Attribution of Seasonal Climate Anomalies March-April-May 2020

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

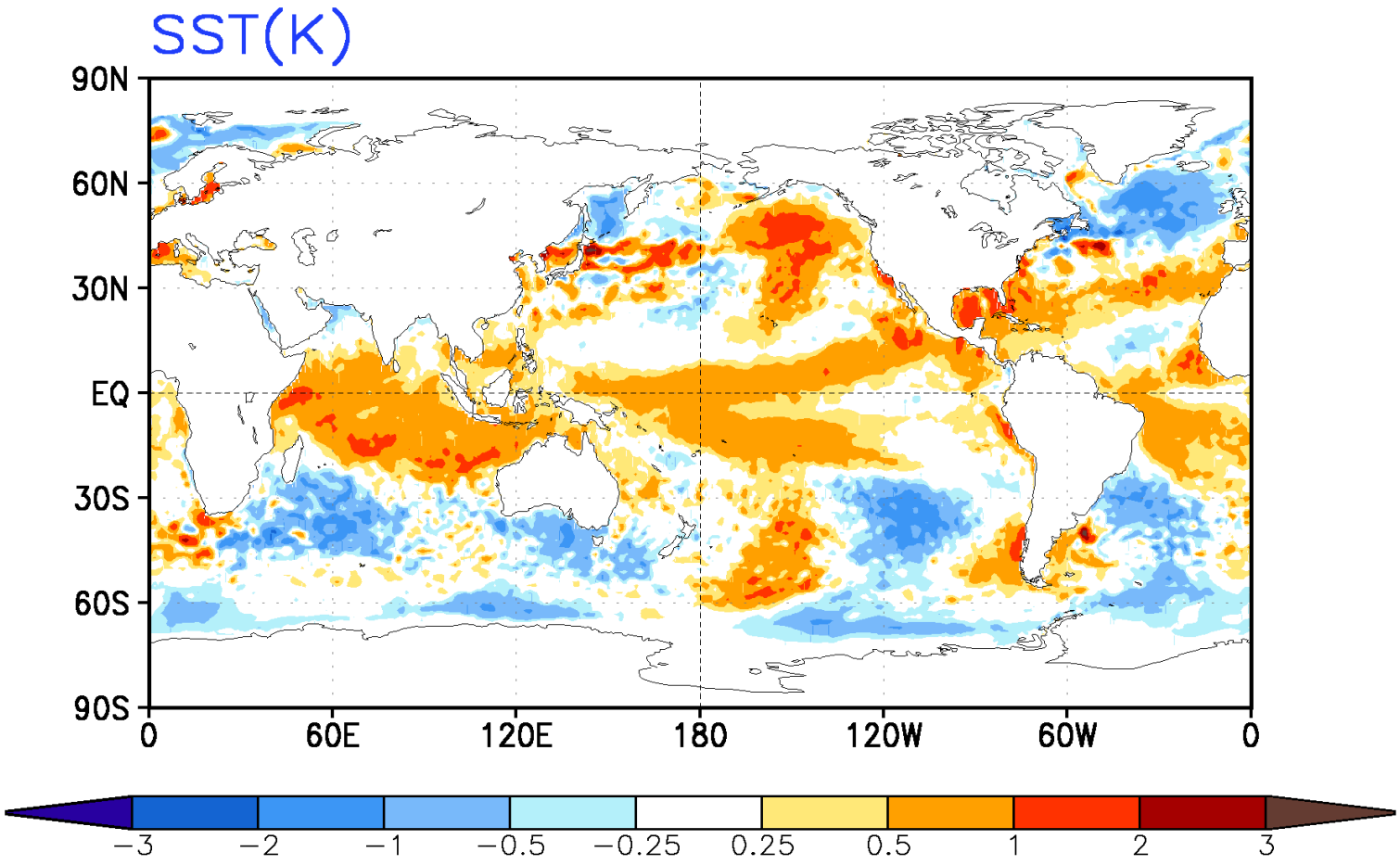
Summary of March-April-May 2020 Observed Conditions and Outlooks

- The sea surface temperature (SST) anomalies in the equatorial central Pacific Ocean continued to be on weak warm side (Slide 4) with central/eastern Pacific getting cooler.
- Except over northern regions of North America, land temperature anomalies everywhere were above normal.
- In tropics, the large-scale distribution of negative and positive precipitation anomalies was predicted in CFSv2 and other multi-model ensemble (MME) forecast systems (slide 11, 33, 34, and 39).
- The large-scale structures of the observed positive height anomalies over the tropical and N. sub-tropical region were well captured in the *initialized* CFSv2 forecasts, while the observed strong negative height anomalies over NA high latitudes region were missed leading to missed cold surface temperature anomalies over Canada and the northern part of central US area (slide 12, 15, & 16)
- The initialized seasonal forecasts well captured negative (positive) precipitation anomalies over the US west coast extending from northern California to Pacific northwest (SE US region including Florida) (slide 14).
- The monthly forecasts from the shortest 3-day-leads initial conditions captured major features of NA precipitation and T2m anomalies, especially for April and May2020 T2m (slides 30 & 31).
- All MME forecasts captured the observed warming over northern regions of Asia (slides 5, 13, 33, 34, 38).
- The north-south pattern of high and low height anomalies between 60^{o}N-90^{o}N (with positive projection on the AO) was captured in initialized predictions (slide 12).

