

# Attribution of Seasonal Climate Anomalies March-April-May 2022

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

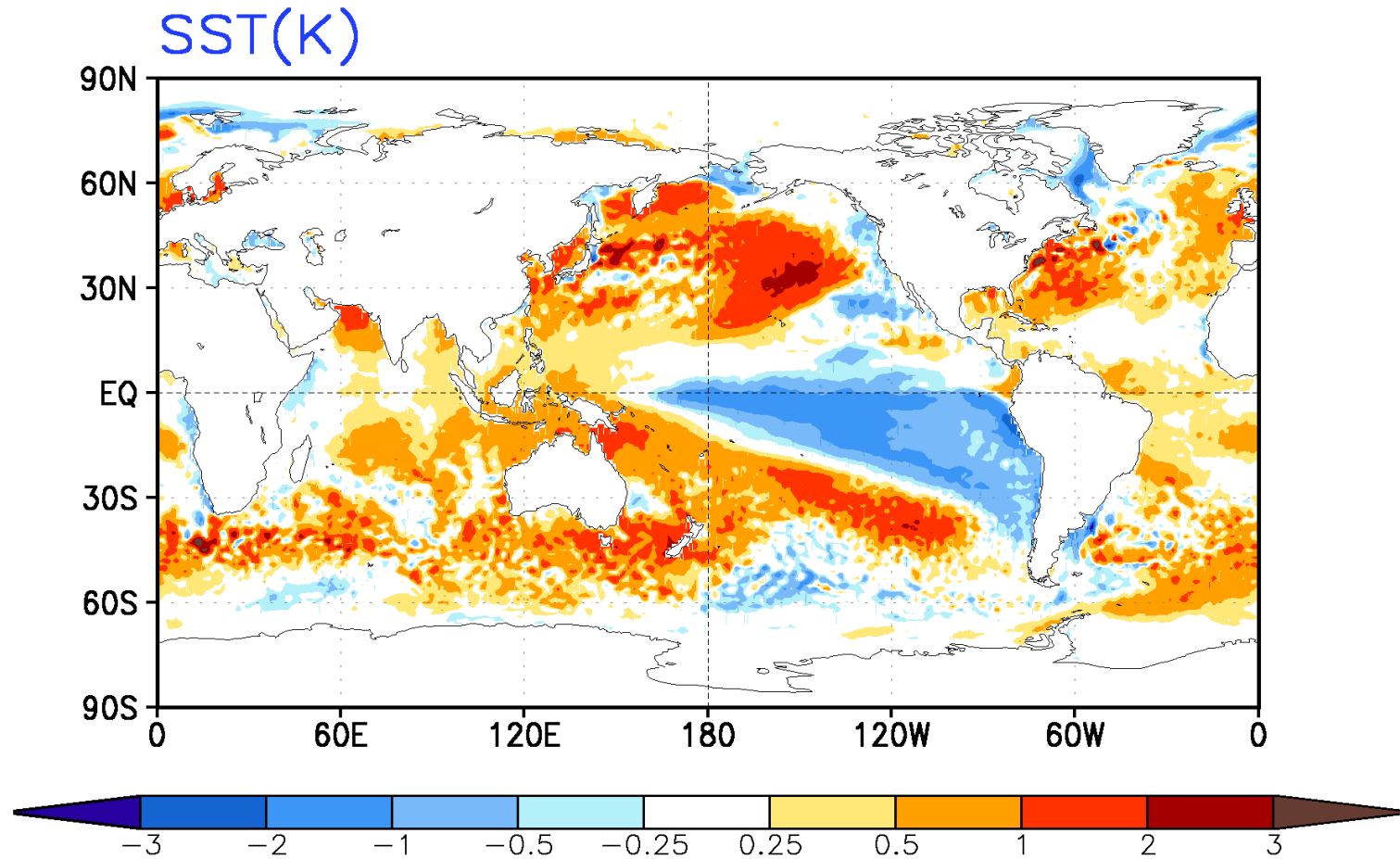
# Summary of Observed Conditions and Outlooks

- Tropical SST anomalies continued in La Nina conditions; the equatorial Atlantic and North Pacific SST anomalies remained on the warm side (slide 4). In general, the large-scale distribution of SST anomalies was predicted well (slide 10);
- Large-scale distribution of wet precipitation anomalies in the equatorial eastern Indian Ocean, Maritime Continent and dry conditions in the equatorial western, central Pacific Ocean ([a reflection of La Niña conditions](#)) were predicted well in the initialized CFSv2 and other MME models (slides 37-39).
- Initialized CFSv2 forecasts predicted the large-scale distribution of observed 200mb height anomalies over tropical and sub-tropical areas (slide 12), while missed the height negative anomalies over the western Canada, leading to erroneous prediction of cold temperature anomalies (slide 15, 16).
- CFSv2 and MME prediction of MAM2022 North American precipitation and temperature anomalies was consistent with [the La Niña composite](#). The precipitation forecast captured the observed dry conditions over California and southwest US, the temperature forecast captured the observed cold anomalies over the northwest and warm anomalies over the southern and northeast areas of US (slide 7, 14, 16).
- May 2022 monthly mean forecasts from the shortest leads predicted most of the observed temperature anomalies (slides 34).

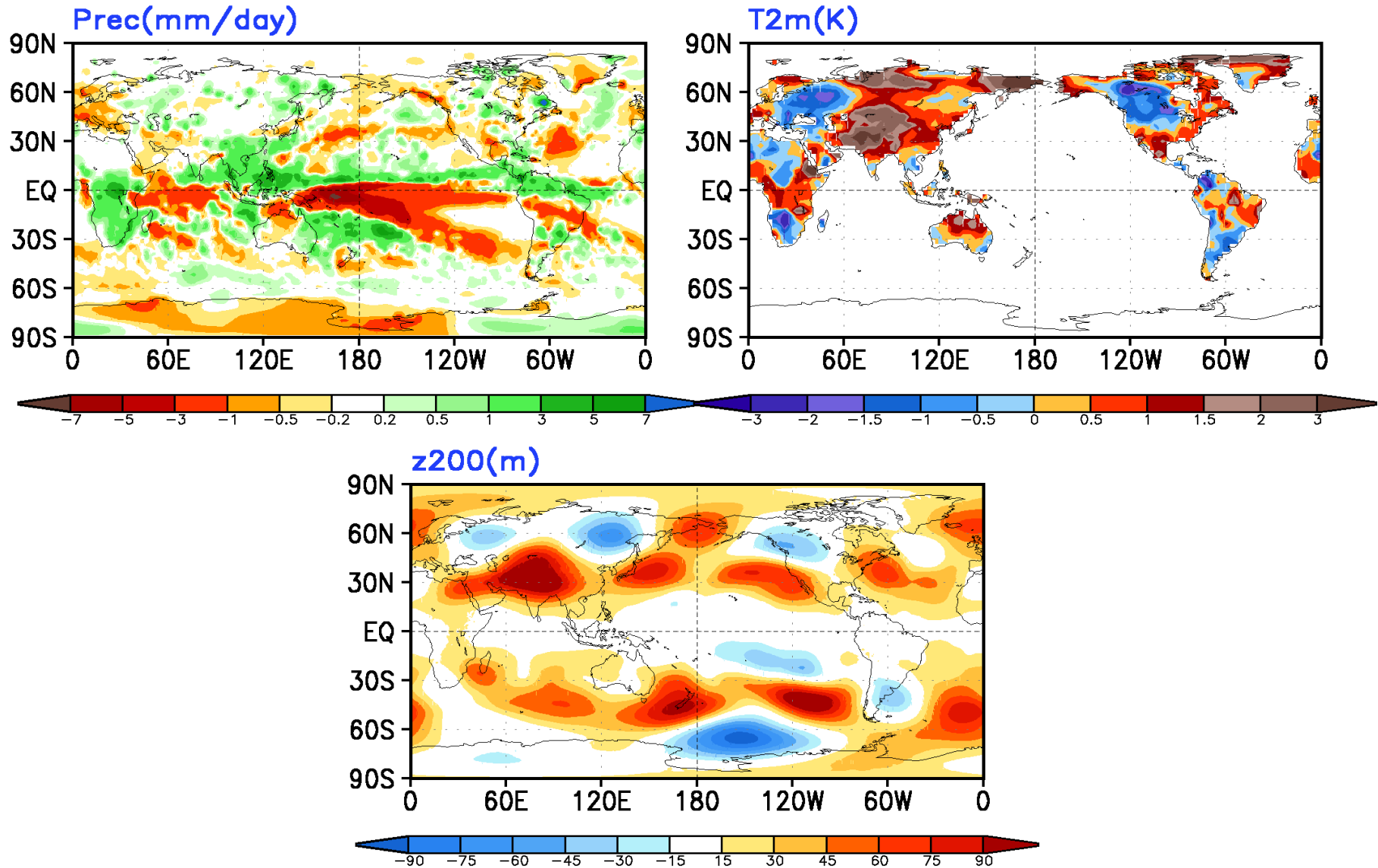
# Observed Seasonal Anomalies

## Global and North America

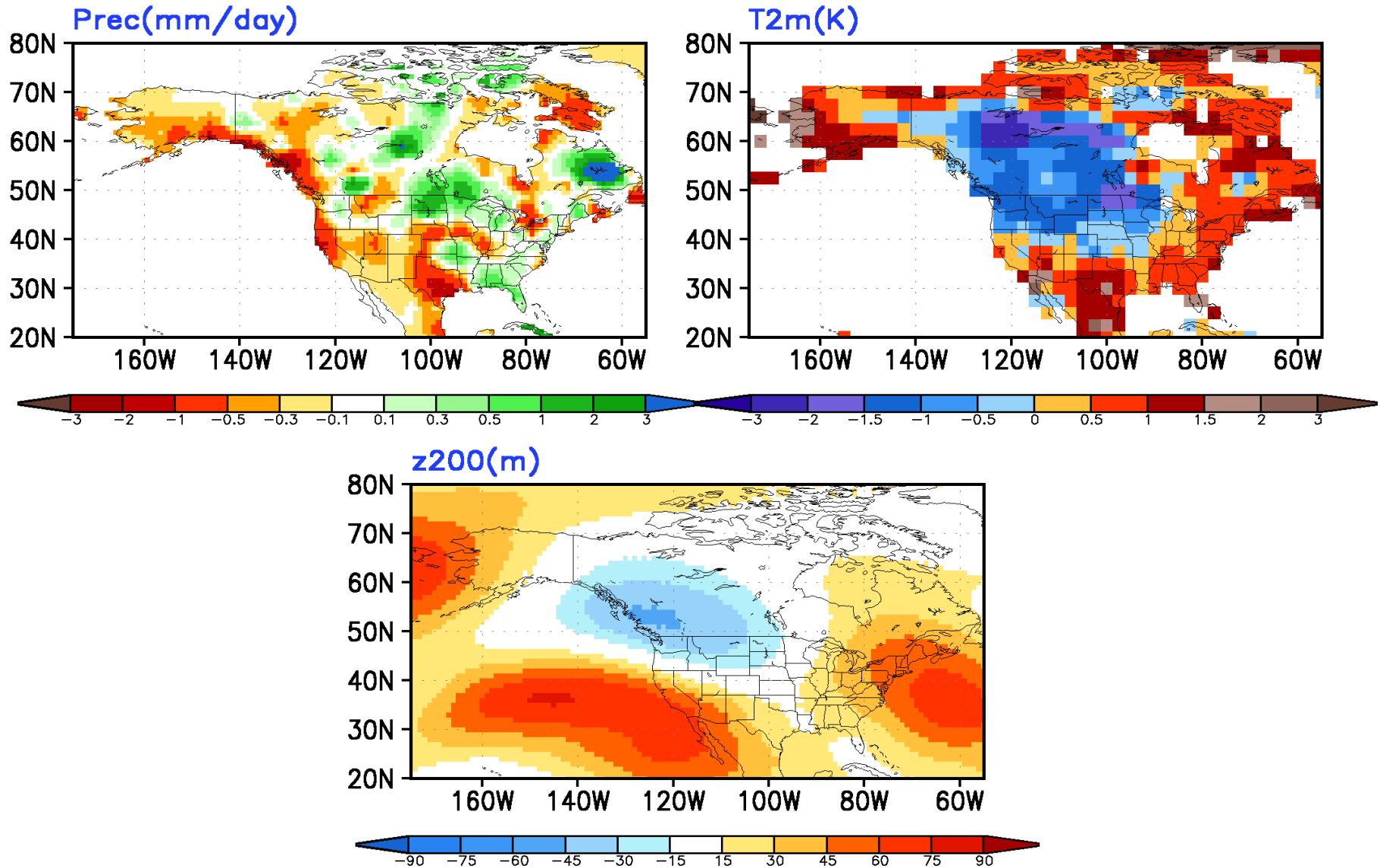
# Observed Anomaly MAM2022



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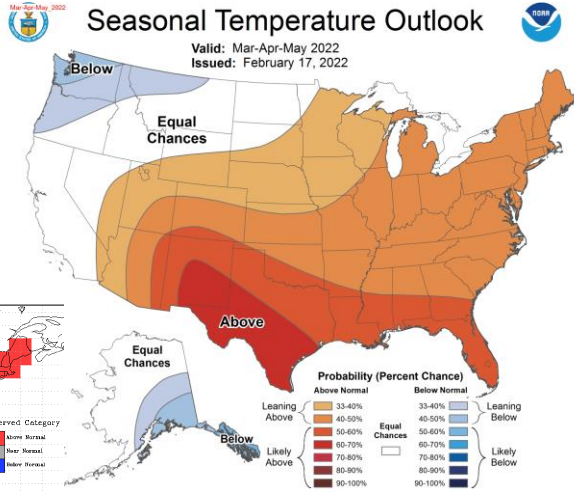
# Observed Anomaly MAM2022



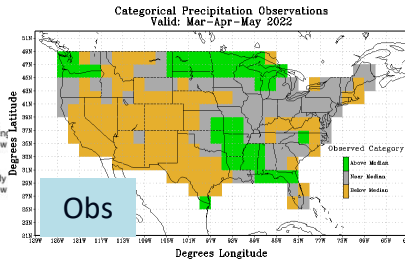
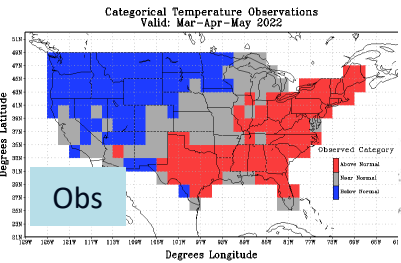
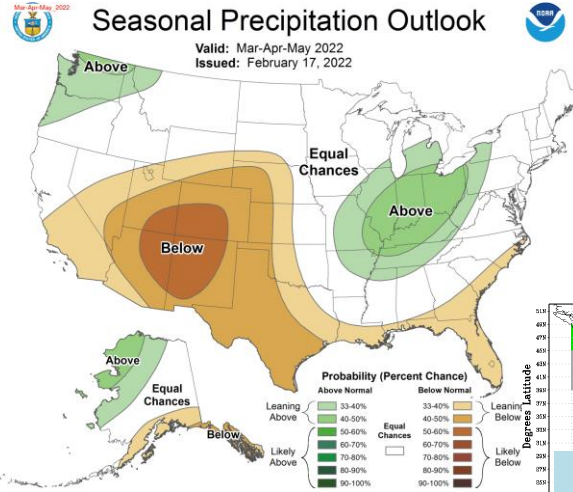
# CPC Seasonal Outlooks and NMME Forecasts

CPC

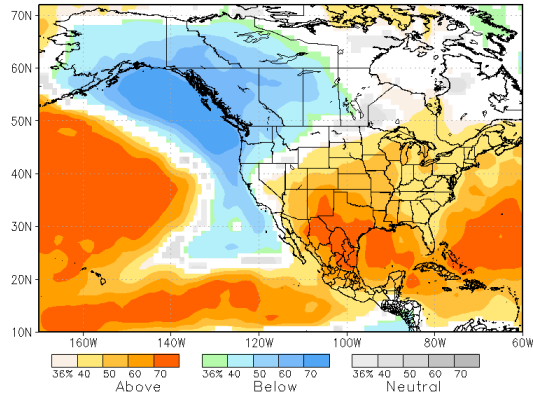
Temp nonEC  
HSS=27



Prec nonEC  
HSS=43

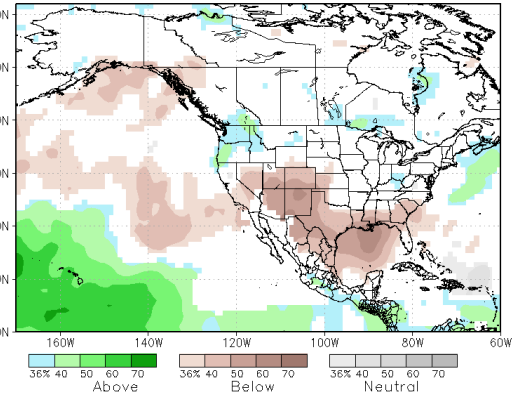


NMME prob fcst TMP2m IC=202202 for lead 1 2022 MAM



NMME

NMME prob fcst Prate IC=202202 for lead 1 2022 MAM



For the rationale behind CPC outlooks see: [https://www.cpc.ncep.noaa.gov/products/archives/long\\_lead/PMD/2022/202202\\_PMD90D](https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2022/202202_PMD90D)

