Attribution of Seasonal Climate Anomalies August-September-October 2021

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

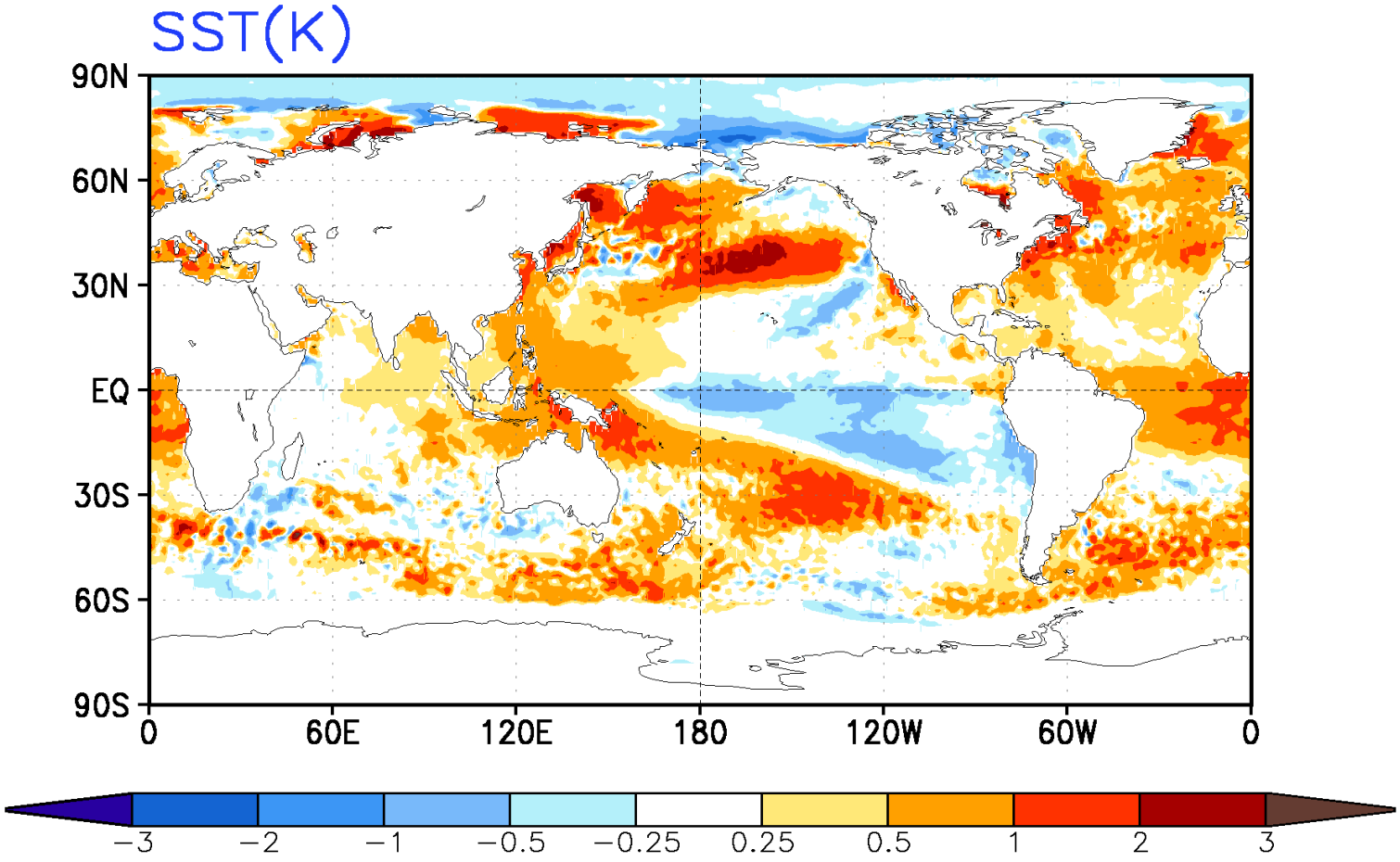
Summary of Observed Conditions and Outlooks

- SST anomalies were near-normal in the equatorial tropical central and eastern Pacific and Indian Ocean; equatorial Atlantic and N Pacific Ocean remained on the warm side (slide 4). In general, the large-scale distribution of SST anomalies were predicted well (slide 10);
- The negative precipitation anomalies over the western equatorial Indian Ocean and the positive (negative) precipitation anomalies over the Maritime Continent in the eastern Indian Ocean (equatorial NW to SW Pacific Ocean) were predicted well in the initialized forecasts of CFSv2 and other MME models (slides 10, 11, 35, 36, 38 & 39).
- Most of observed large scale 200mb height anomalies were predicted in the initialized CFSv2 forecasts that led to reasonable predictions in the large-scale distribution of temperature anomalies in general. The center of positive height anomalies over the large areas of northeast North America was predicted well and resulted in good prediction of large warm temperature anomalies (slides 12, 13, 15, &16).
- The CFSv2 predicted the observed positive precipitation anomalies over the southeast US, while missed some of observed anomalies over other regions (slide 14);
- The monthly mean forecasts with the shortest leads captured the large warm temperature anomalies over the northeast NA in Oct. 2021 (slide 32).

Observed Seasonal Anomalies

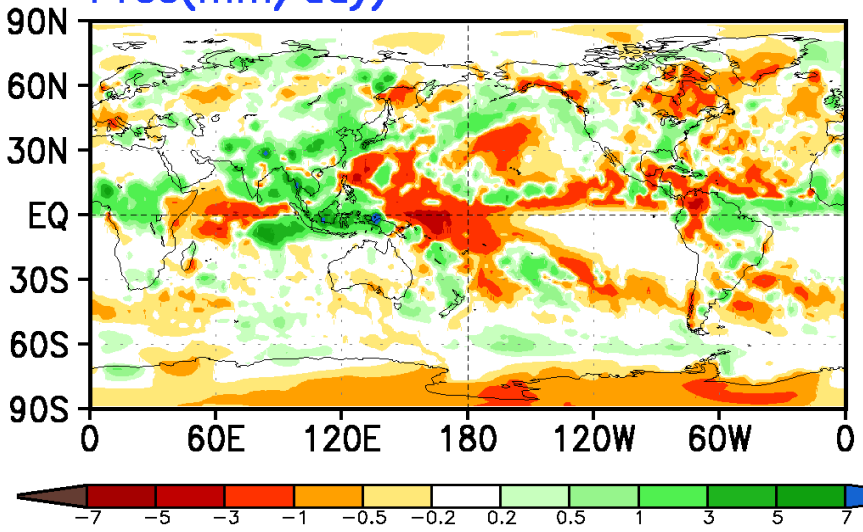
Global and North America

Observed Anomaly ASO2021

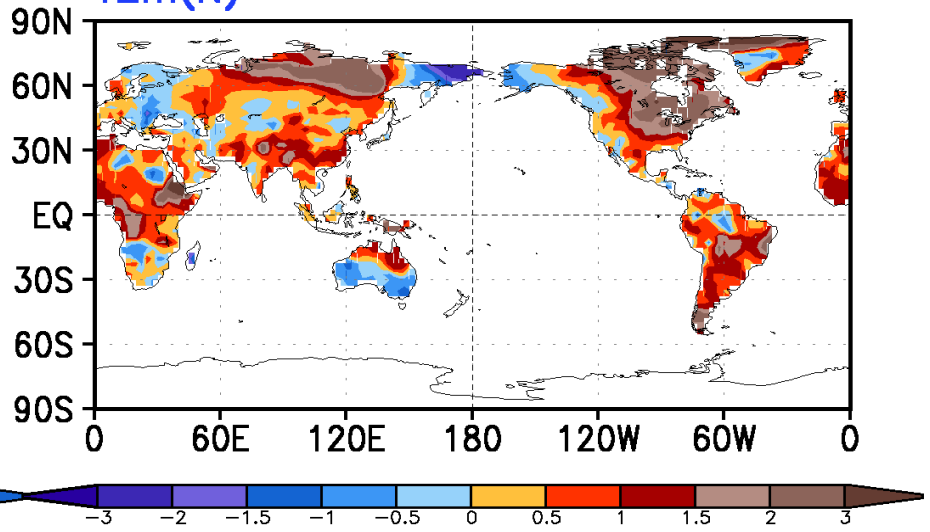


Observed Anomaly ASO2021

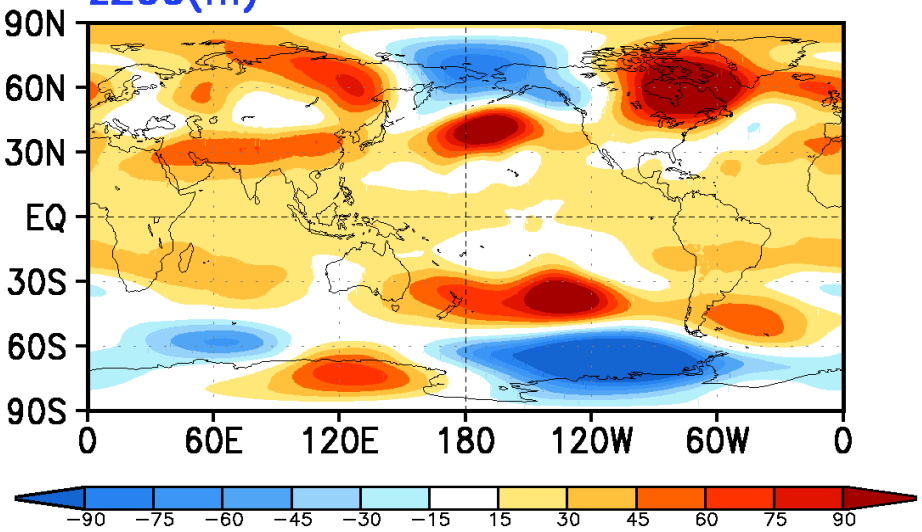
Prec(mm/day)



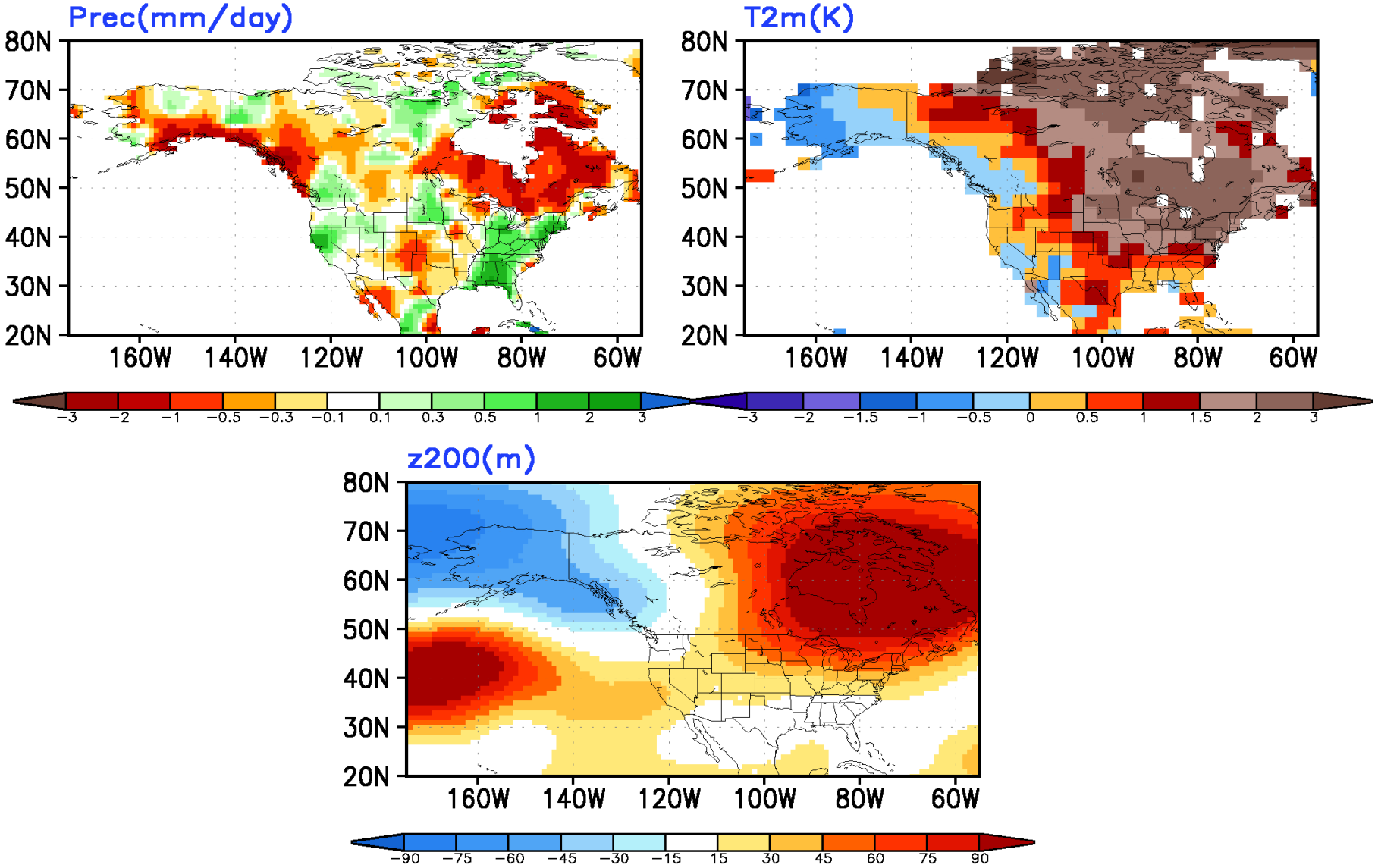
T2m(K)



z200(m)



