

Attribution of Seasonal Climate Anomalies February-March-April 2026

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

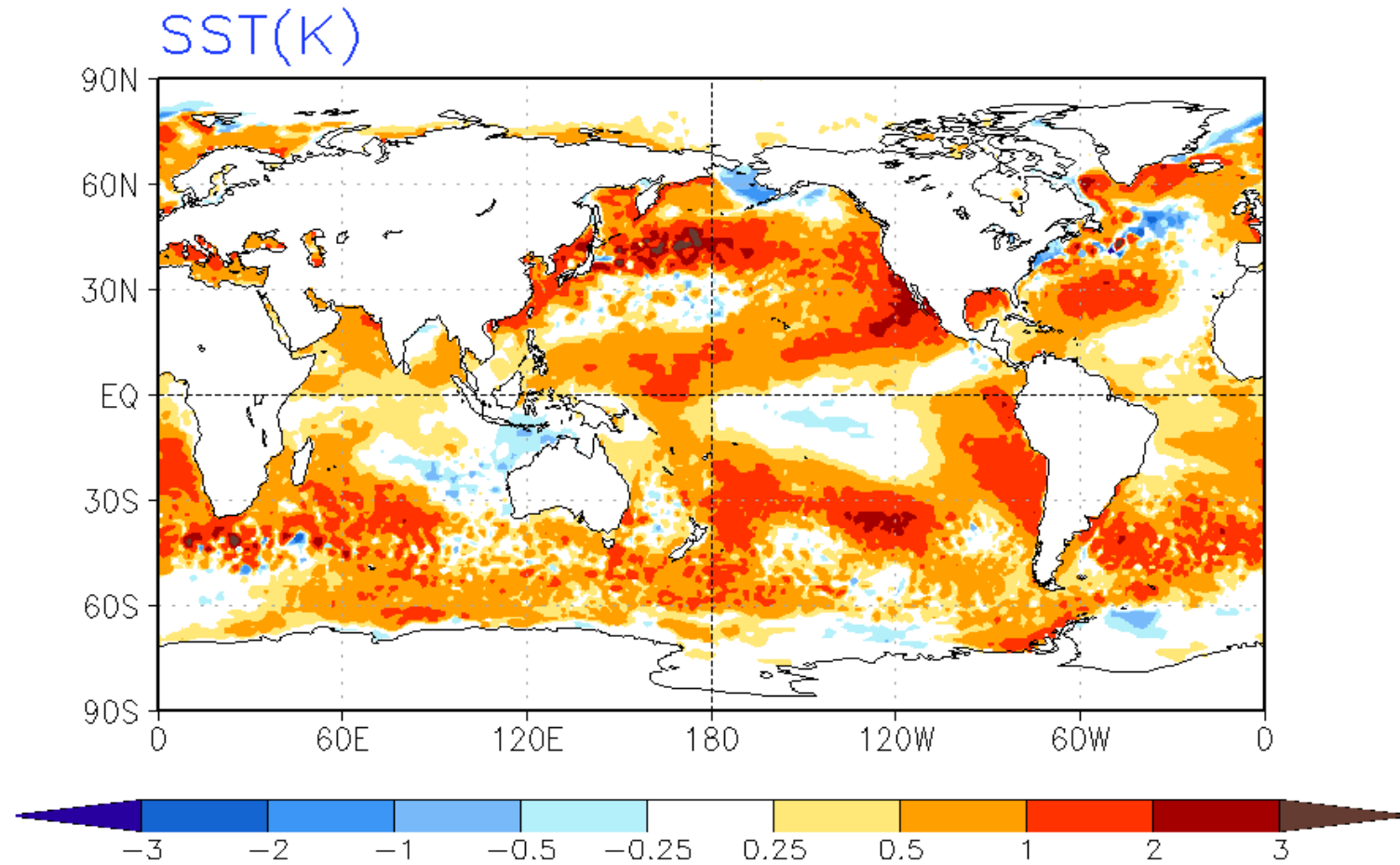
Summary of Observed Conditions and Outlooks

- In FMA 2026, near zero SST anomalies emerged over the equatorial central-eastern Pacific and extended southward in eastern Pacific. Warm anomalies over the far eastern South Pacific along the South American coast remained at a similar strength to the previous season. Warm anomalies continued to dominate across the mid-latitude North and South Pacific, the southern Indian Ocean, and the northern and southern Atlantic (Slide 4).
- CFSv2 reasonably captured large-scale SST patterns but exhibited cold biases over the far eastern Pacific along the South American coast (Slide 10).
- CFSv2 and MME forecasts generally captured key tropical precipitation patterns typical of La Niña (wet Maritime Continent/eastern Indian Ocean; dry central-eastern Pacific) (Slides 11, 37-39).
- Forecasts captured the global land warming trend but missed significant, broad cold anomalies over northwestern Asia and across northern North America (from Alaska to Canada). While CFSv2 largely missed these feature, MME forecasts successfully captured portions of the cold anomalies there (Slides 13, 37-39). These surface errors likely stem from CFSv2 missing negative 200-mb height anomalies over northwestern Asia and in high-latitude regions of North America (Slides 12, 13, 15, 16).
- NMME North America precipitation anomalies are attributable to the SST ENSO and trend modes relatively equally, with both contributing to dry conditions along the US west and southeast coasts. Extratropical height and T2m anomalies are driven mainly by the forecast SST warming trend mode, which offset the negative height and cold T2m anomaly responses to ENSO mode over northern North America (Slides 40, 41).
- For the April 2026 forecast, North America z200 and precipitation showed improved skill at the shortest leads, whereas T2m forecast skill showed no improvement (Slide 33-34).

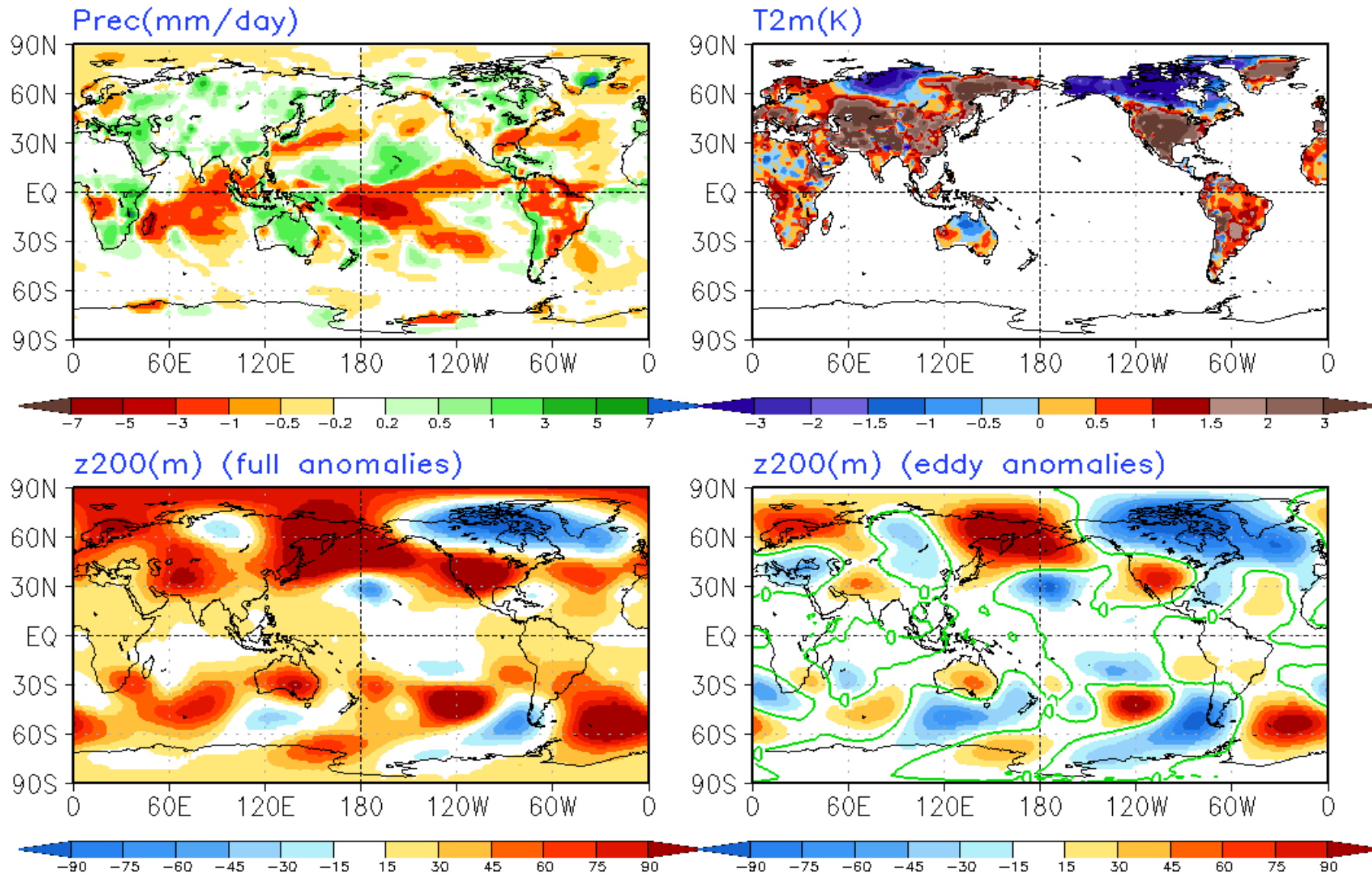
Observed Seasonal Anomalies

Global and North America

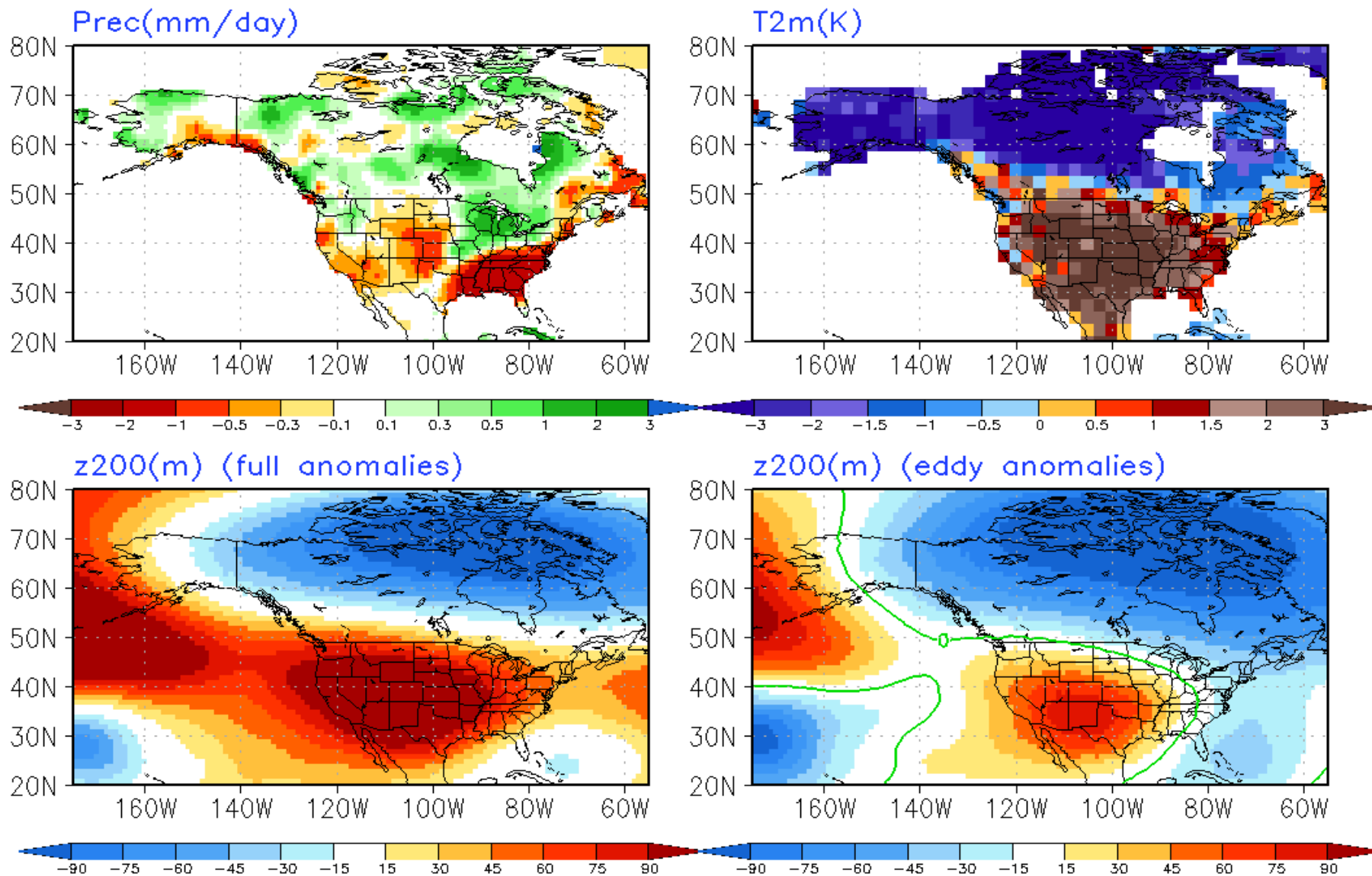
Observed Anomaly FMA2026



Observed Anomaly FMA2026



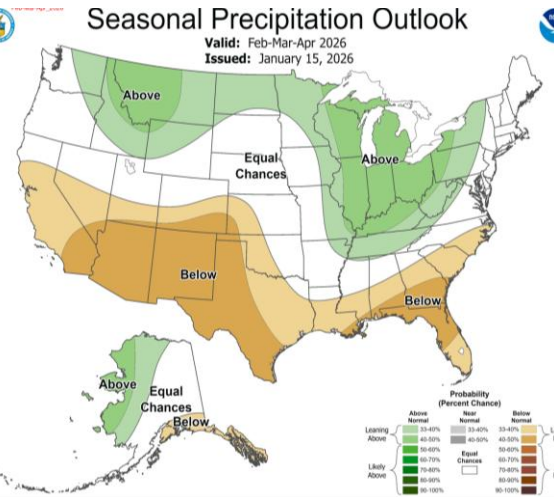
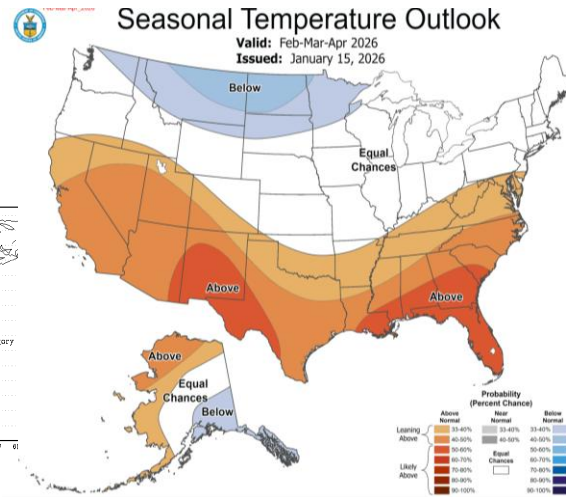
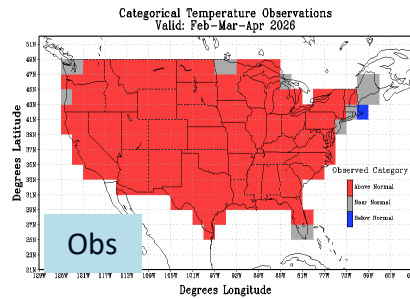
Observed Anomaly FMA2026



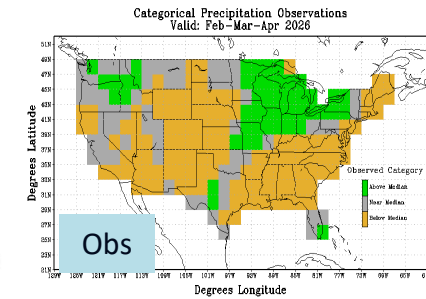
CPC Seasonal Outlooks and NMME Forecasts