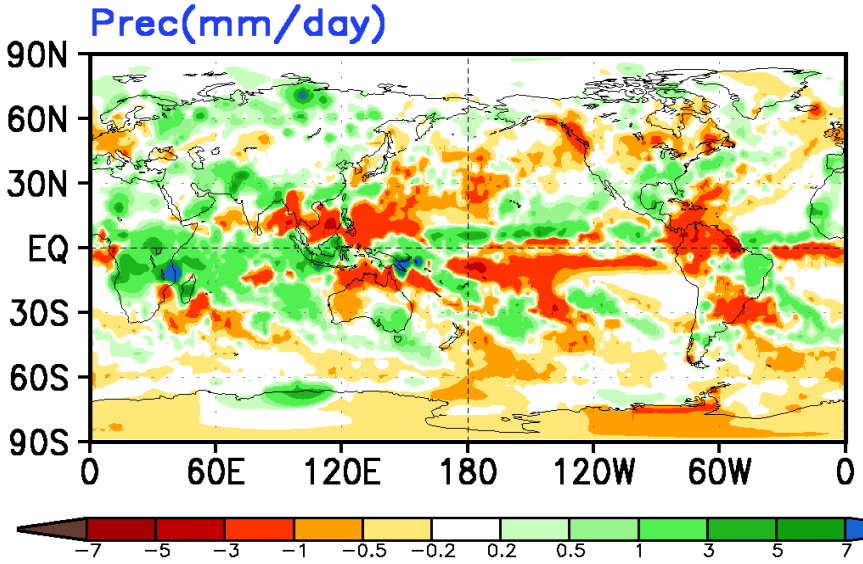
Observed Seasonal Anomalies

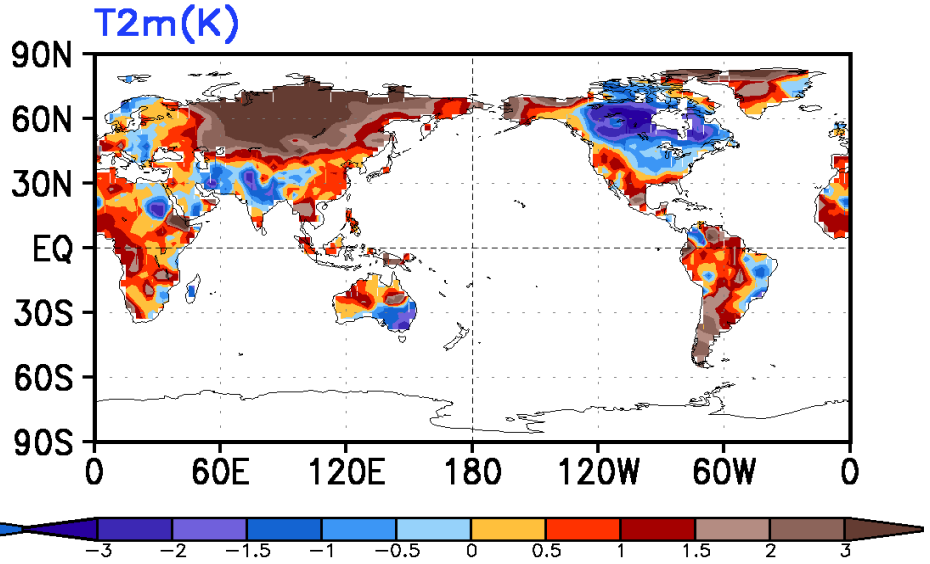
Global and North America

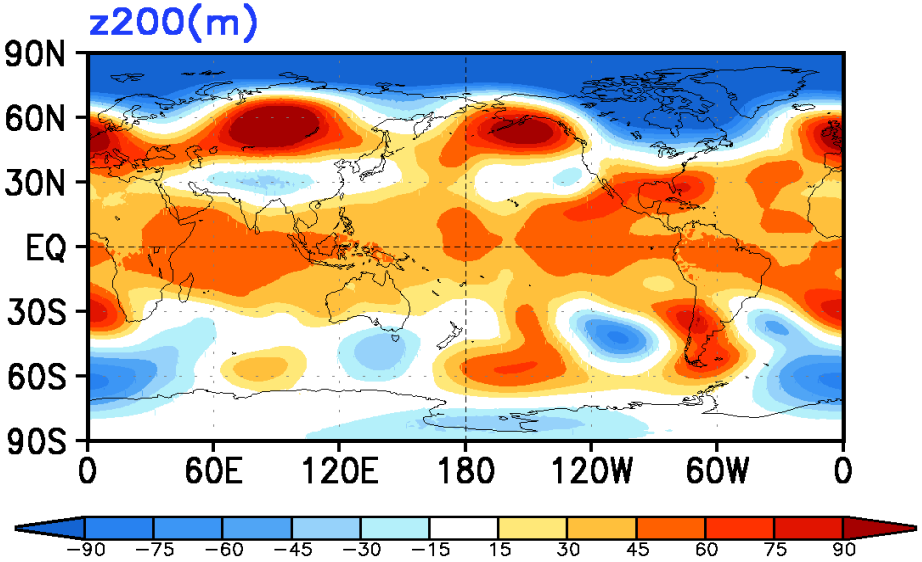
Observed Anomaly MAM2020



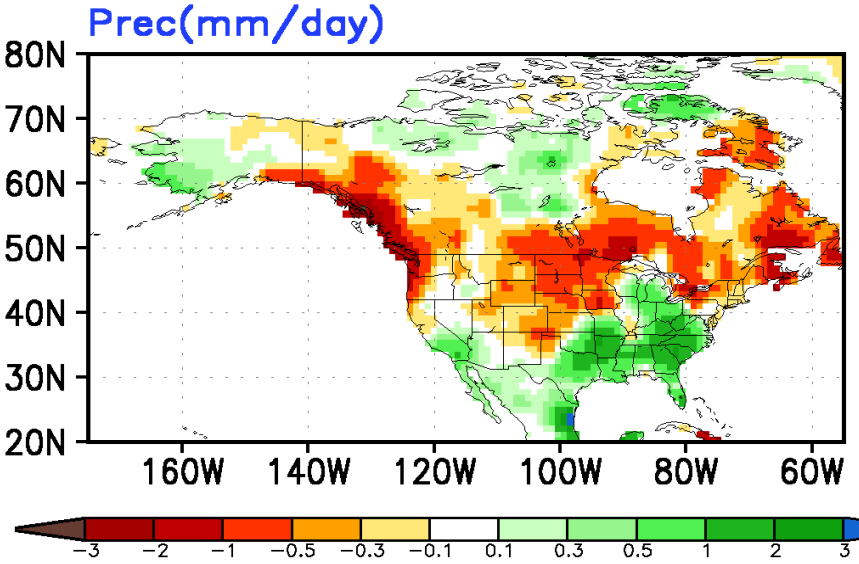
Observed Anomaly MAM2020

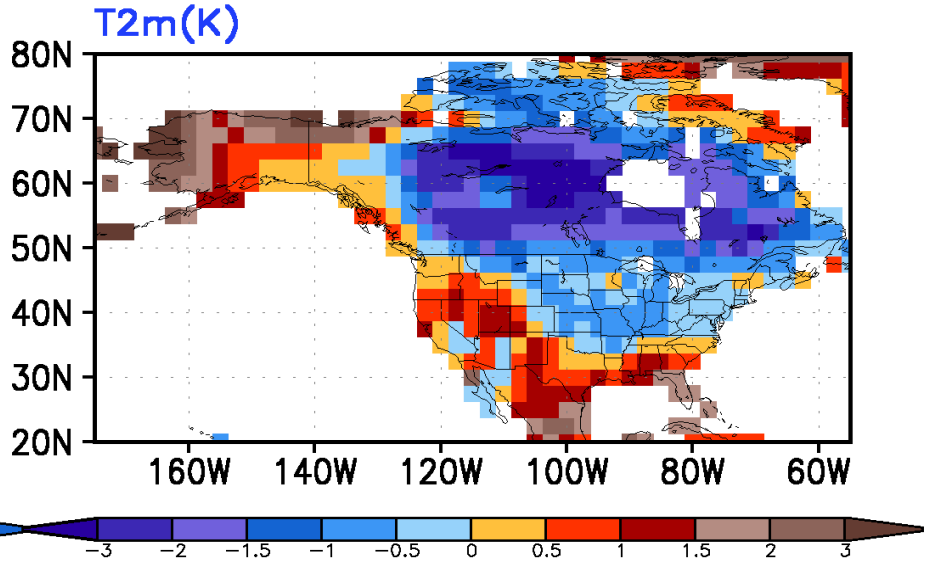


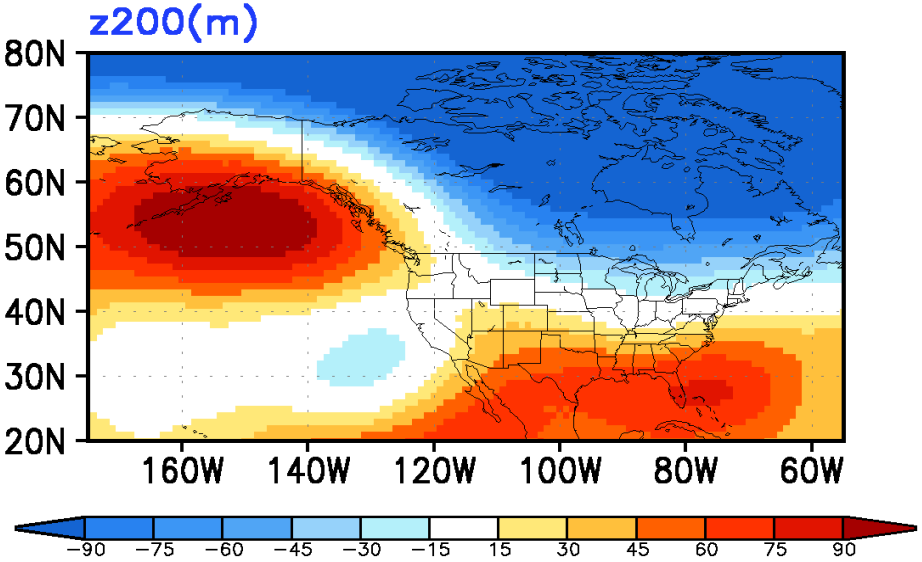




Observed Anomaly MAM2020







MAM2020 CPC Seasonal Outlooks and NMME Forecasts

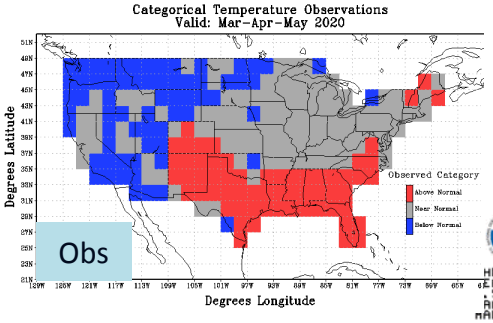
Temperature

Precipitation

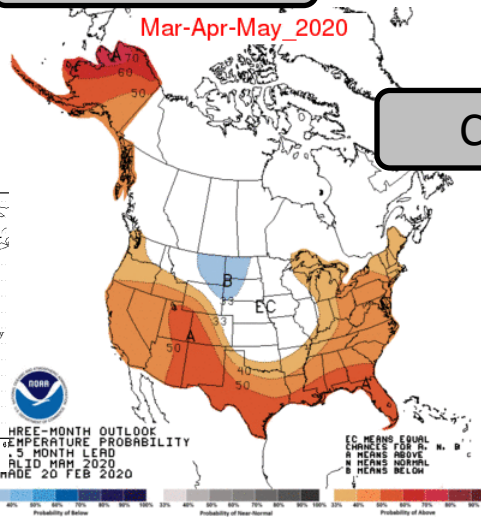
Temp nonEC
HSS=7

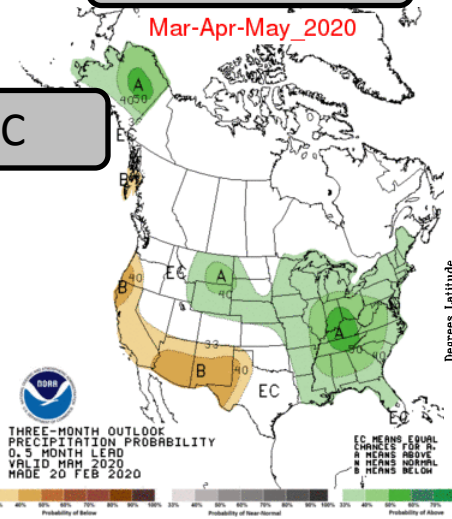
Prec nonEC
HSS=2

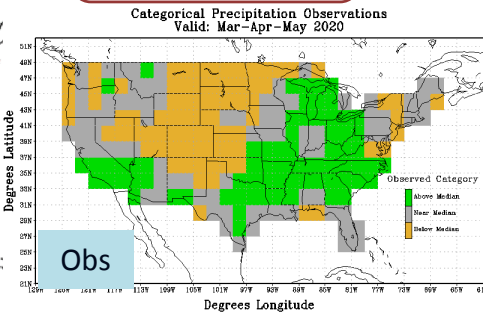
CPC



Obs

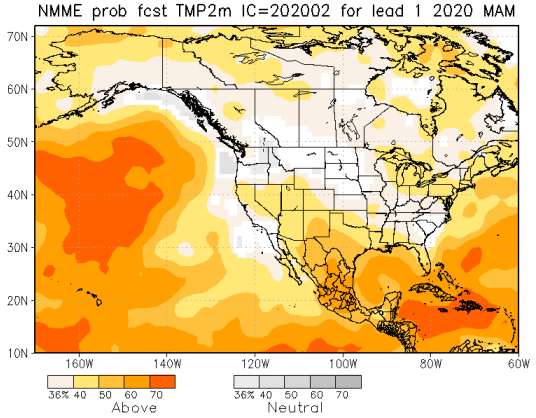


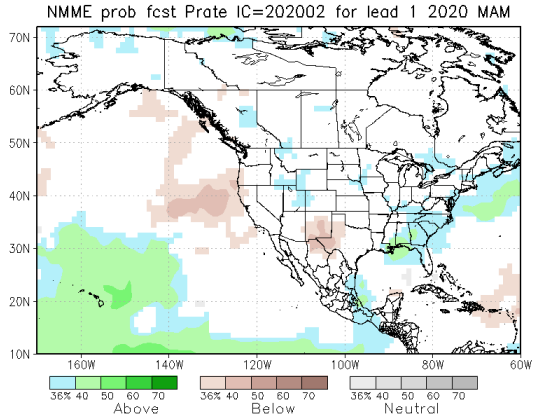




Obs

NMME





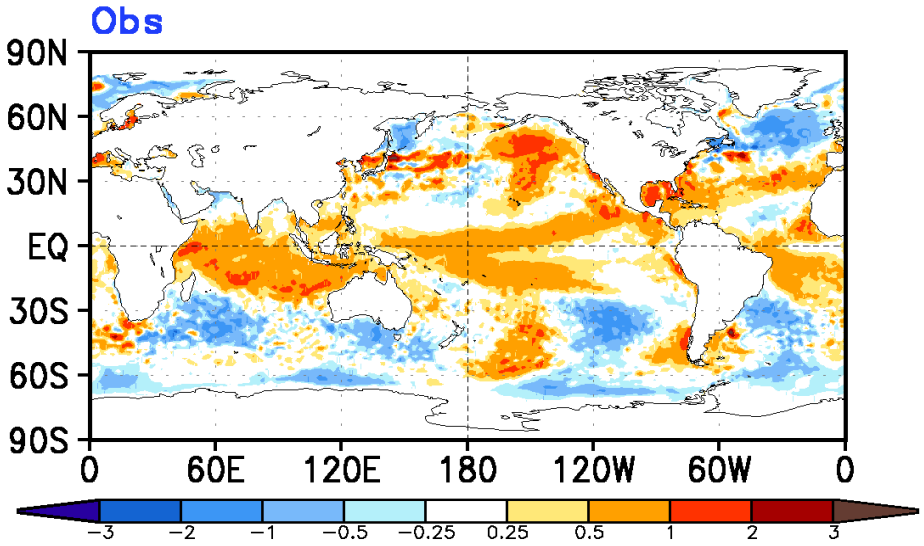
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2020/202002_PMD90D

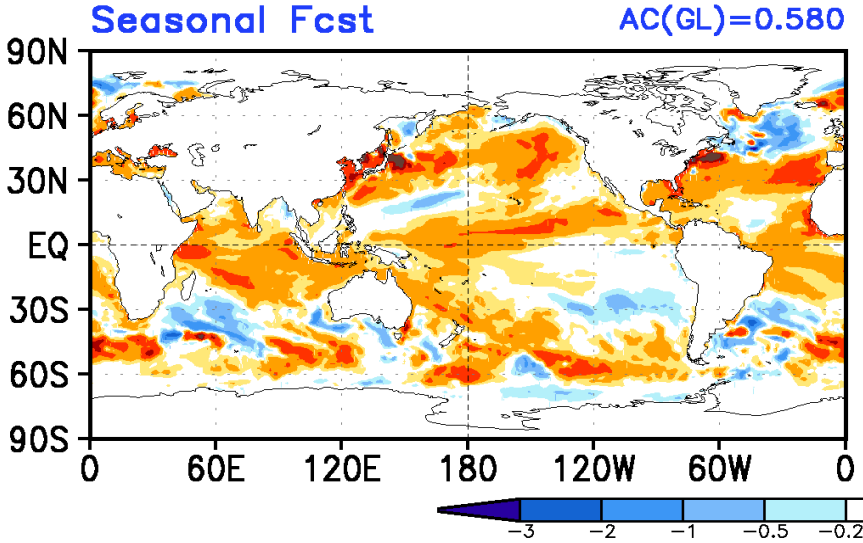
Model Simulated/Forecast Ensemble Mean Anomalies

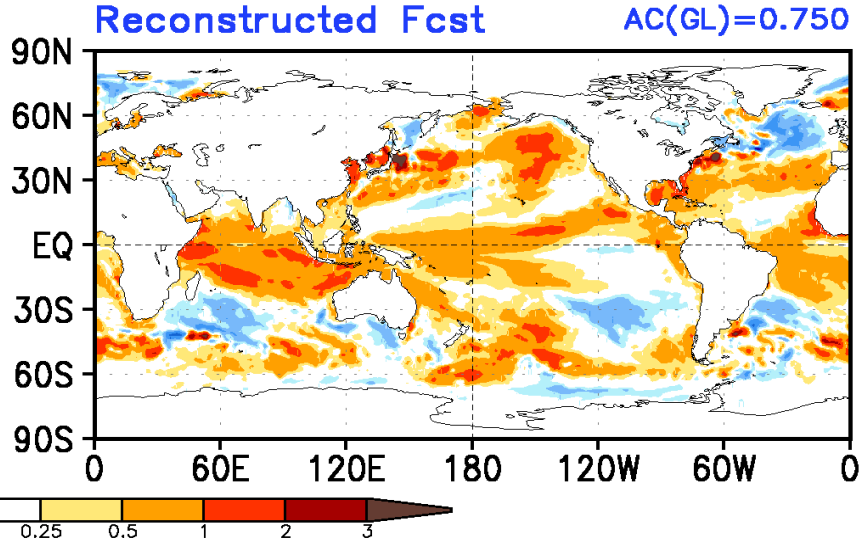
Model Simulated/Forecast Ensemble Average Anomalies

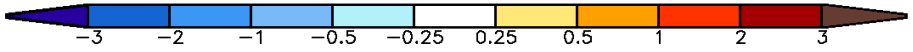
- CFS AMIP simulations forced with observed sea surface temperatures (18 members ensemble)
- CFSv2 real time operational forecasts
  - Seasonal forecast: the seasonal mean forecasts based on 40 members from the latest 10 days before the target season (0-month-lead). For example, 2016AMJ seasonal mean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

MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)

