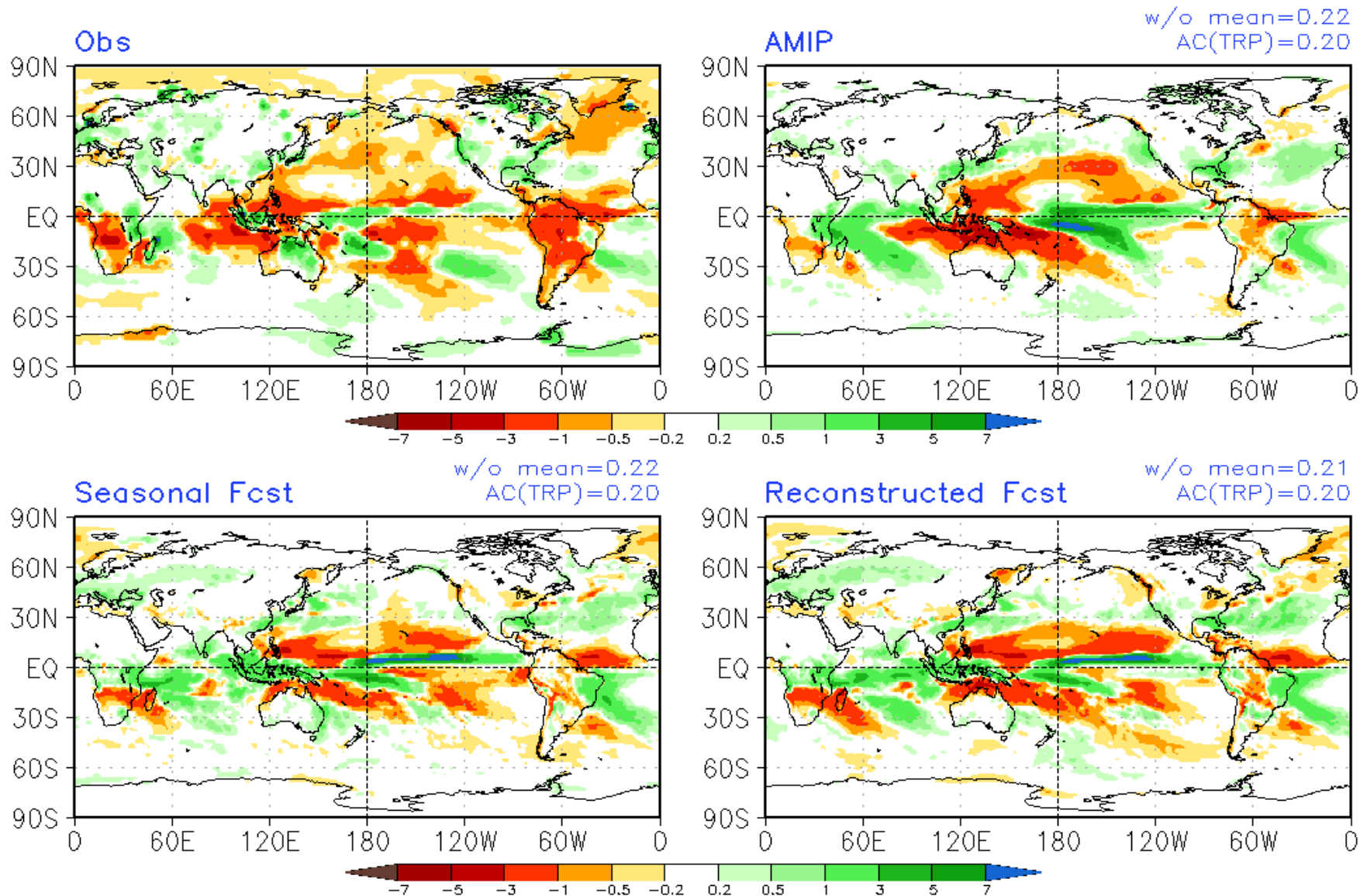
# Model Simulated/Forecast Ensemble Average Anomalies

- **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.

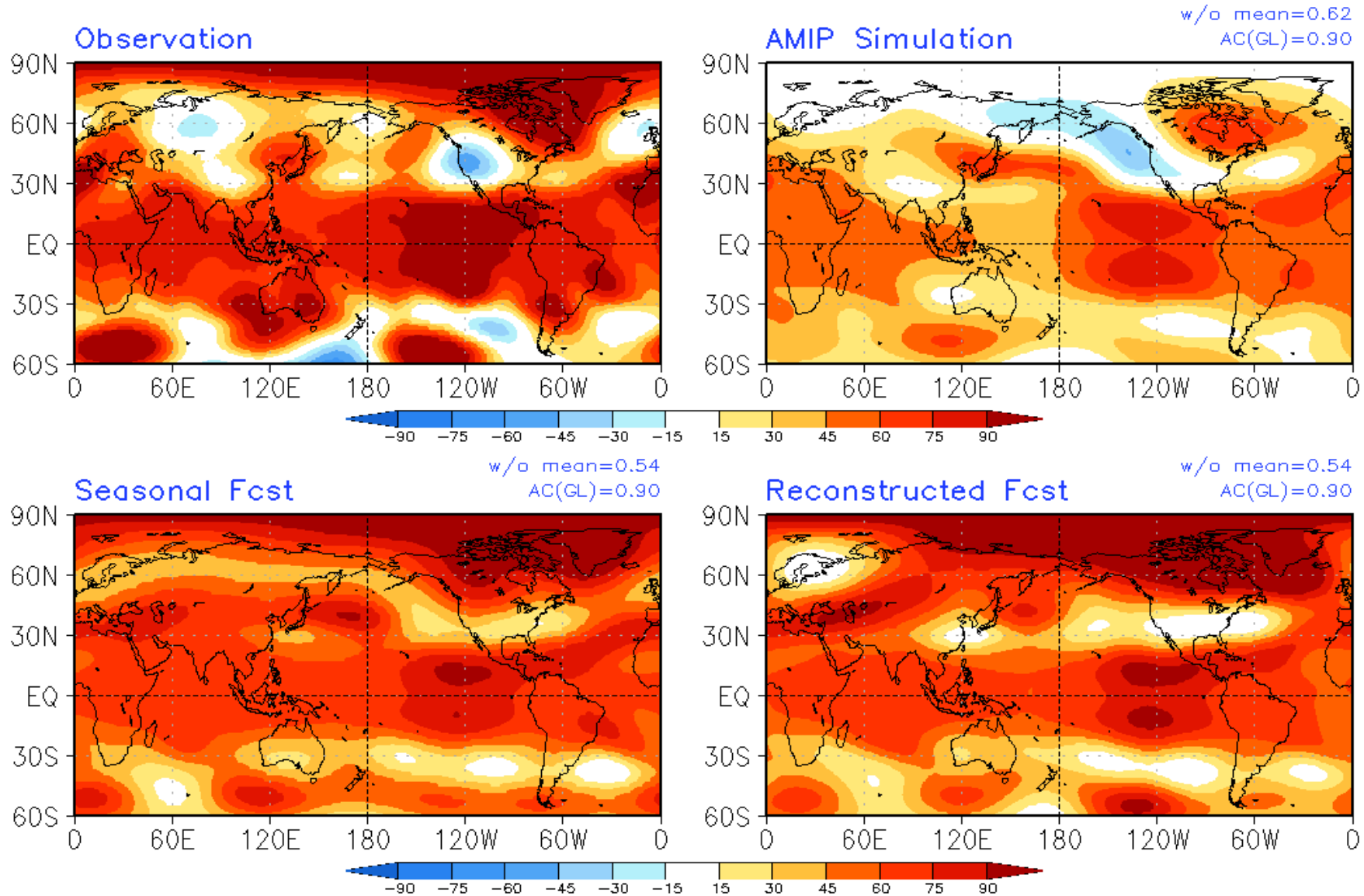
# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



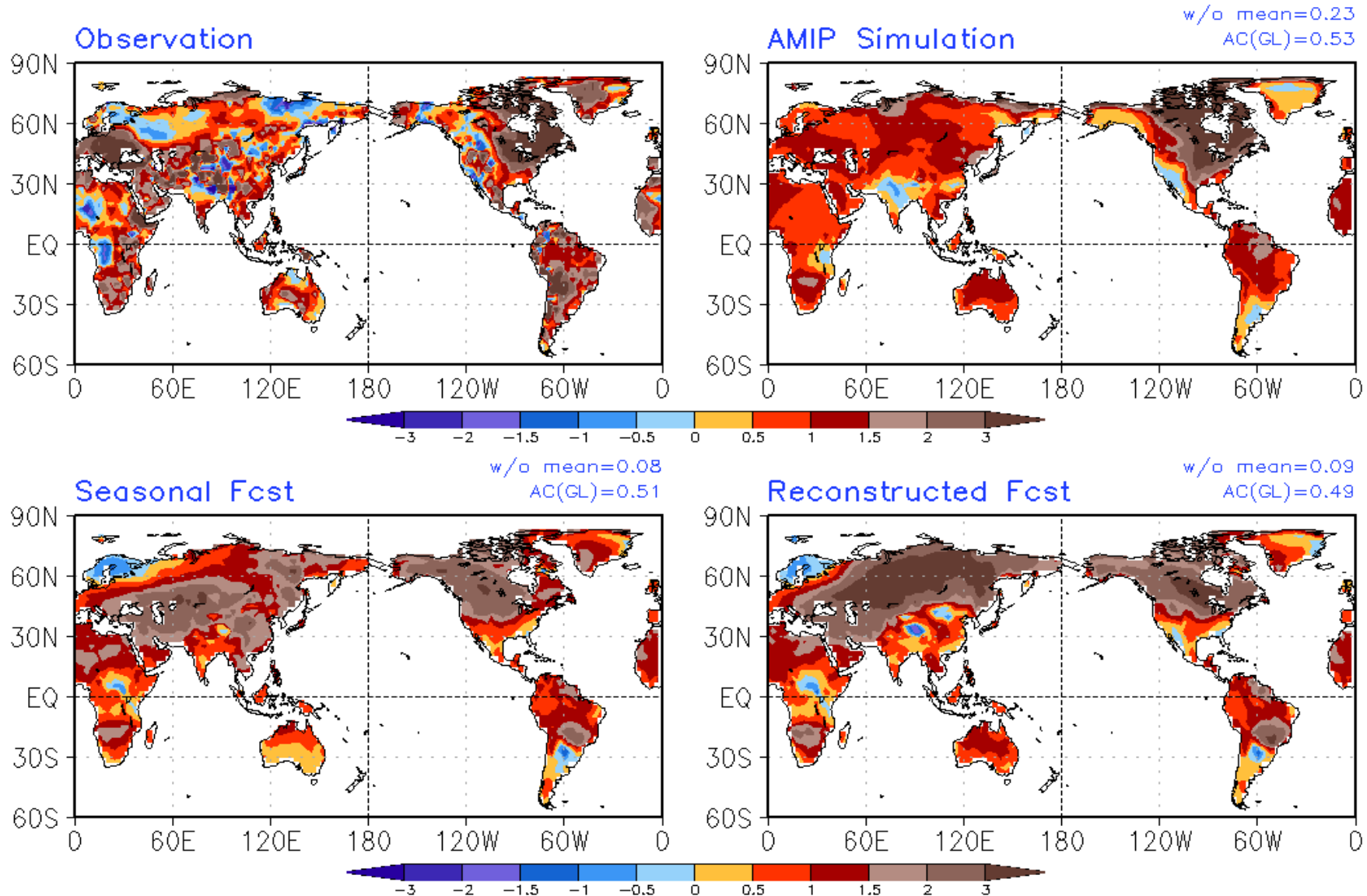
# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



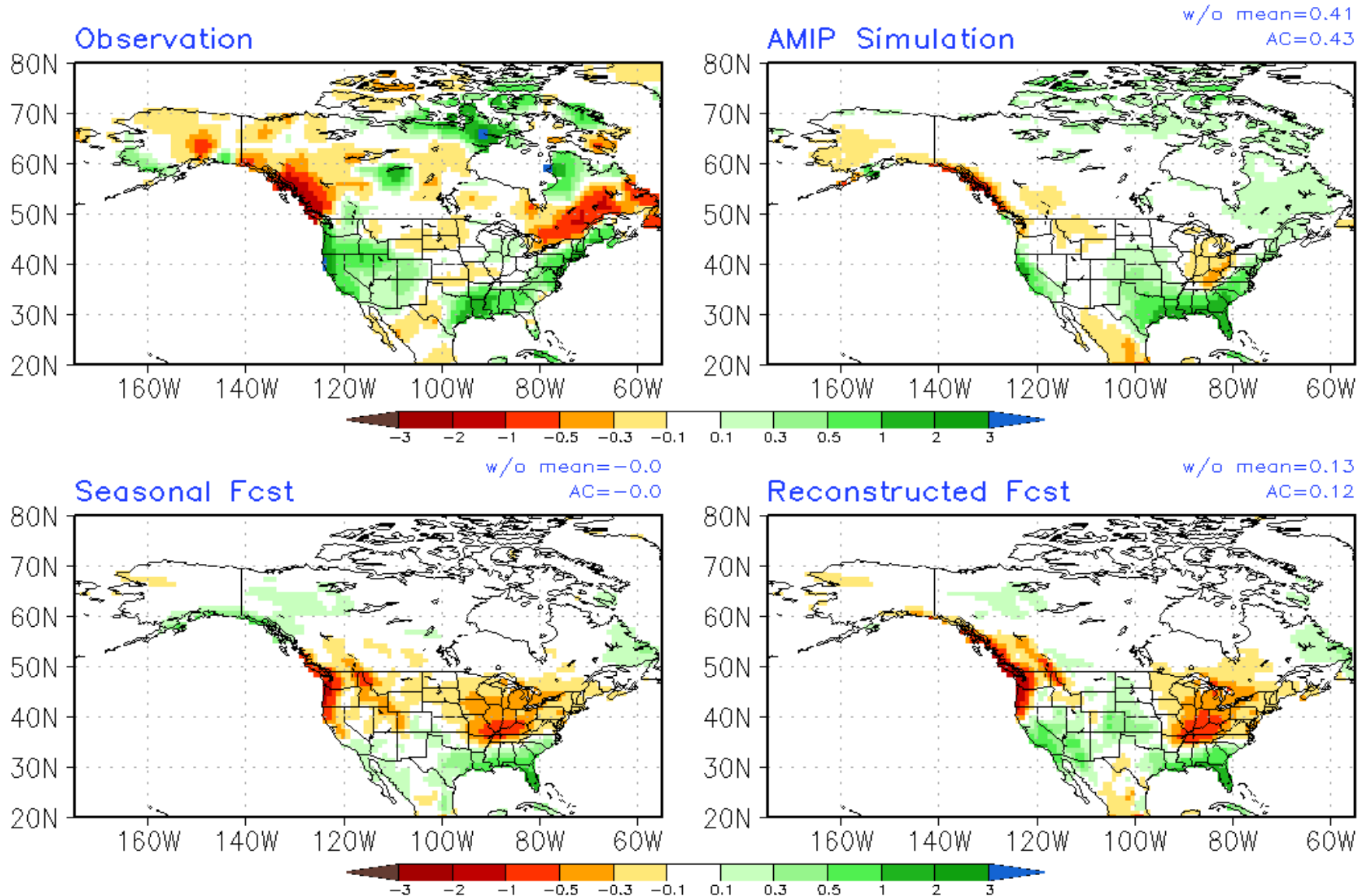
# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