Observed Anomaly ASO2021



CPC Seasonal Outlooks and NMME Forecasts

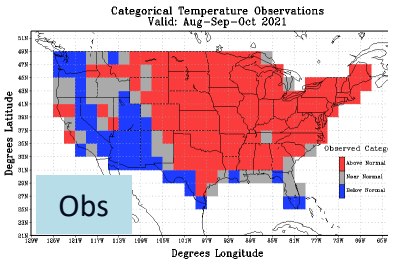
Temperature

Precipitation

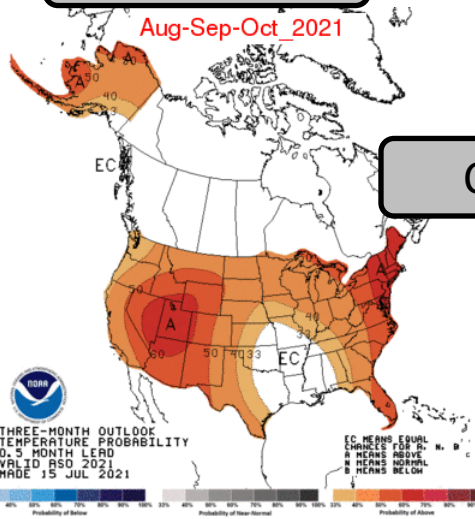
Temp nonEC
HSS=42

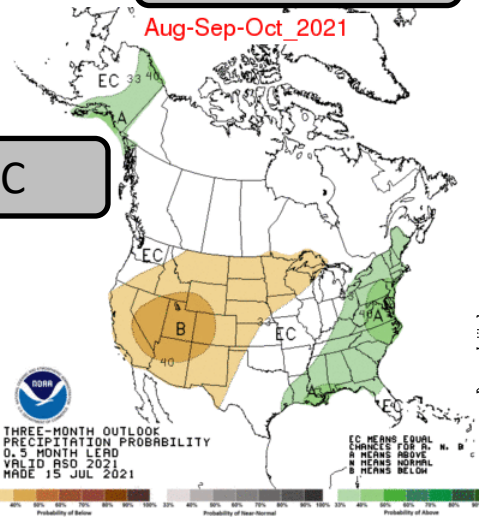
Prec nonEC
HSS=8

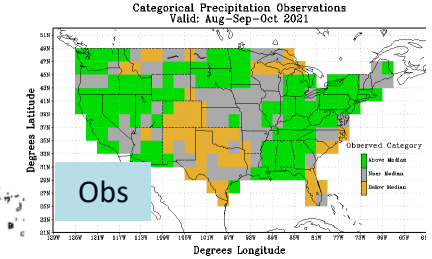
CPC



Obs

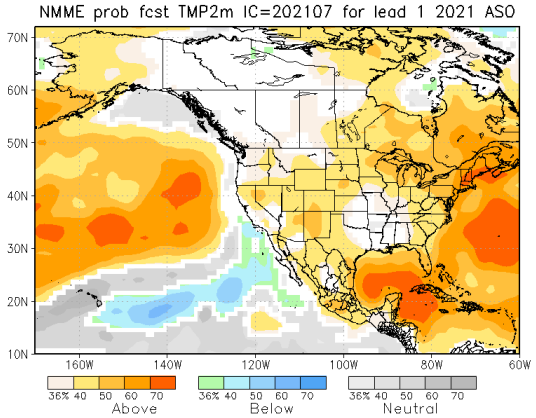


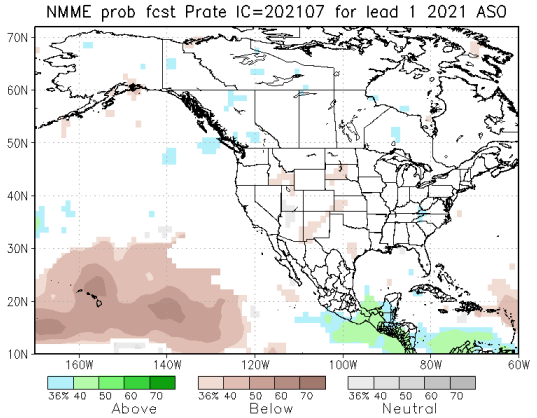




Obs

NMME





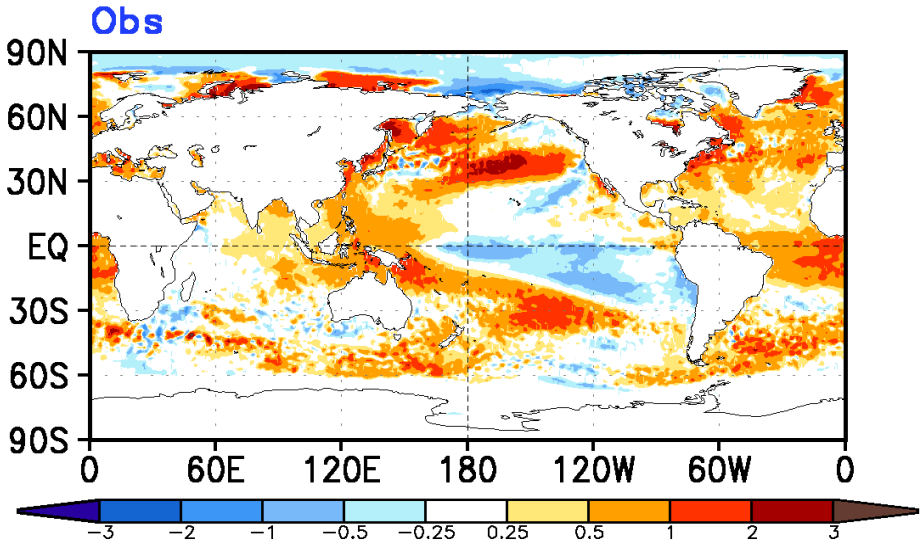
For the rationale behind CPC outlooks see: https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2021/202107_PMD90D

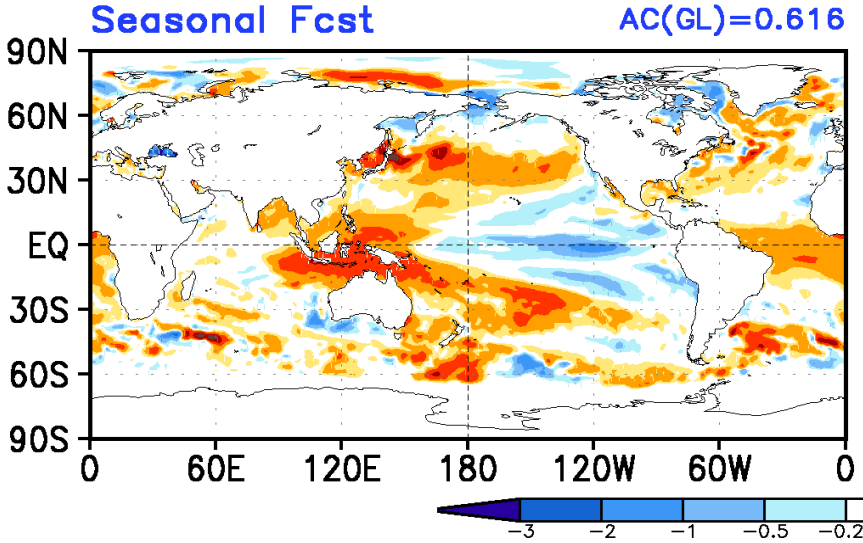
Model Simulated/Forecast Ensemble Mean Anomalies

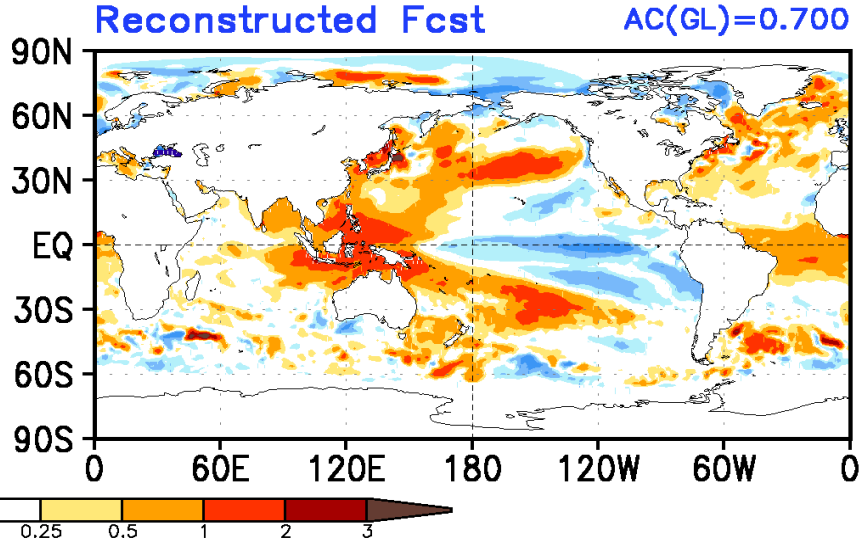
Model Simulated/Forecast Ensemble Average Anomalies

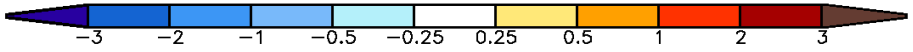
- CFS AMIP simulations forced with observed sea surface temperatures (18 members ensemble)
- CFSv2 real time operational forecasts
  - Seasonal forecast: the seasonal mean forecasts based on 40 members from the latest 10 days before the target season (0-month-lead). For example, 2016AMJ seasonal mean 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).

ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)

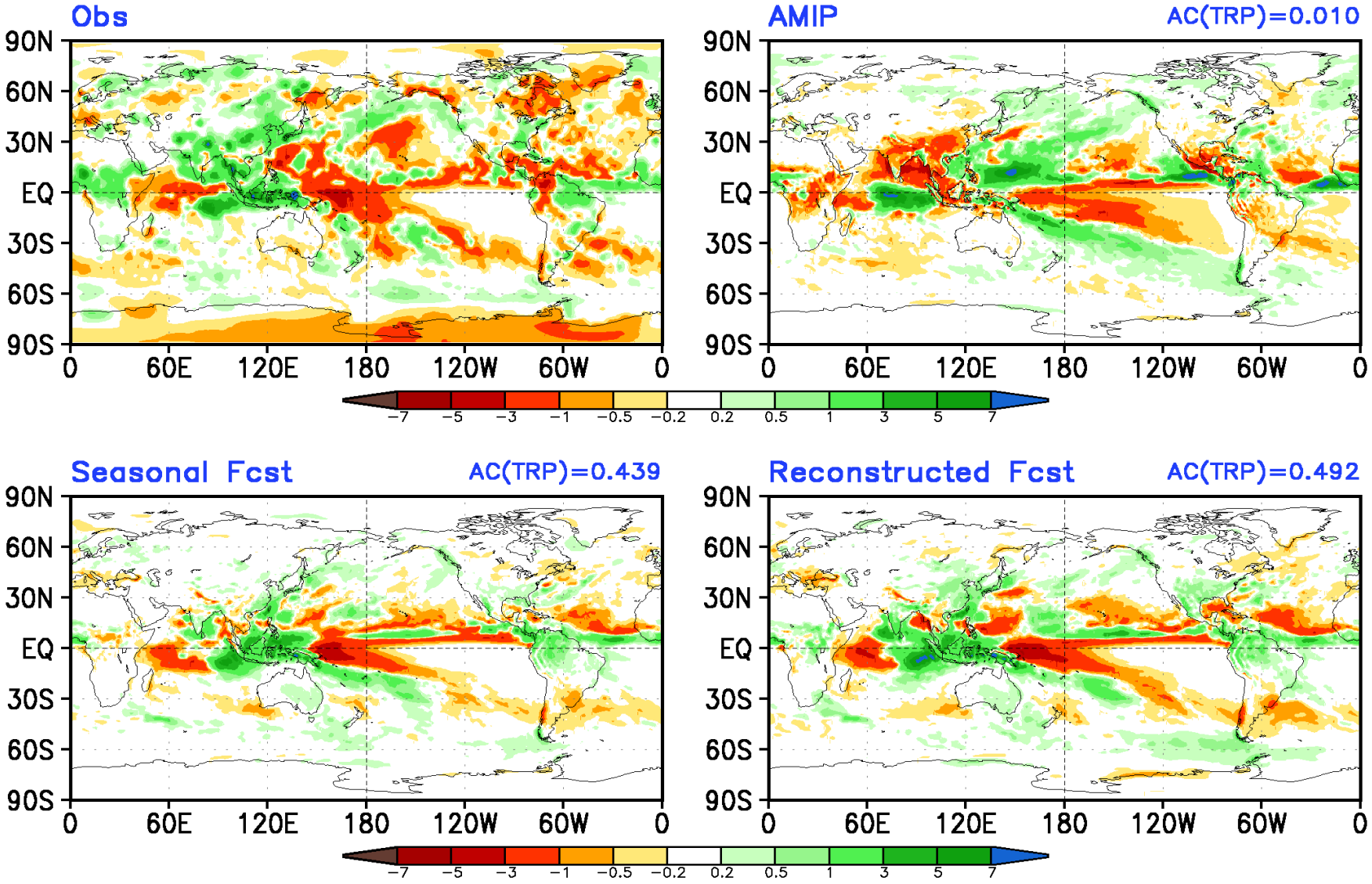




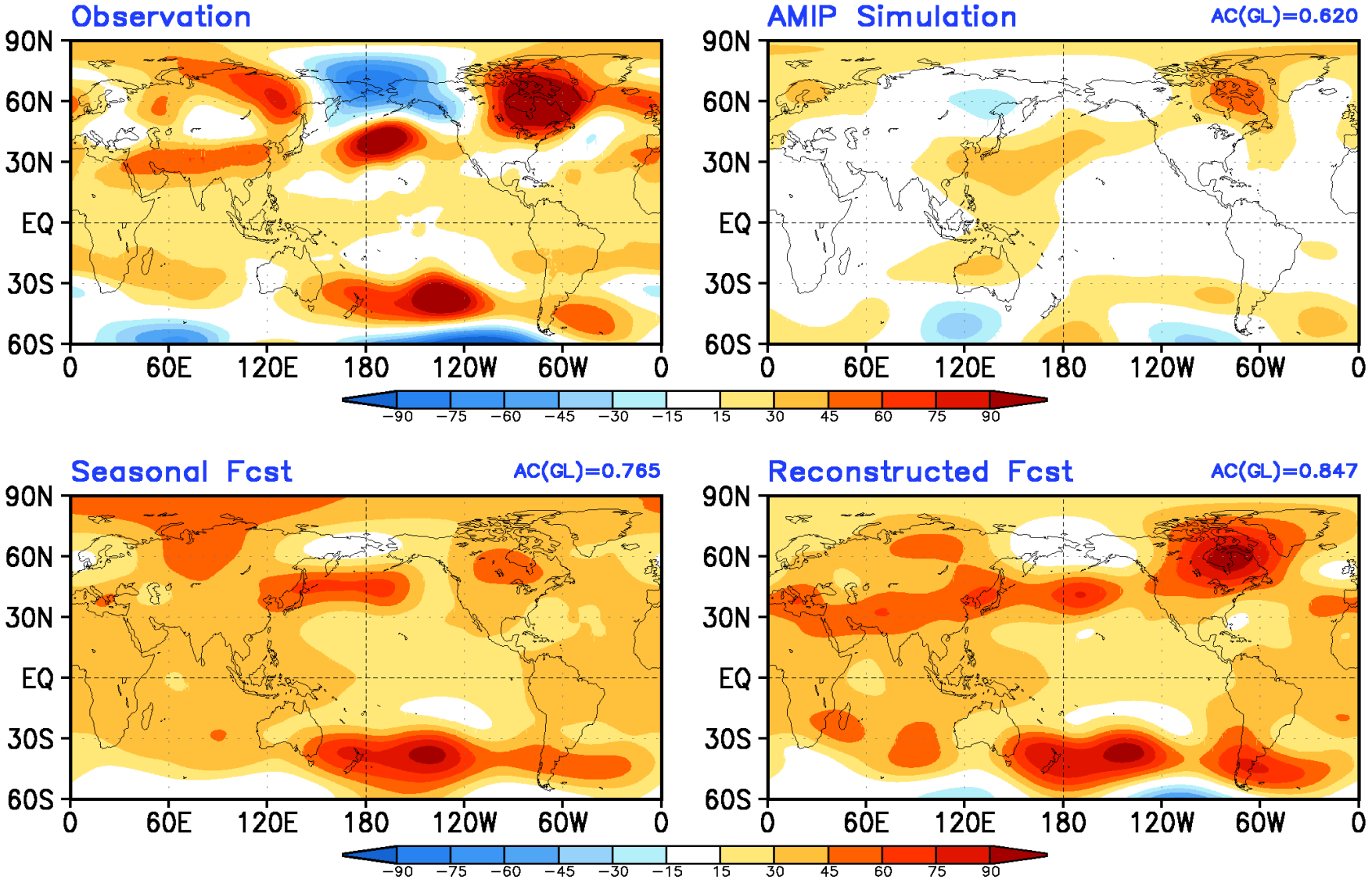




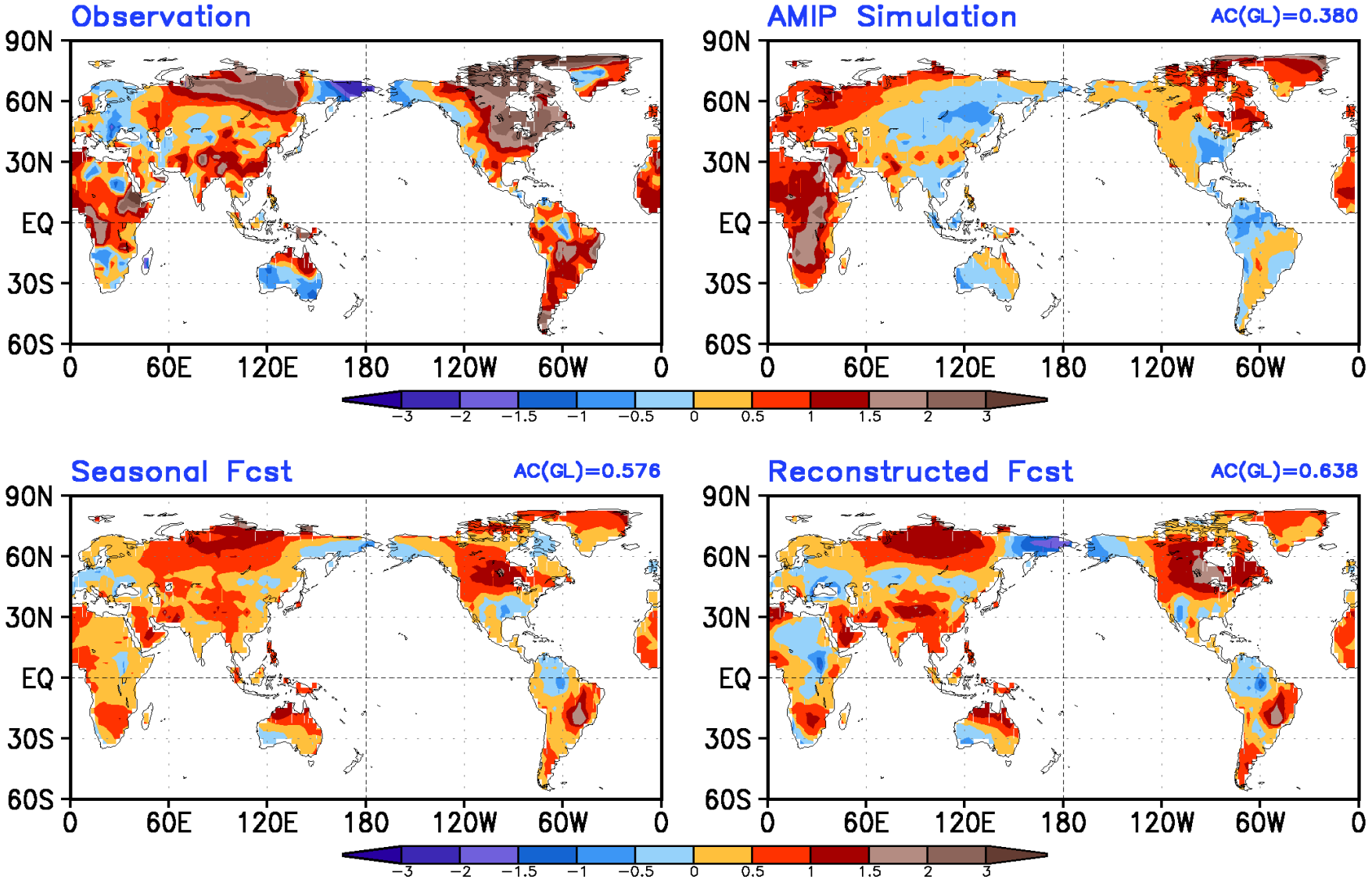
ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



