

Attribution of Seasonal Climate Anomalies September-October-November 2025

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

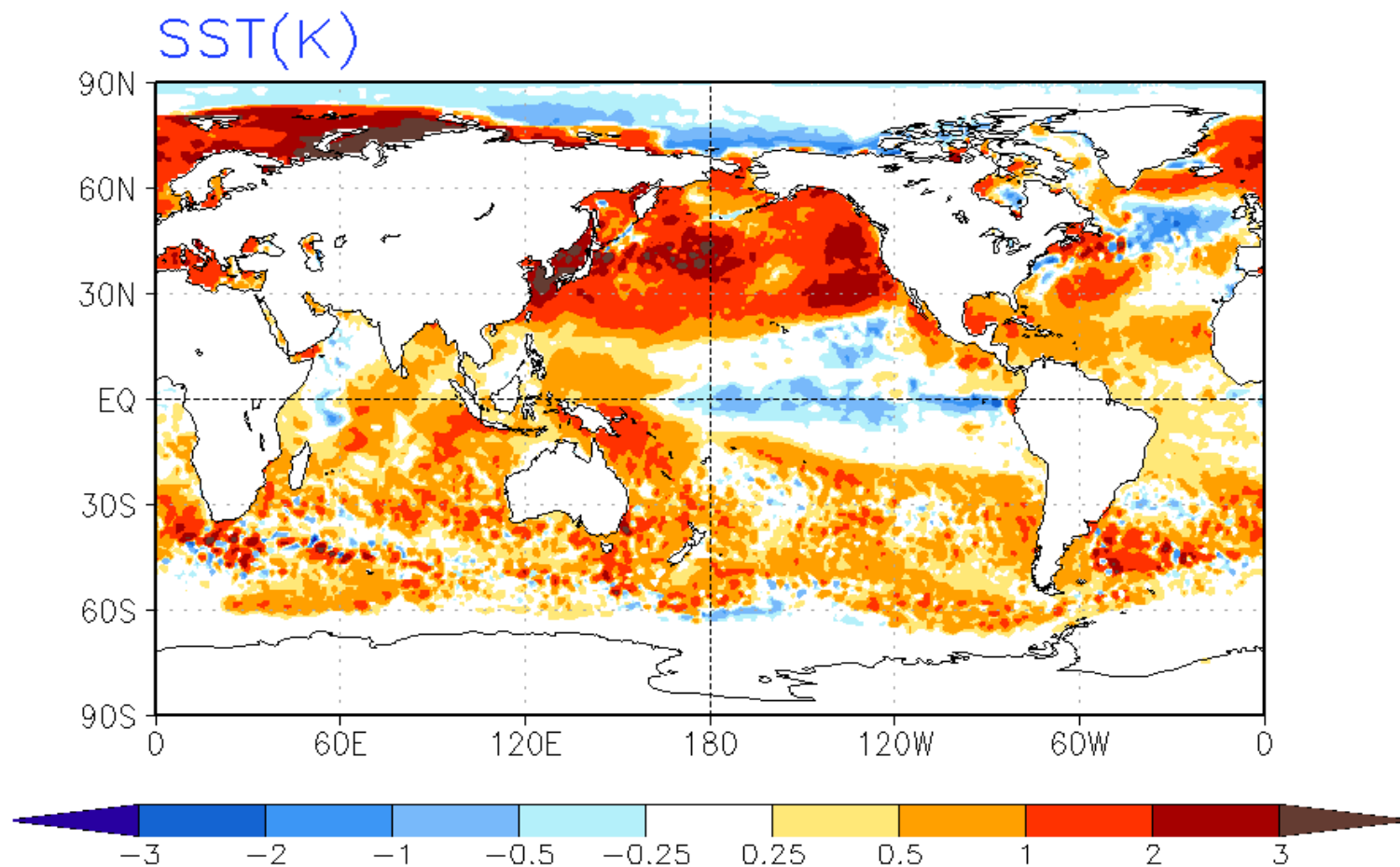
Summary of Observed Conditions and Outlooks

- In SON2025, negative SST anomalies intensified slightly over the equatorial central and eastern Pacific, maintaining a La Niña-like east-west gradient. Warm anomalies persisted across the mid-latitude Pacific, Indian Ocean, and Atlantic (Slide 4).
- CFSv2 reasonably captured large-scale SST patterns but exhibited cold biases over the northern Pacific, tropical Indian Ocean, and equatorial central Pacific (Slide 10).
- CFSv2 and MME forecasts captured key tropical precipitation patterns typical of La Niña (wet Maritime Continent/eastern Indian Ocean; dry central-eastern Pacific). However, models overestimated rainfall anomalies over the tropical western Pacific (Slides 11, 37-39).
- Despite weak central Pacific cooling, models produced a canonical La Niña atmospheric response, likely driven by the contrast with widespread background ocean warming.
- Forecasts captured the global land warming trend but missed cold anomalies over northeastern Asia and the southwestern U.S. (Slides 13, 37–39). These surface errors likely stem from CFSv2 missing negative 200-mb height anomalies extending from NE Asia to the U.S. West Coast and along the East Coast, while missing strong positive anomalies over northern North America (Slides 12, 13, 15, 16).
- Attribution analysis indicates NMME extratropical height anomalies and T2m are driven mainly by the forecast SST warming trend mode (Slides 40, 41).
- CFSv2 failed to capture most observed precipitation anomalies over North America (Slide 14).
- For October 2025, forecast skill for North America precipitation, Z200, and T2m showed no improvement at the shortest lead time (Slide 34-36).

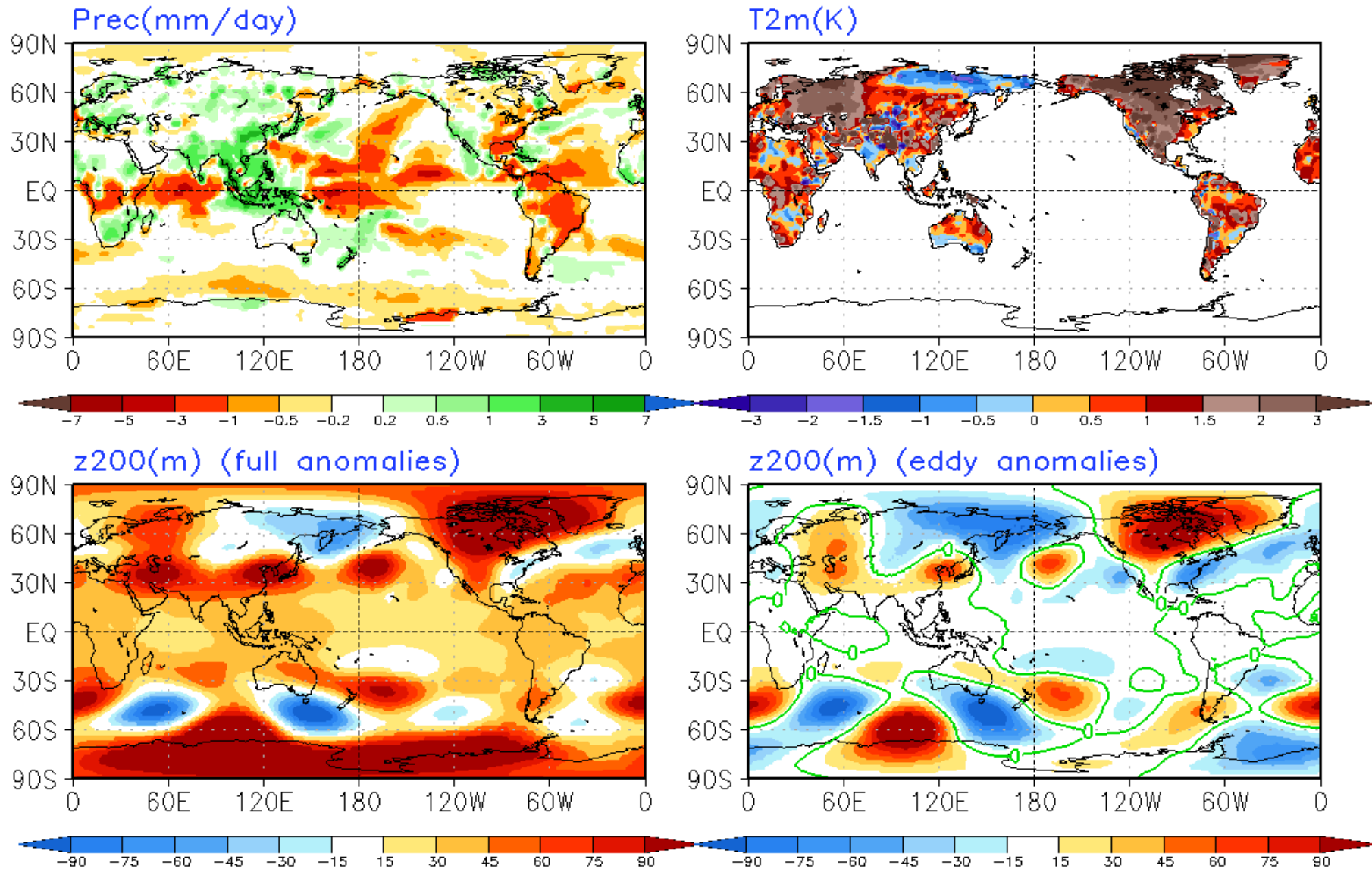
Observed Seasonal Anomalies

Global and North America

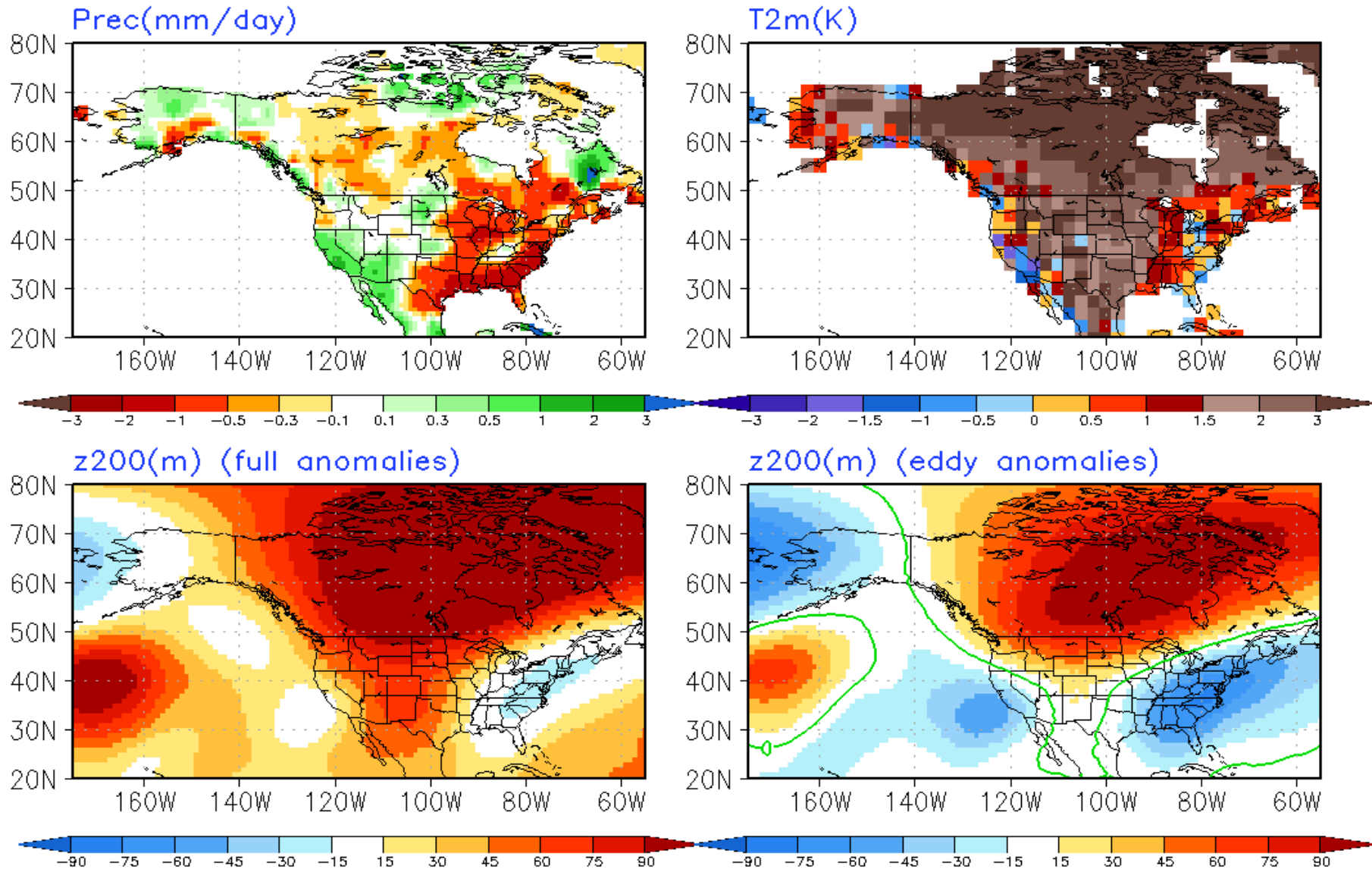
Observed Anomaly SON2025



Observed Anomaly SON2025



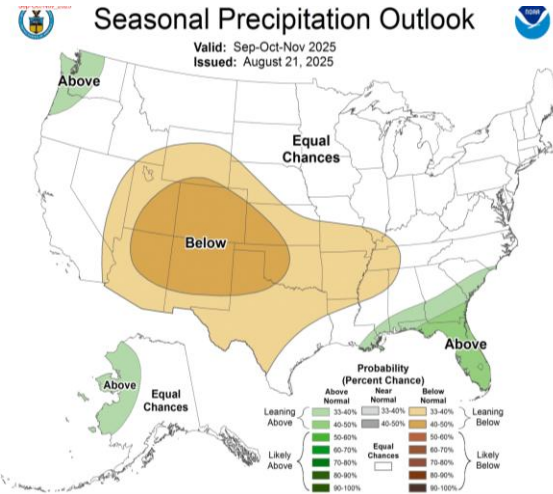
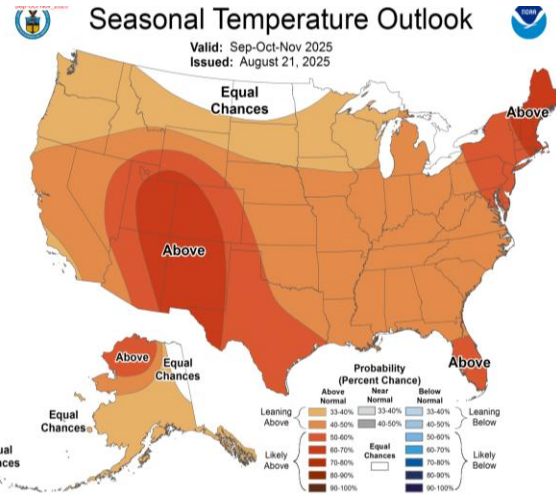
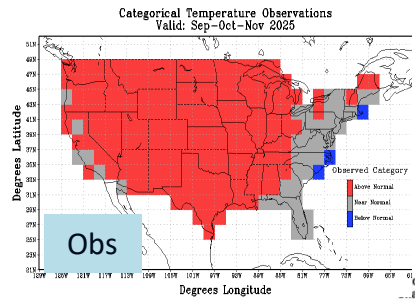
Observed Anomaly SON2025



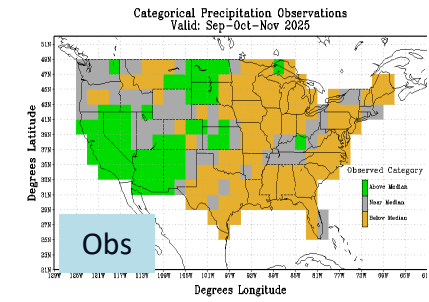
CPC Seasonal Outlooks and NMME Forecasts

