

Attribution of Seasonal Climate Anomalies July-August-September 2025

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

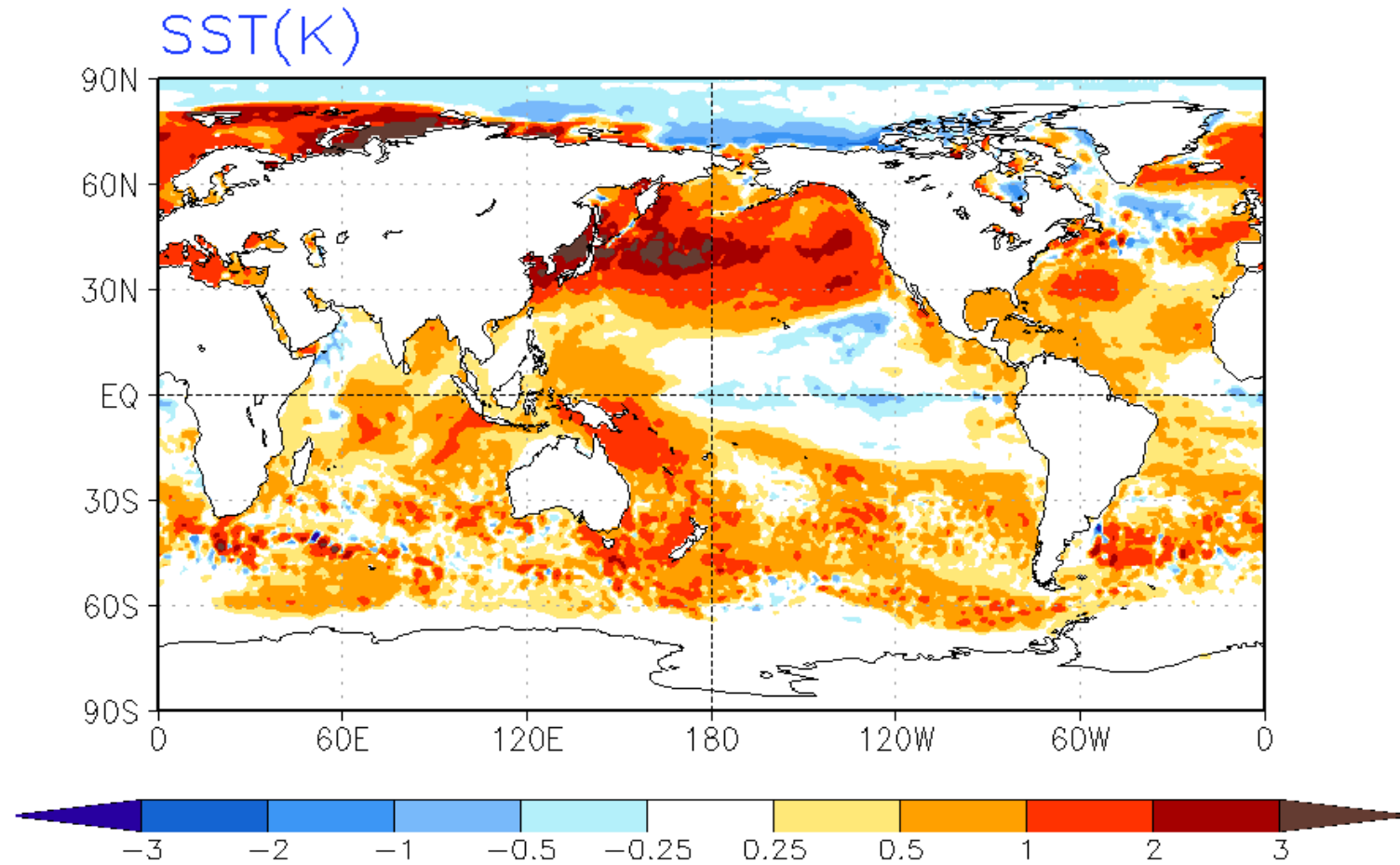
Summary of Observed Conditions and Outlooks

- Similar to JJA2025, SSTs negative anomalies in JAS2025 were slightly enhanced over the equatorial eastern Pacific, with an east-to-west SST gradient characteristic of La Niña persisting. Warm anomalies remained in the northern and southern Pacific, the Indian Ocean, and both sides of the Atlantic (Slide 4).
- CFSv2 reasonably captured the large-scale SST anomaly patterns, though it exhibited slight mixed warm and cold biases over the tropical oceans (slide 10).
- CFSv2 and MME forecasts were able to capture parts of the large-scale precipitation anomaly pattern across the tropics, notably enhanced rainfall over the Maritime Continent and tropical western Pacific, and reduced rainfall over the tropical central to eastern Pacific (Slide 11, 37-39).
- Despite only weak cold SST anomalies in the central Pacific, models produced a [canonical La Nina response](#), likely due to the contrast with widespread background ocean warming.
- All CFSv2 and MME forecasts captured the overall warming trend in land surface temperature but failed to reproduce the observed cold anomalies over the northern parts of North America and from southwest to southern US (Slides 13, 37–39). In particular, CFSv2's 200-mb height forecasts missed the negative height anomalies that extended from the polar region to northern Asia and from northeastern North America to the Labrador Sea, as well as those over the southwestern to southern U.S., likely contributing to the surface temperature errors (Slides 12, 13, 15, 16).
- **A new attribution analysis shows that the NMME's forecast atmospheric anomalies are mainly contributed from the responses to the forecast SST warming trend mode (slides 40, 41).**
- CFSv2 also failed to capture most of the observed precipitation anomalies over North America (slide 14).
- However, in September 2025, forecast skill improved for precipitation at the shortest lead time (slides 35).

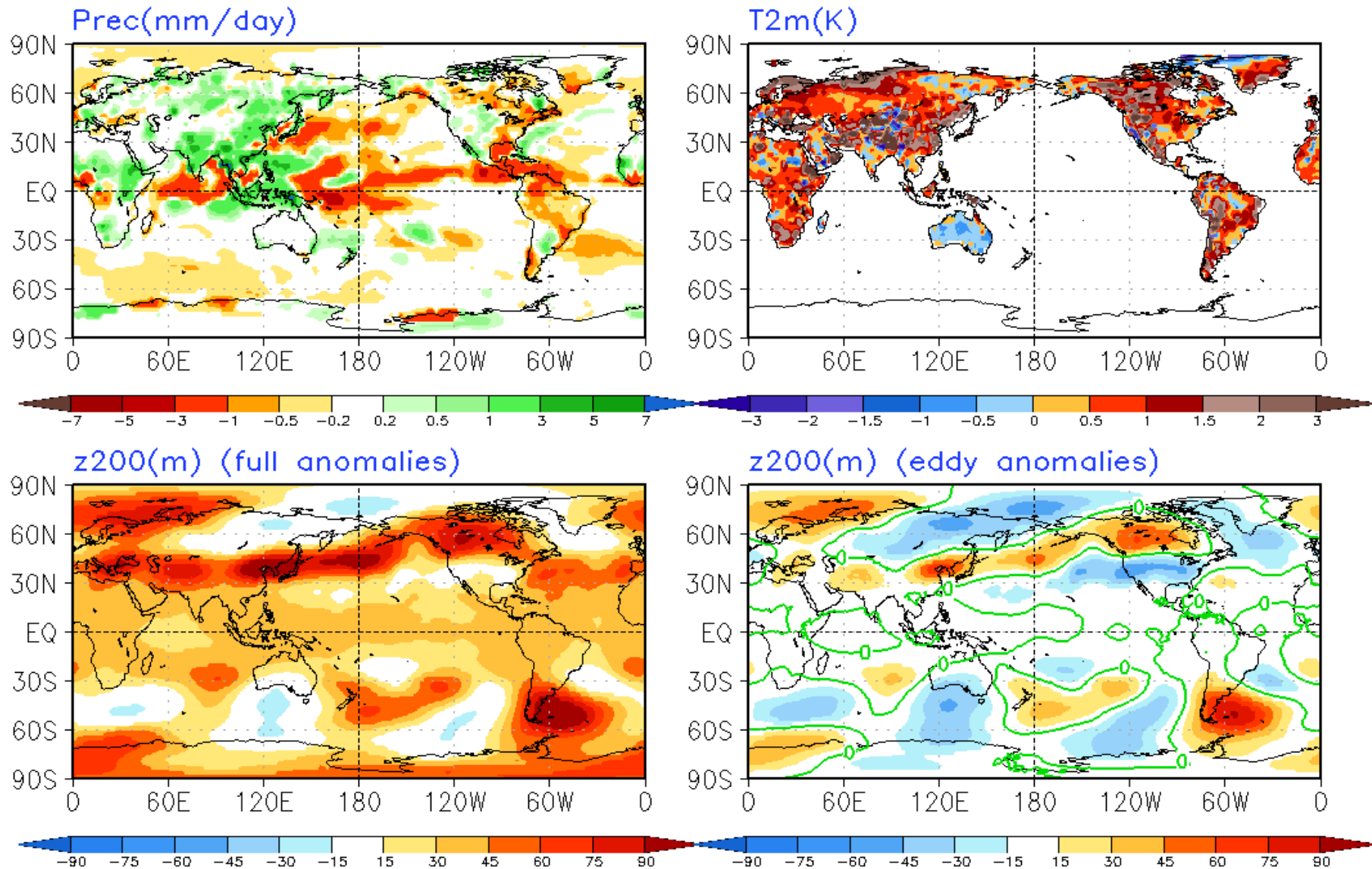
Observed Seasonal Anomalies

Global and North America

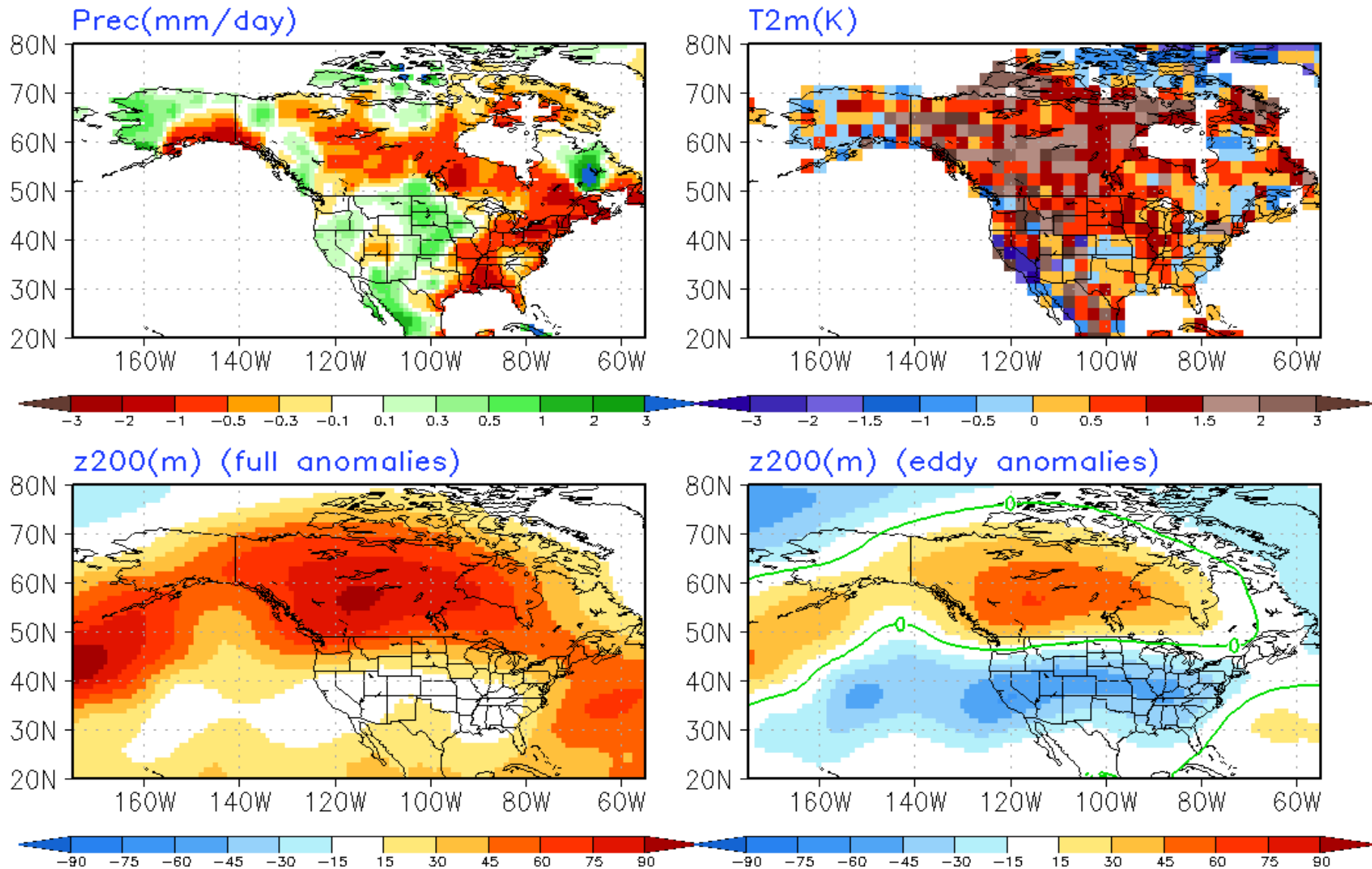
Observed Anomaly JAS2025



Observed Anomaly JAS2025



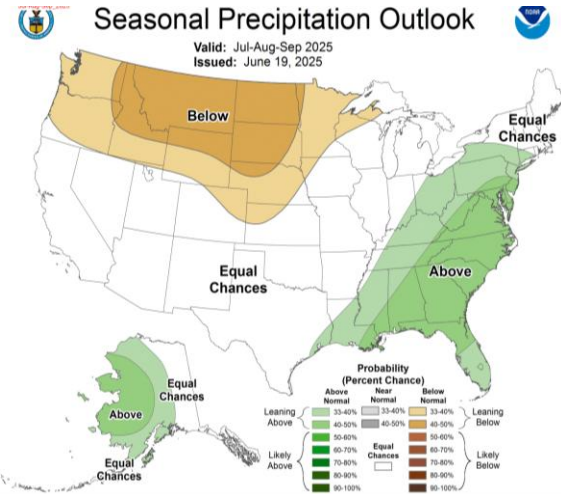
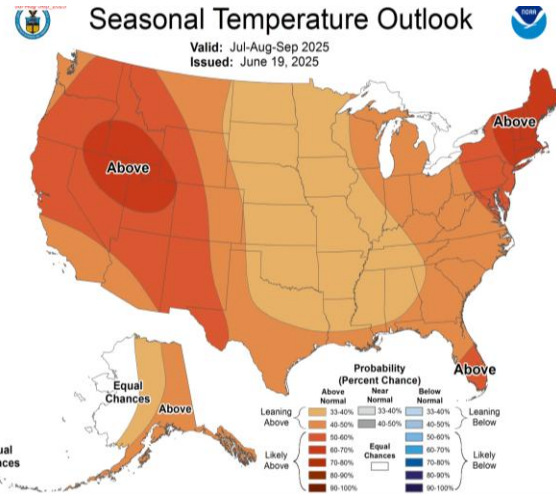
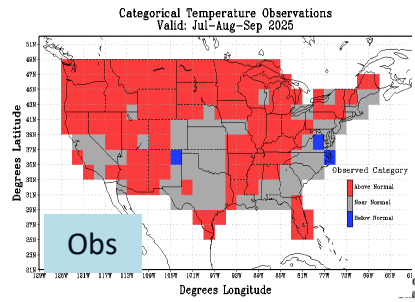
Observed Anomaly JAS2025