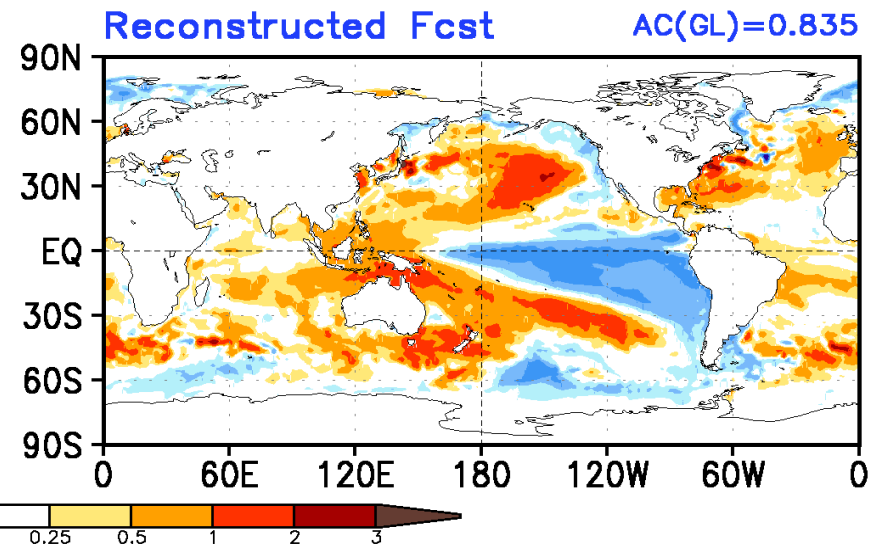
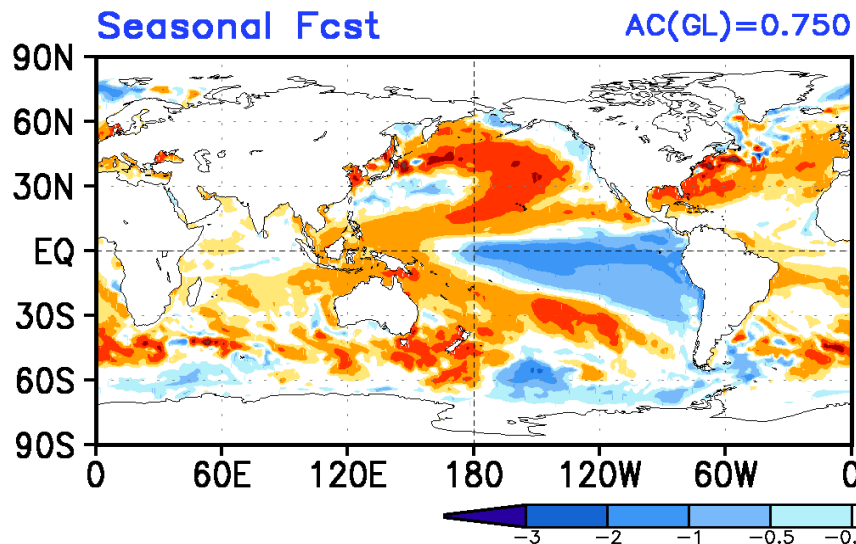
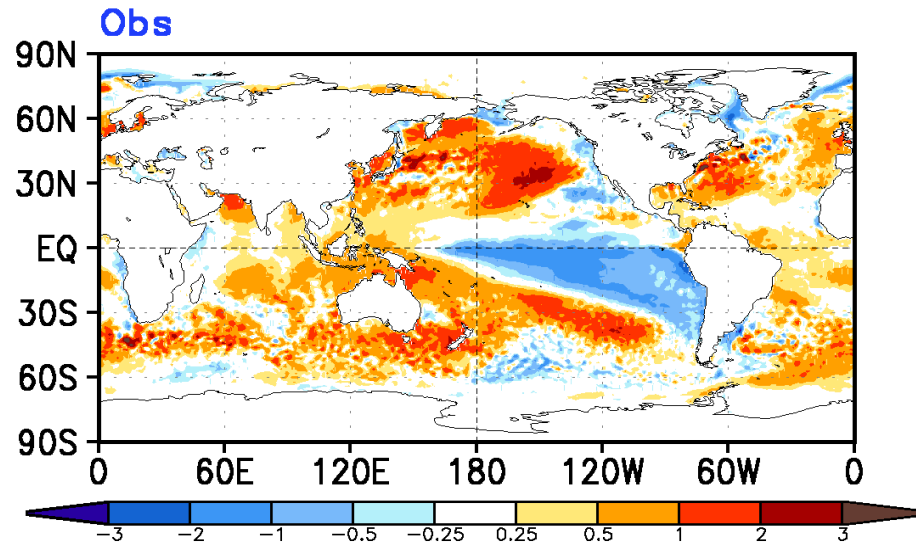
# Model Simulated/Forecast Ensemble Mean Anomalies



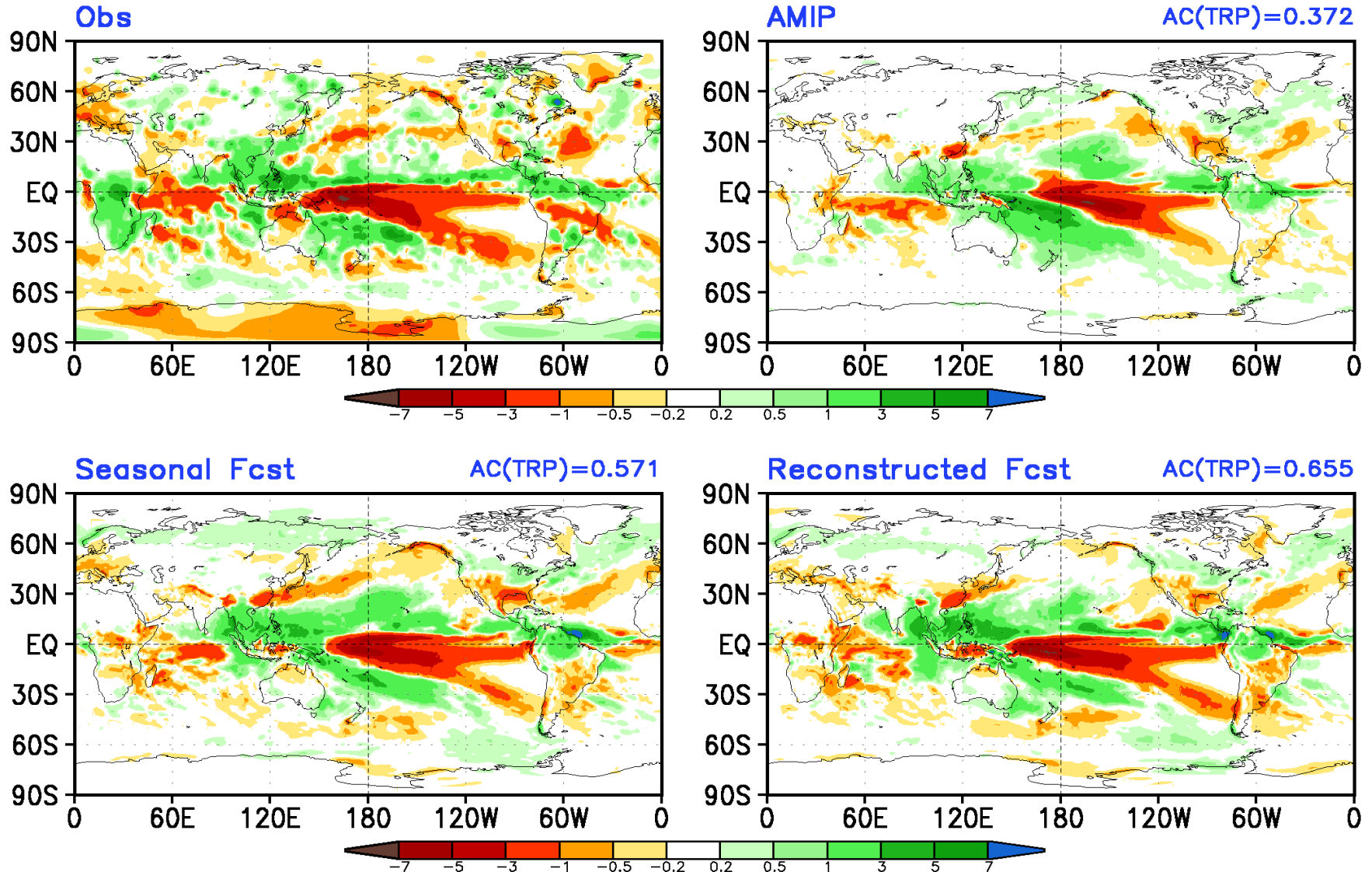
# Model Simulated/Forecast Ensemble Average Anomalies

- **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).

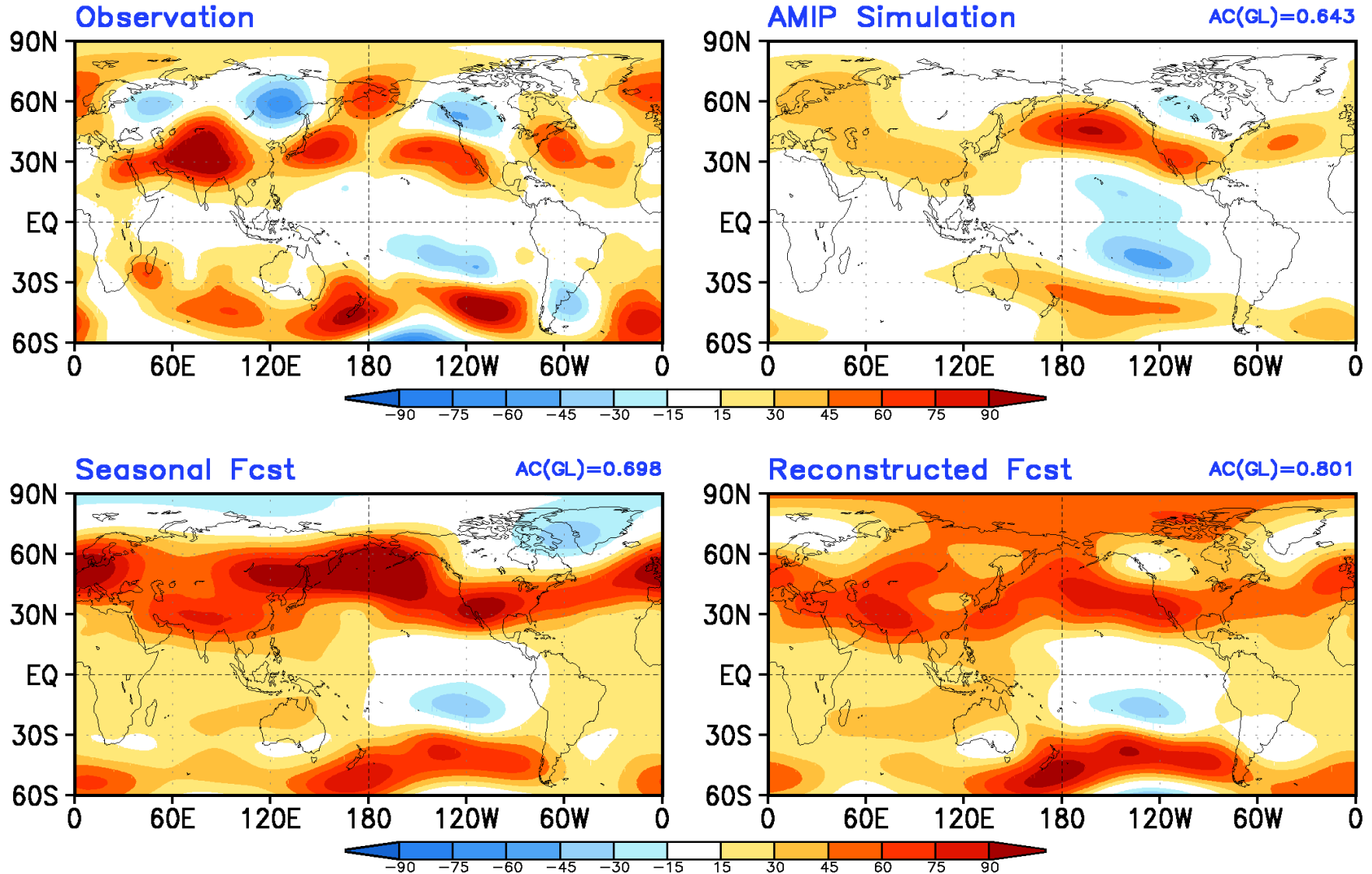
# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



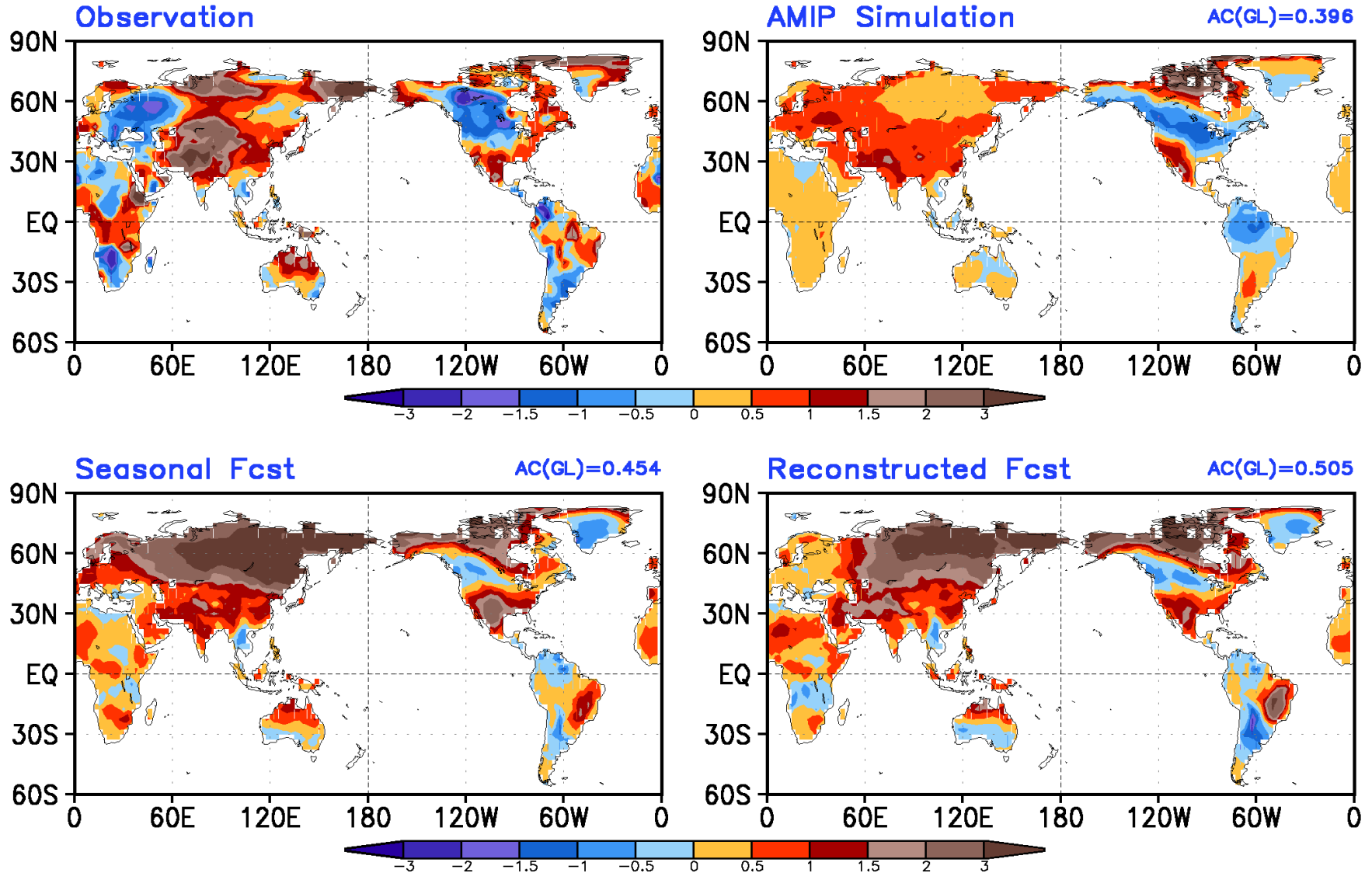
# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