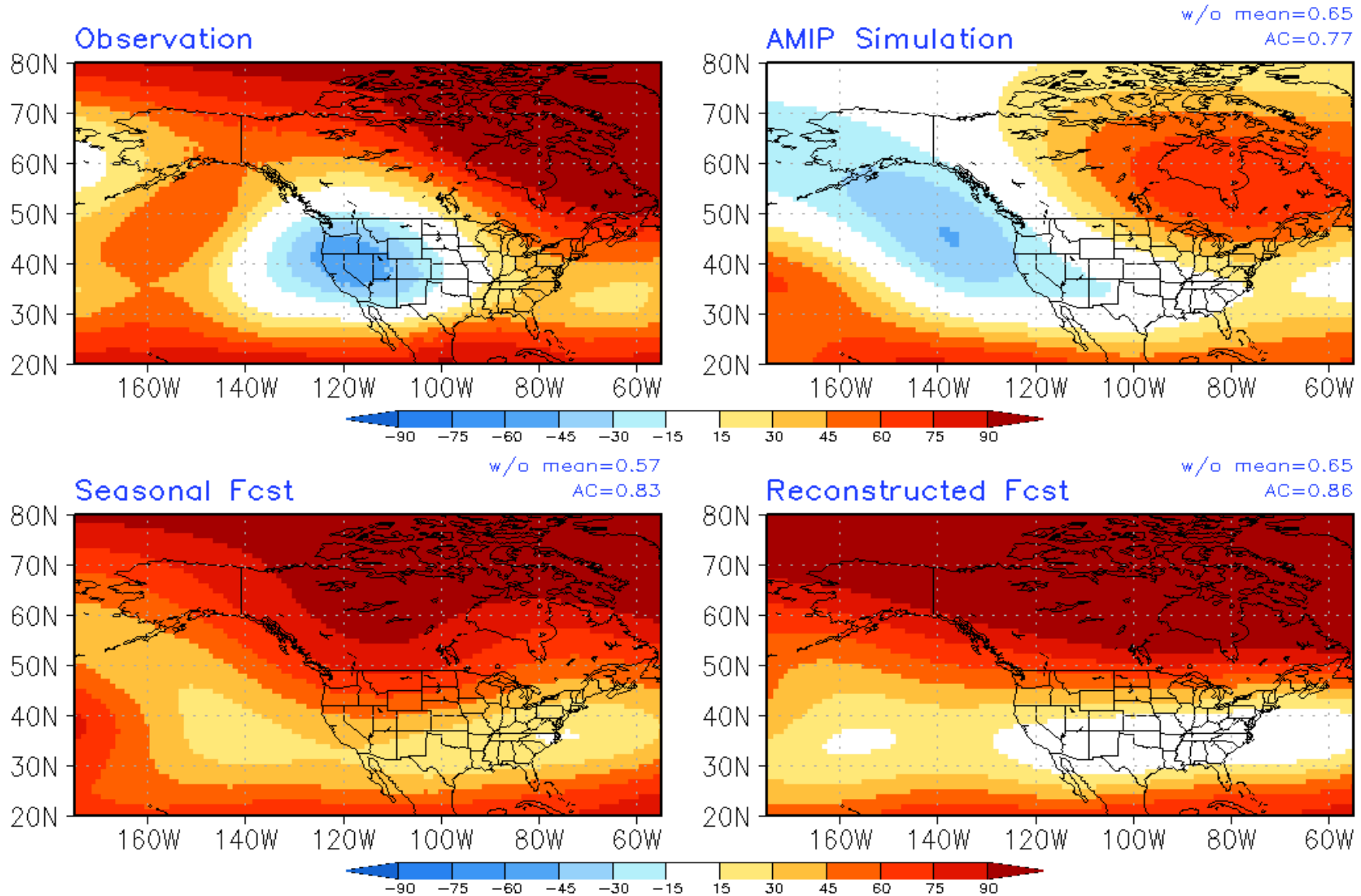
# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



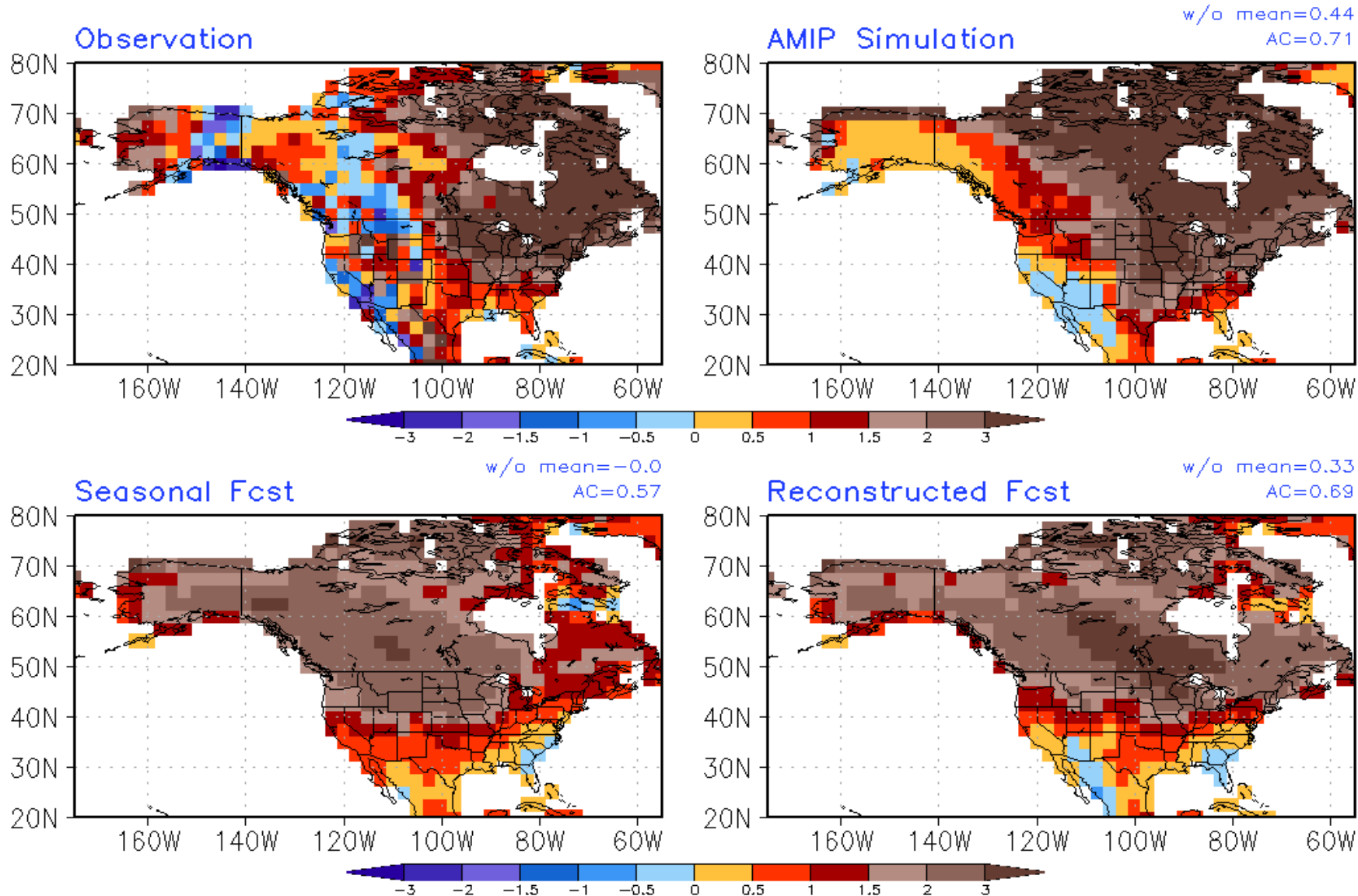
# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