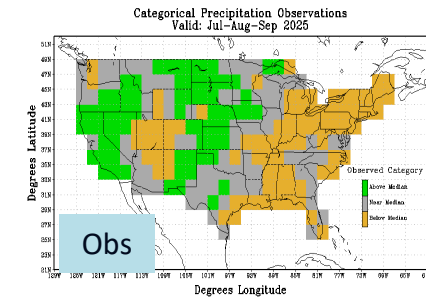
CPC Seasonal Outlooks and NMME Forecasts

CPC

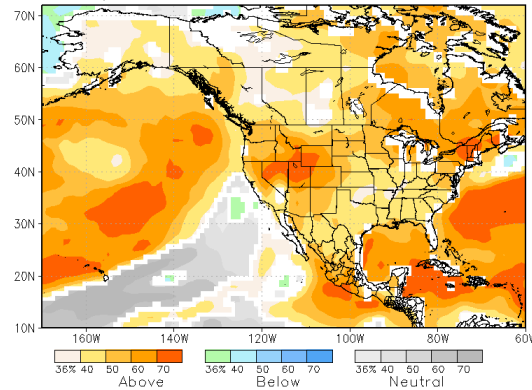
Temp nonEC
HSS=52



Prec nonEC
HSS=-41

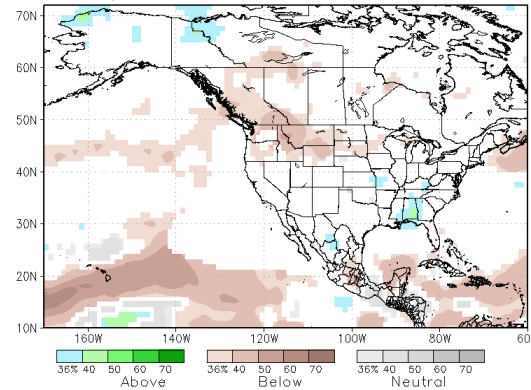


NMME prob fest TMP2m IC=202506 for lead 1 2025 JAS



NMME

NMME prob fest Prate IC=202506 for lead 1 2025 JAS



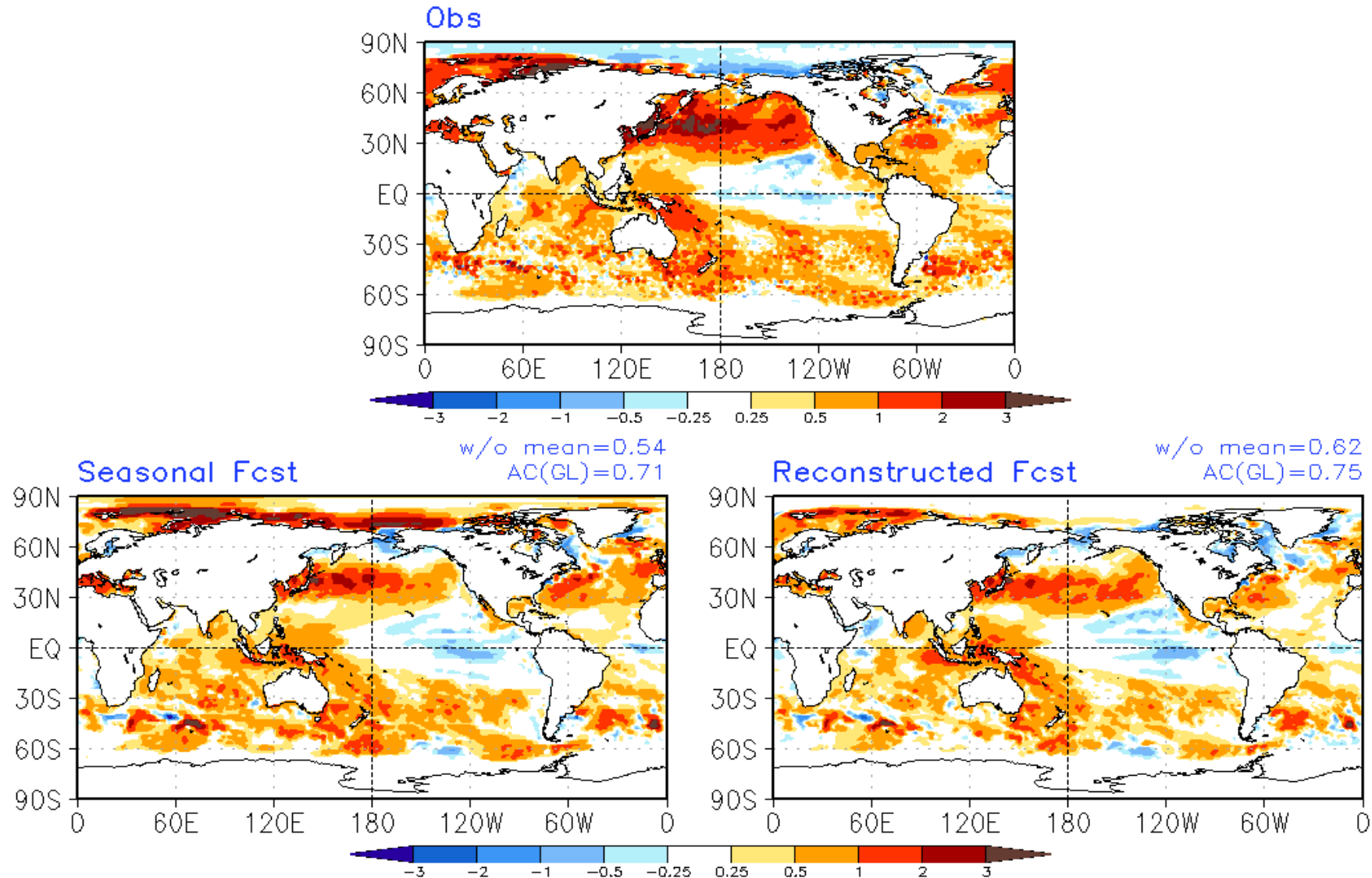
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2025/202506_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

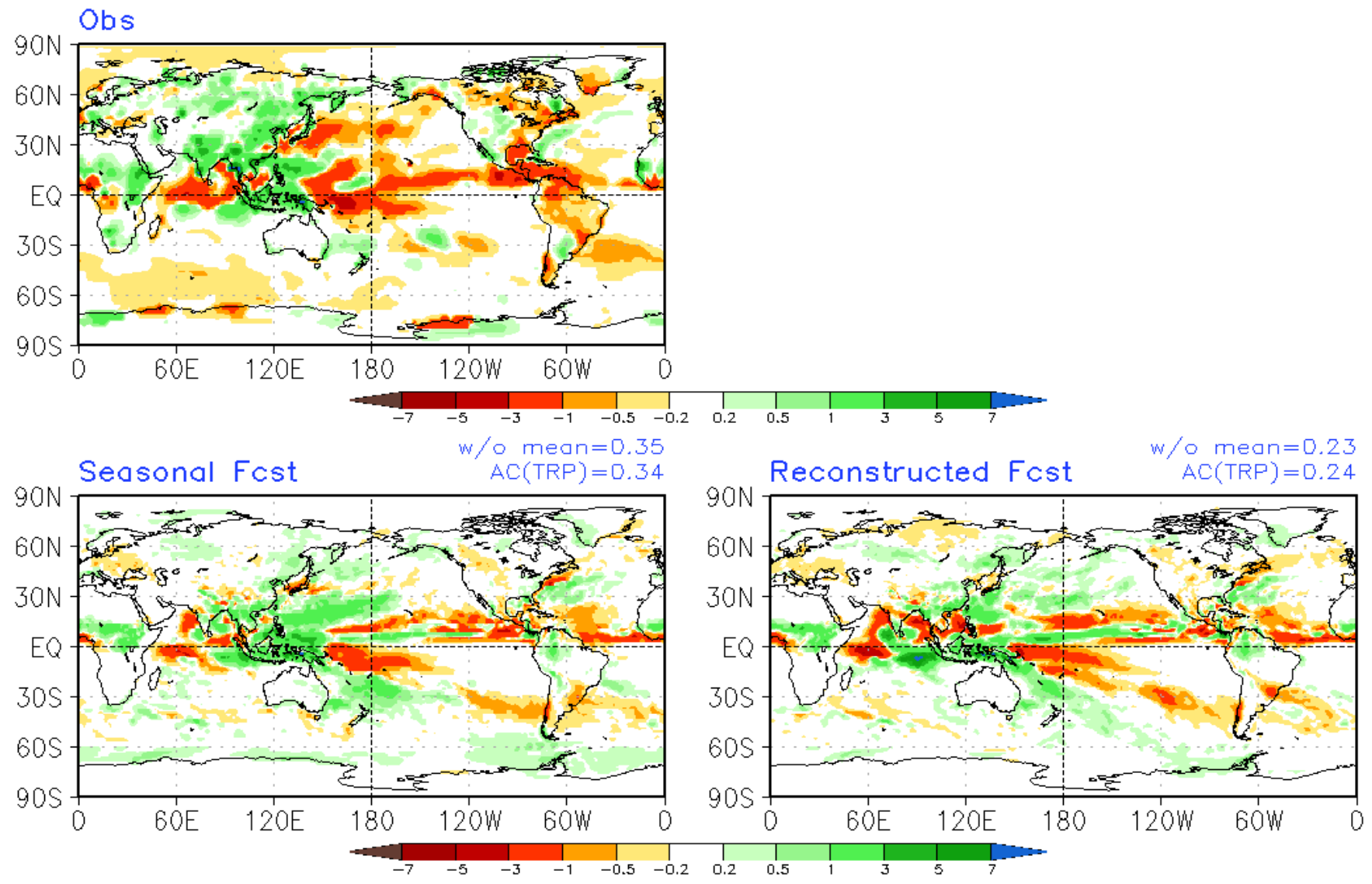
Model Simulated/Forecast Ensemble Average Anomalies

- **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.

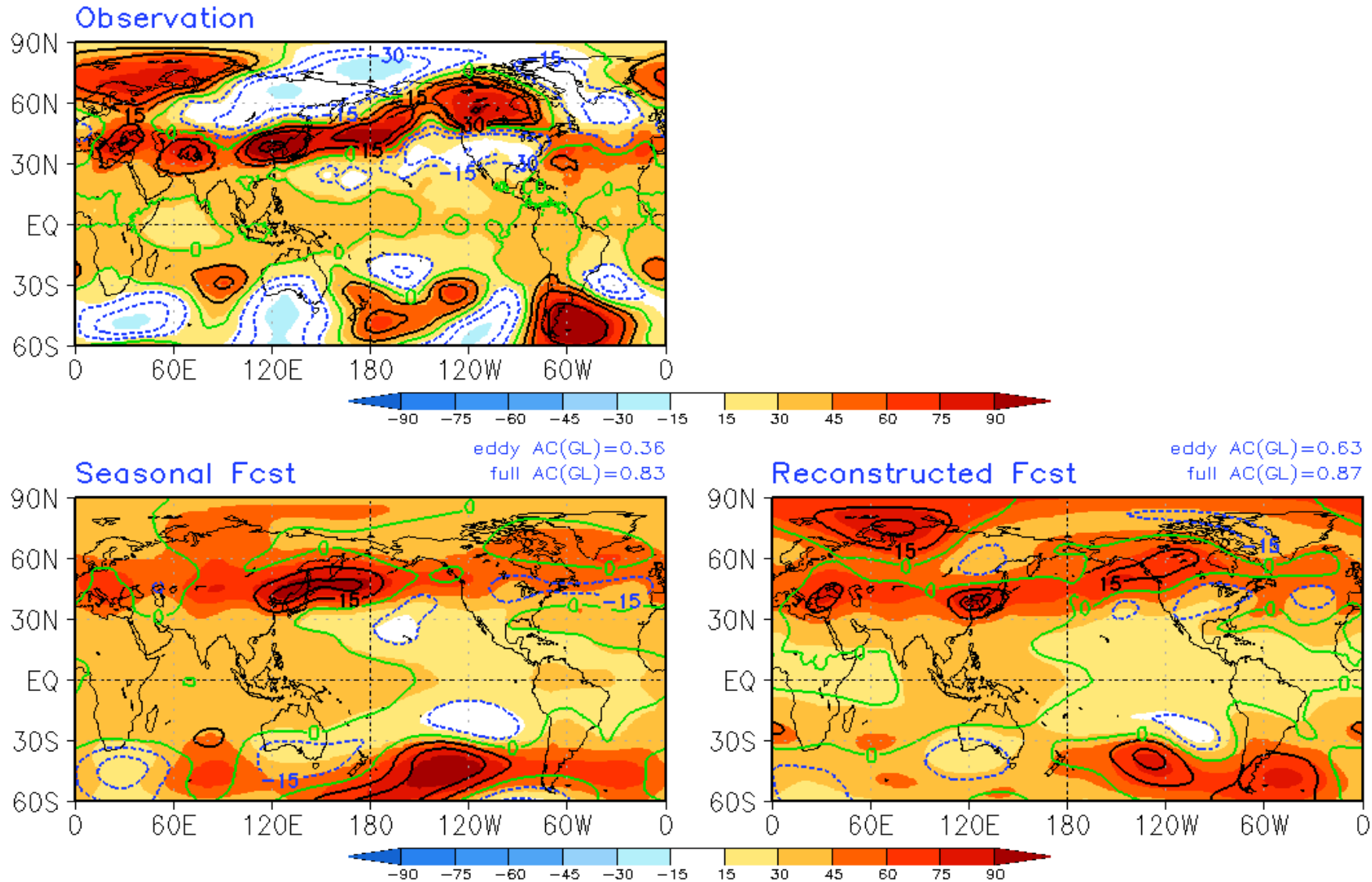
JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



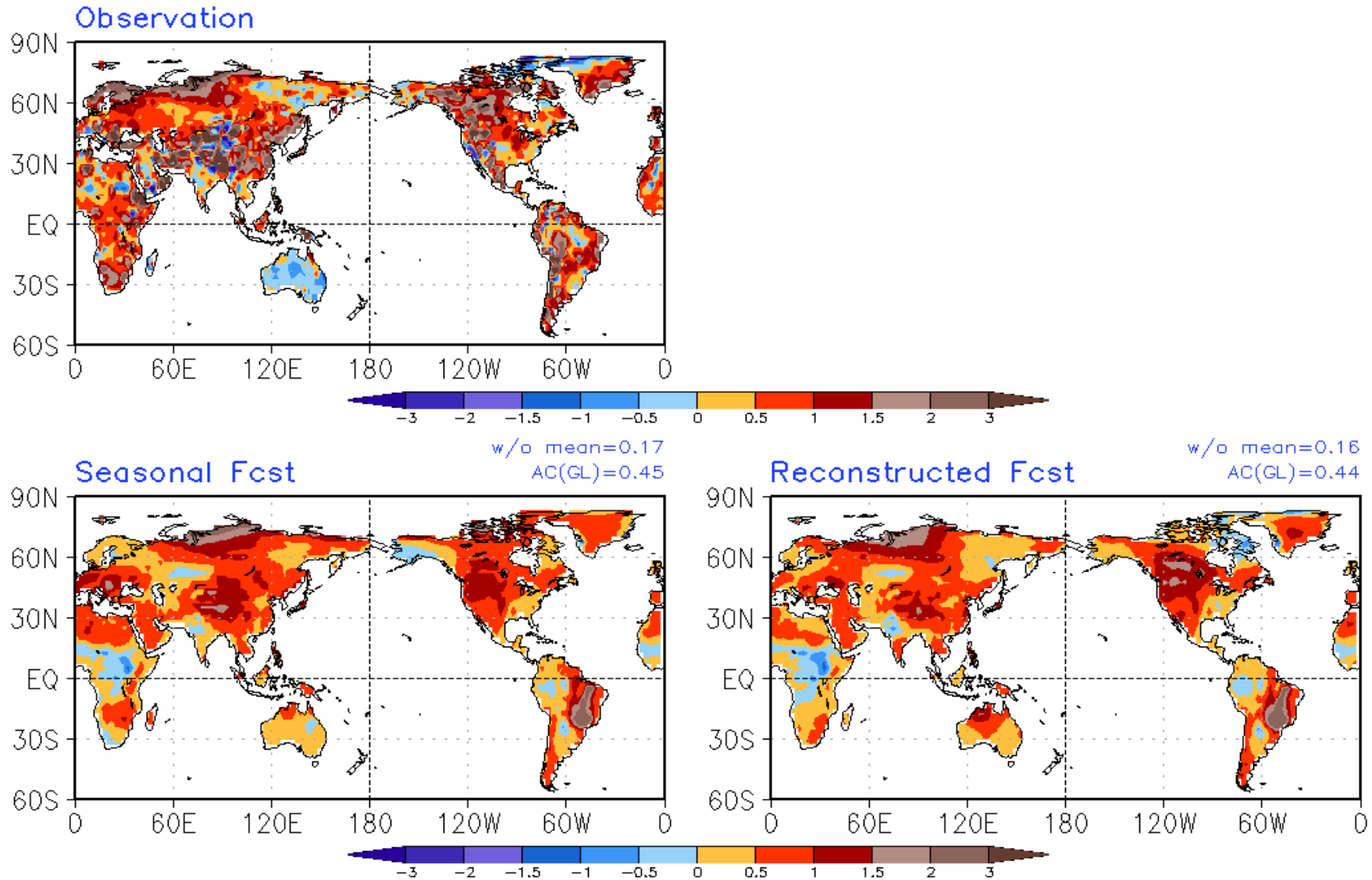
JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