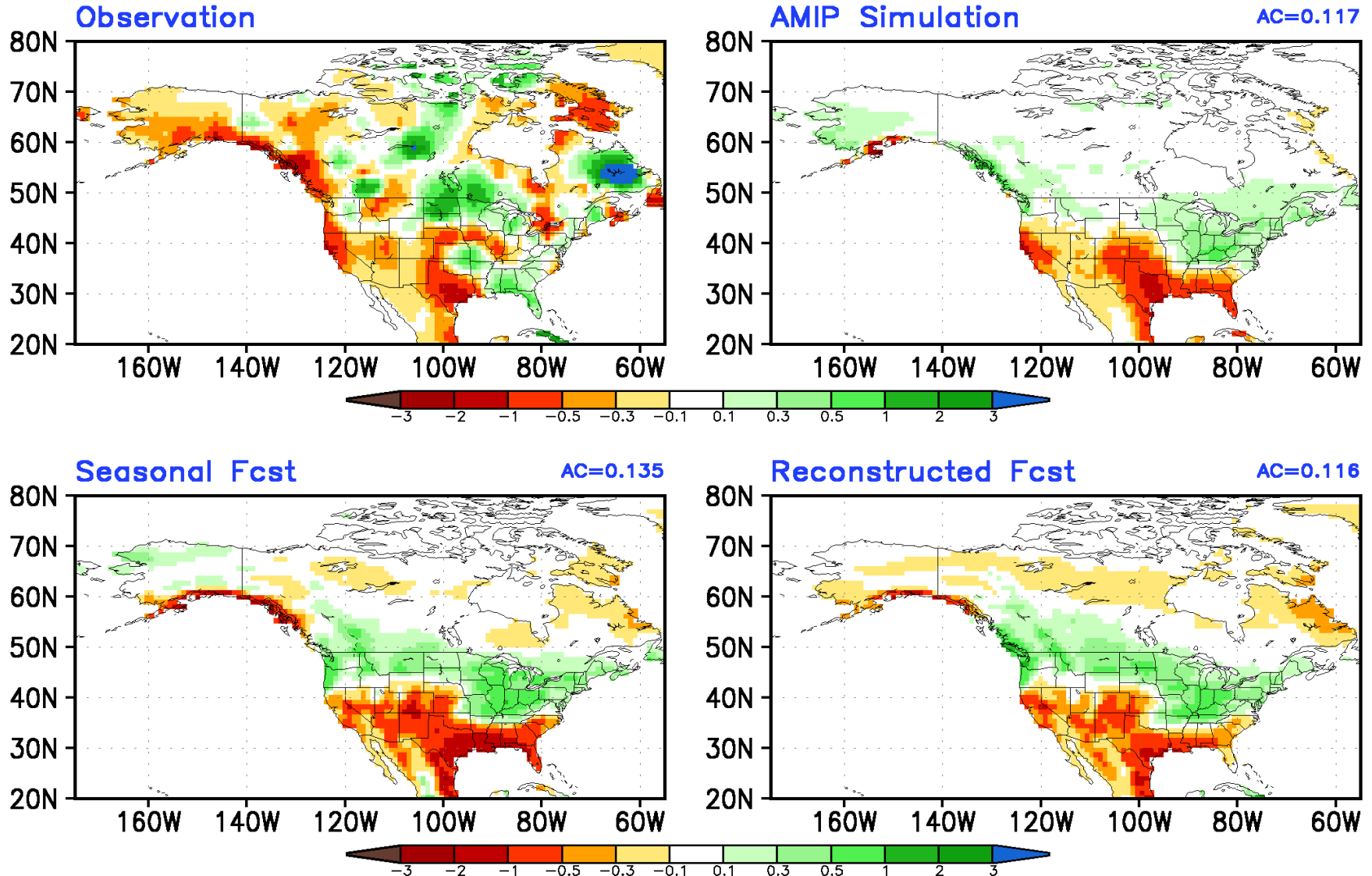
# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



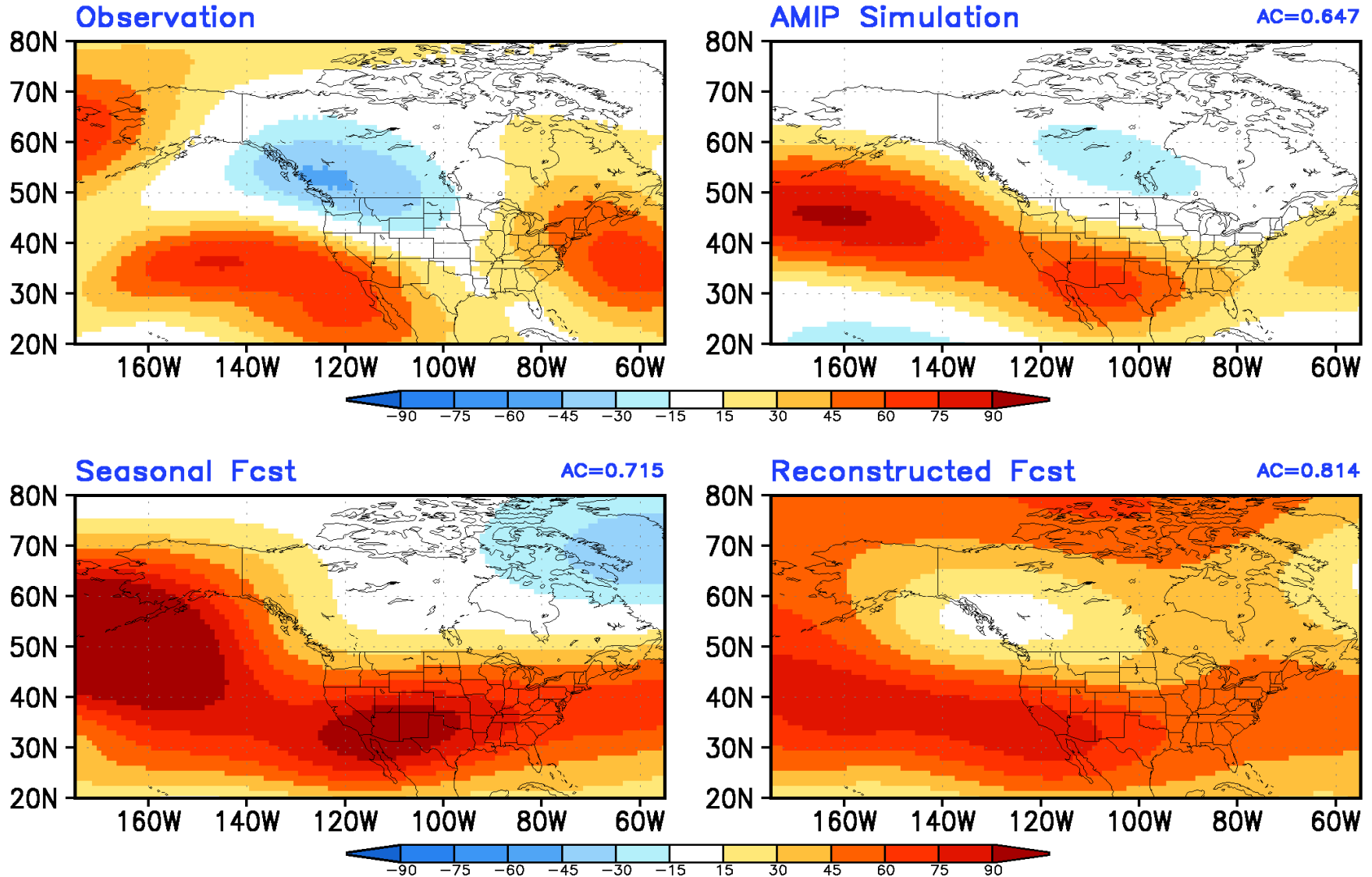
# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



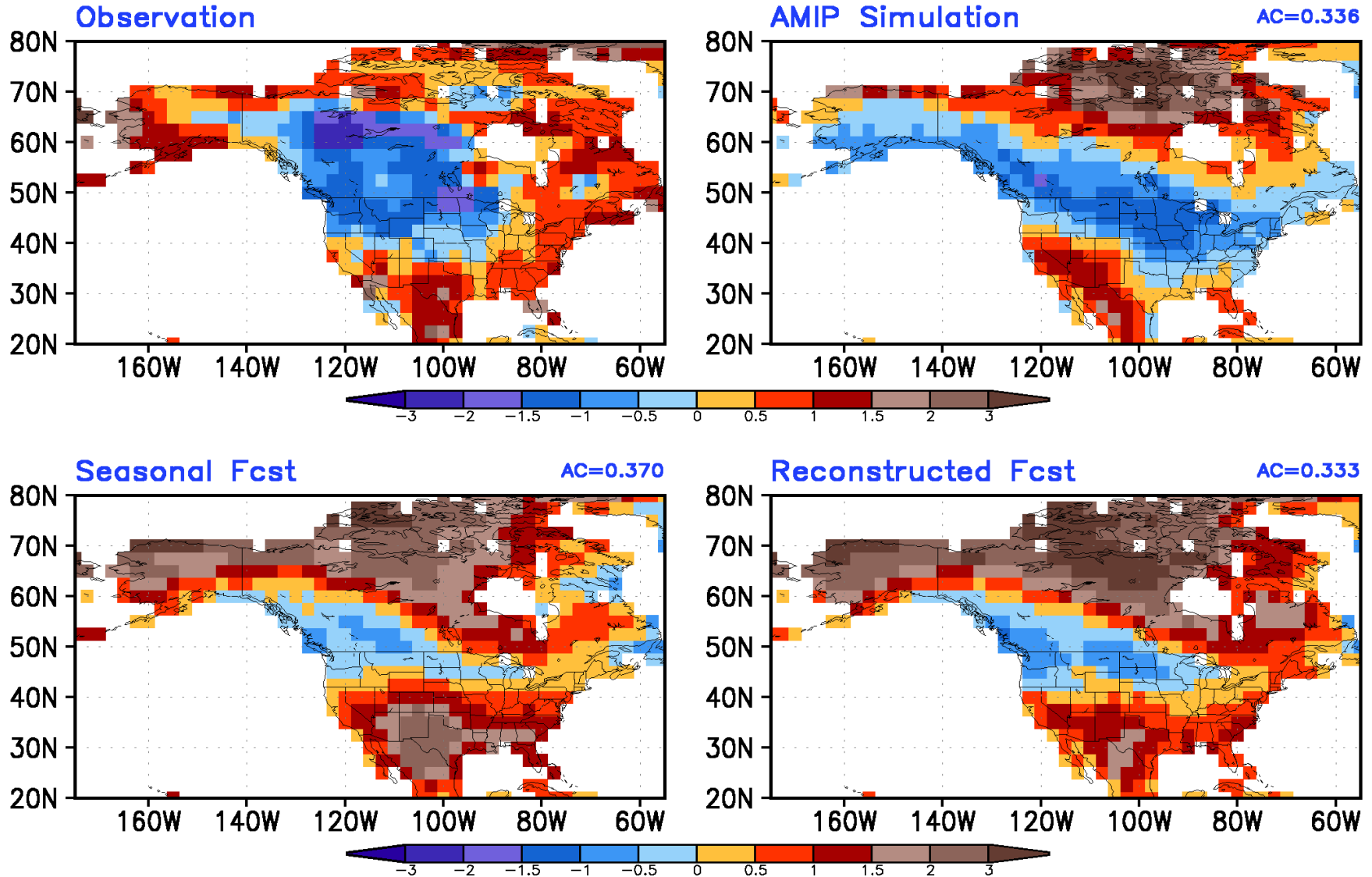
# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



# MAM2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



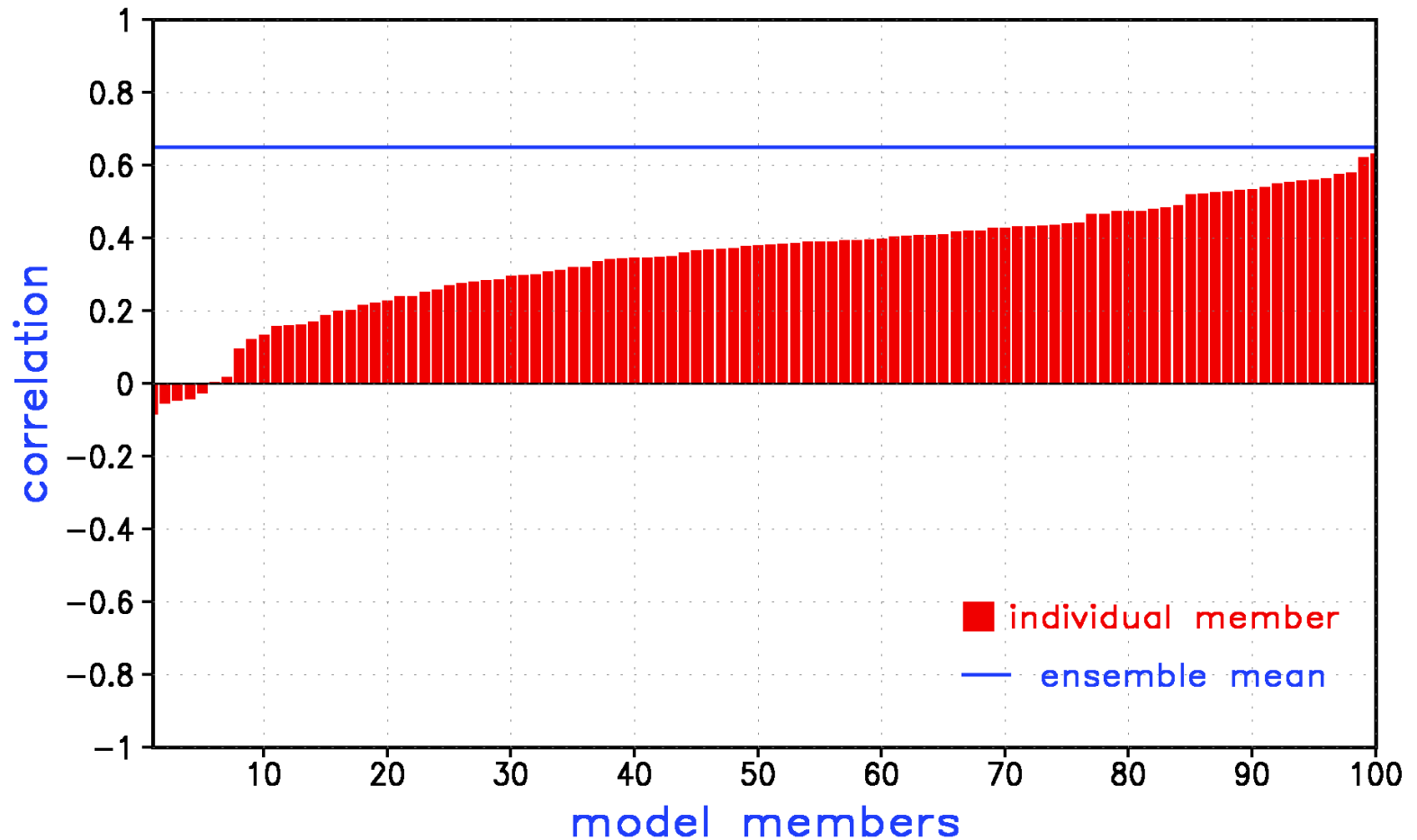


# Model Simulated/Forecast Anomalies: Individual Runs

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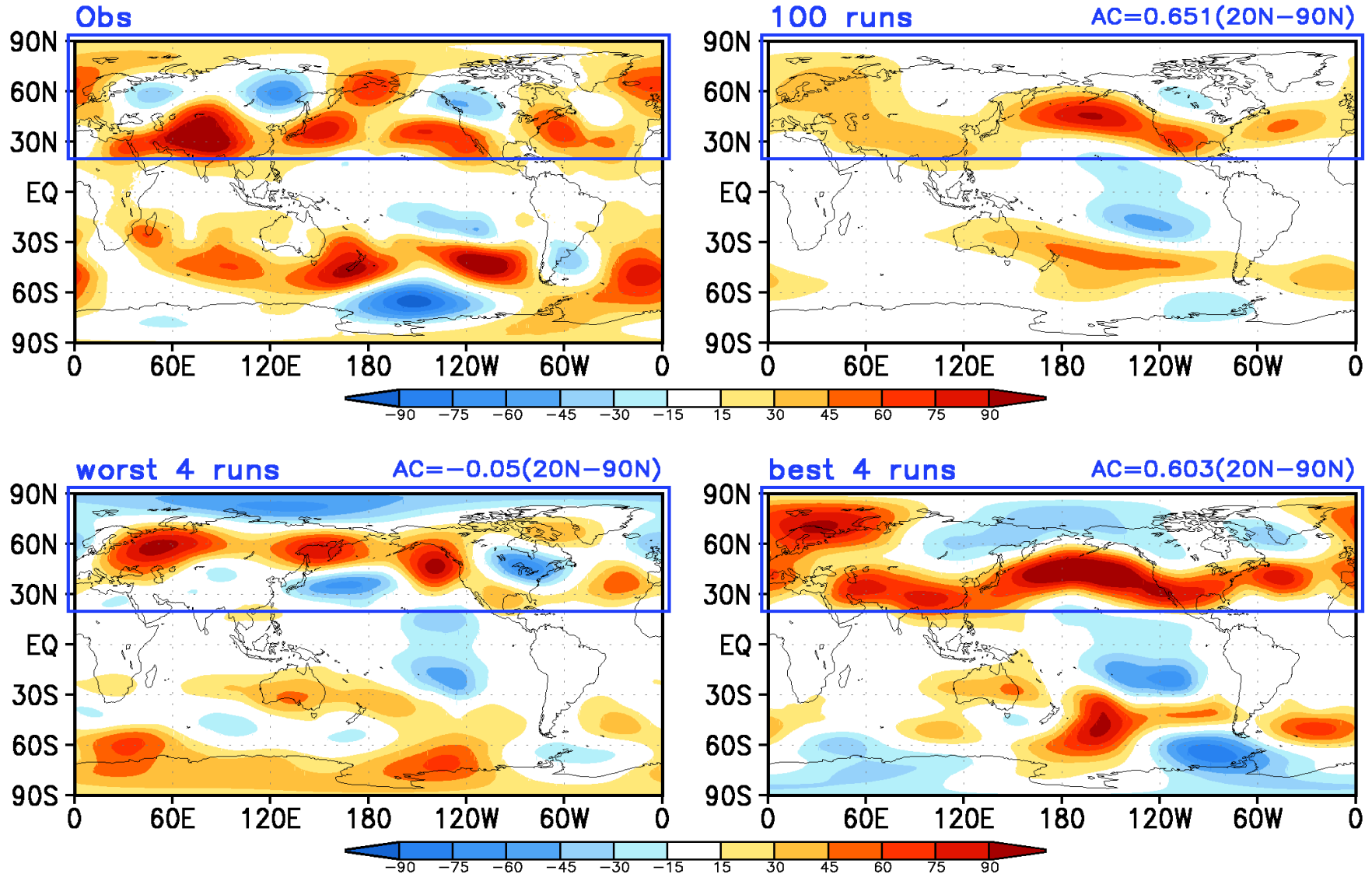
- In this analysis, anomalies from individual model runs are compared against the observed seasonal mean anomalies. The spatial resemblance between them is quantified based on anomaly correlation (AC).
- The distribution of AC across all model simulations is indicative of probability of observed anomalies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