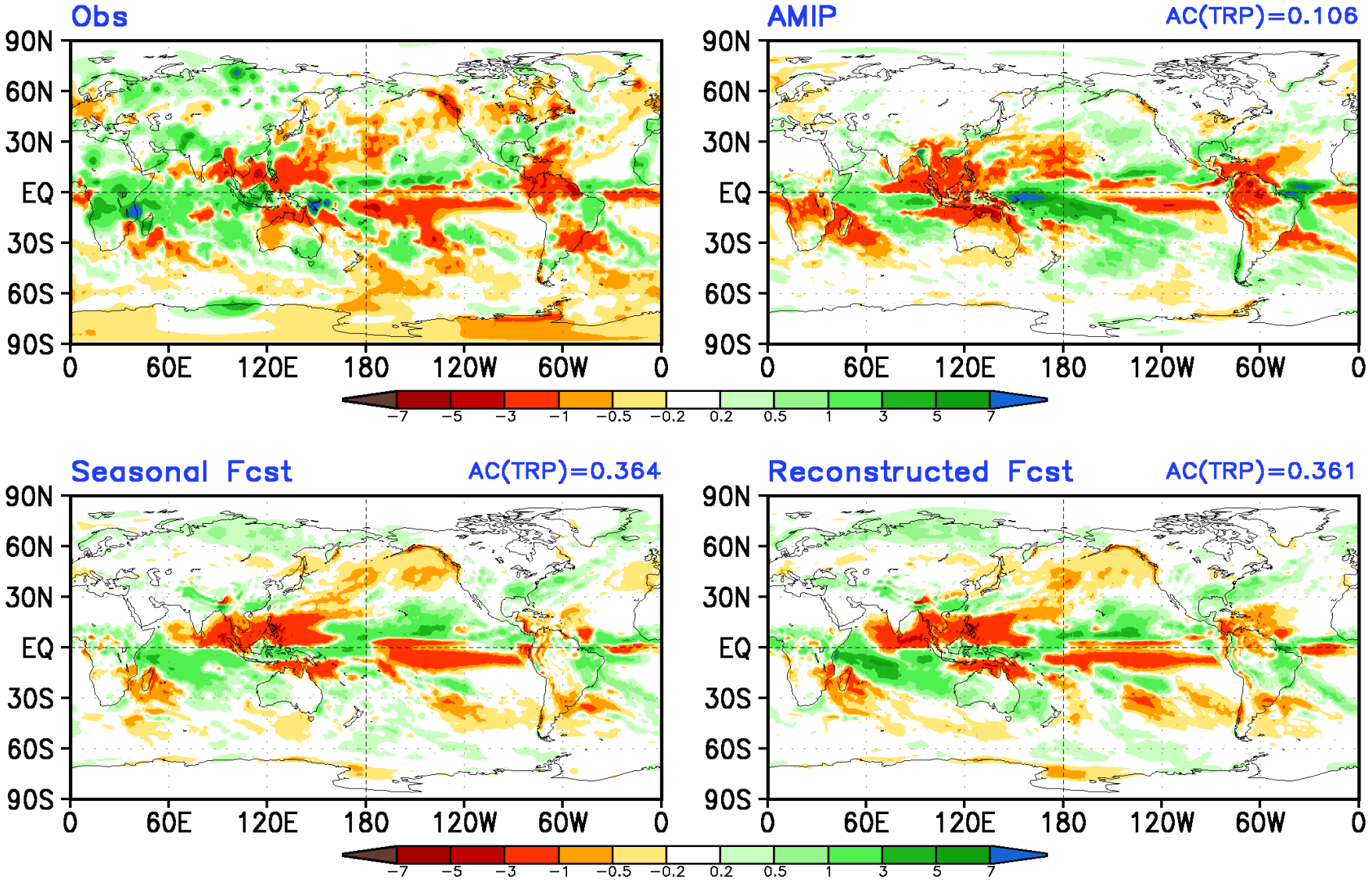




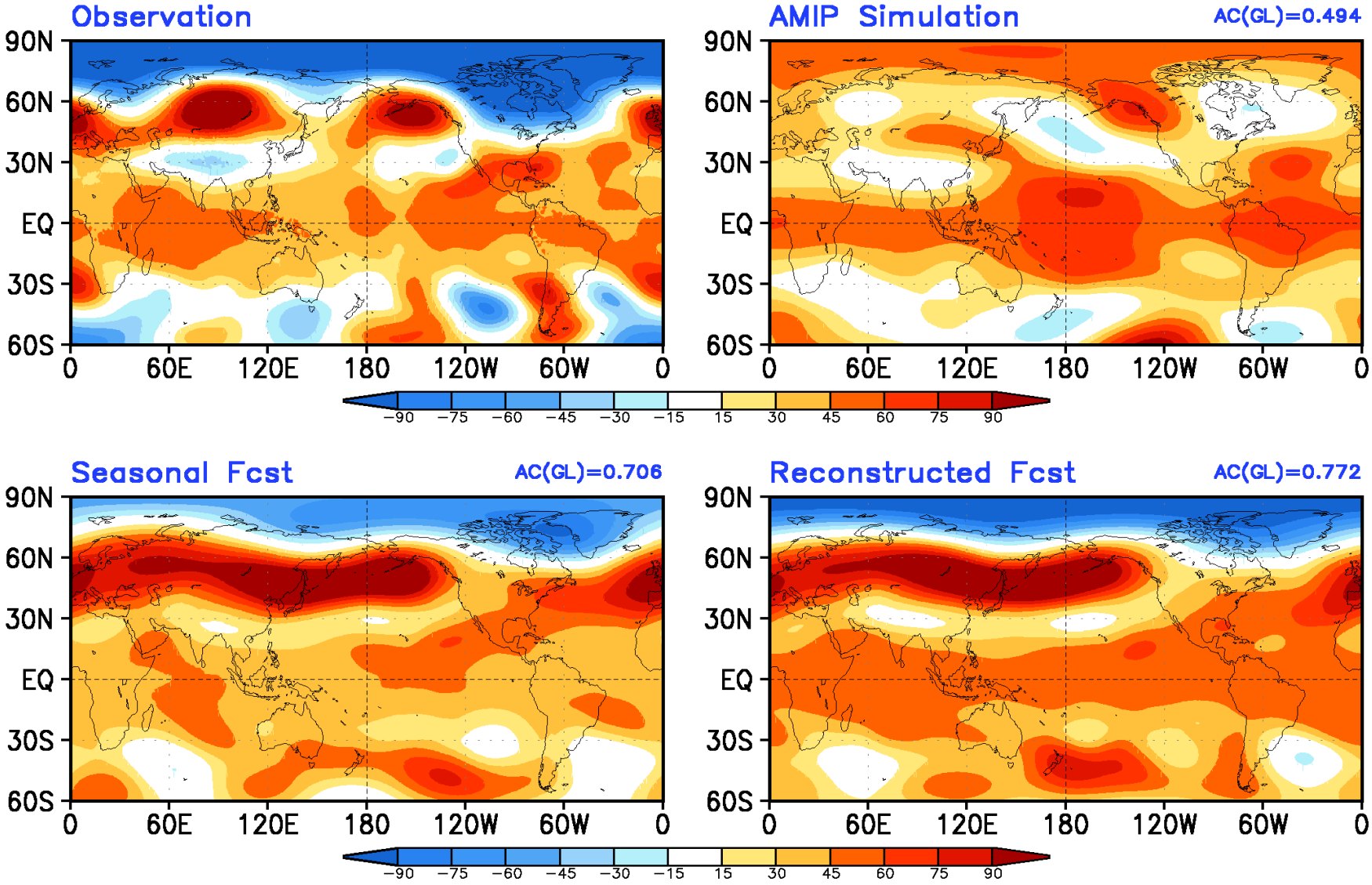




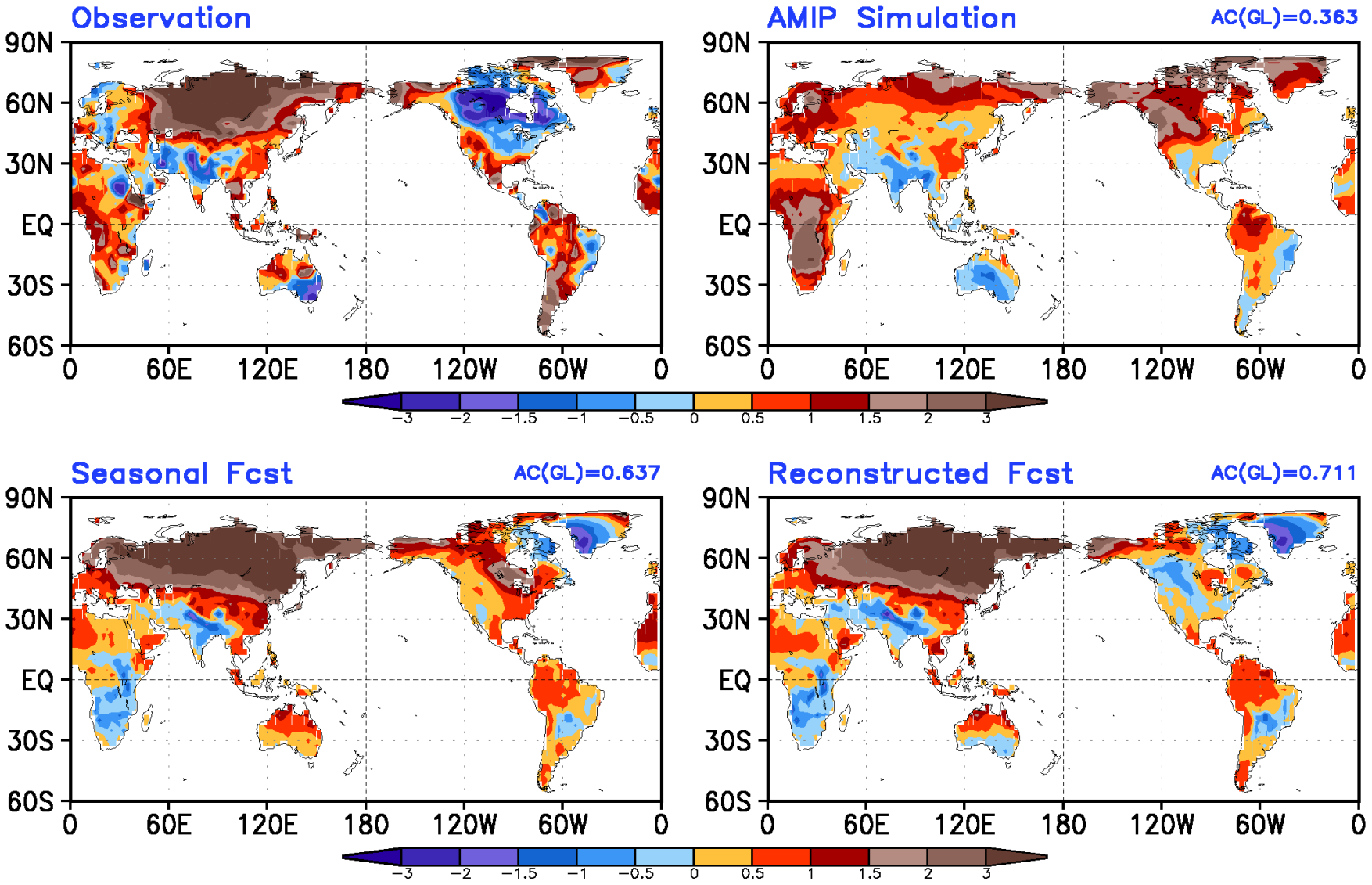
MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



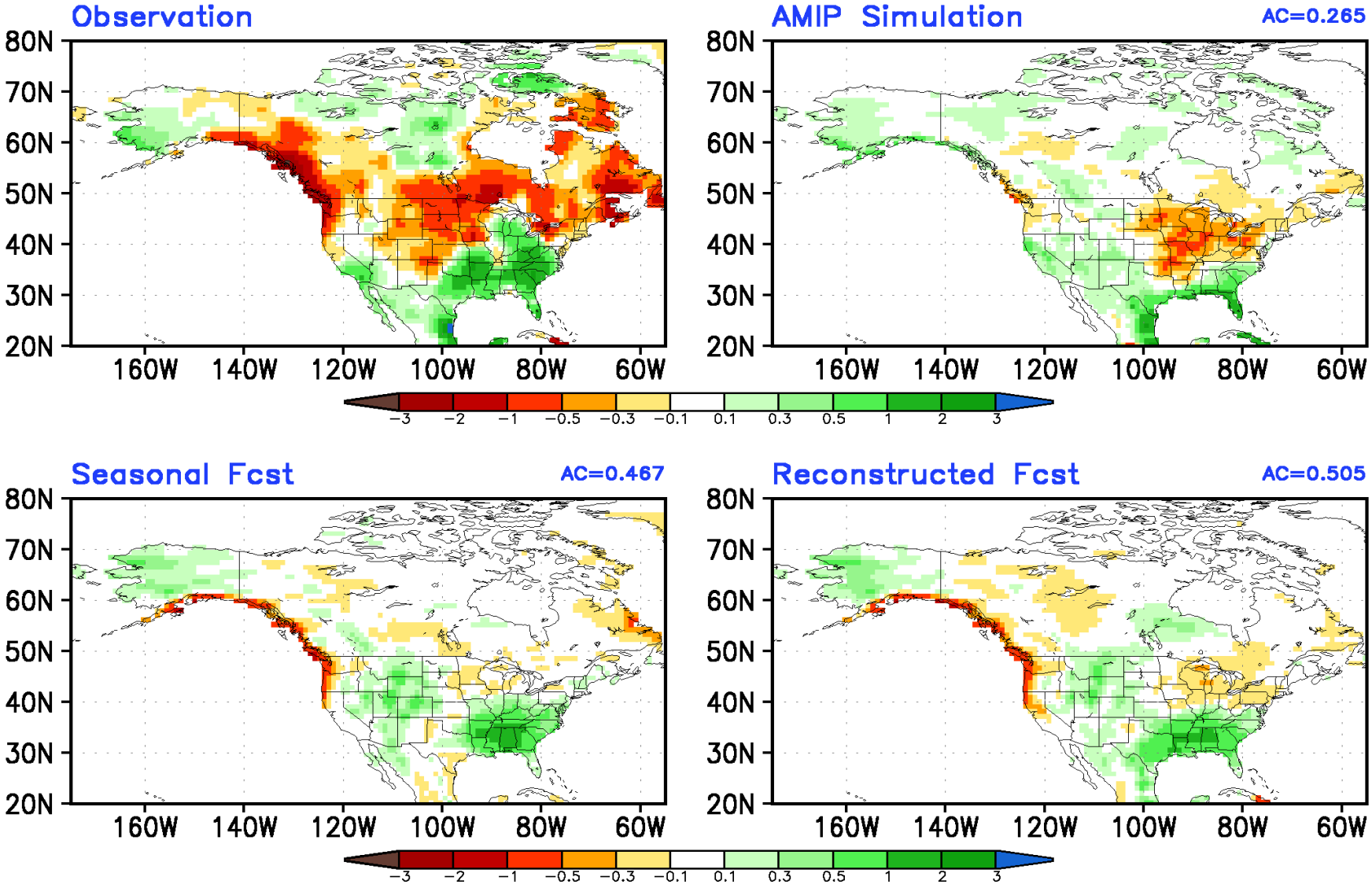
MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



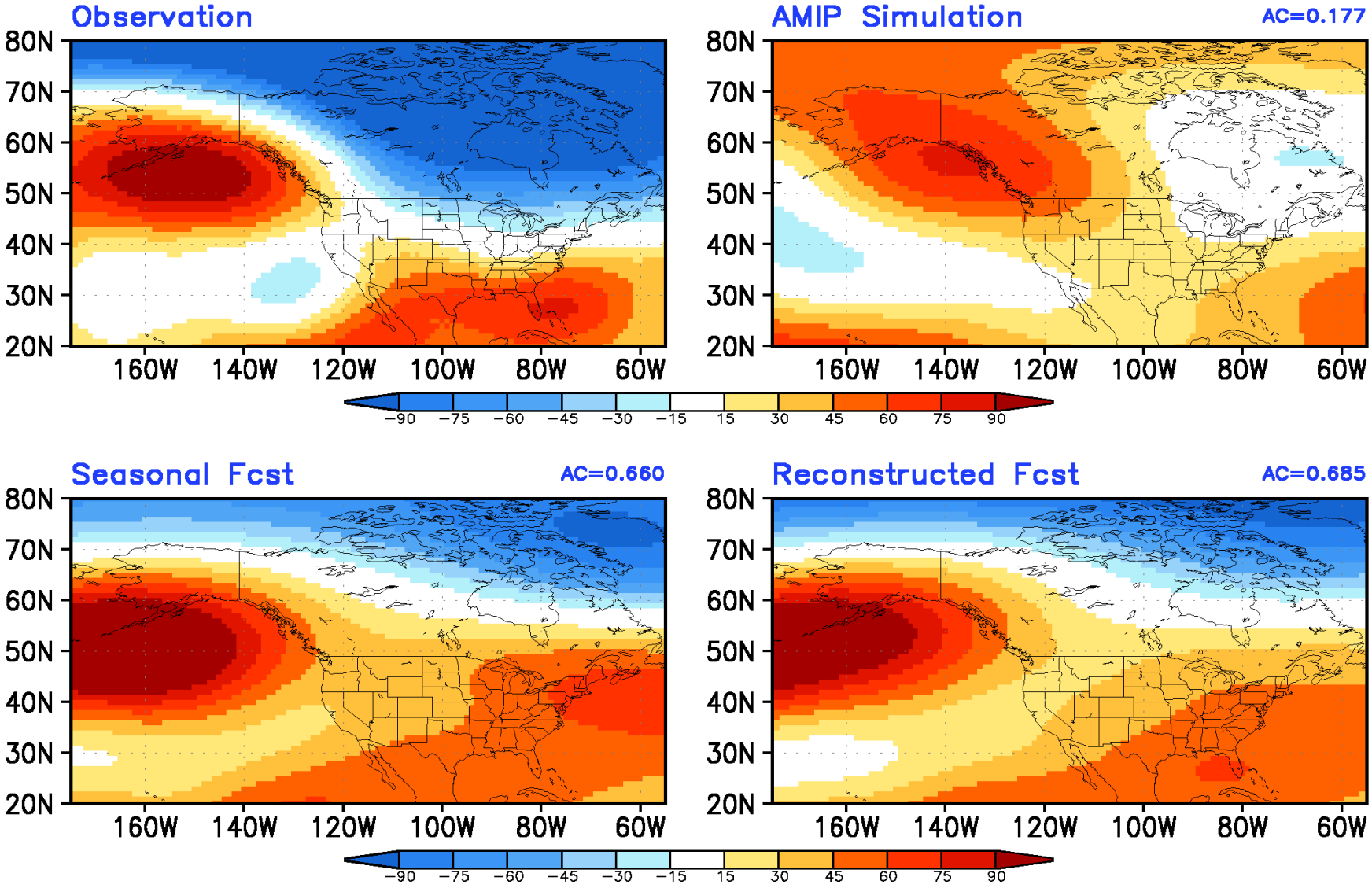
MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



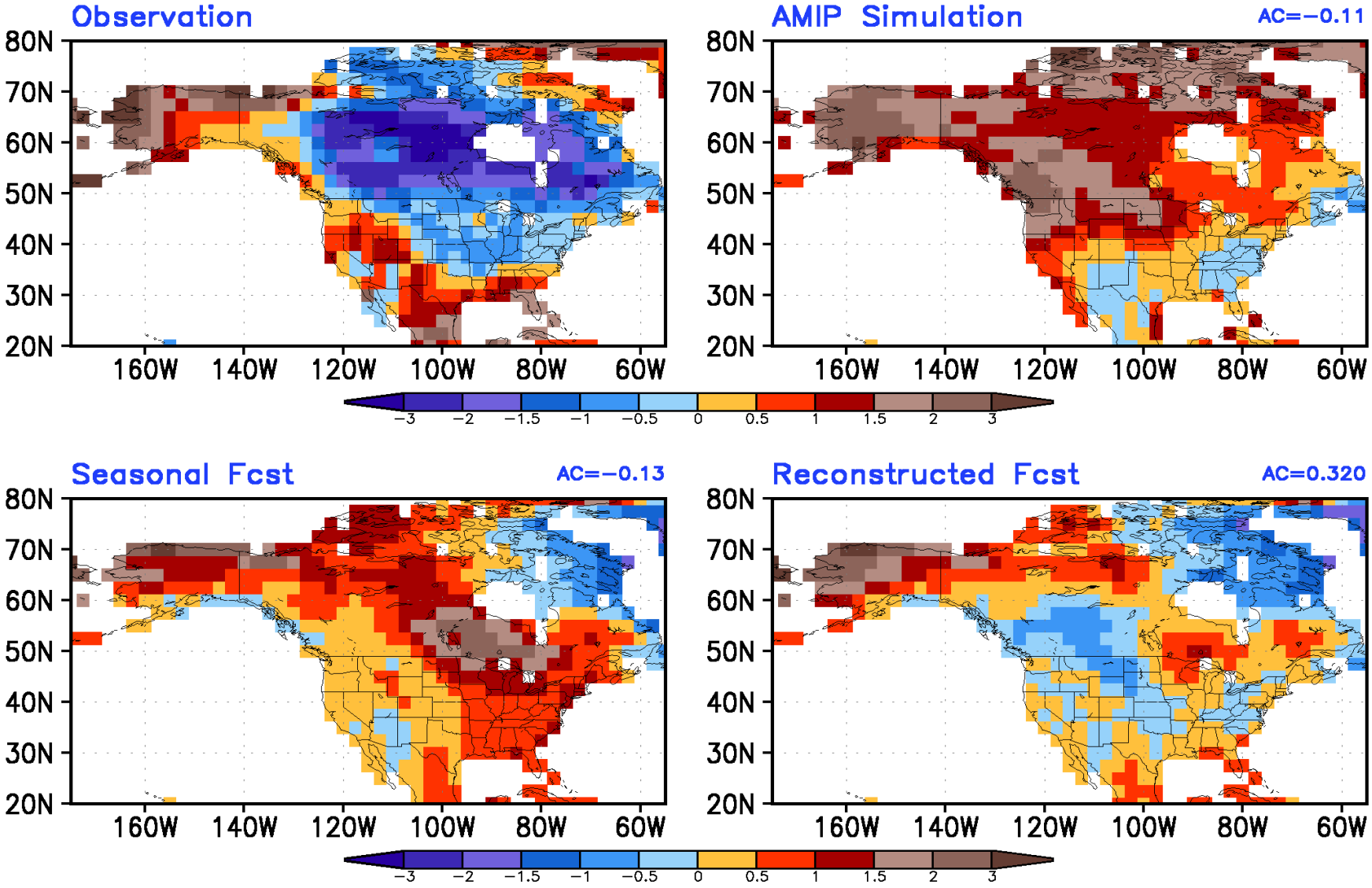
MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