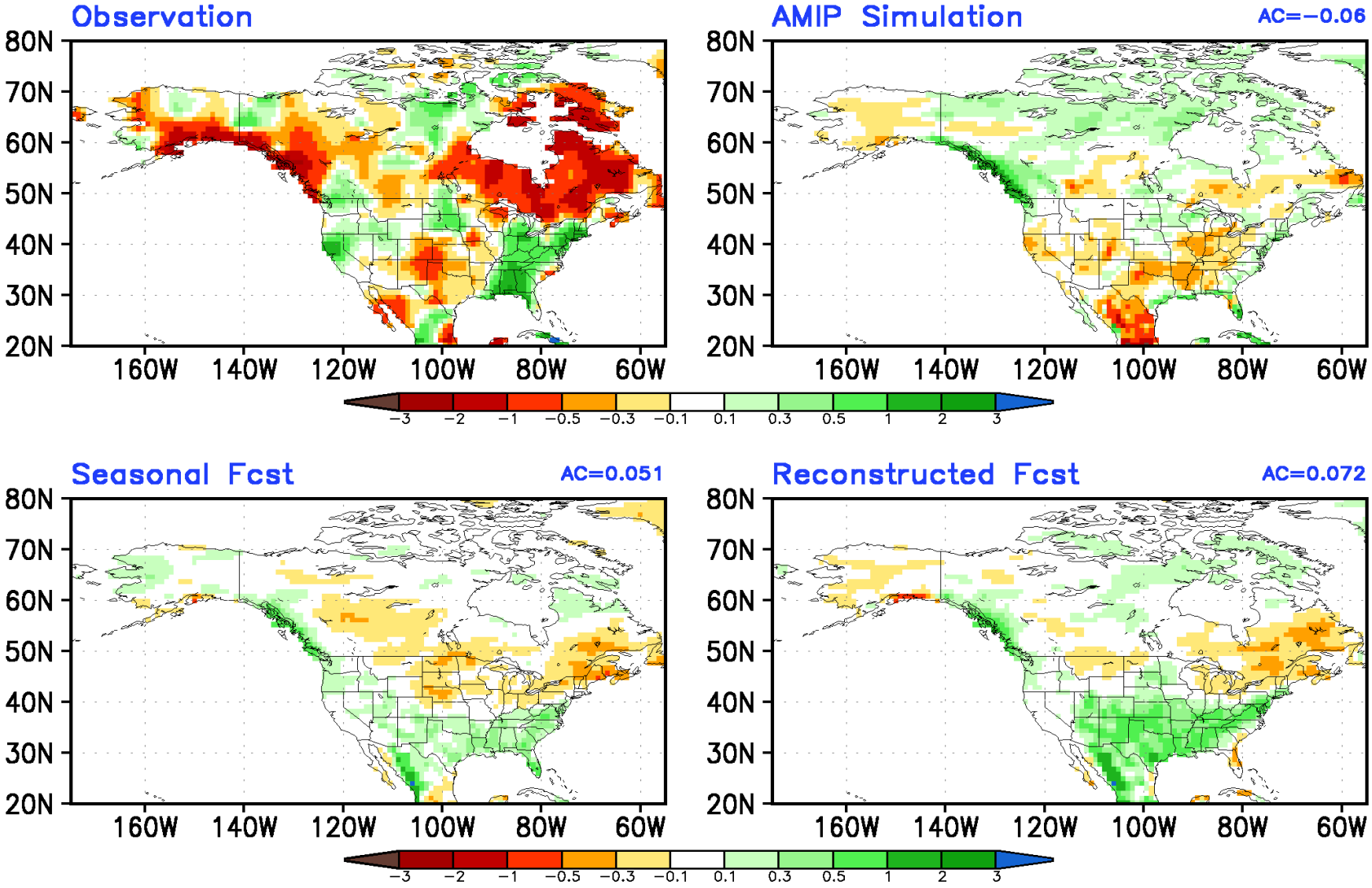
ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



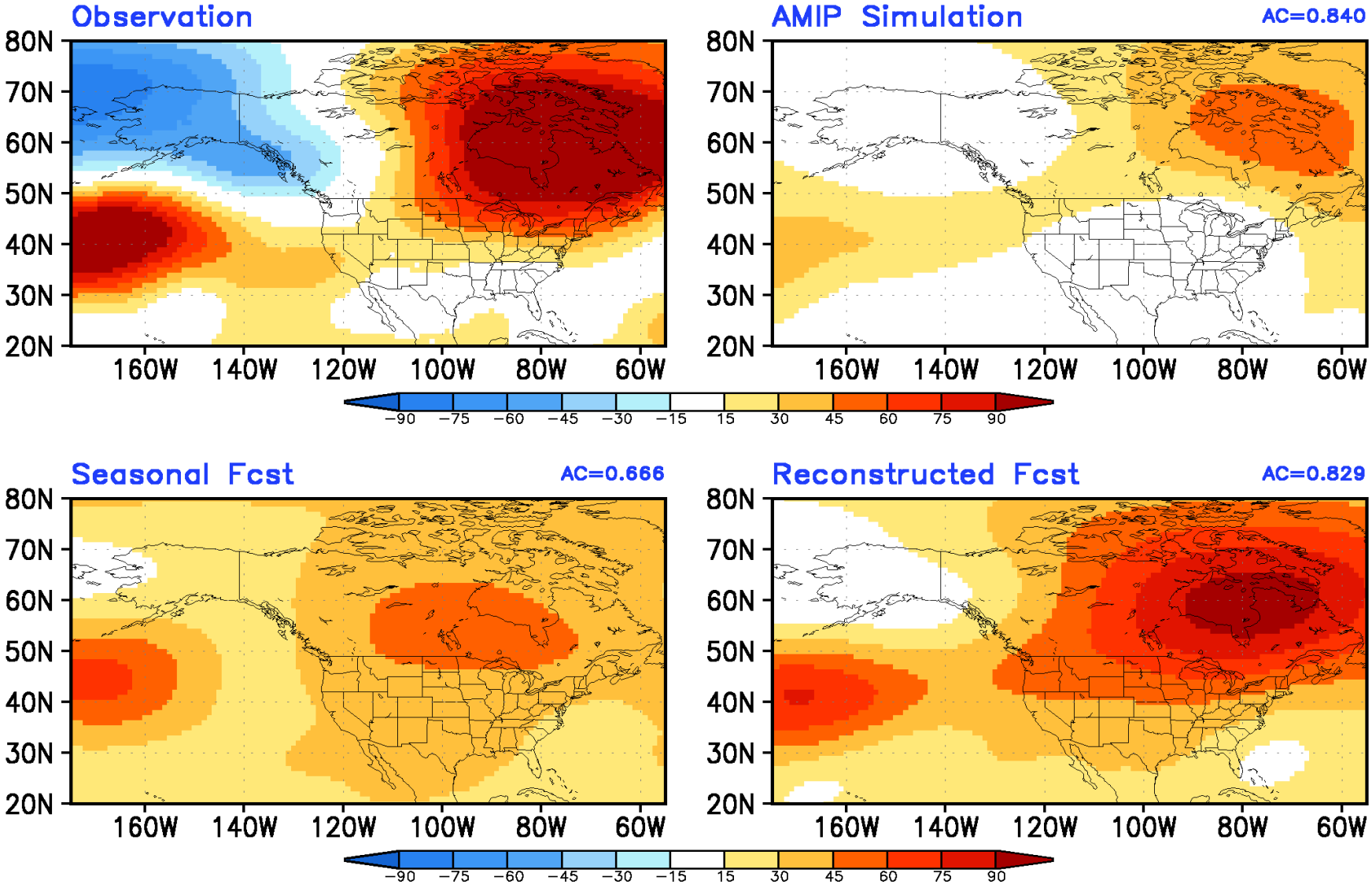
ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



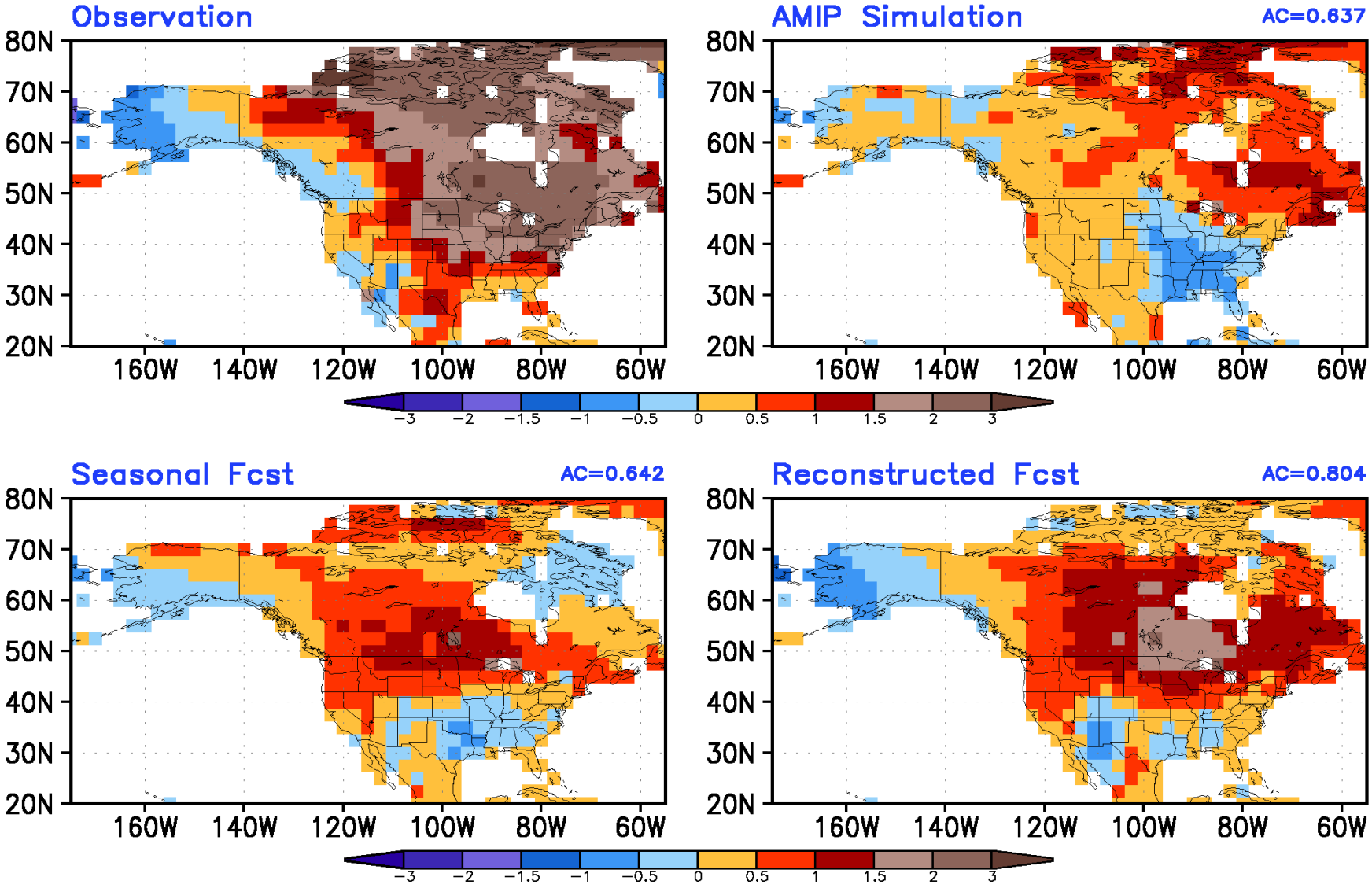
ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