CPC

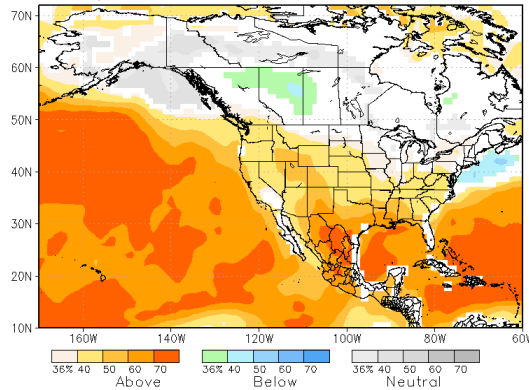
Temp nonEC
HSS=68



Prec nonEC
HSS=38

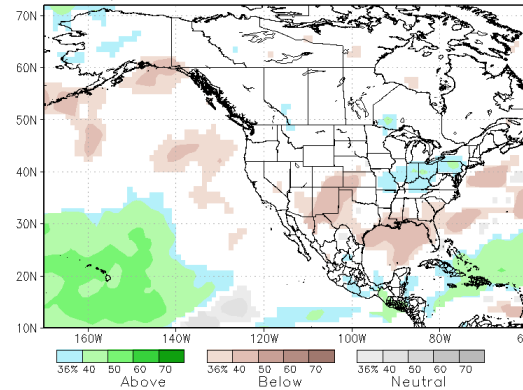


NMME prob fcast TMP2m IC=202601 for lead 1 2026 FMA



NMME

NMME prob fcast Prate IC=202601 for lead 1 2026 FMA



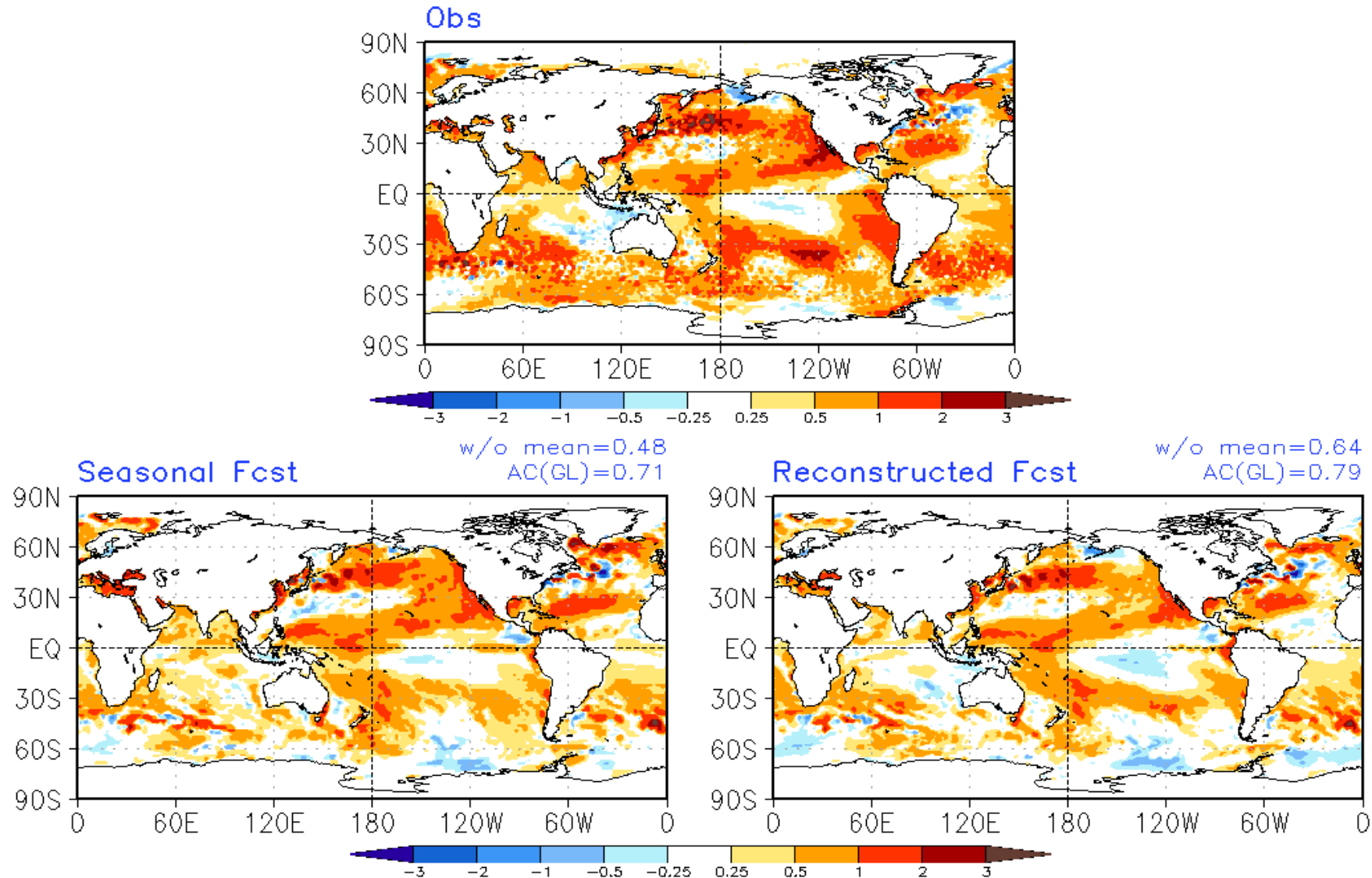
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2026/202601_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

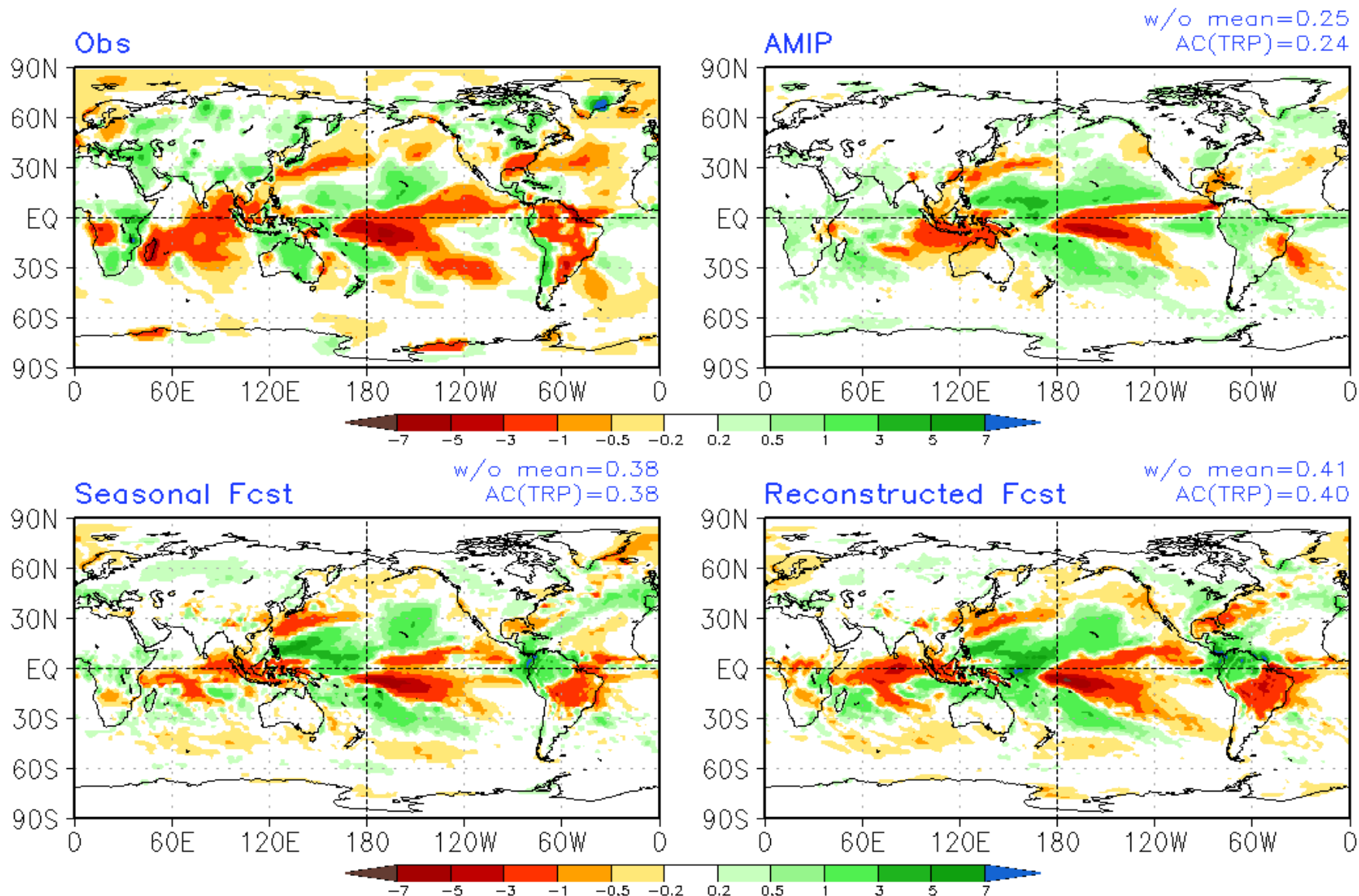
Model Simulated/Forecast Ensemble Average Anomalies

- **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.

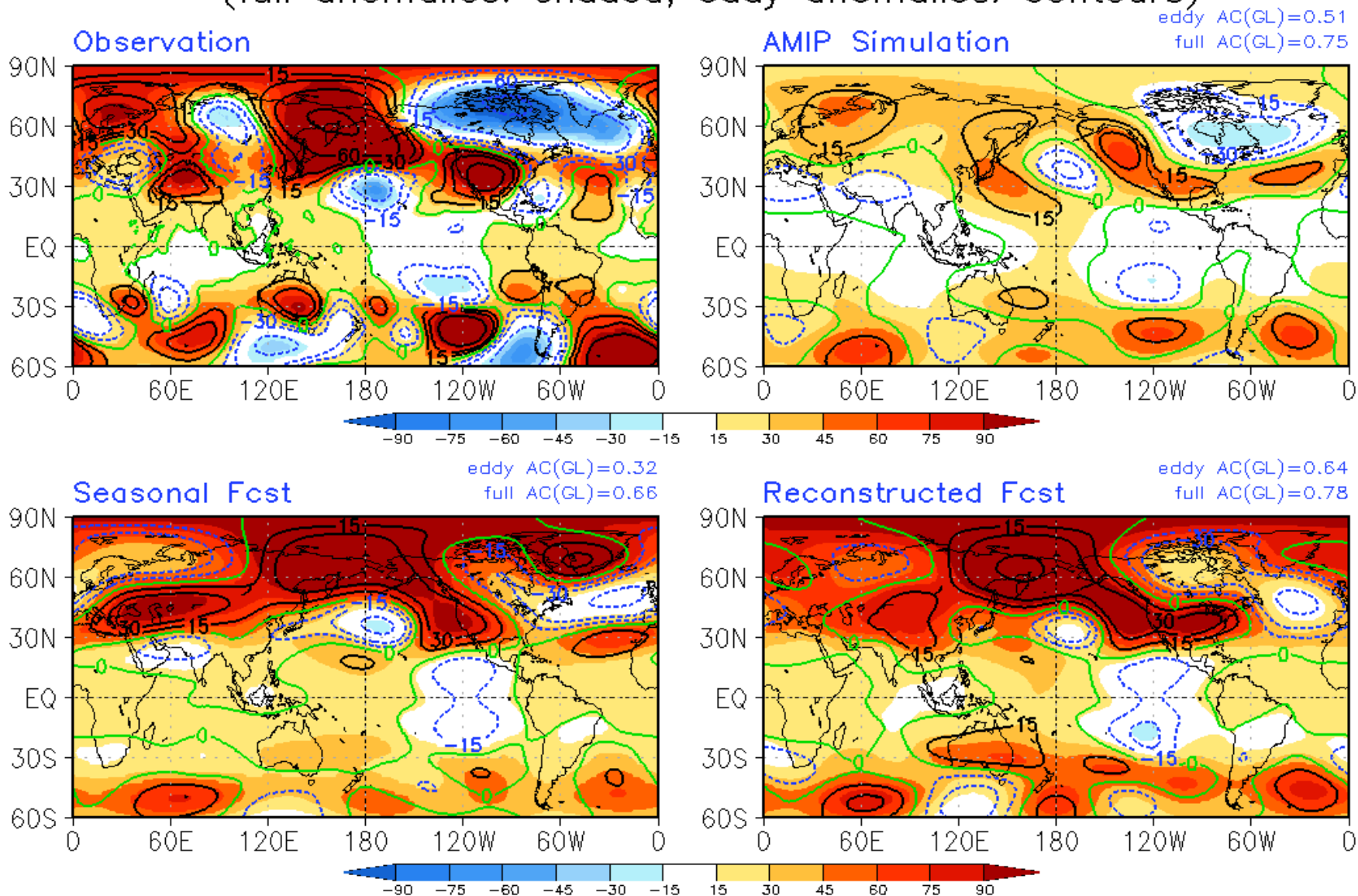
FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



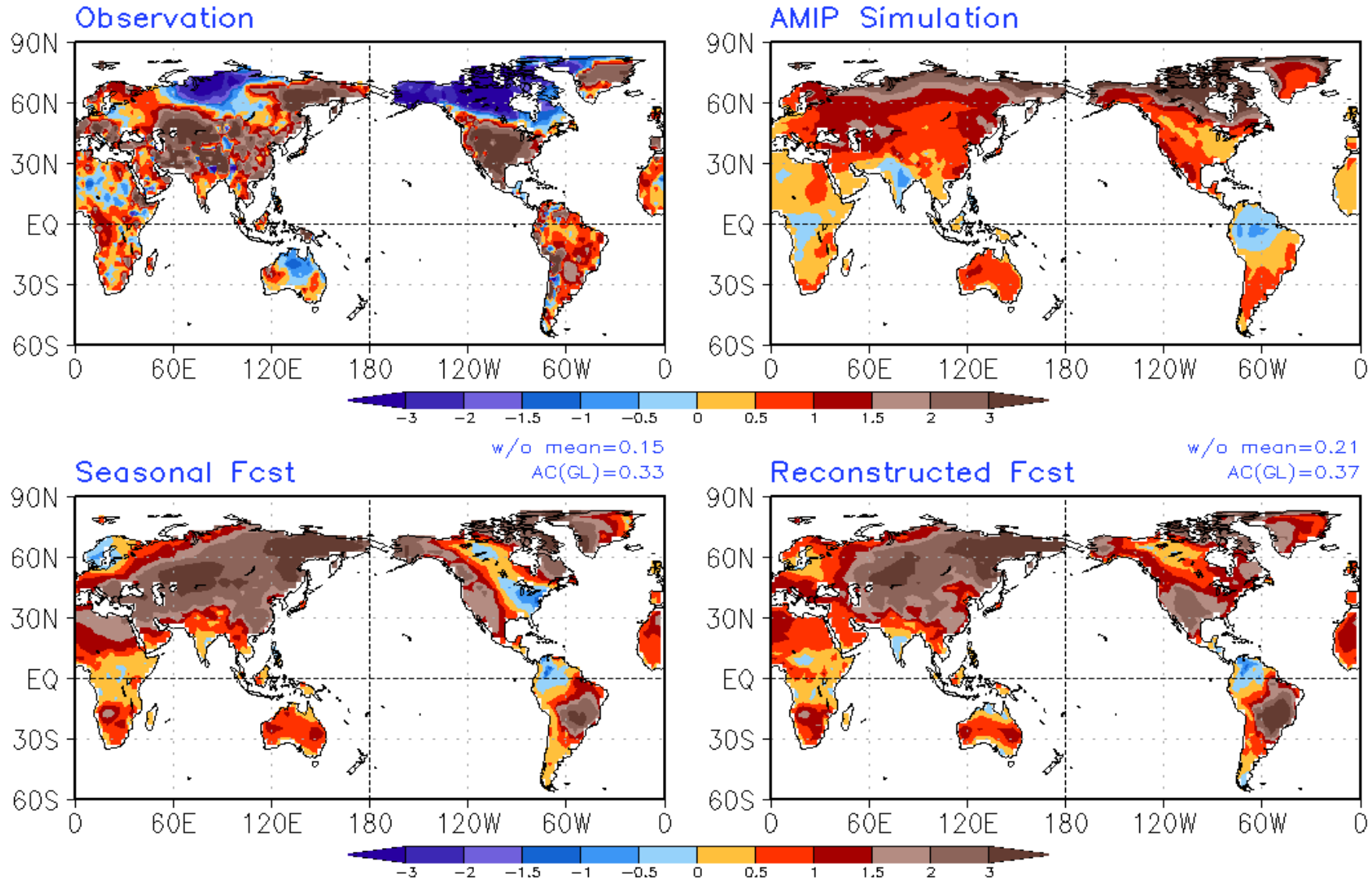
FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