# JFM2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



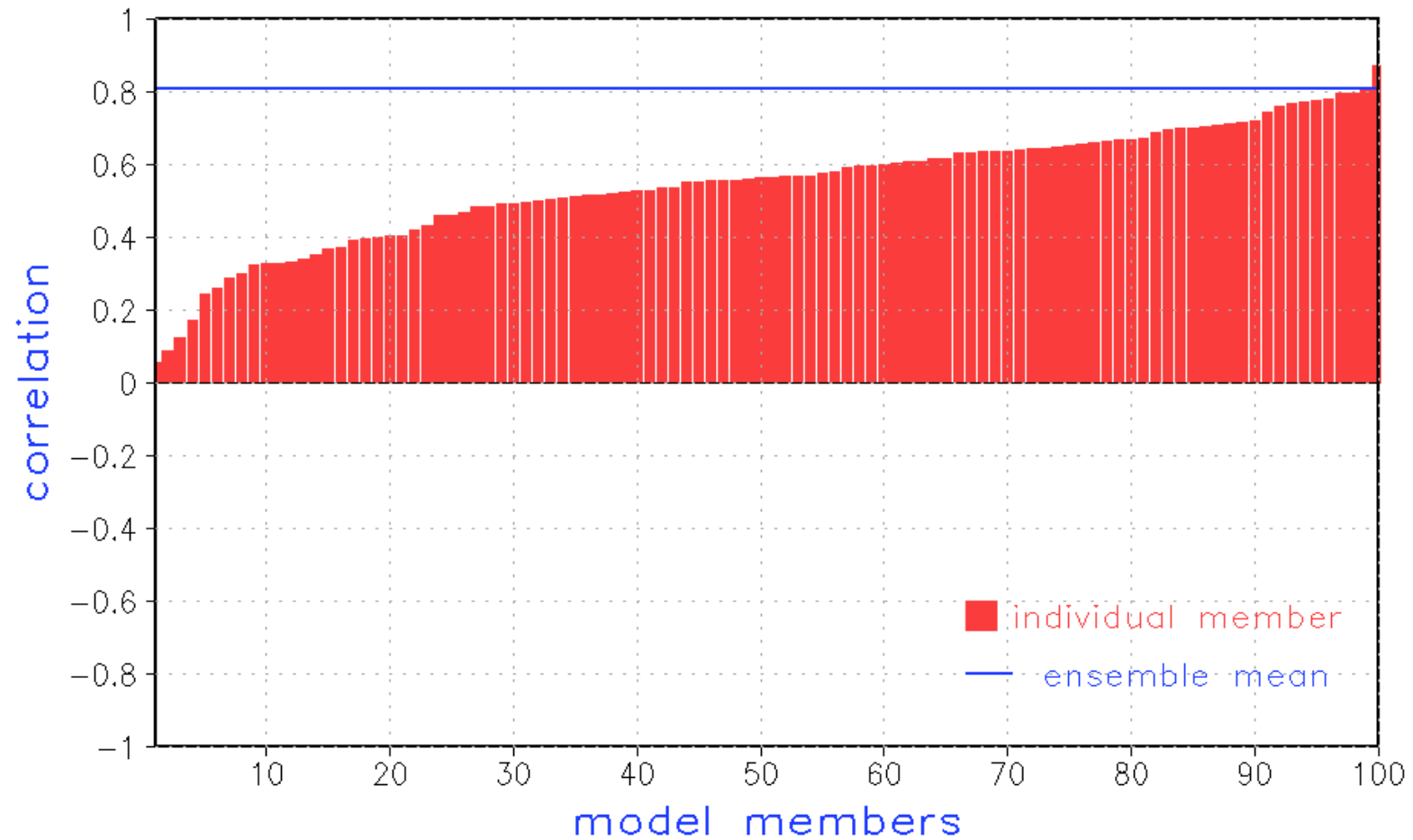


## Model Simulated/Forecast Anomalies: Individual Runs

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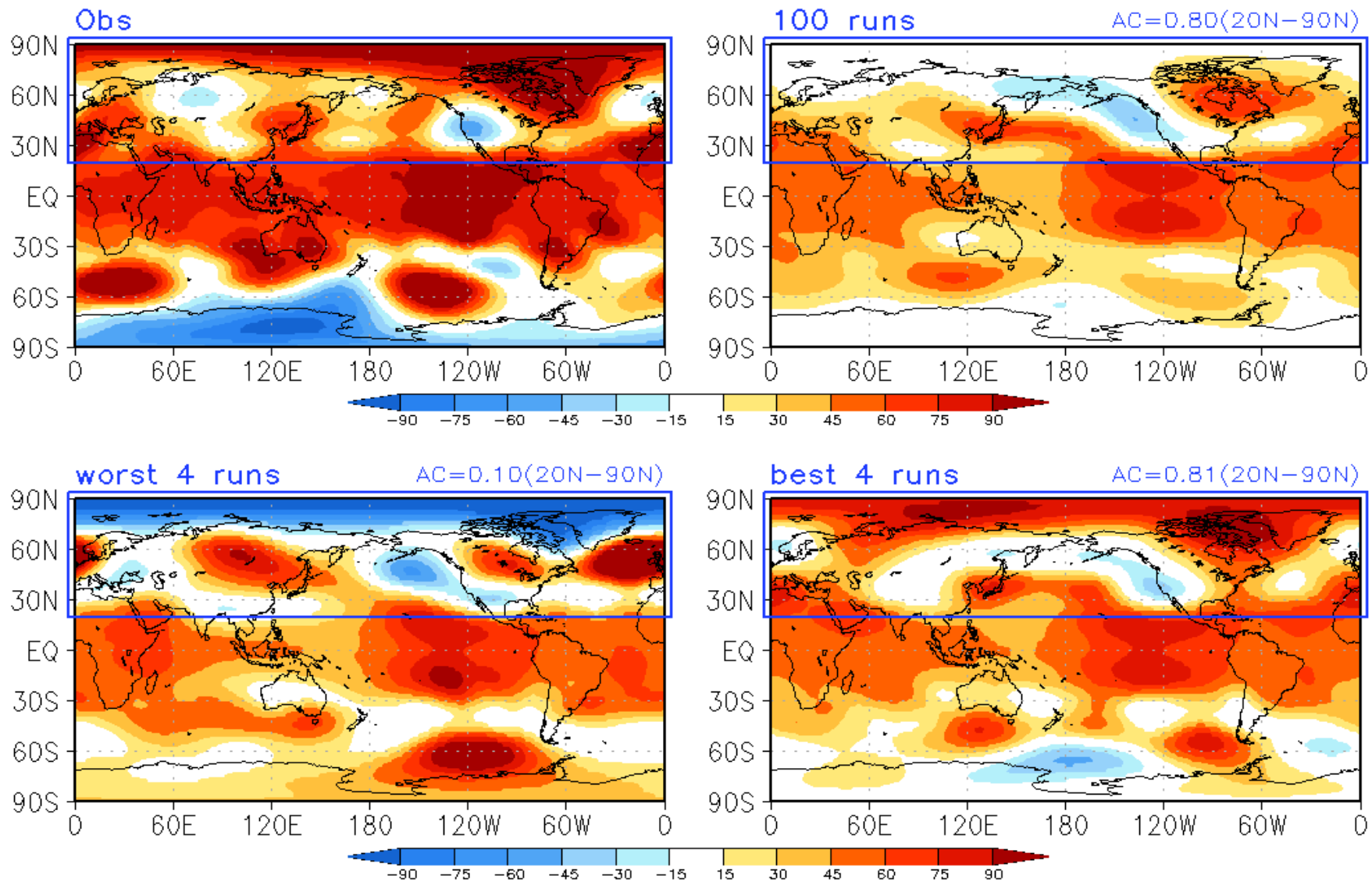
- In this analysis, anomalies from individual model runs are compared against the observed seasonal mean anomalies. The spatial resemblance between them is quantified based on anomaly correlation (AC).
- The distribution of AC across all model simulations is indicative of probability of observed anomalies 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).

# JFM2024 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)

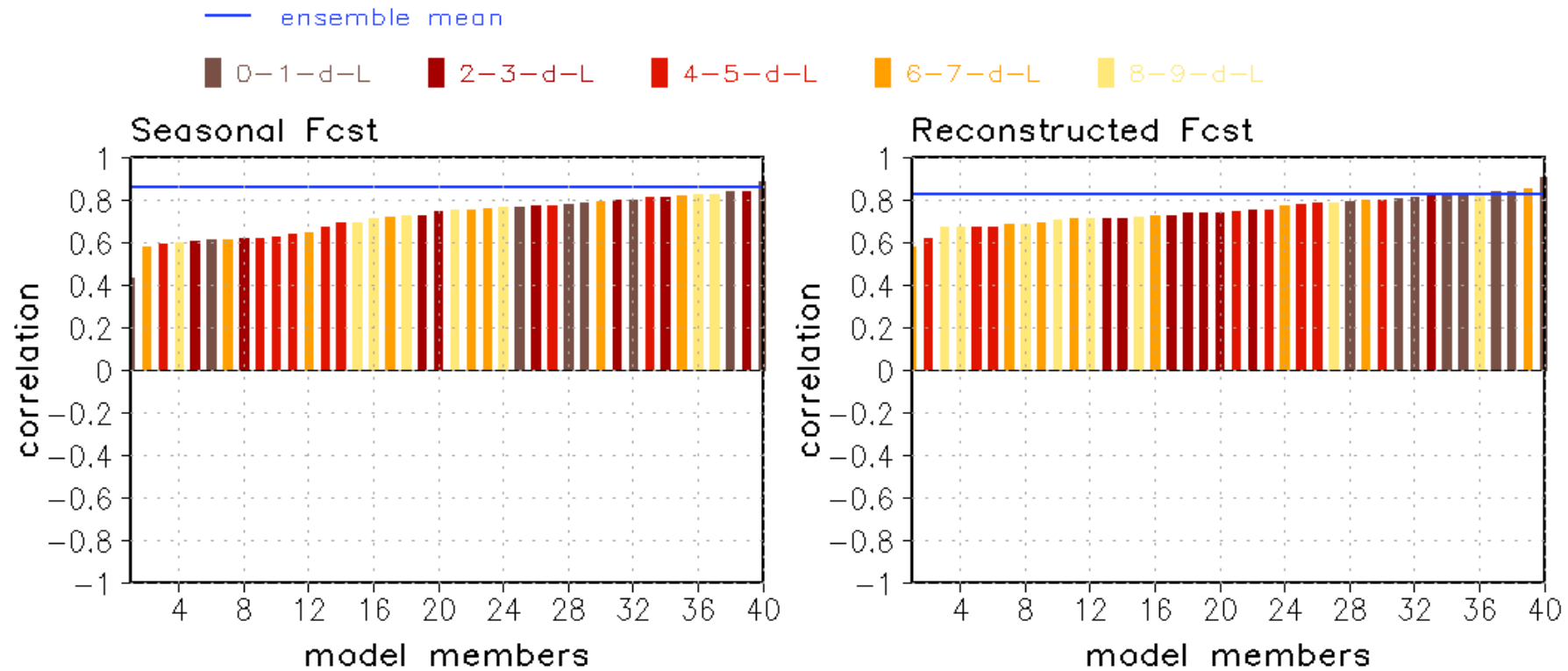


# Observed & AMIP Ensemble Mean Anomalies

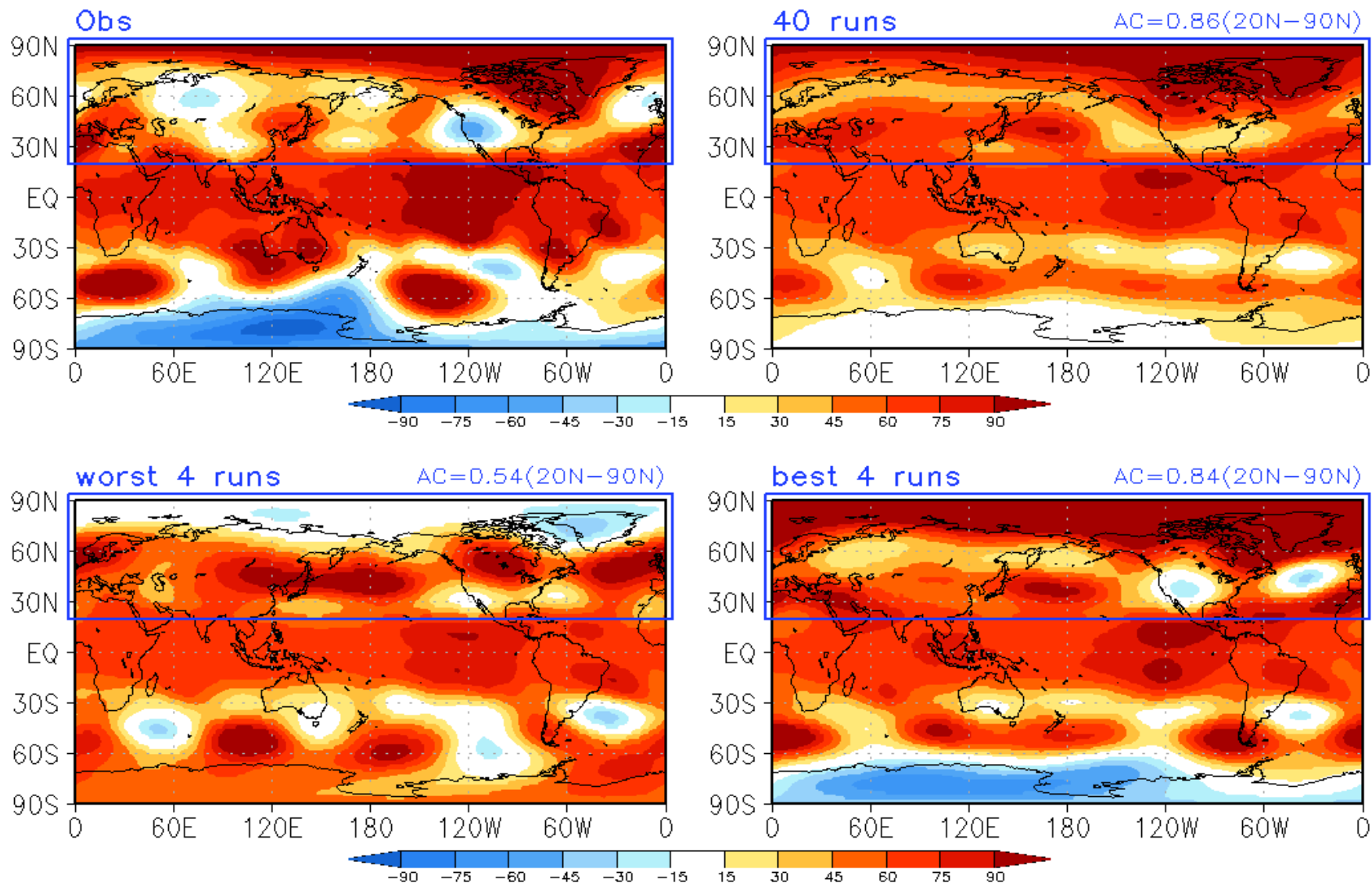
## JFM2024 z200(m) 100 runs/worst 4 runs/best 4 runs



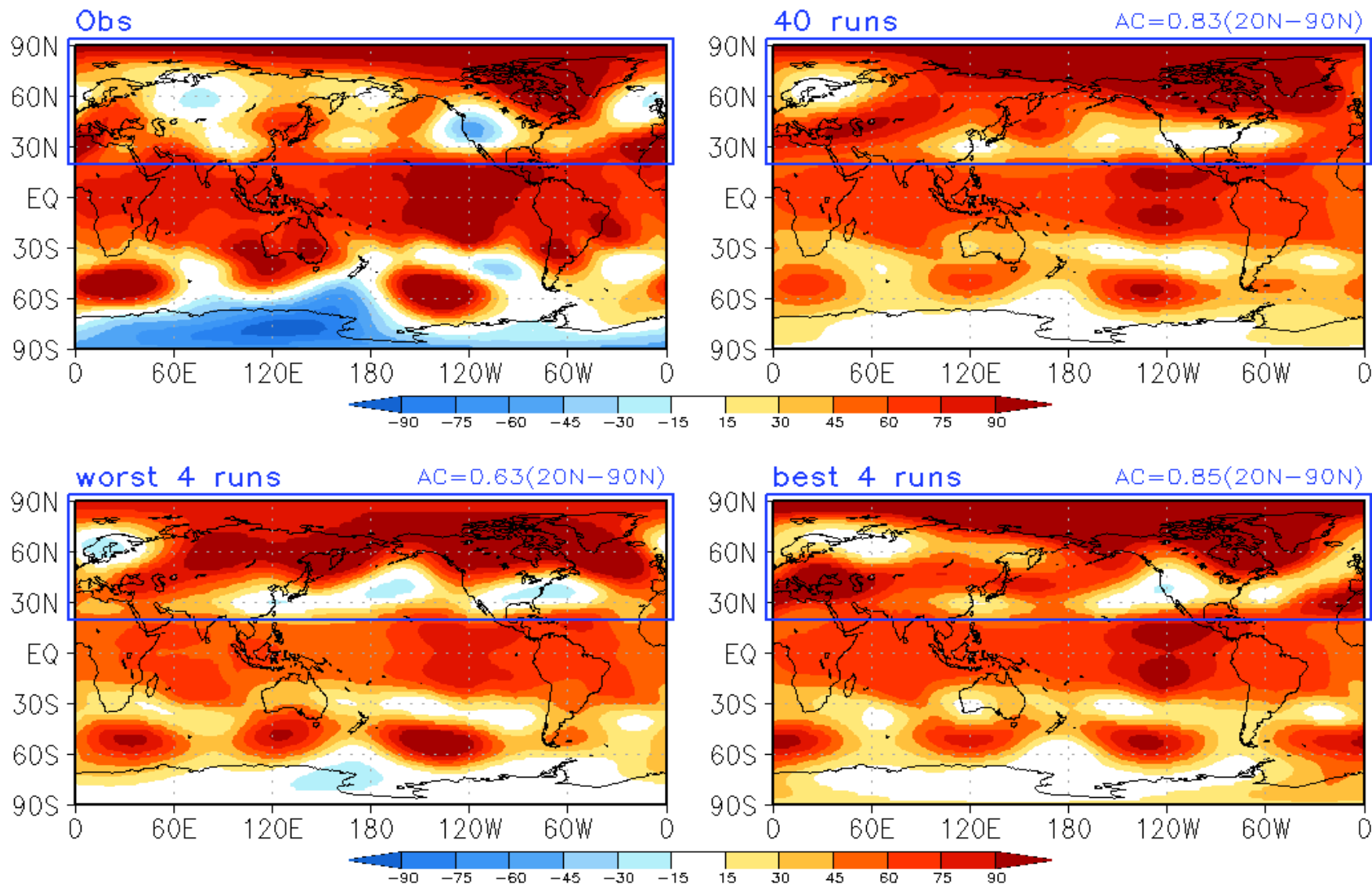
# JFM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