ASO2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

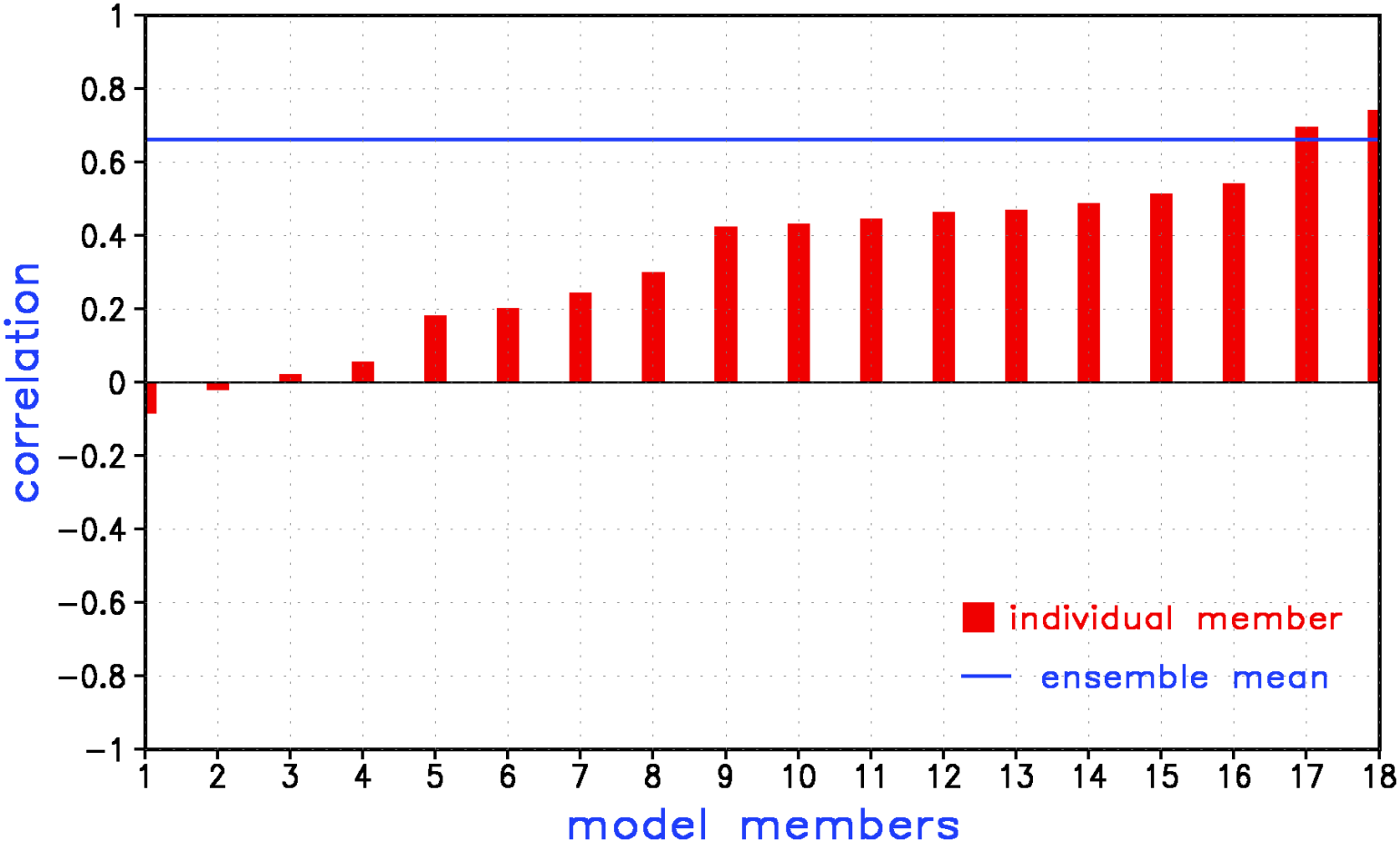


Model Simulated/Forecast Anomalies: Individual Runs

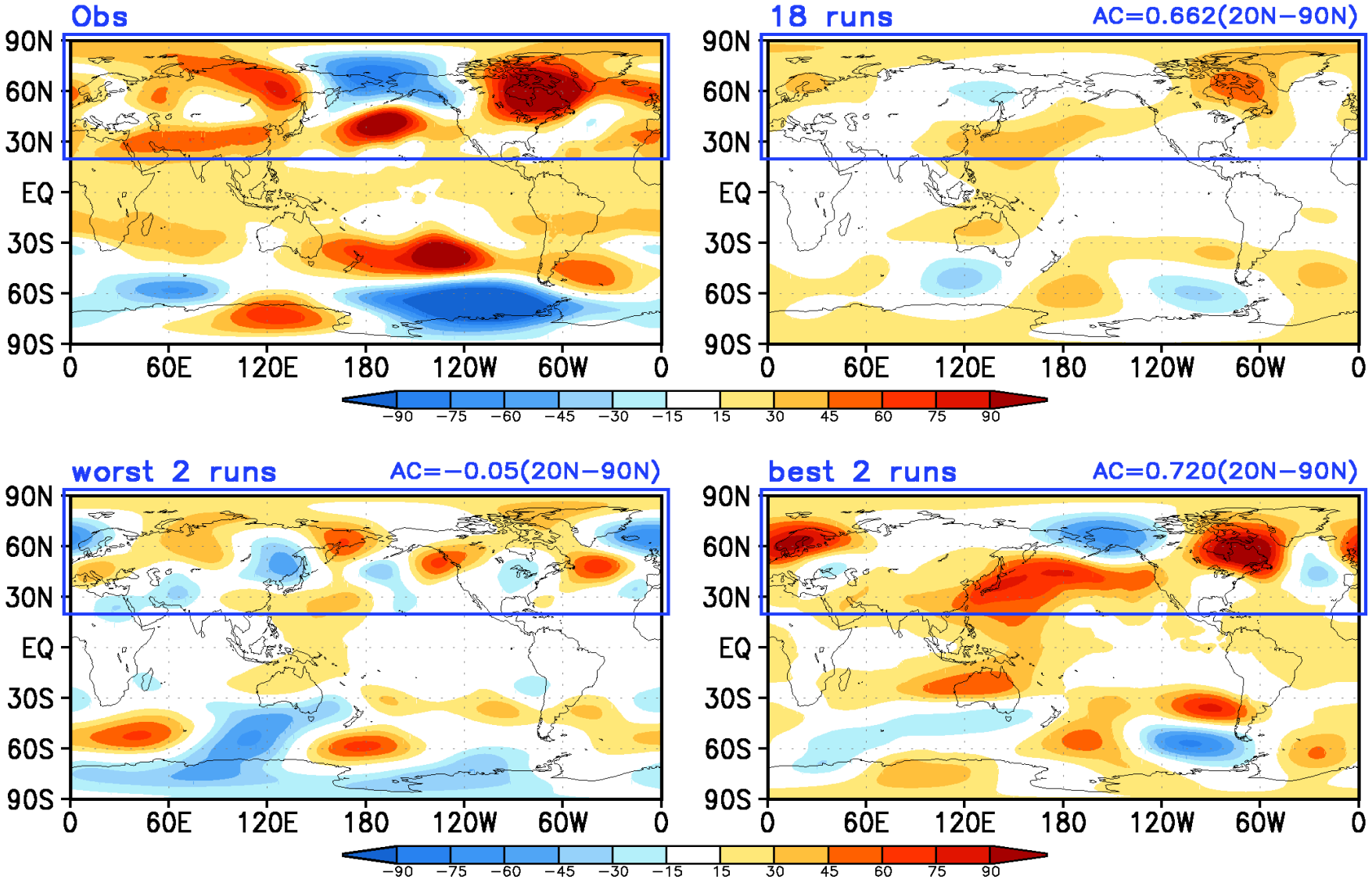
Model Simulated/Forecast Anomalies: Individual Runs

- 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.

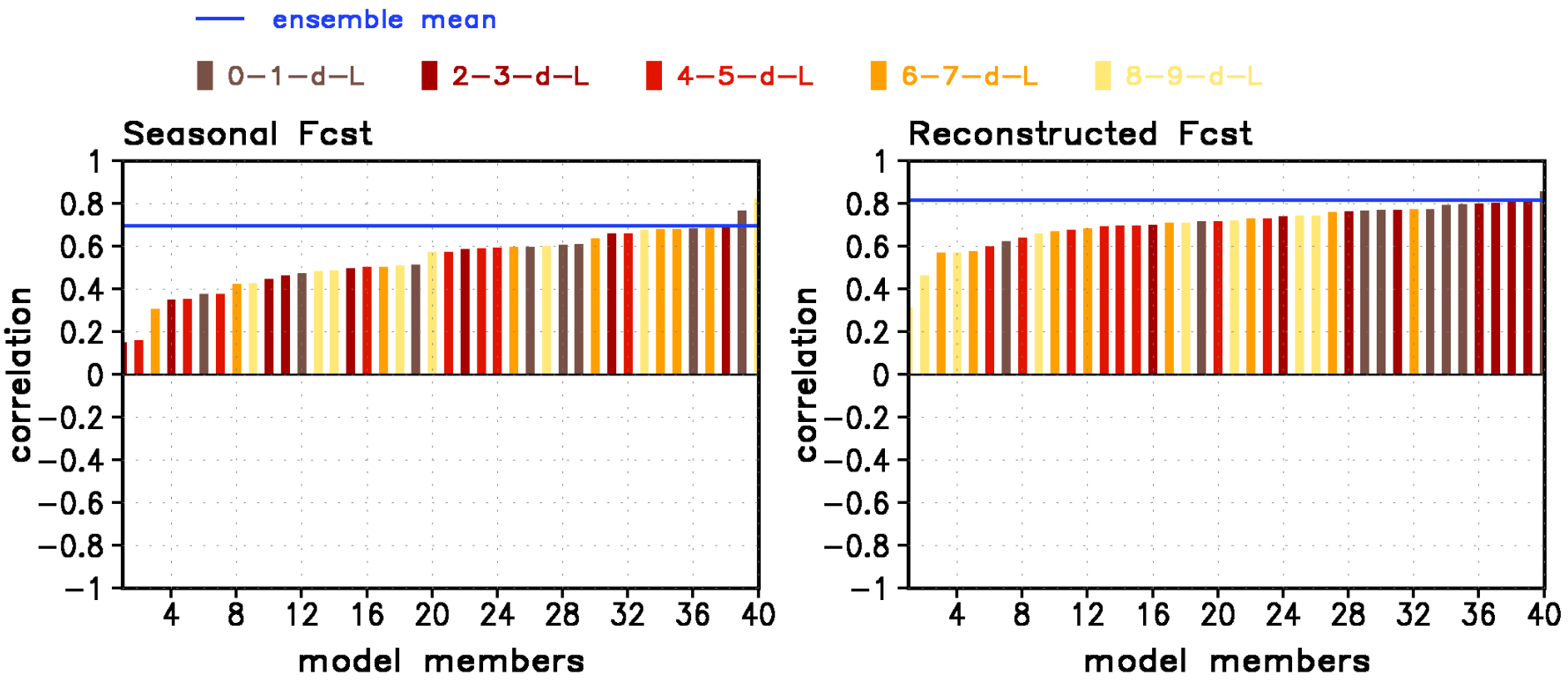
ASO2021 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)



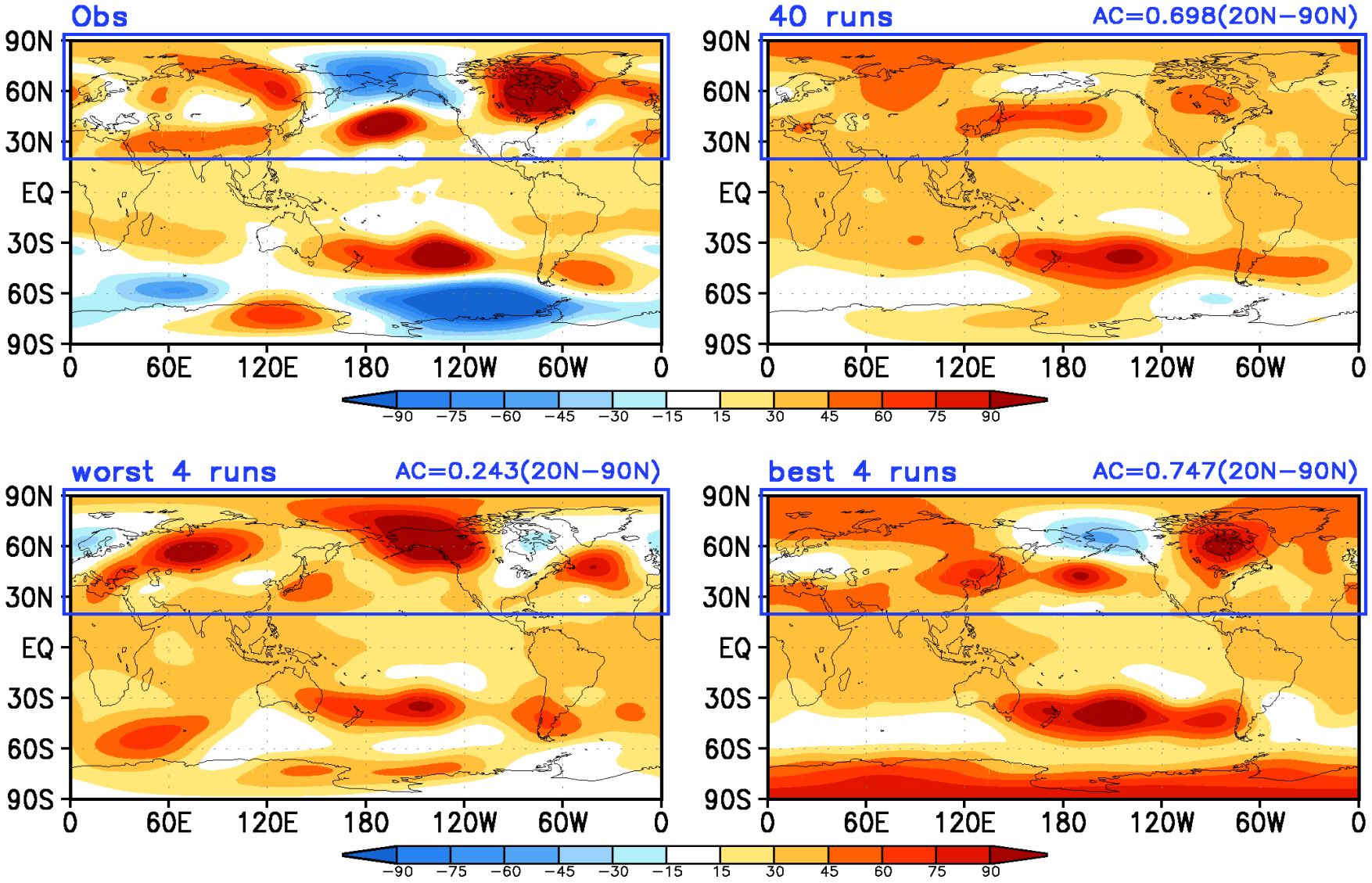
Observed & AMIP Ensemble Average Anomalies
ASO2021 z200(m) 18 runs/worst 2 runs/best 2 runs



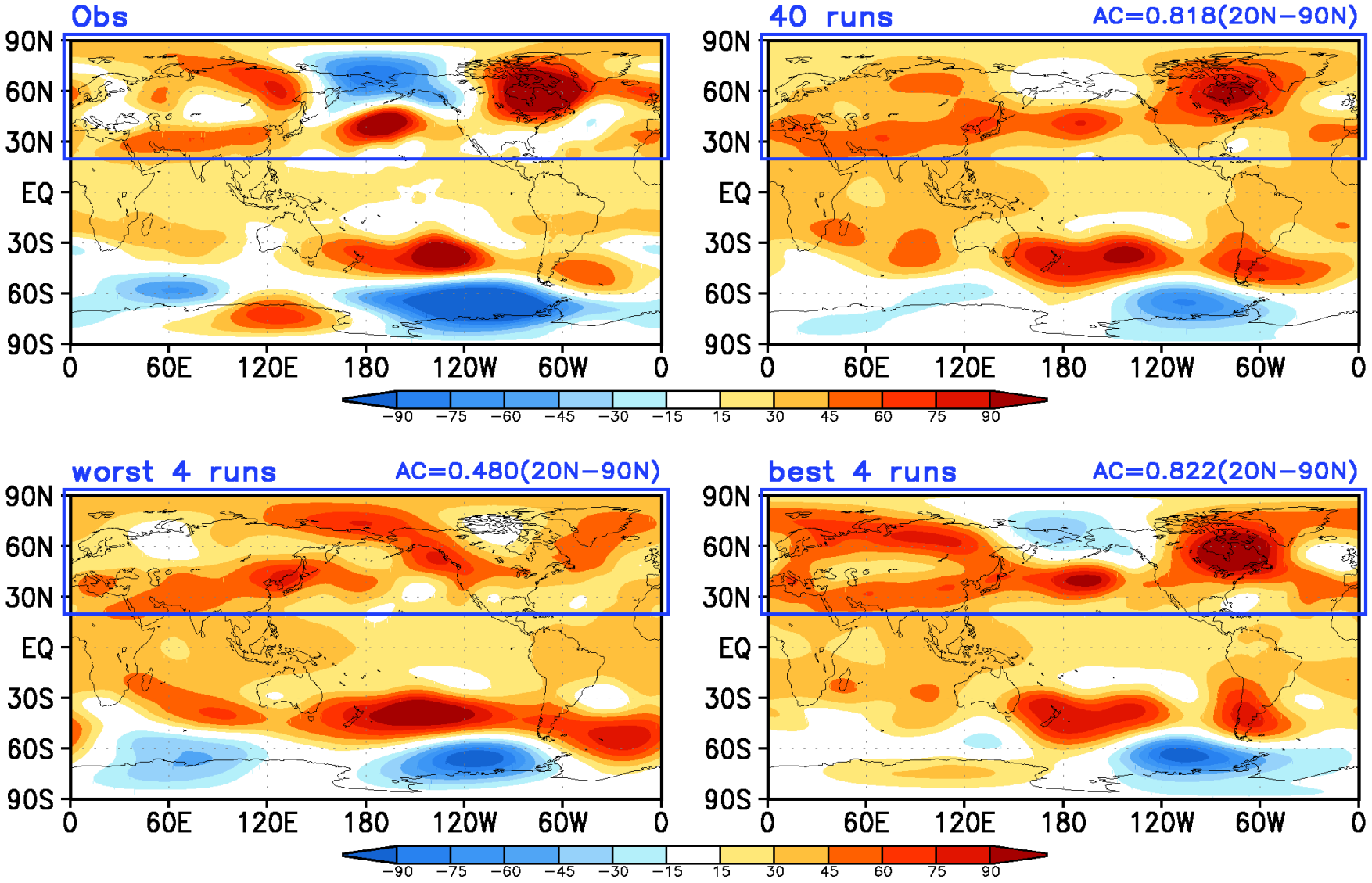
ASO2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