CPC

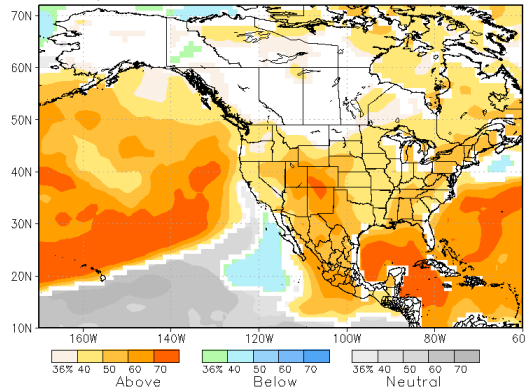
Temp nonEC
HSS=72



Prec nonEC
HSS=-9

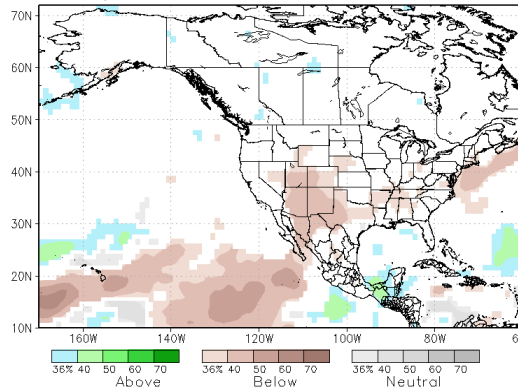


NMME prob fcst TMP2m IC=202508 for lead 1 2025 SON



NMME

NMME prob fcst Prate IC=202508 for lead 1 2025 SON



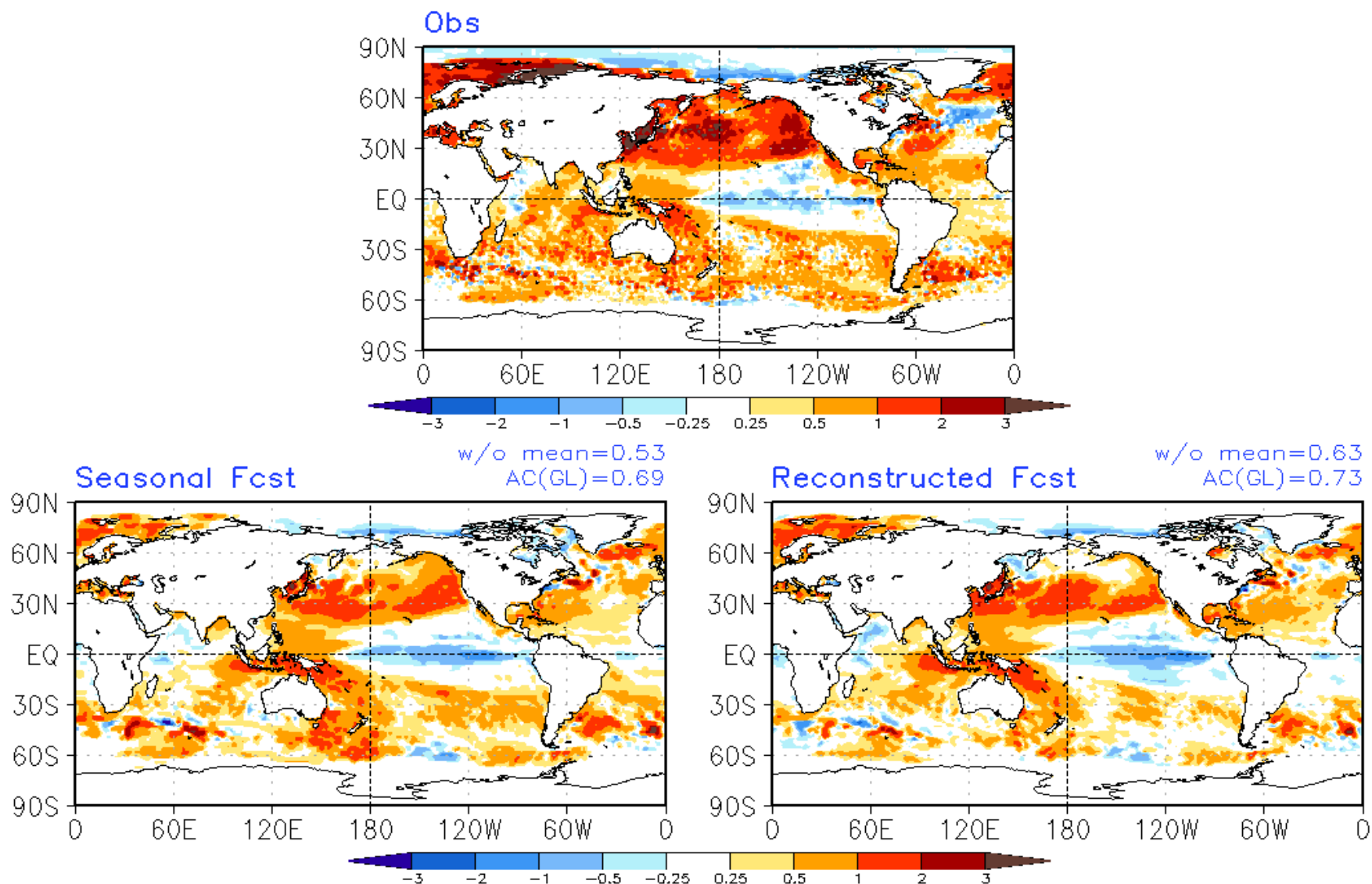
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2025/202507_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

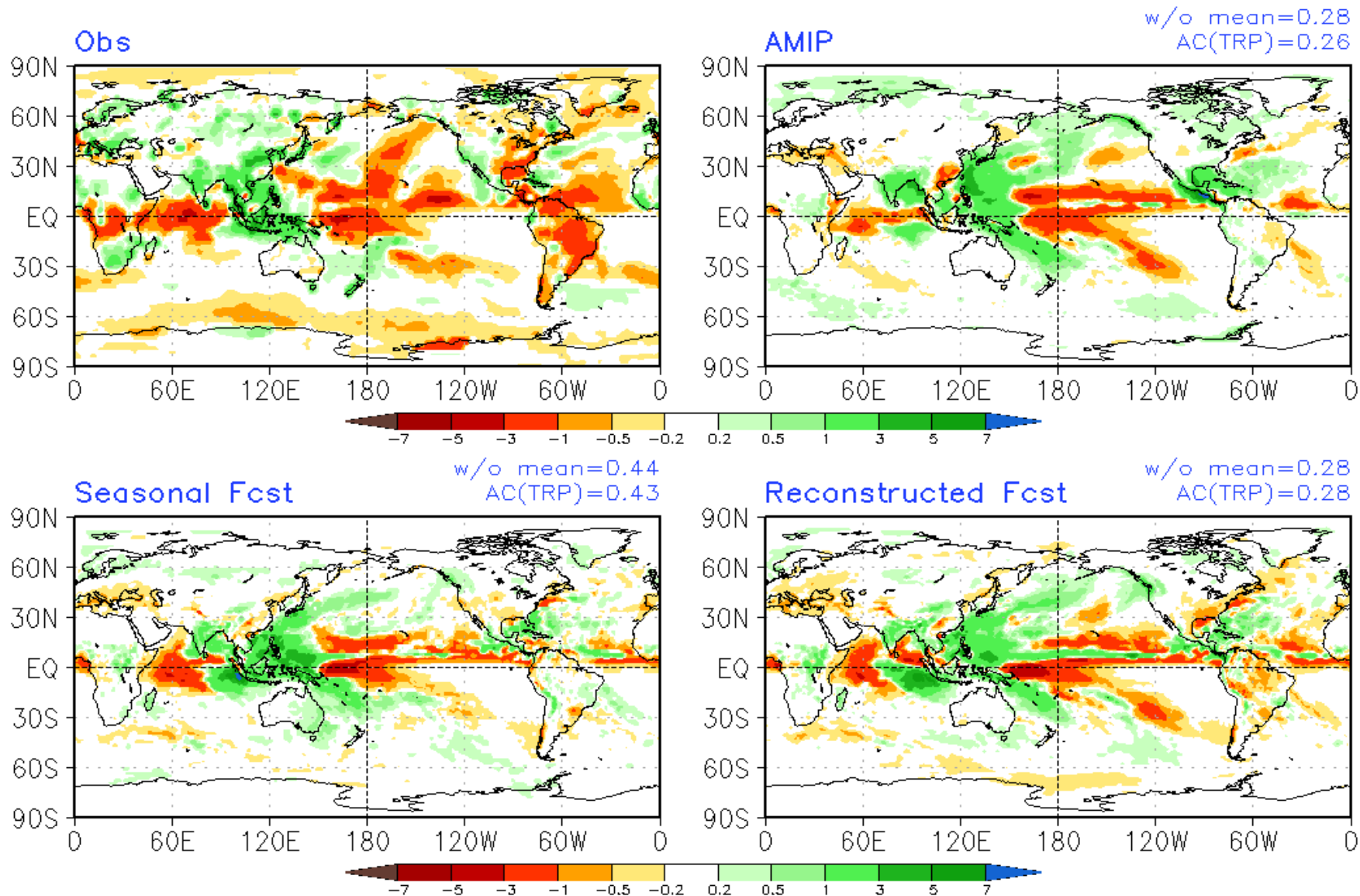
Model Simulated/Forecast Ensemble Average Anomalies

- **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.

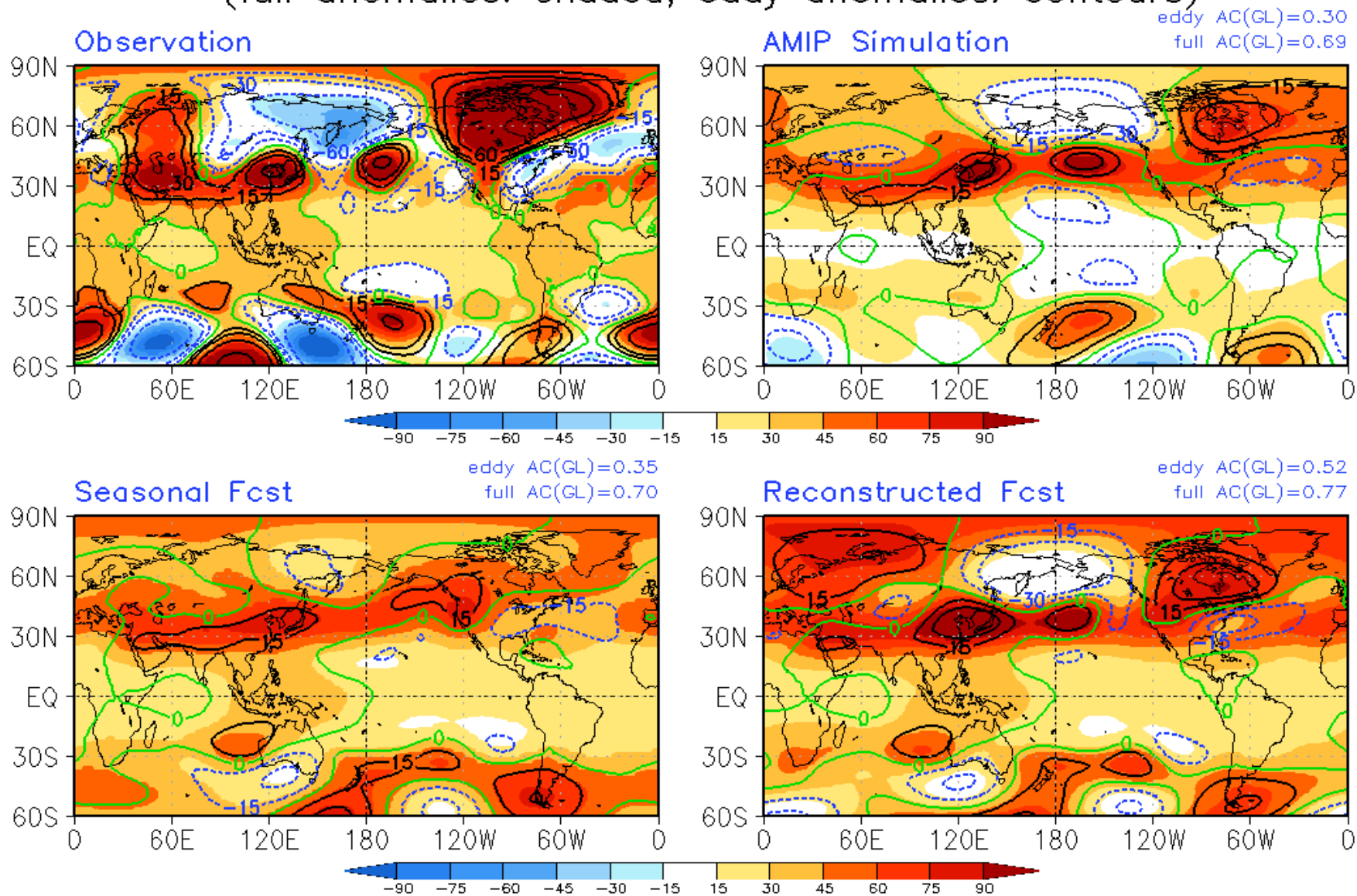
SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



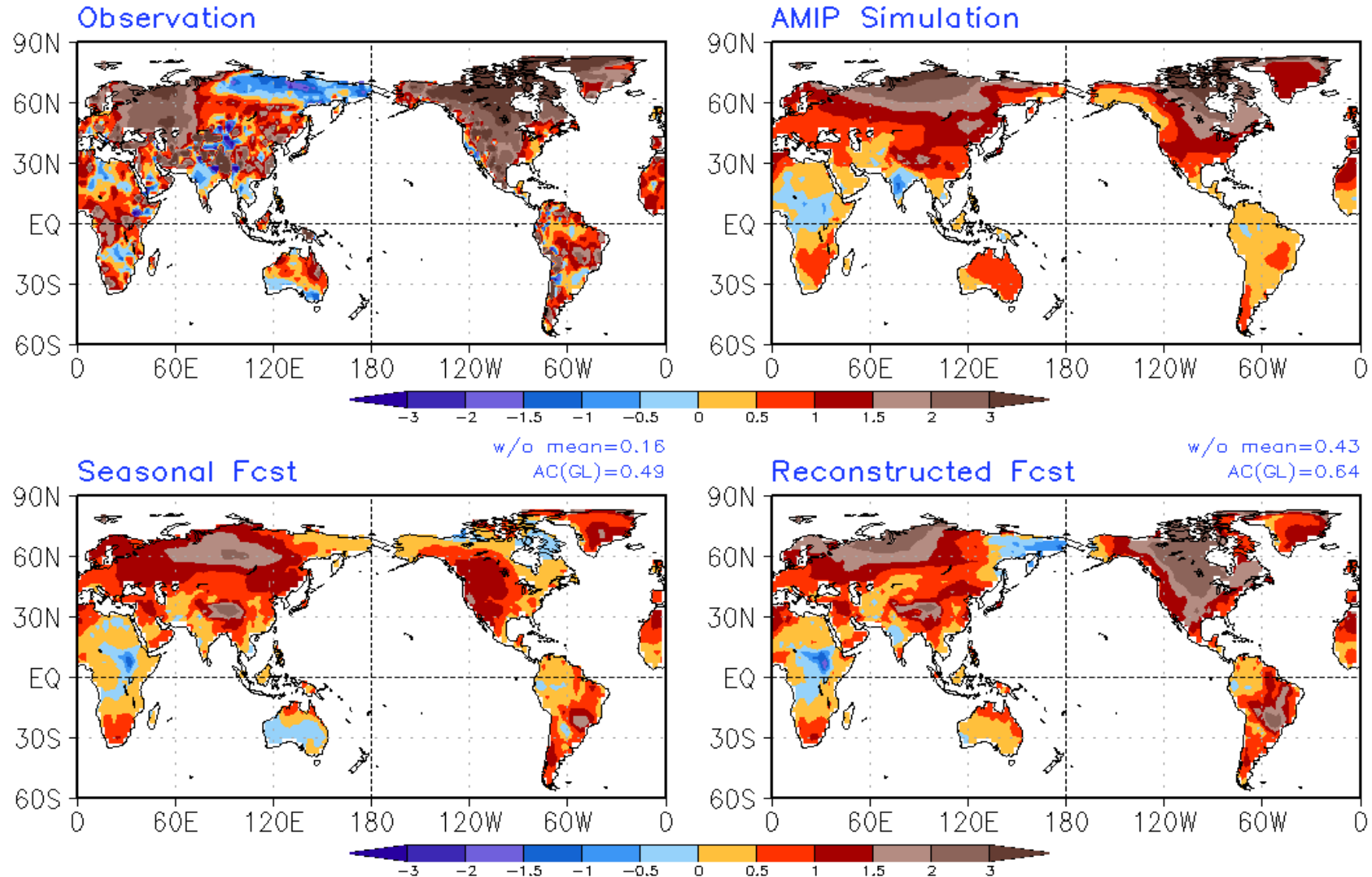
SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