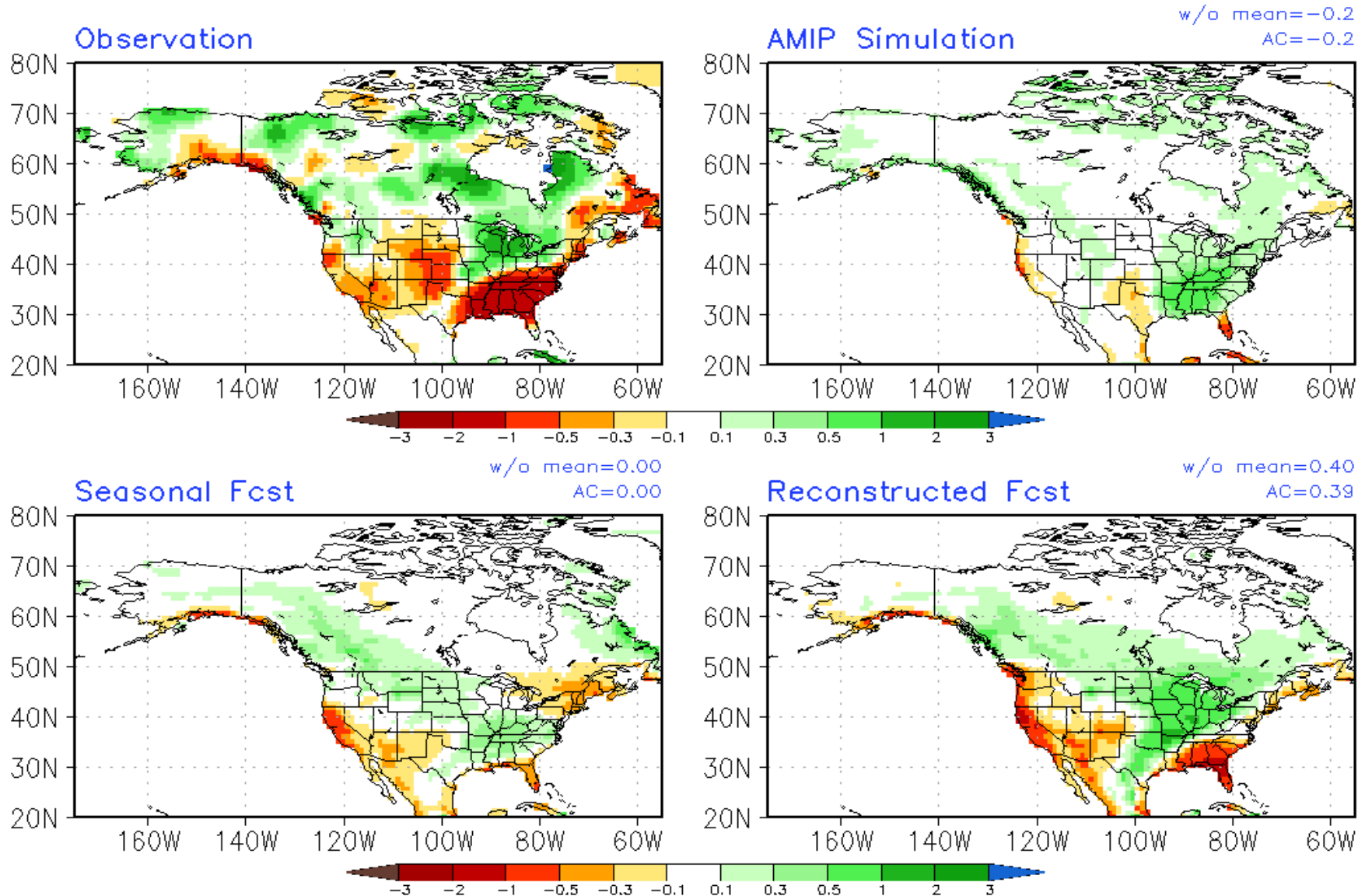
FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m) (full anomalies: shaded; eddy anomalies: contours)



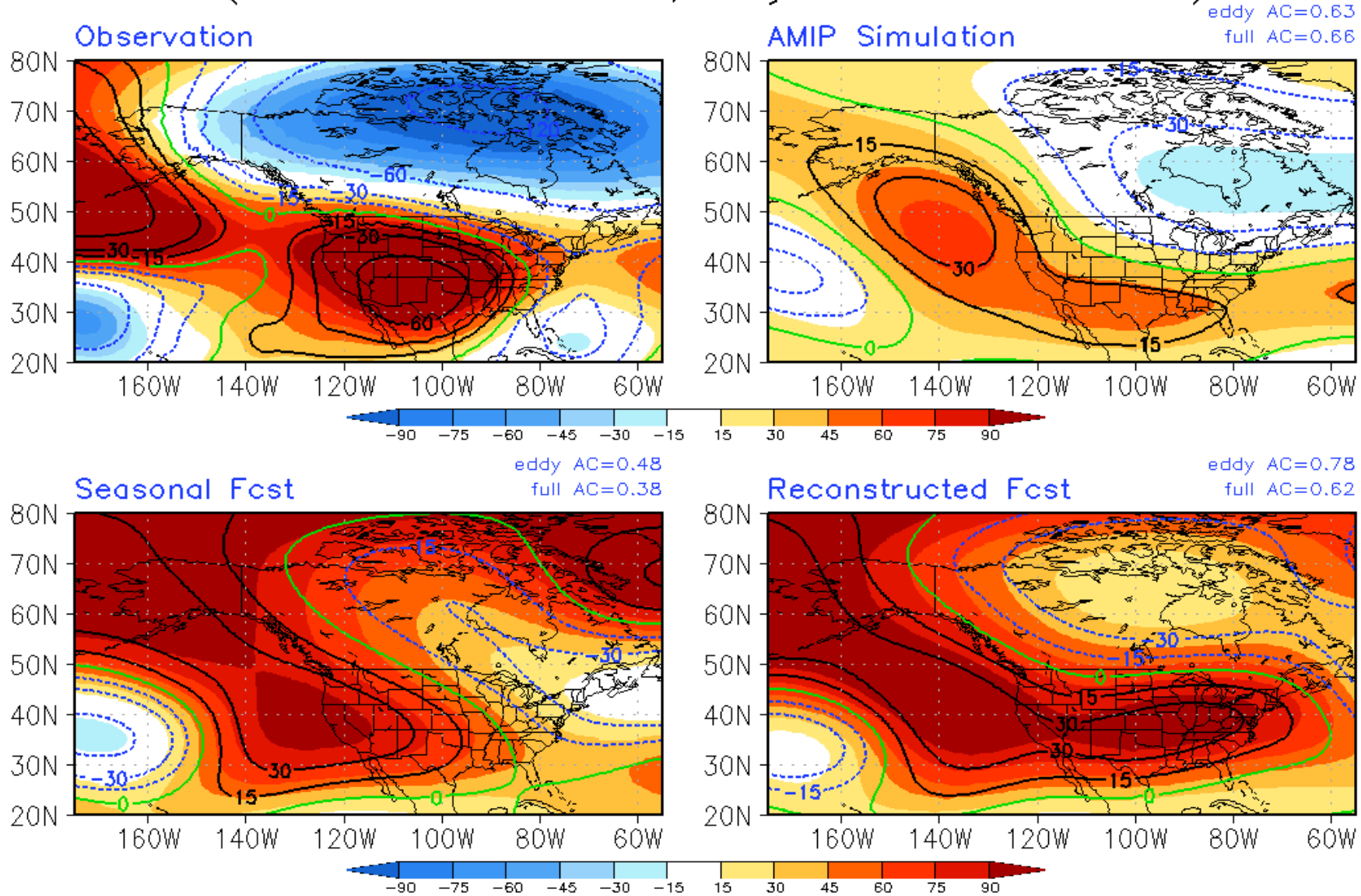
FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



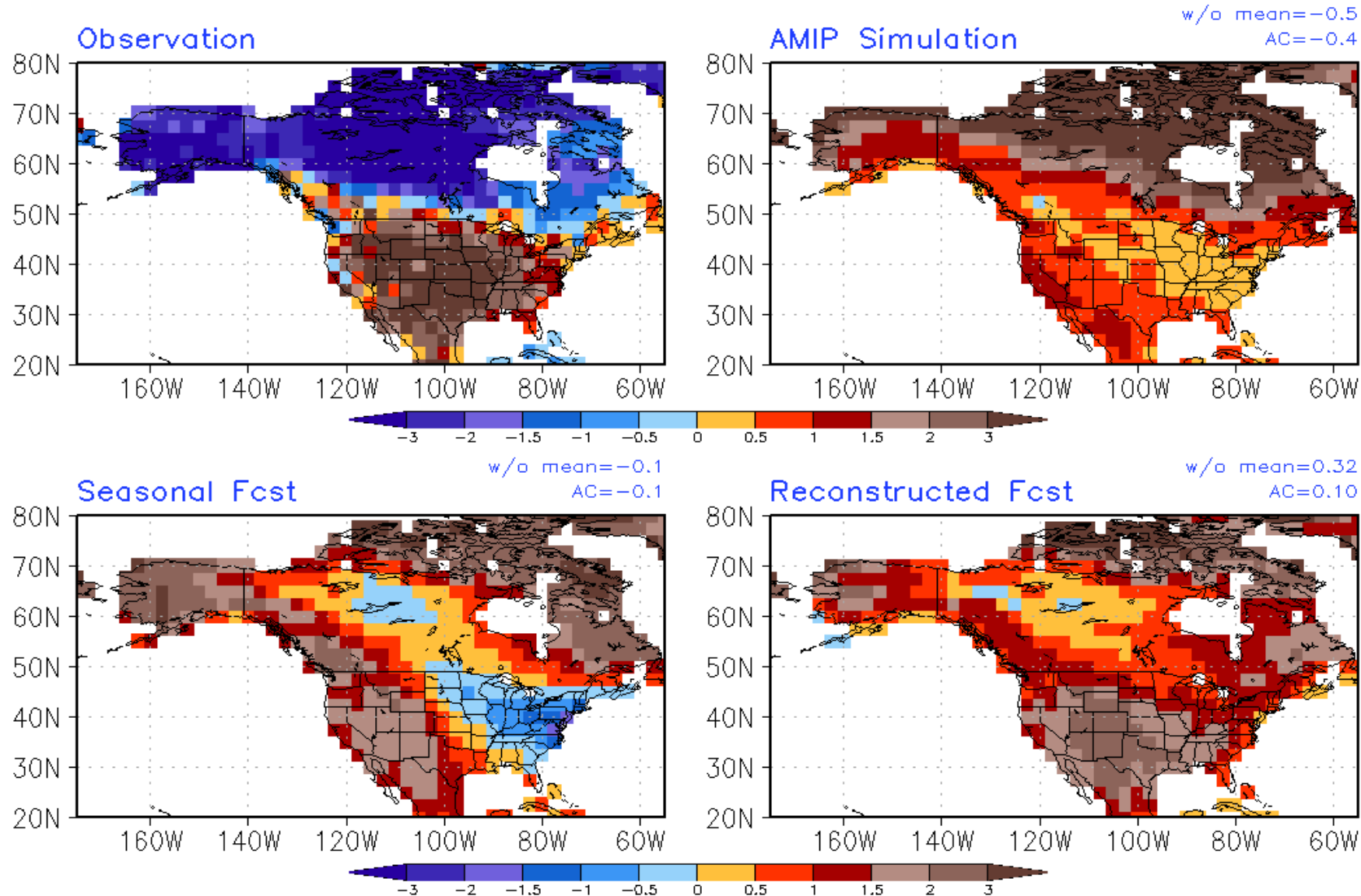
FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m) (full anomalies: shaded; eddy anomalies: contours)



FMA2026 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

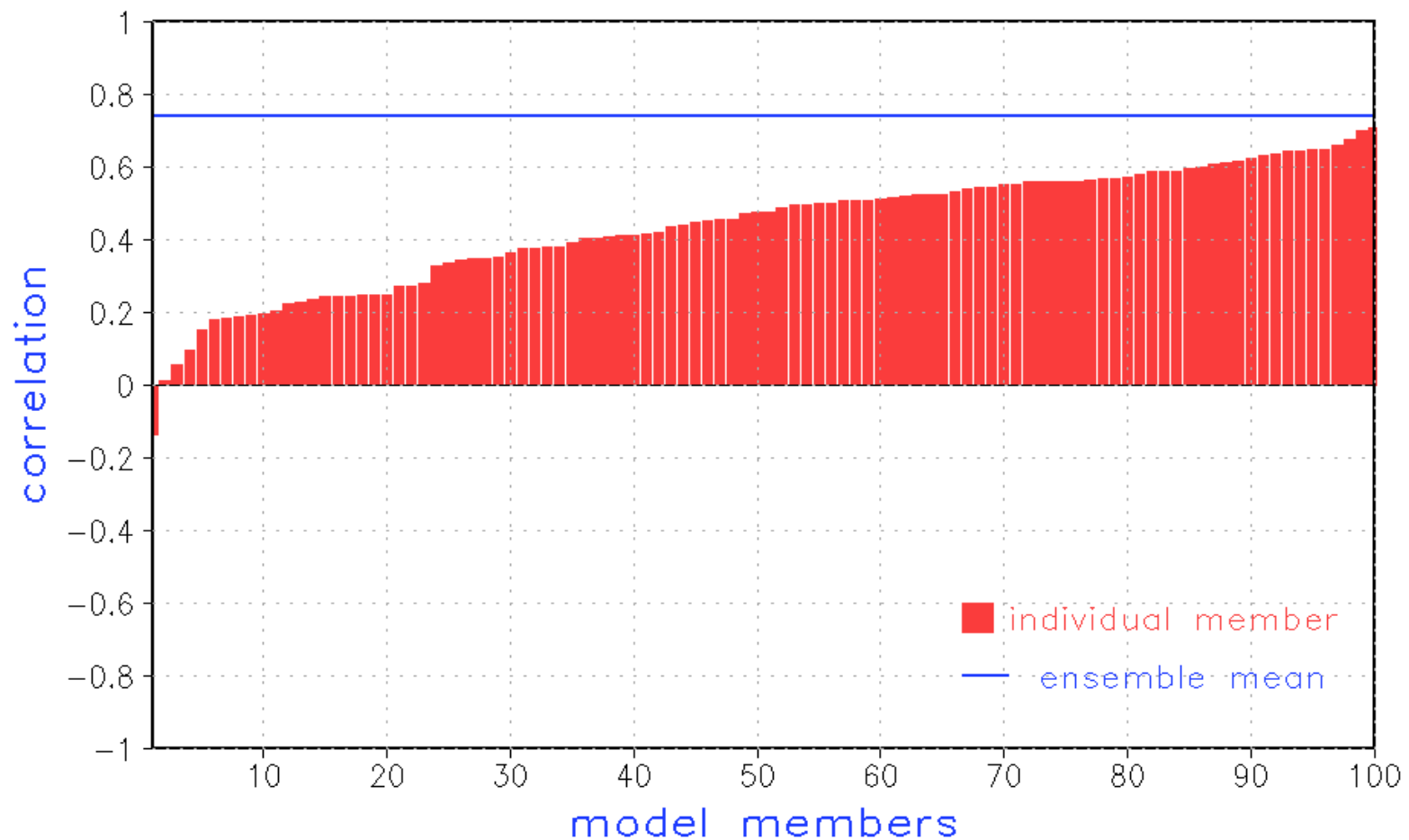


Model Simulated/Forecast Anomalies: Individual Runs

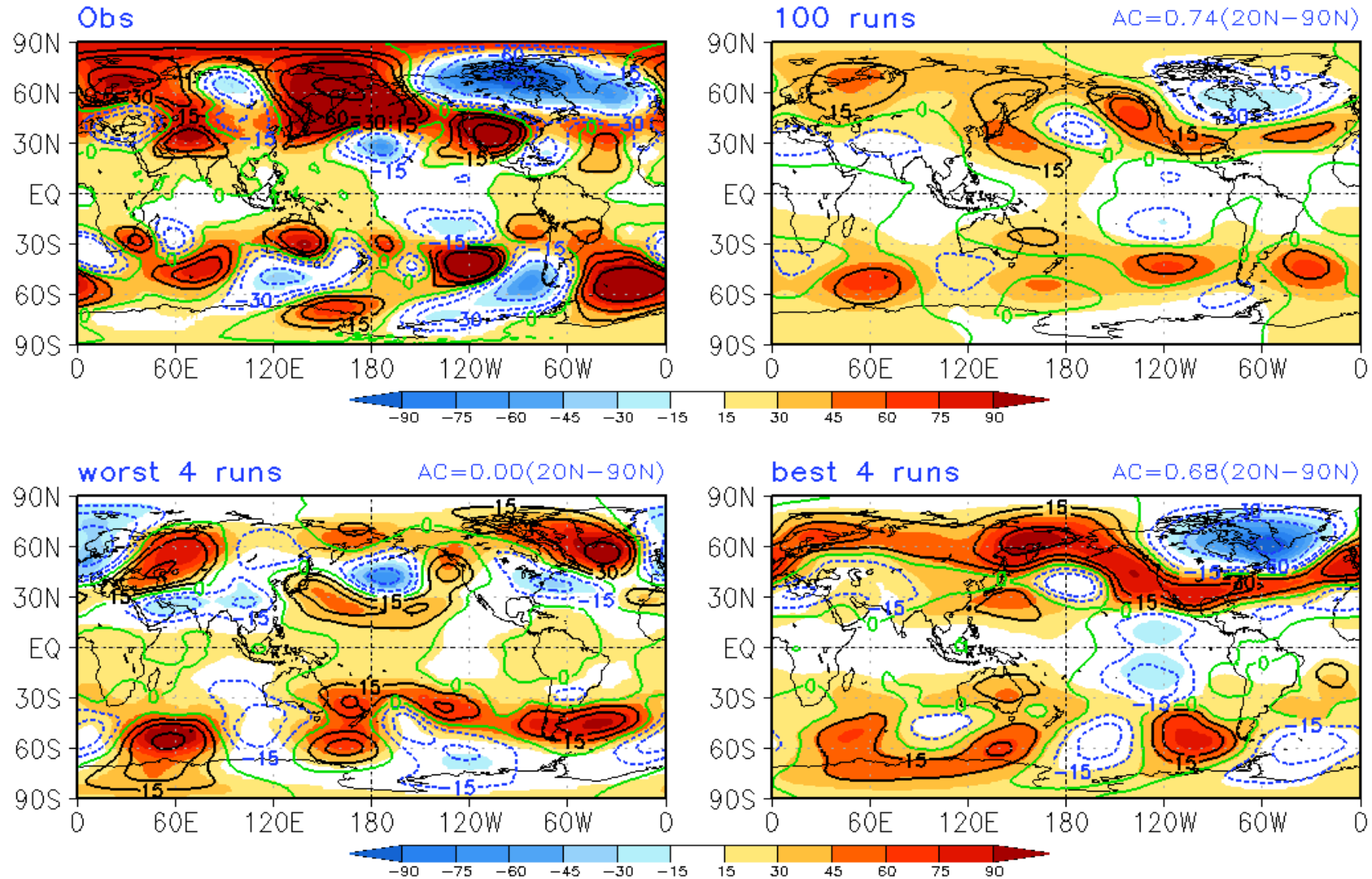
Model Simulated/Forecast Anomalies: Individual Runs

- 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](https://doi.org/10.1002/grl.50657).