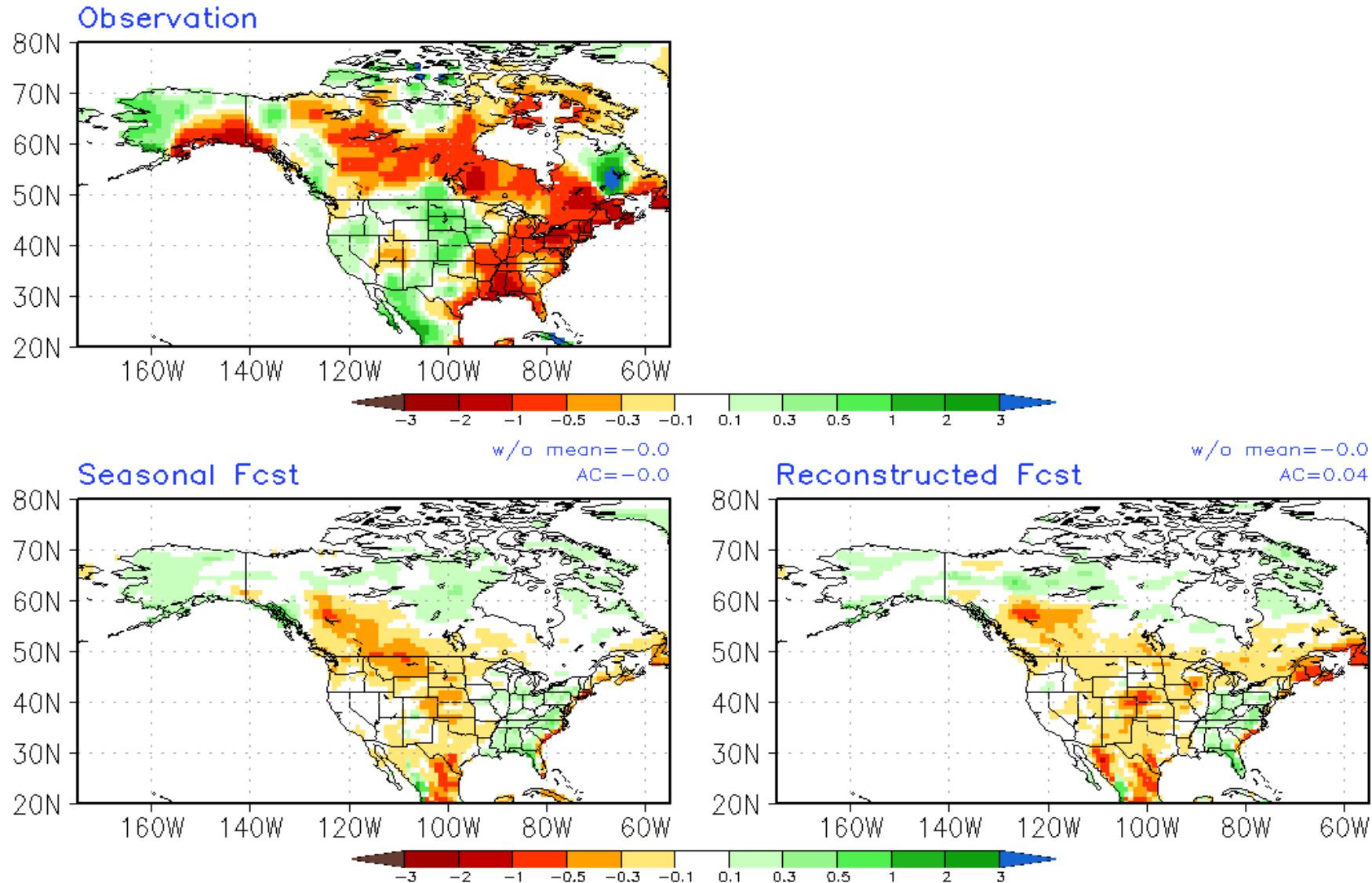
JAS2025 Observed & Model Simulated/Forecast
Ensemble Average Anomalies z200(m)
(full anomalies: shaded; eddy anomalies: contours)



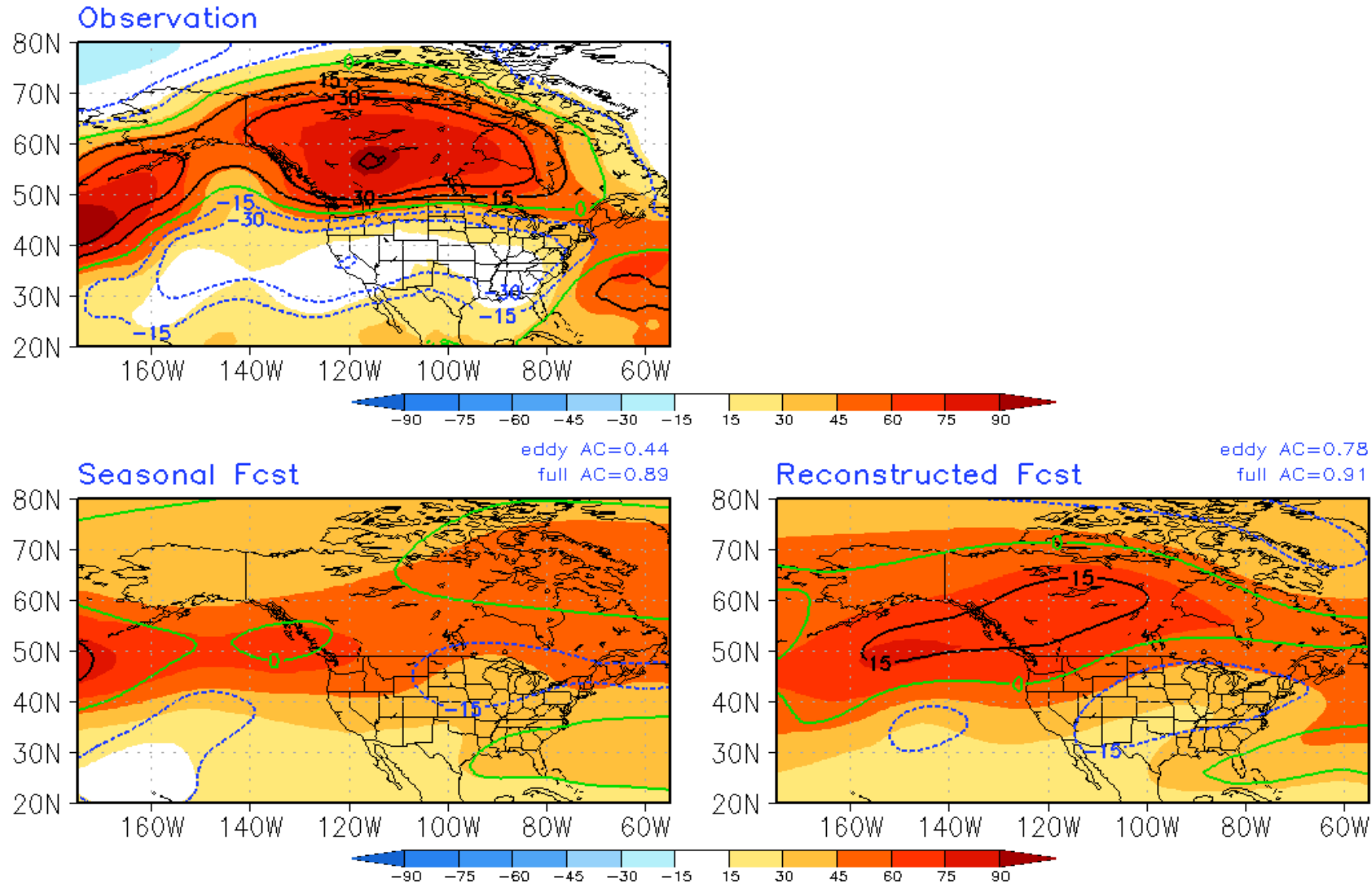
JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



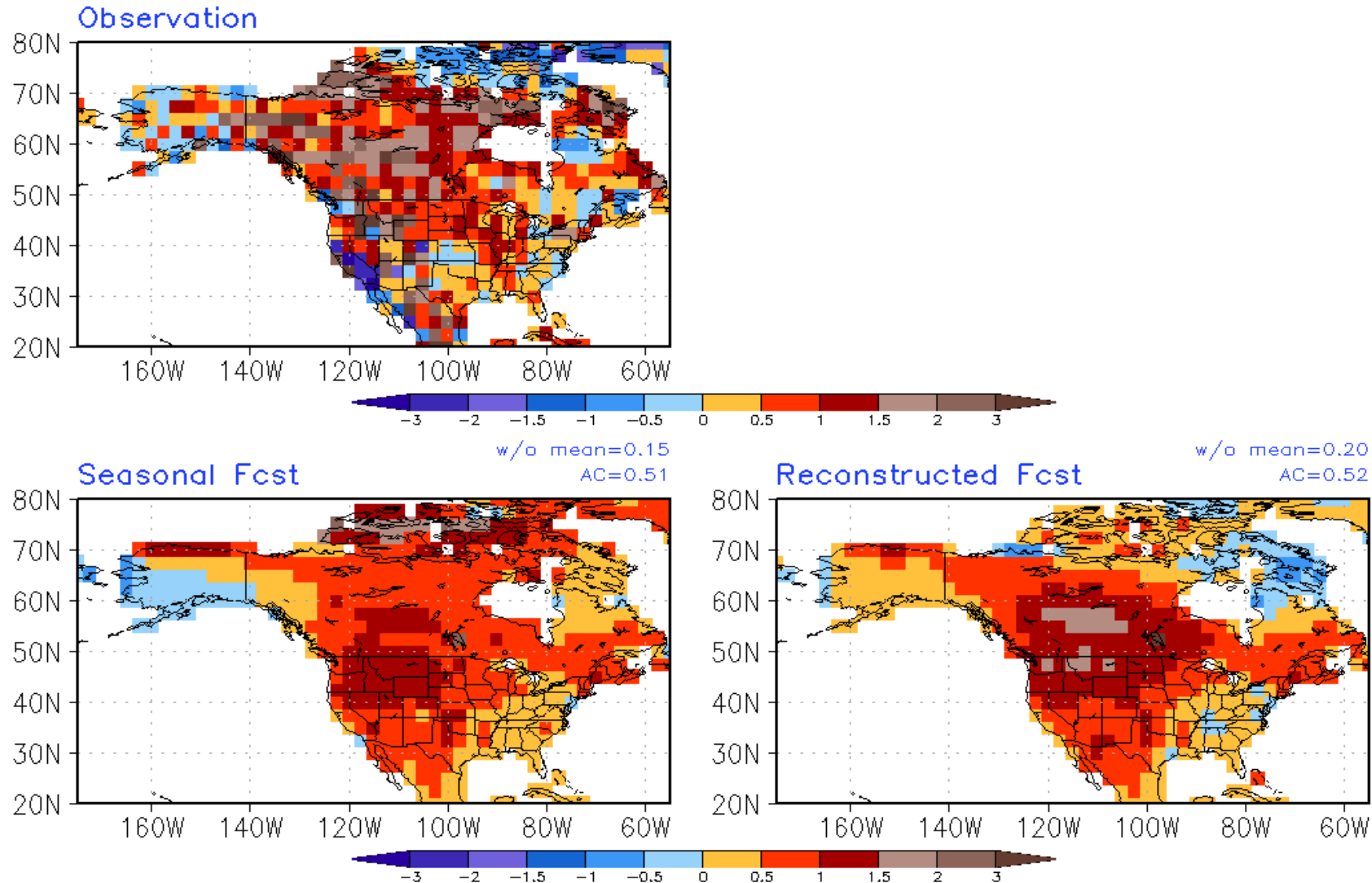
JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m) (full anomalies: shaded; eddy anomalies: contours)



JAS2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



Model Simulated/Forecast Anomalies: Individual Runs

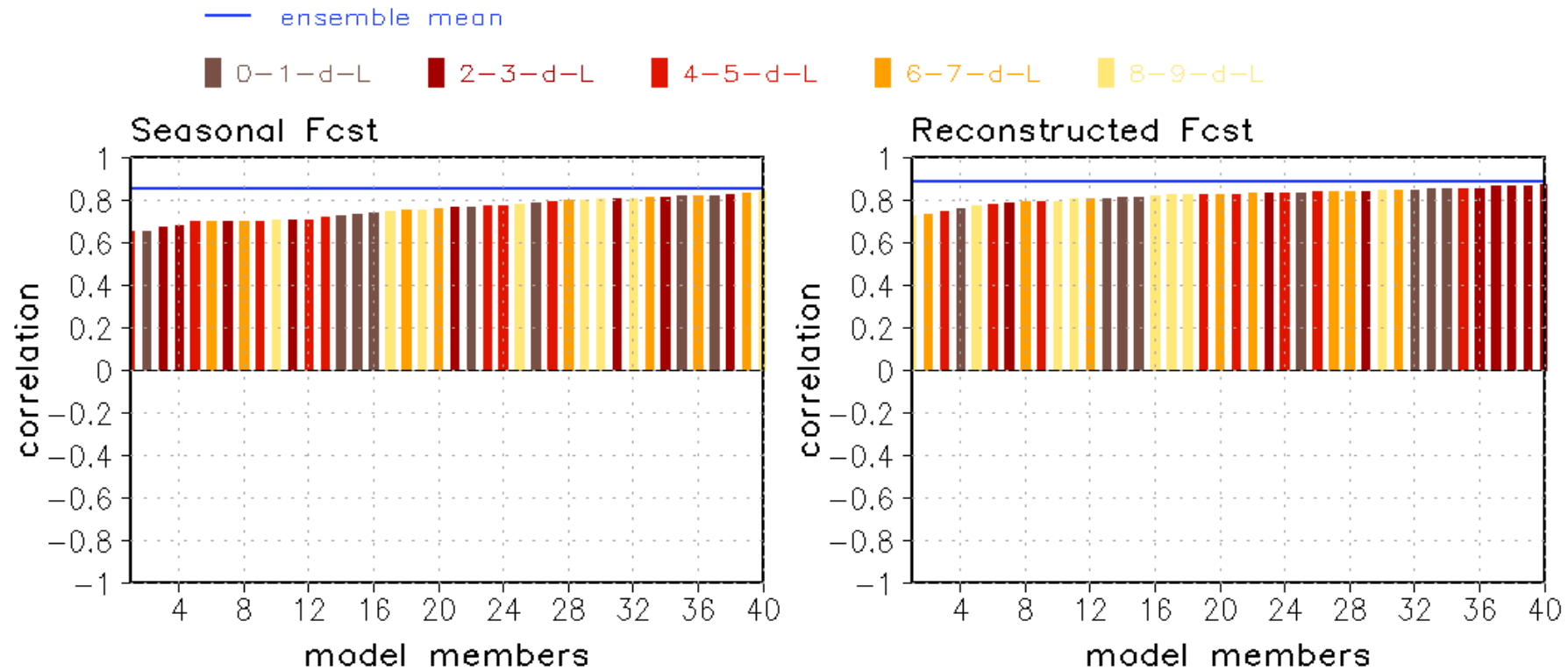
Model Simulated/Forecast Anomalies: Individual Runs

- 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).