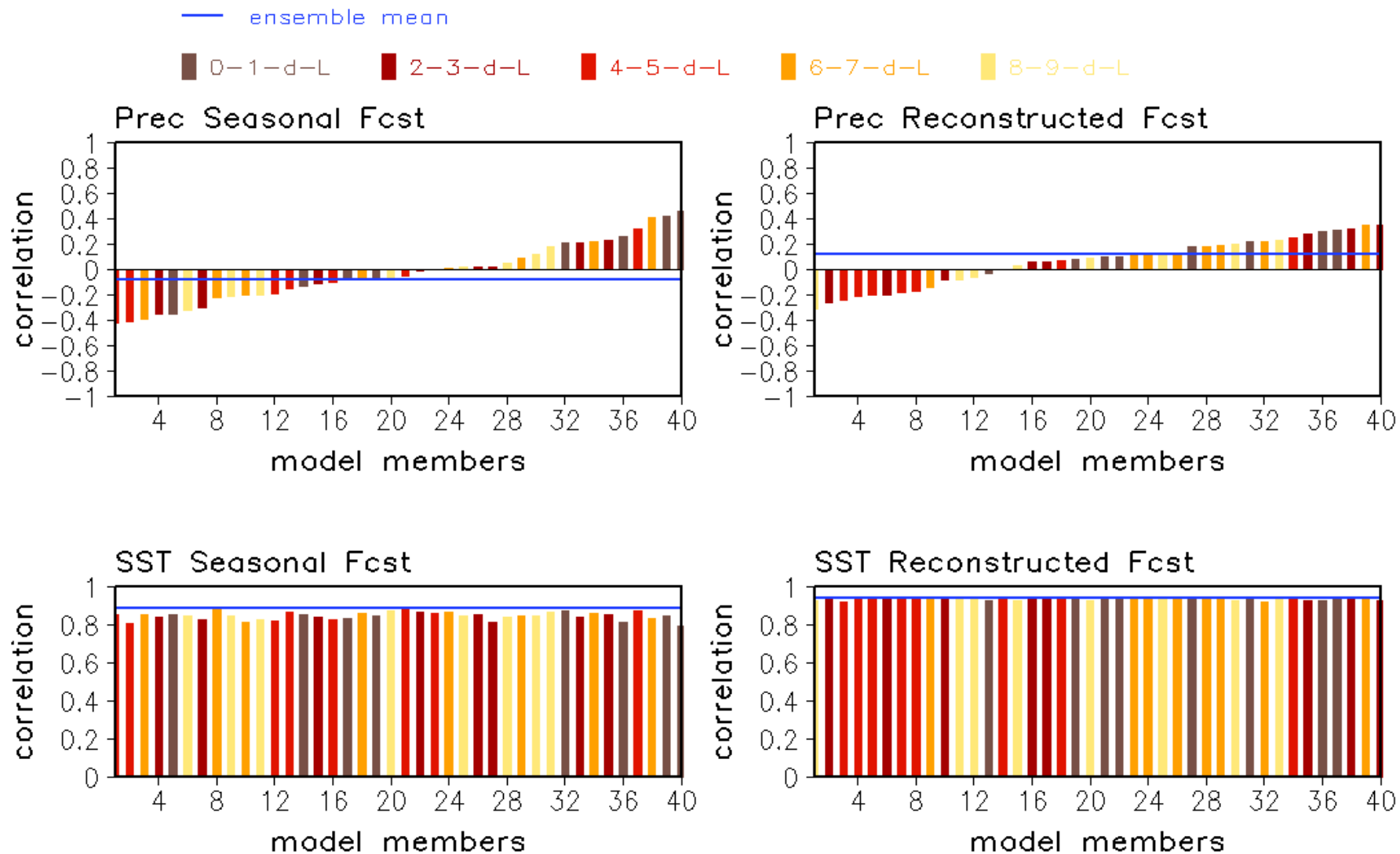
Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 z200(m) 40 runs/worst 4 runs/best 4 runs  
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 z200(m) 40 runs/worst 4 runs/best 4 runs  
Reconstructed Forecast