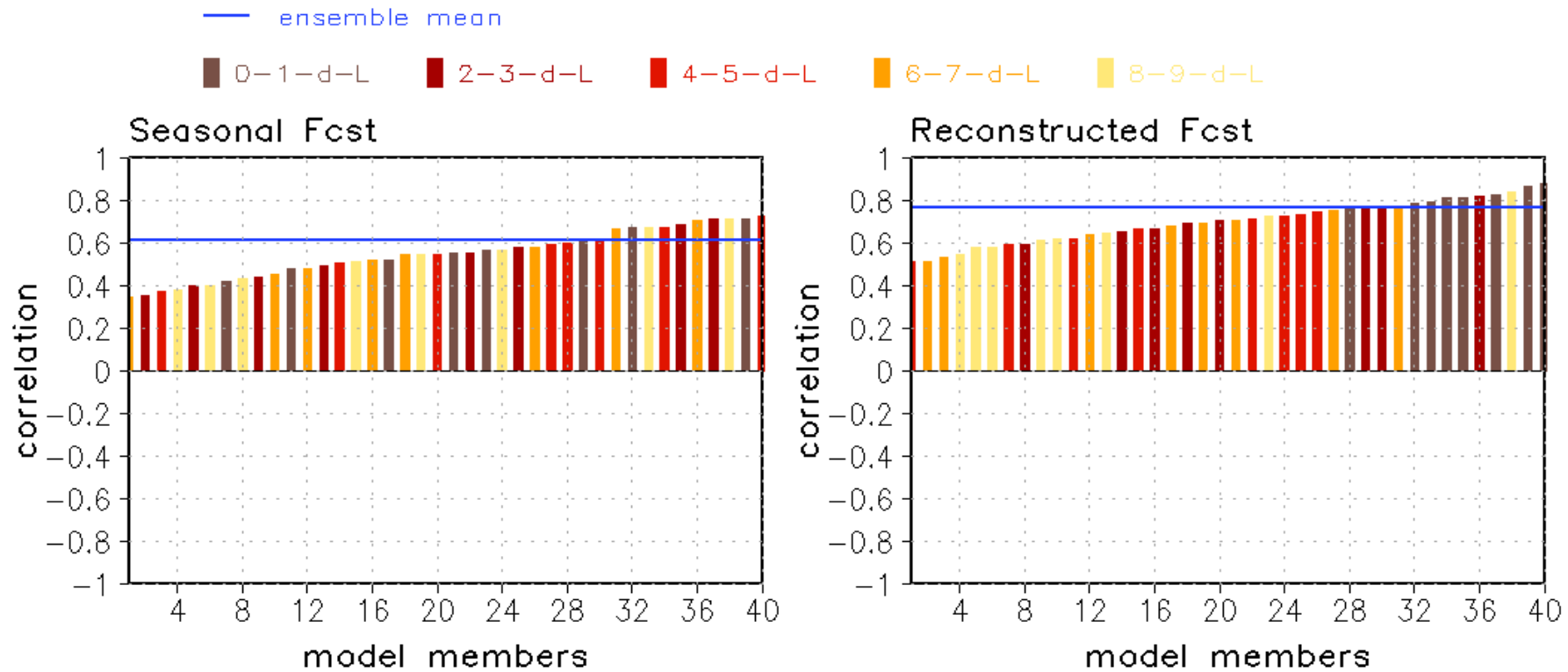
FMA2026 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)



Observed & AMIP Ensemble Mean Anomalies
FMA2026 z200(m) 100 runs/worst 4 runs/best 4 runs
(full anomalies: shaded; eddy anomalies: contours)



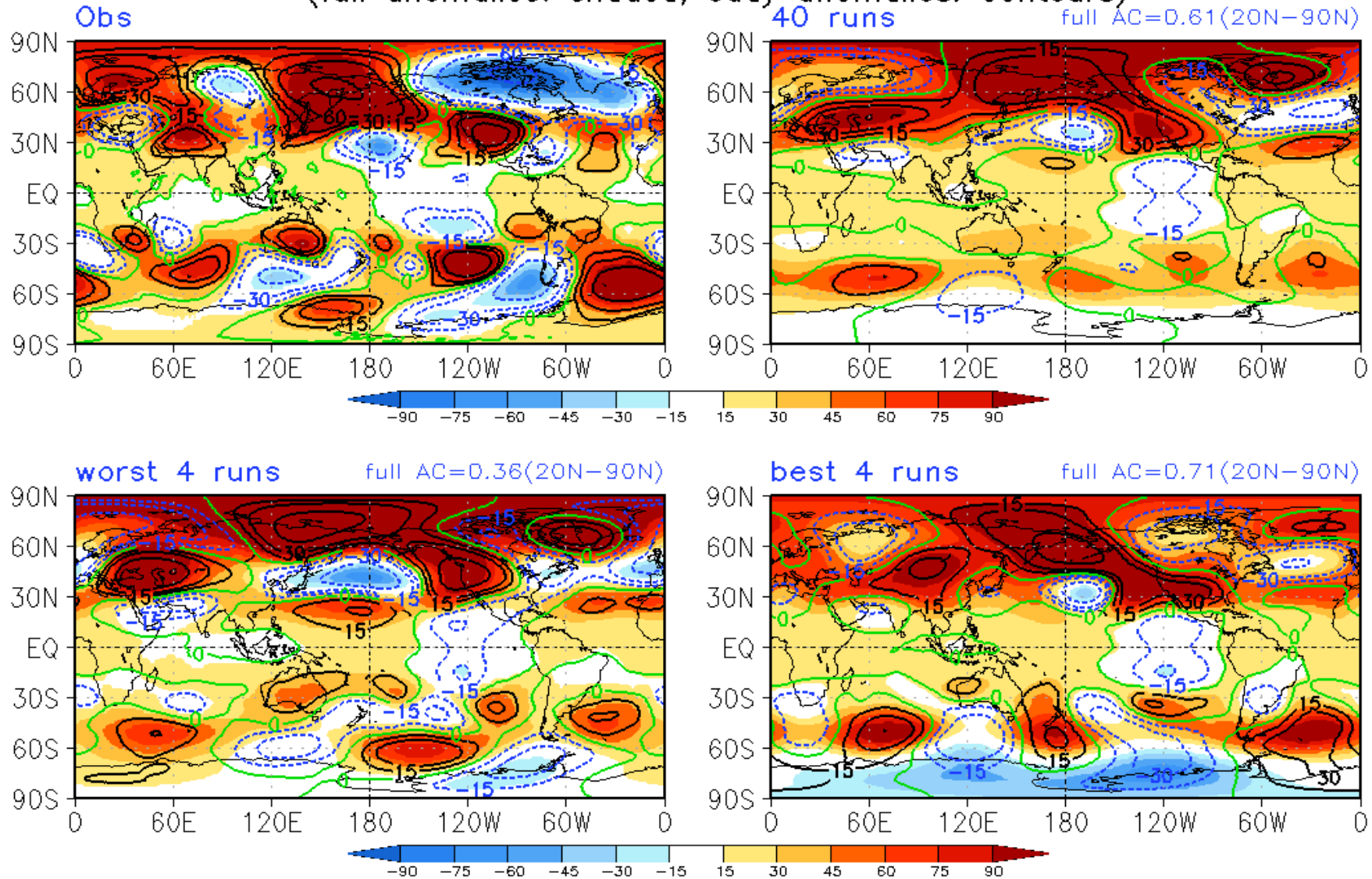
FMA2026 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 z200(m) 40 runs/worst 4 runs/best 4 runs

Seasonal Forecast

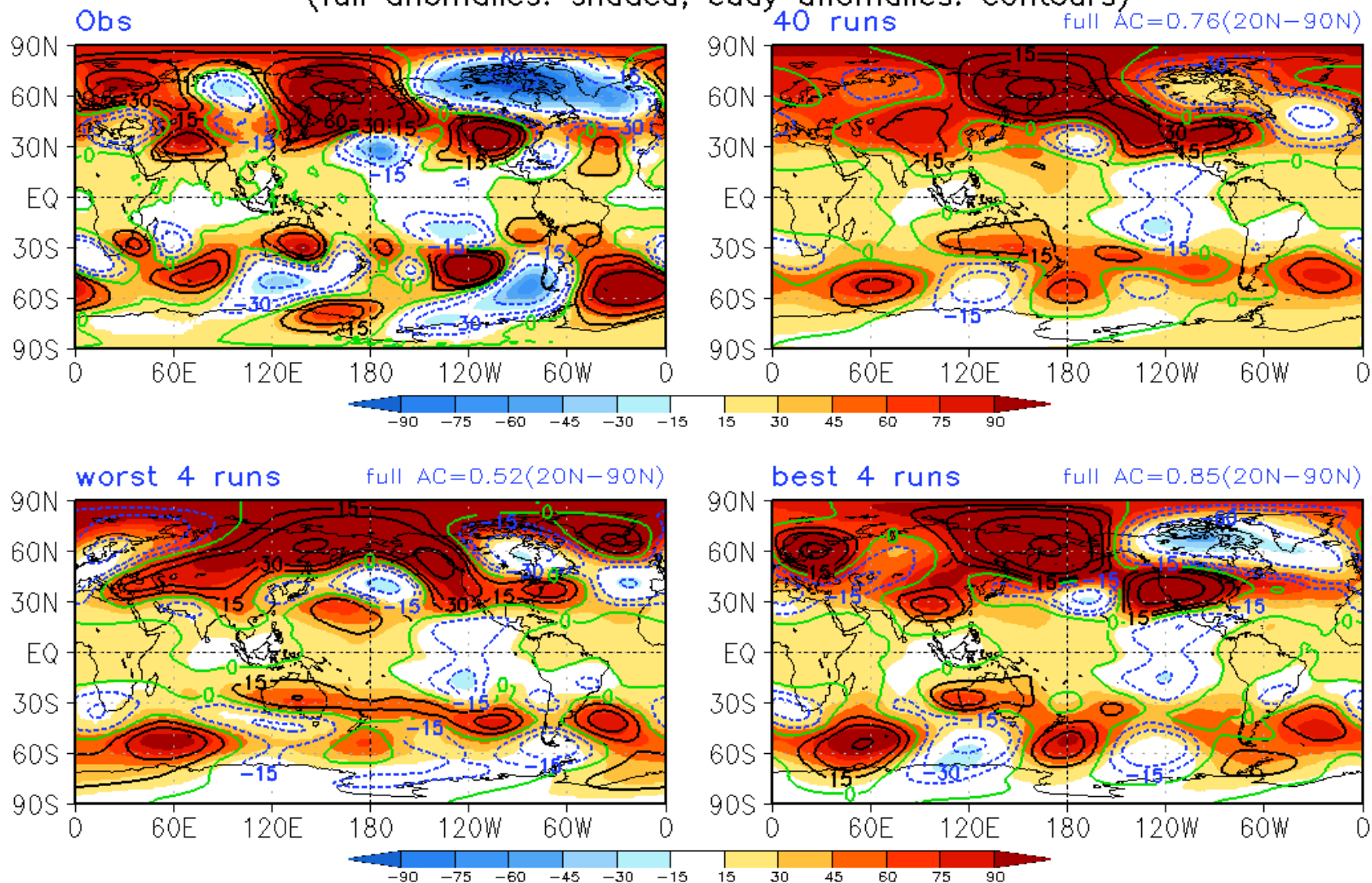
(full anomalies: shaded; eddy anomalies: contours)



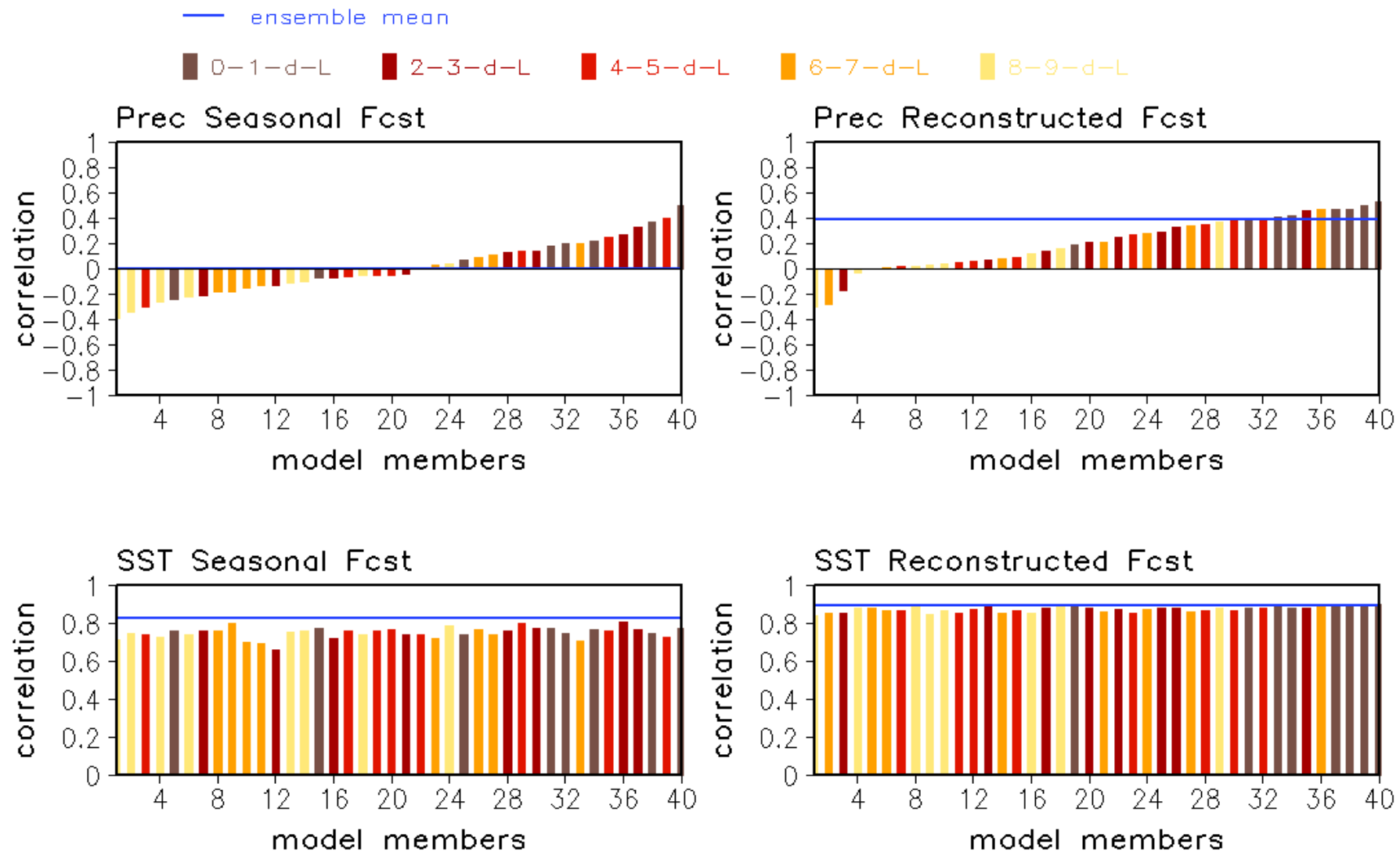
Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 z200(m) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast

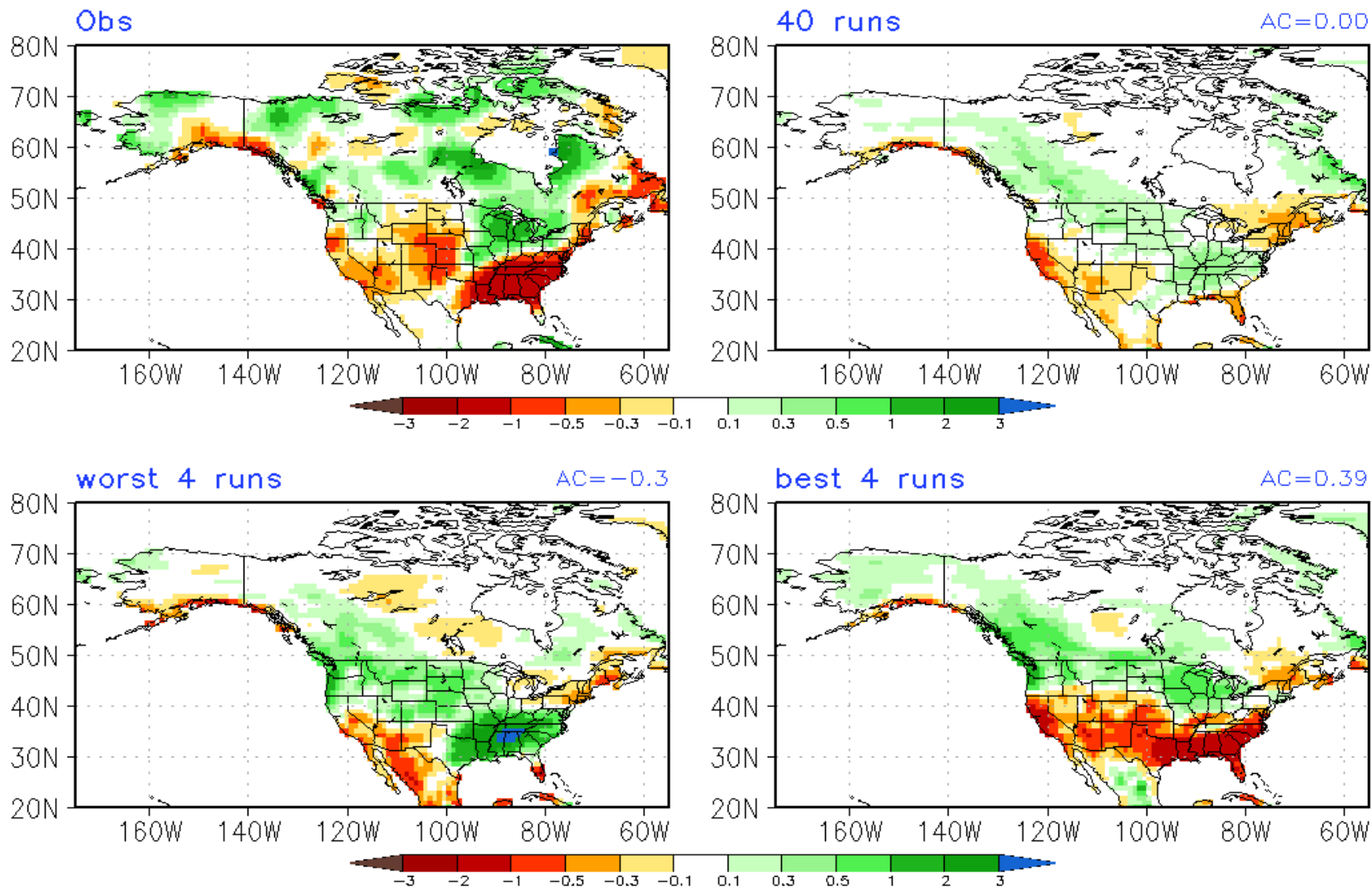
(full anomalies: shaded; eddy anomalies: contours)



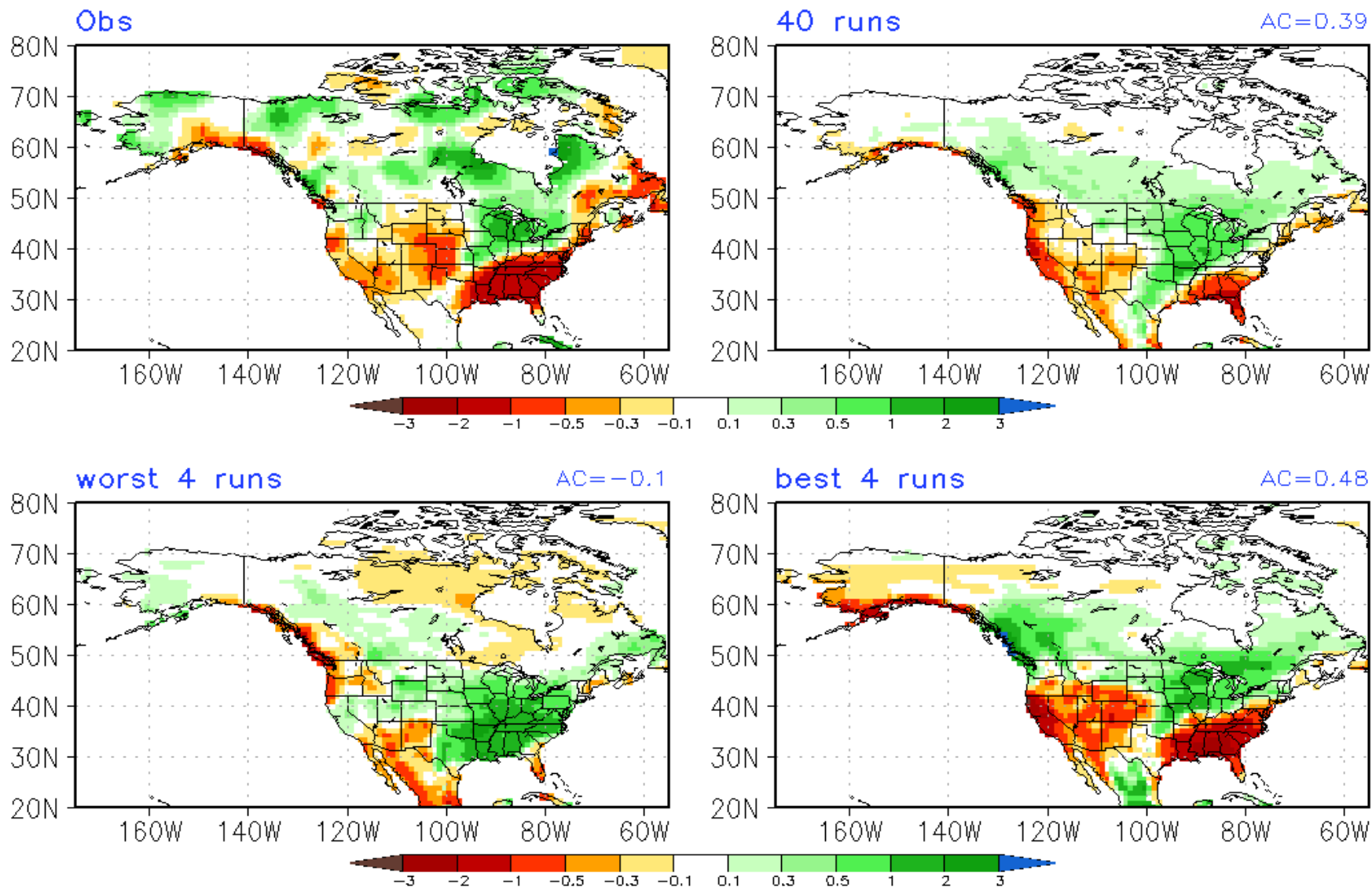
FMA2026 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



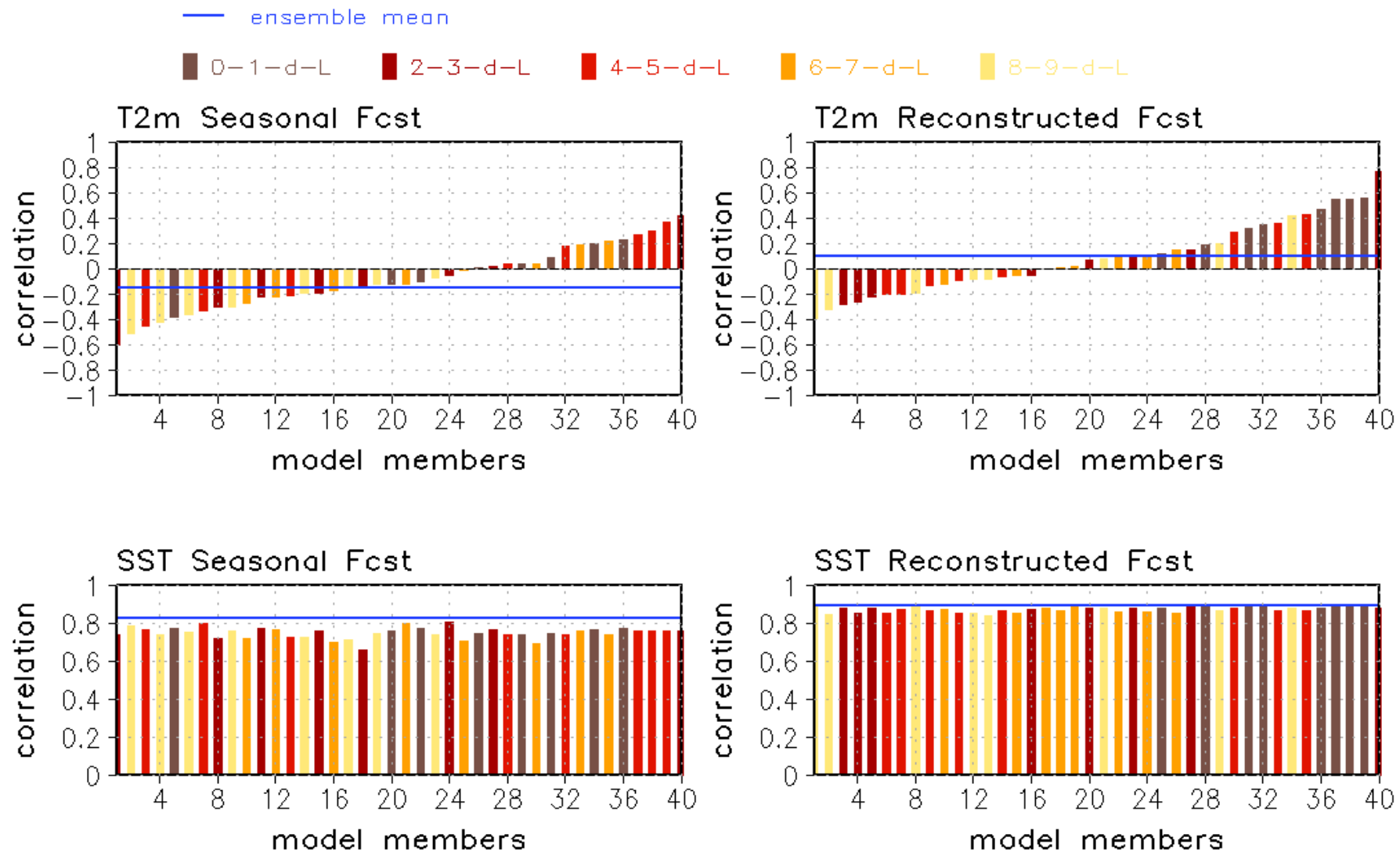
Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



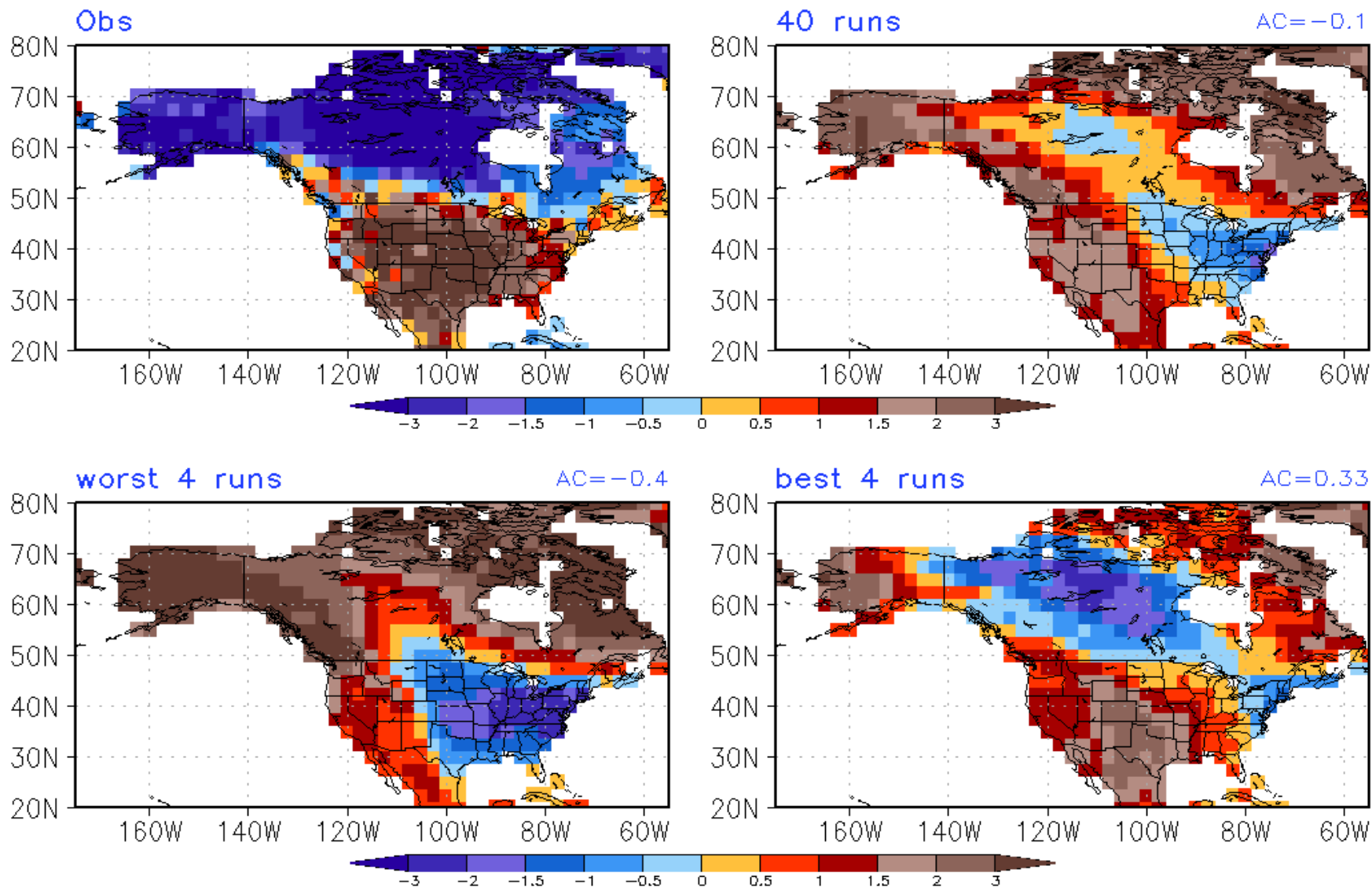
Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