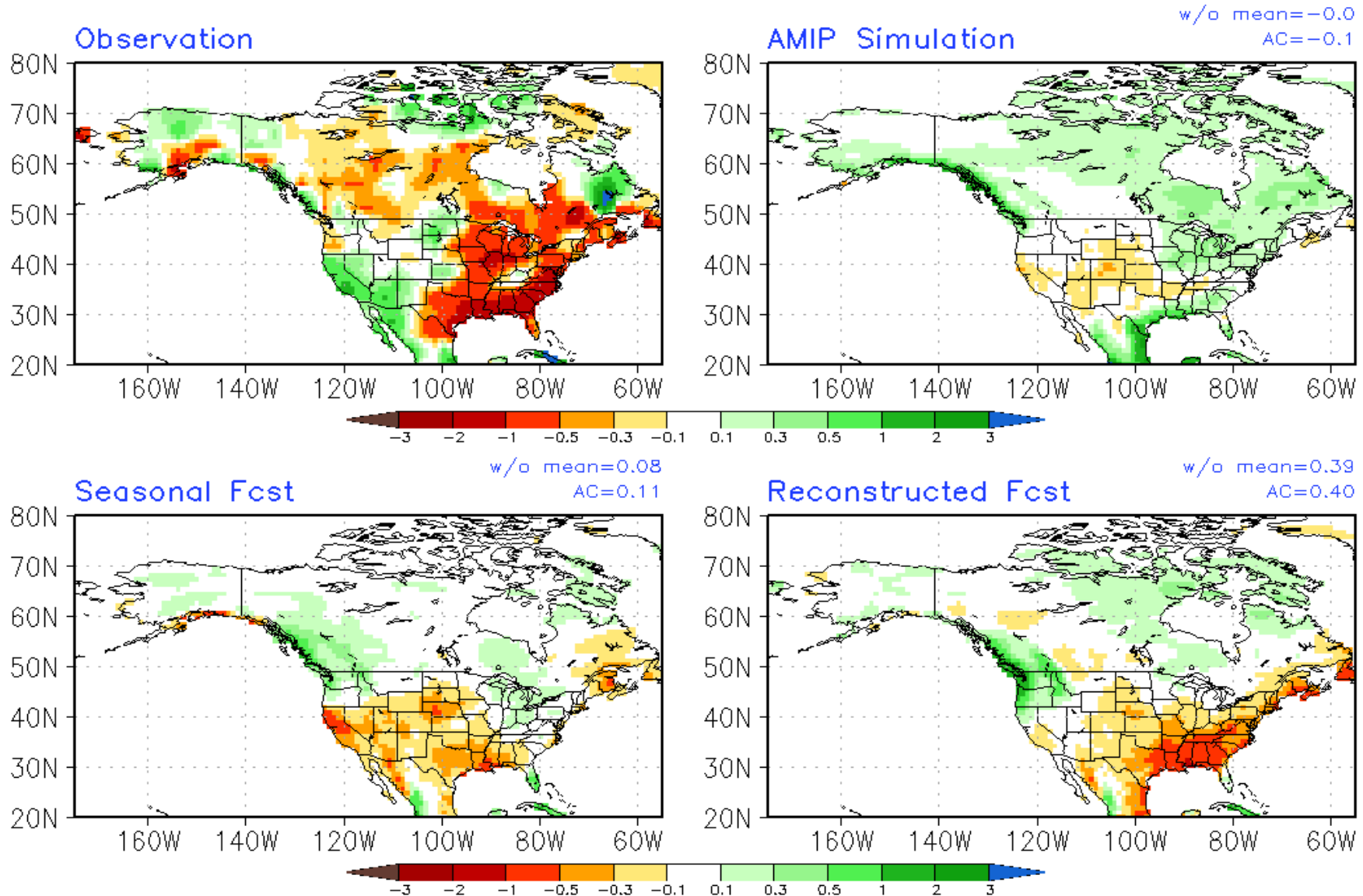
SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m) (full anomalies: shaded; eddy anomalies: contours)



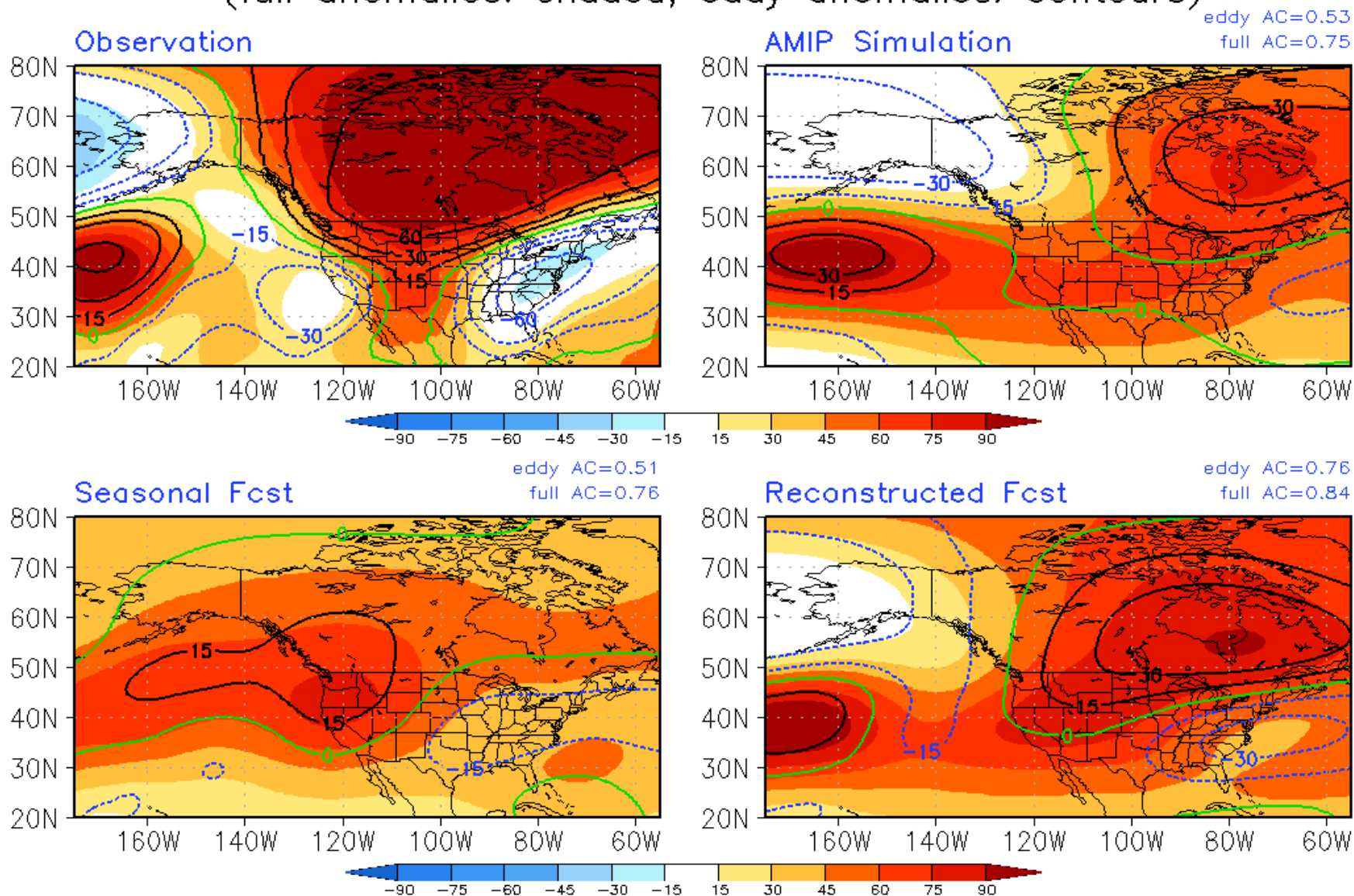
SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



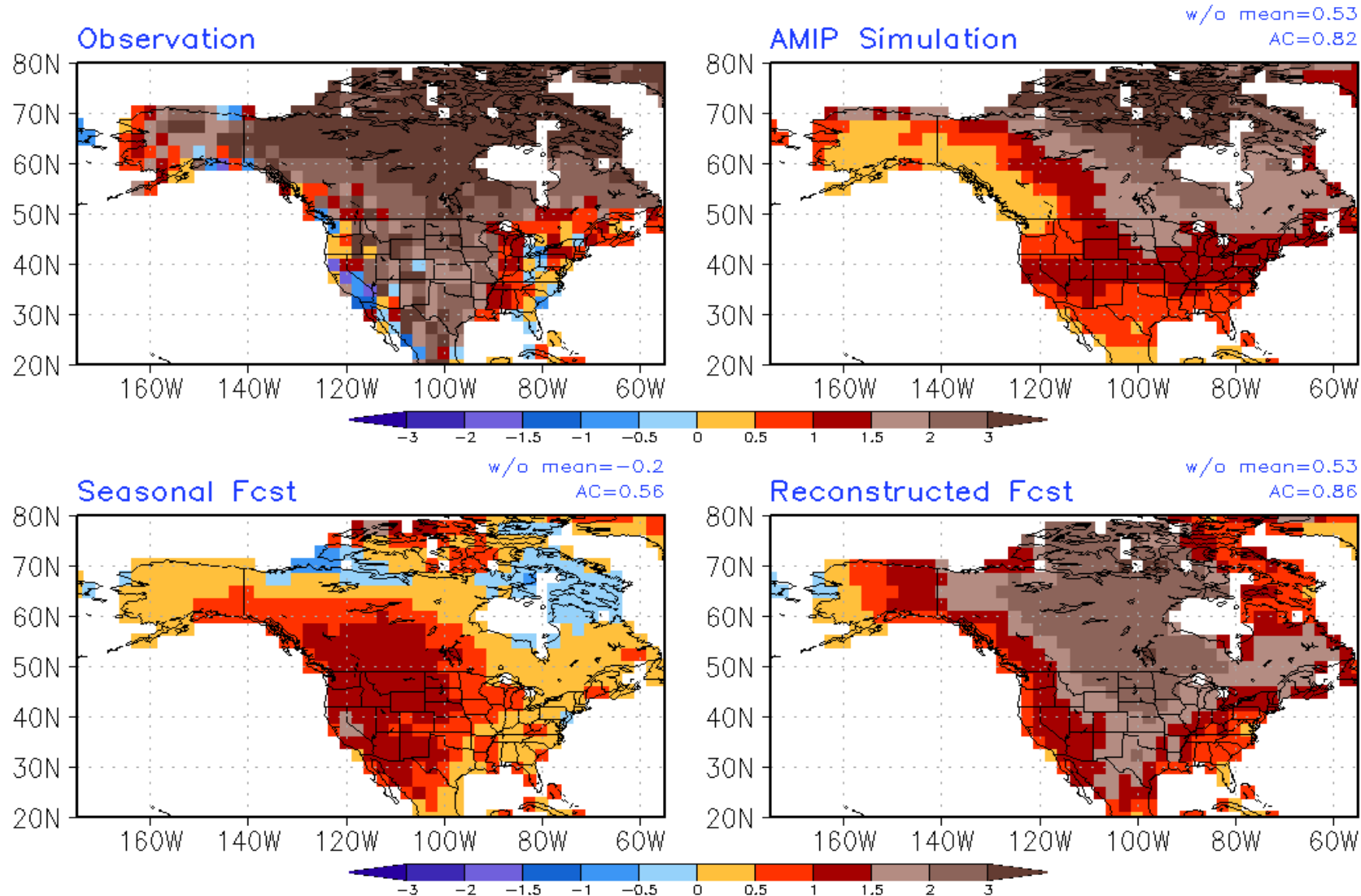
SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m) (full anomalies: shaded; eddy anomalies: contours)