# MAM2022 Anomaly Correlation for Individual AMIP Simulation with Observation — z200(20N–90N)

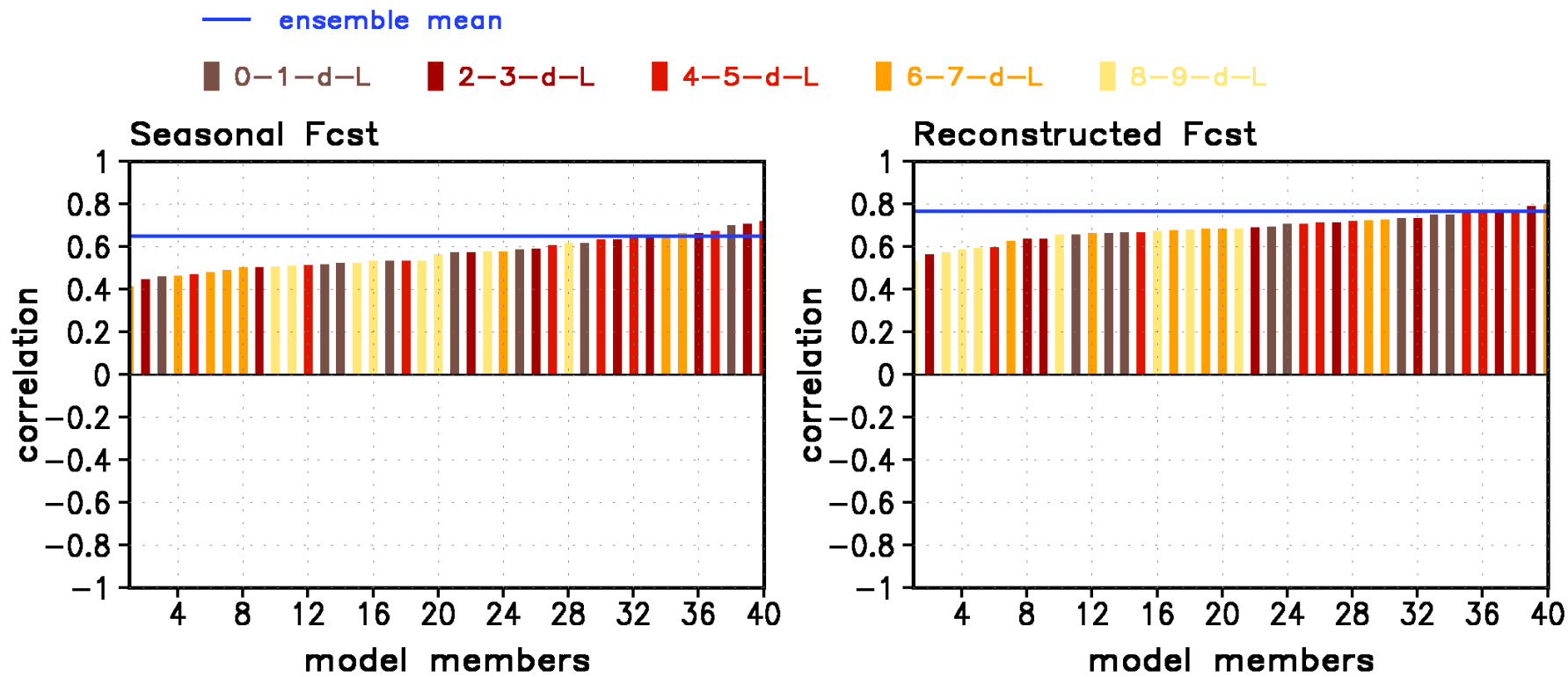


# Observed & AMIP Ensemble Mean Anomalies

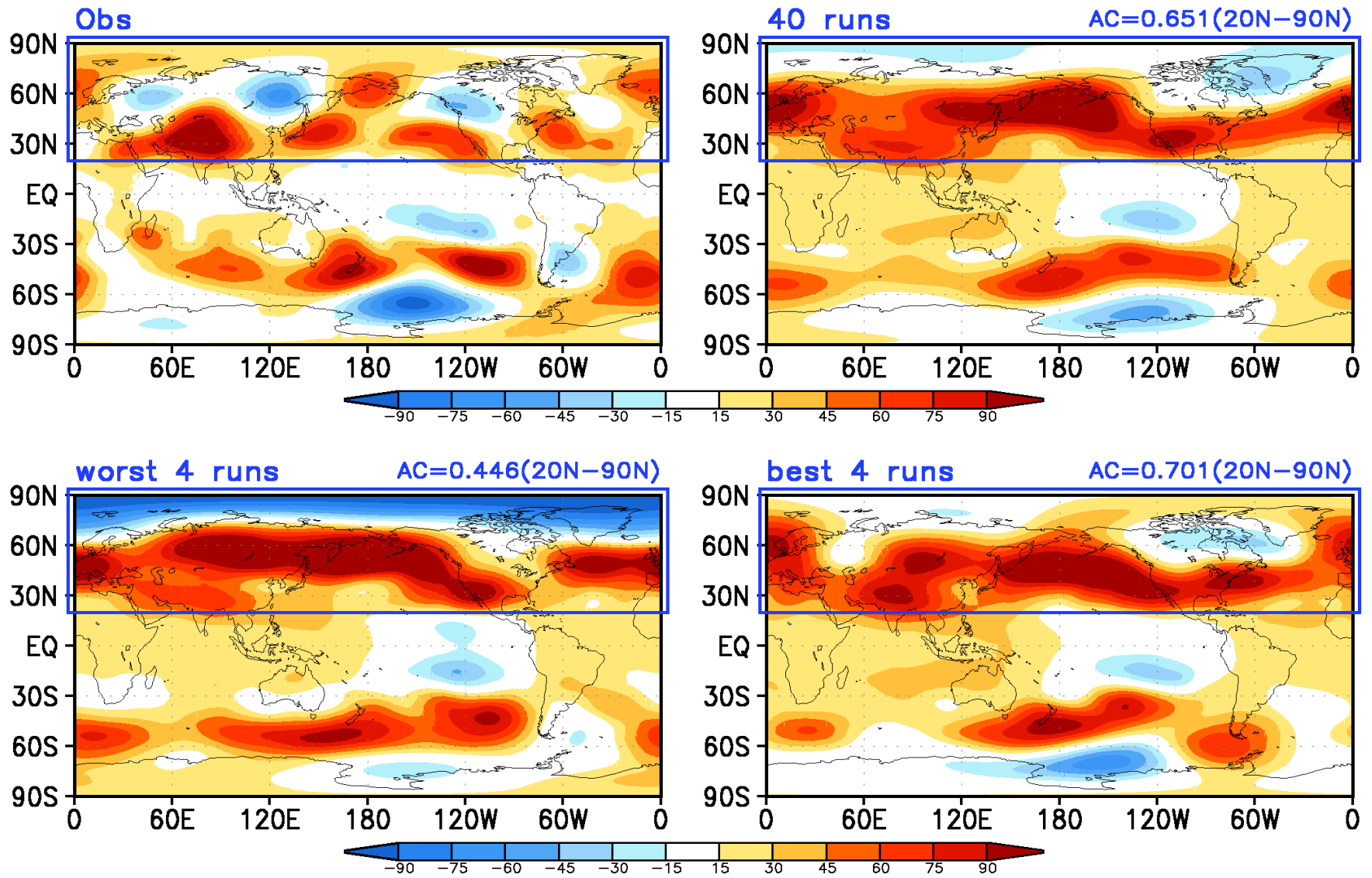
## MAM2022 z200(m) 100 runs/worst 4 runs/best 4 runs



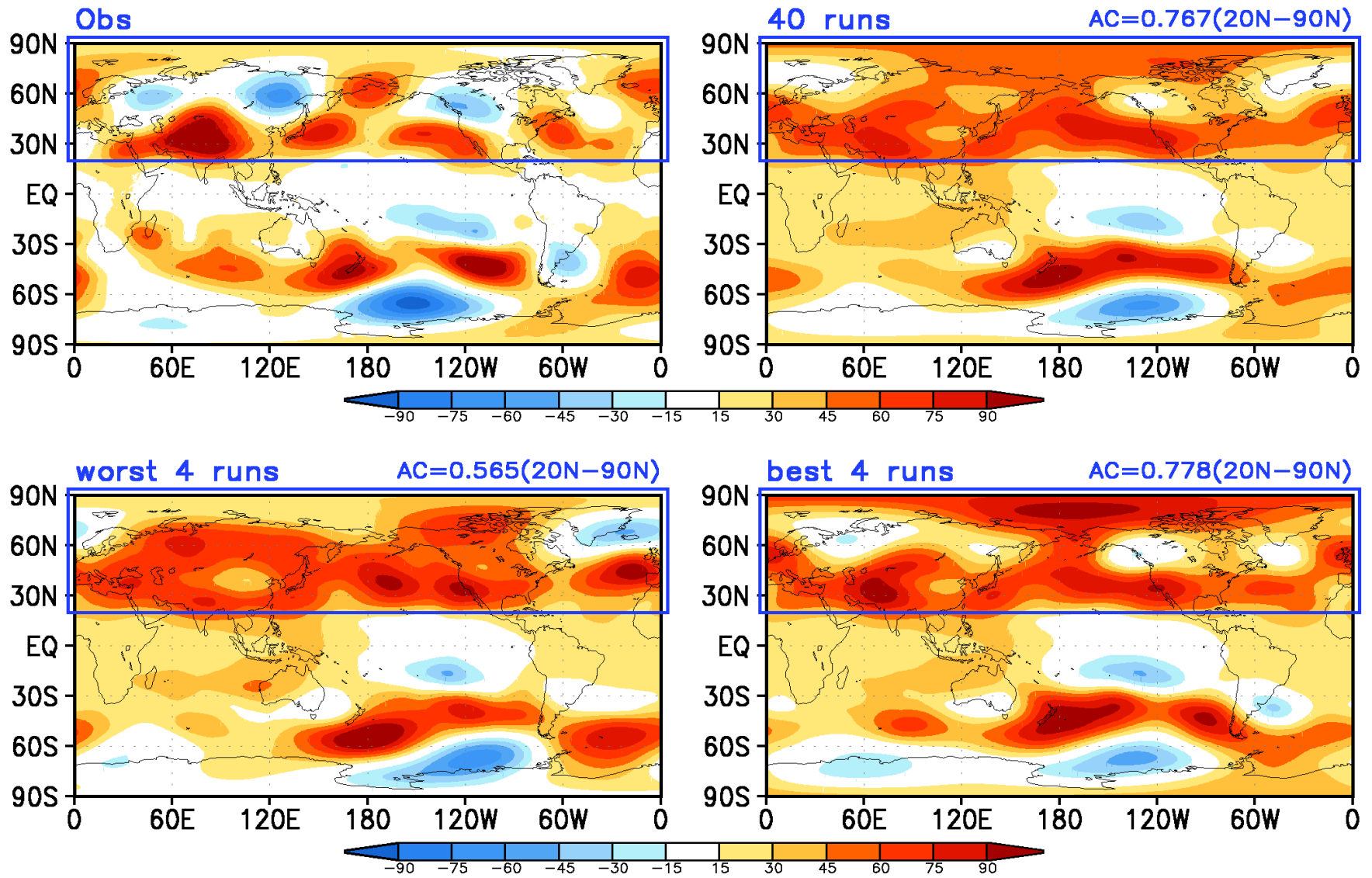
# MAM2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



# Observed & CFSv2 Forecast Ensemble Average Anomalies MAM2022 z200(m) 40 runs/worst 4 runs/best 4 runs Seasonal Forecast



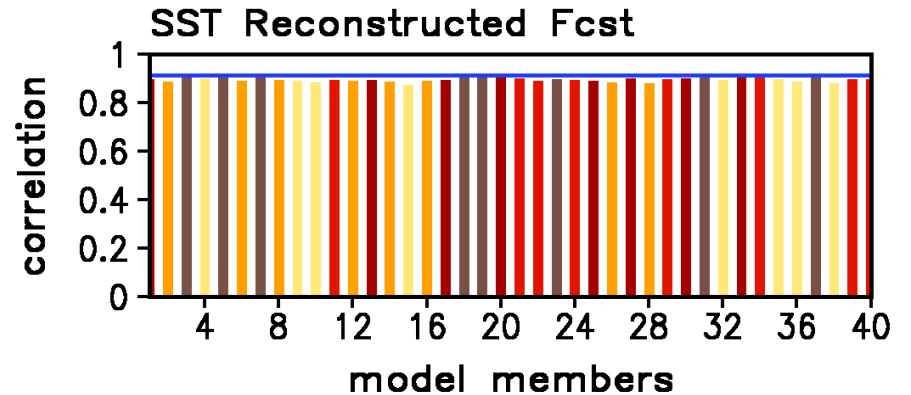
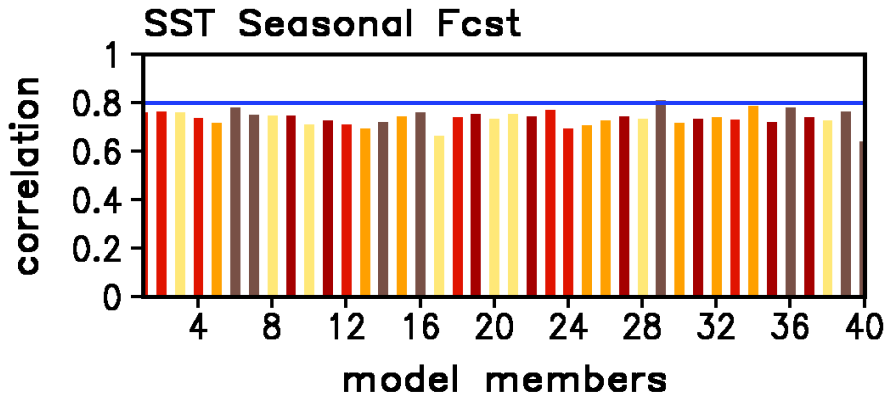
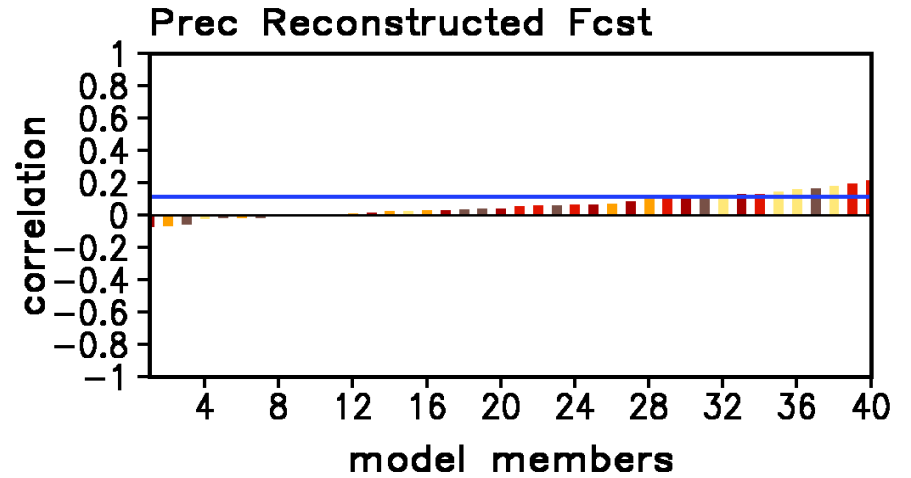
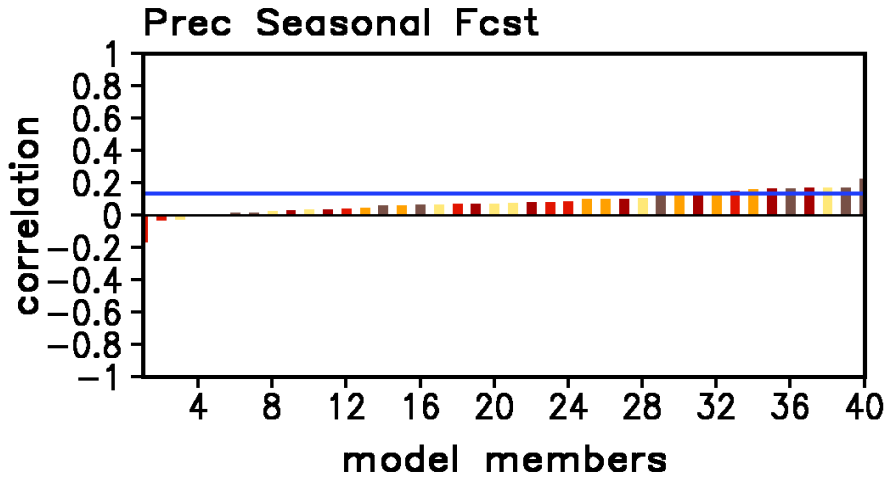
# Observed & CFSv2 Forecast Ensemble Average Anomalies MAM2022 z200(m) 40 runs/worst 4 runs/best 4 runs Reconstructed Forecast