JAS2025 Anomaly Correlation for Individual AMIP Simulation
with Observation -- z200(20N-90N)

Observed & AMIP Ensemble Mean Anomalies
JAS2025 z200(m) 100 runs/worst 4 runs/best 4 runs
(full anomalies: shaded; eddy anomalies: contours)

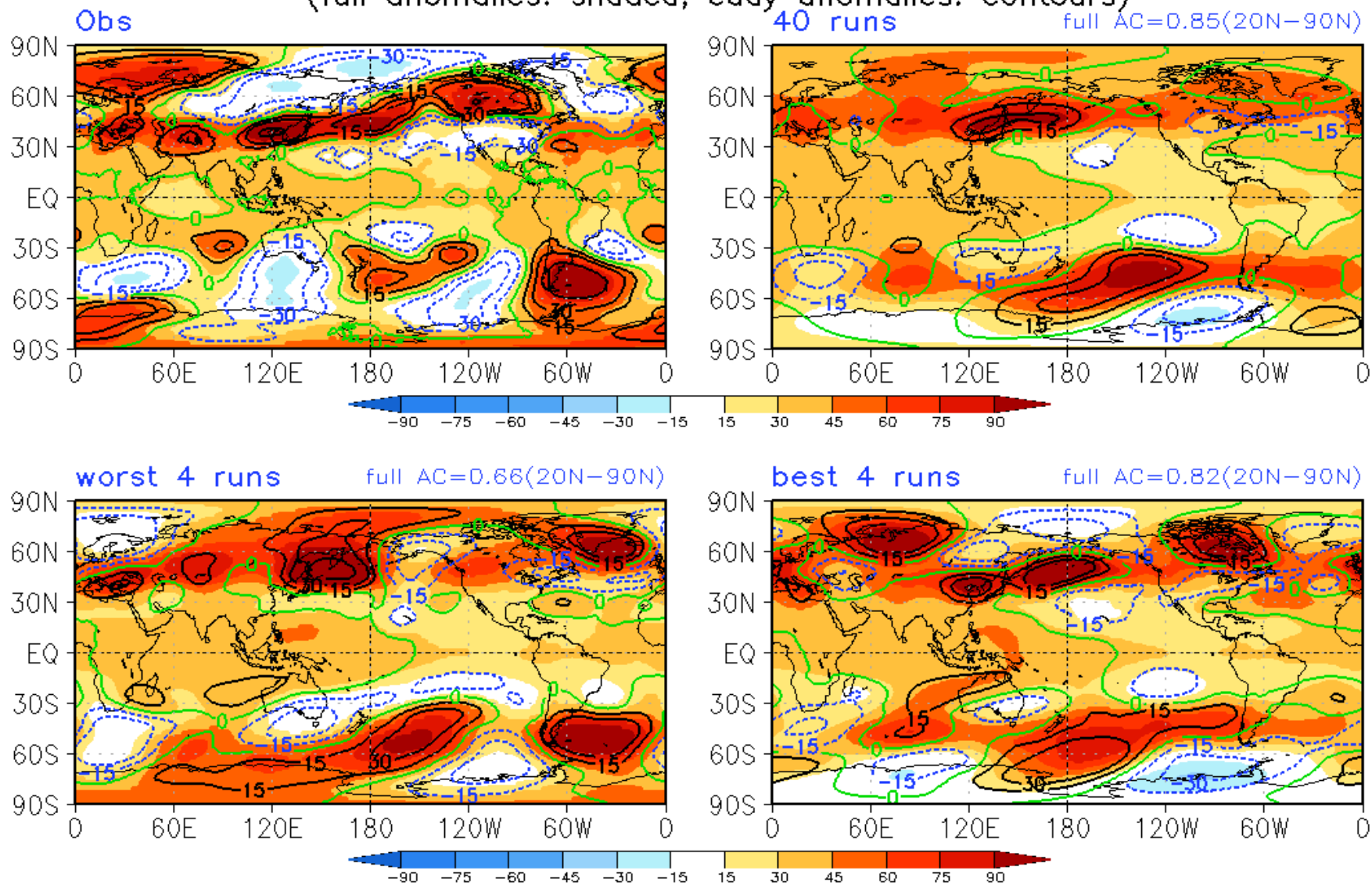
JAS2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 z200(m) 40 runs/worst 4 runs/best 4 runs

Seasonal Forecast

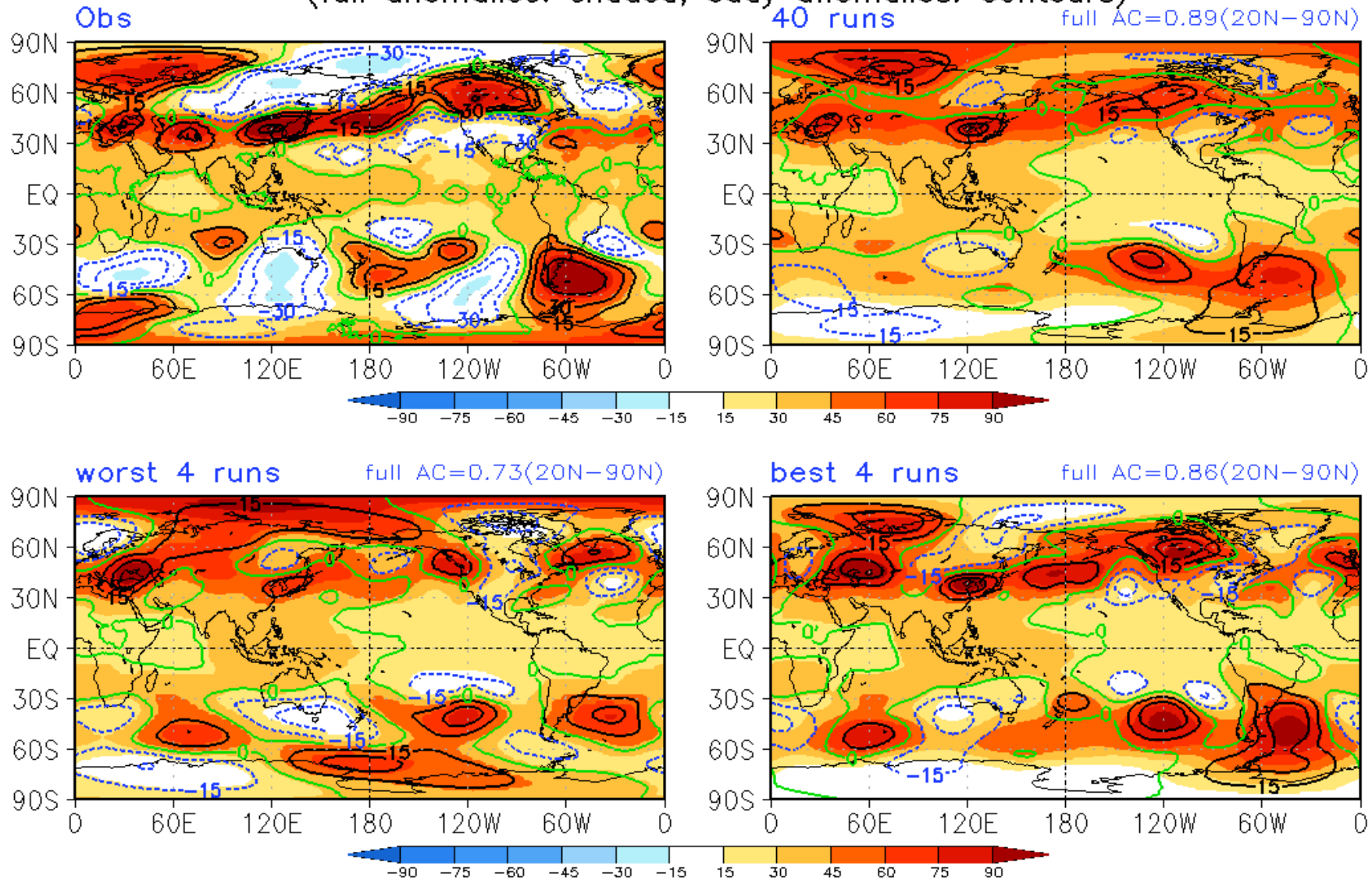
(full anomalies: shaded; eddy anomalies: contours)



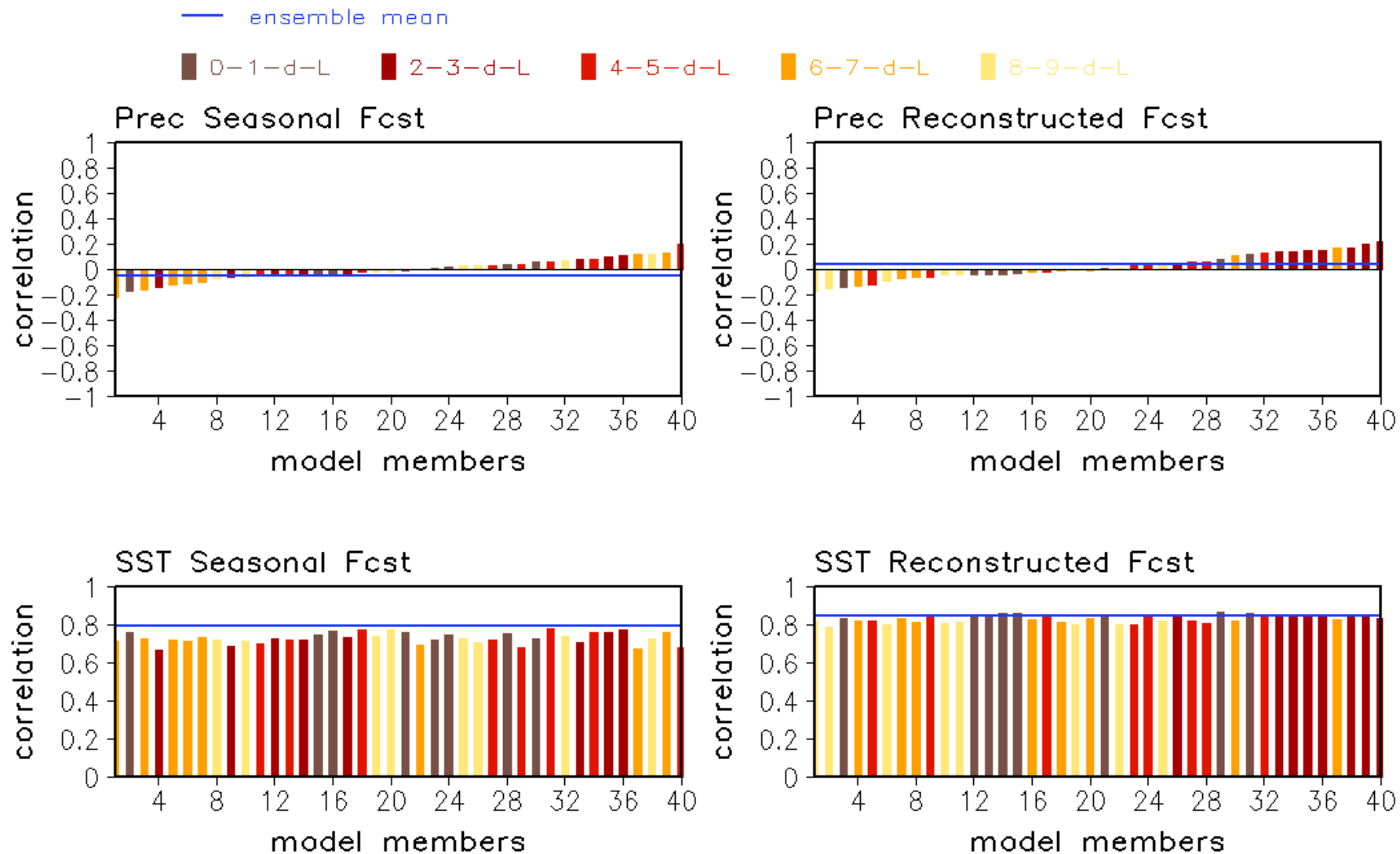
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 z200(m) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast

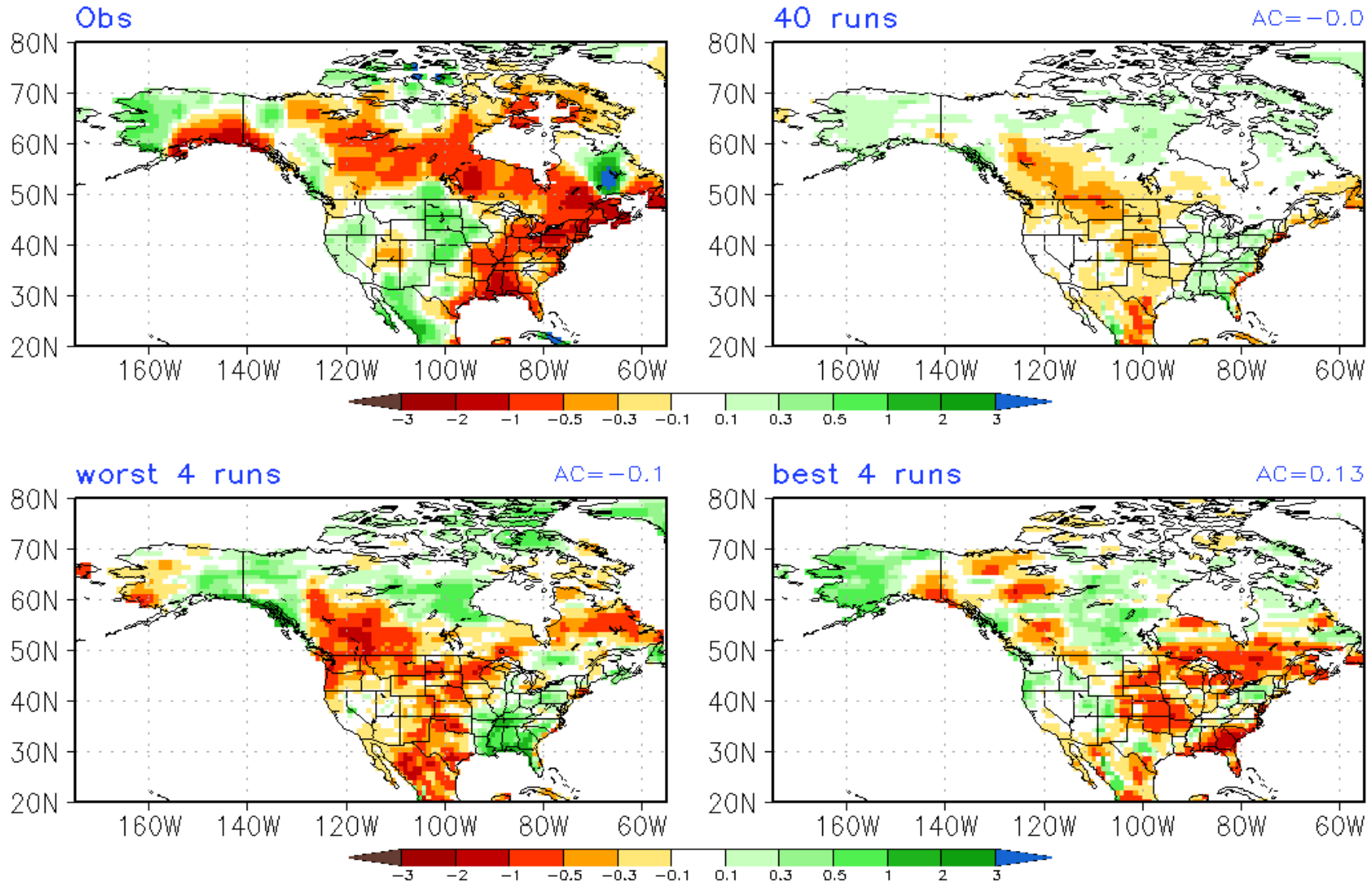
(full anomalies: shaded; eddy anomalies: contours)