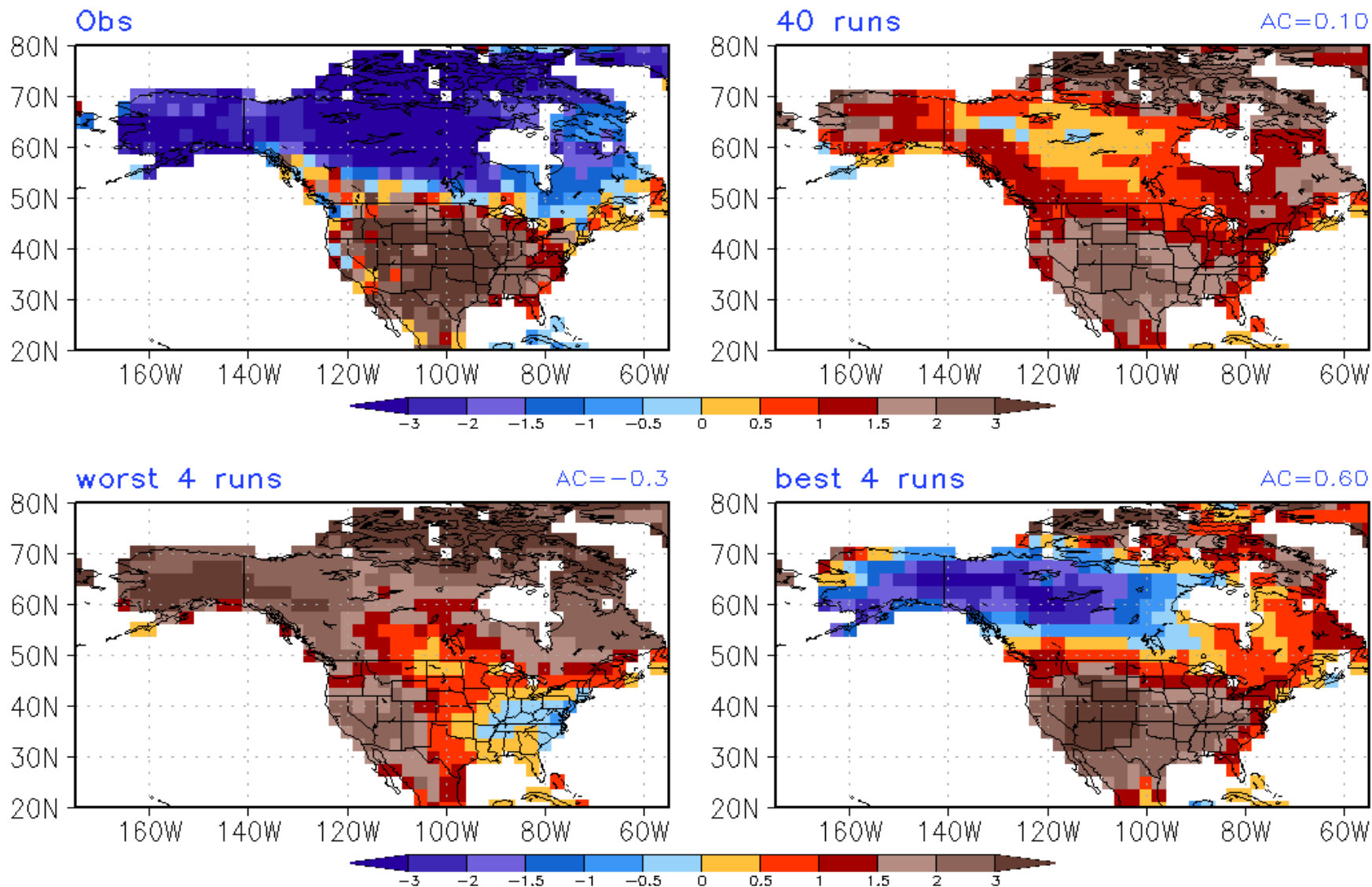
FMA2026 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

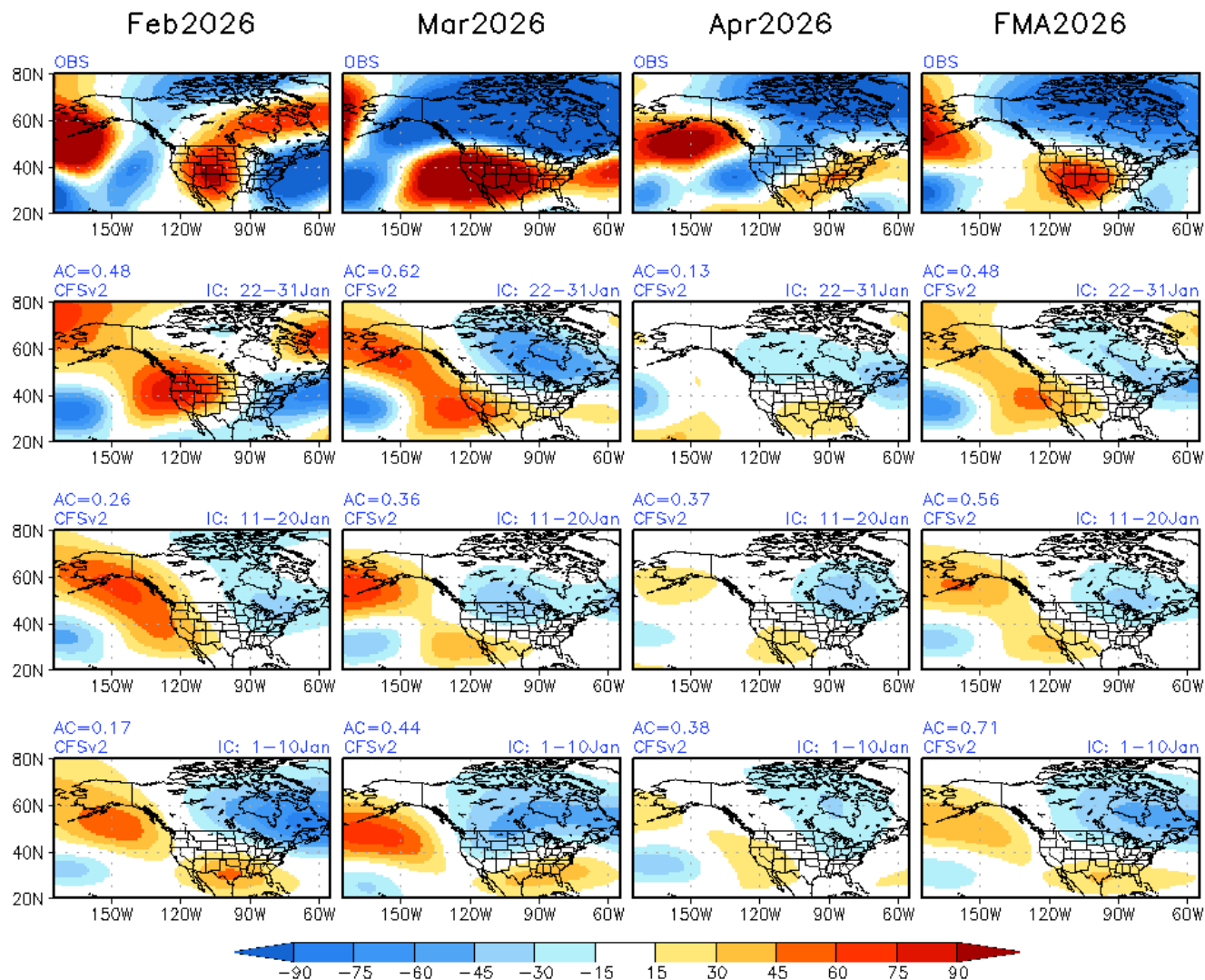


Observed & CFSv2 Forecast Ensemble Average Anomalies
FMA2026 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) FMA2026 z200(m) eddy & Obs



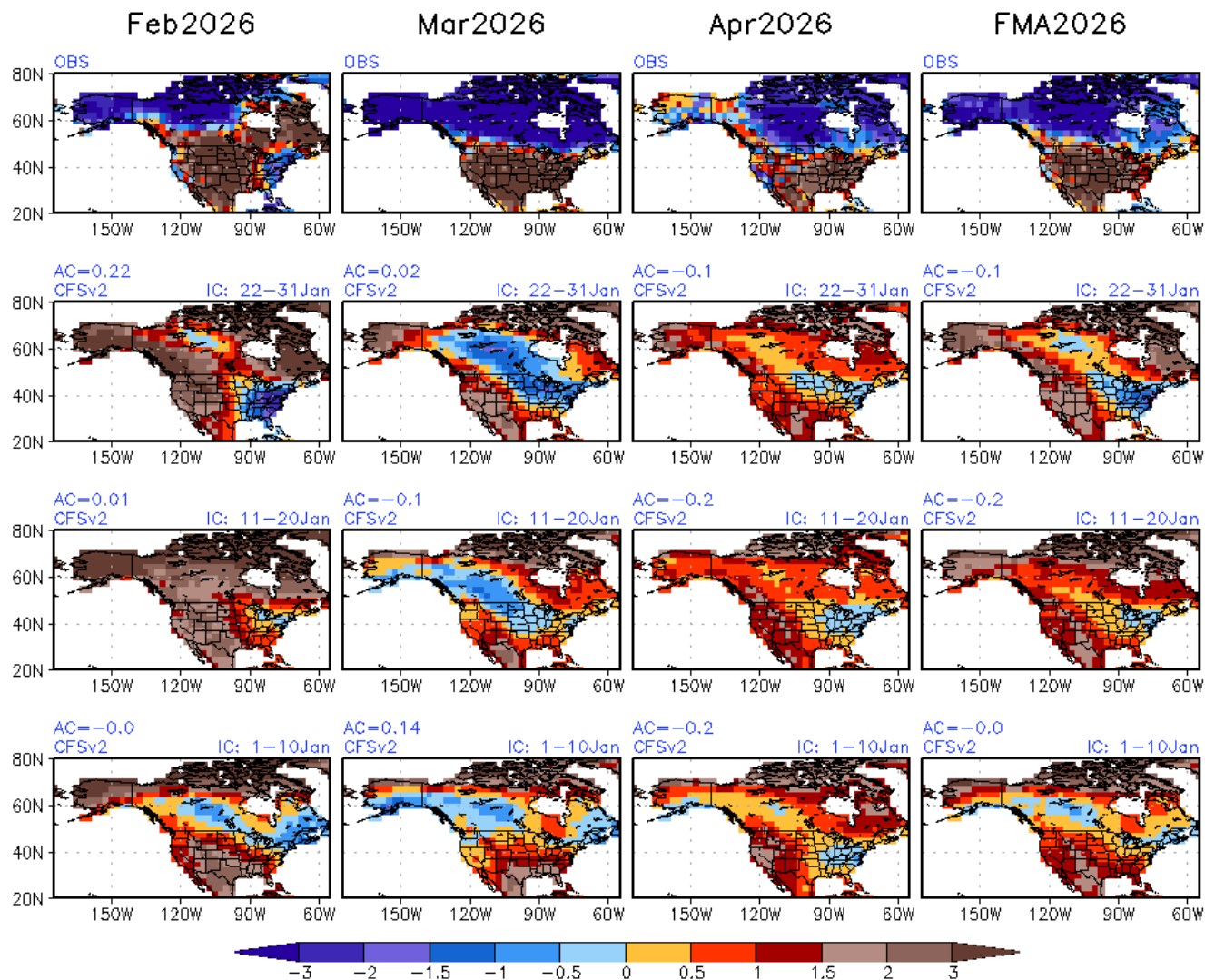
Top row: Observed anomaly.

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

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

T2m(k) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) FMA2026 T2m(K) & Obs



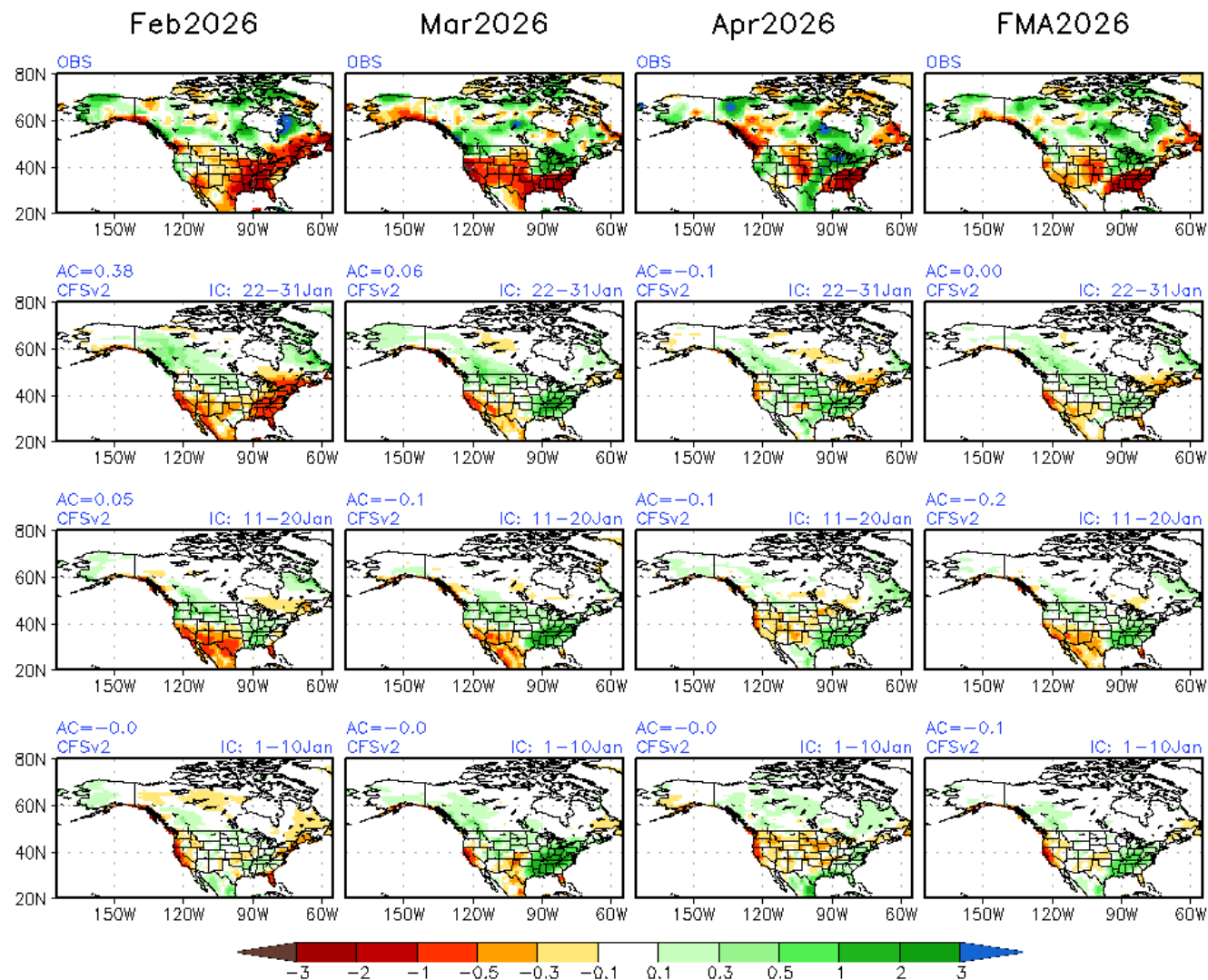
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Prec(mm/day) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) FMA2026 Prec(mm/day) & Obs



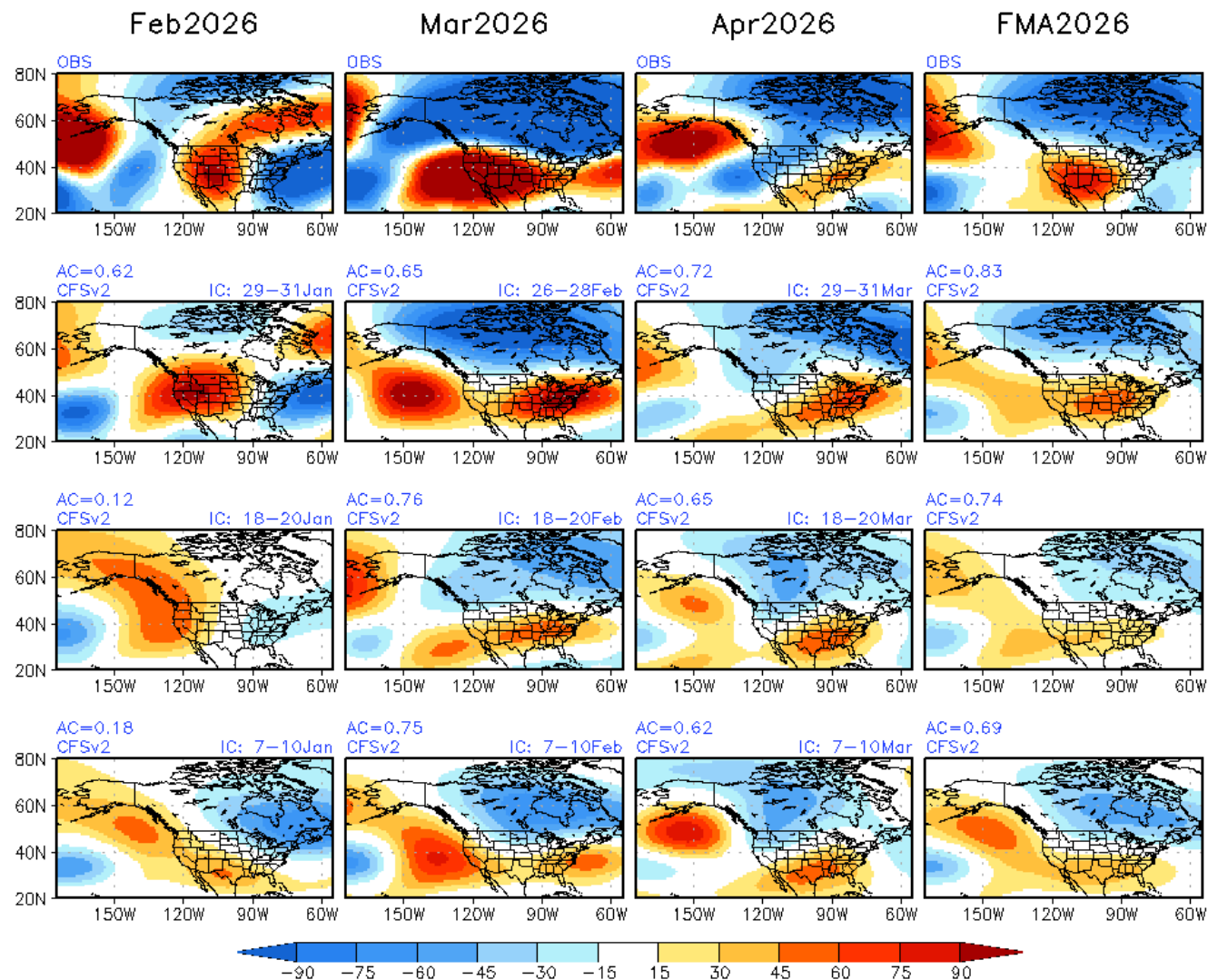
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z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst FMA2026 z200(m) eddy & Obs



