Attribution of Seasonal Climate Anomalies December-January-February 2024-25

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

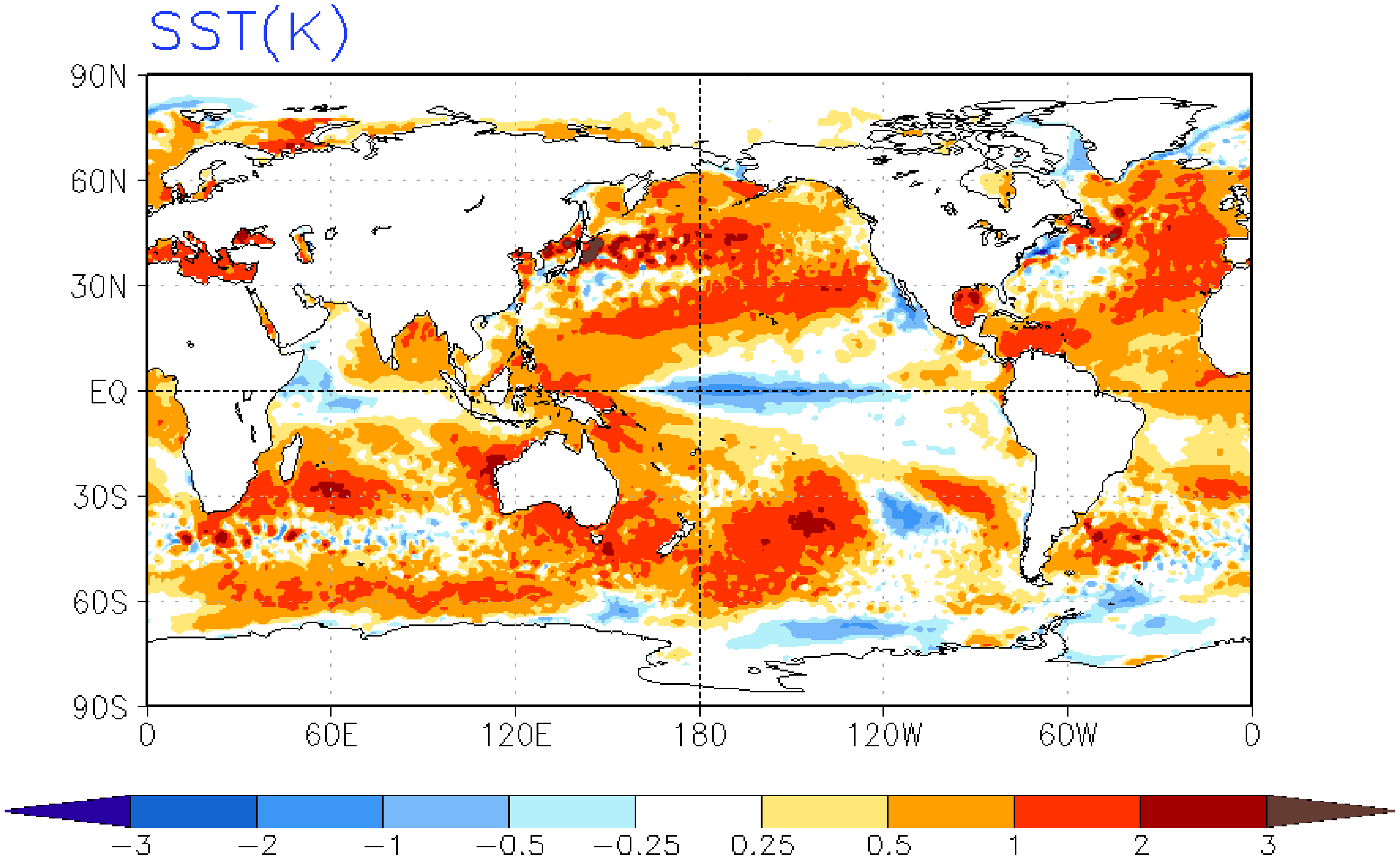
Summary of Observed Conditions and Outlooks