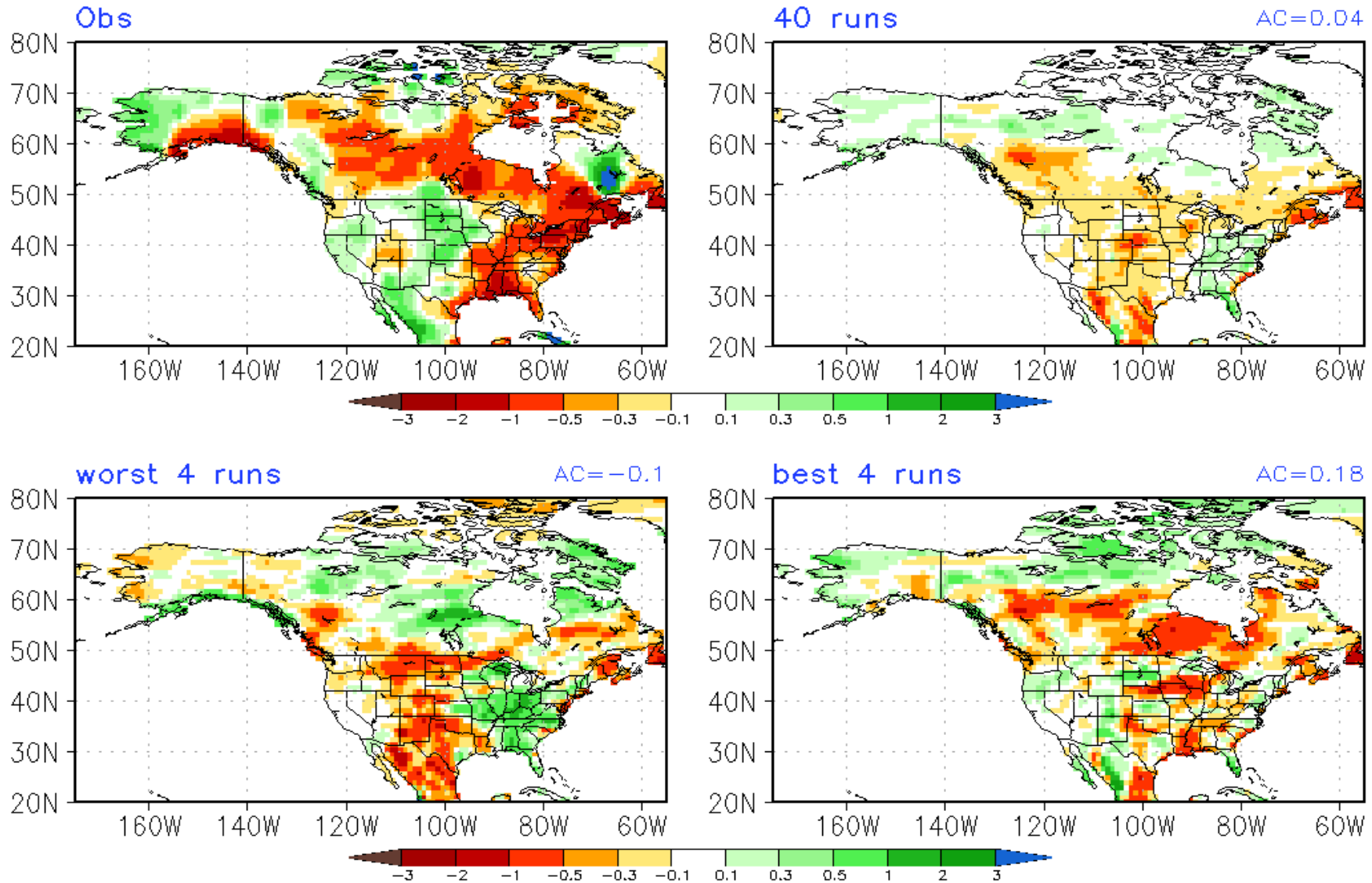
JAS2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



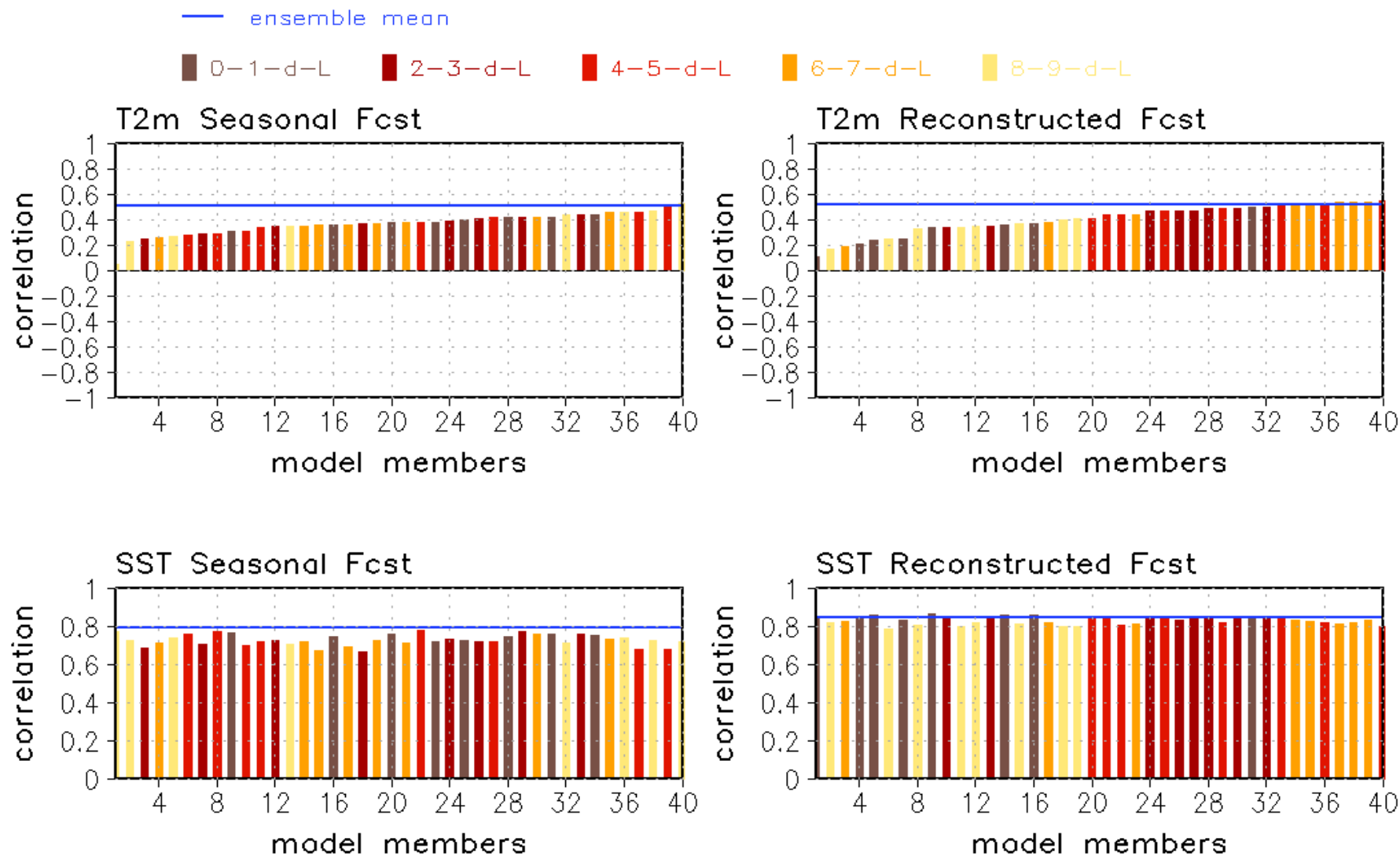
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



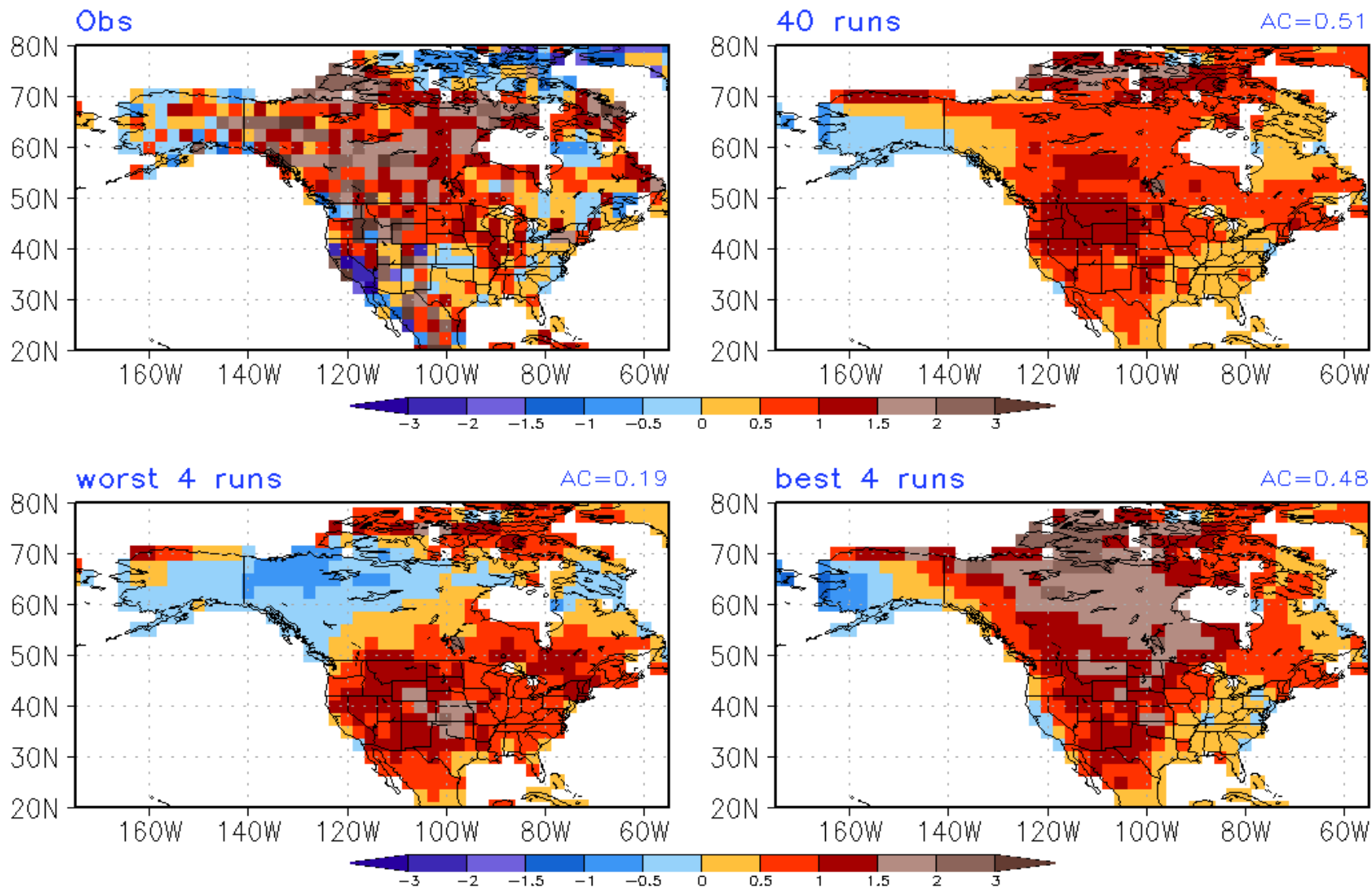
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



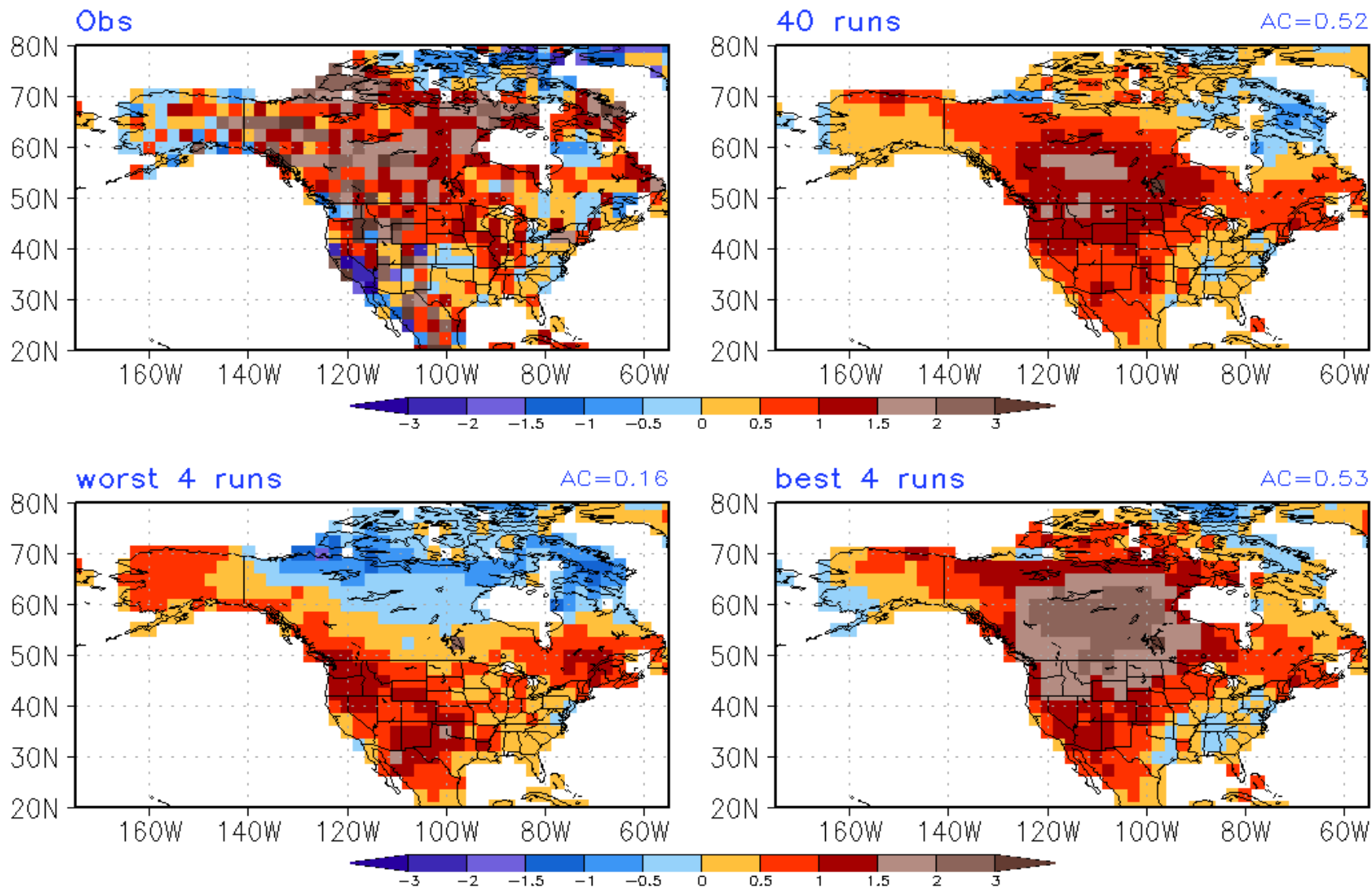
JAS2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