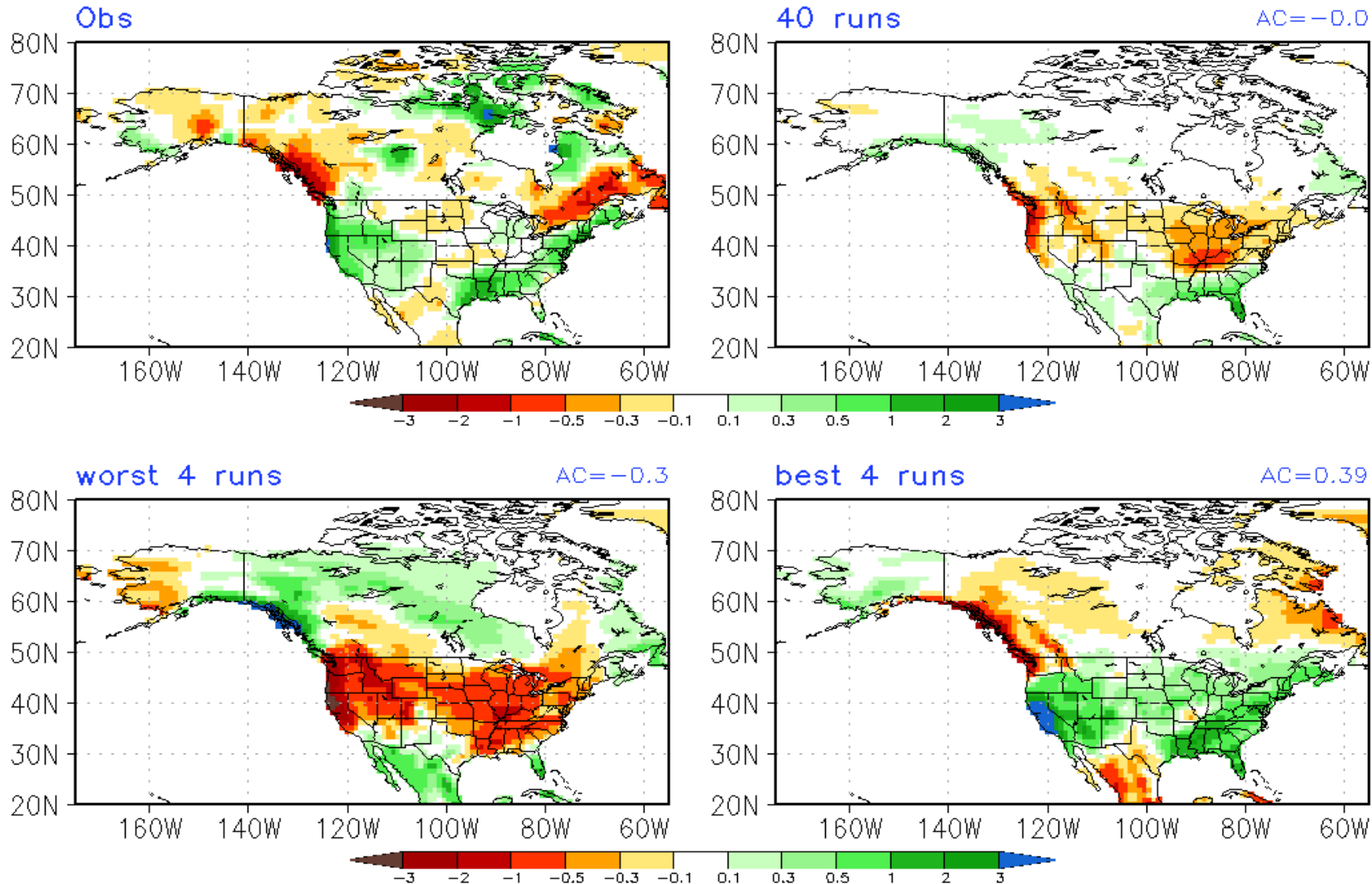


# JFM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

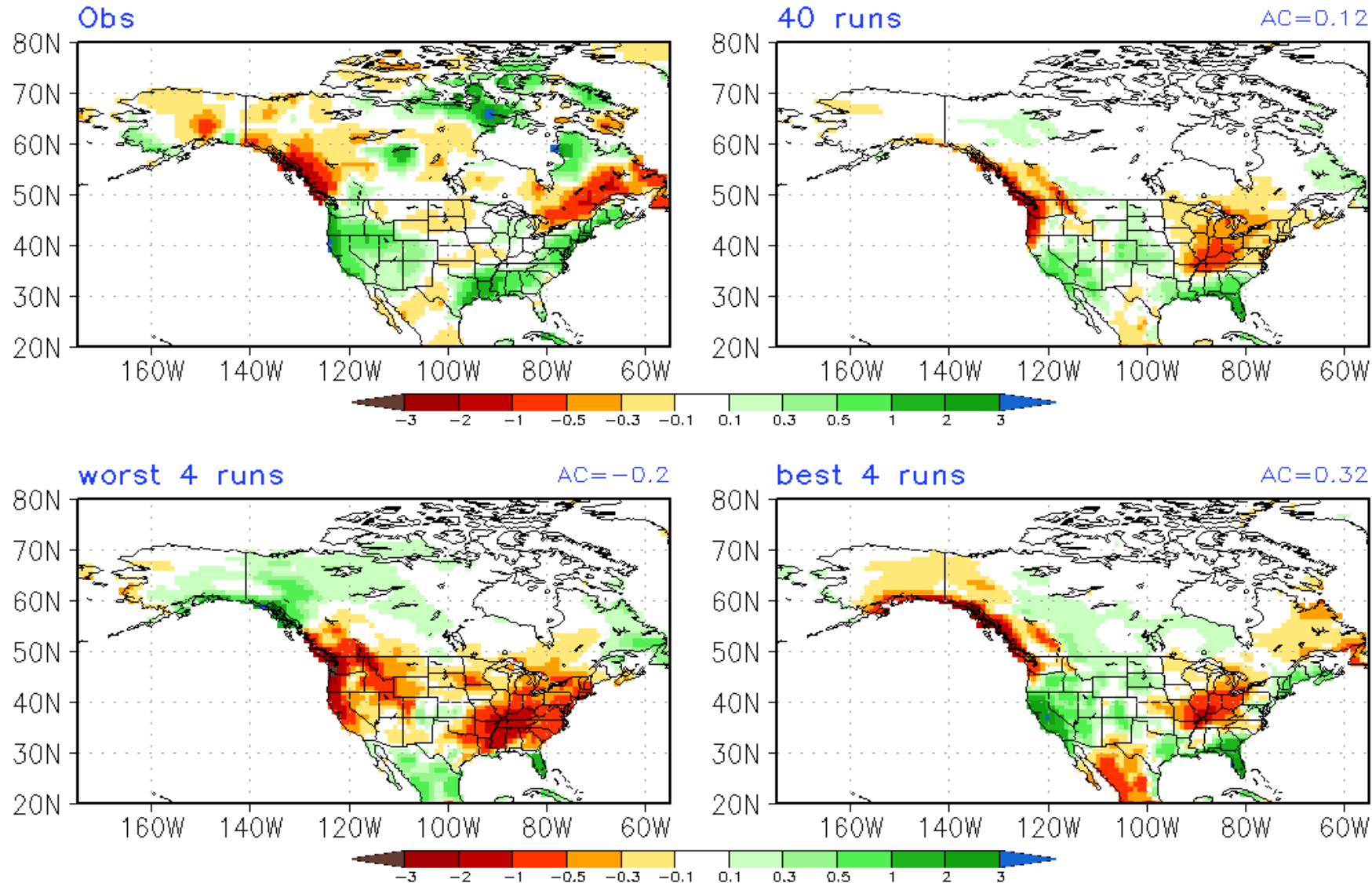




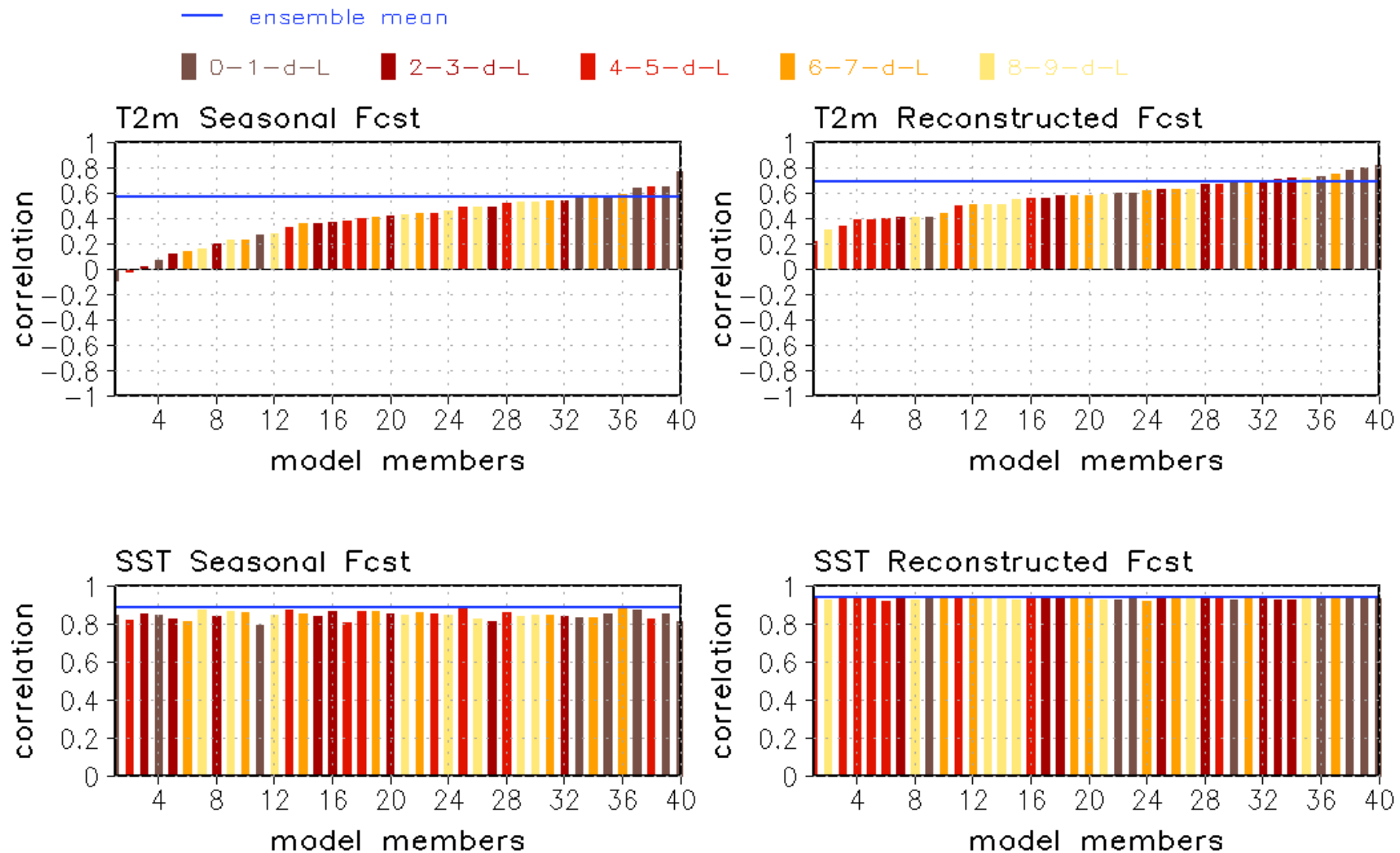
Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs  
Seasonal Forecast



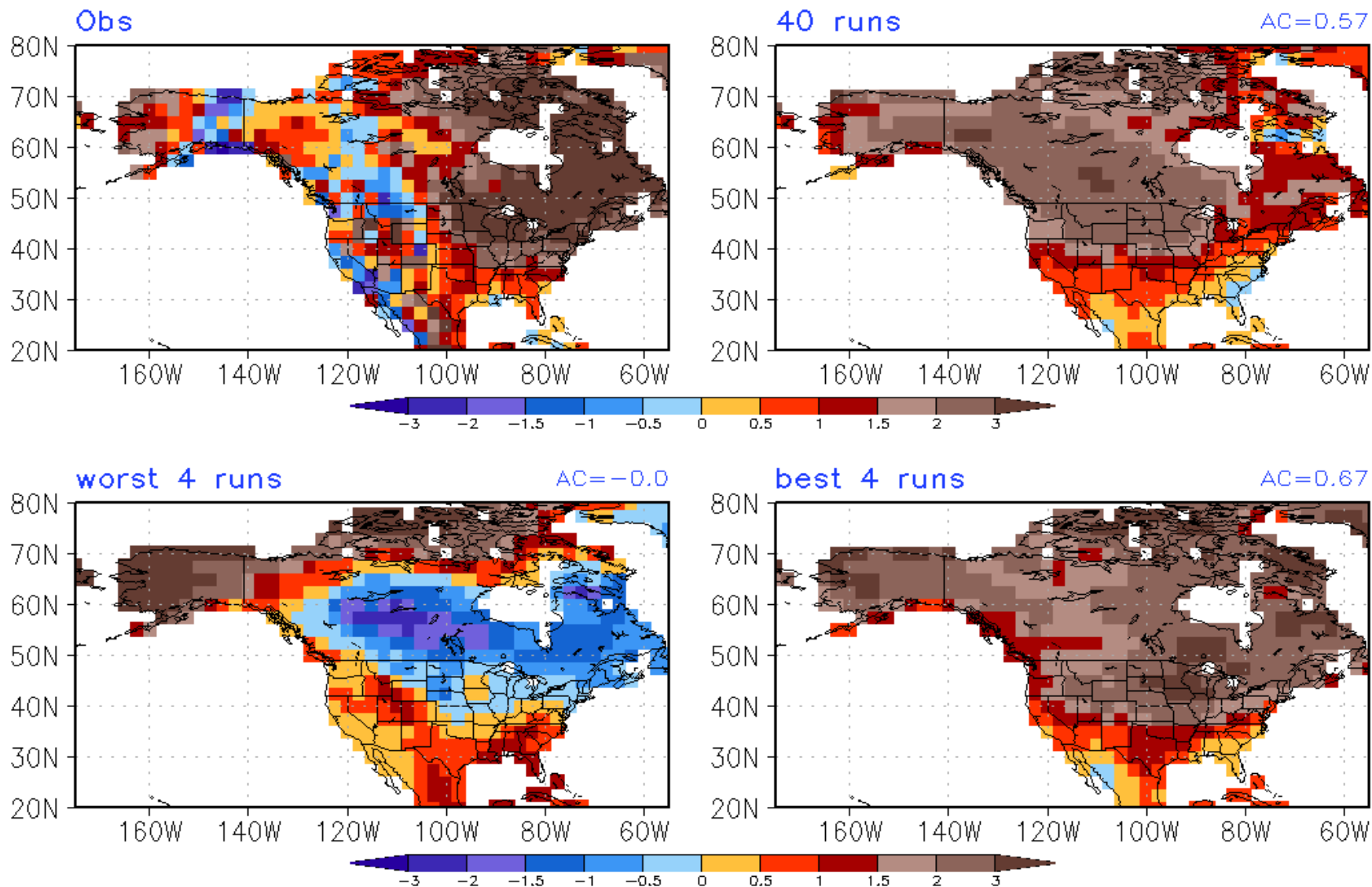
Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs  
Reconstructed Forecast



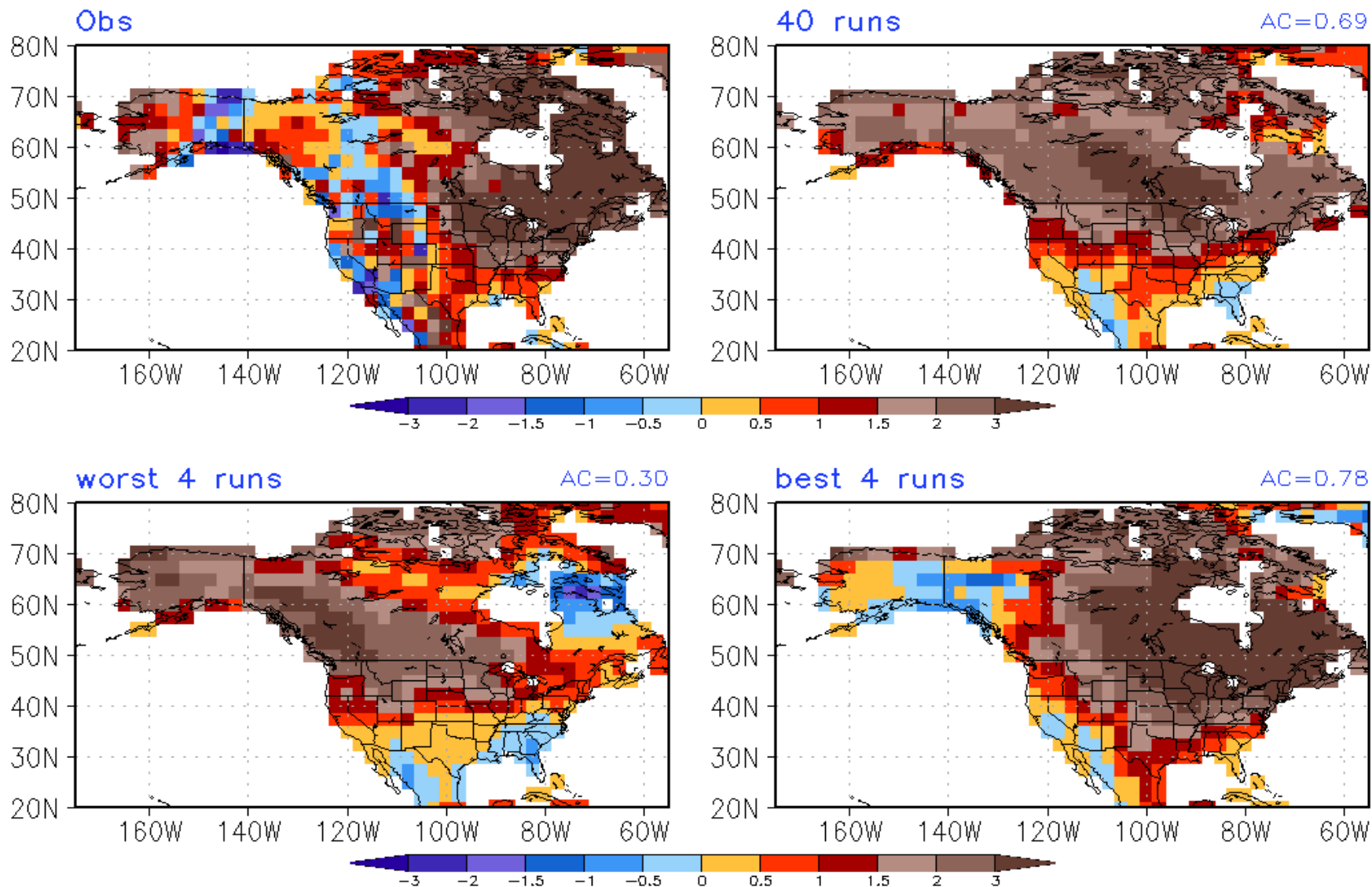
# JFM2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 T2m(K) 40 runs/worst 4 runs/best 4 runs  
Seasonal Forecast

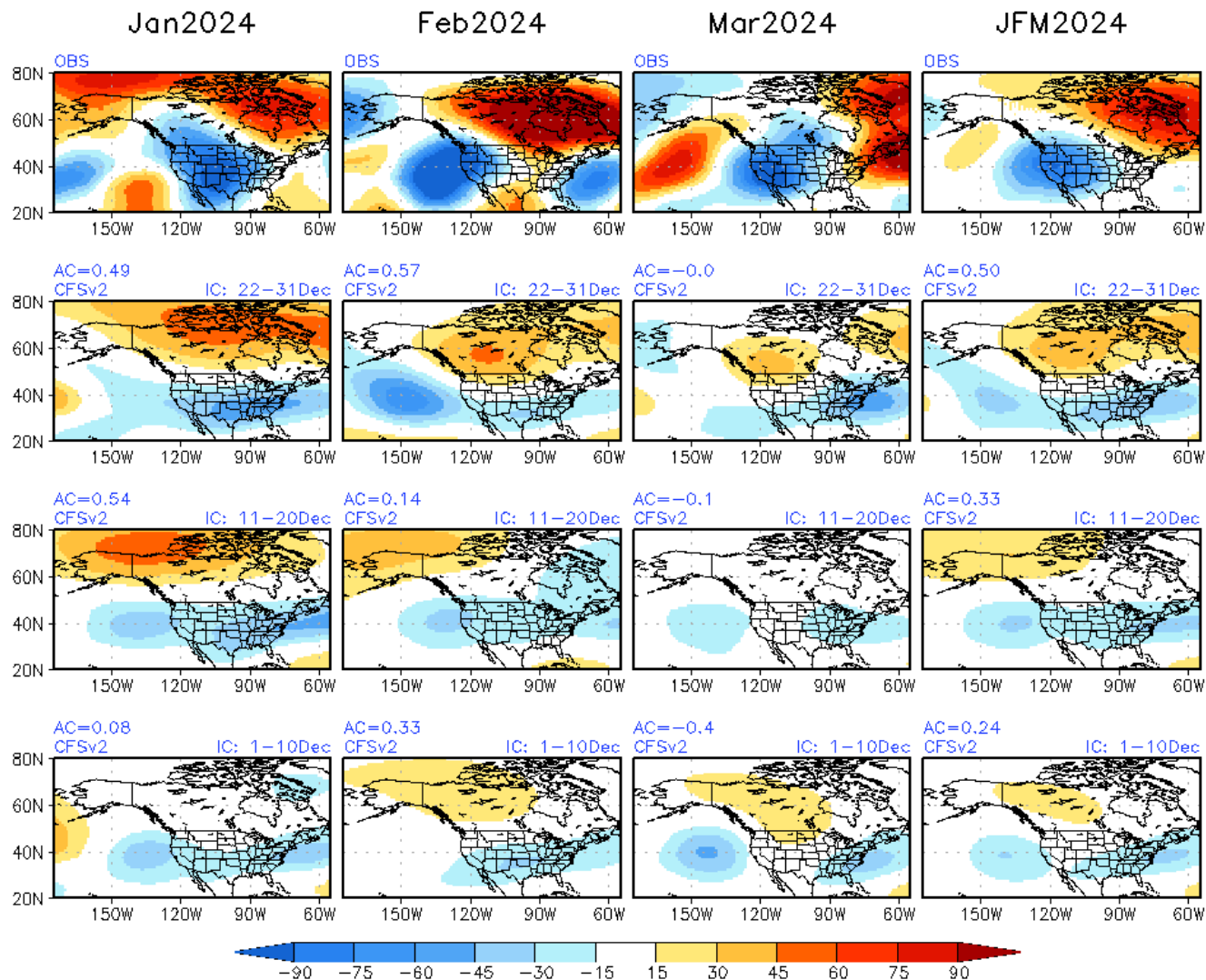


Observed & CFSv2 Forecast Ensemble Average Anomalies  
JFM2024 T2m(K) 40 runs/worst 4 runs/best 4 runs  
Reconstructed Forecast