- DJF2024-25 continued with weak below-normal SST anomalies in the central-eastern equatorial Pacific resembling La Niña. Meanwhile, persistent warm SST anomalies continued in the northern and southern Indian Ocean, the northwest and the Southern Pacific, as well as the tropical and North Atlantic Oceans. Notably, the tropical Atlantic remained abnormally warm for over a year.
- The CFSv2 model forecasts effectively captured the large-scale structure of observed SST anomalies but had a cold bias in the equatorial eastern Pacific, southern Pacific, and southeast Indian Ocean (slide 10).
- Both the AMIP simulation and the initialized CFSv2 forecast, along with other MME forecasts, predicted positive anomalous rainfall over the Maritime Continent, extending into the southwestern Pacific, and dry conditions over the central and eastern equatorial Pacific, a pattern typically associated with the La Nina response. Overall, the forecast pattern was consistent with the large-scale distribution of the observed precipitation anomalies across the tropics (Slide 11, 37-39).
- Although the cold SST anomalies in the central and eastern Pacific were marginally below average on an absolute basis, the models' the canonical La Nina response could be because with a general warming of tropical and global oceans, the relative SST anomalies in the central Pacific were colder.
- Models successfully captured the general observed warming trend in 200-mb height and land surface temperature. However, the positive anomalies over the North America regions were shifted slightly northward, resulting in missed cold anomalies in land surface temperature over the eastern US (slides 12, 13, 15, 16).
- Models predicted precipitation anomaly pattern was consistent with the La Nina response and captured most of the observed below-normal precipitation in the southern regions of North America (slide 14).
- Feb 2025 North America's 200-mb height, T2m, and precipitation showed improved forecast skill at shortest leads (slides 33-35).