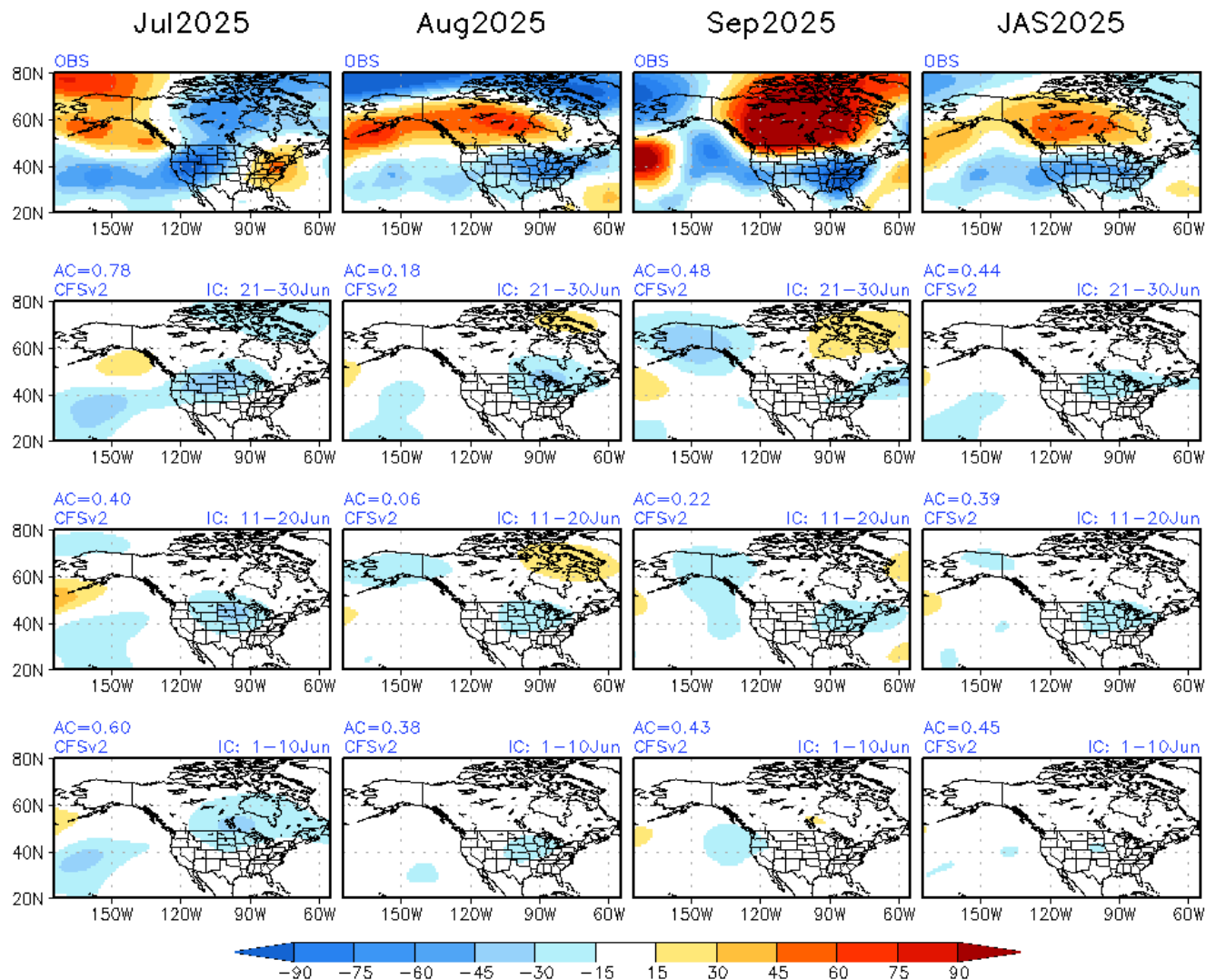


Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2025 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) JAS2025 z200(m) eddy & Obs



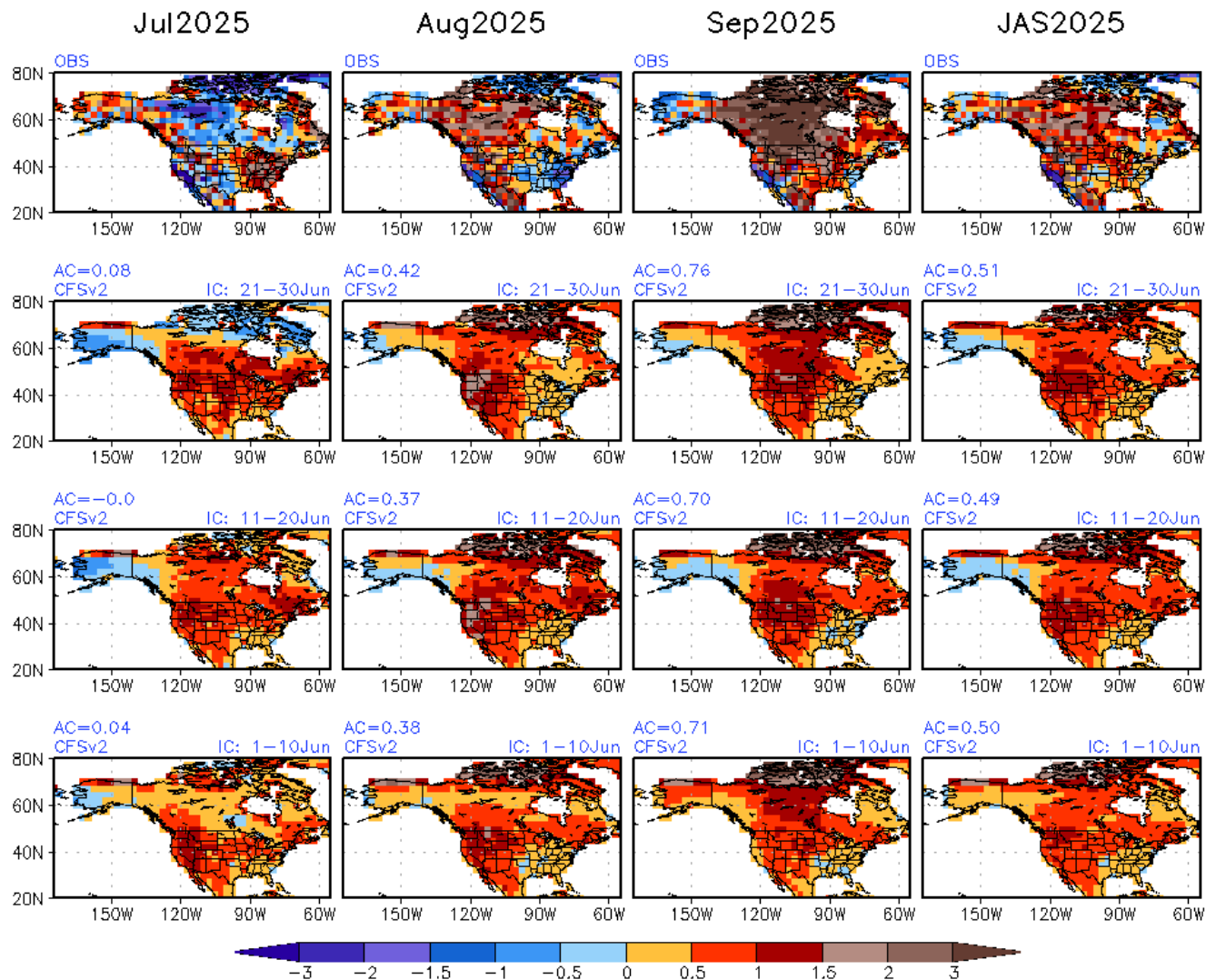
Top row: Observed anomaly.

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) JAS2025 T2m(K) & Obs



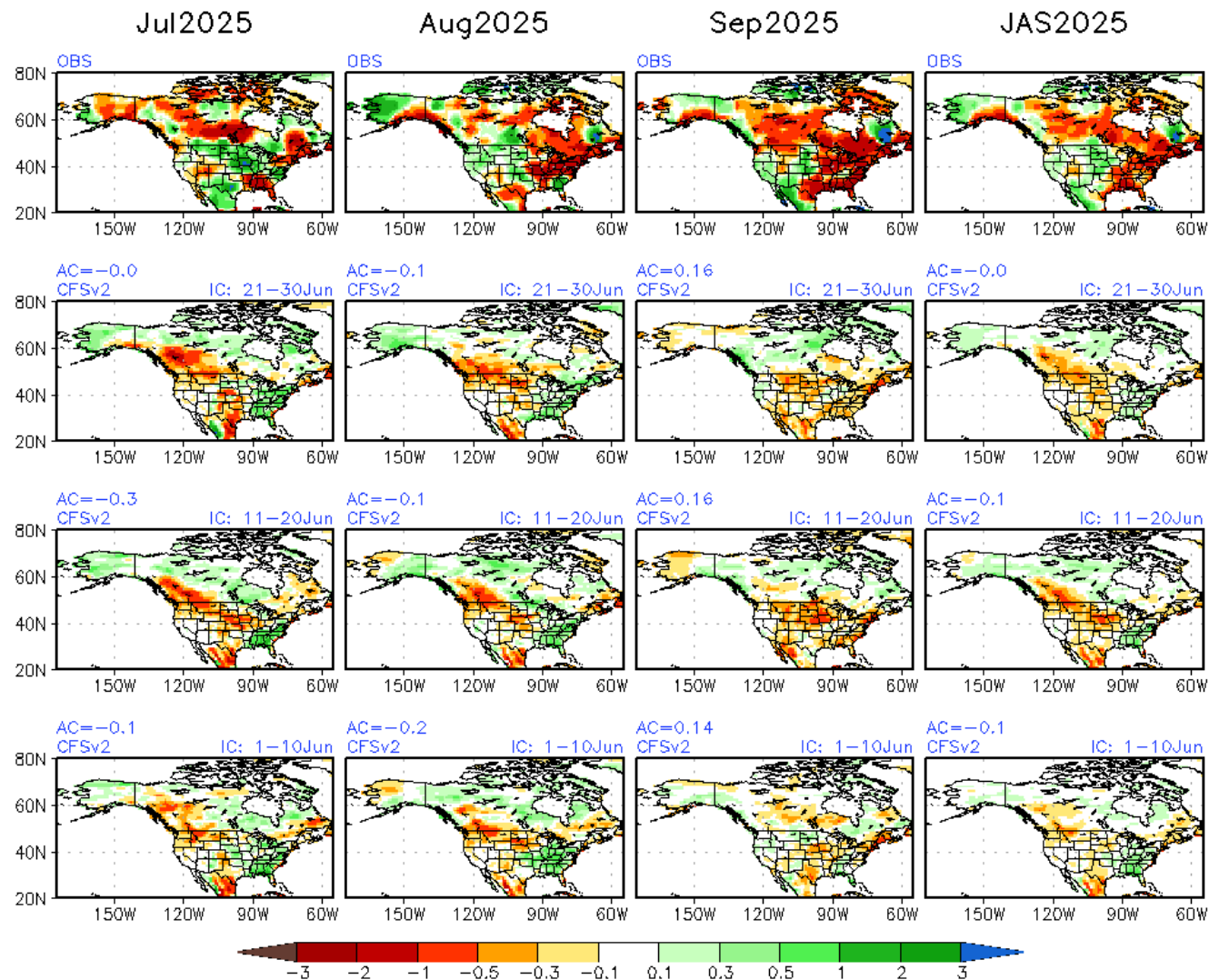
Top row: Observed anomaly.

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.

Prec(mm/day) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) JAS2025 Prec(mm/day) & Obs



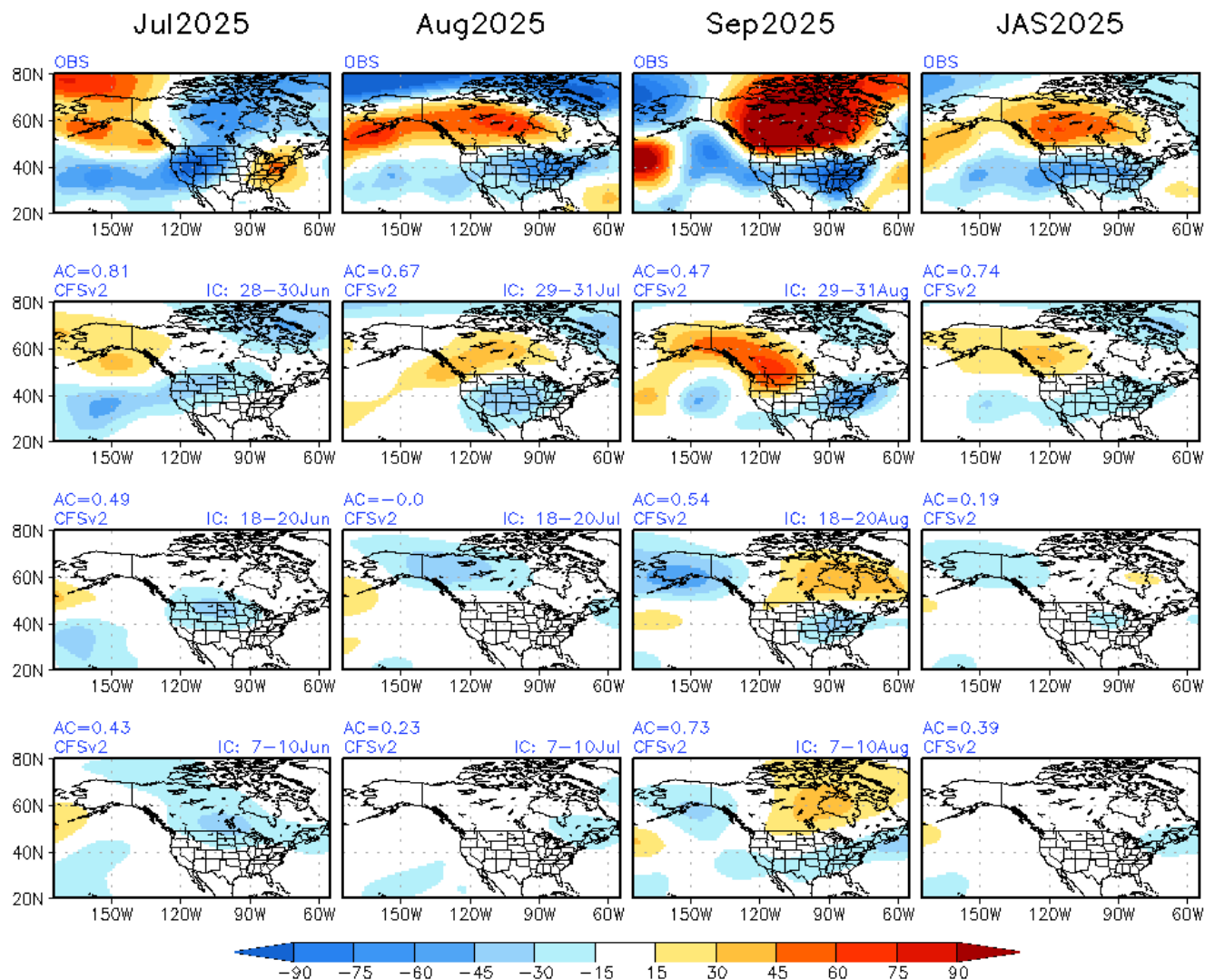
Top row: Observed anomaly.