MAM2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

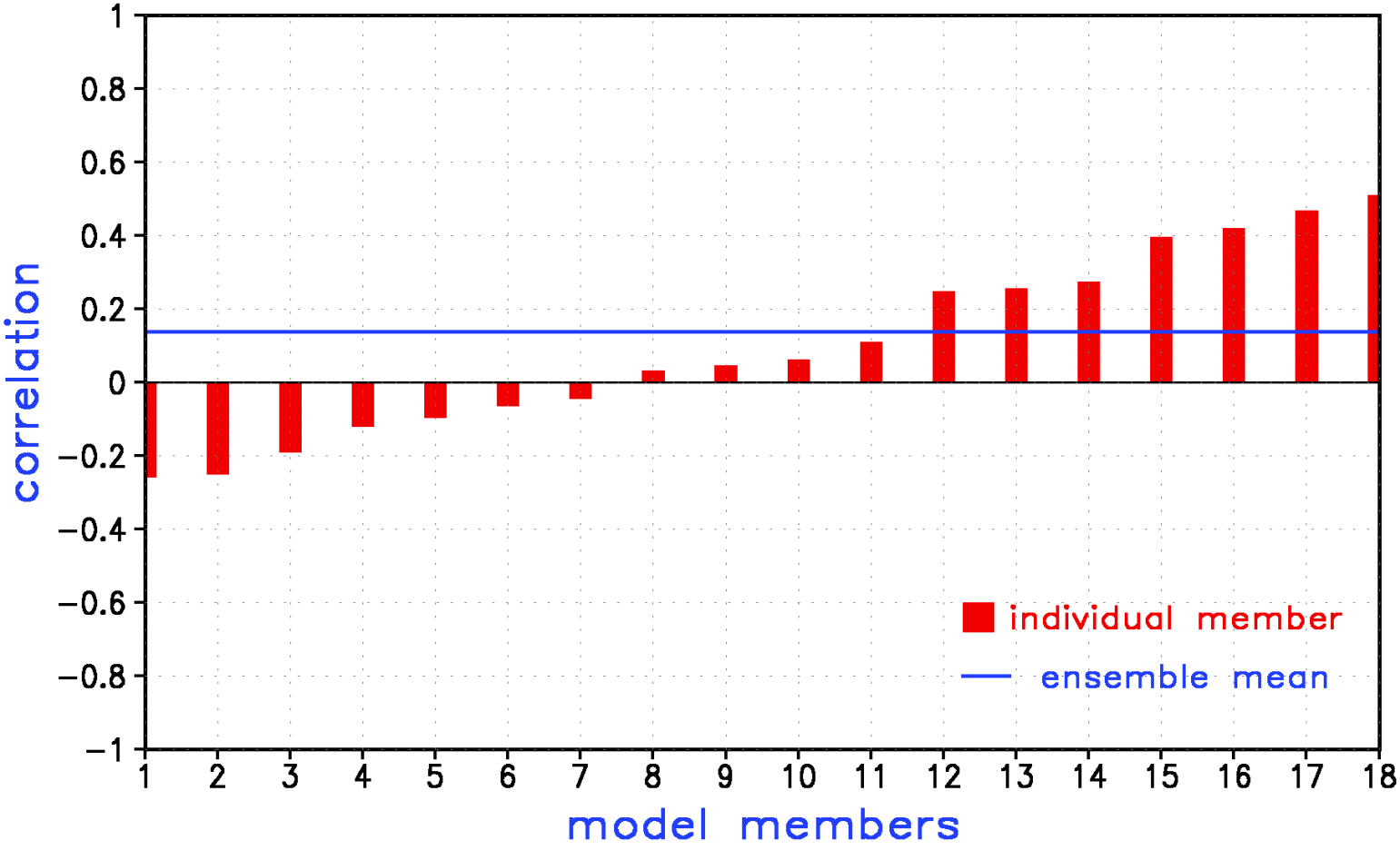


Model Simulated/Forecast Anomalies: Individual Runs

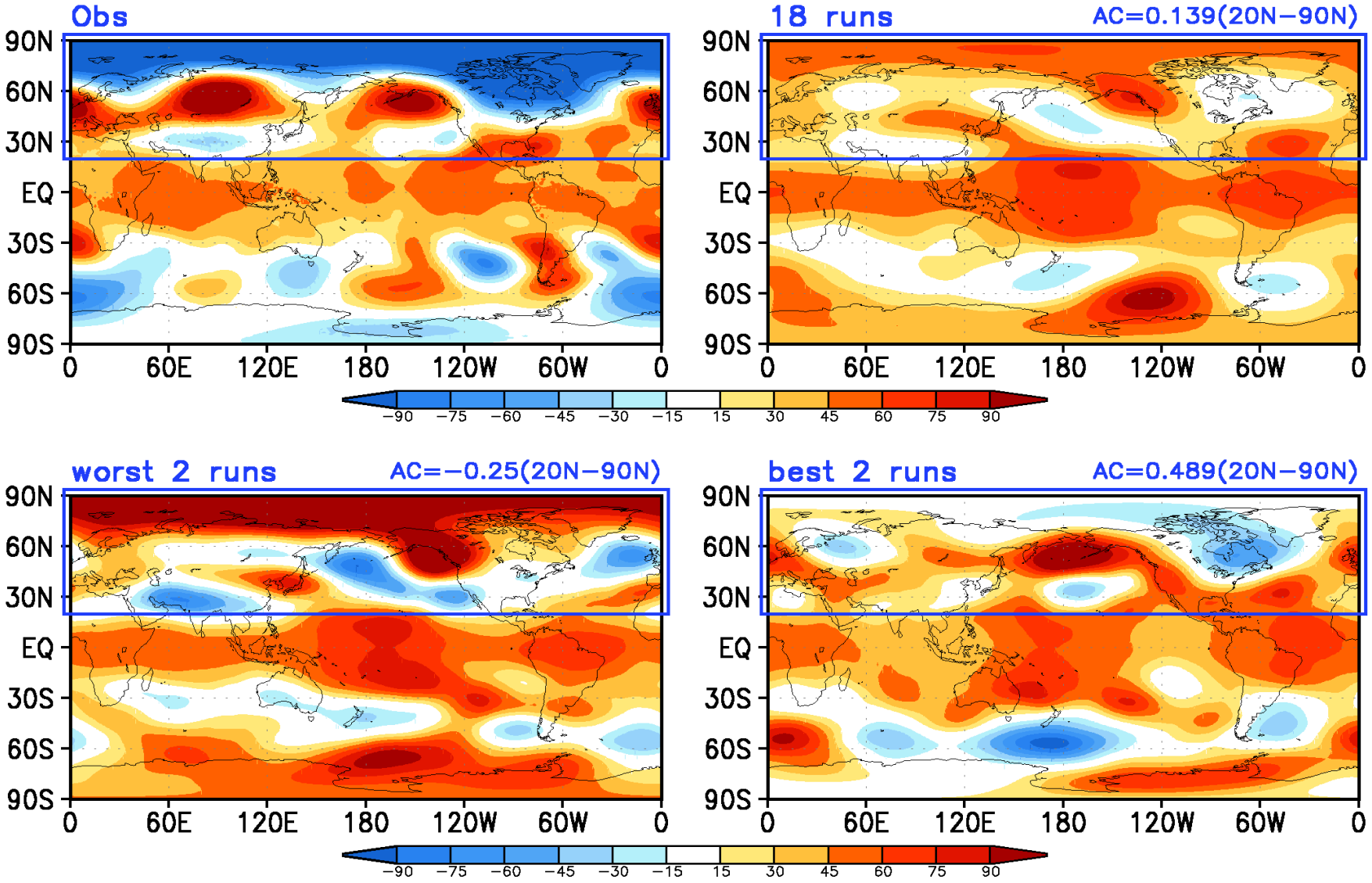
Model Simulated/Forecast Anomalies: Individual Runs

- 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.

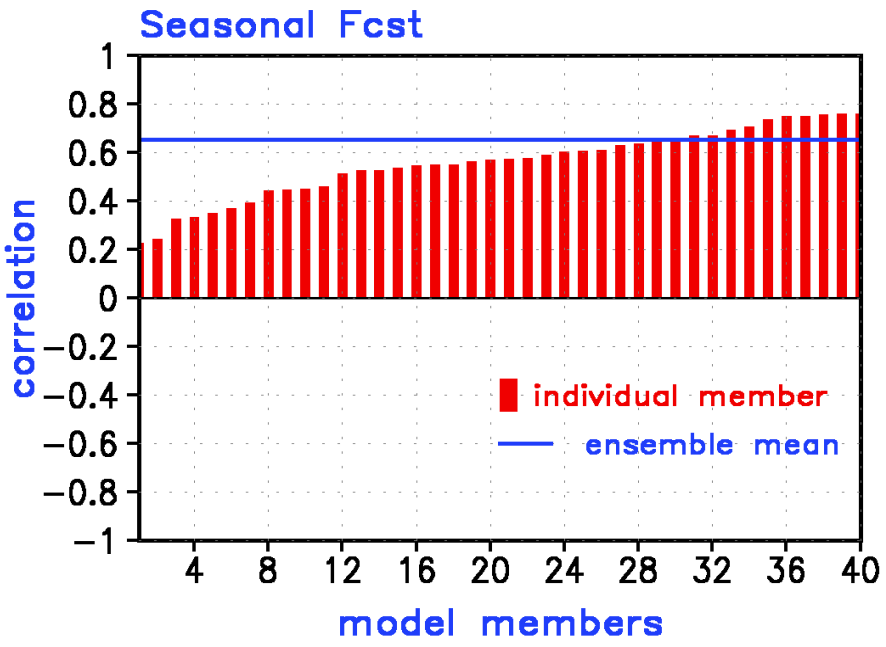
MAM2020 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)

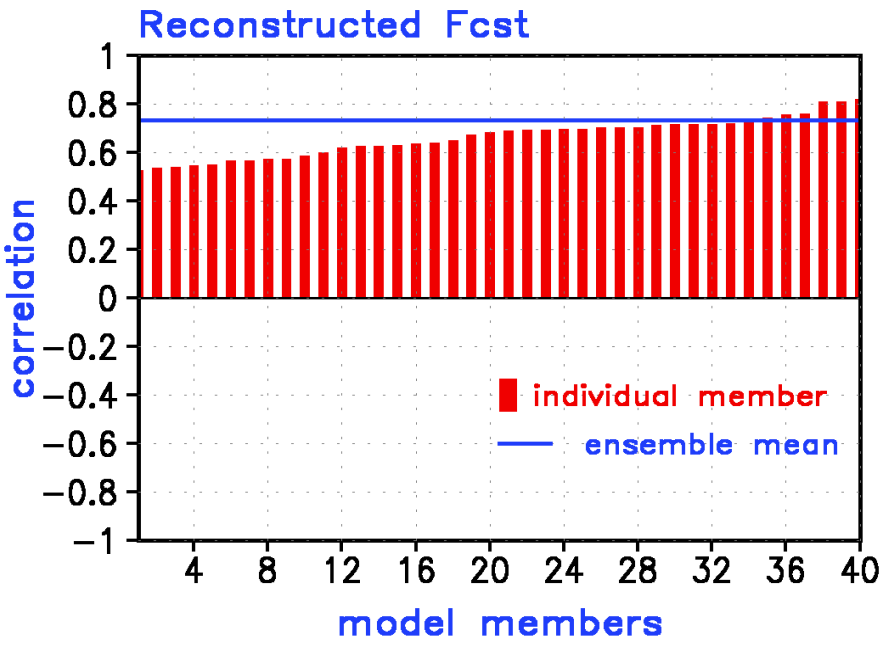


Observed & AMIP Ensemble Average Anomalies
MAM2020 z200(m) 18 runs/worst 2 runs/best 2 runs

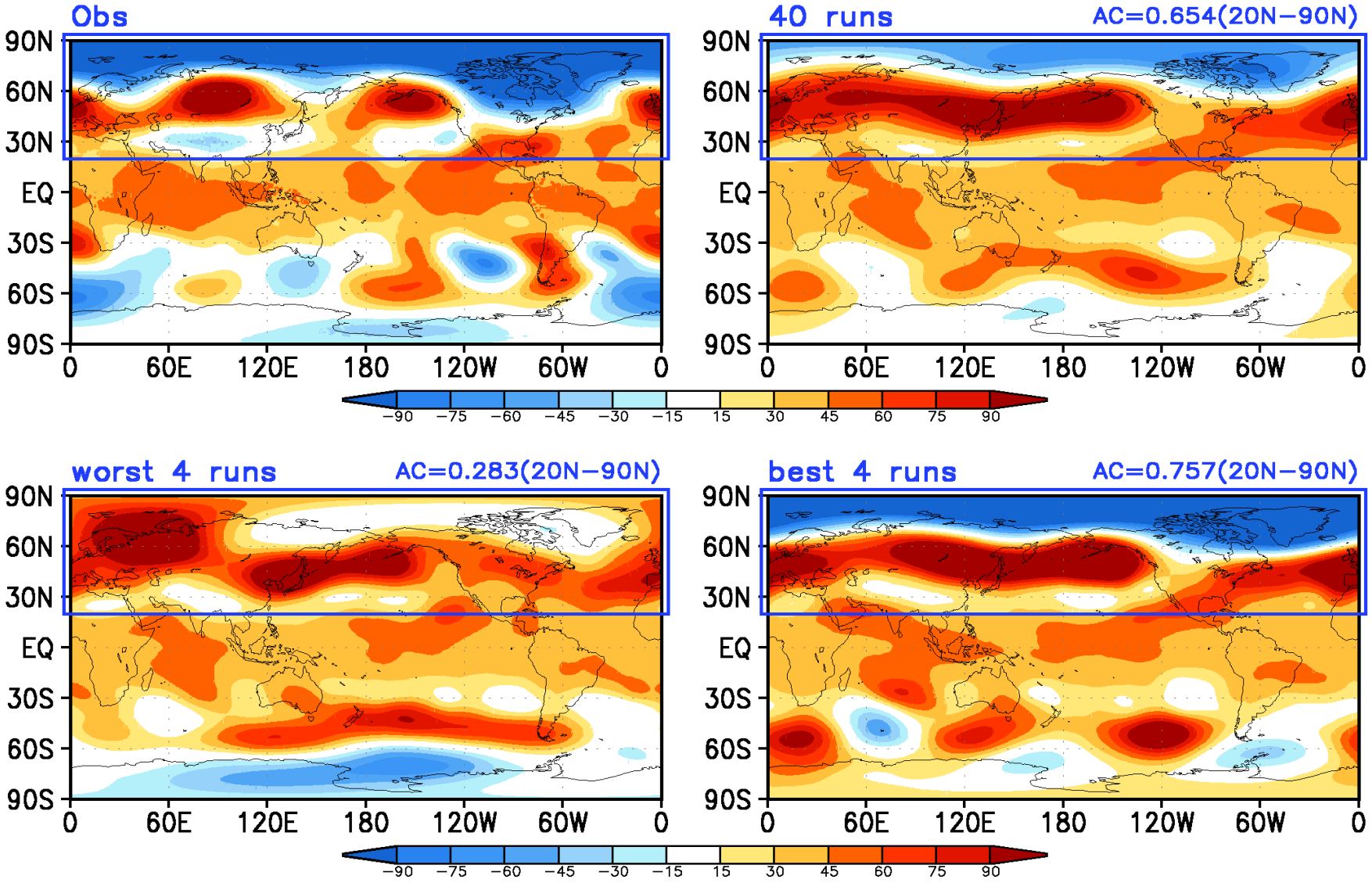


MAM2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)

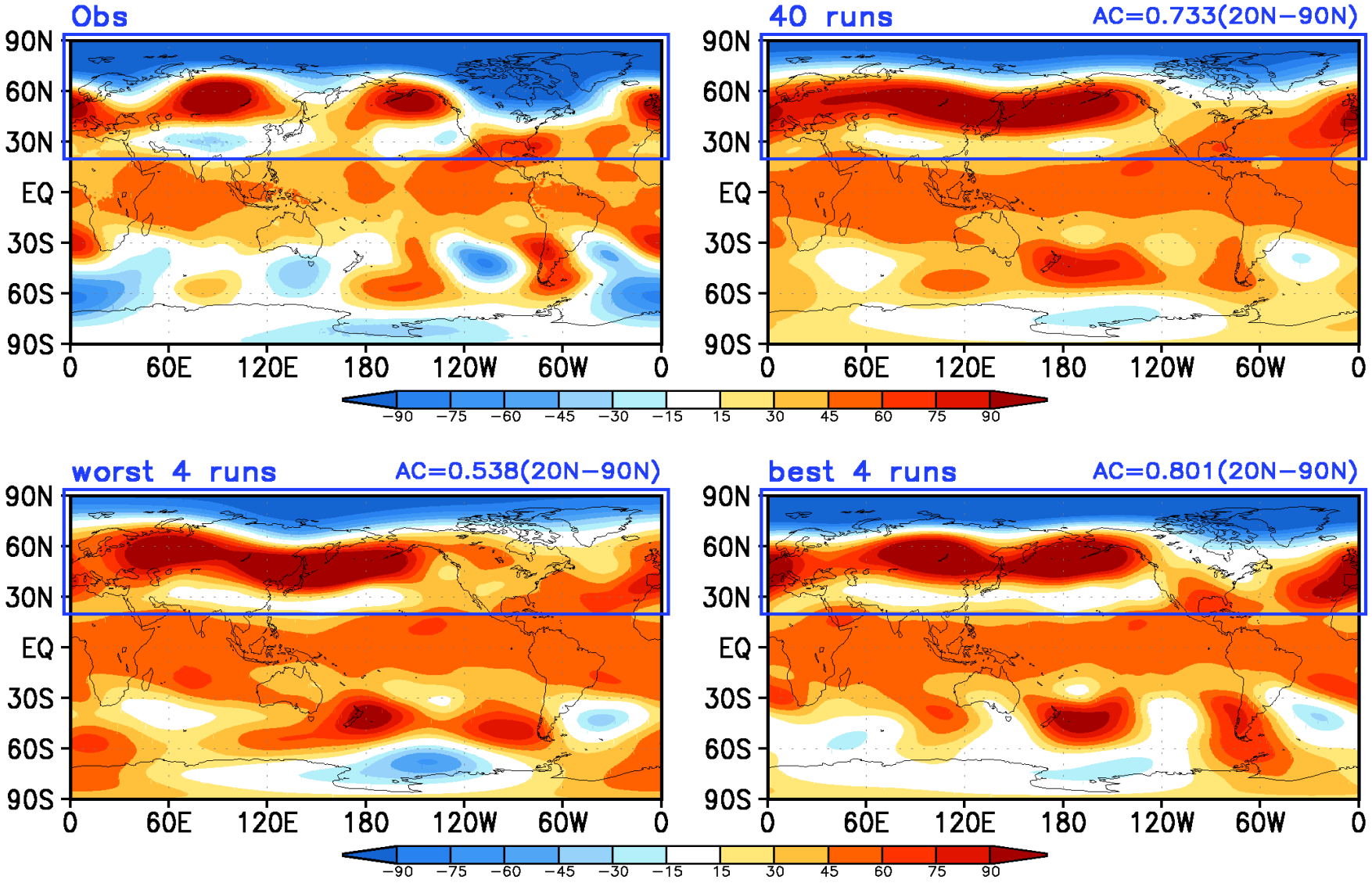




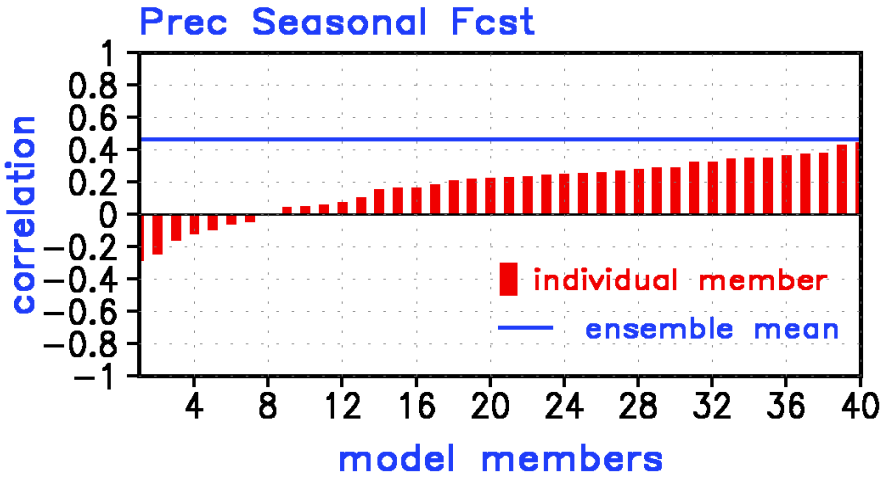
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