# MAM2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

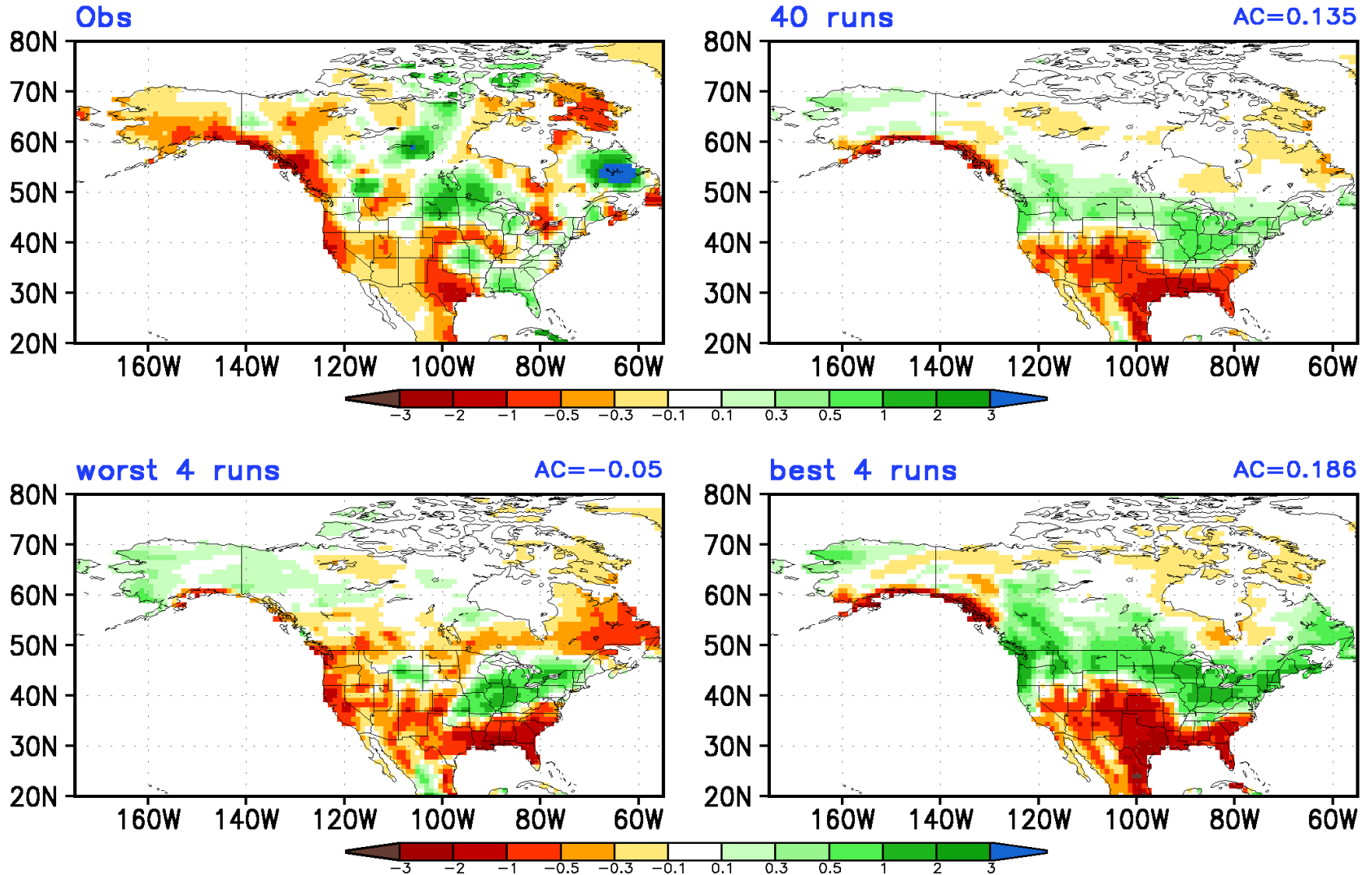
— ensemble mean

■ 0-1-d-L ■ 2-3-d-L ■ 4-5-d-L ■ 6-7-d-L ■ 8-9-d-L

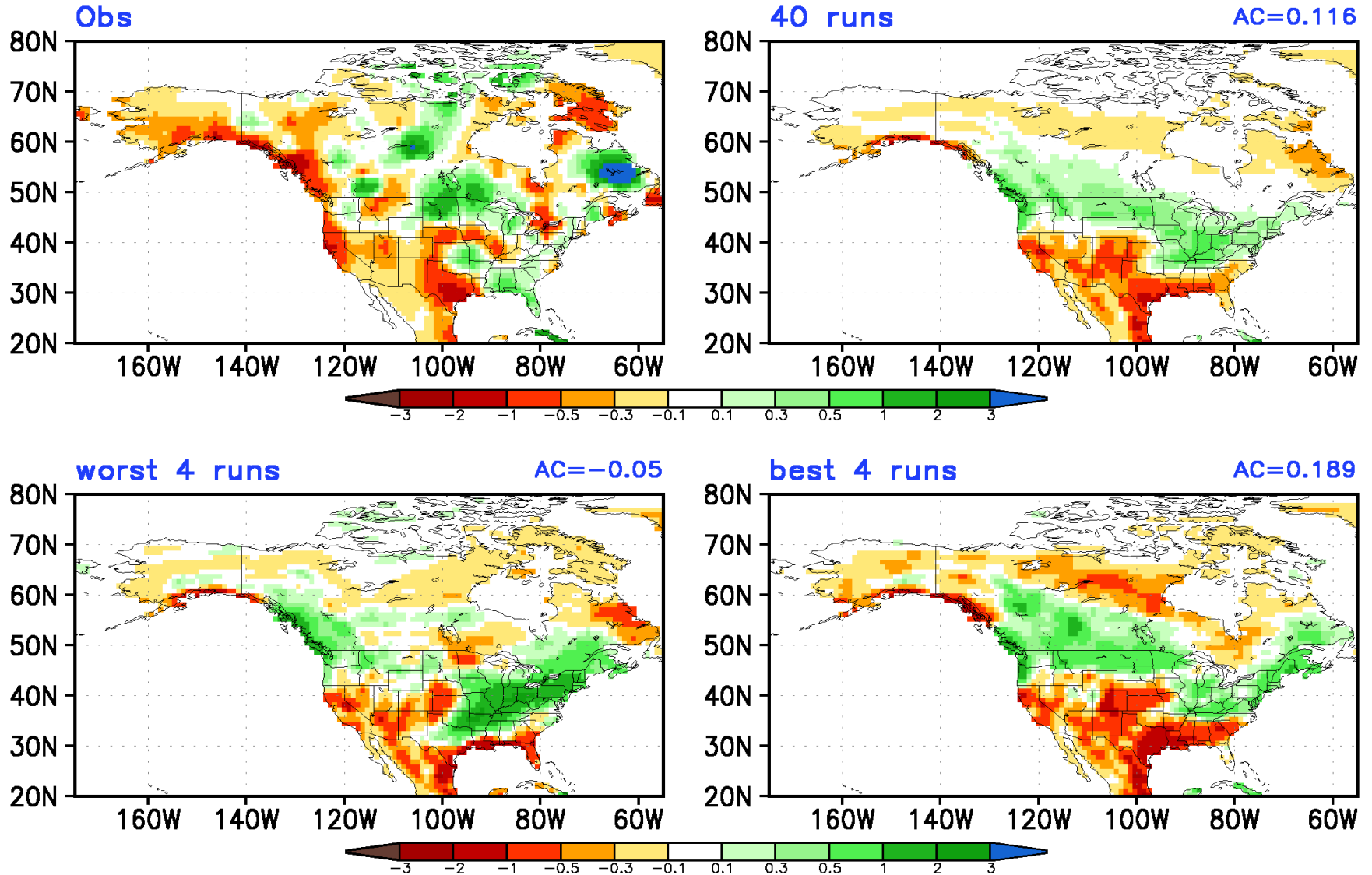




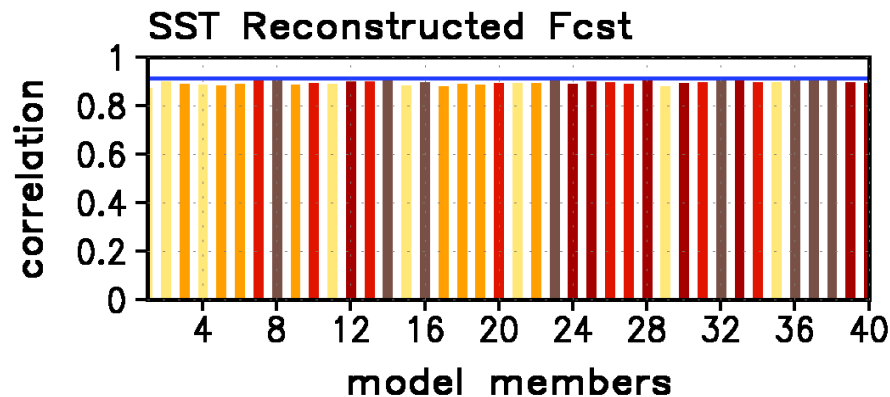
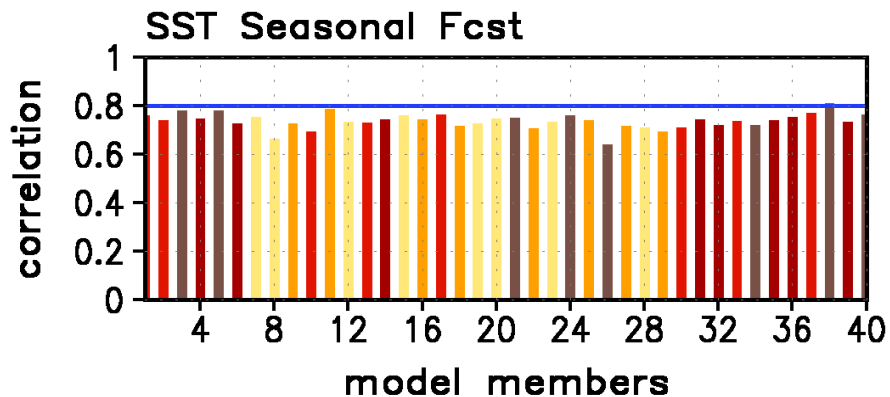
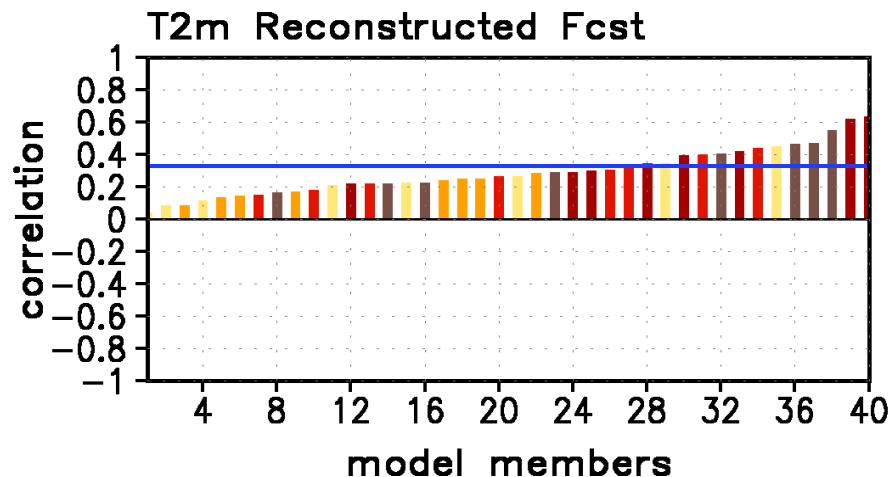
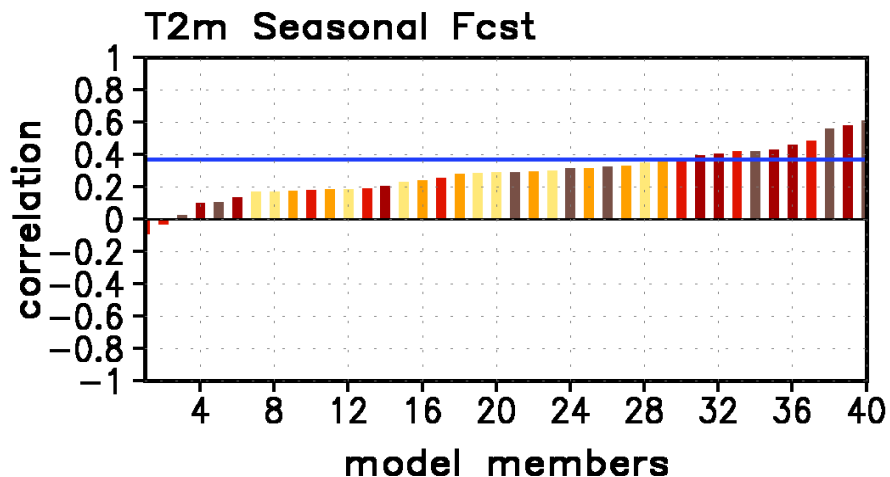
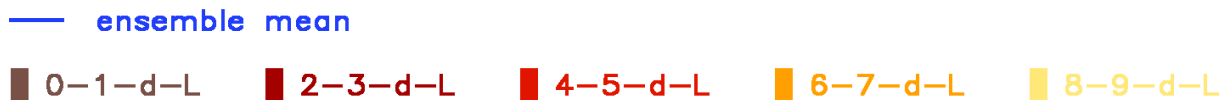
# Observed & CFSv2 Forecast Ensemble Average Anomalies MAM2022 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs Seasonal Forecast