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.

z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst JAS2025 z200(m) eddy & Obs



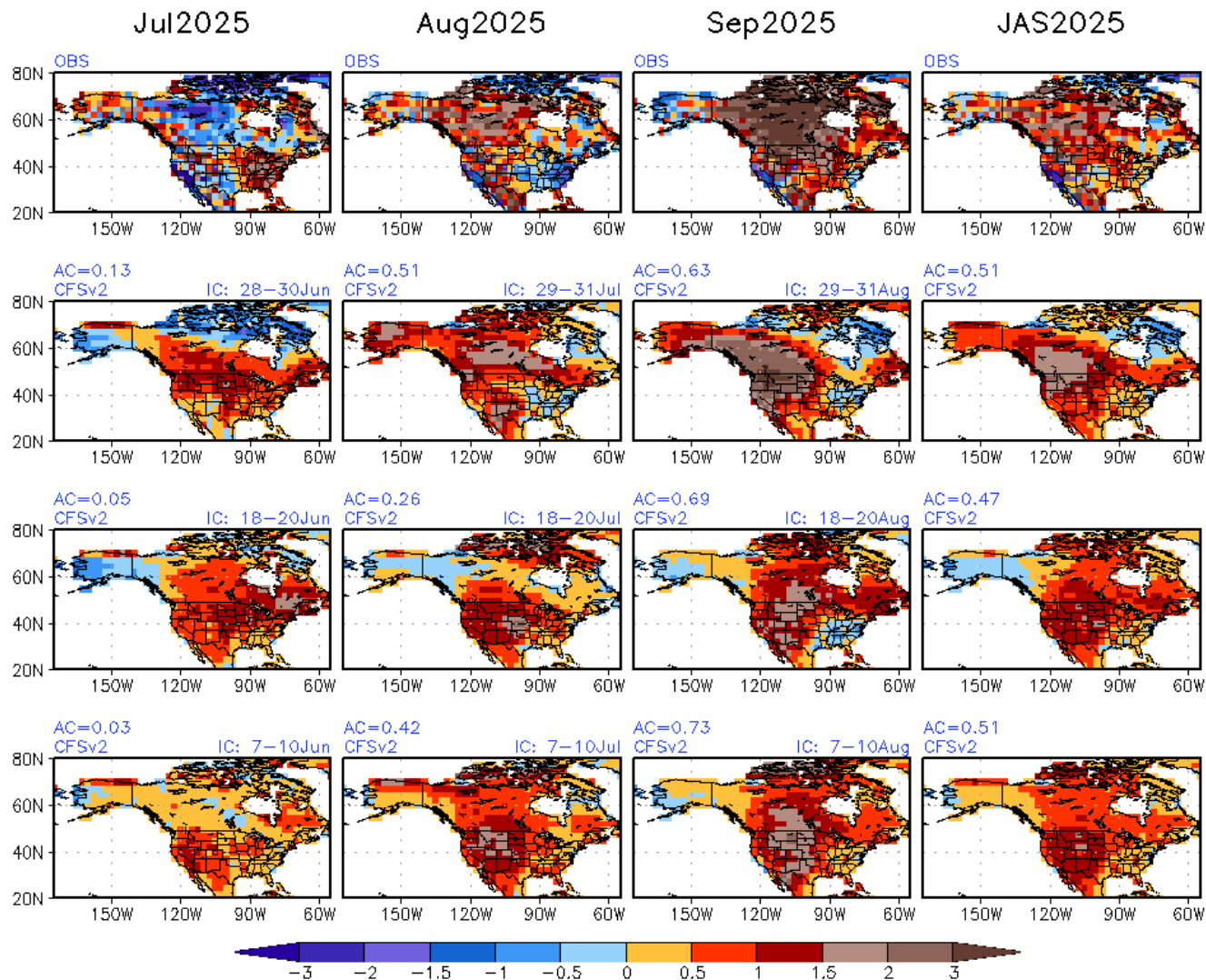
Top row: Observed anomaly.

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 JAS2025 T2m(K) & Obs



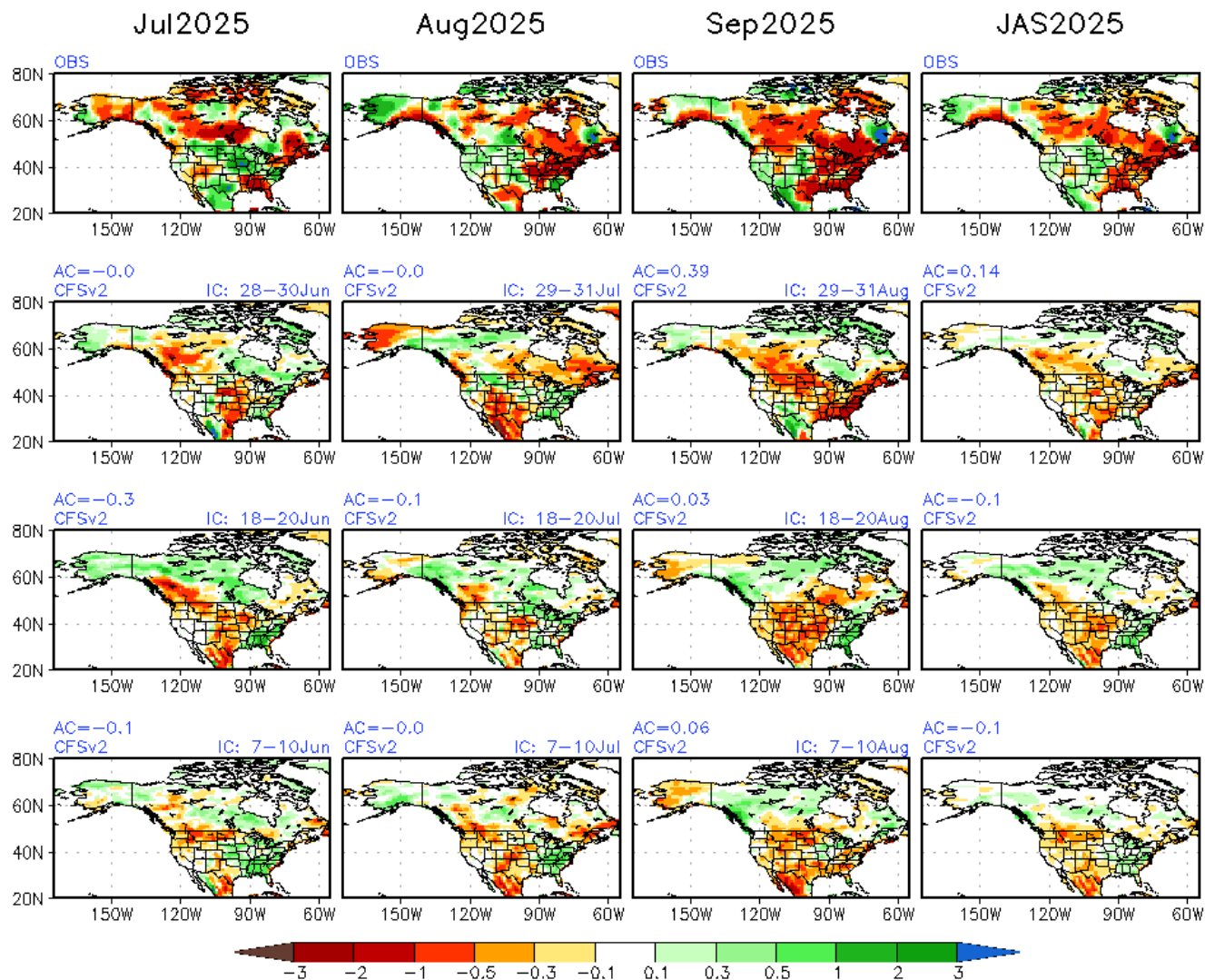
Top row: Observed anomaly.

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.

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

Monthly Means from Monthly Fcst JAS2025 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.
- 3rd row: 18th – 20th of the prior month.
- 4th row: 7th – 10th of the prior month.

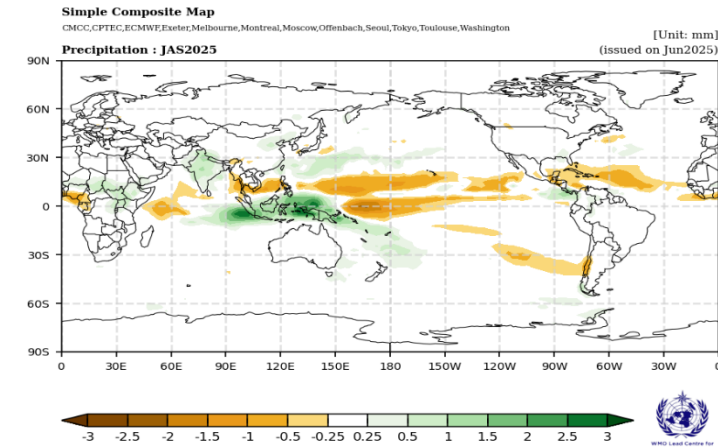
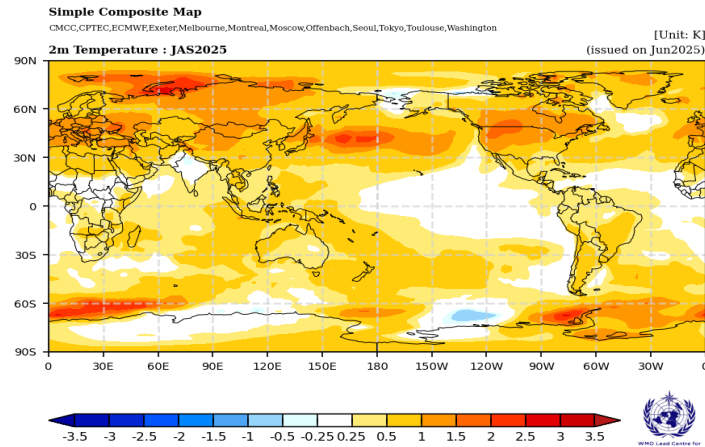
Seasonal Forecasts from Multi-Model Ensemble Systems

- 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/>

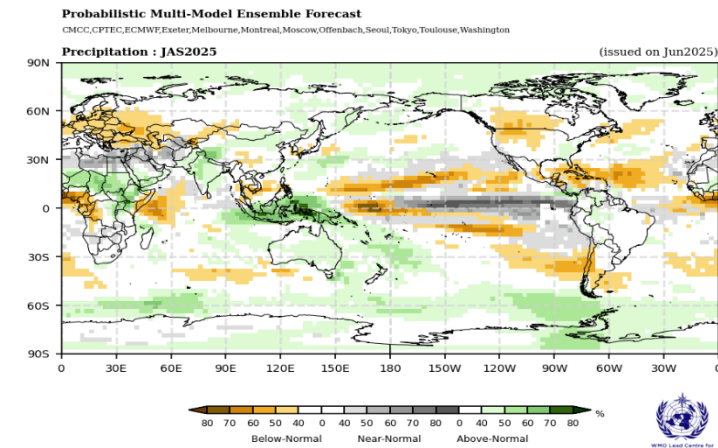
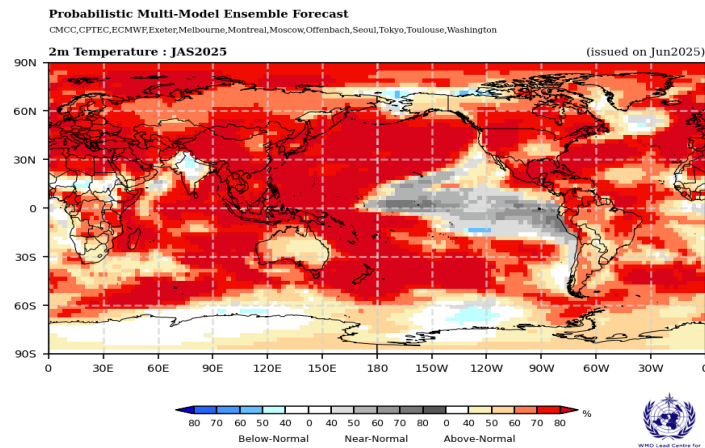
LC-LRFMM Seasonal Forecasts

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

Ensemble means



Probabilities



C3S Seasonal Forecast

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

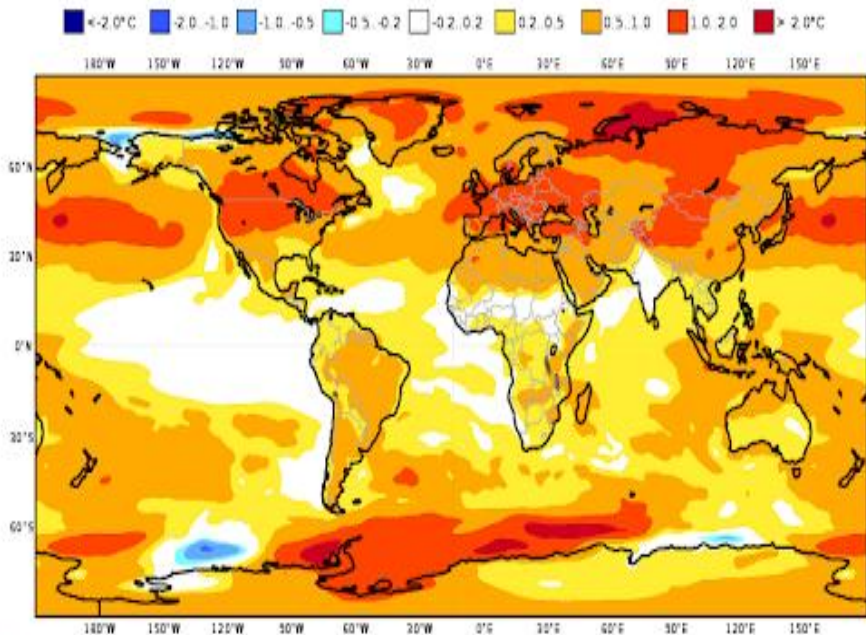
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Mean 2m temperature anomaly

JAS 2025

Nominal forecast start: 01/06/25

Variance-standardized mean



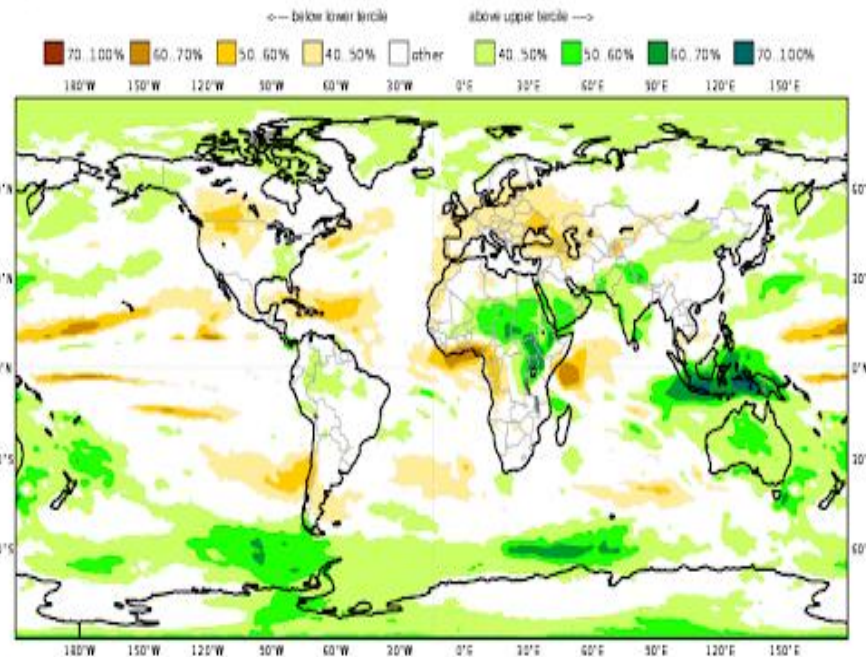
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Prob(most likely category of precipitation)