SON2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

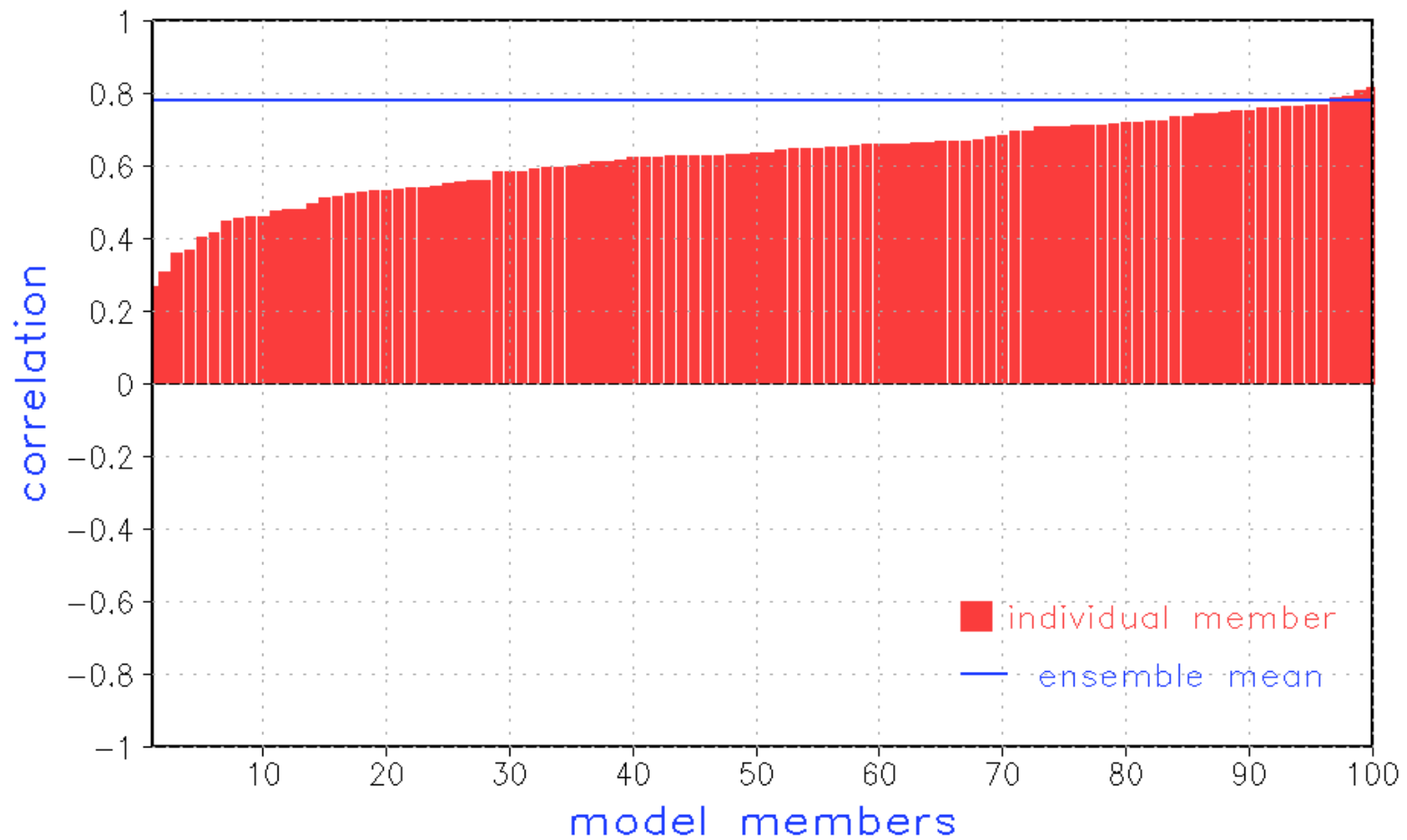


Model Simulated/Forecast Anomalies: Individual Runs

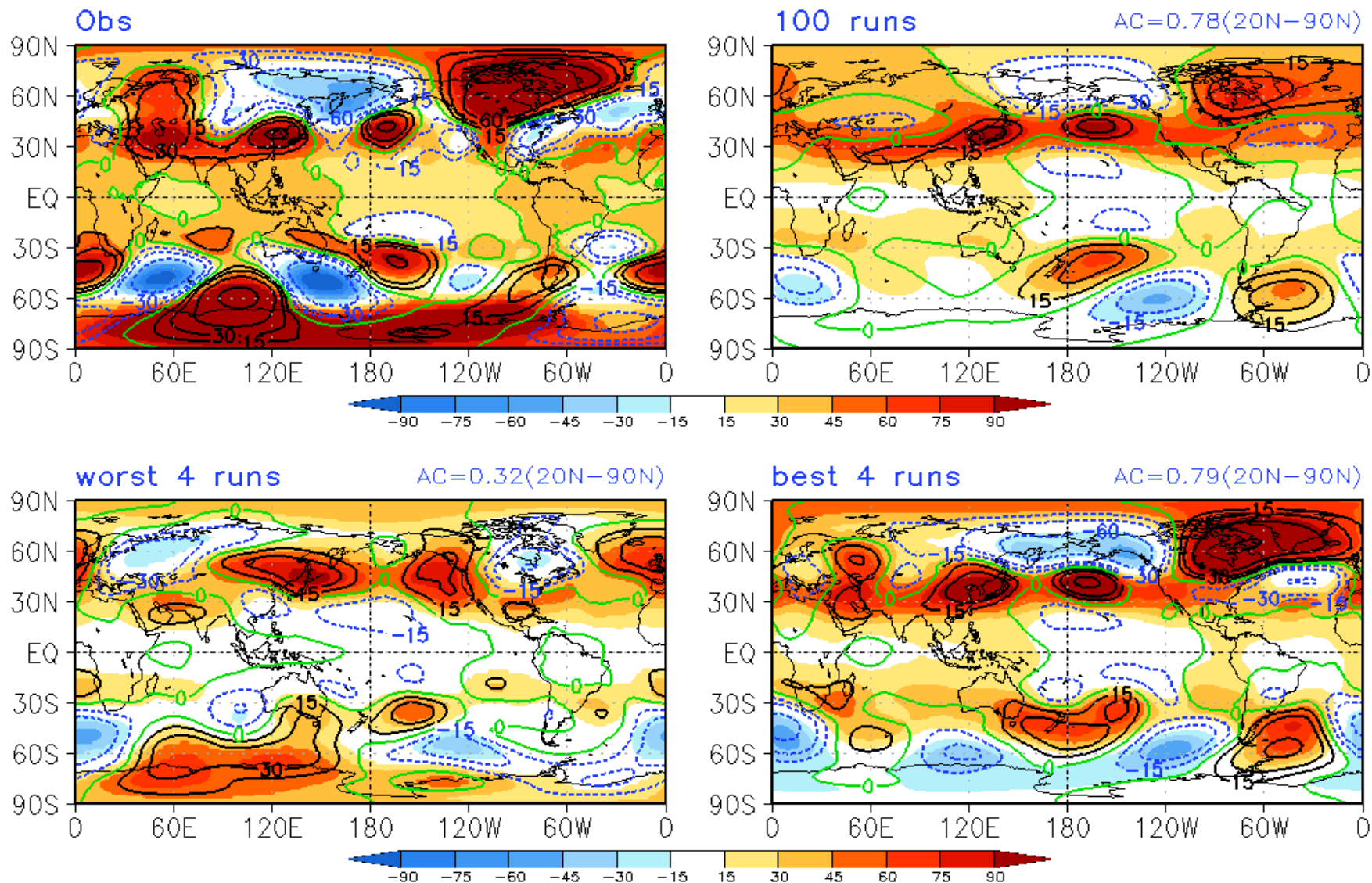
Model Simulated/Forecast Anomalies: Individual Runs

- 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).

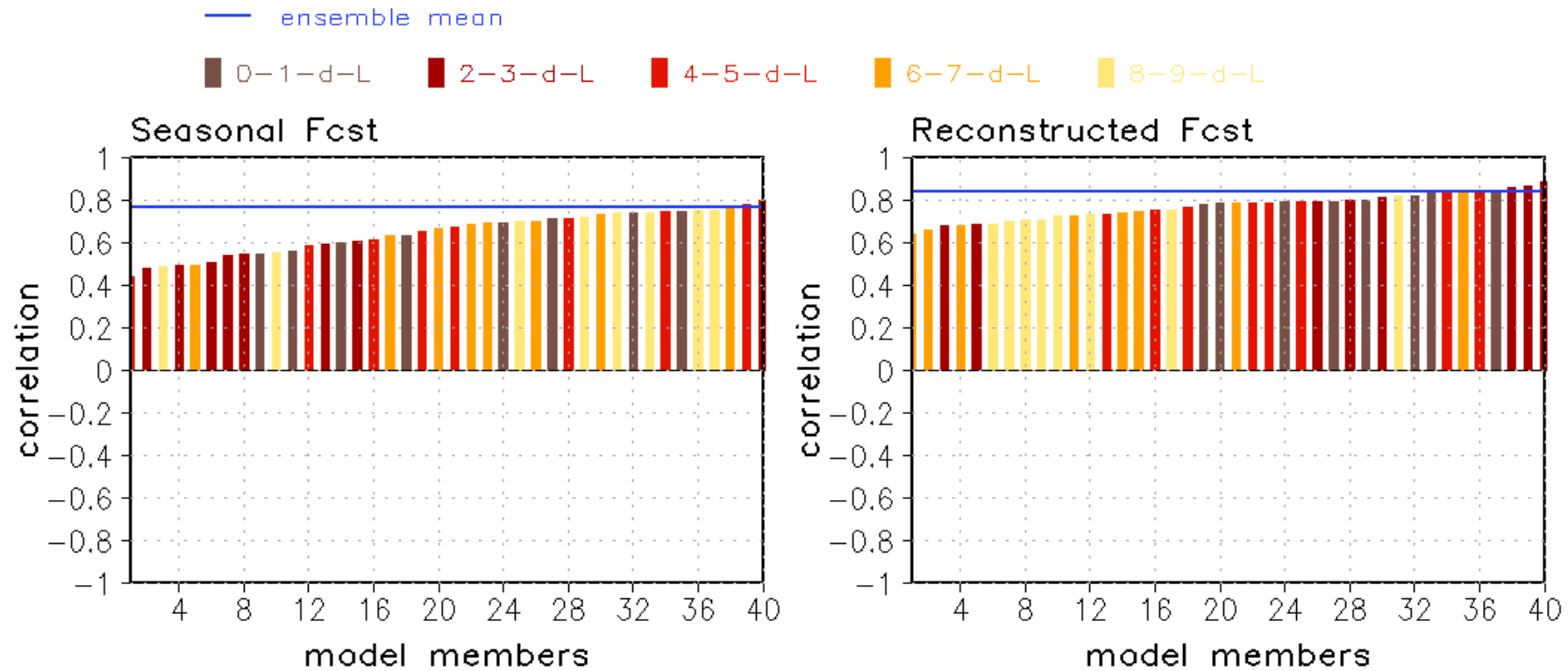
SON2025 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)



Observed & AMIP Ensemble Mean Anomalies
SON2025 z200(m) 100 runs/worst 4 runs/best 4 runs
(full anomalies: shaded; eddy anomalies: contours)



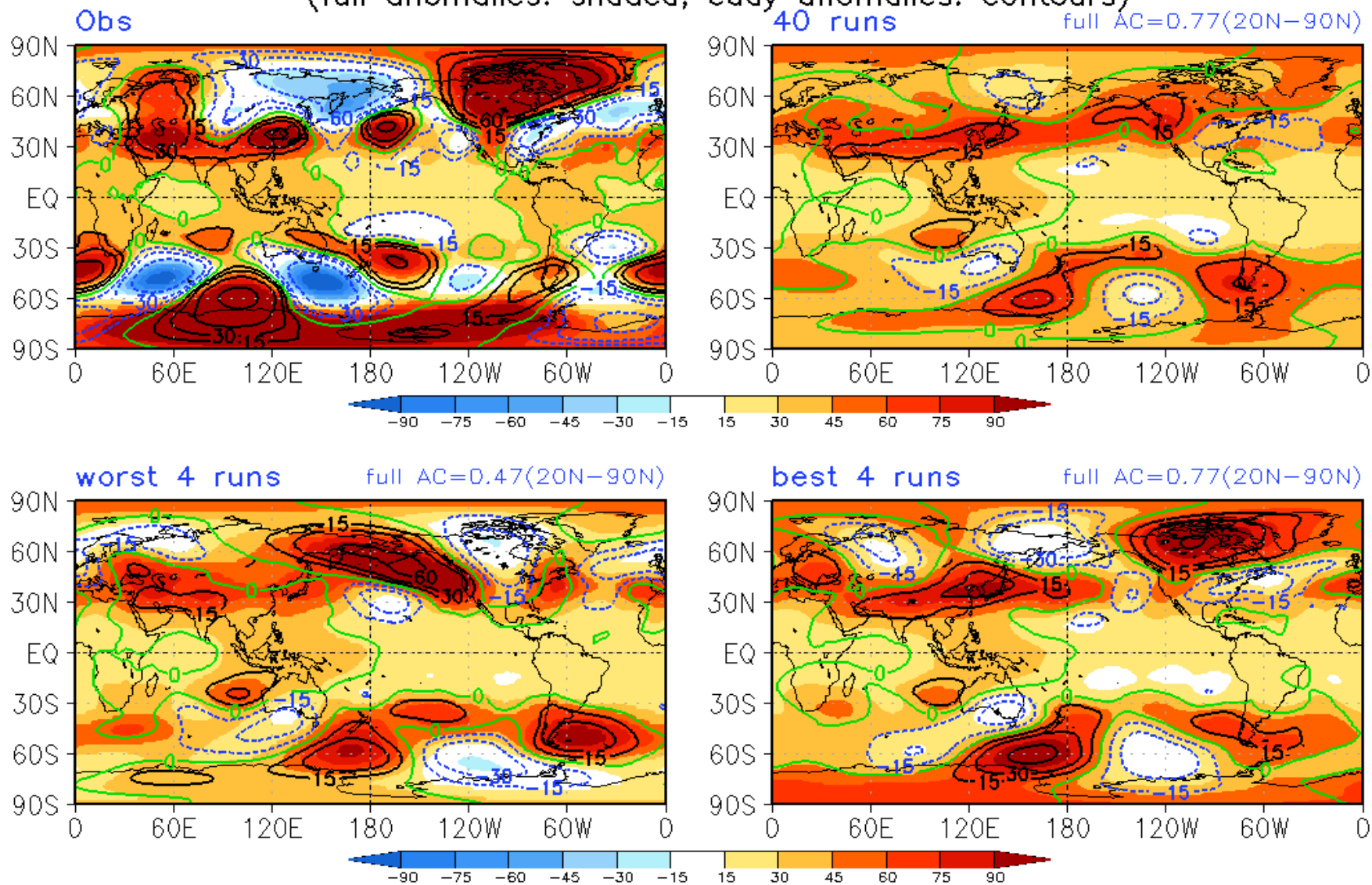
SON2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 z200(m) 40 runs/worst 4 runs/best 4 runs

Seasonal Forecast

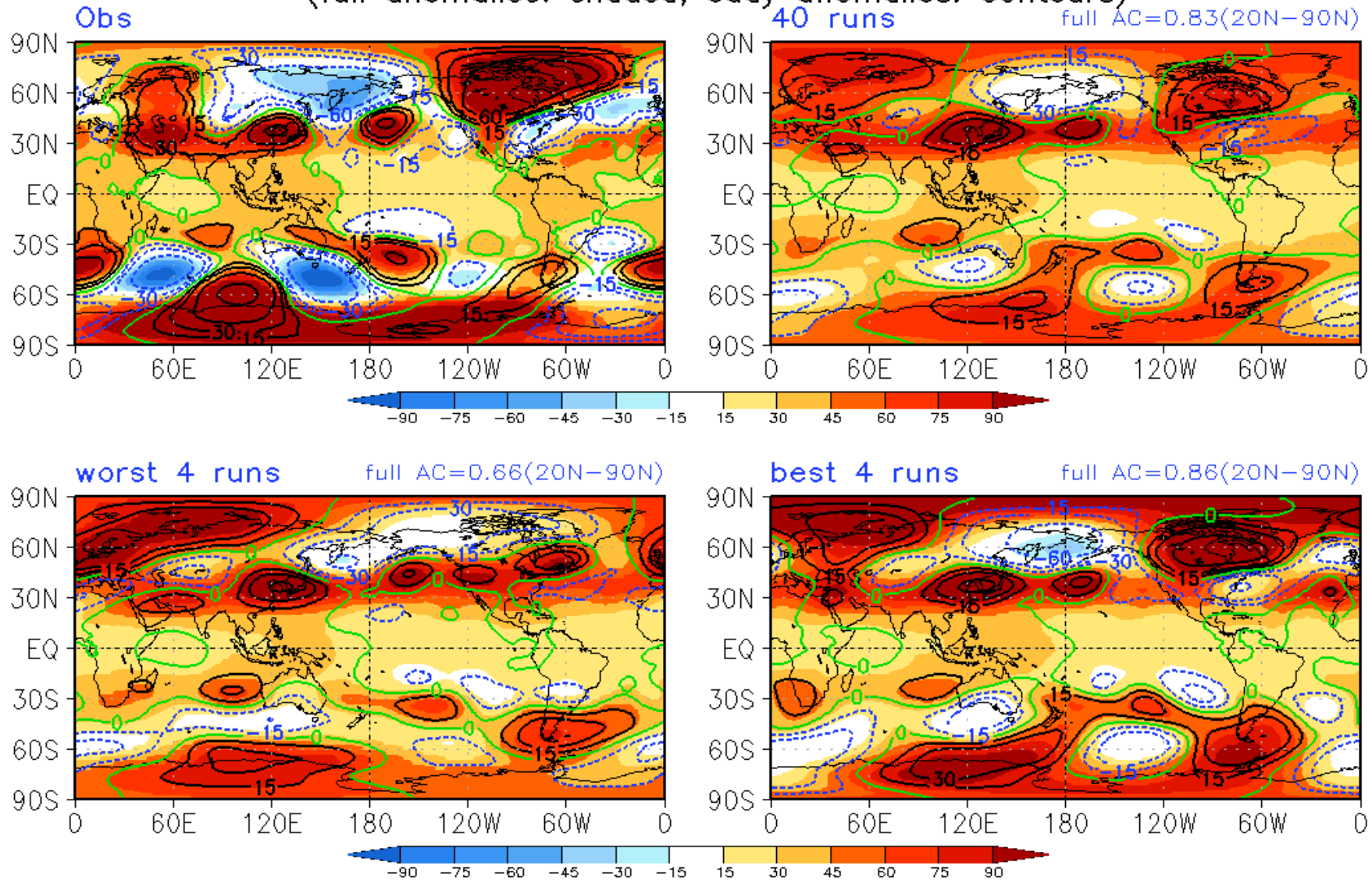
(full anomalies: shaded; eddy anomalies: contours)