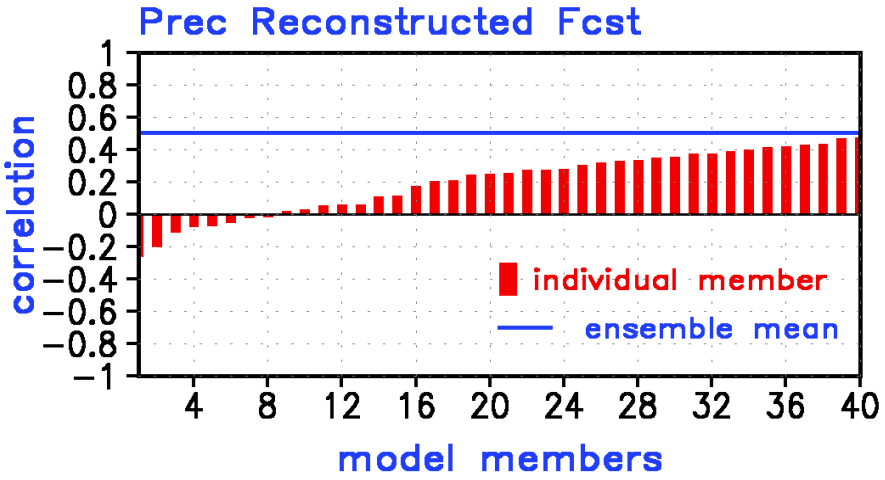


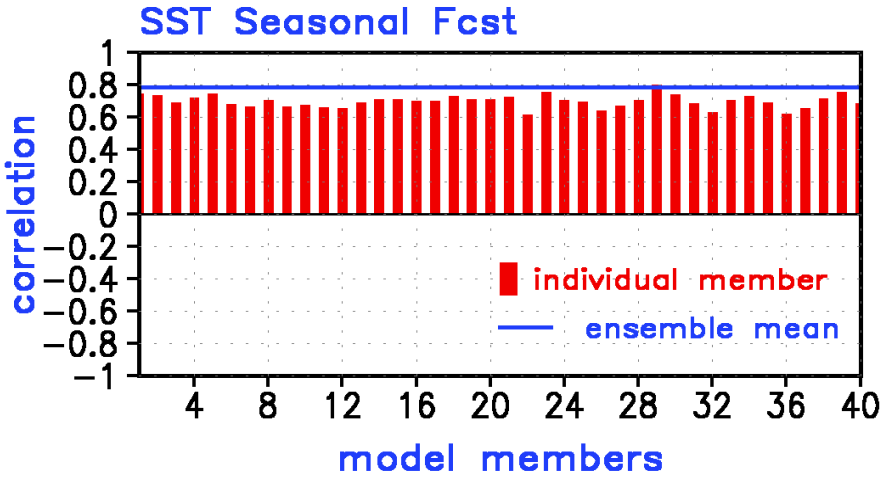
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

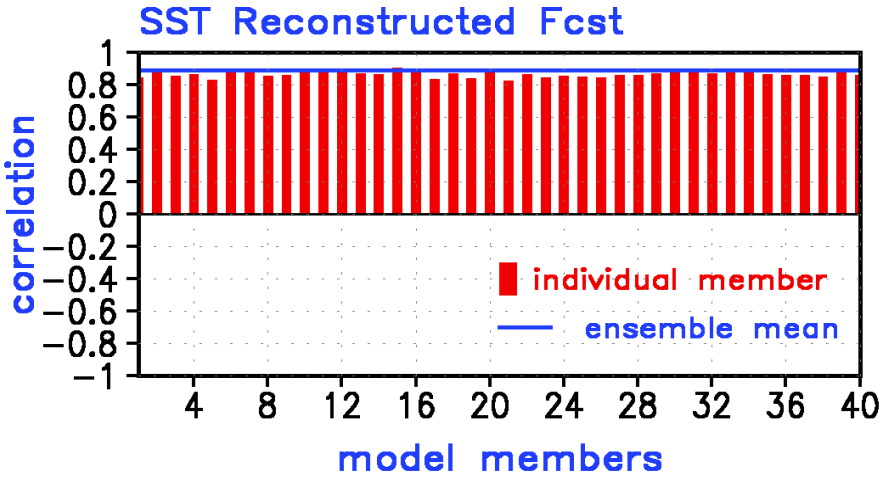


MAM2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

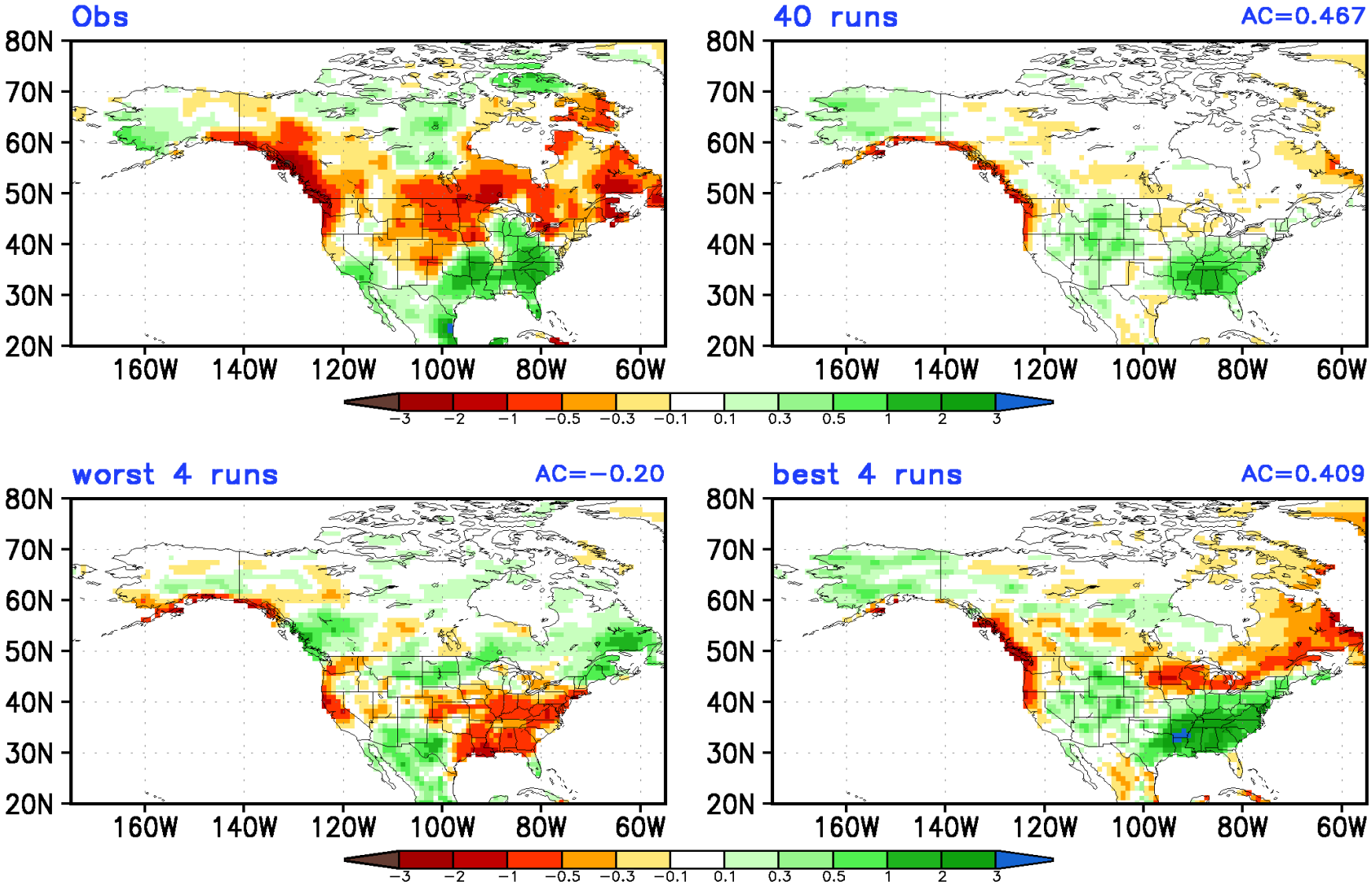




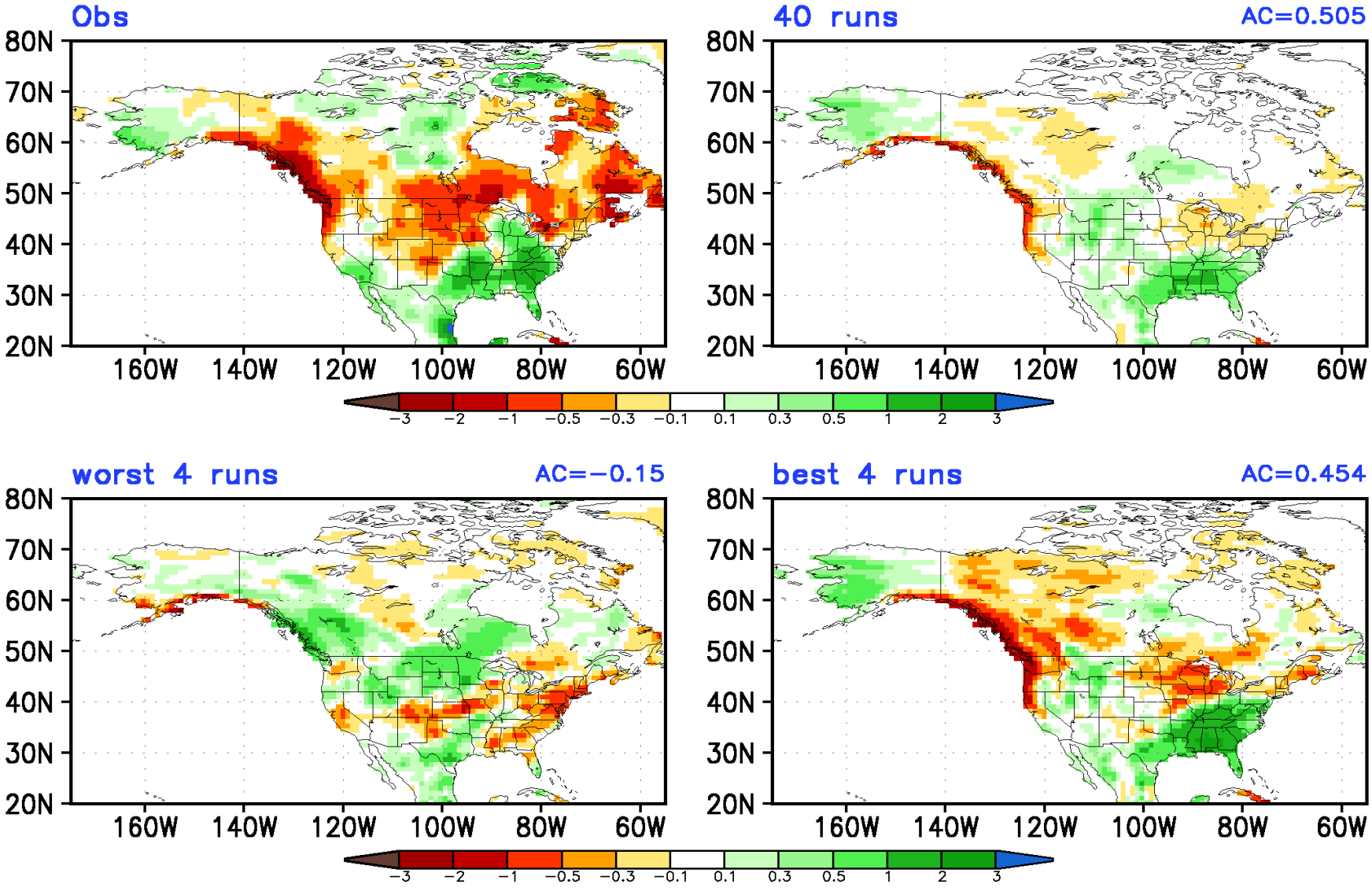




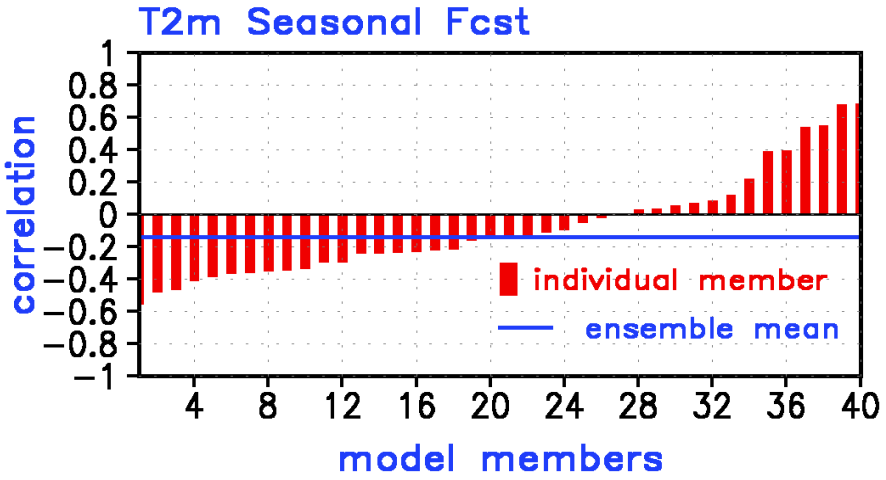
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