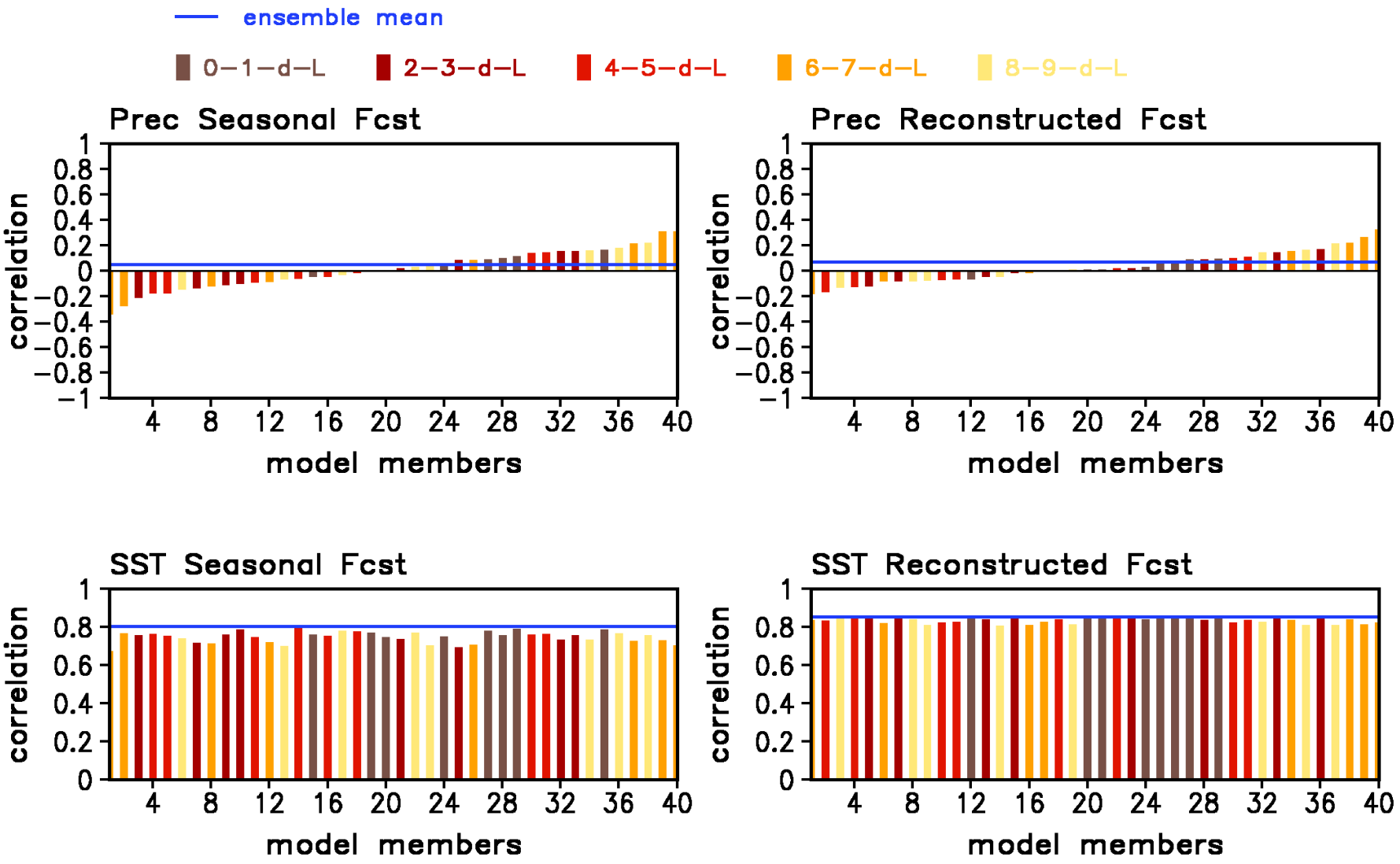
Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



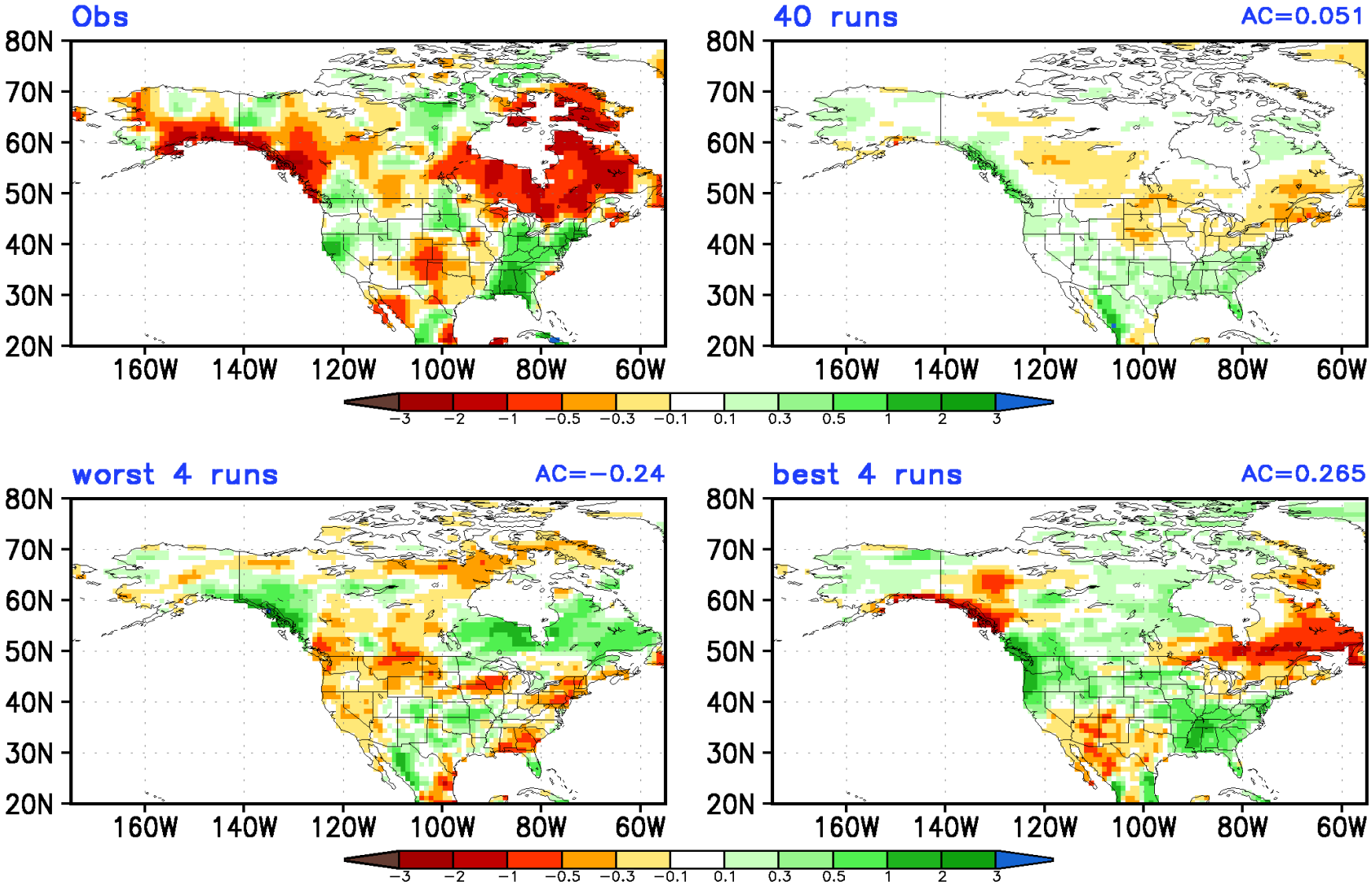
Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



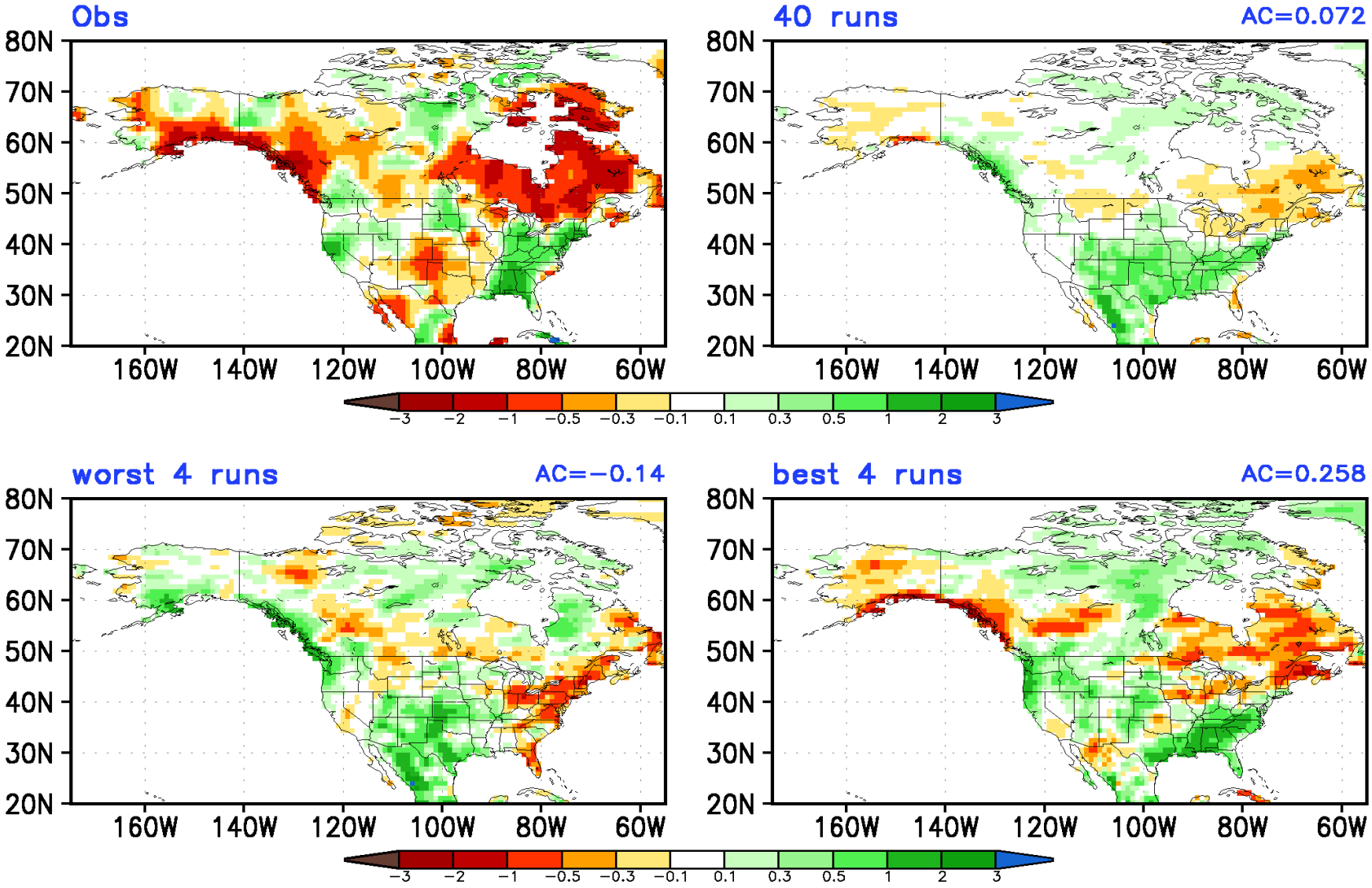
ASO2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



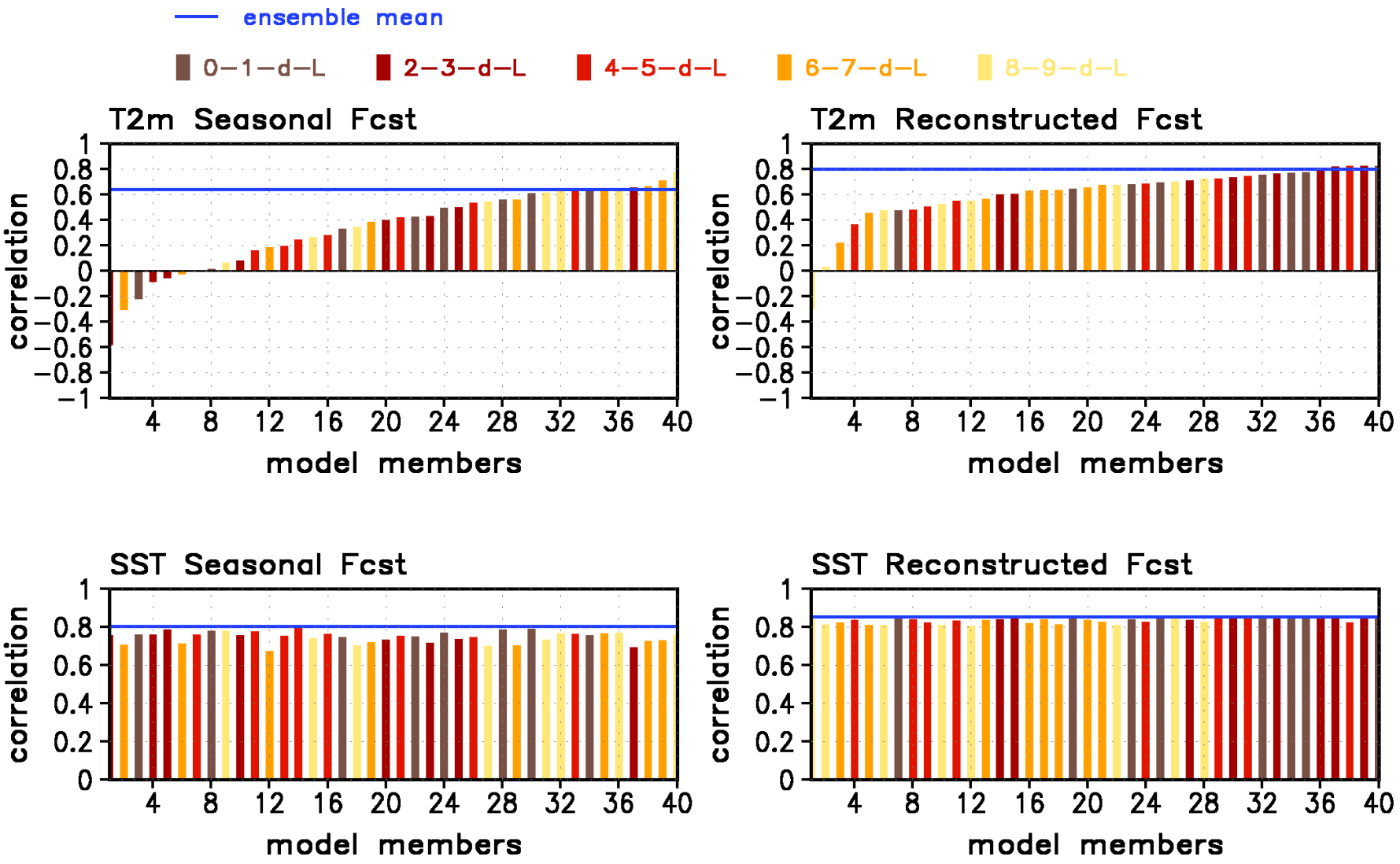
Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