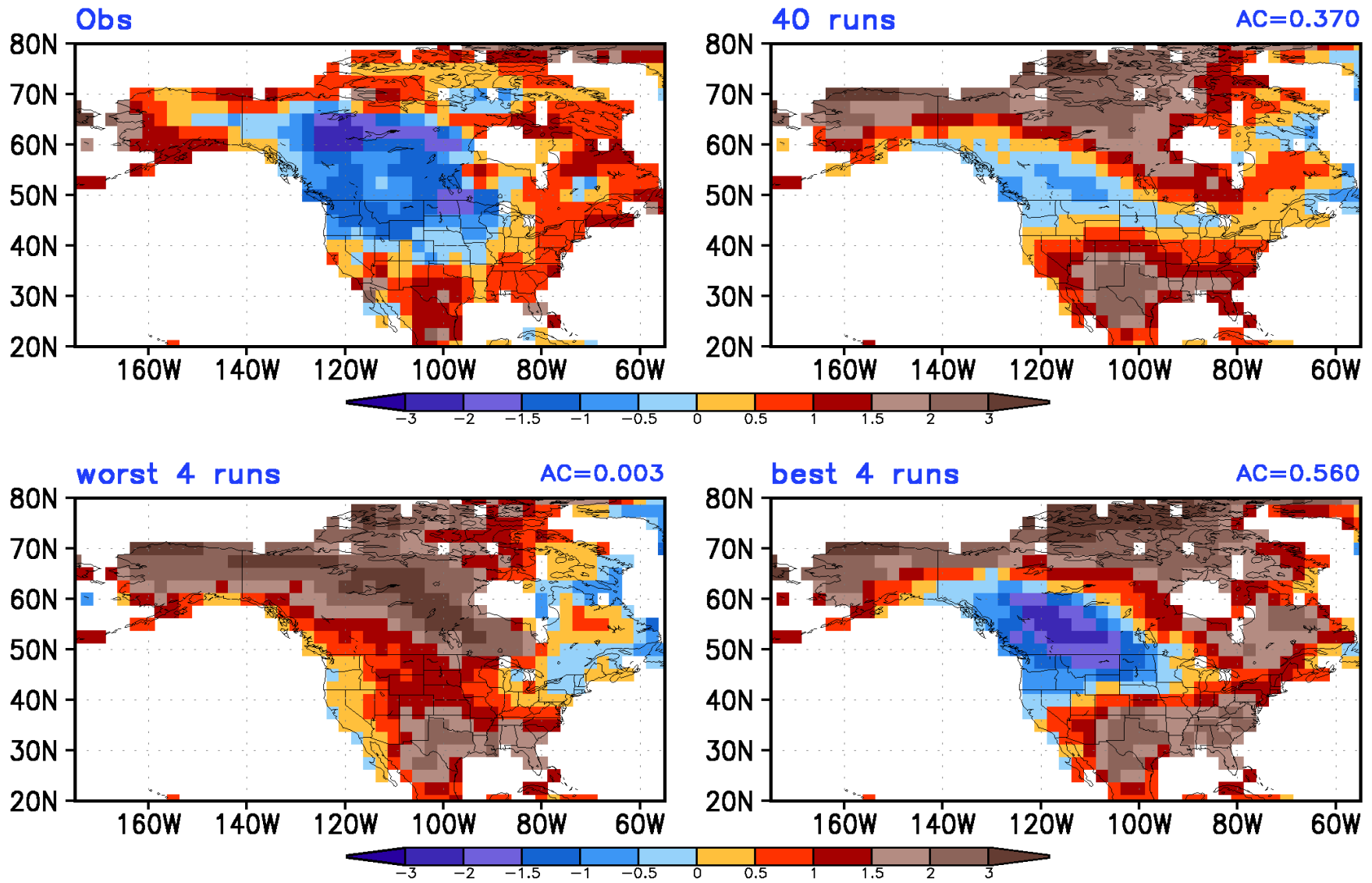
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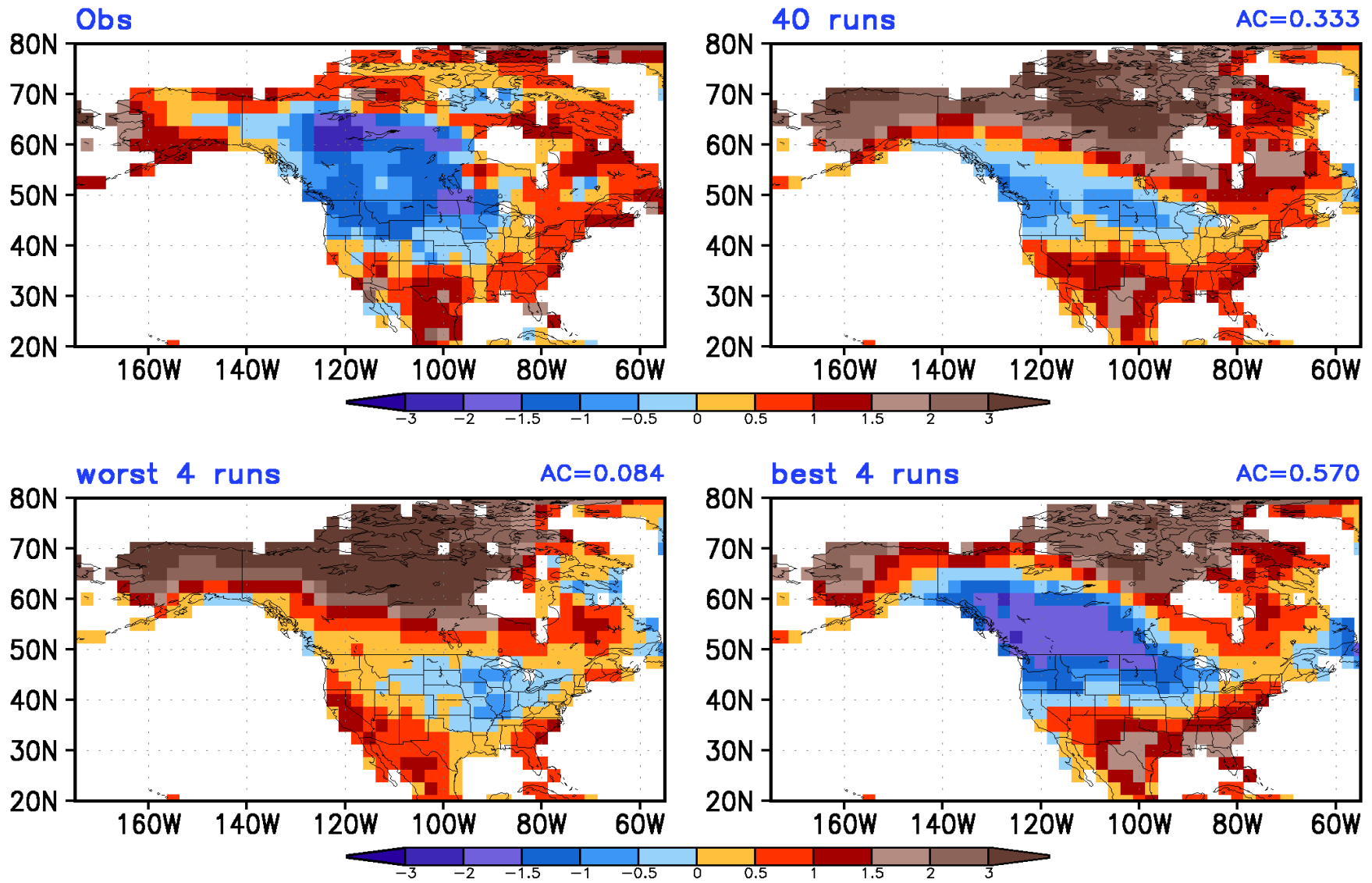
# MAM2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



# Observed & CFSv2 Forecast Ensemble Average Anomalies MAM2022 T2m(K) 40 runs/worst 4 runs/best 4 runs Seasonal Forecast

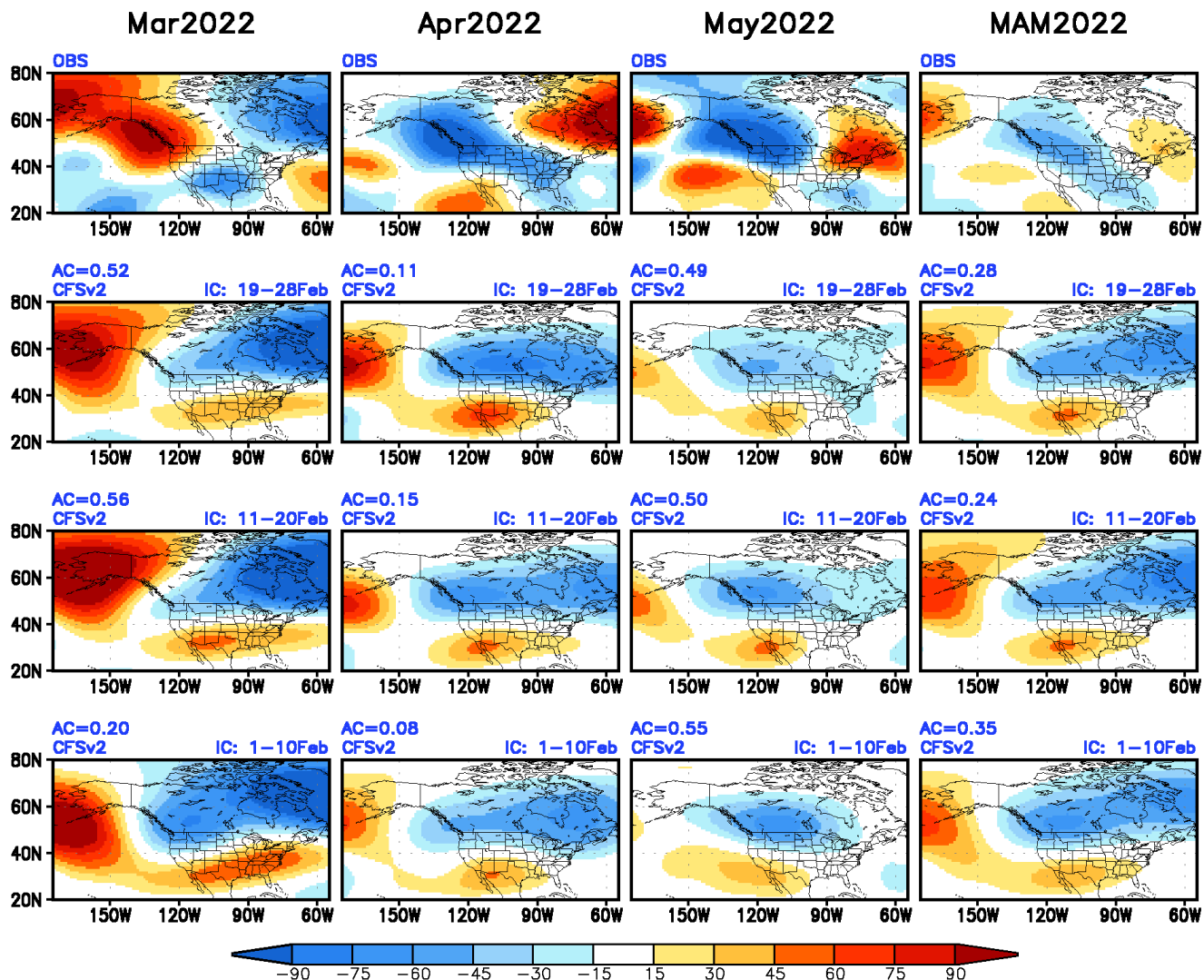


# Observed & CFSv2 Forecast Ensemble Average Anomalies MAM2022 T2m(K) 40 runs/worst 4 runs/best 4 runs Reconstructed Forecast



# z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) MAM2022 z200(m) eddy & Obs



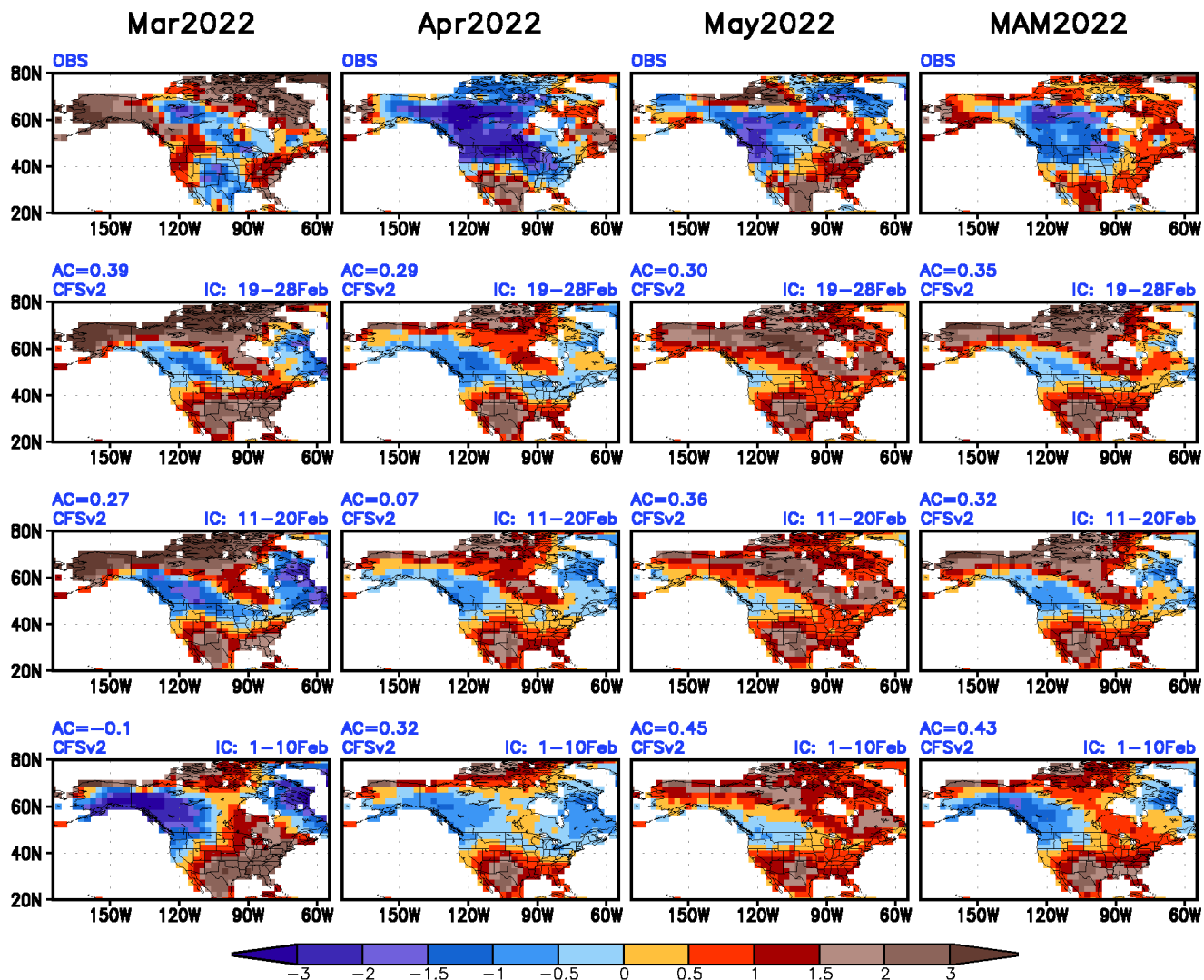
Top row: Observed anomaly.

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) MAM2022 T2m(K) & Obs



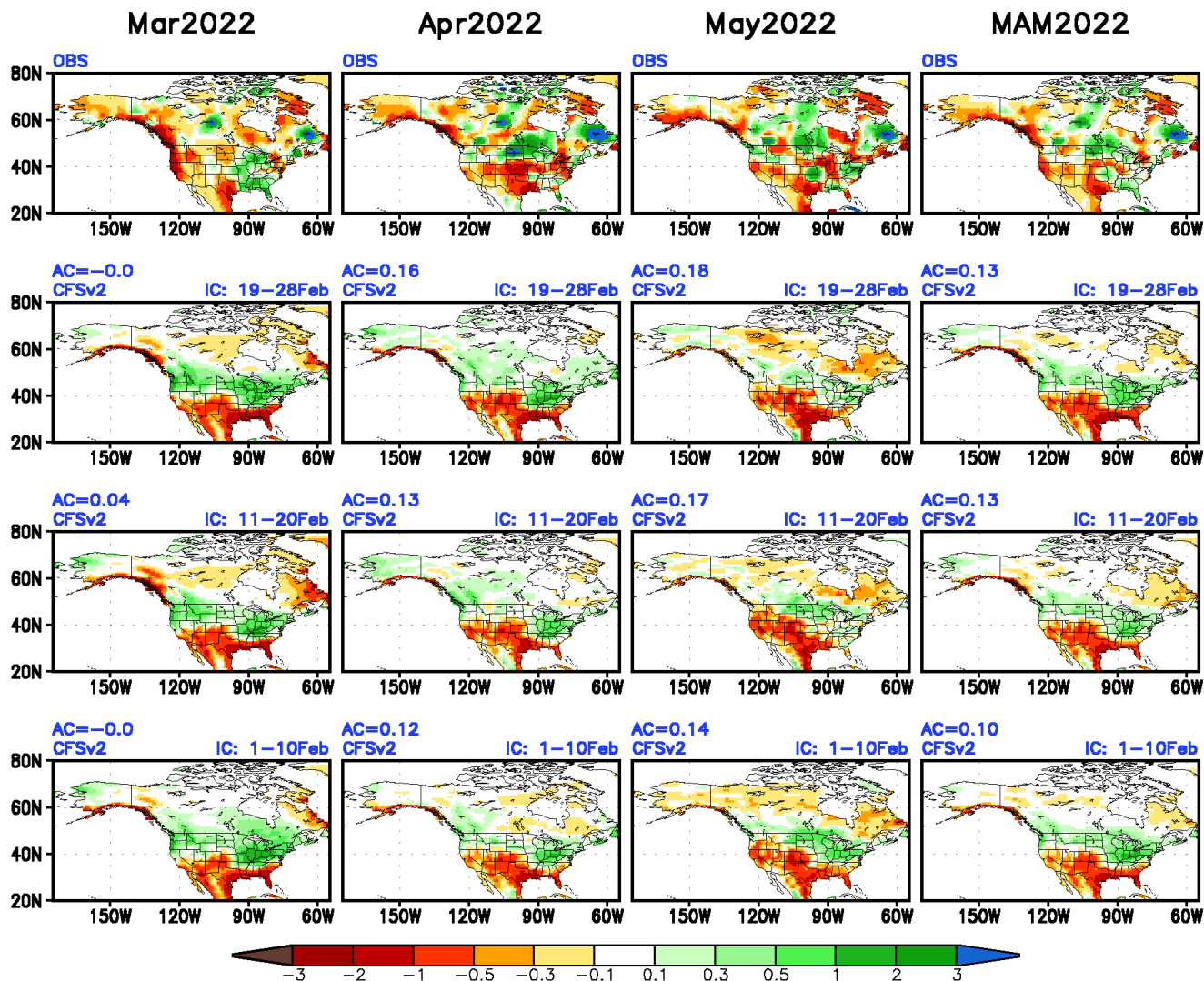
Top row: Observed anomaly.