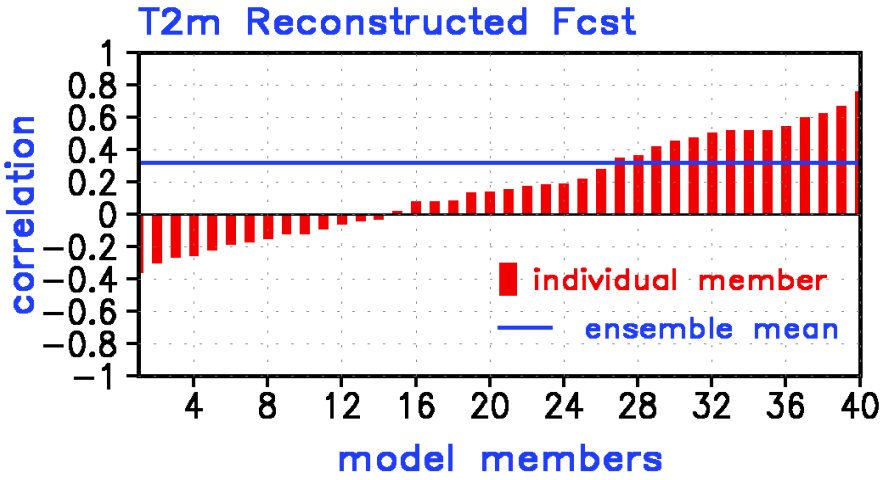


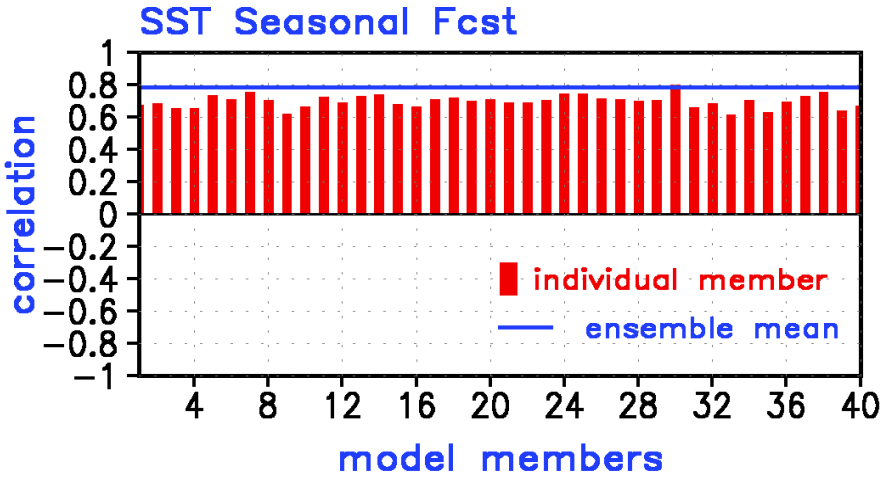
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

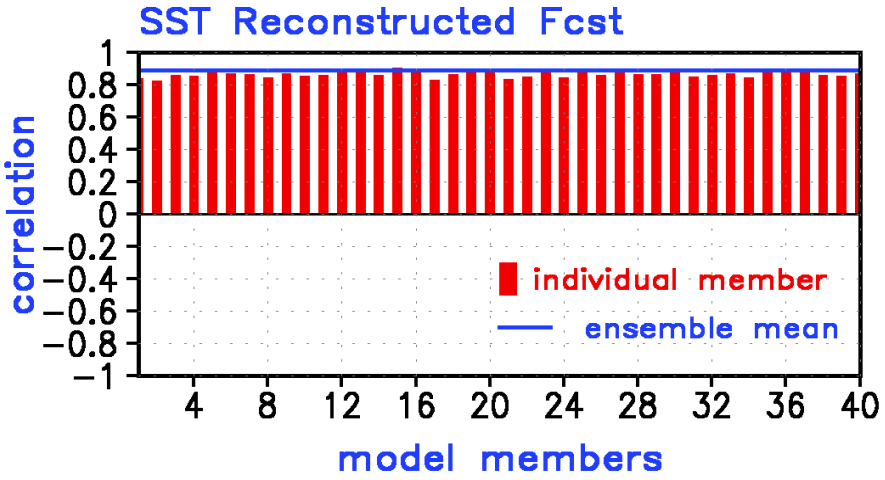


MAM2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)

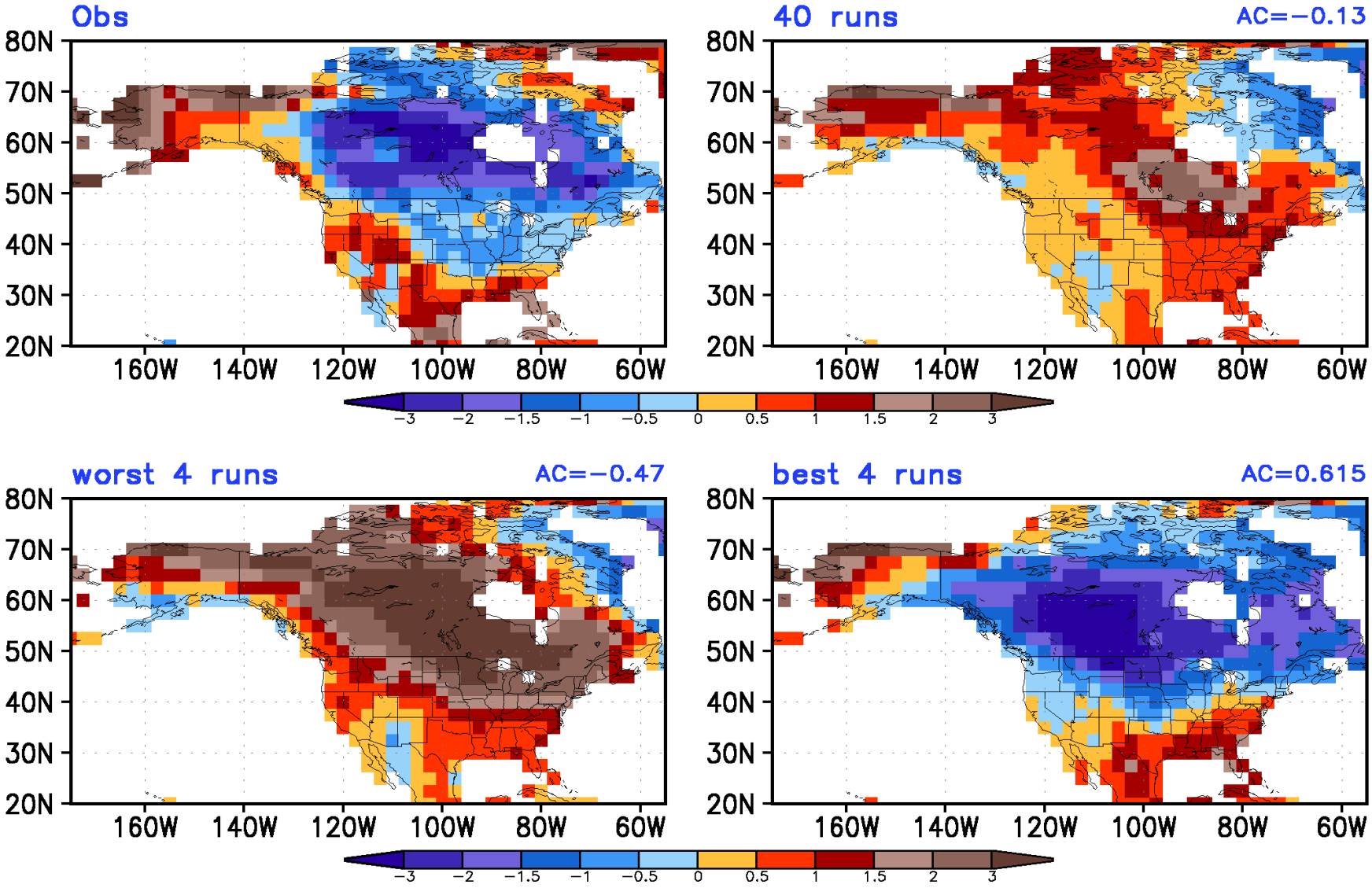




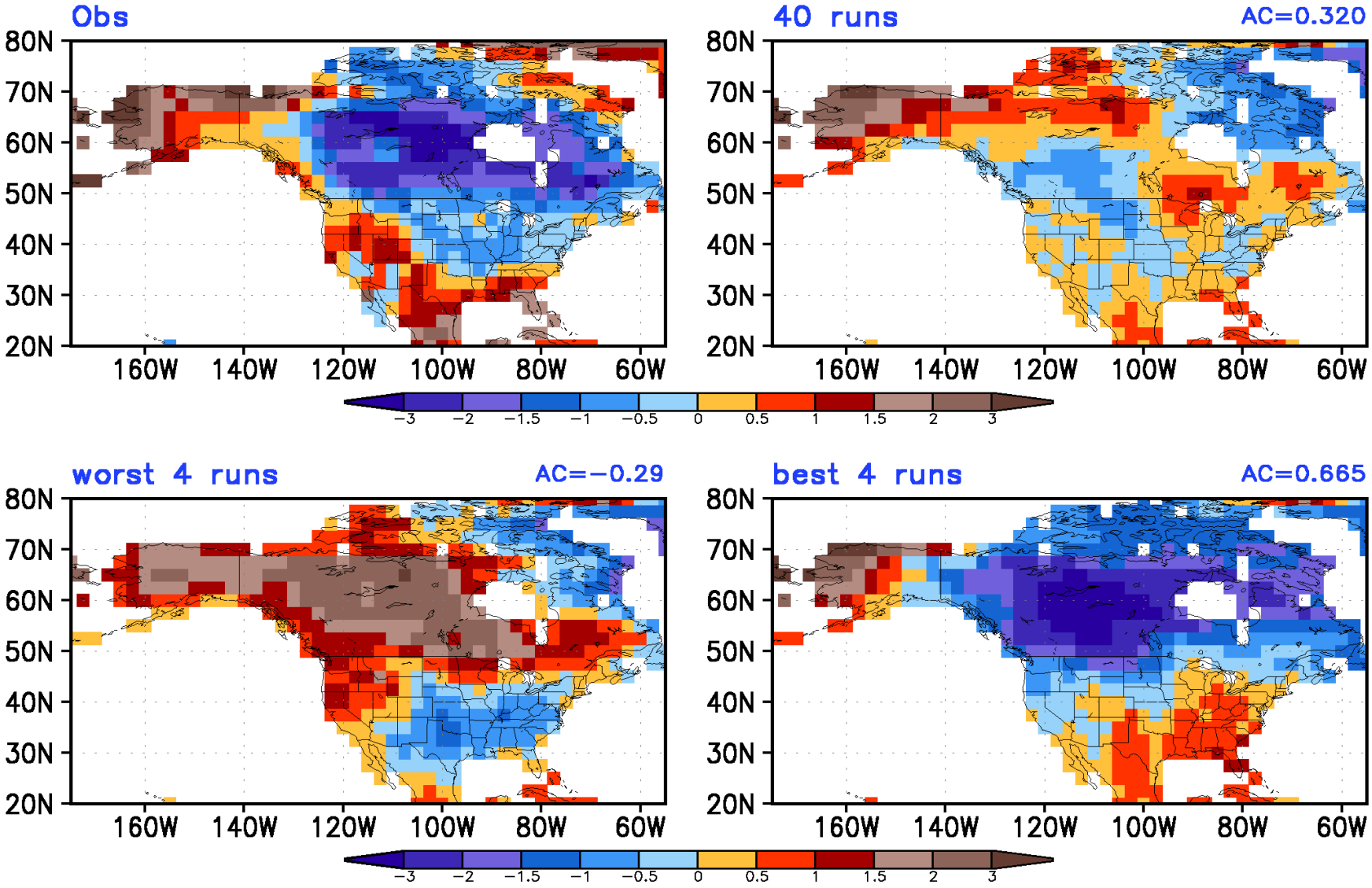




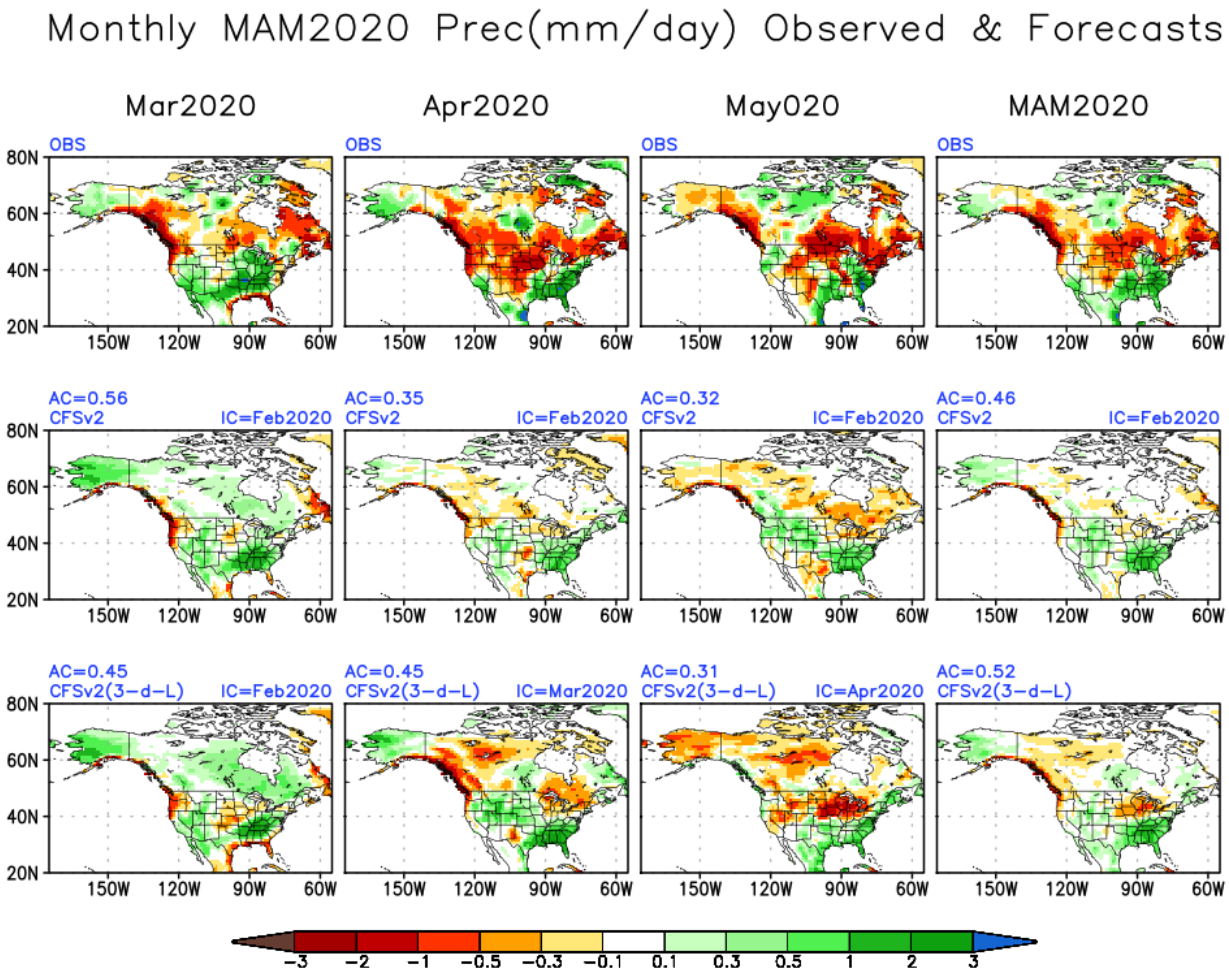
Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
MAM2020 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