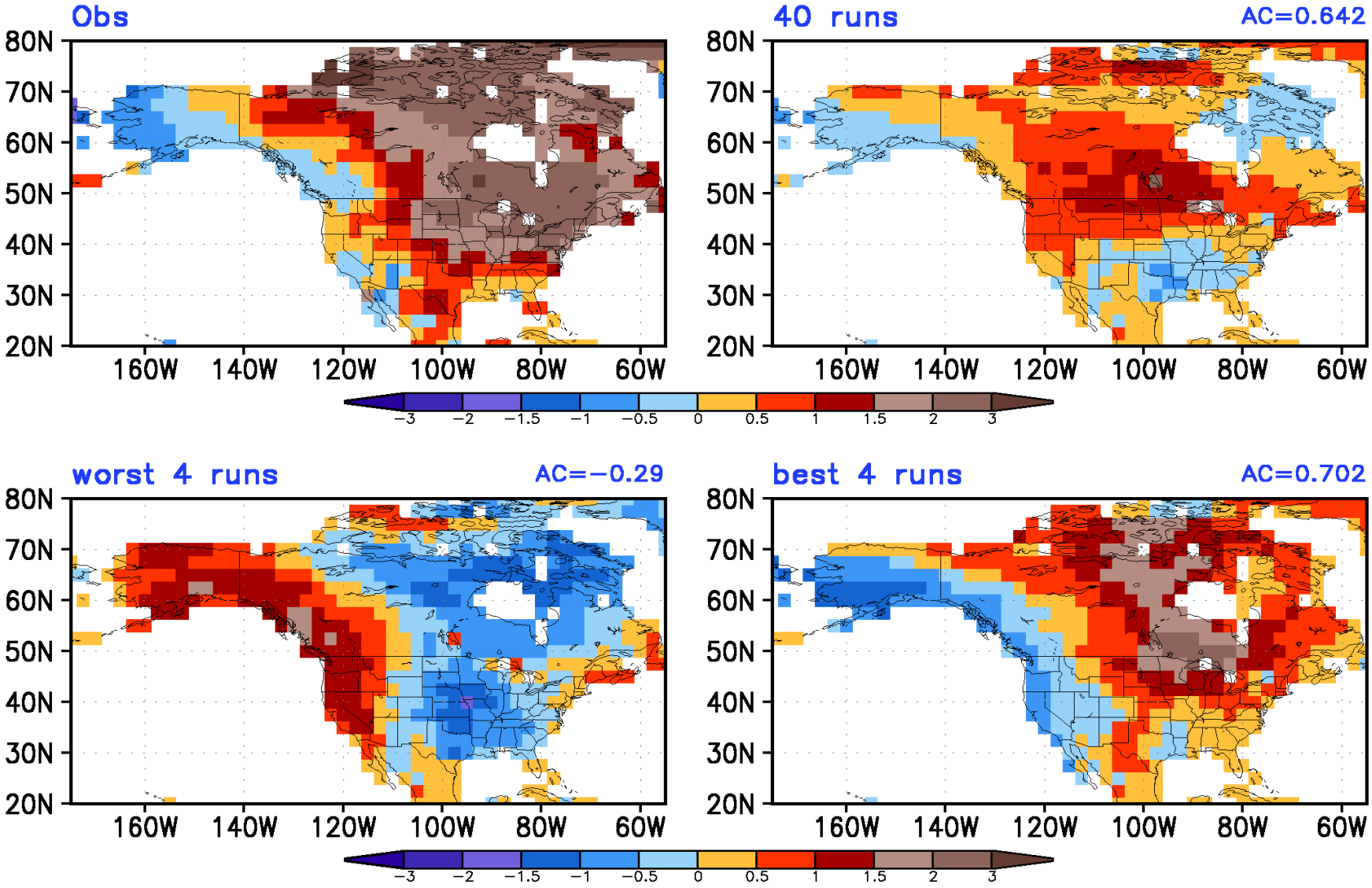
Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



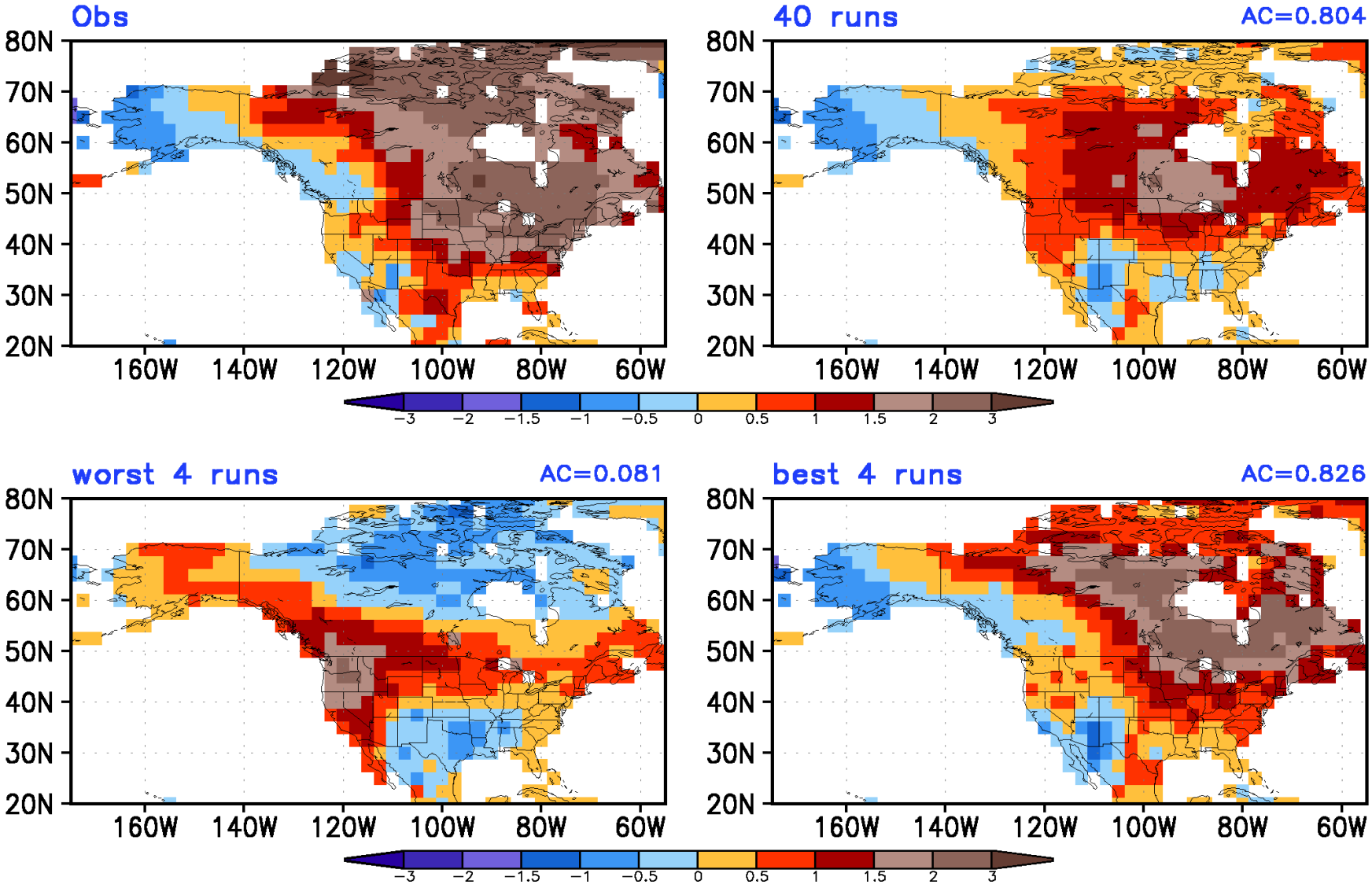
ASO2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



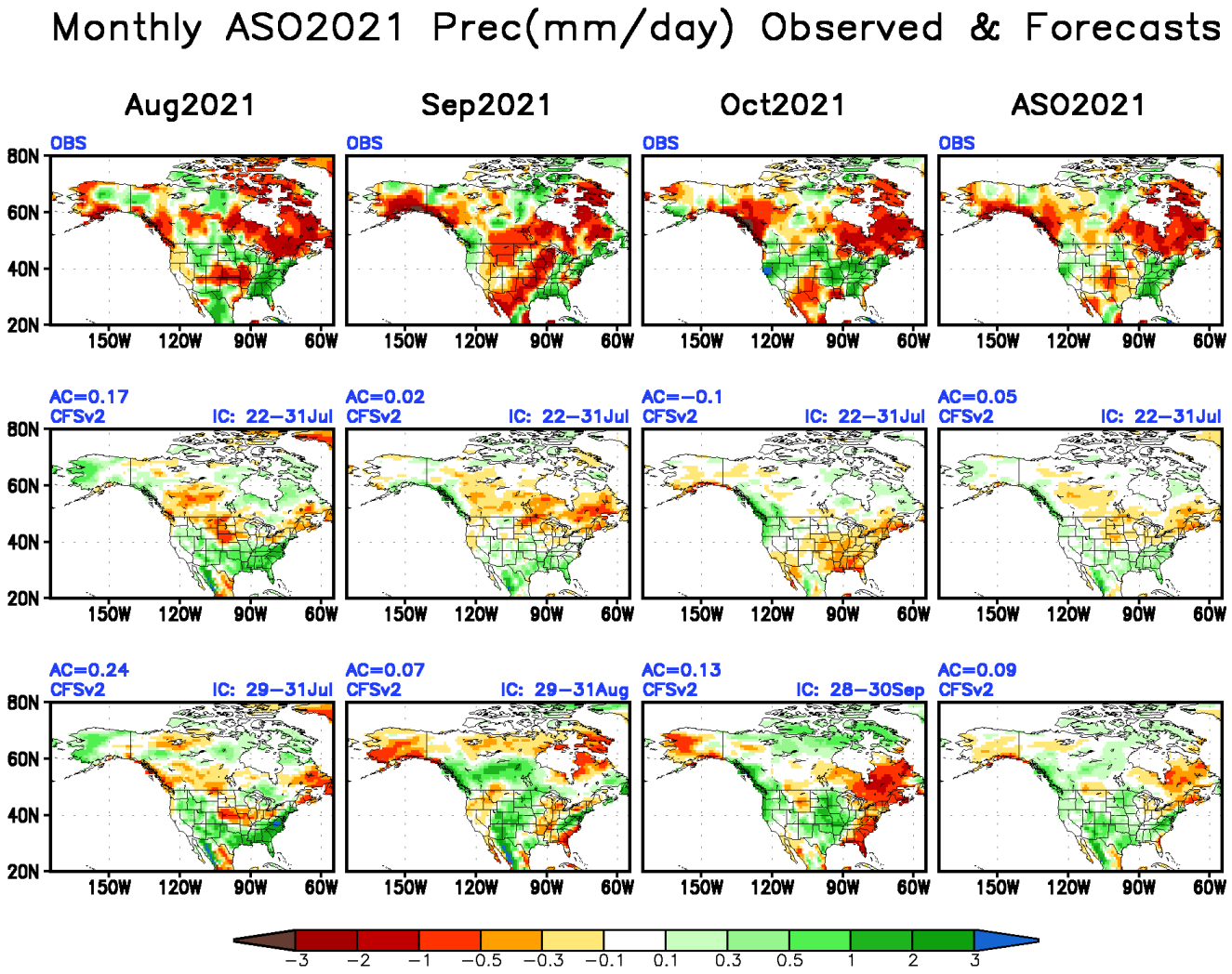
Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
ASO2021 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



Monthly Means Prec(mm/day) Observed & Forecasts



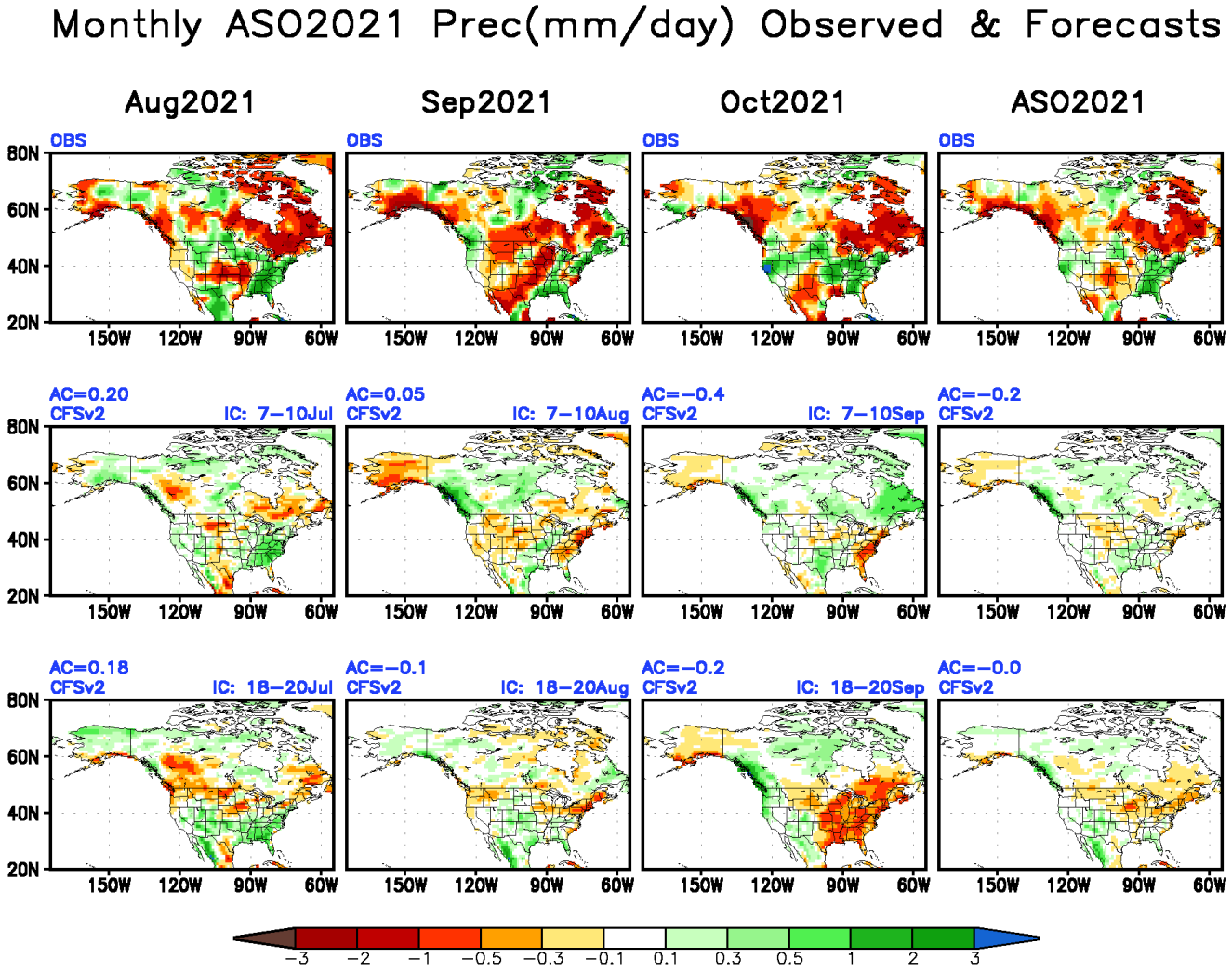
(at shortest leads)

Top row: Observed anomaly

Middle row: CFSv2 seasonal forecasts from the initial conditions from the month prior to the target season.

Bottom row: CFSv2 monthly forecasts from the last three days of the month prior to the target month.