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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) MAM2022 Prec(mm/day) & Obs



Top row: Observed anomaly.

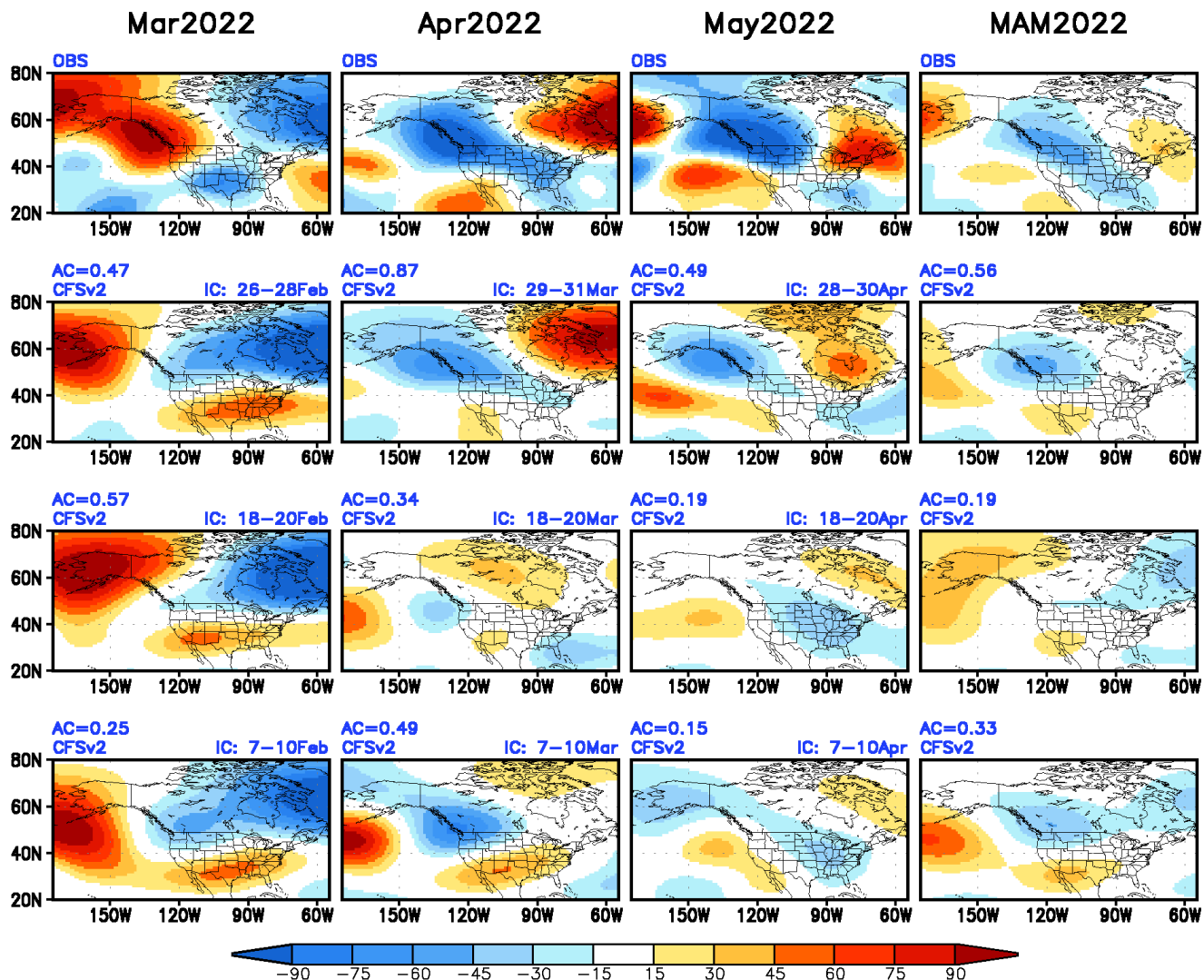
CFSv2 seasonal forecasts from different initial conditions in the month prior to the target season:

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# z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst MAM2022 z200(m) eddy & Obs



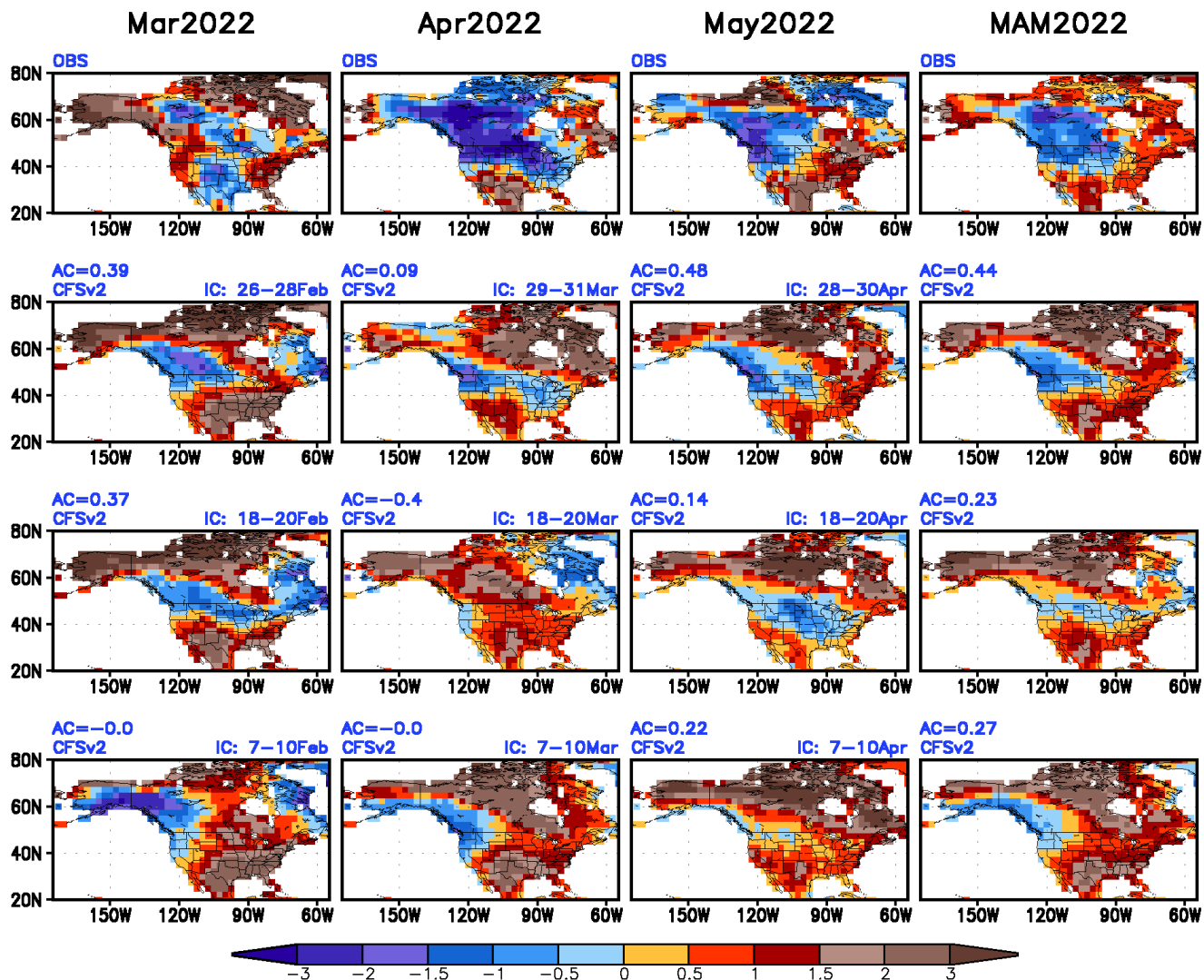
Top row: Observed anomaly.

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 MAM2022 T2m(K) & Obs



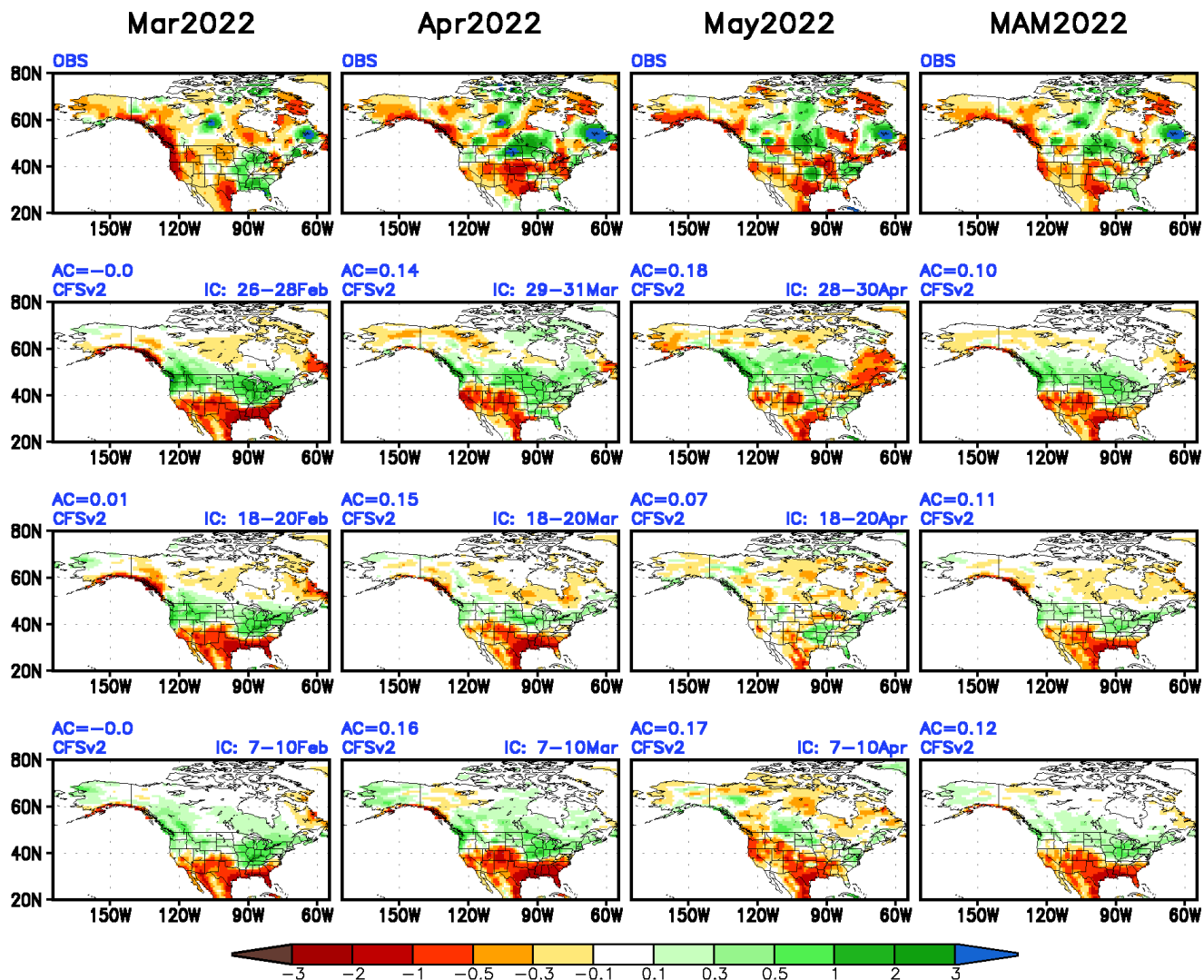
Top row: Observed anomaly.

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

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- 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 MAM2022 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.
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- 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

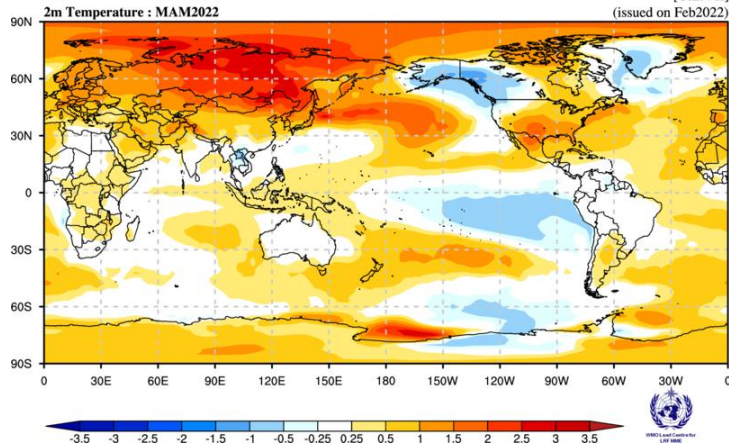
(<https://www.wmolc.org/>)

## Ensemble means

Simple Composite Map

Beijing,CMCC,CPTec,ECMWF,Exeter,Melbourne,Monreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

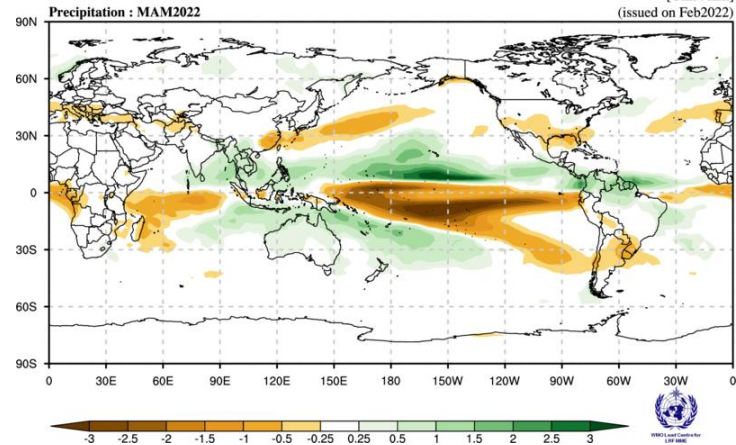
[Unit : K]



Simple Composite Map

Beijing,CMCC,CPTec,ECMWF,Exeter,Melbourne,Monreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

[Unit : mm]

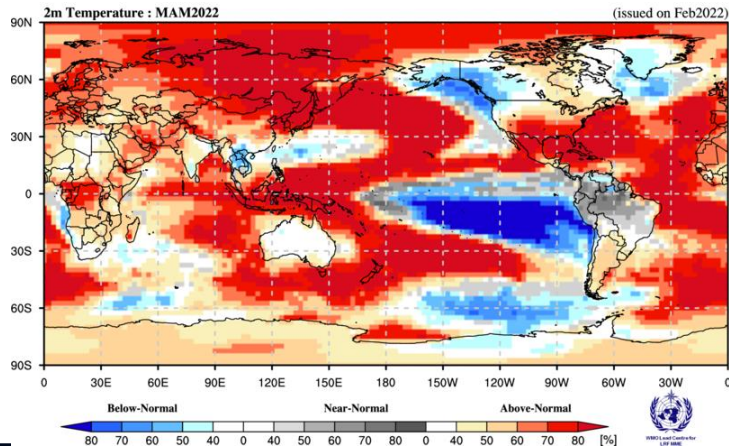


## Probabilities

Probabilistic Multi-Model Ensemble Forecast

Beijing,CMCC,CPTec,ECMWF,Exeter,Melbourne,Monreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