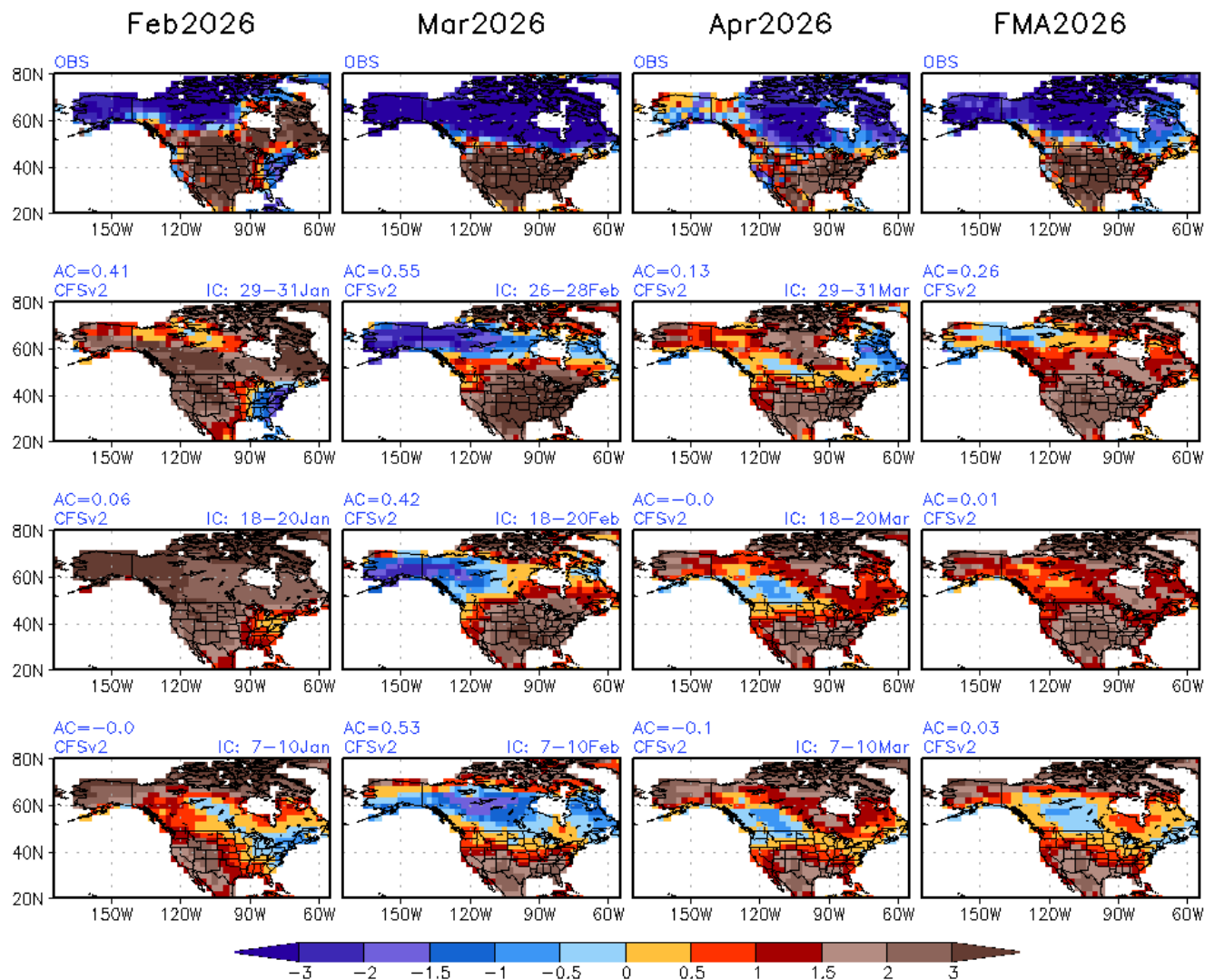
Top row: Observed anomaly.

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

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

T2m(k) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst FMA2026 T2m(K) & Obs



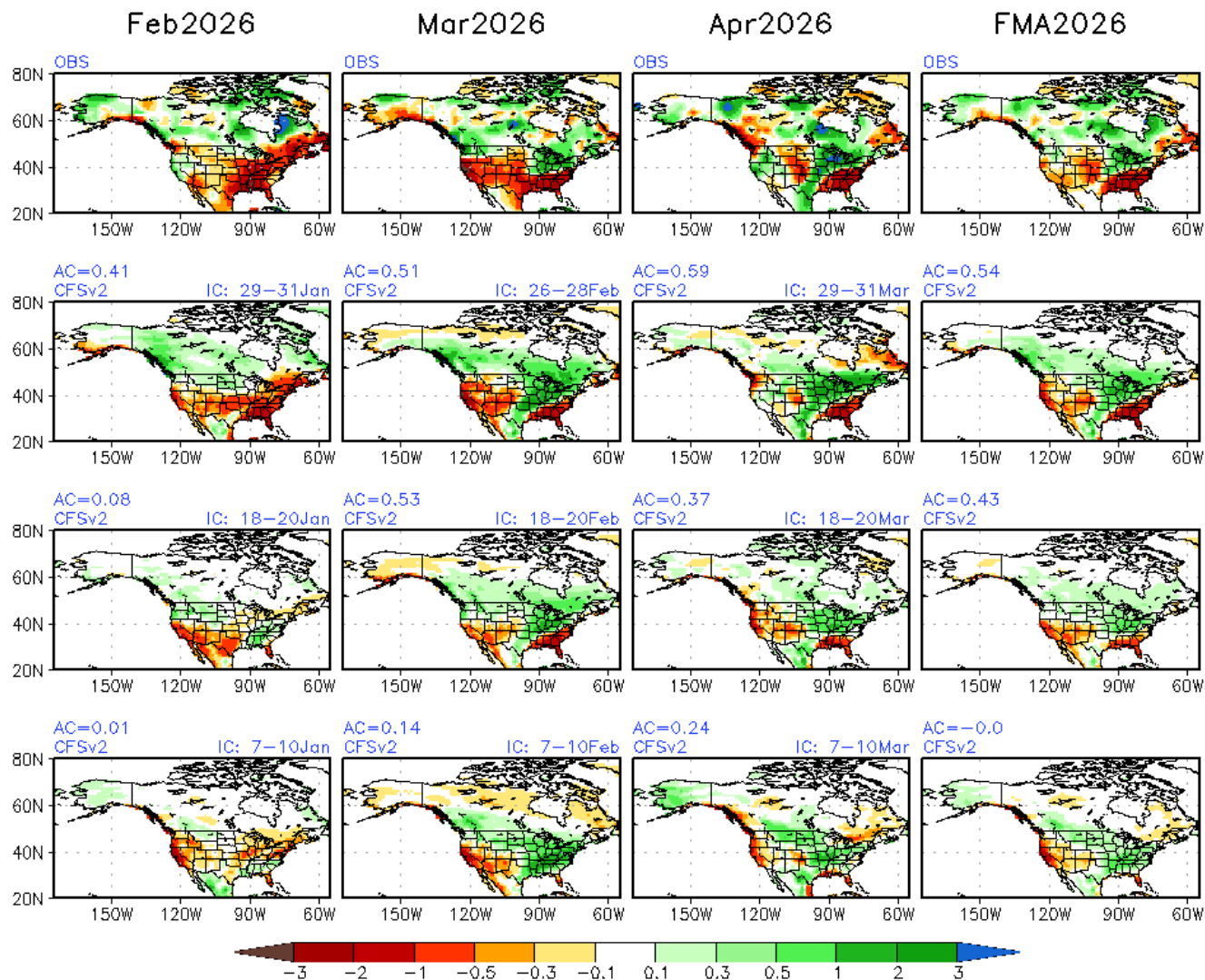
Top row: Observed anomaly.

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

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

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

Monthly Means from Monthly Fcst FMA2026 Prec(mm/day) & Obs



Top row: Observed anomaly.

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

- 2nd row: last 3 days of the prior month.
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- 4th row: 7th – 10th of the prior month.

Seasonal Forecasts from Multi-Model Ensemble Systems

- WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME).
<https://www.wmolc.org/>
- Copernicus Climate Change Service (C3S) Multi-model seasonal forecasts.
https://climate.copernicus.eu/charts/c3s_seasonal/
- North American Multi-Model Ensemble (NMME) seasonal forecasts.
<https://www.cpc.ncep.noaa.gov/products/NMME/>

LC-LRFMM Seasonal Forecasts

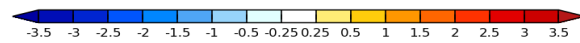
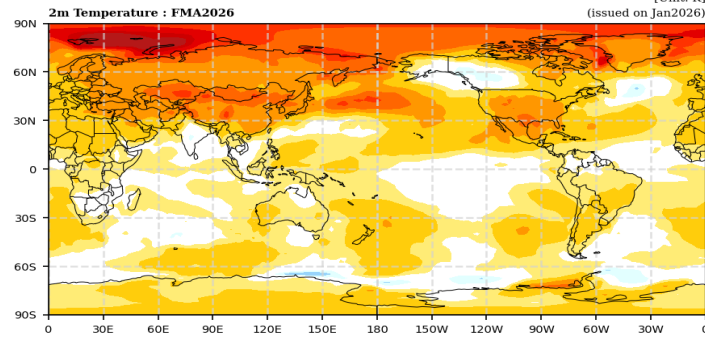
(<https://www.wmolc.org/>)

Ensemble means

Simple Composite Map

CMCC, CPTeC, ECMWF, Exeter, Melbourne, Montreal, Moscow, Offenbach, Seoul, Tokyo, Toulouse, Washington

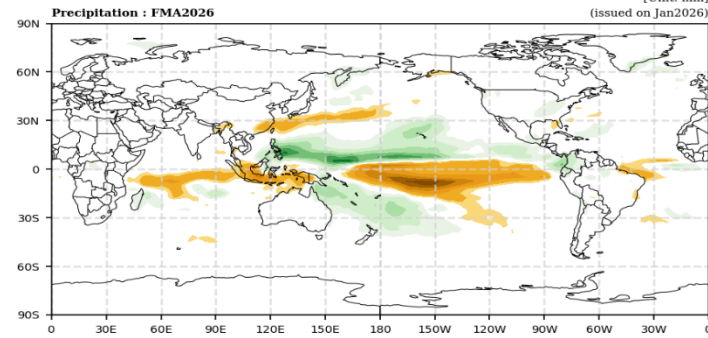
[Unit: K]
(issued on Jan2026)



Simple Composite Map

CMCC, CPTeC, ECMWF, Exeter, Melbourne, Montreal, Moscow, Offenbach, Seoul, Tokyo, Toulouse, Washington

[Unit: mm]
(issued on Jan2026)

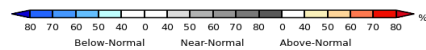
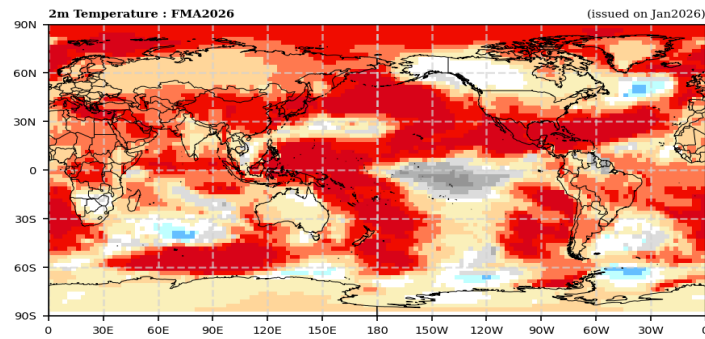


Probabilities

Probabilistic Multi-Model Ensemble Forecast

CMCC, CPTeC, ECMWF, Exeter, Melbourne, Montreal, Moscow, Offenbach, Seoul, Tokyo, Toulouse, Washington

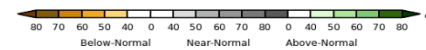
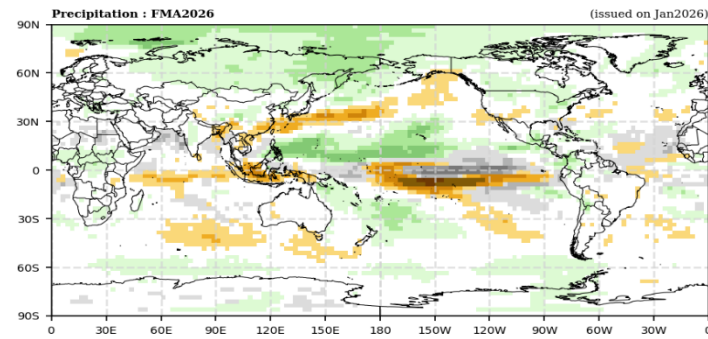
(issued on Jan2026)



Probabilistic Multi-Model Ensemble Forecast

CMCC, CPTeC, ECMWF, Exeter, Melbourne, Montreal, Moscow, Offenbach, Seoul, Tokyo, Toulouse, Washington

(issued on Jan2026)



C3S Seasonal Forecast

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

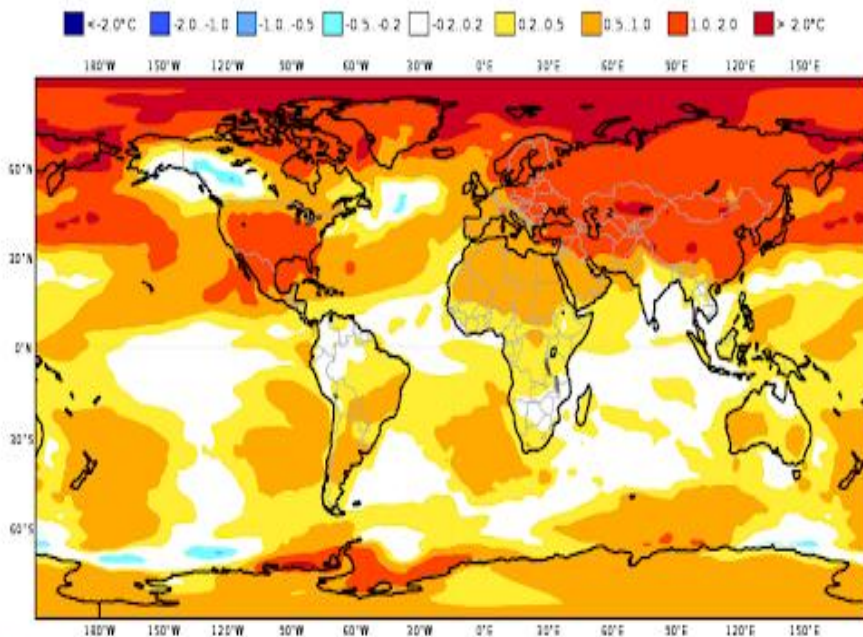
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Mean 2m temperature anomaly