Monthly Means Prec(mm/day) Observed & Forecasts

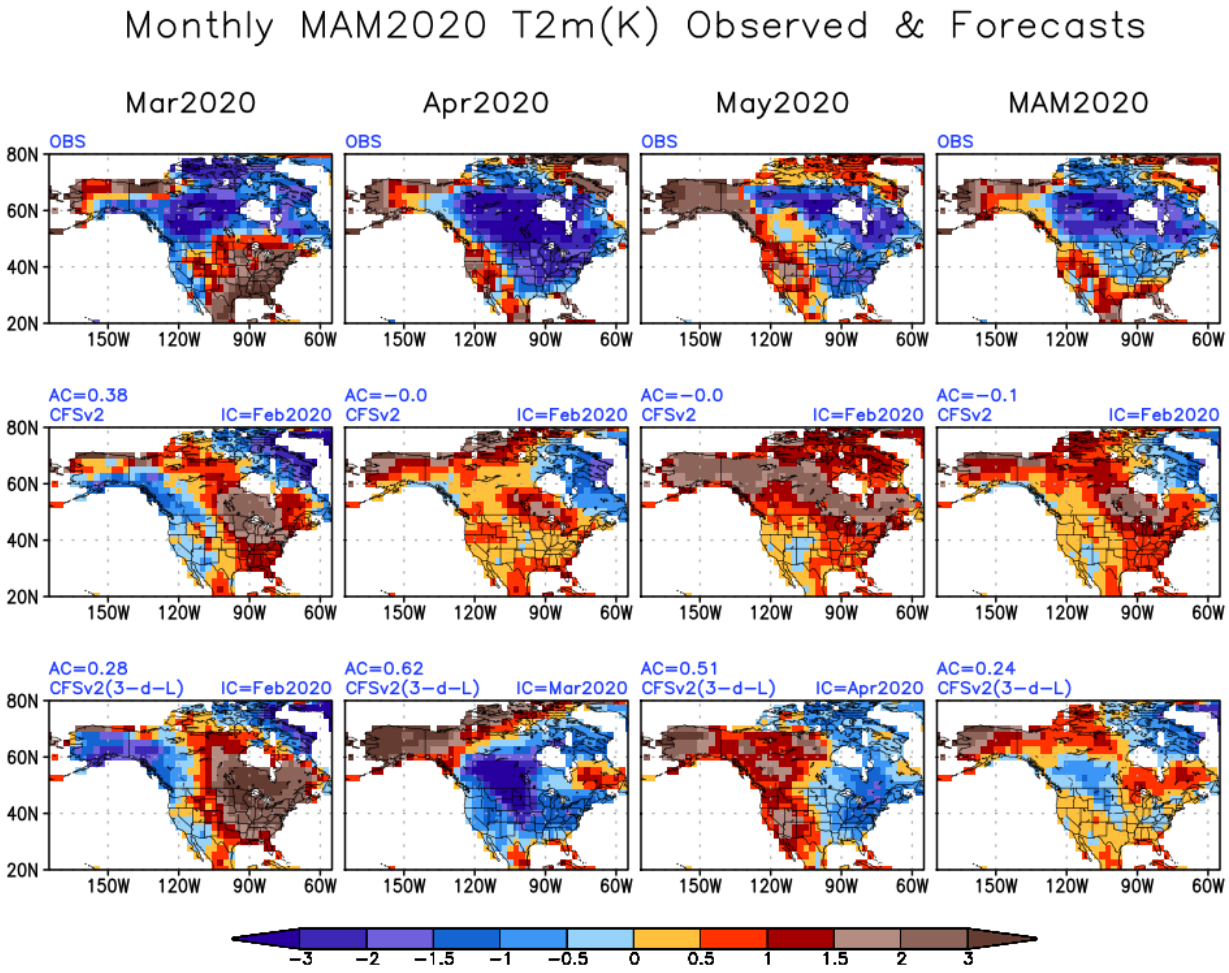


Top row: Observed anomaly

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



Top row: Observed anomaly

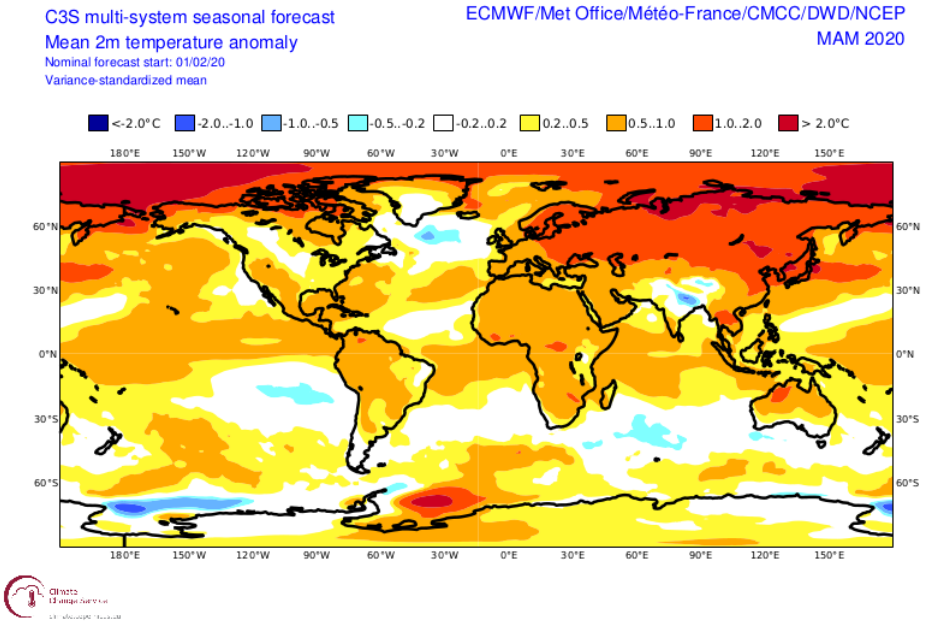
Middle row: CFSv2 seasonal forecasts from the initial conditions from the month prior to the target season.

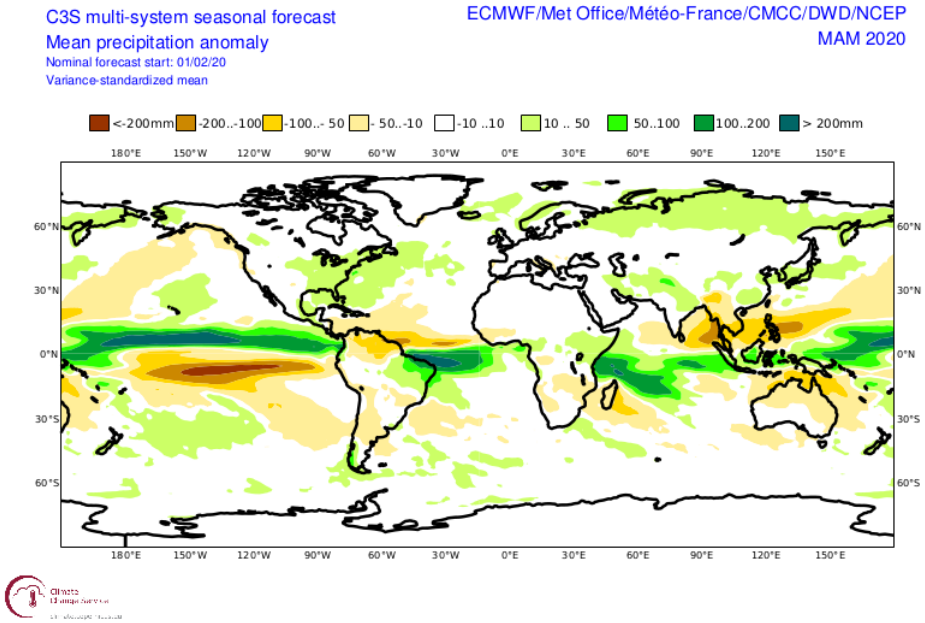
Bottom row: CFSv2 monthly forecasts from the last three days of the month prior to the target month.

Seasonal Forecasts from other multi-model systems and linear models

C3S Seasonal Forecast

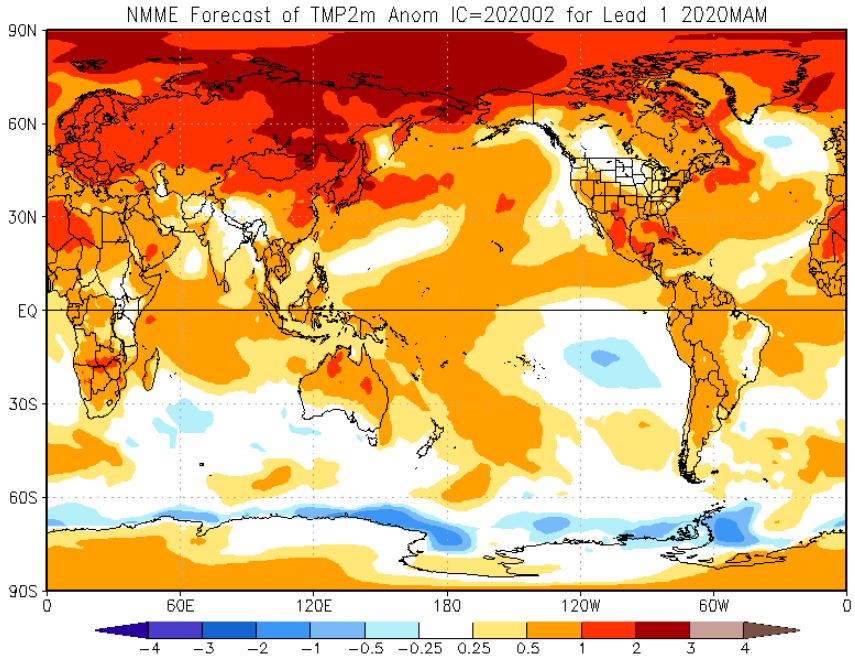
(https://climate.copernicus.eu/charts/c3s_seasonal/)

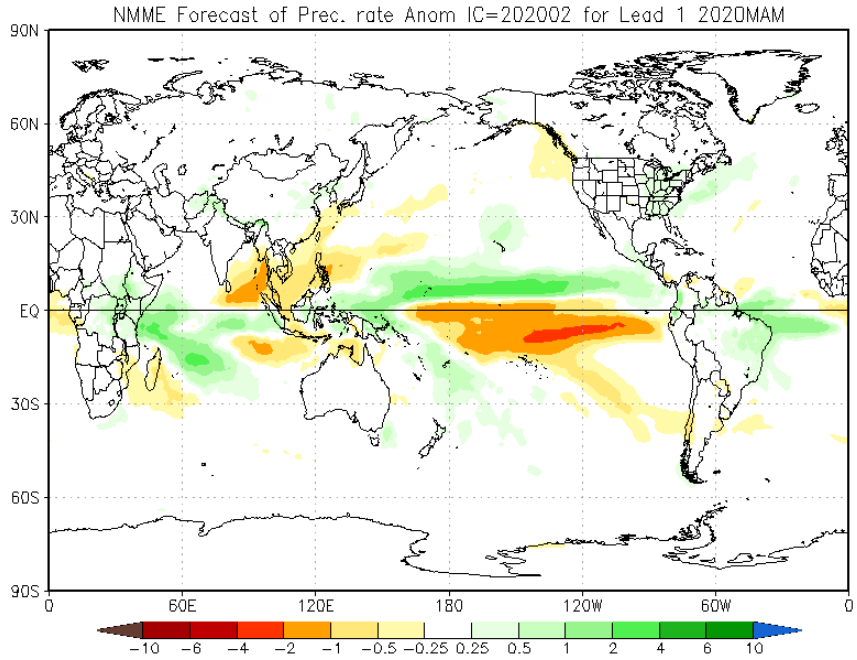




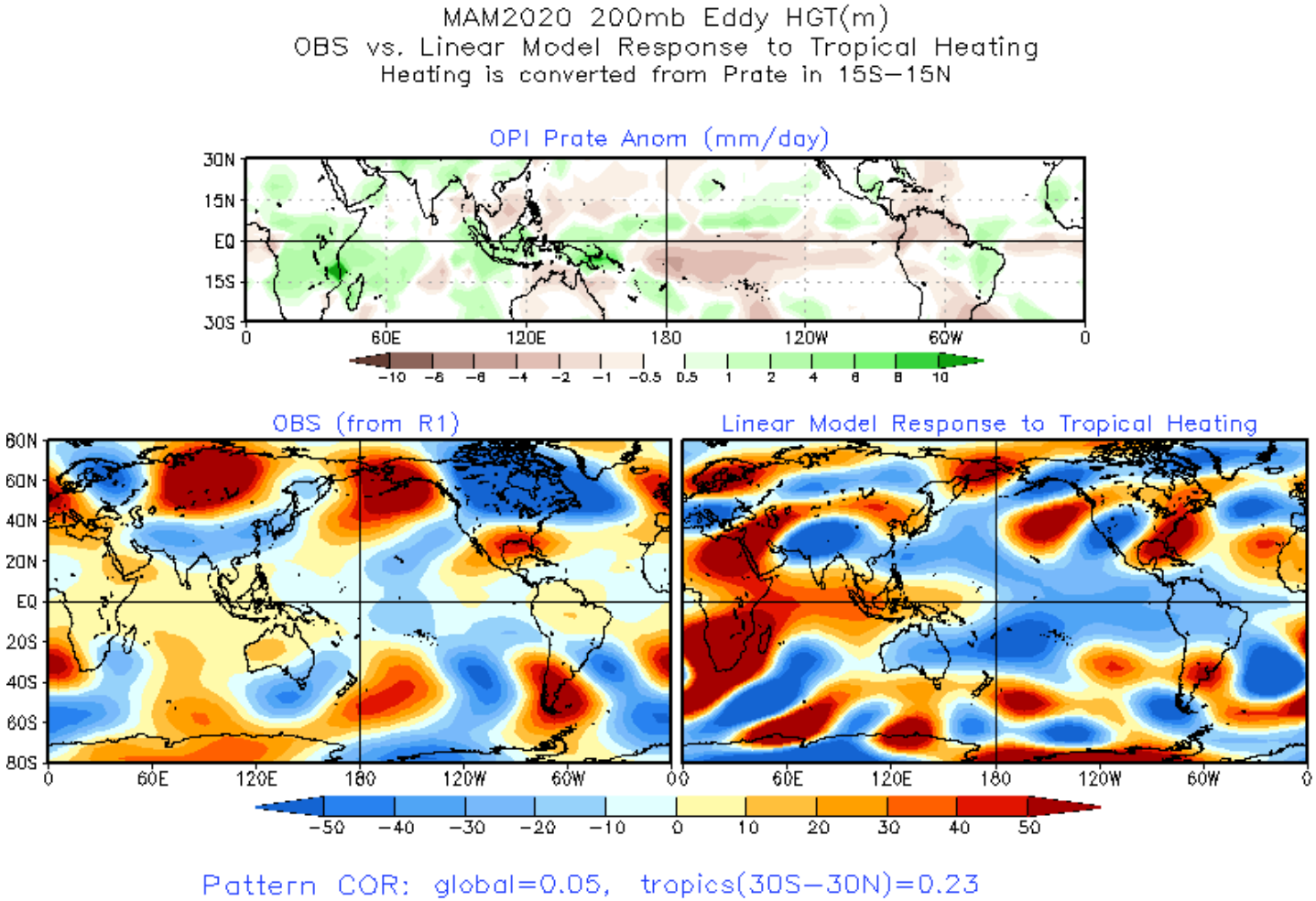
North American Multi-Model Ensemble Seasonal Forecast