Monthly Means Prec(mm/day) Observed & Forecasts



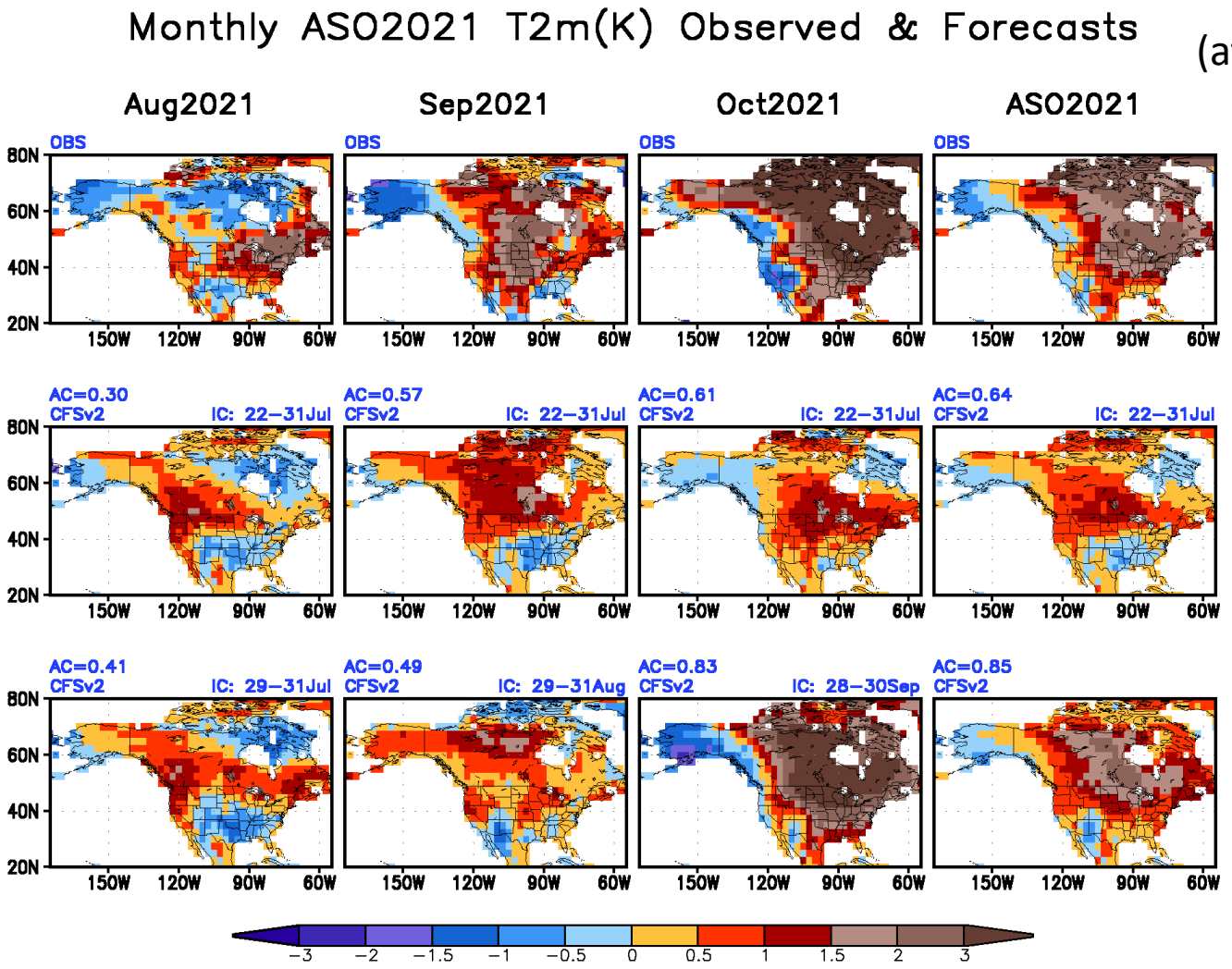
(at long leads)

Top row: Observed anomaly

Middle row: CFSv2 monthly forecasts from the initial conditions near 10th day of the month prior to the target month.

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20th day of the month prior to the target month.

Monthly Means T2m(K) Observed & Forecasts



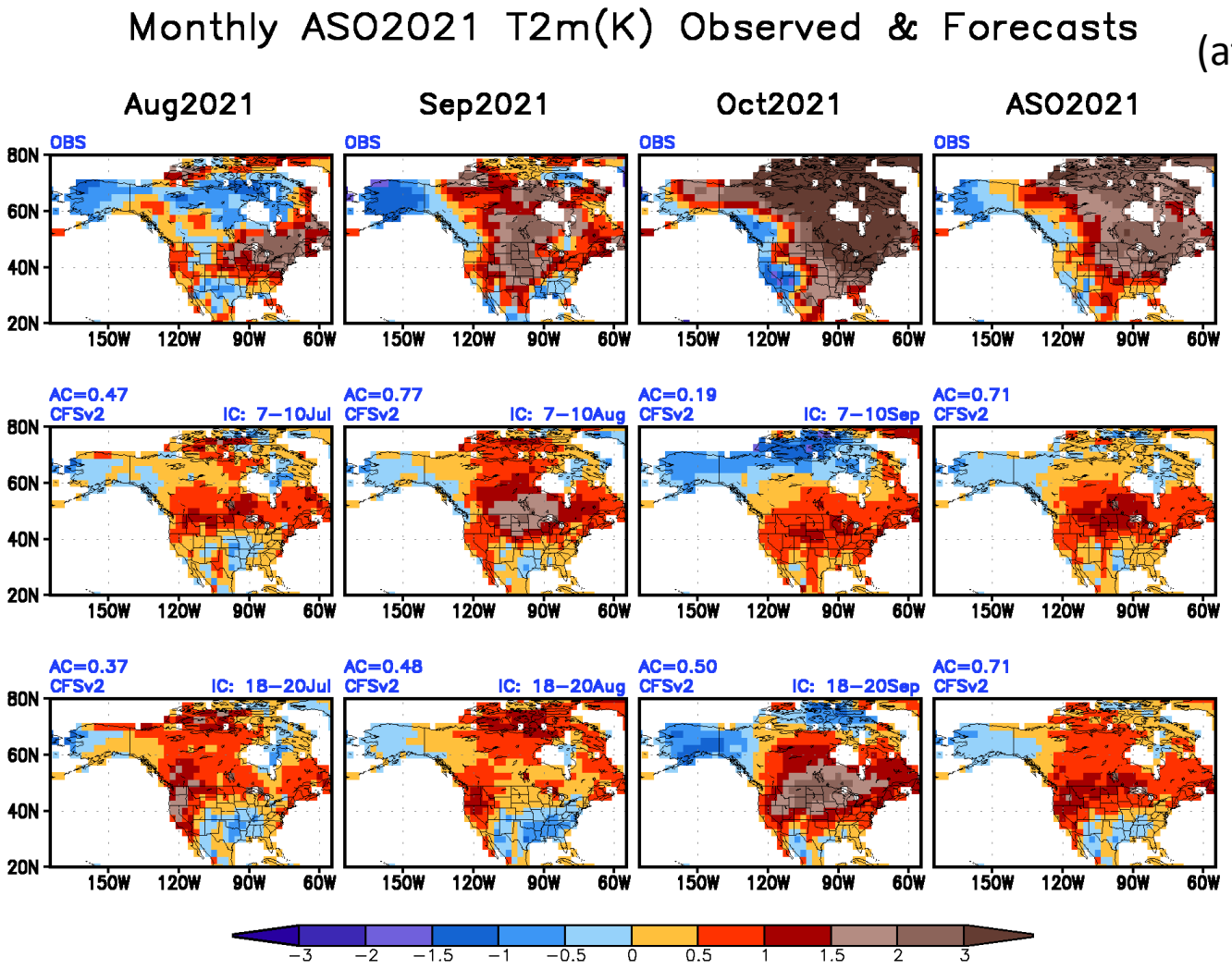
(at shortest leads)

Top row: Observed anomaly

Middle row: CFSv2 seasonal forecasts from the initial conditions from the month prior to the target season.

Bottom row: CFSv2 monthly forecasts from the last three days of the month prior to the target month.

Monthly Means T2m(K) Observed & Forecasts



(at long leads)

Top row: Observed anomaly

Middle row: CFSv2 monthly forecasts from the initial conditions near 10th day of the month prior to the target month.

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20th day of the month prior to the target month.

Seasonal Forecasts from WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME)

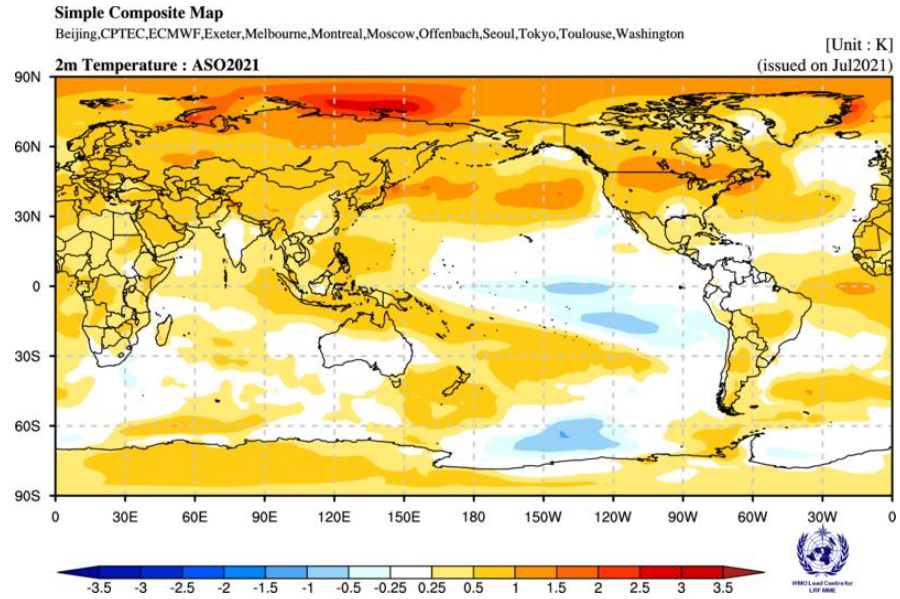
https://www.wmolc.org/

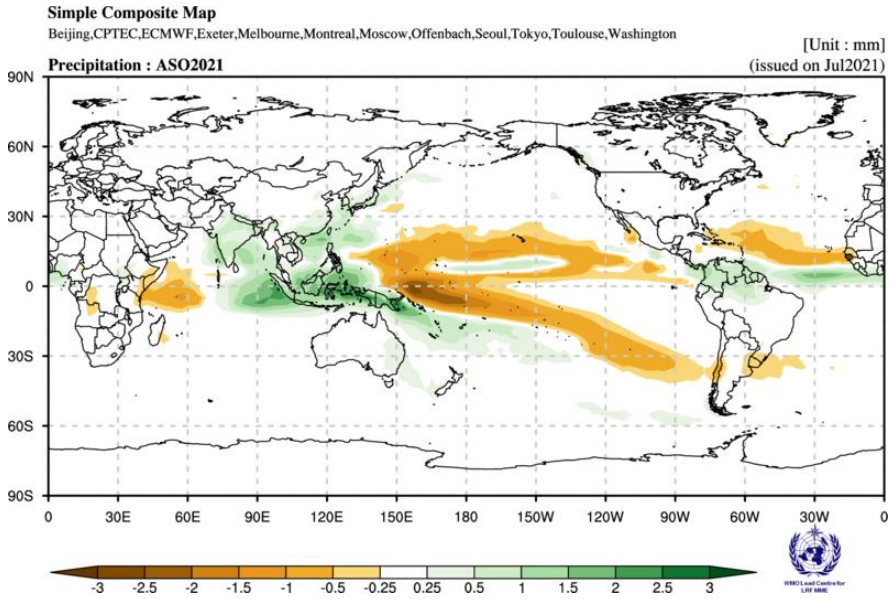
- LC-LRFMME seasonal forecast are based on forecasts provided by WMO recognized Global Producing Centers (GPCs) for Long-Range Forecasts to the LC-LRFMME. Contribution of all GPCs is acknowledged.
- Seasonal forecasts from GPCs are merged into a multi-model ensemble forecast.
- LC-LRFMME forecasts are based on GPC seasonal forecast systems run during the first week of the month for the next season. For example, forecasts runs in first week of January for the seasonal mean of February-March-April.
- Forecasts in slides 42-45 are from the Lead Center.
- For latest seasonal outlook guidance see http://www.wmo.int/pages/prog/wcp/wcasp/LC-LRFMME/index.php

- *For more information see visit Lead Center website; also see Graham, R., and Co-authors, 2011: New perspectives for GPCs, their role in the GFCS and a proposed contribution to a 'World Climate Watch'. Climate Research, **47**, 47-55.*

LC-LRFMM Seasonal Forecasts (ensemble means)

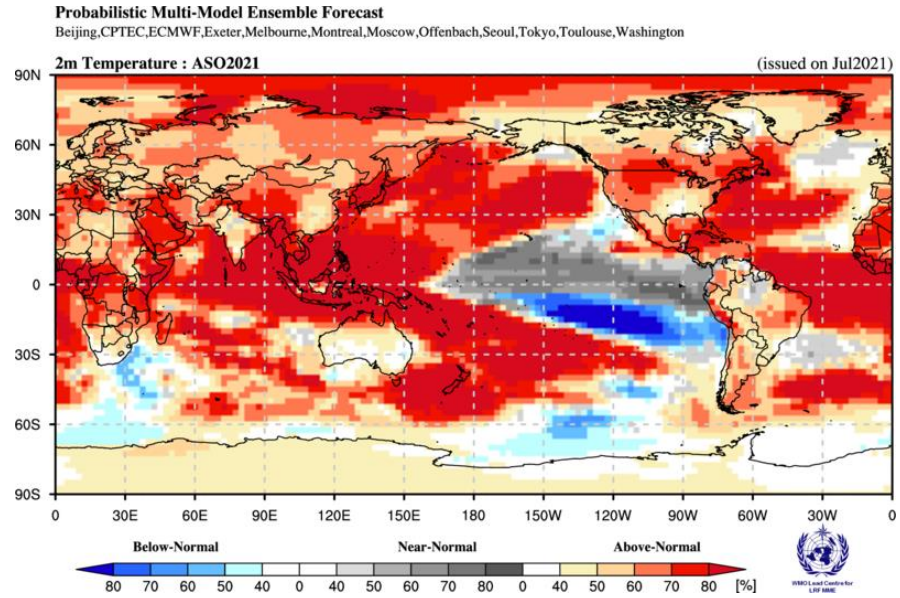
(https://www.wmolc.org/)

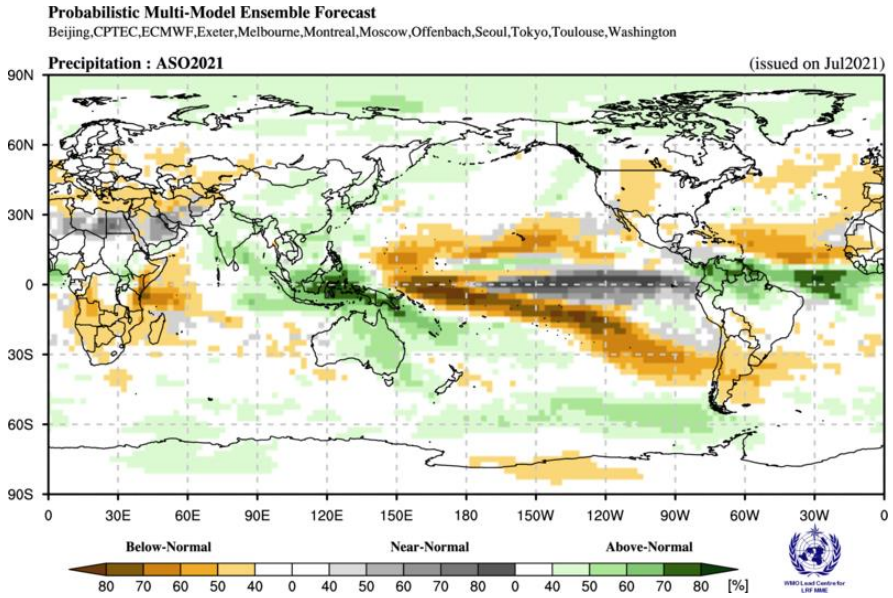




LC-LRFMM Seasonal Forecasts (probabilities)