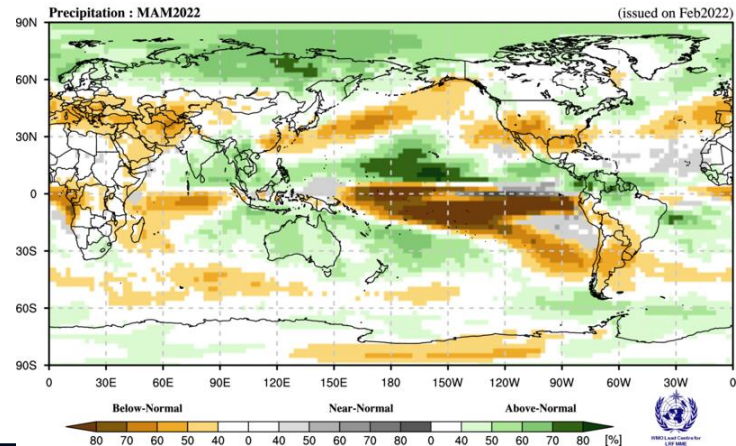
(issued on Feb2022)



Probabilistic Multi-Model Ensemble Forecast

Beijing,CMCC,CPTec,ECMWF,Exeter,Melbourne,Monreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington

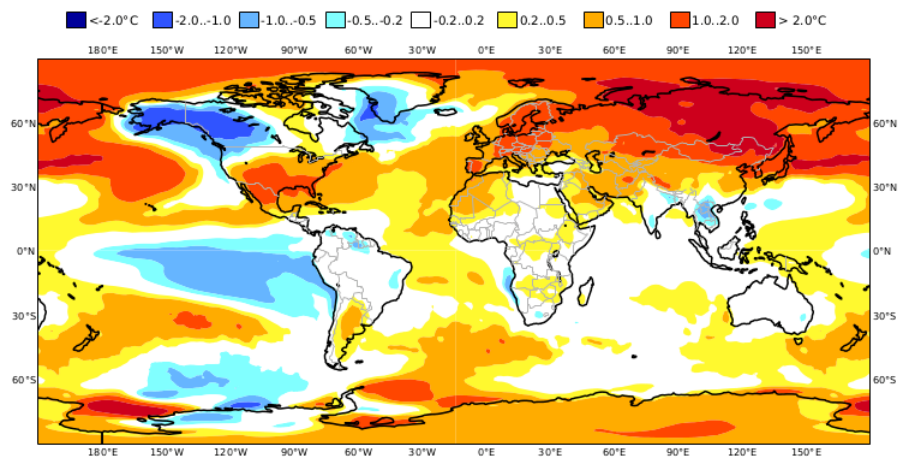
(issued on Feb2022)



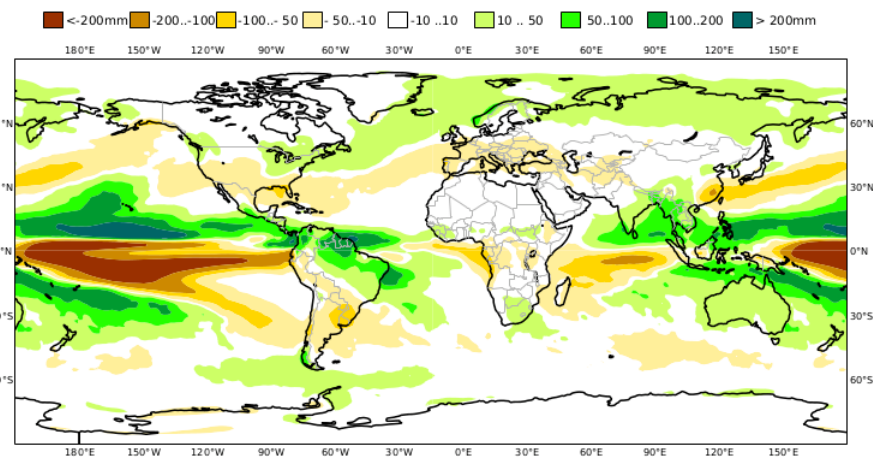
# C3S Seasonal Forecast

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

C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC  
Mean 2m temperature anomaly MAM 2022  
Nominal forecast start: 01/02/22  
Variance-standardized mean



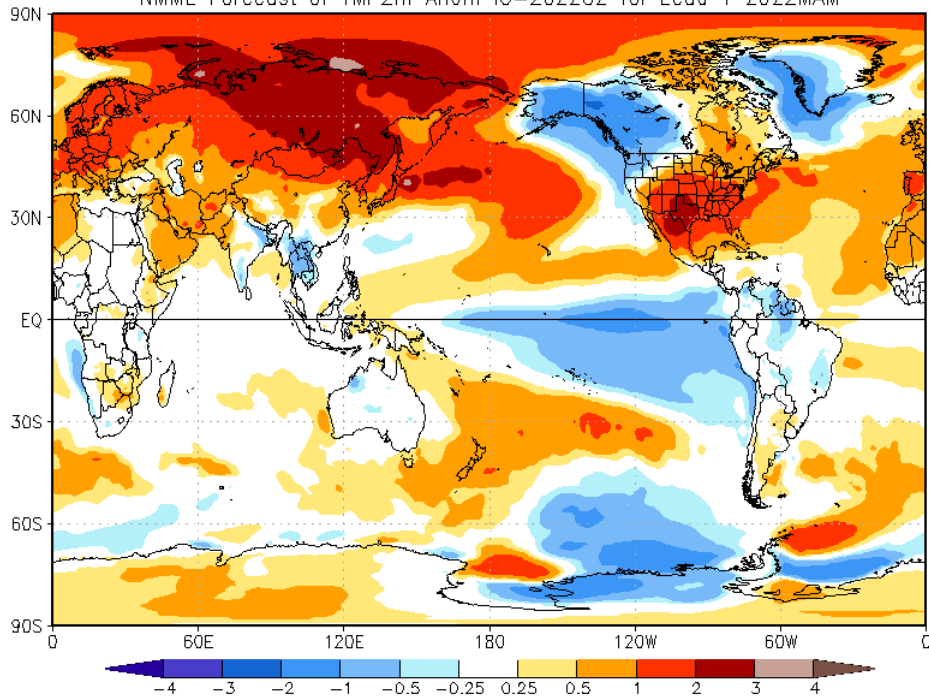
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC  
Mean precipitation anomaly MAM 2022  
Nominal forecast start: 01/02/22  
Variance-standardized mean



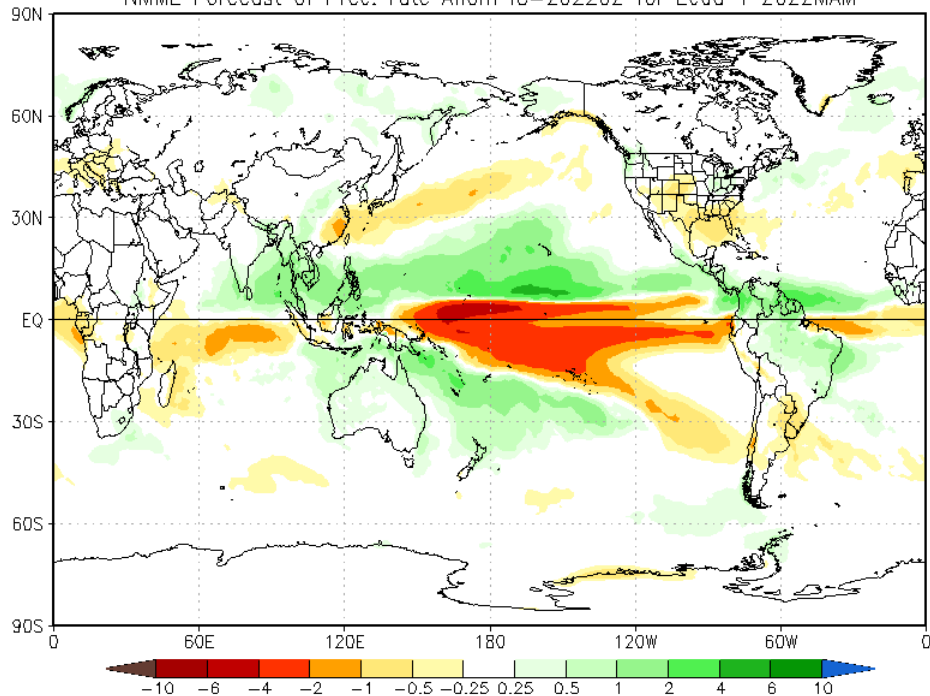
# North American Multi-Model Ensemble Seasonal Forecast

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

NMME Forecast of TMP2m Anom IC=202202 for Lead 1 2022MAM

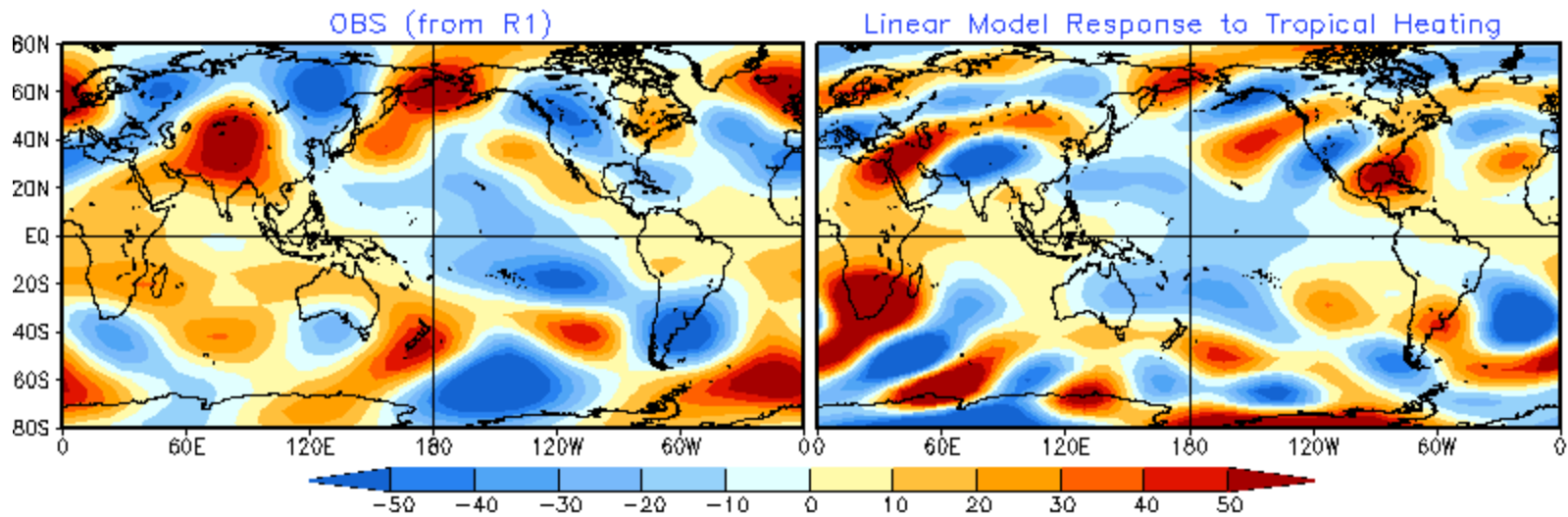
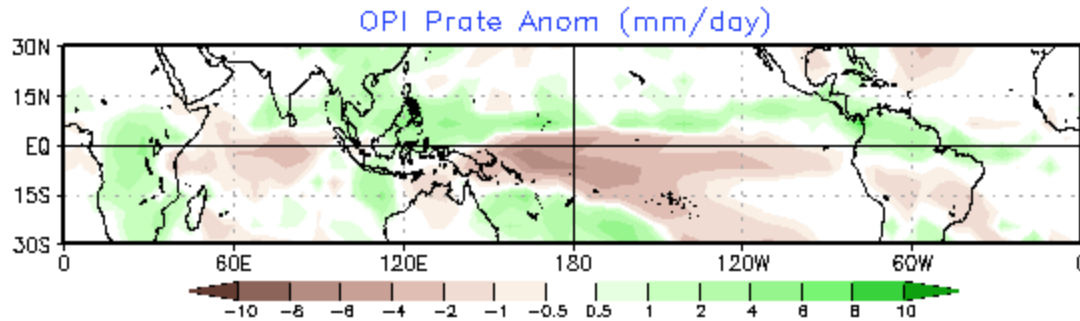


NMME Forecast of Prec. rate Anom IC=202202 for Lead 1 2022MAM



# 200mb Height from Linear Model

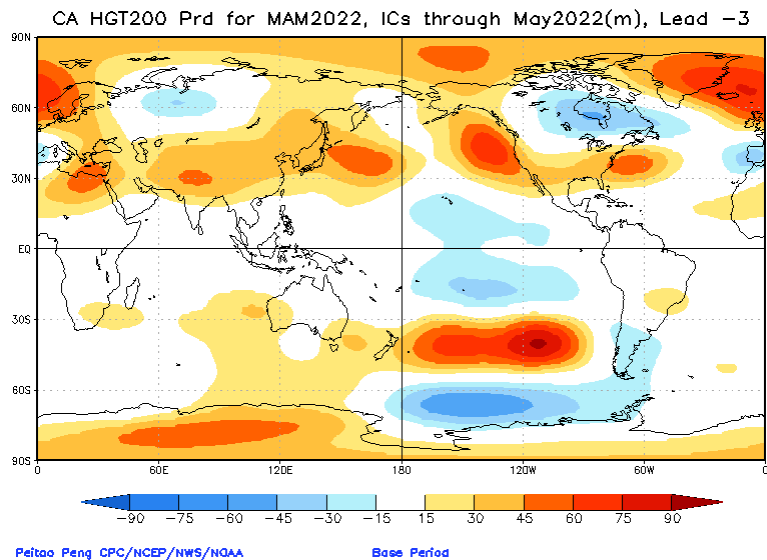
MAM2022 200mb Eddy HGT(m)  
OBS vs. Linear Model Response to Tropical Heating  
Heating is converted from Prate in 15S-15N



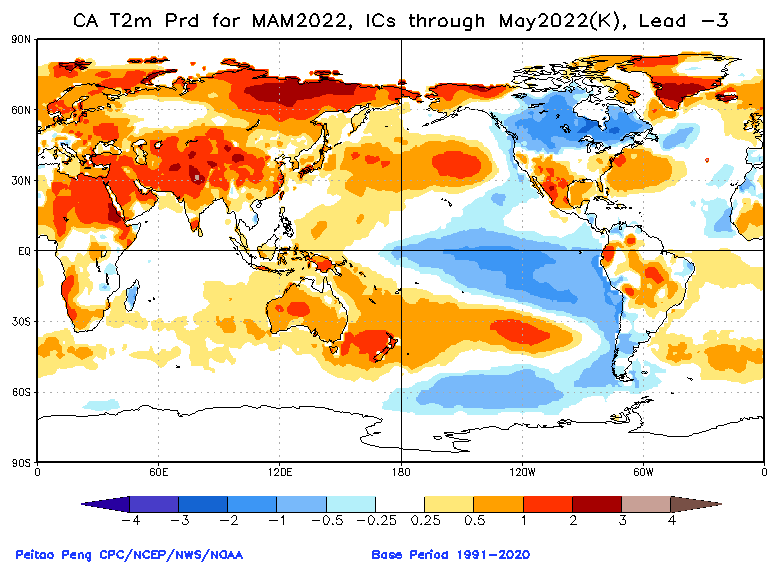
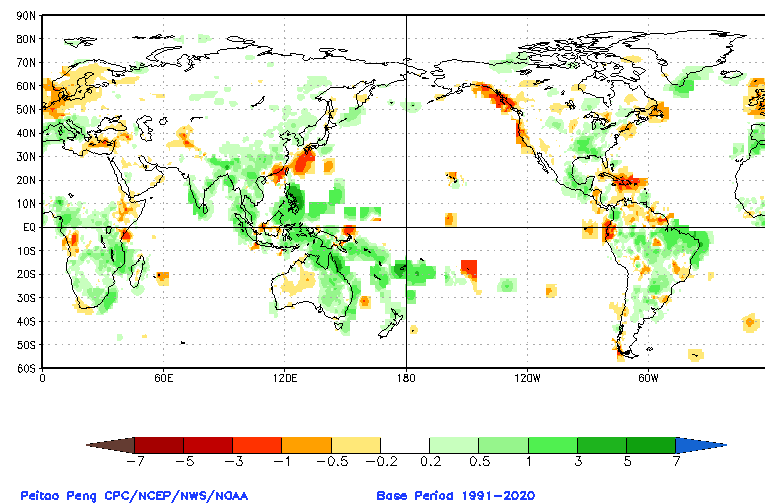
Pattern COR: global=0.03, tropics(30S-30N)=0.07



# Seasonal Forecasts from the Constructed Analog Model



CA Prec Prd for MAM2022, ICs through May2022(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.

# 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 (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)