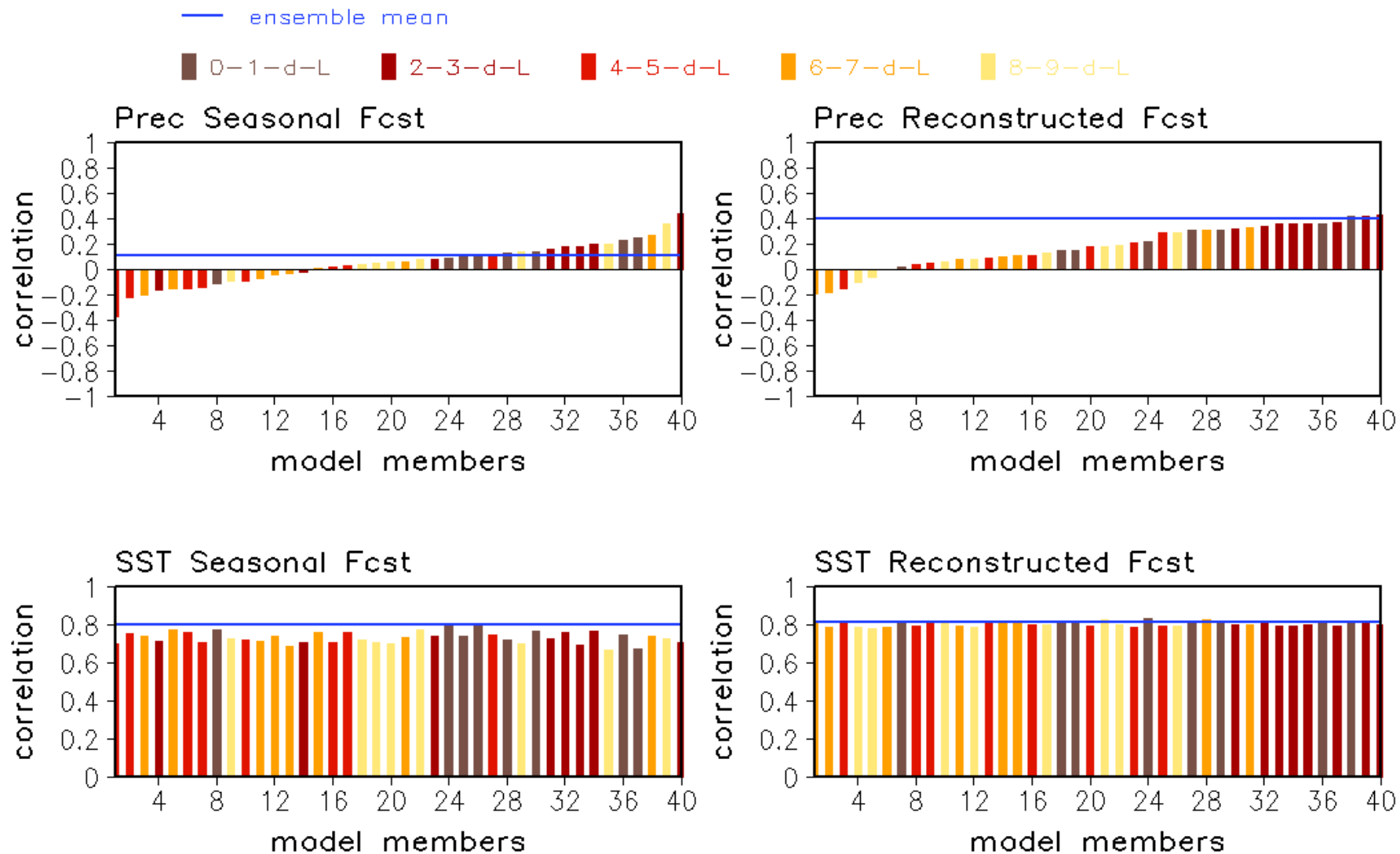
Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 z200(m) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast

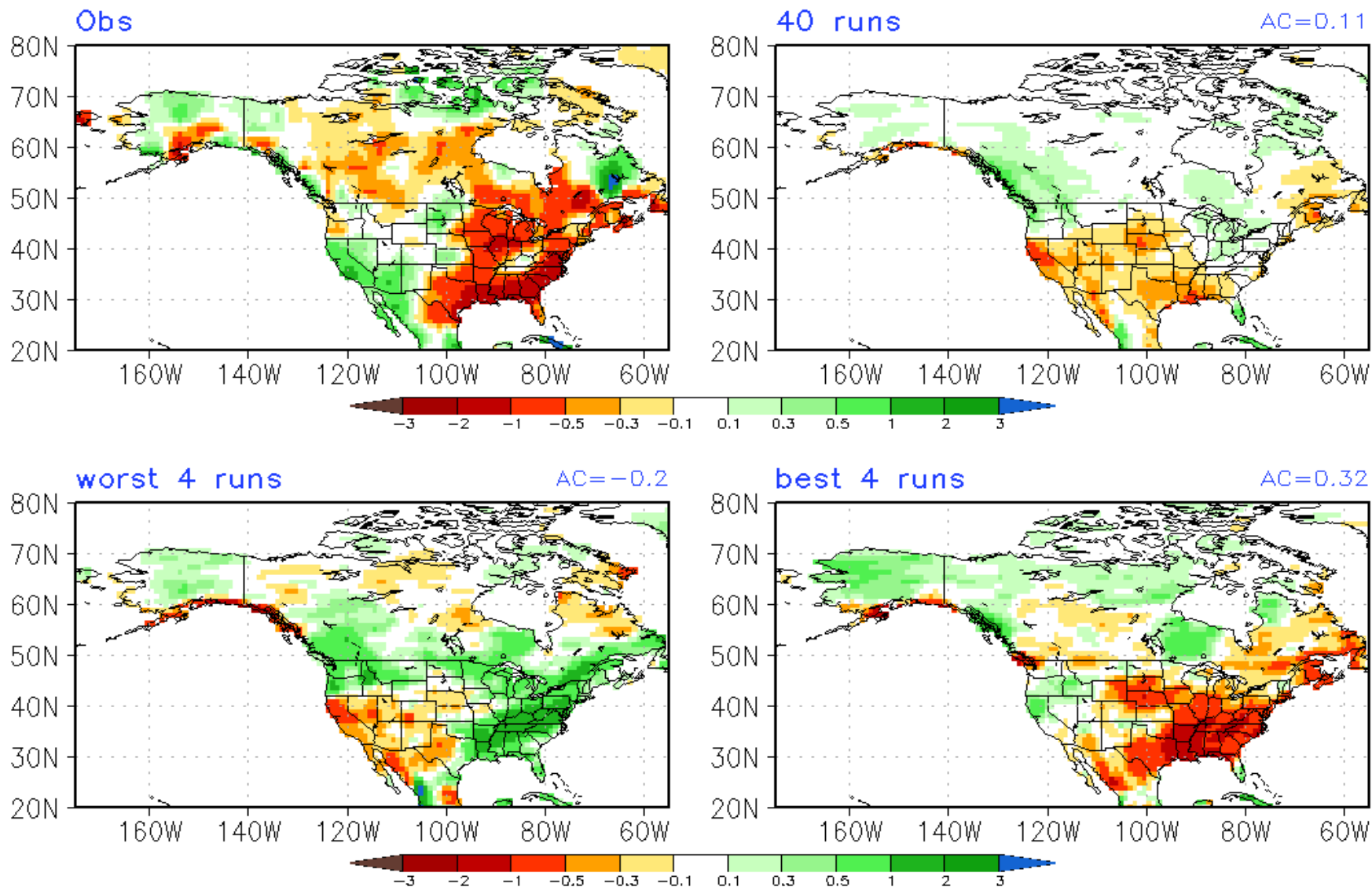
(full anomalies: shaded; eddy anomalies: contours)



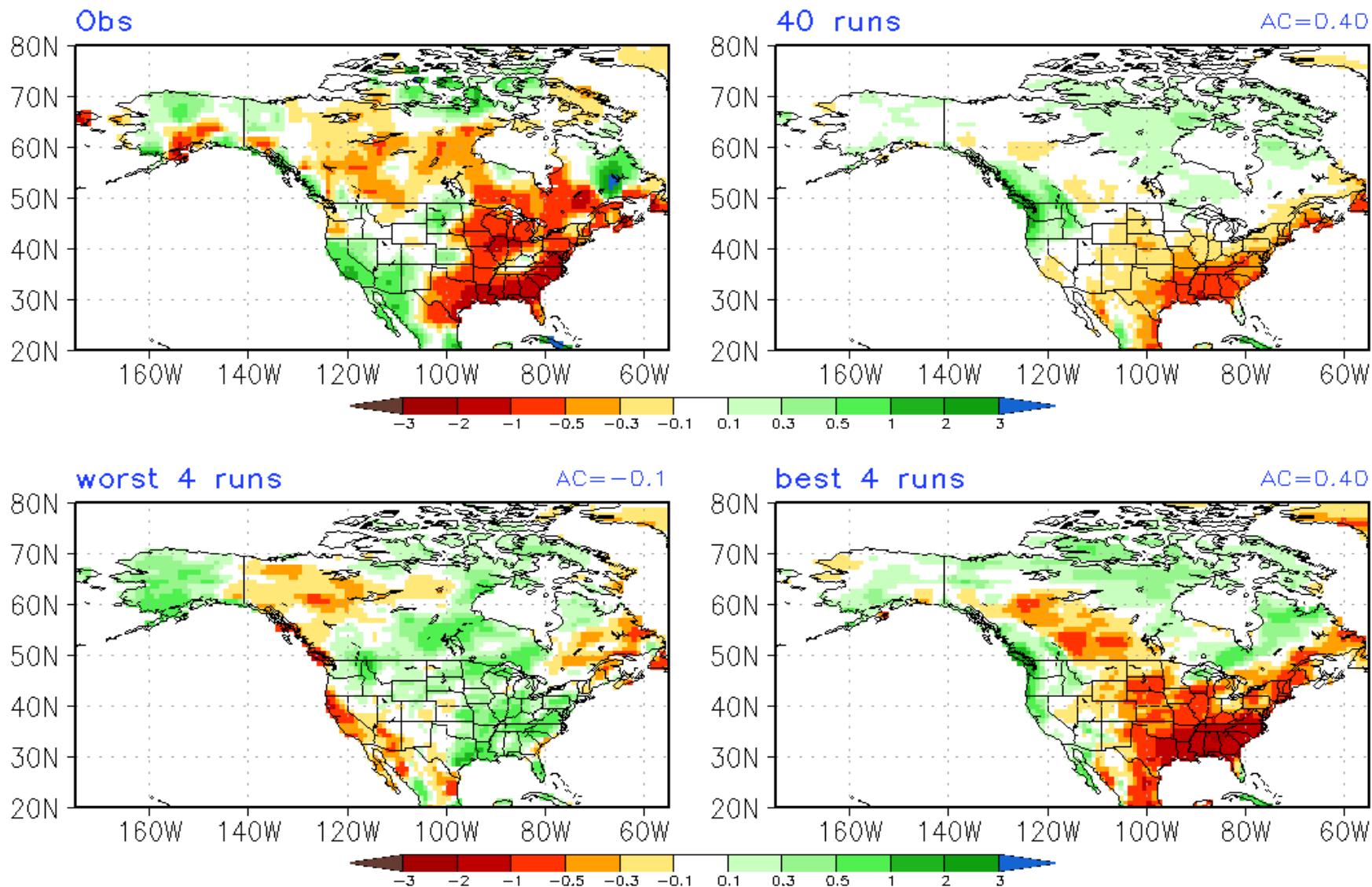
SON2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



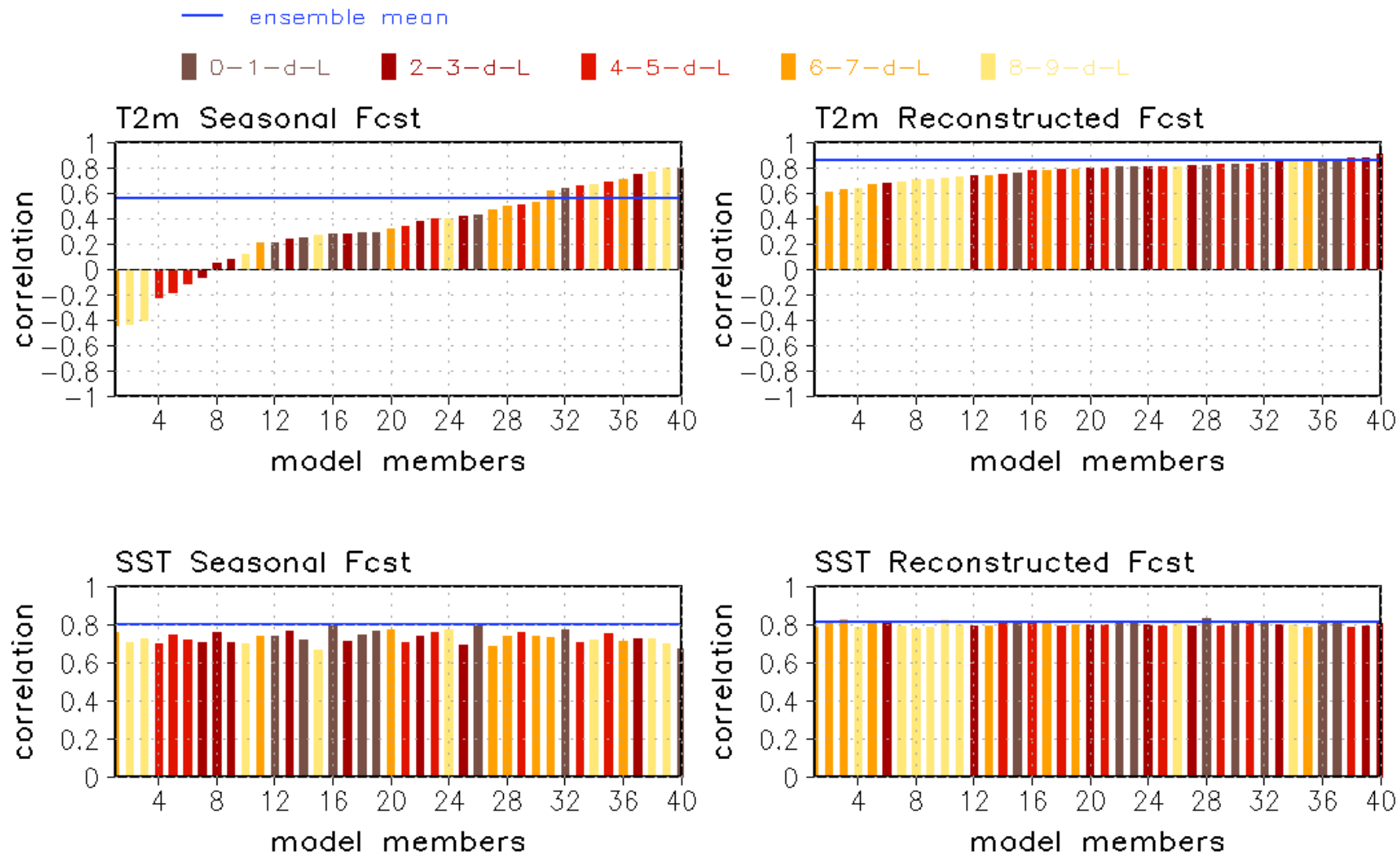
Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



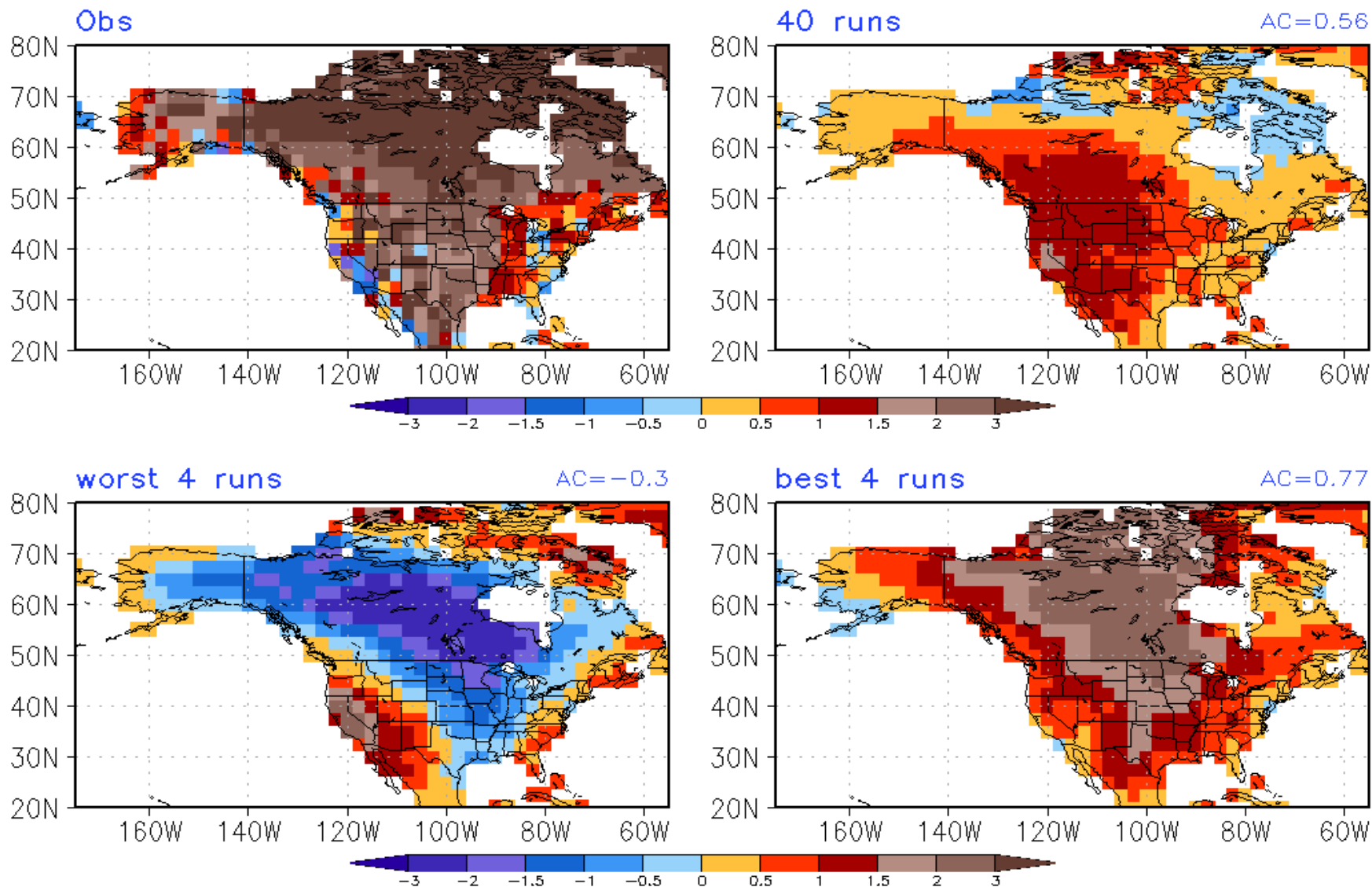
Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