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

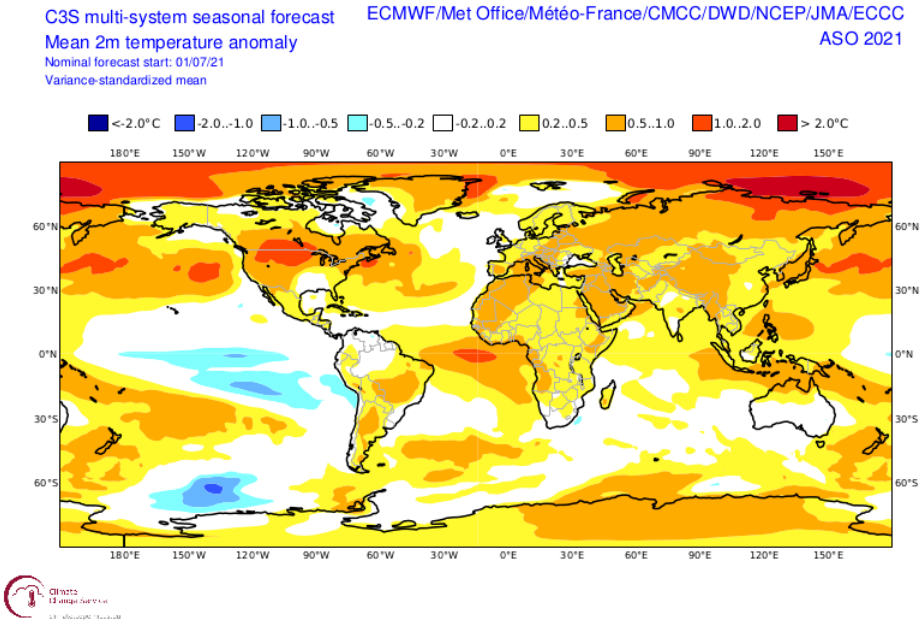


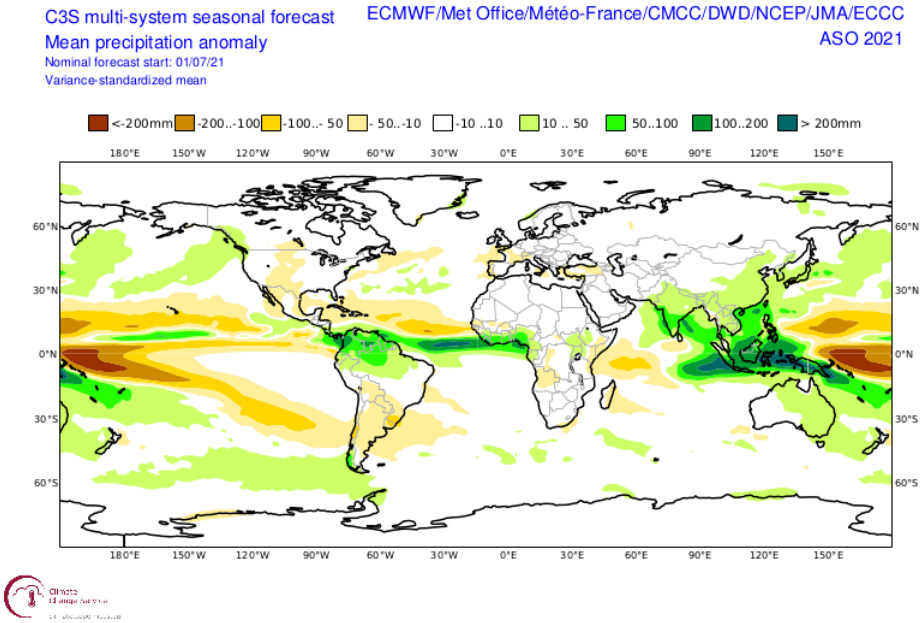


Seasonal Forecasts from other multi-model systems and linear models

C3S Seasonal Forecast

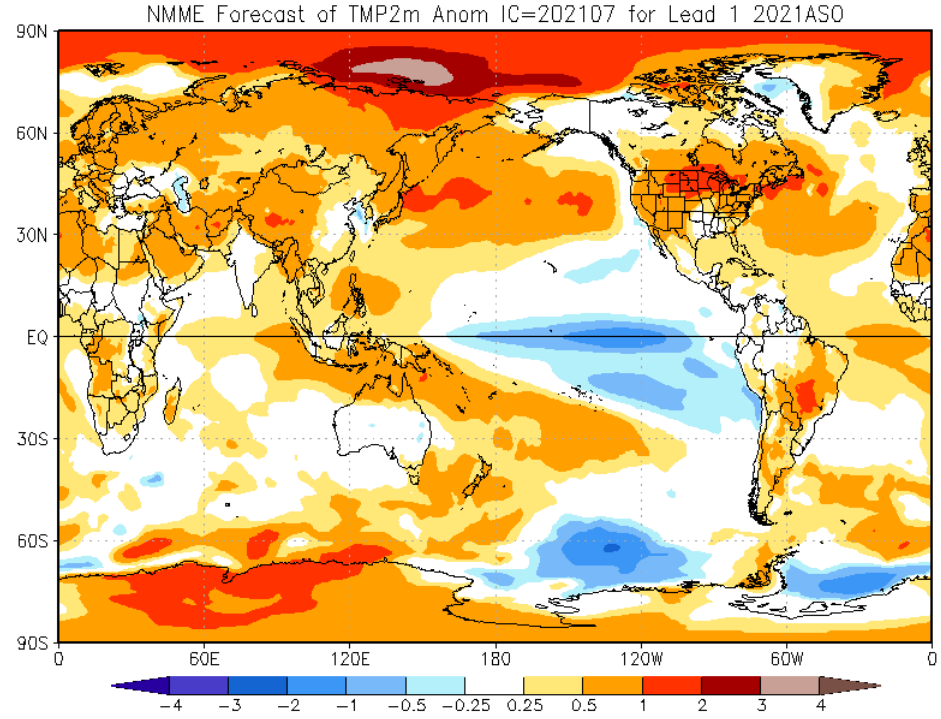
(https://climate.copernicus.eu/charts/c3s_seasonal/)

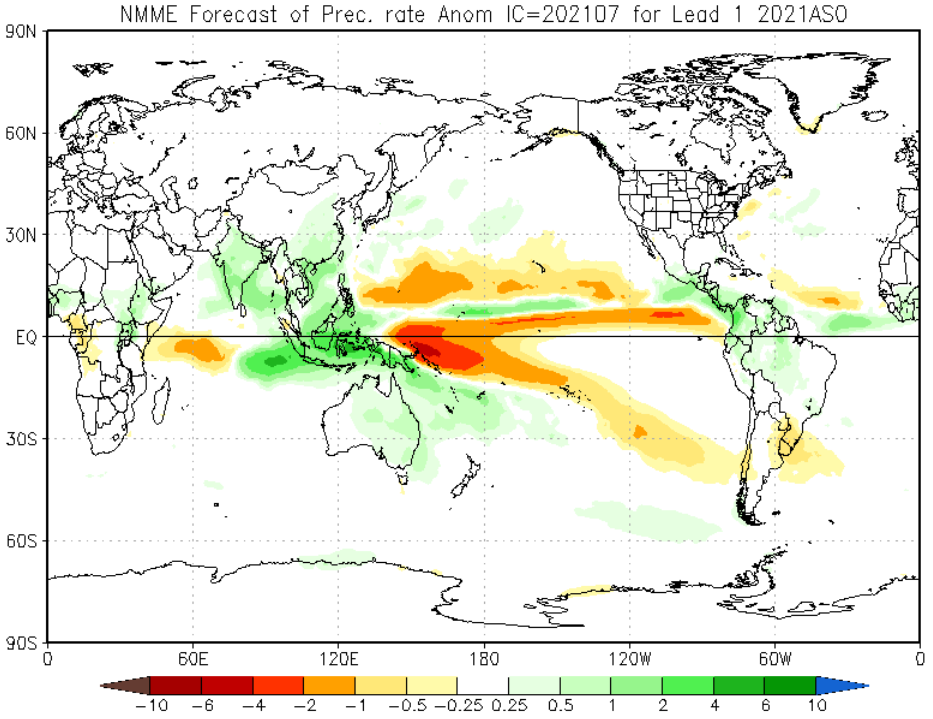




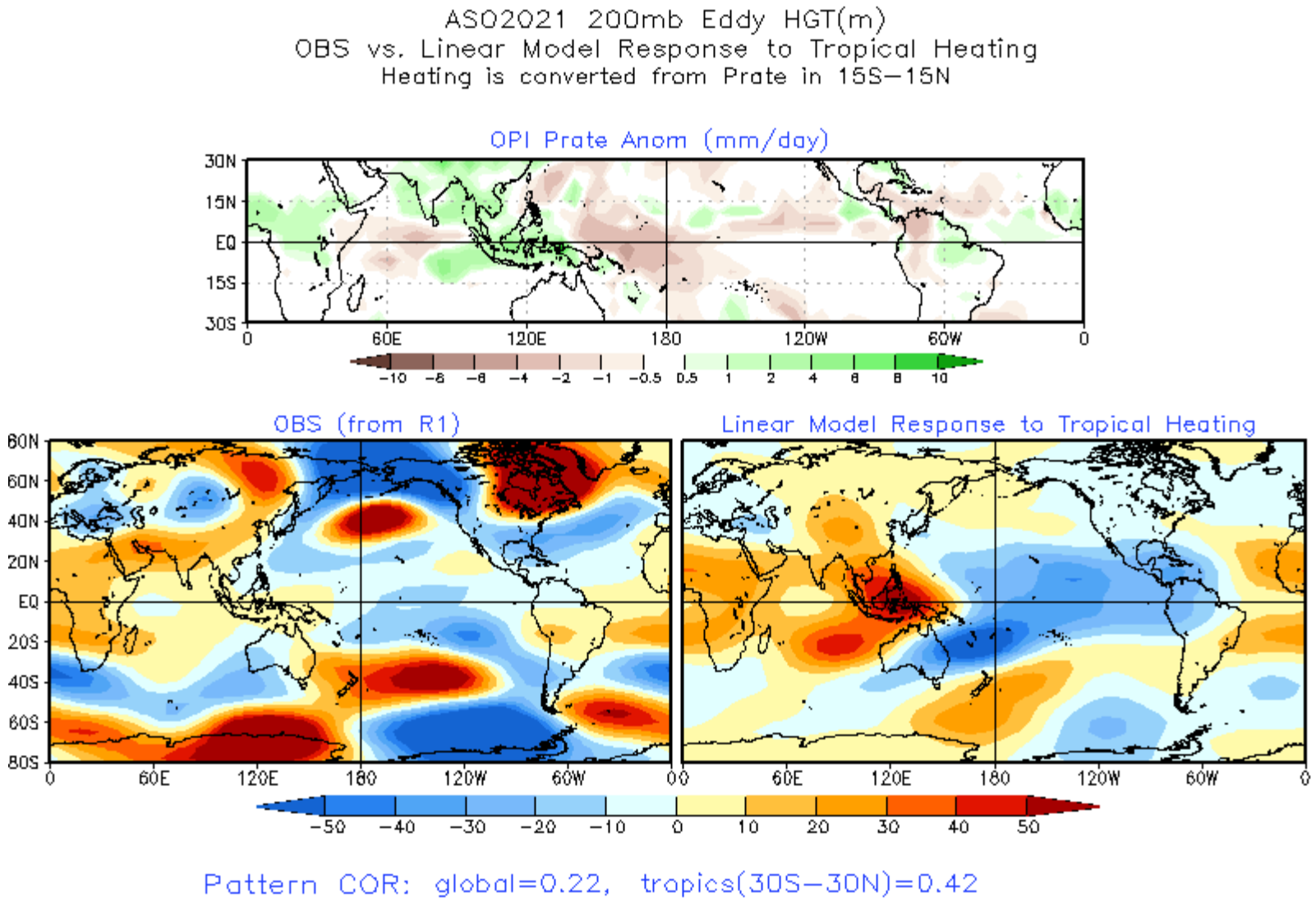
North American Multi-Model Ensemble Seasonal Forecast

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

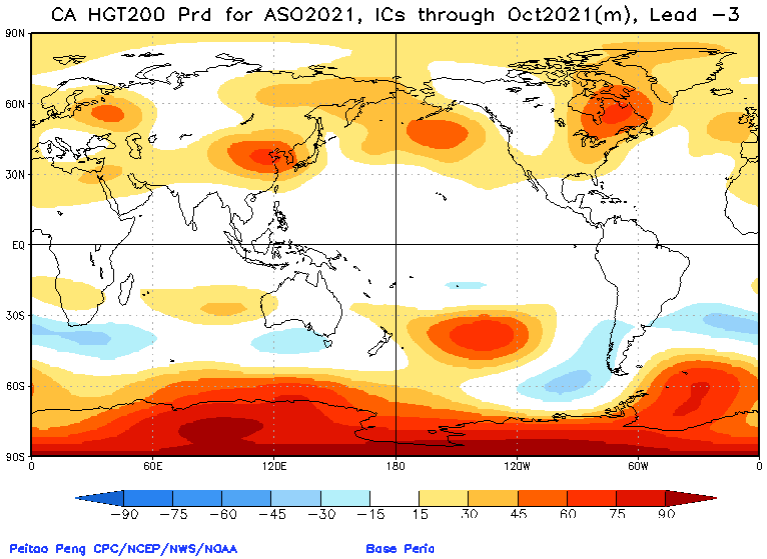


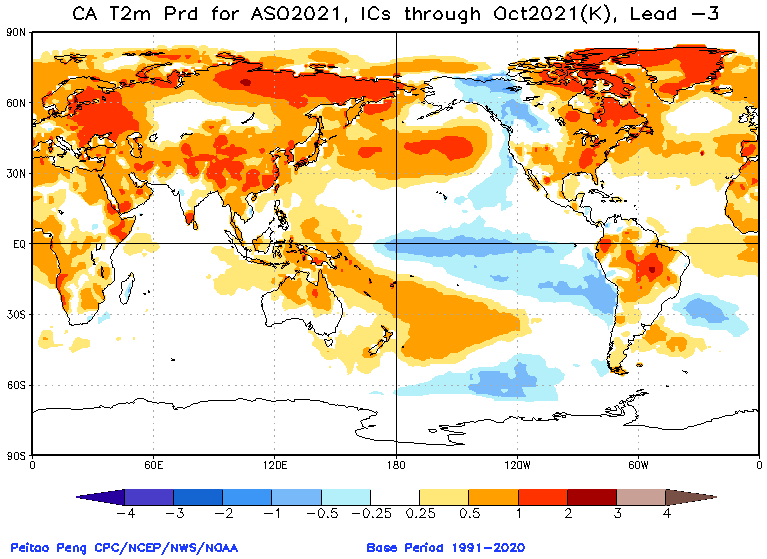


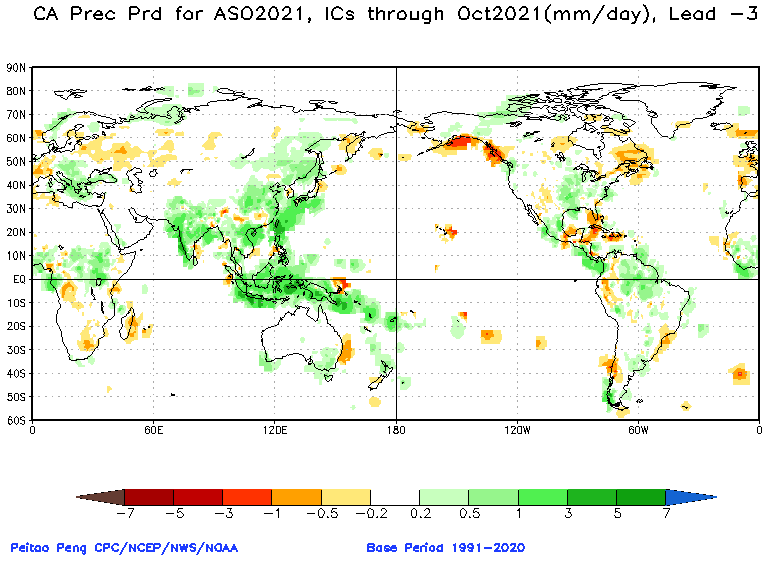
200mb Height from Linear Model



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 from CFSv2 (provided by Dr. Bhaskar Jha/CPC)
  - 18 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)