# z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) JFM2024 z200(m) eddy & Obs



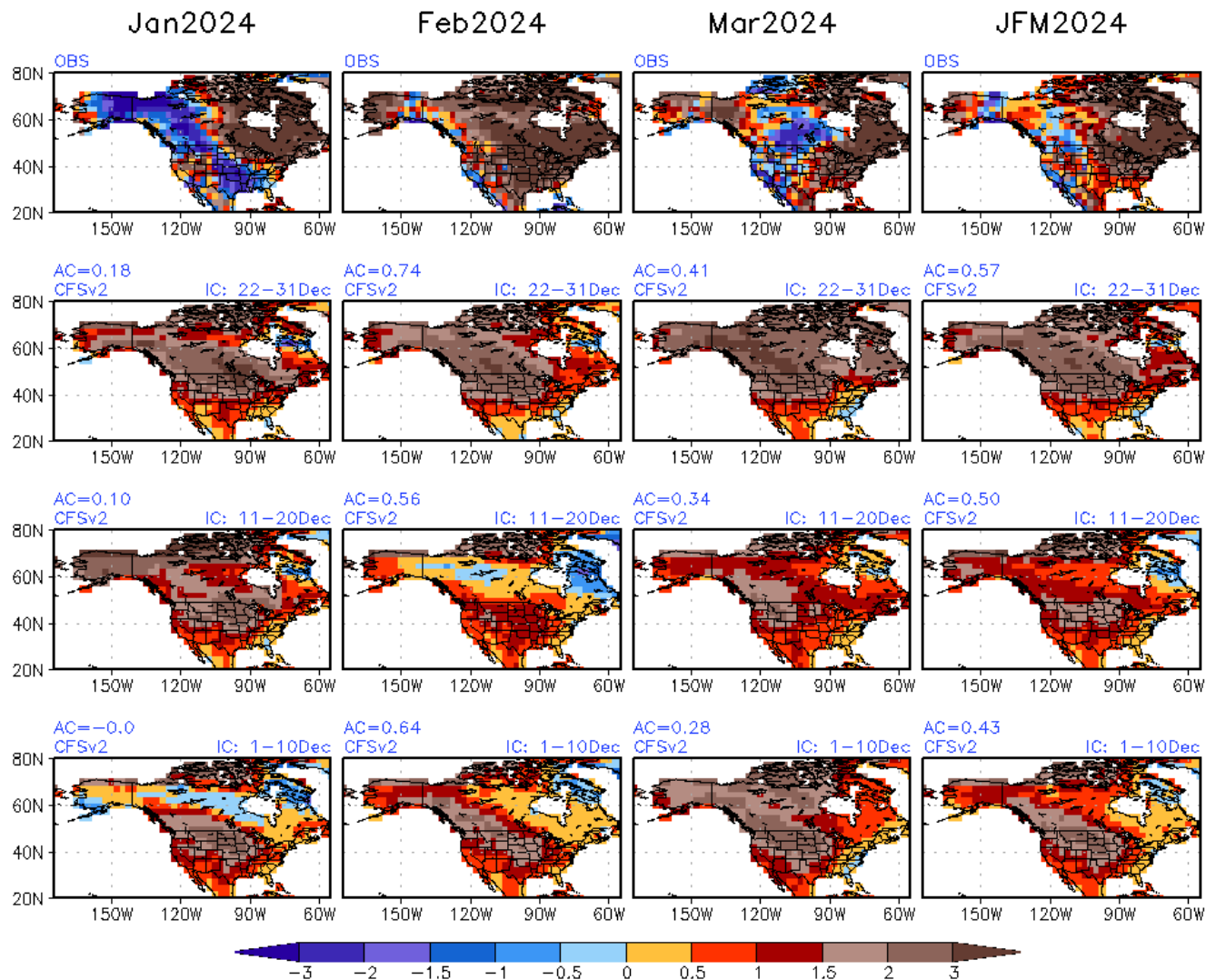
Top row: Observed anomaly.

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

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

# T2m(k) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) JFM2024 T2m(K) & Obs



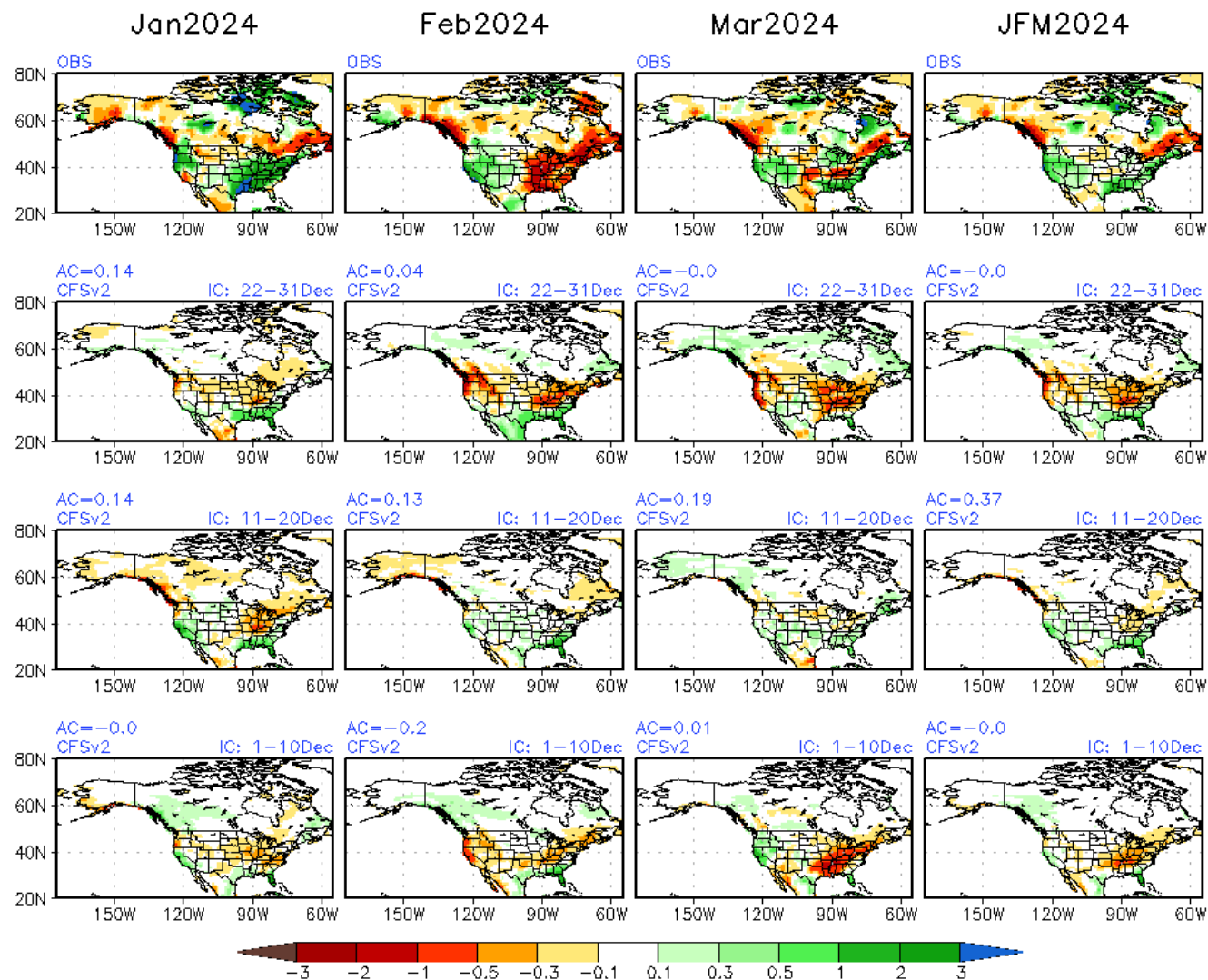
Top row: Observed anomaly.

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

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- 4<sup>th</sup> row: 1<sup>st</sup> - 10<sup>th</sup> of the prior month.

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

Monthly Means from Seasonal Fcst (40ensm) JFM2024 Prec(mm/day) & Obs



Top row: Observed anomaly.

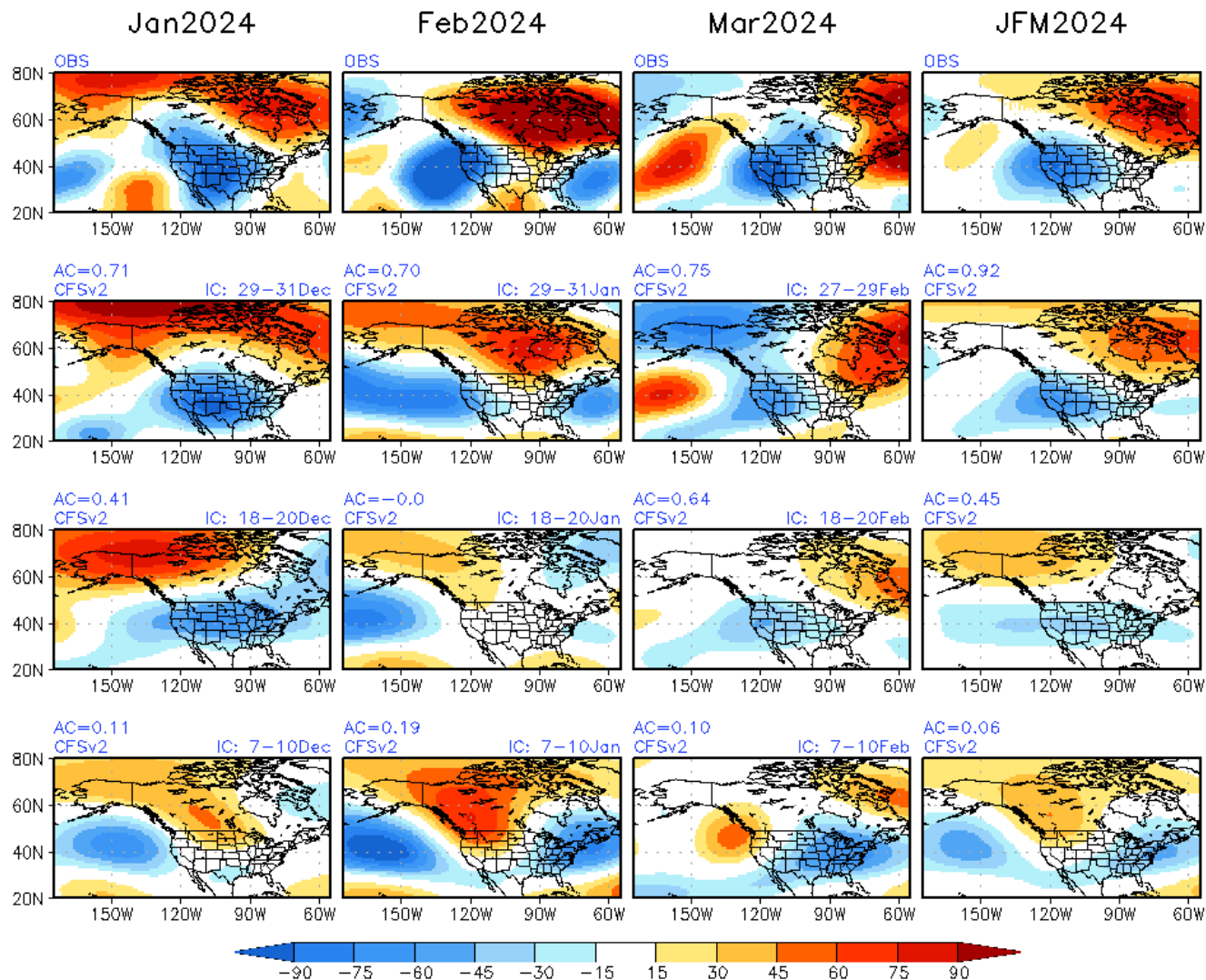
CFSv2 seasonal forecasts from different initial conditions in the month prior to the target season:

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



# z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst JFM2024 z200(m) eddy & Obs



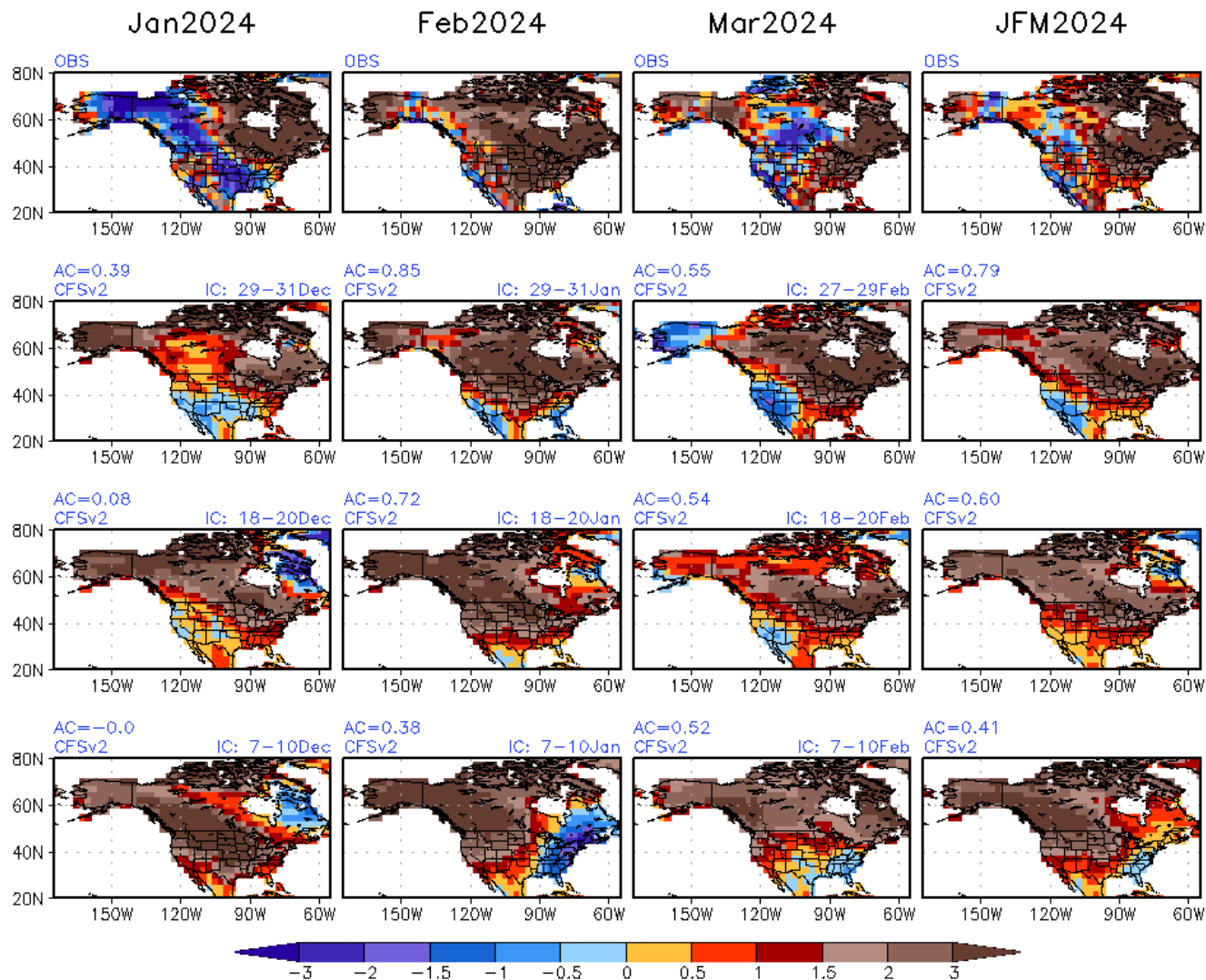
Top row: Observed anomaly.

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

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

# T2m(k) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst JFM2024 T2m(K) & Obs



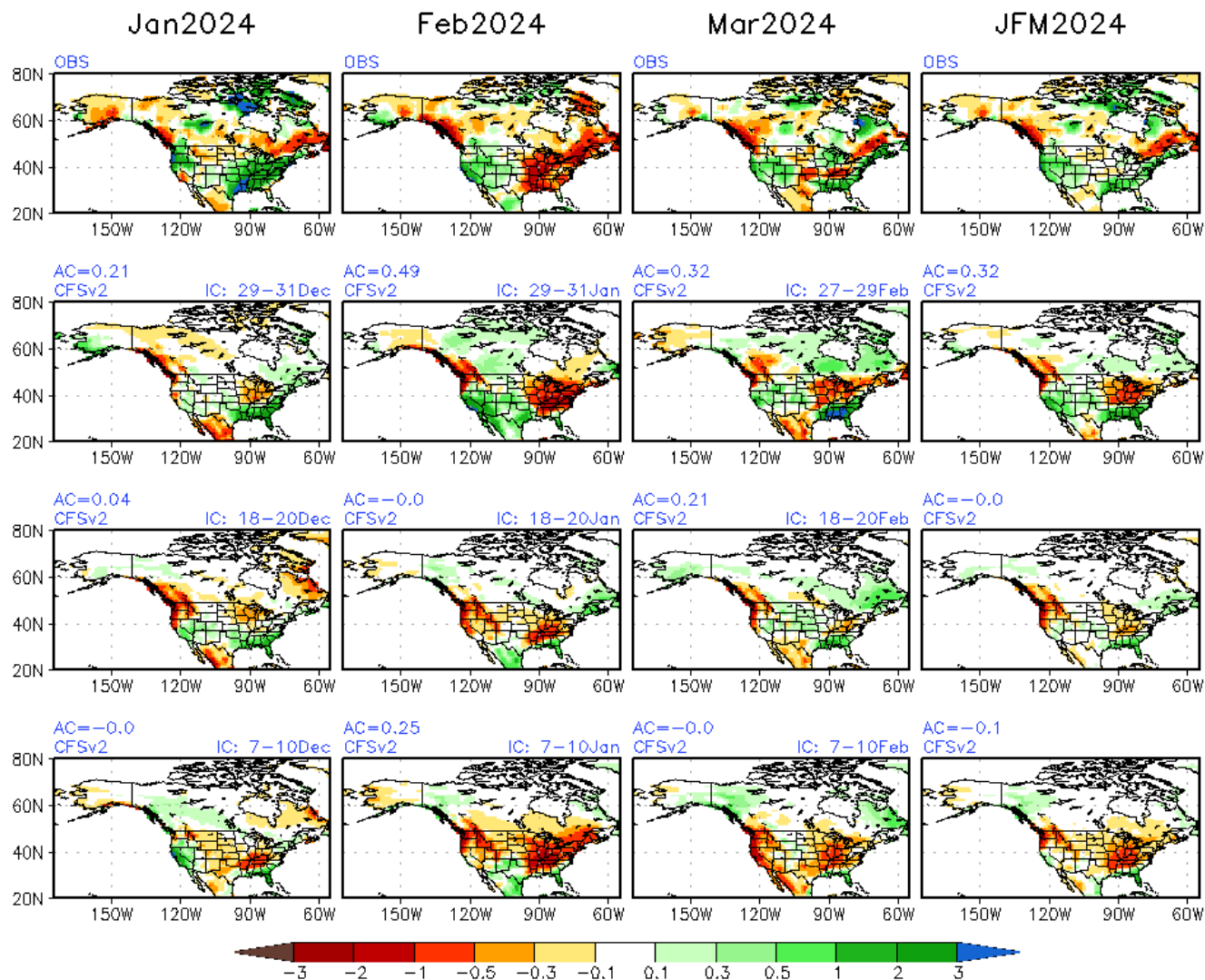
Top row: Observed anomaly.

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

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

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

Monthly Means from Monthly Fcst JFM2024 Prec(mm/day) & Obs



Top row: Observed anomaly.

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

- 2<sup>nd</sup> row: last 3 days of the prior month.
- 3<sup>rd</sup> row: 18<sup>th</sup> – 20<sup>th</sup> of the prior month.
- 4<sup>th</sup> row: 7<sup>th</sup> – 10<sup>th</sup> 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/](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

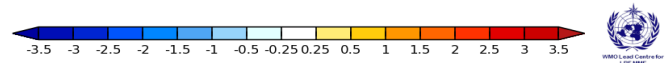
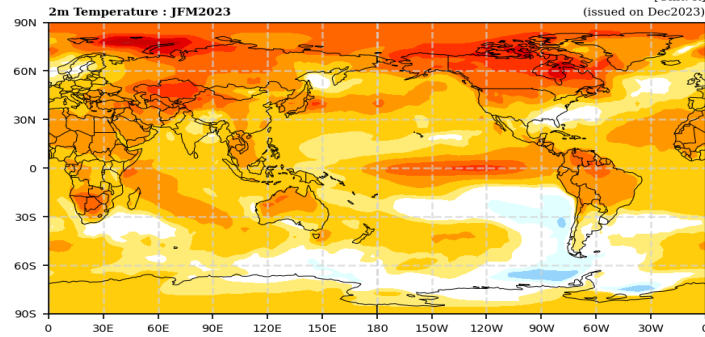
(<https://www.wmolc.org/>)

## Ensemble means

### Simple Composite Map

Beijing,CMCC,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Pretoria,Seoul,Tokyo,Toulouse,Washington

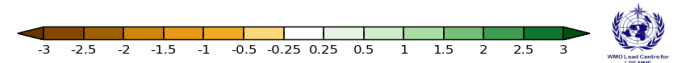
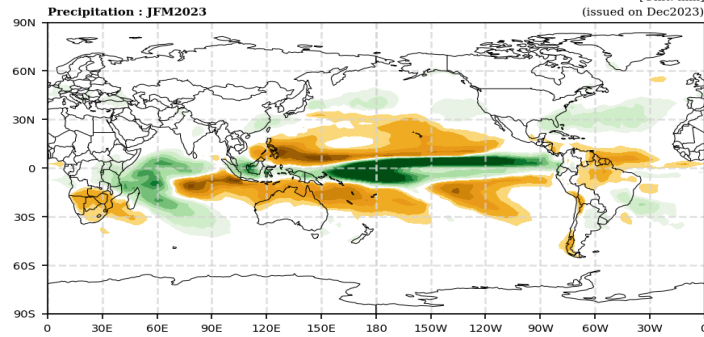
[Unit: K]  
(issued on Dec2023)



### Simple Composite Map

Beijing,CMCC,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Pretoria,Seoul,Tokyo,Toulouse,Washington

[Unit: mm]  
(issued on Dec2023)

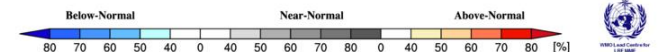
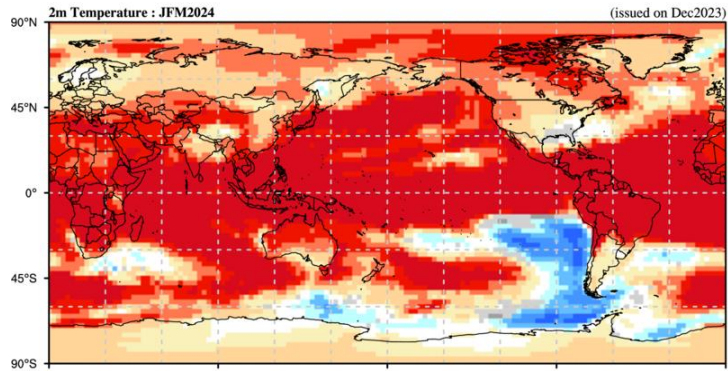


## Probabilities

### Probabilistic Multi-Model Ensemble Forecast

Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

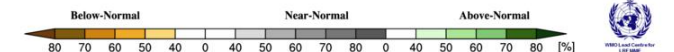
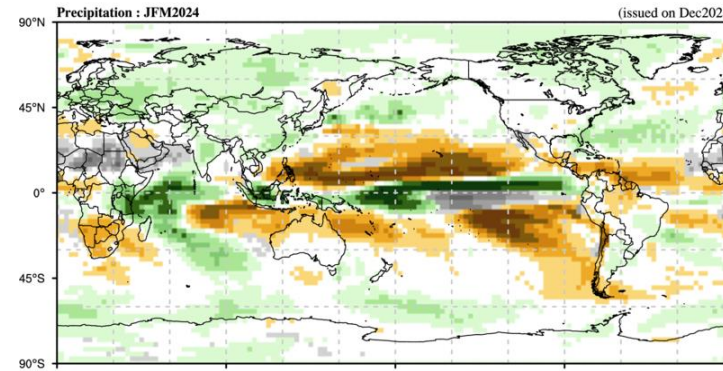
(issued on Dec2023)



### Probabilistic Multi-Model Ensemble Forecast

Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

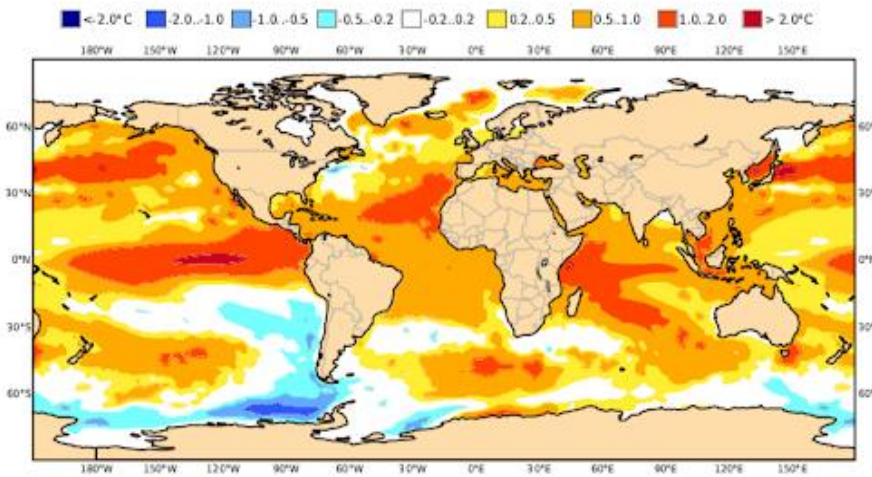
(issued on Dec2023)