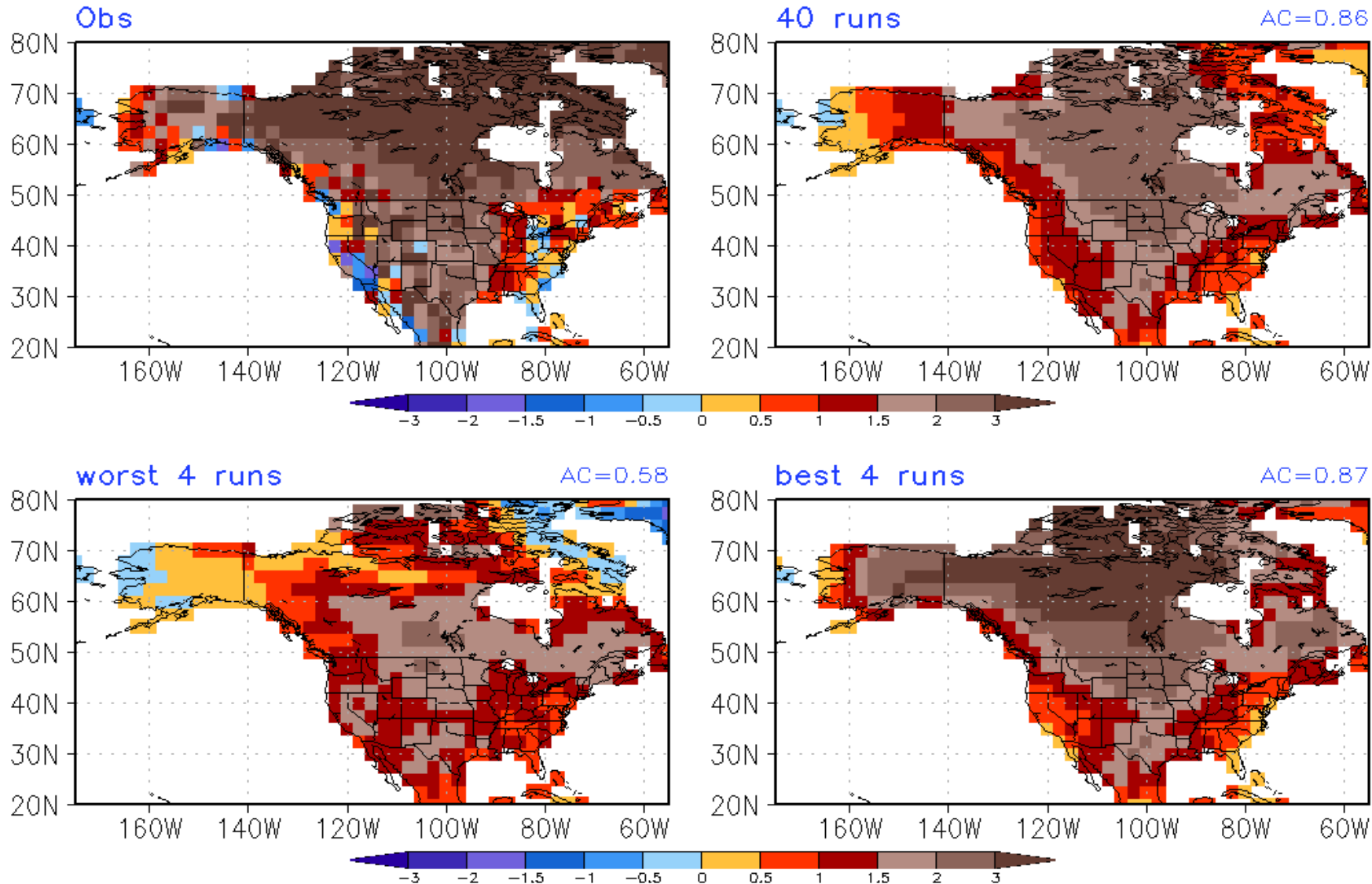
SON2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

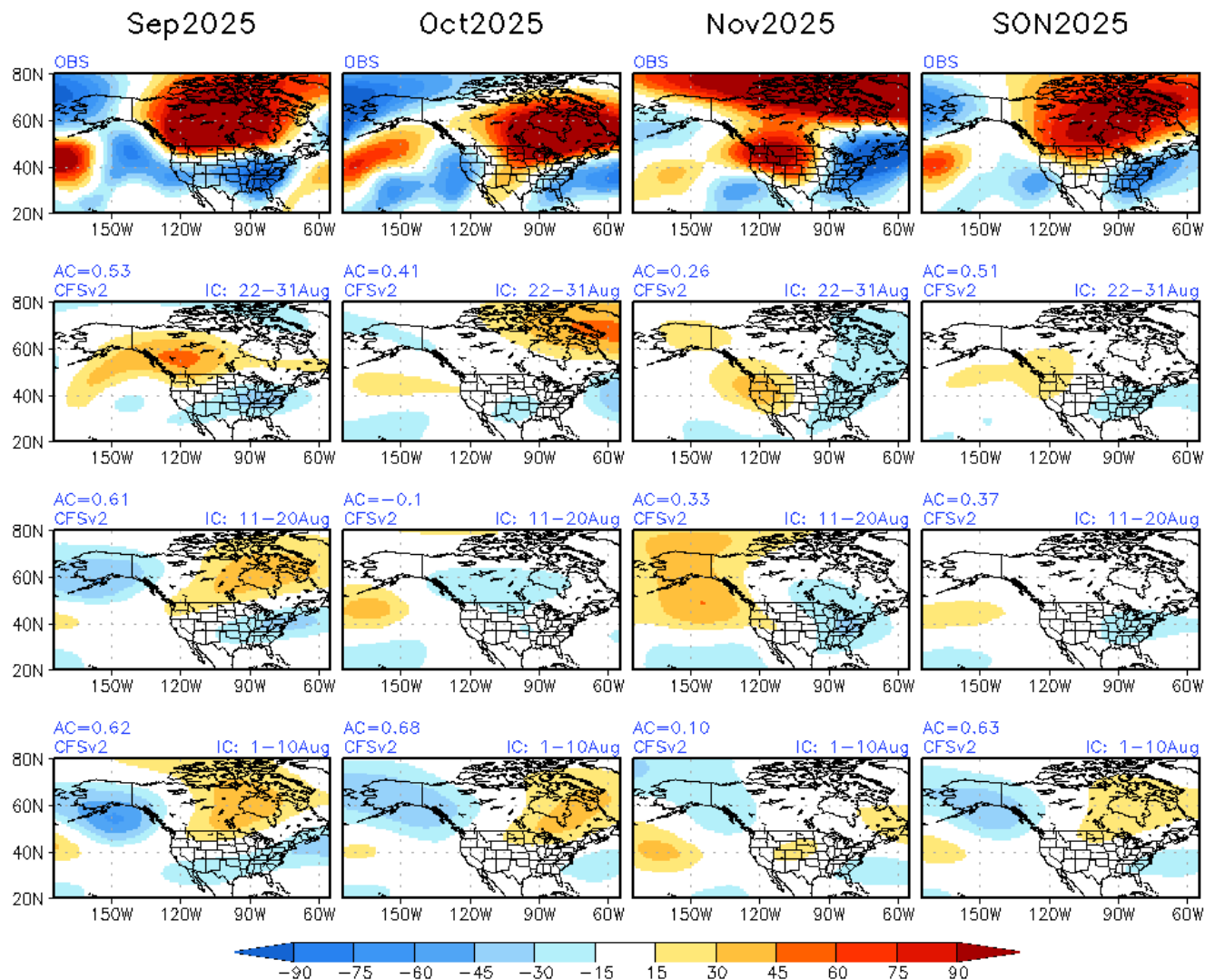


Observed & CFSv2 Forecast Ensemble Average Anomalies
SON2025 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) SON2025 z200(m) eddy & Obs



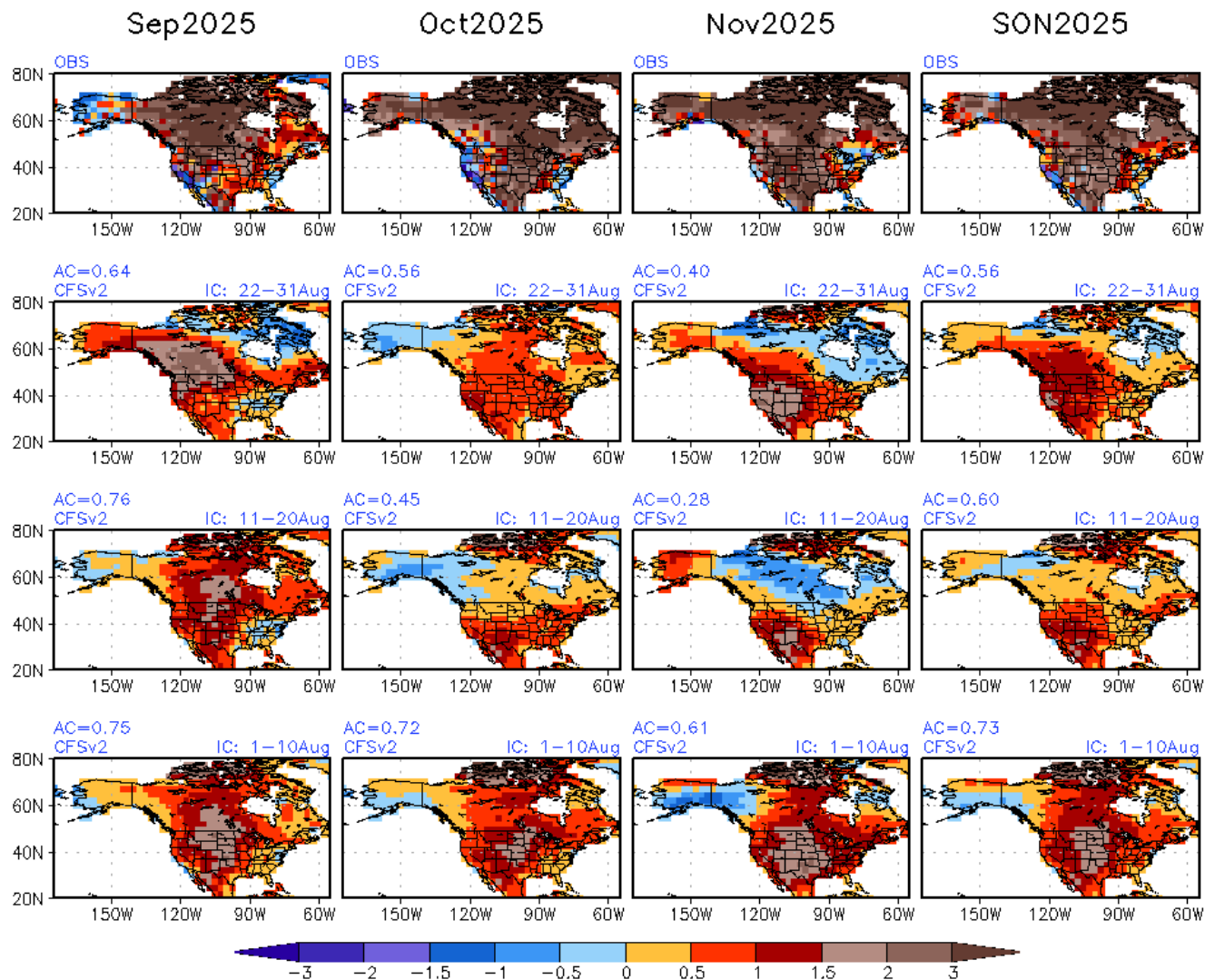
Top row: Observed anomaly.

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) SON2025 T2m(K) & Obs



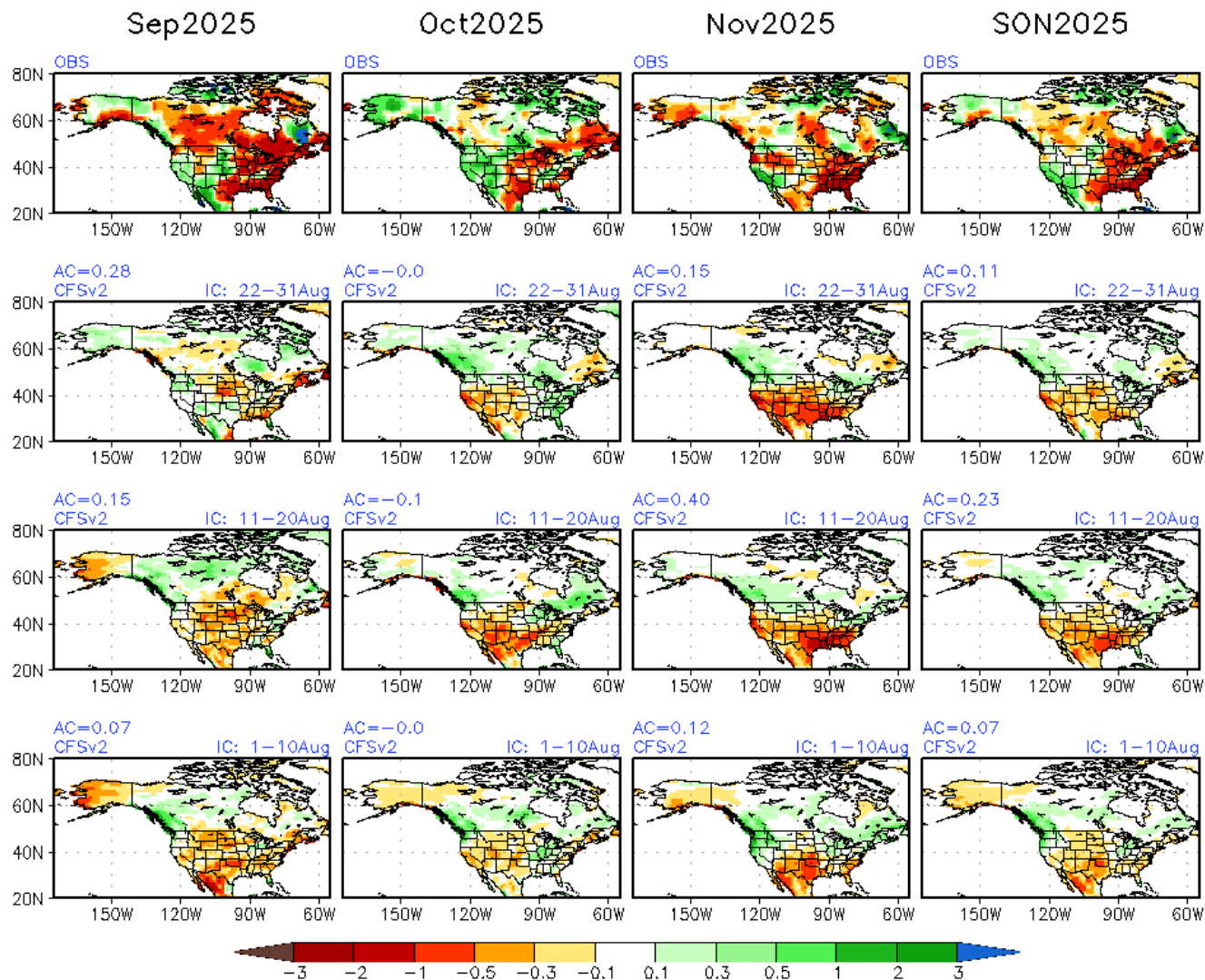
Top row: Observed anomaly.