FMA 2026

Nominal forecast start: 01/01/26

Variance-standardized mean



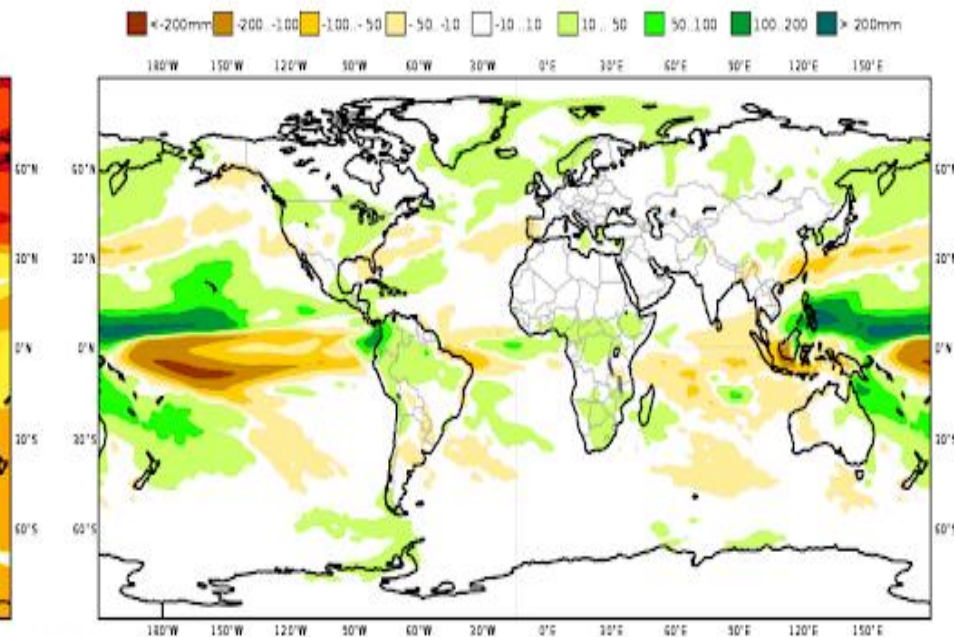
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Mean precipitation anomaly

FMA 2026

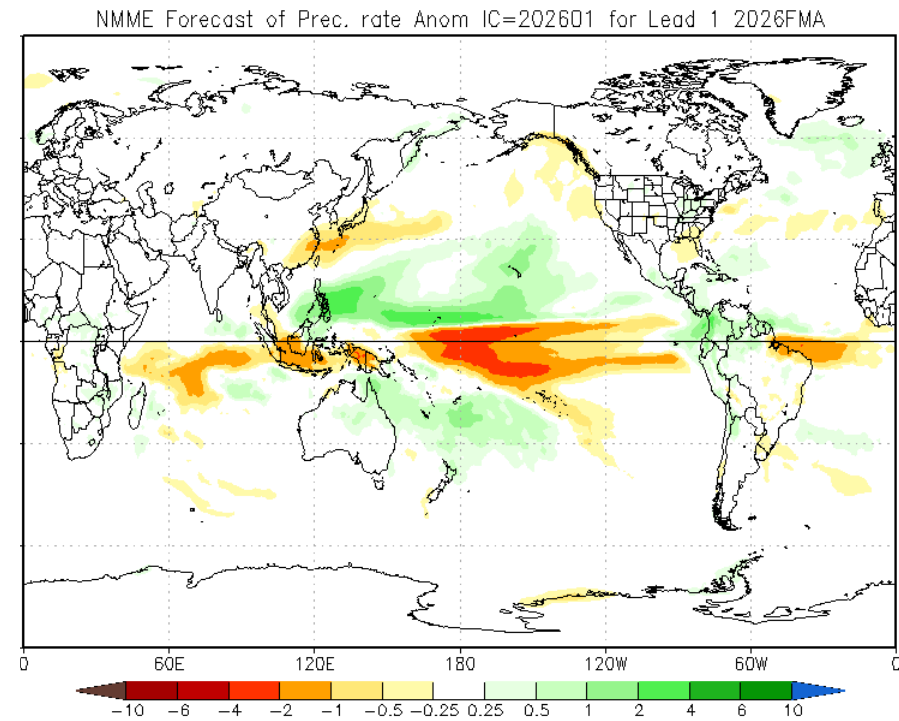
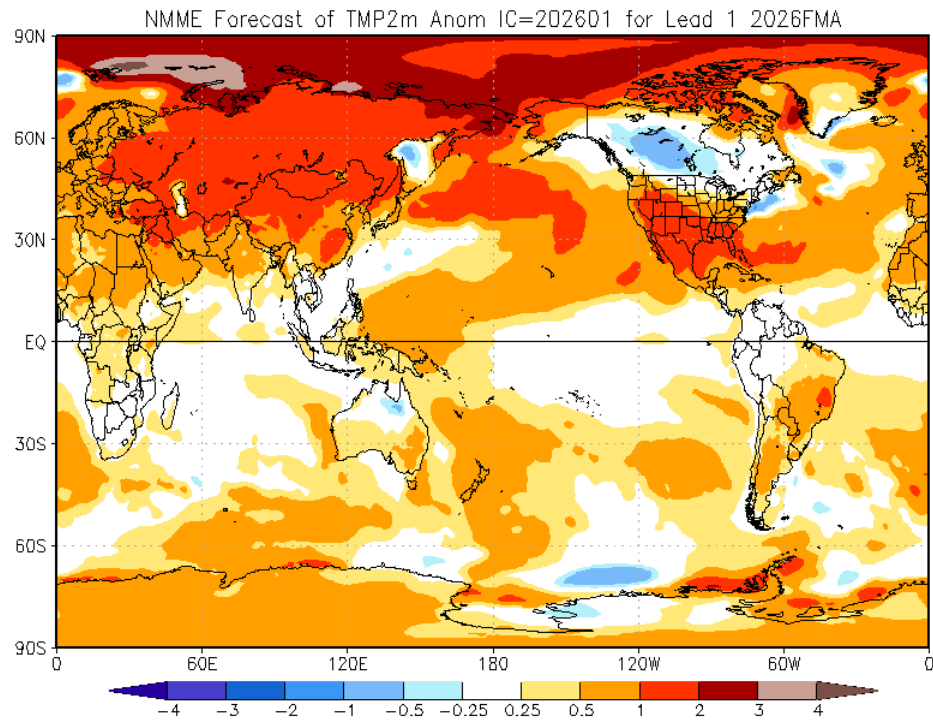
Nominal forecast start: 01/01/26

Variance-standardized mean



North American Multi-Model Ensemble Seasonal Forecast

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



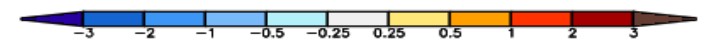
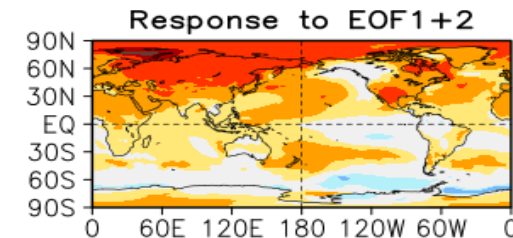
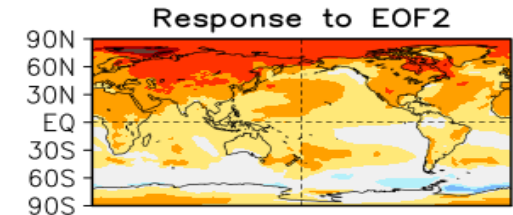
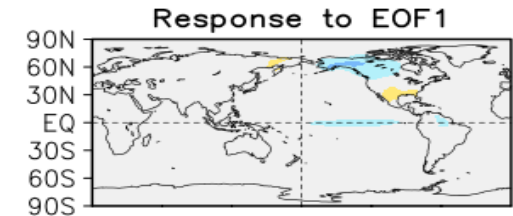
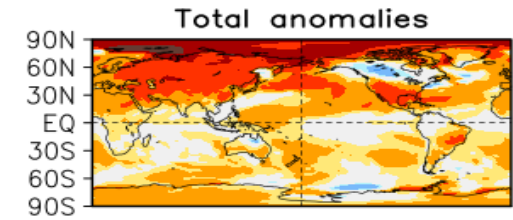
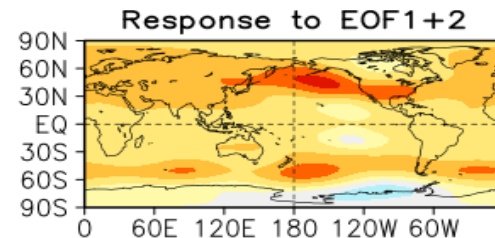
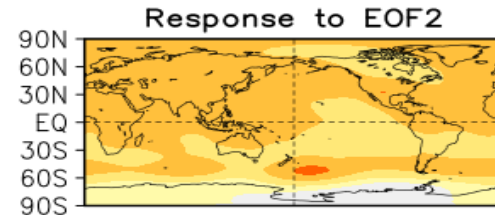
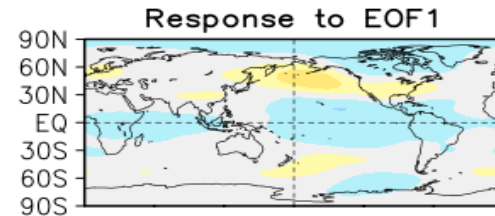
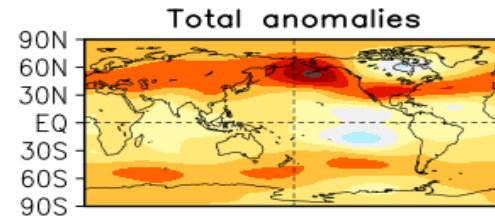
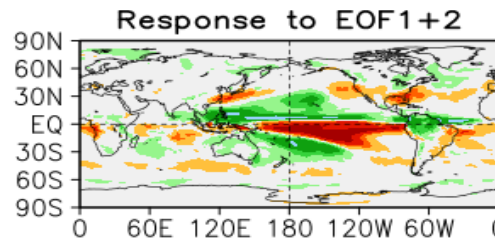
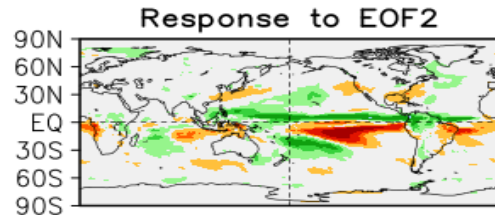
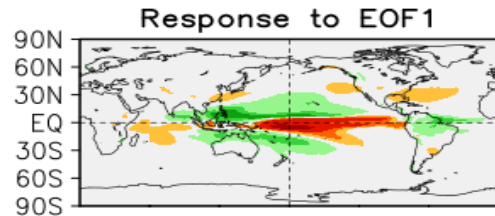
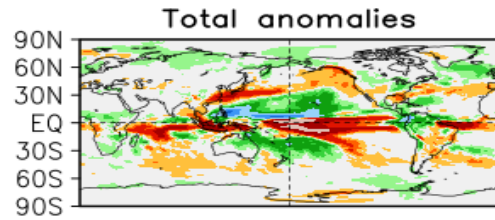
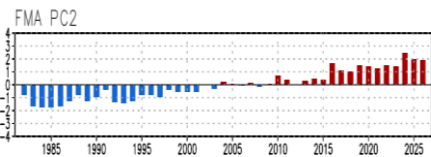
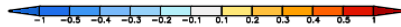
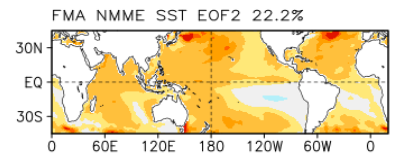
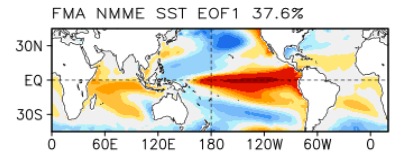
NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME FMA2026 Forecast from Jan2026 Initial Conditions

Prec(mm/day)

Z200(m)

T2m(k)



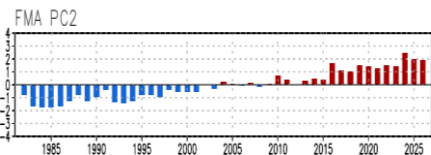
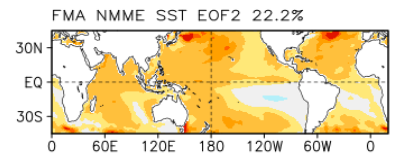
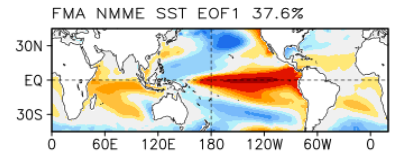
NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME FMA2026 Forecast from Jan2026 Initial Conditions

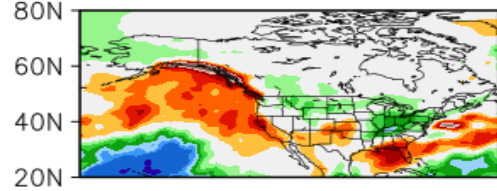
Prec(mm/day)

Z200(m)

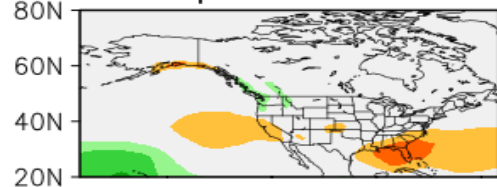
T2m(k)



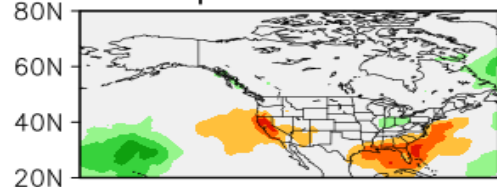
Total anomalies



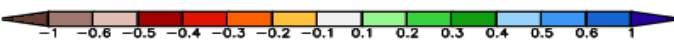
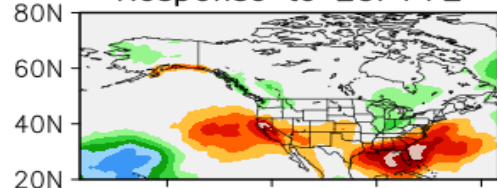
Response to EOF1



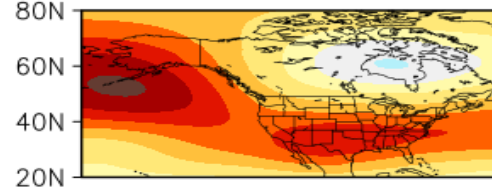
Response to EOF2



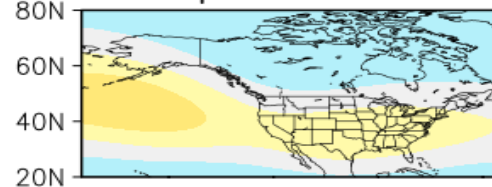
Response to EOF1+2



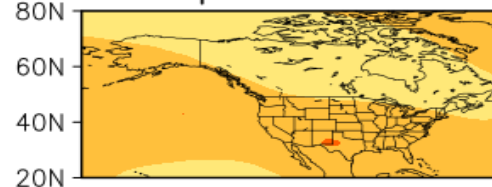
Total anomalies



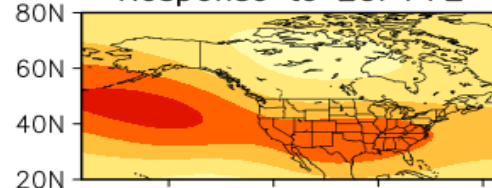
Response to EOF1



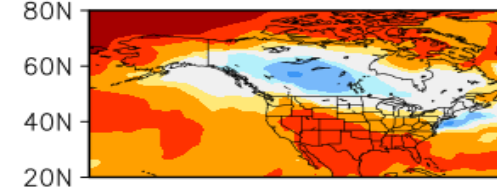
Response to EOF2



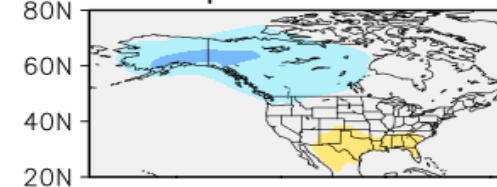
Response to EOF1+2



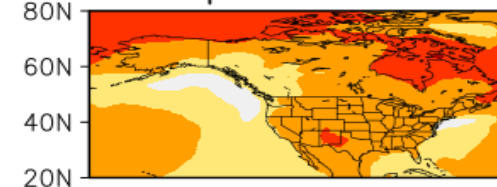
Total anomalies



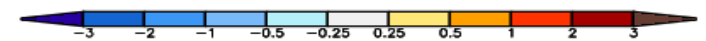
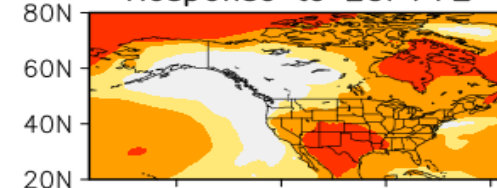
Response to EOF1



Response to EOF2



Response to EOF1+2



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.