JAS 2025

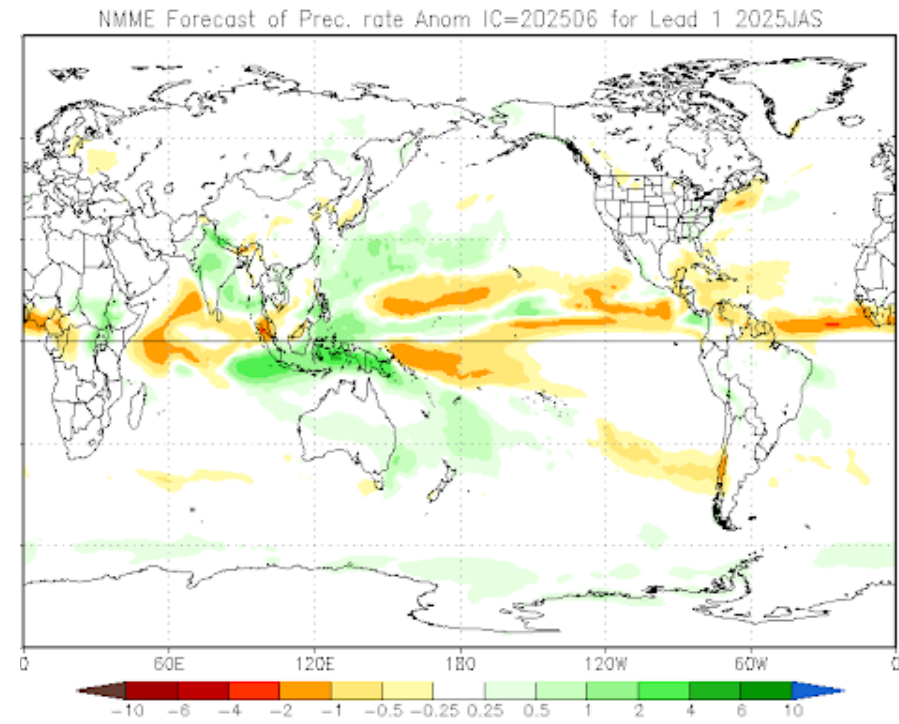
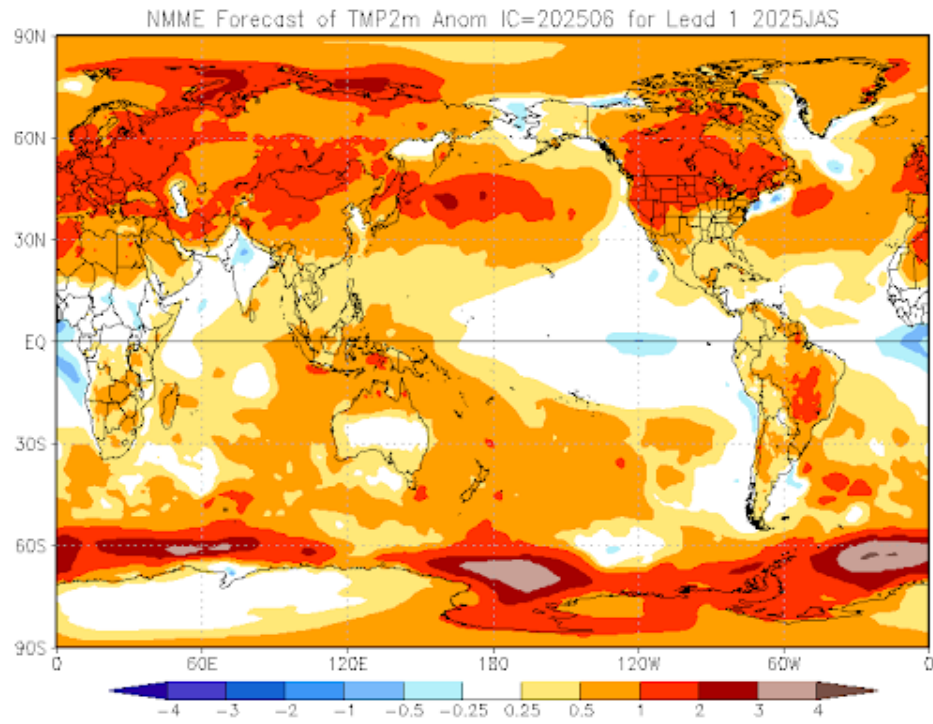
Nominal forecast start: 01/06/25

Unweighted mean



North American Multi-Model Ensemble Seasonal Forecast

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

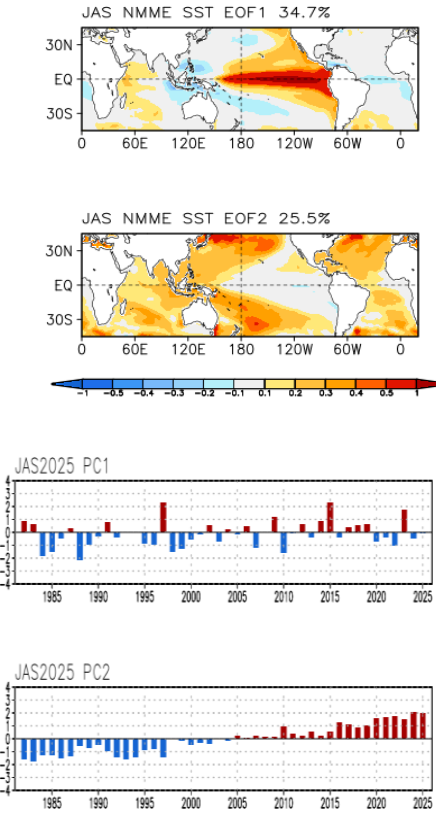
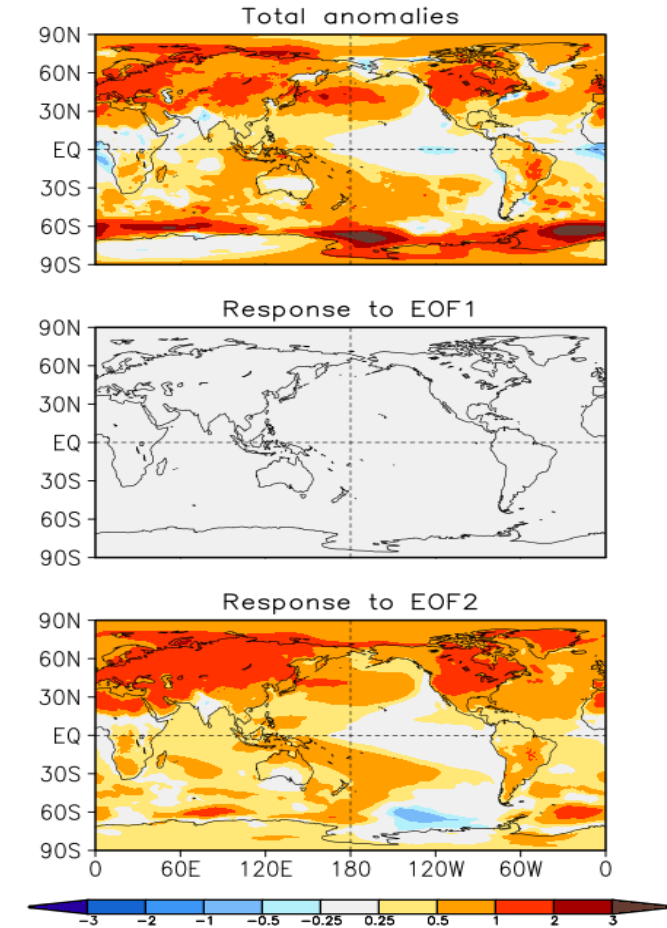
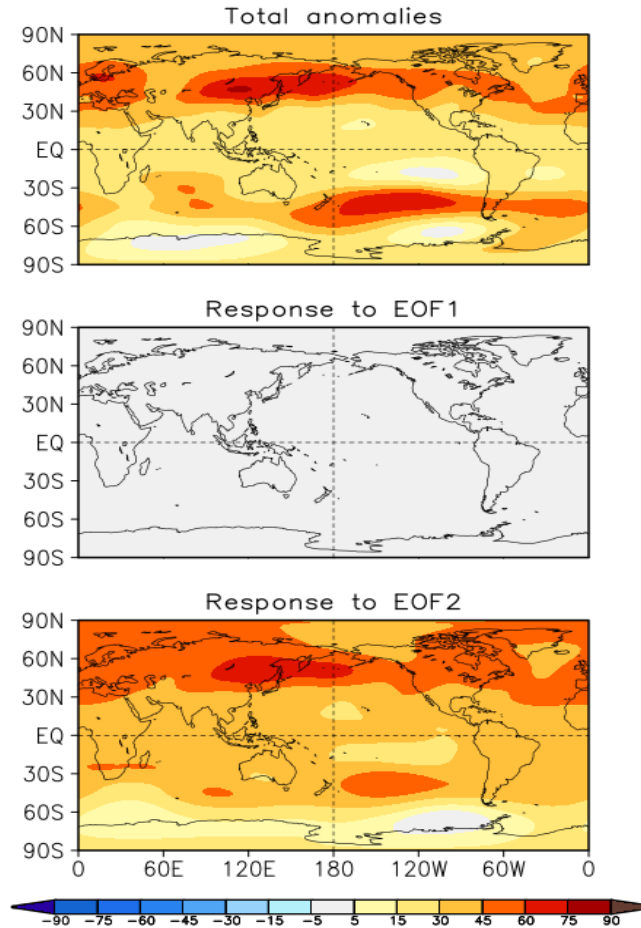
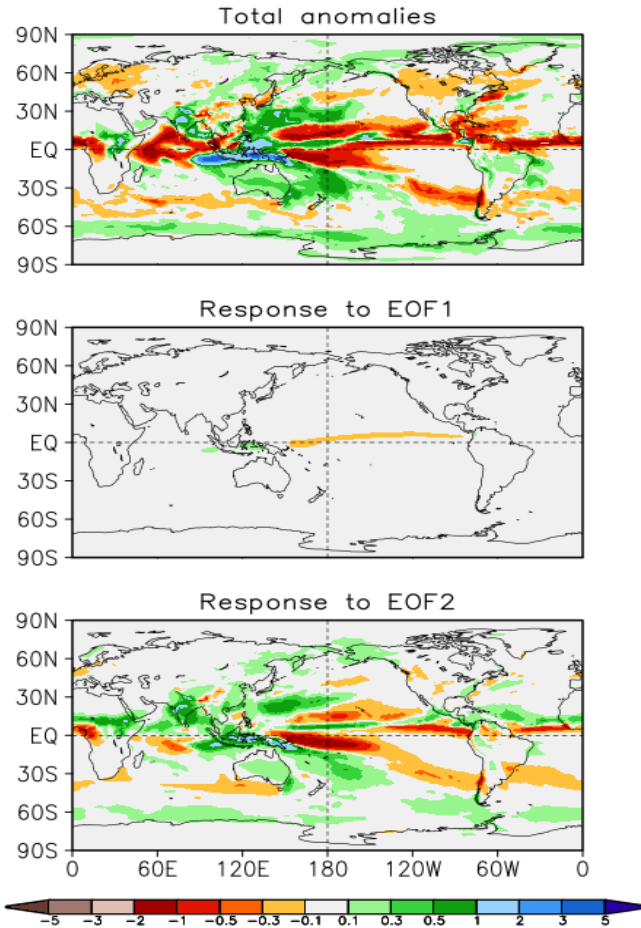


NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME JAS2025 Precip (mm/day)

NMME JAS2025 z200 (m)

NMME JAS2025 T2m (K)

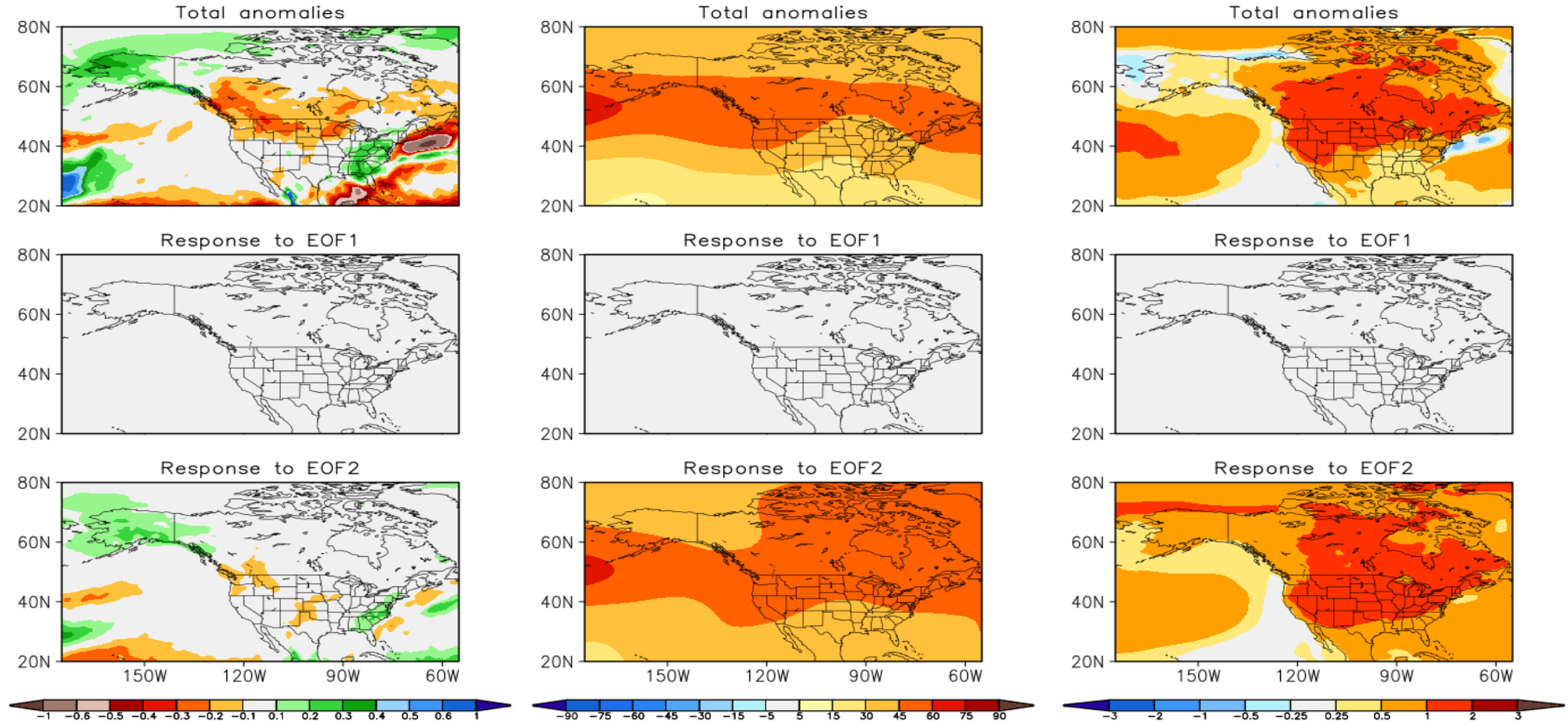


NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME JAS2025 Precip (mm/day)

NMME JAS2025 z200 (m)

NMME JAS2025 T2m (K)



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.