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- 4th row: 1st - 10th of the prior month.

Prec(mm/day) Monthly Means from Seasonal Forecast

Monthly Means from Seasonal Fcst (40ensm) SON2025 Prec(mm/day) & Obs



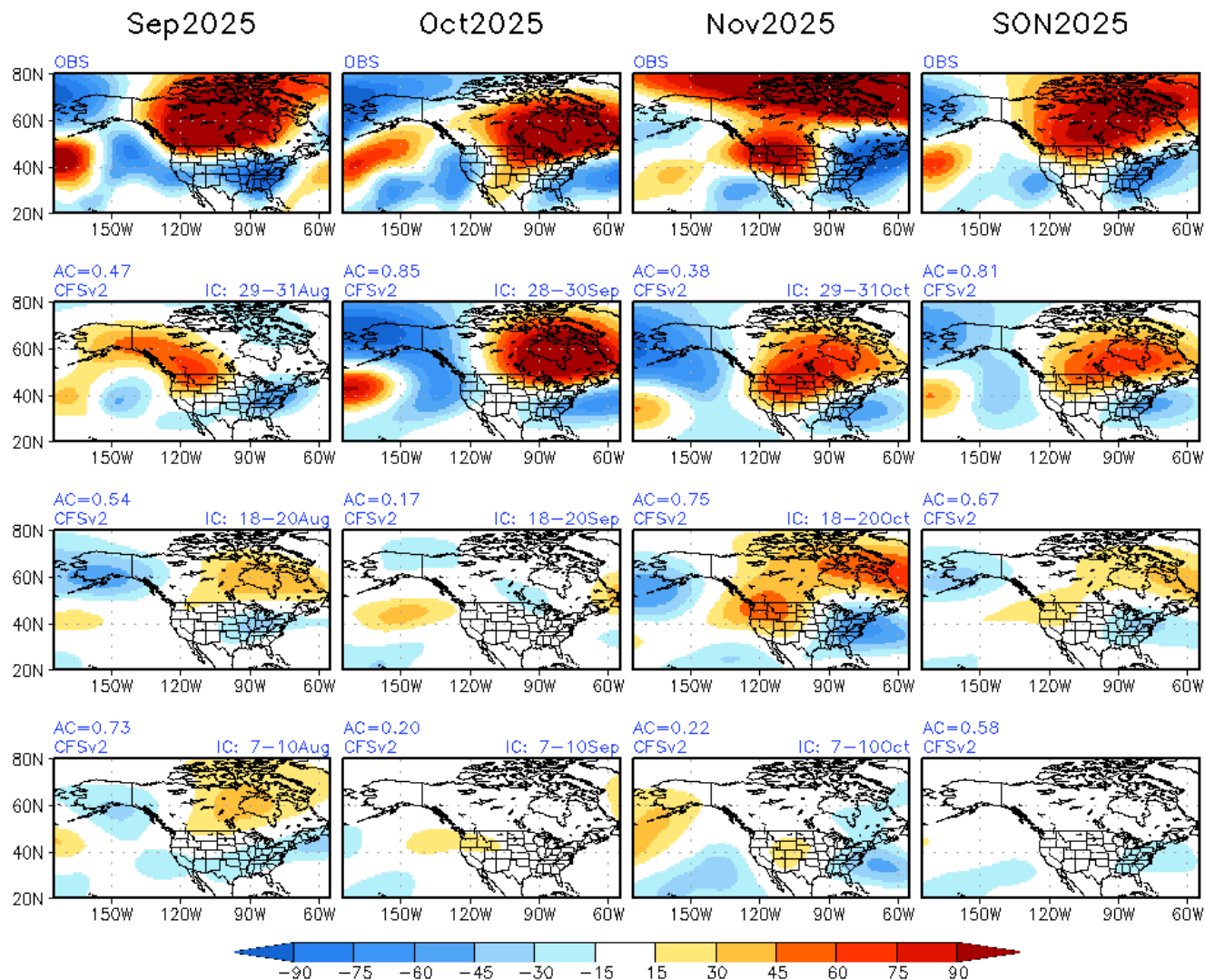
Top row: Observed anomaly.

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

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

z200(m) Monthly Means from Monthly Forecast

Monthly Means from Monthly Fcst SON2025 z200(m) eddy & Obs



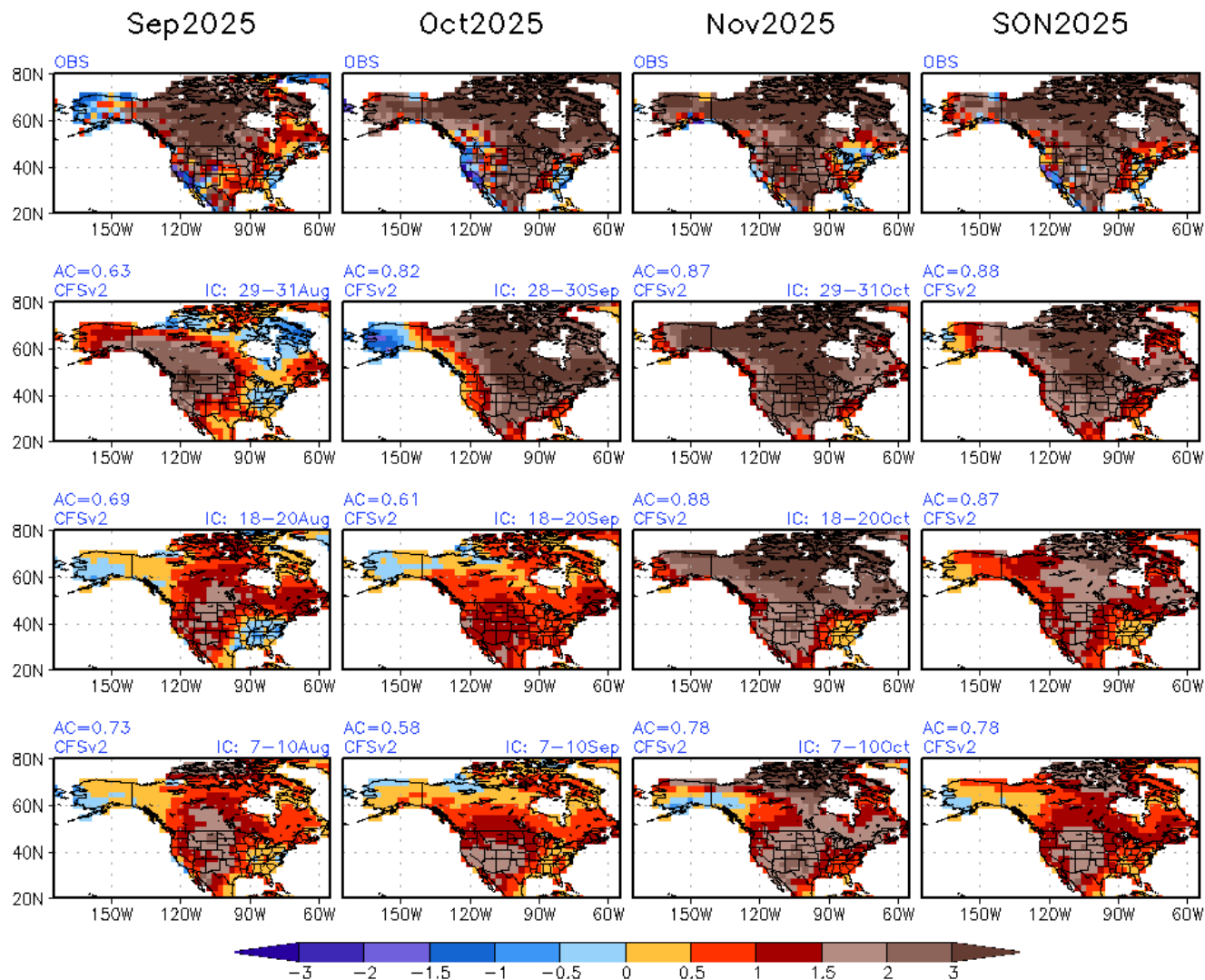
Top row: Observed anomaly.

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 SON2025 T2m(K) & Obs



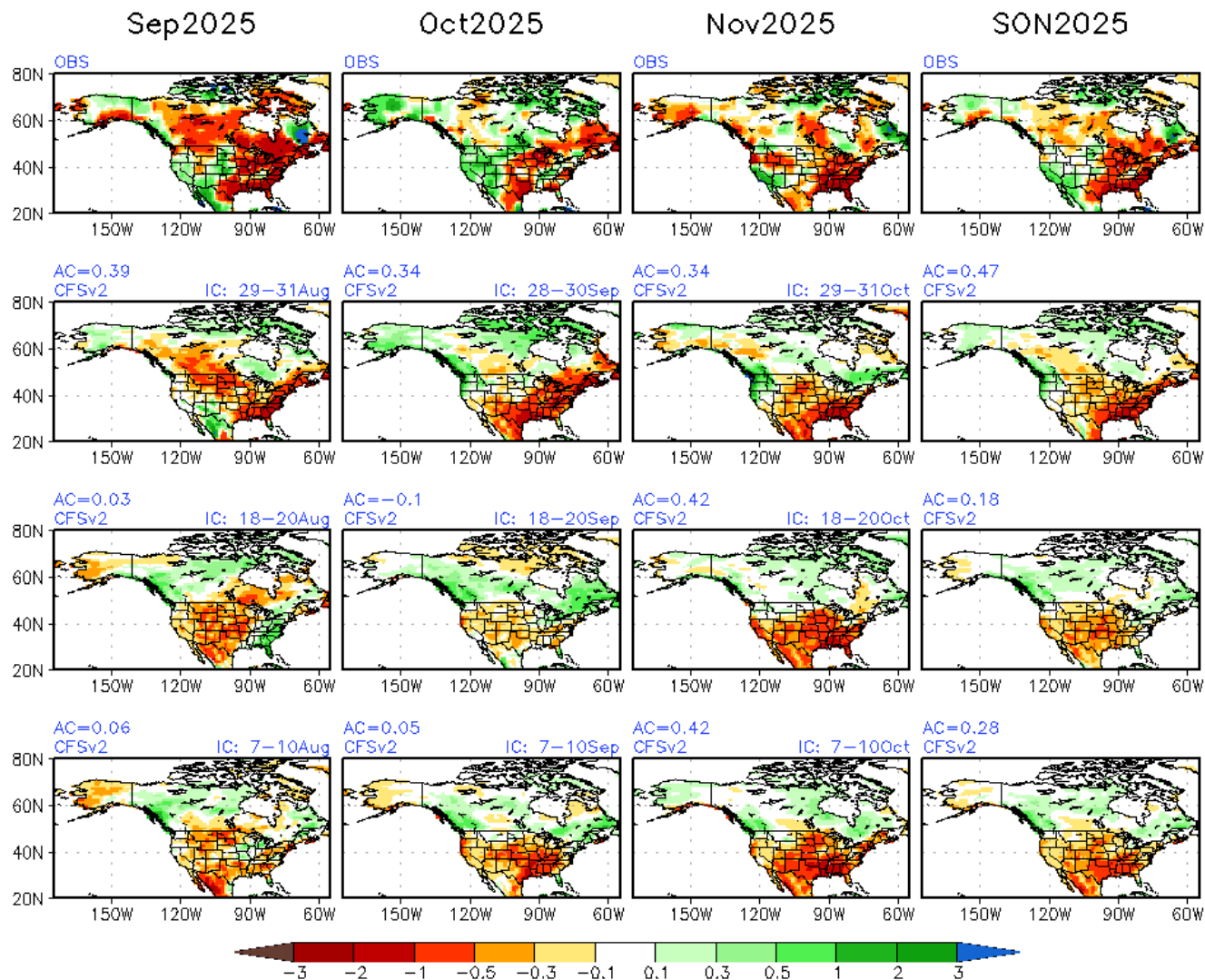
Top row: Observed anomaly.

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 SON2025 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

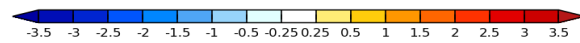
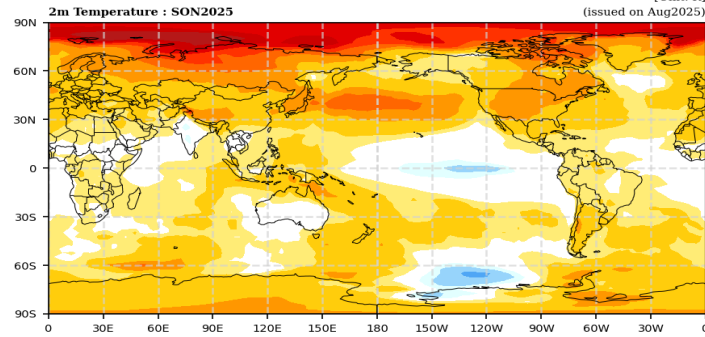
(<https://www.wmolc.org/>)

Ensemble means

Simple Composite Map

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

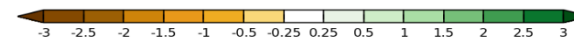
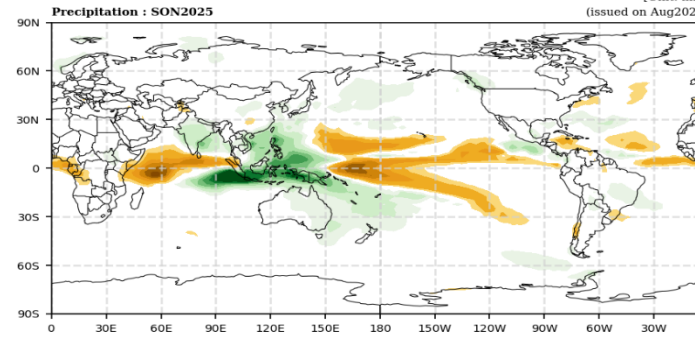
[Unit: K]
(issued on Aug2025)



Simple Composite Map

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

[Unit: mm]
(issued on Aug2025)

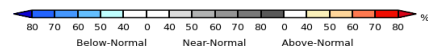
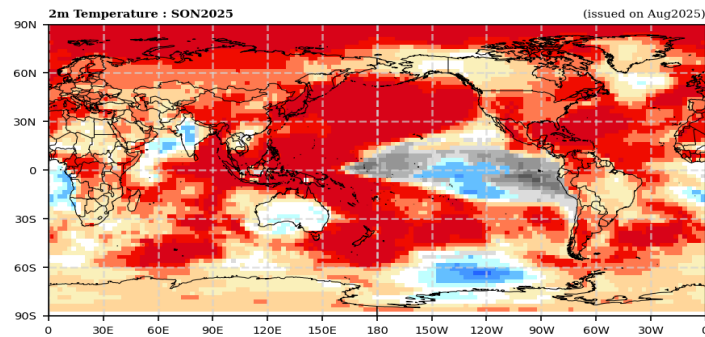


Probabilities

Probabilistic Multi-Model Ensemble Forecast

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

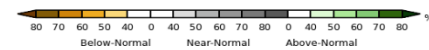
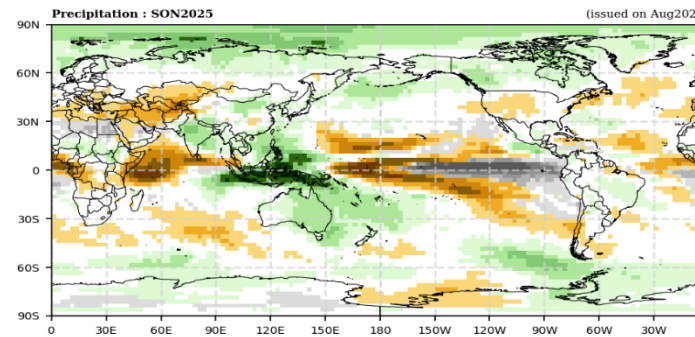
(issued on Aug2025)