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

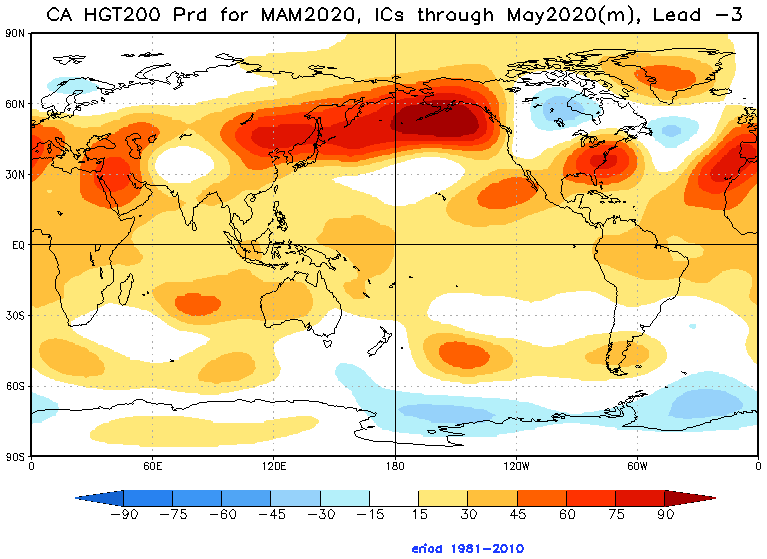


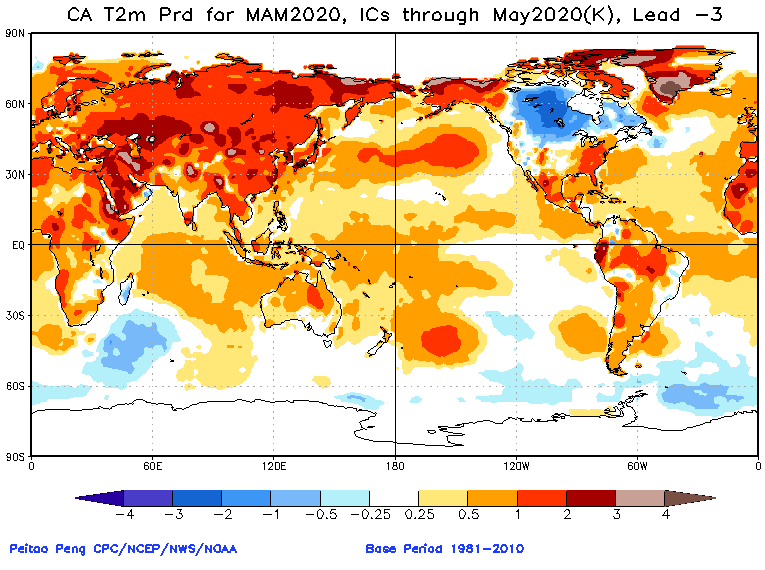


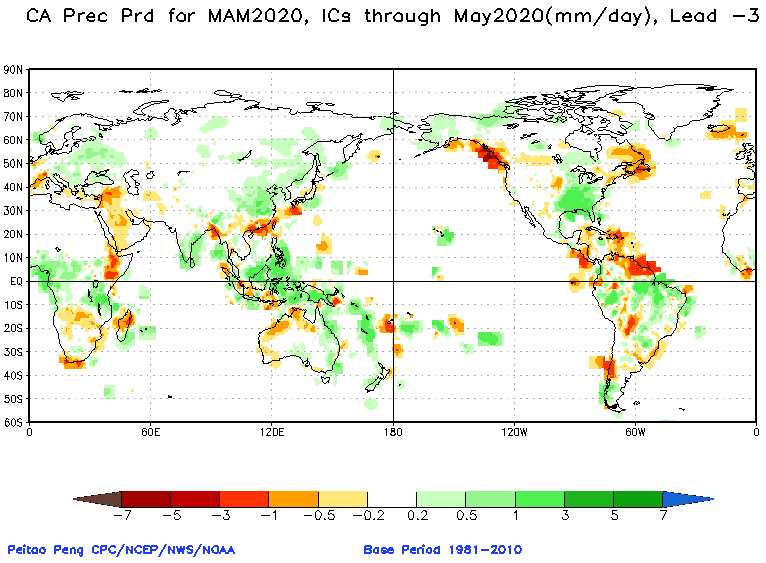
200mb Height from Linear Model



Seasonal Forecasts from the Constructed Analog Model







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.*

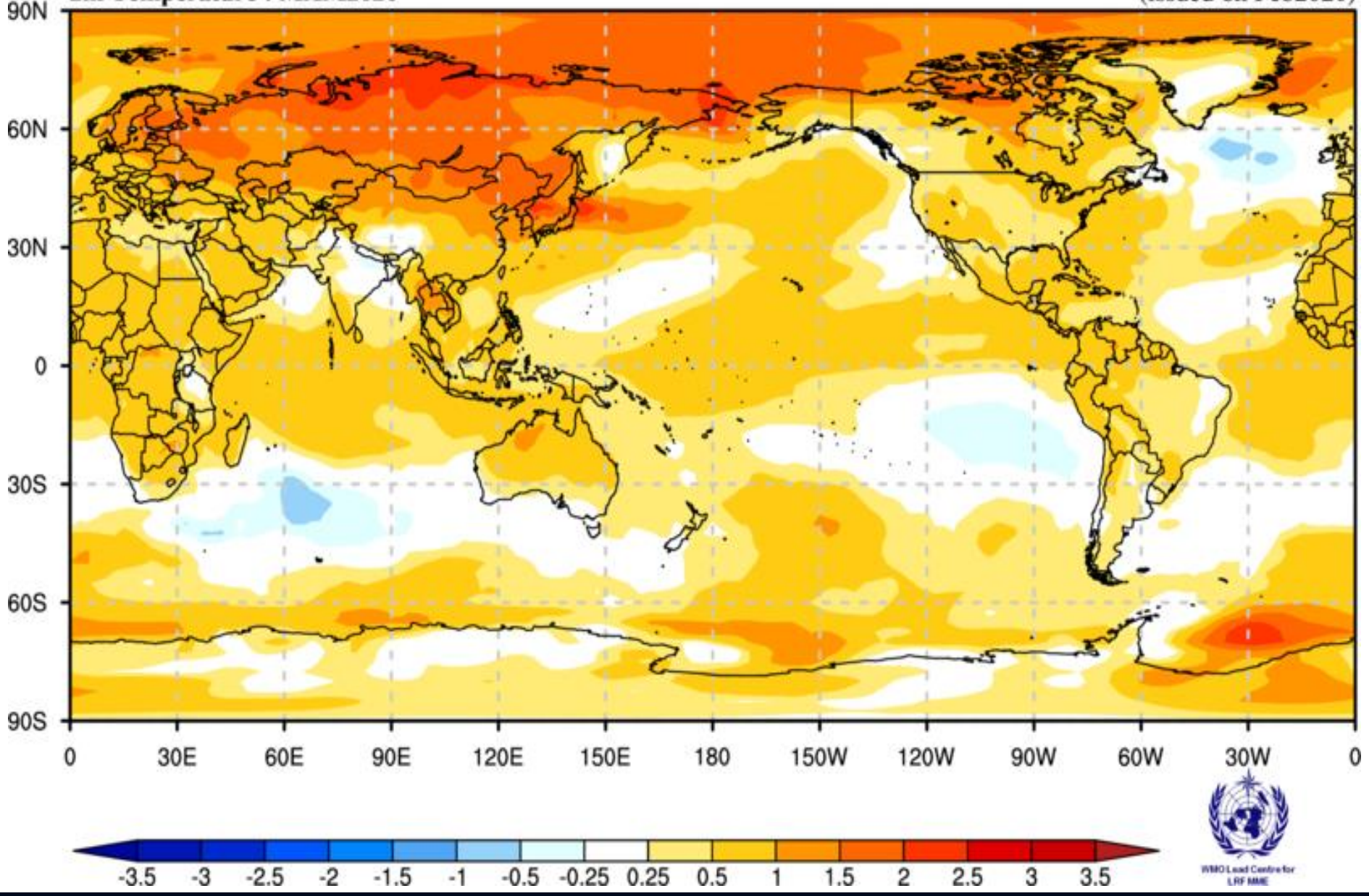
Simple Composite Map

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

[Unit : K]

2m Temperature : MAM2020

(issued on Feb2020)



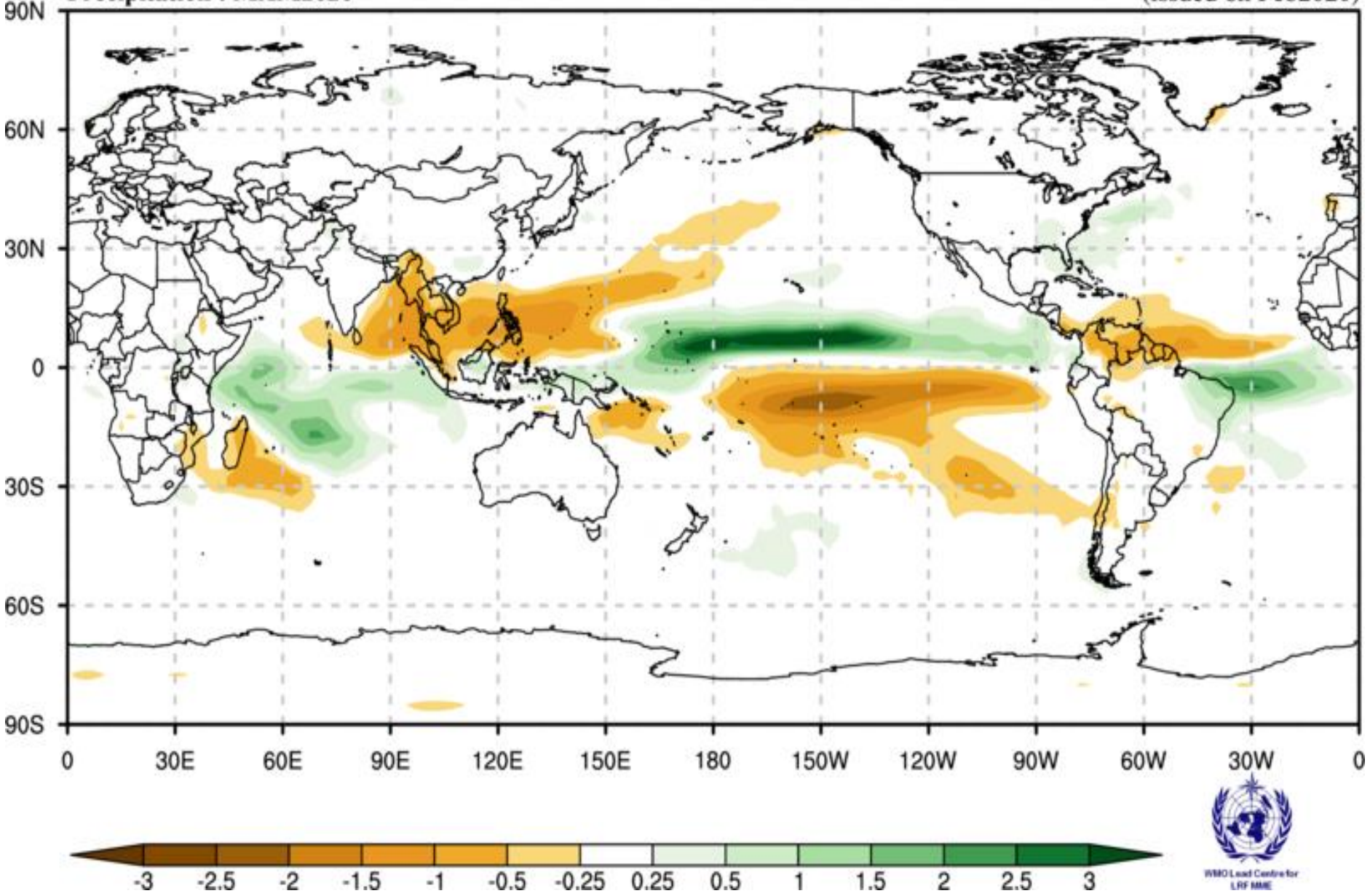
Simple Composite Map

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

[Unit : mm]

Precipitation : MAM2020

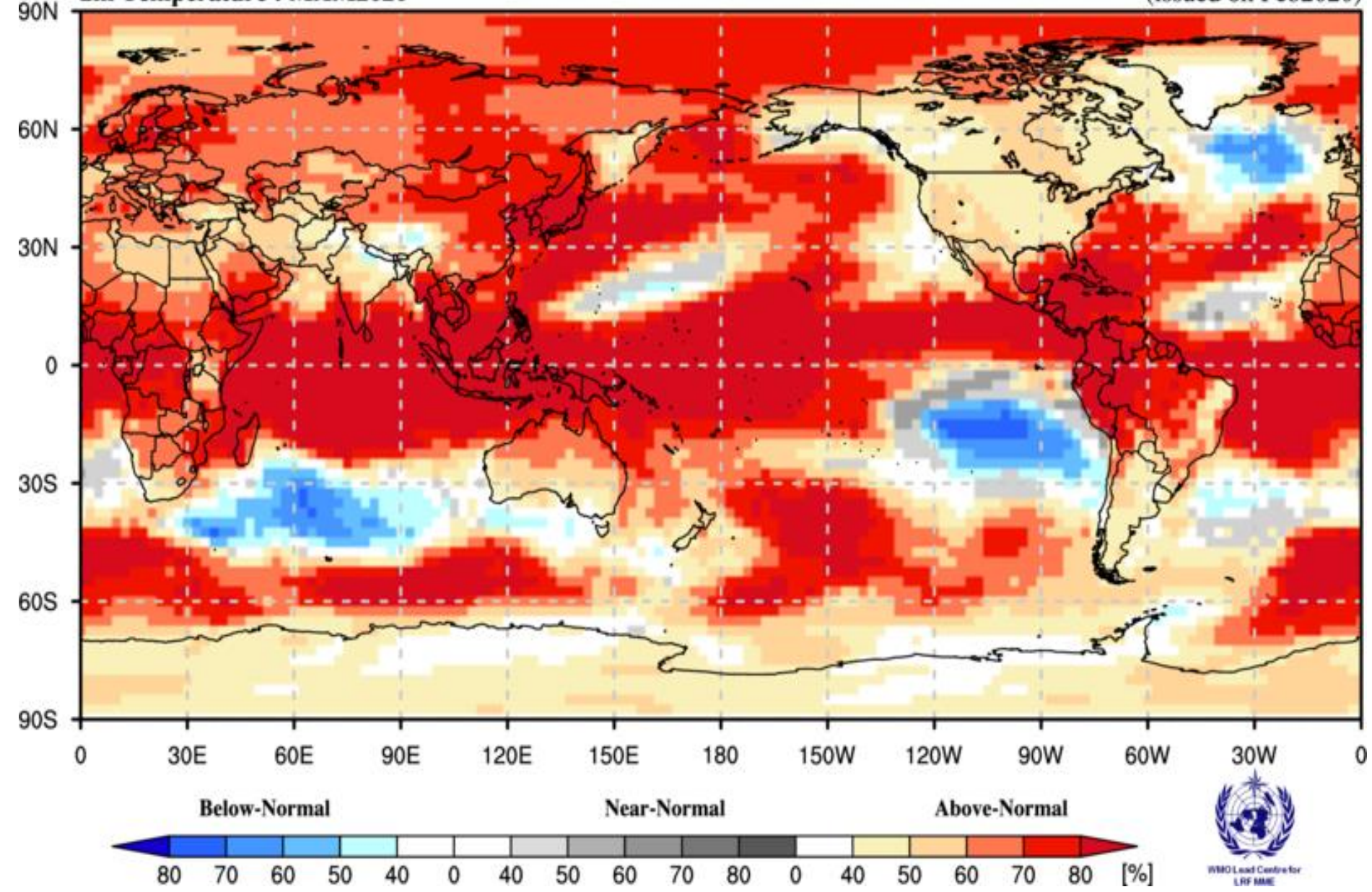
(issued on Feb2020)



Probabilistic Multi-Model Ensemble Forecast

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

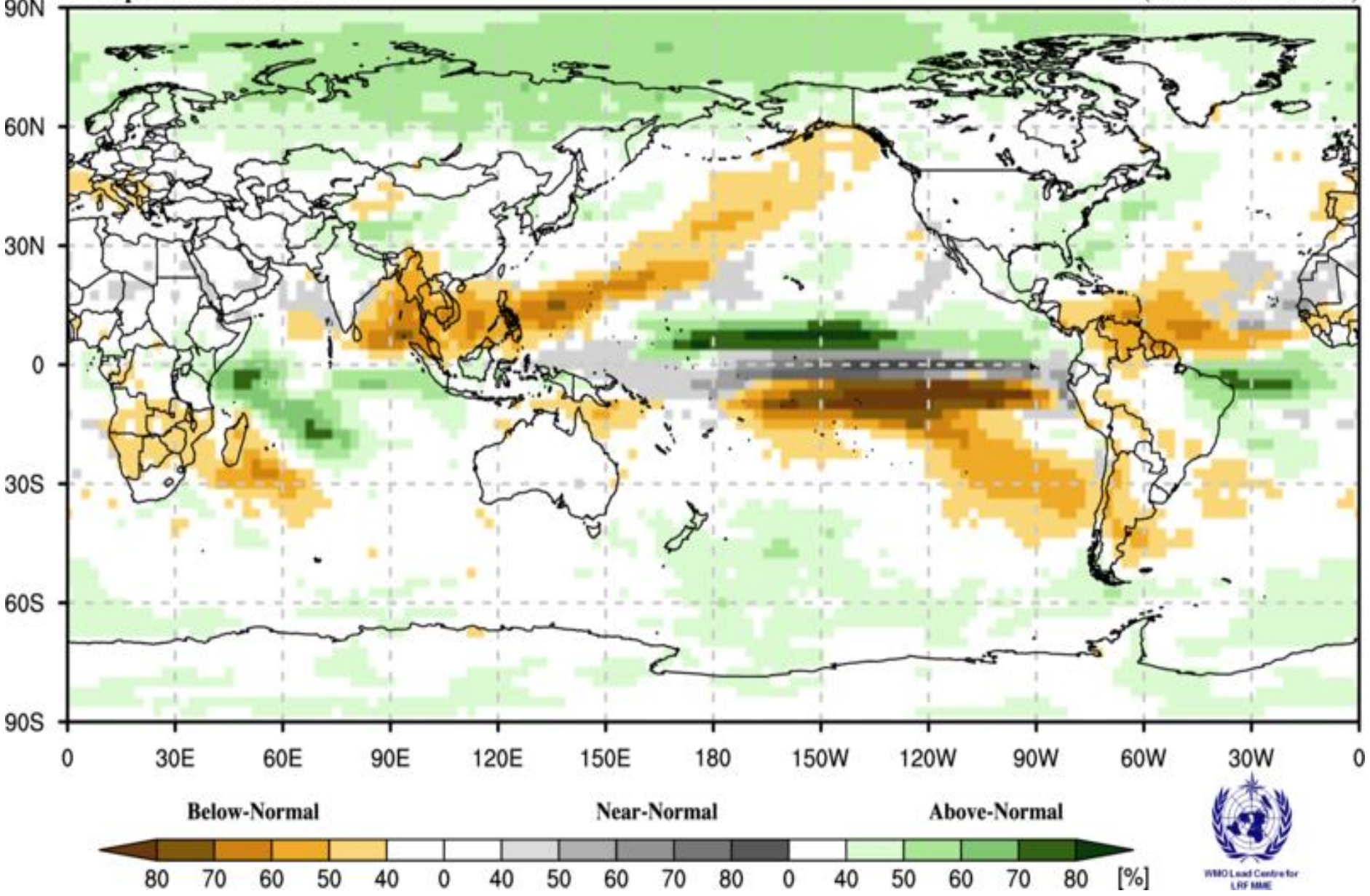
2m Temperature : MAM2020 (issued on Feb2020)



Probabilistic Multi-Model Ensemble Forecast

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

Precipitation : MAM2020 (issued on Feb2020)



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: NCDC daily OI 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 1999-2010 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)