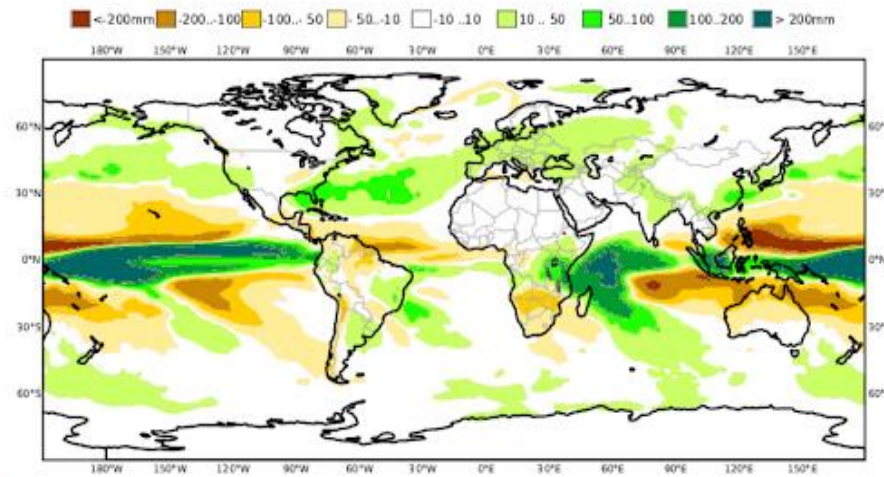
# C3S Seasonal Forecast

([https://climate.copernicus.eu/charts/c3s\\_seasonal/](https://climate.copernicus.eu/charts/c3s_seasonal/))

C3S multi-system seasonal forecast  
 Mean forecast SST anomaly  
 ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC  
 JFM 2024  
 Nominal forecast start: 01/12/23  
 Variance-standardized mean

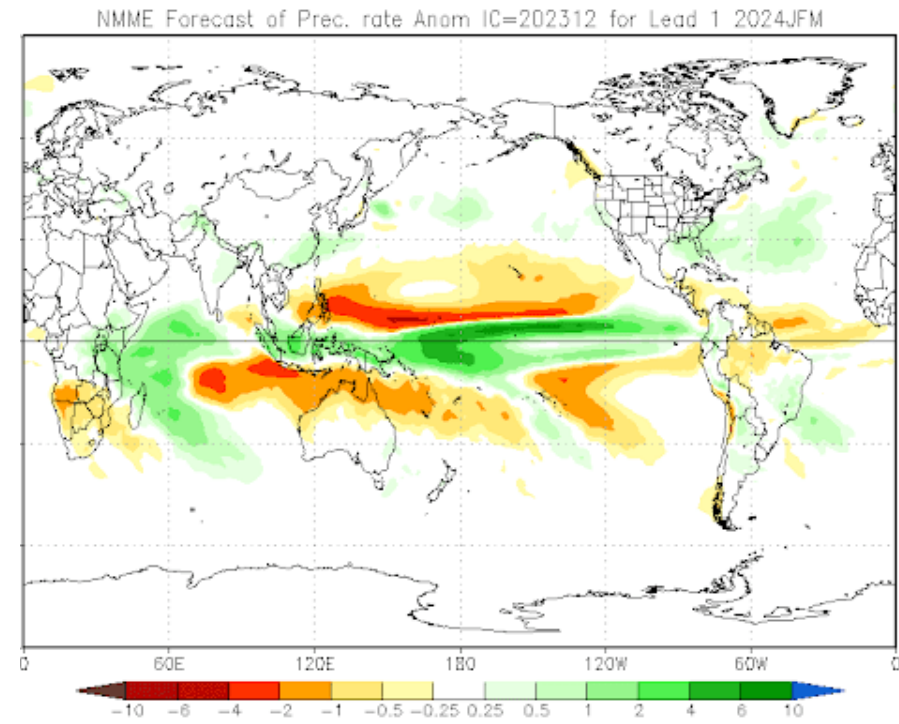
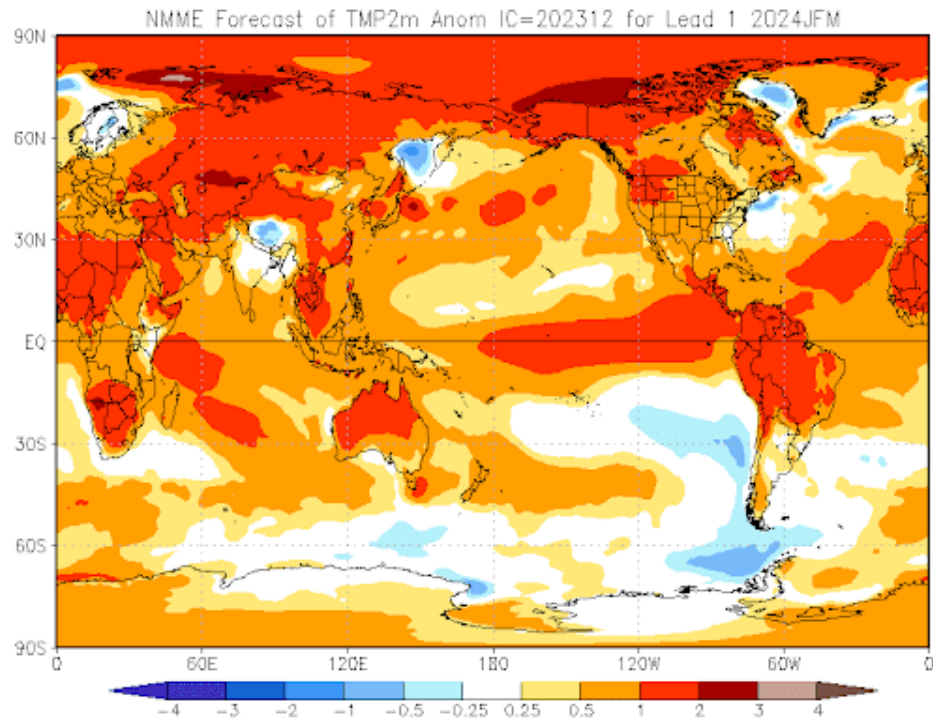


C3S multi-system seasonal forecast  
 Mean precipitation anomaly  
 ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC  
 JFM 2024  
 Nominal forecast start: 01/12/23  
 Variance-standardized mean



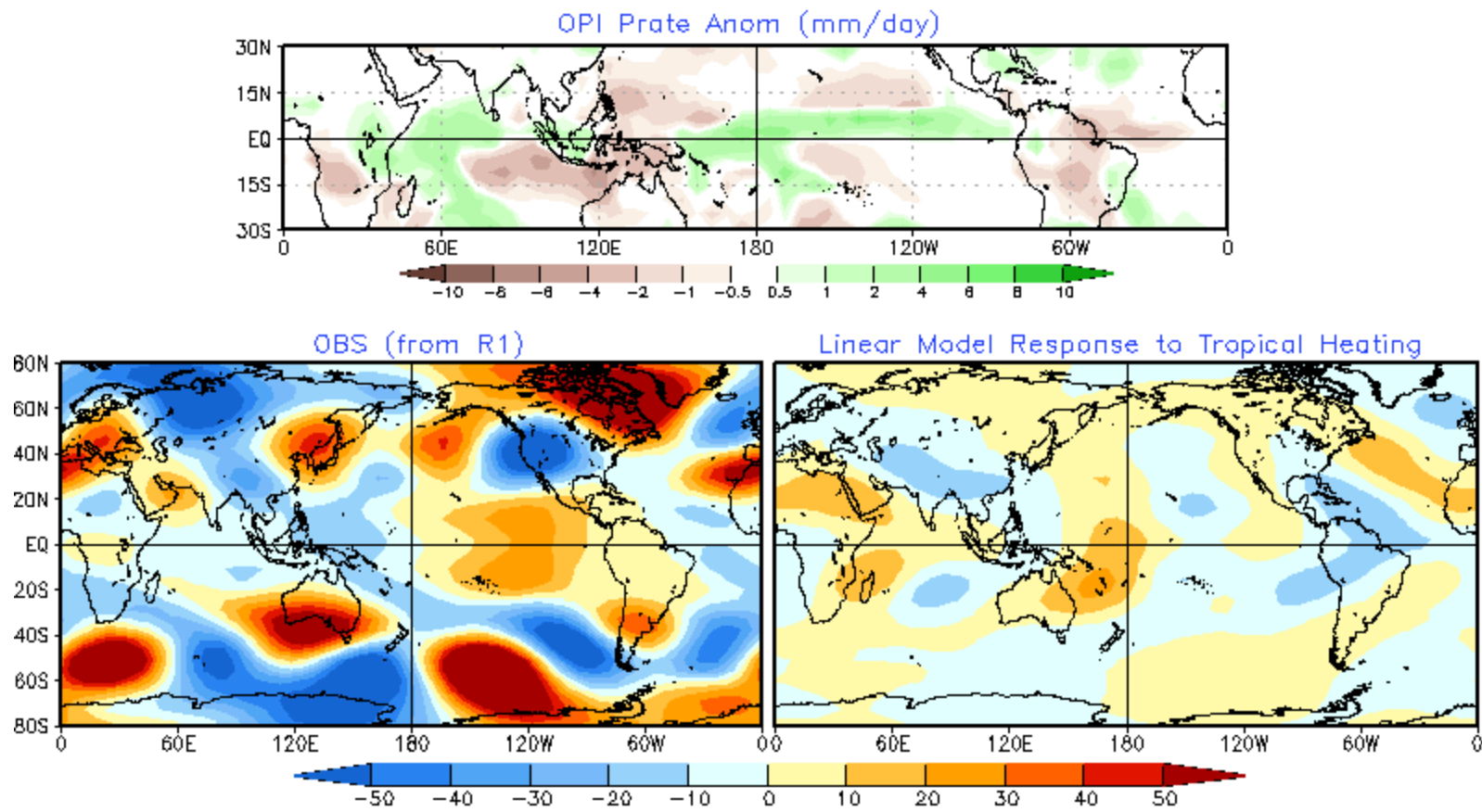
# North American Multi-Model Ensemble Seasonal Forecast

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



# 200mb Height from Linear Model

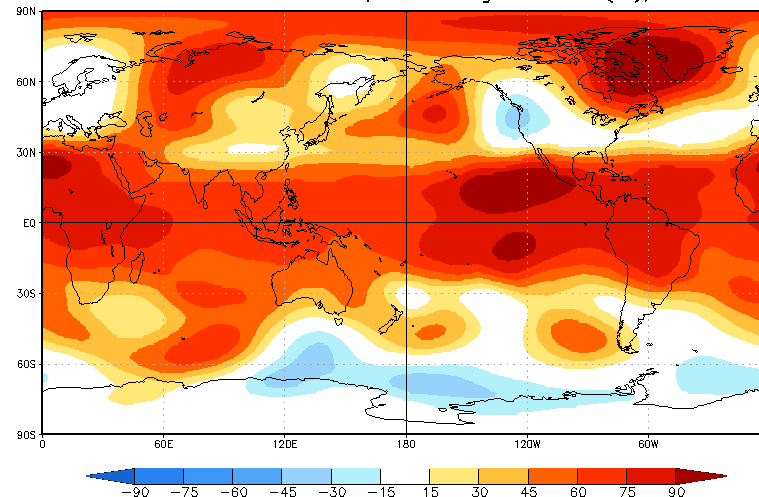
JFM2024 200mb Eddy HGT(m)  
OBS vs. Linear Model Response to Tropical Heating  
Heating is converted from Prate in 15S-15N





# Seasonal Forecasts from the Constructed Analog Model

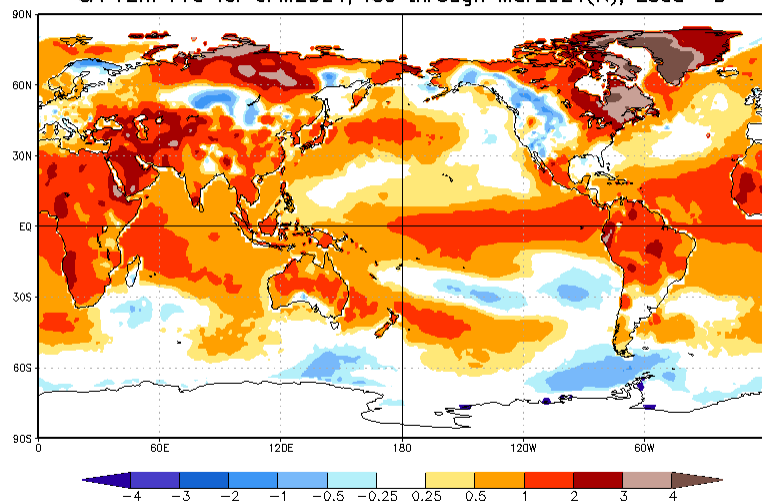
CA HGT200 Prd for JFM2024, ICs through Mar2024(m), Lead -3



Peitao Peng CPC/NCEP/NWS/NOAA

Base Period 1991-2020

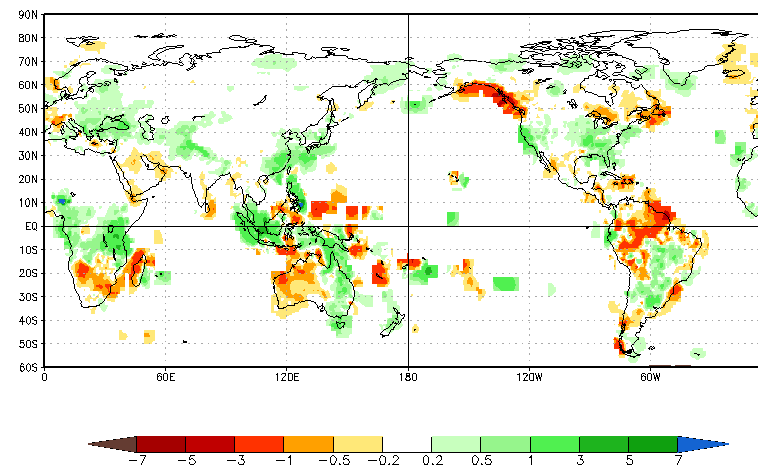
CA T2m Prd for JFM2024, ICs through Mar2024(K), Lead -3



Peitao Peng CPC/NCEP/NWS/NOAA

Base Period 1991-2020

CA Prec Prd for JFM2024, ICs through Mar2024(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.