Probabilistic Multi-Model Ensemble Forecast

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

(issued on Aug2025)



C3S Seasonal Forecast

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

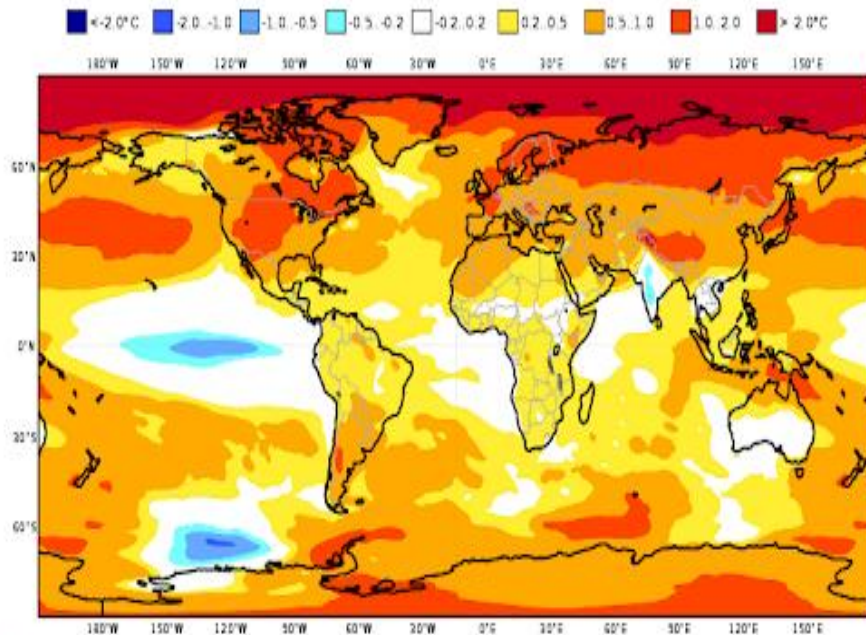
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Mean 2m temperature anomaly

SON 2025

Nominal forecast start: 01/08/25

Variance-standardized mean



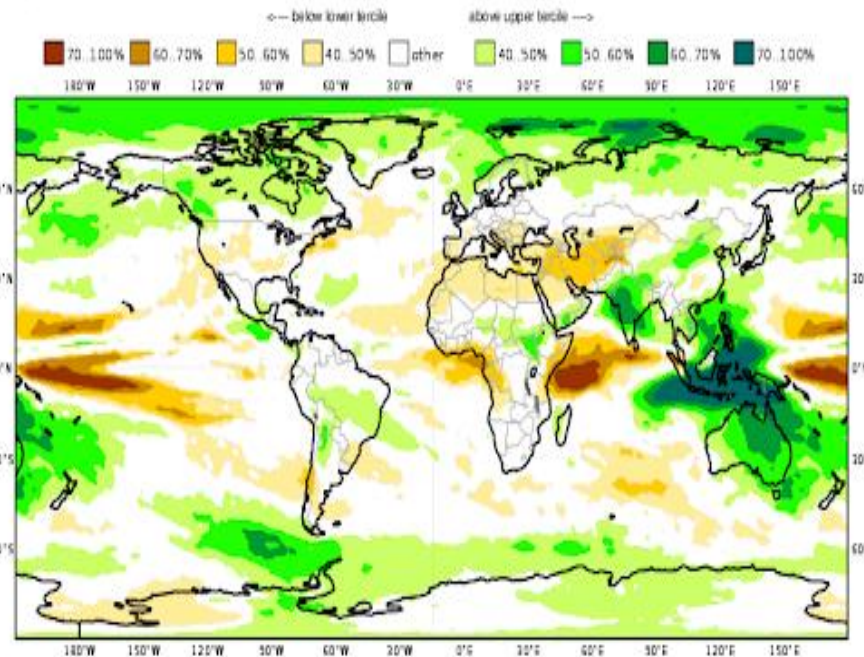
C3S multi-system seasonal forecast ECMWF/Met Office/Météo-France/CMCC/DWD/NCEP/JMA/ECCC/BOM

Prob(most likely category of precipitation)

SON 2025

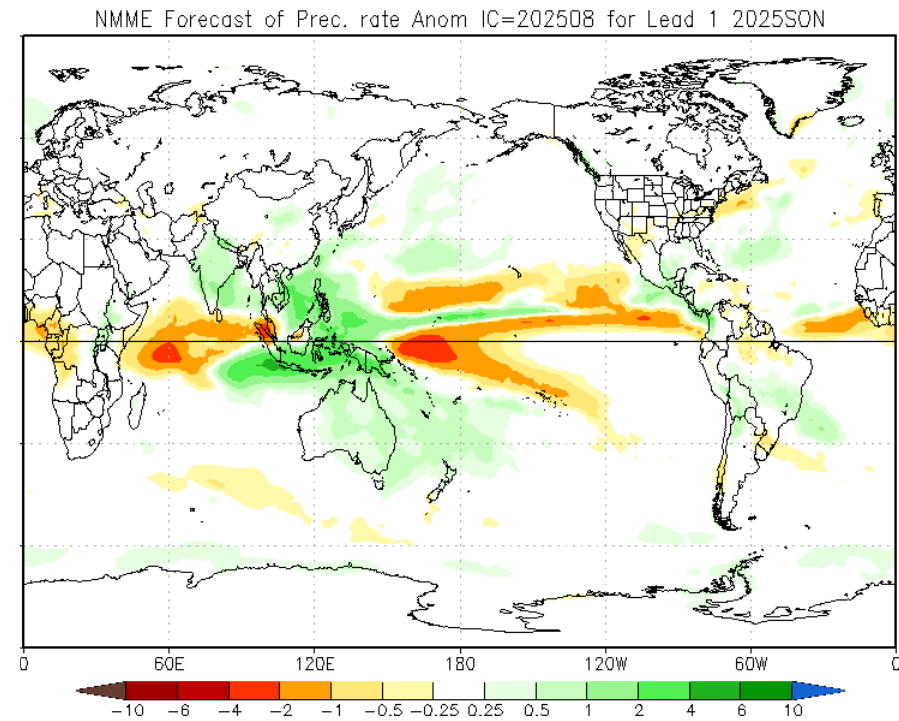
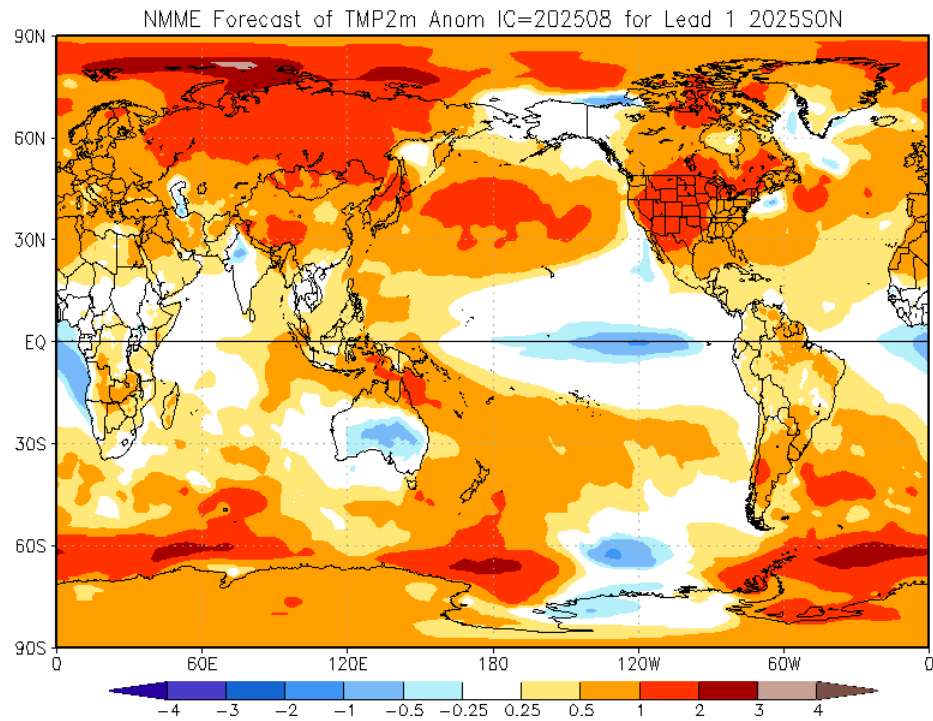
Nominal forecast start: 01/08/25

Unweighted mean



North American Multi-Model Ensemble Seasonal Forecast

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

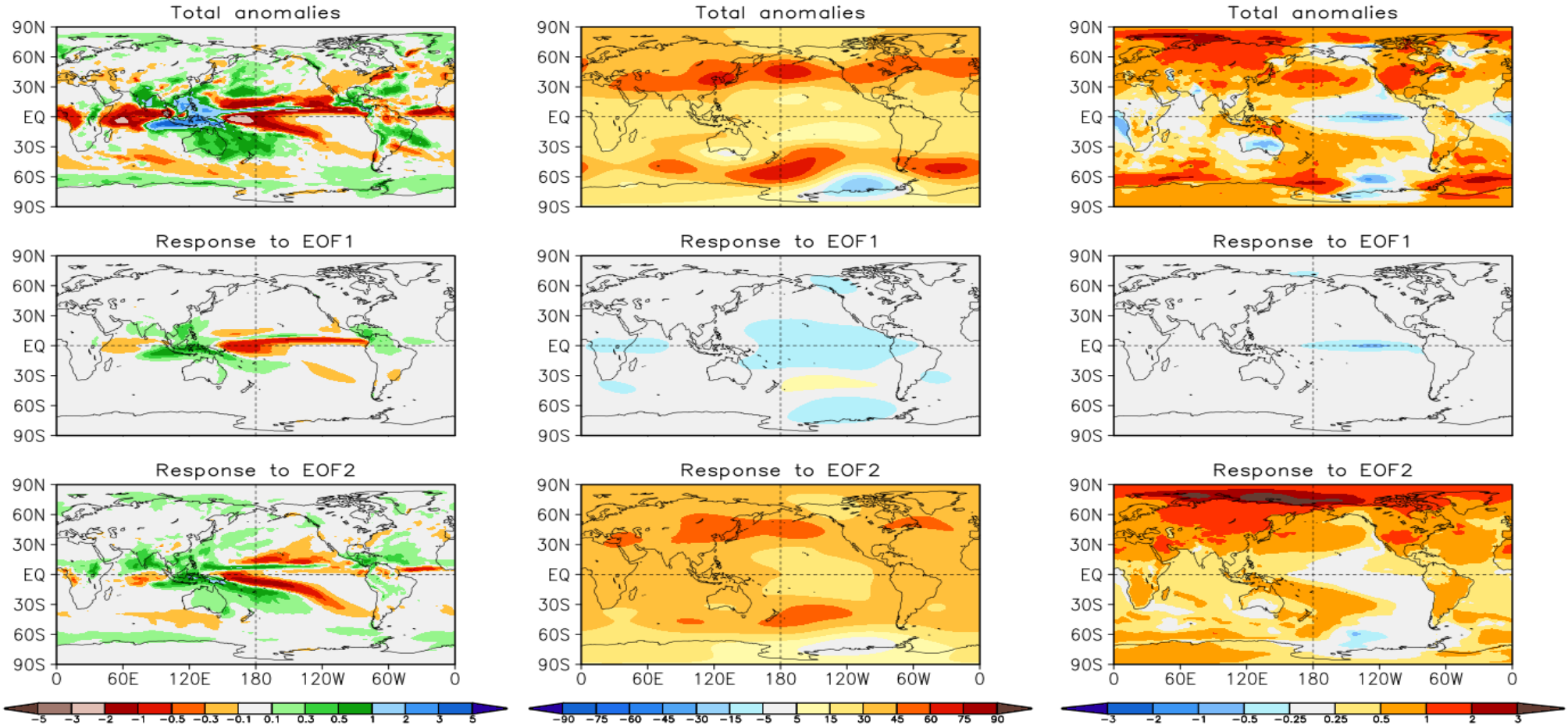


NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME SON2025 Precip (mm/day)

NMME SON2025 z200 (m)

NMME SON2025 T2m (K)

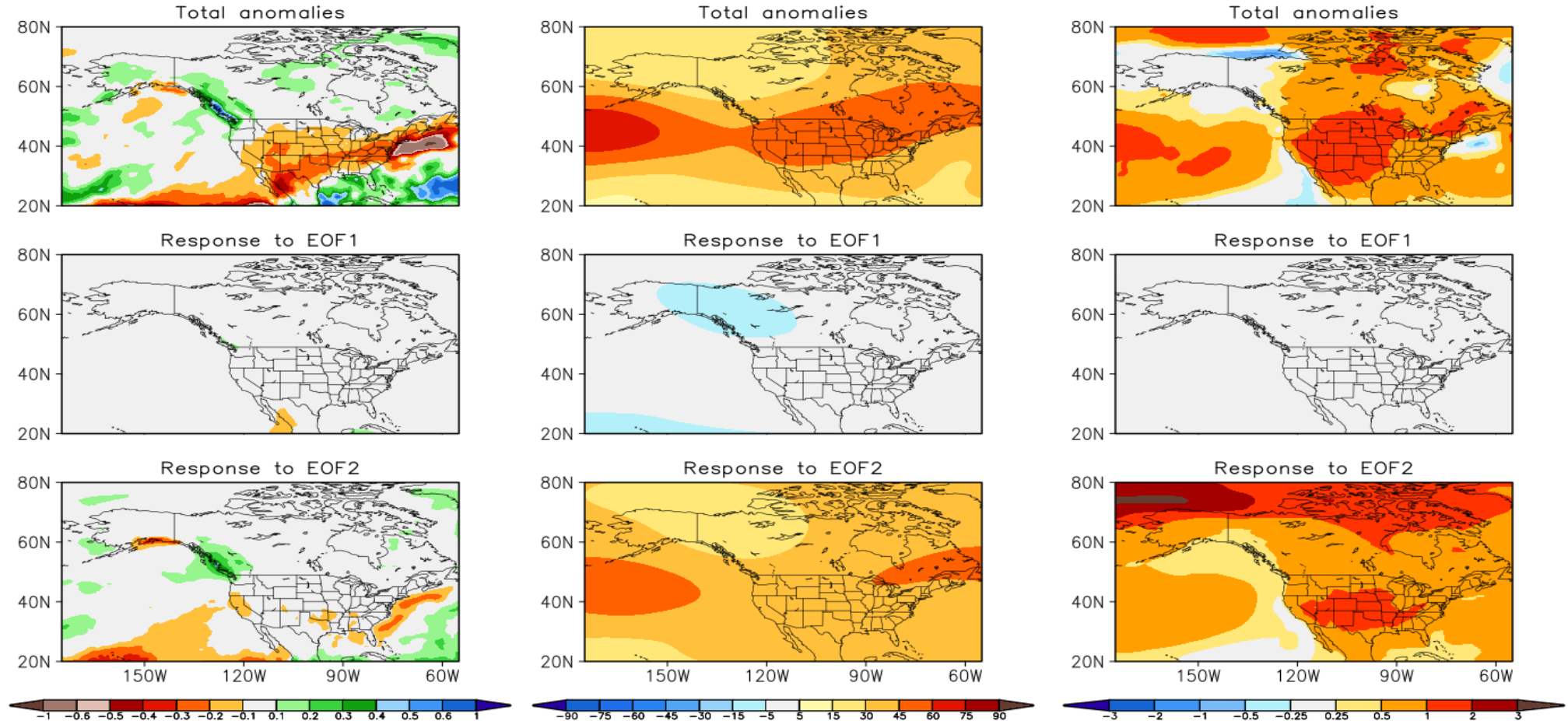


NMME Forecast Atmospheric Anomalies Response to Leading SST EOFs

NMME SON2025 Precip (mm/day)

NMME SON2025 z200 (m)

NMME SON2025 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.