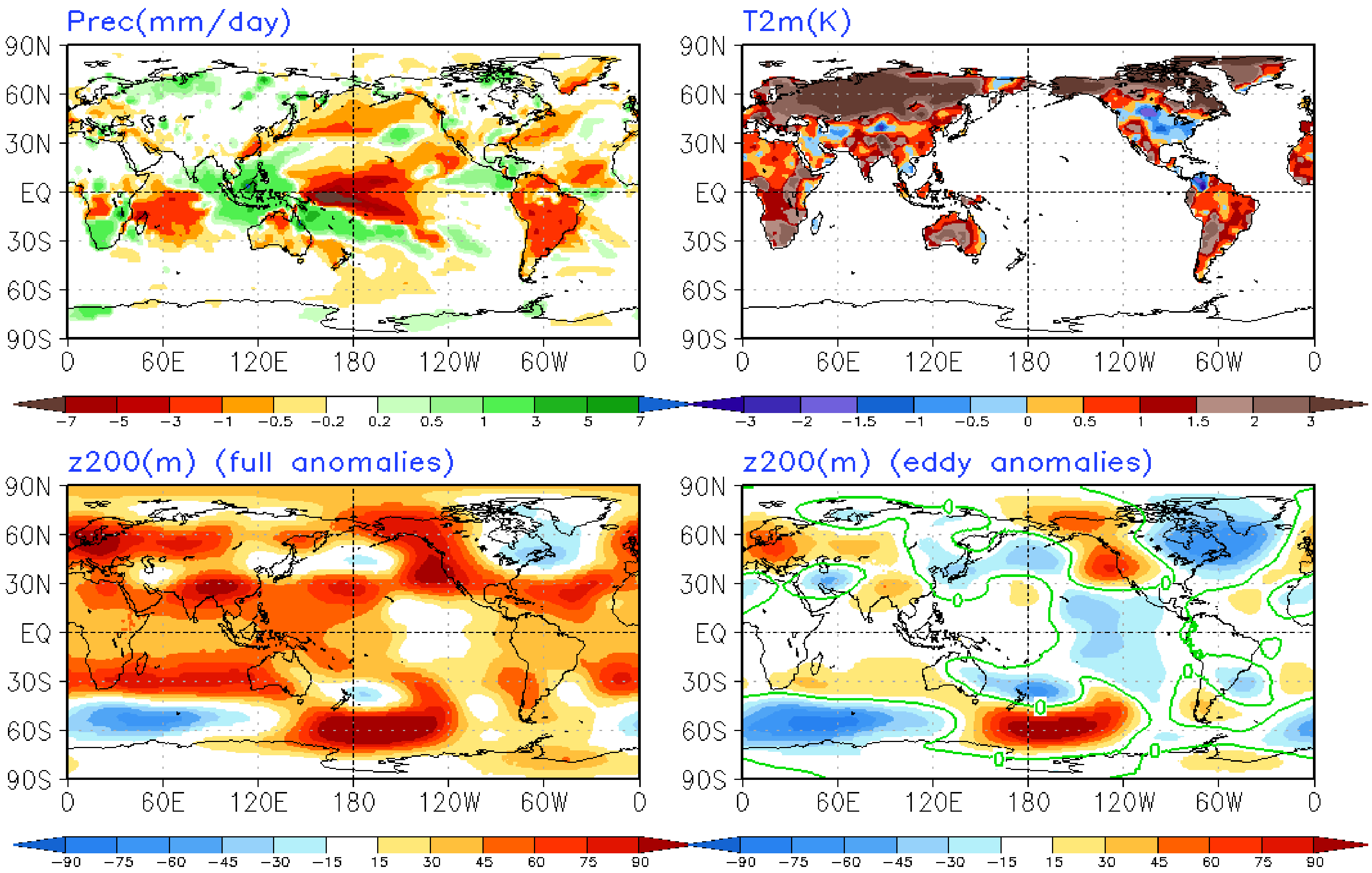
Observed Seasonal Anomalies

Global and North America

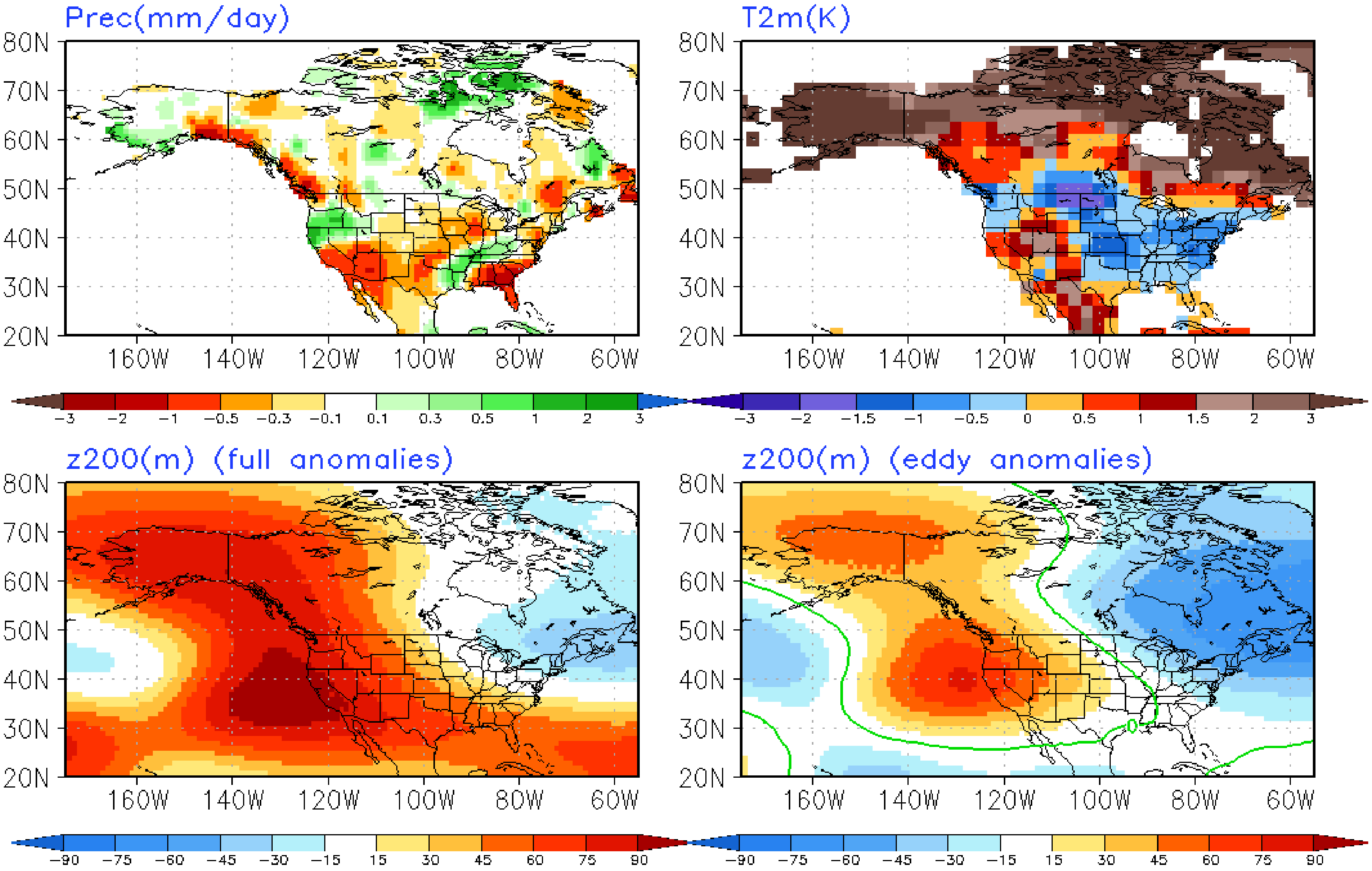
Observed Anomaly DJF2024/2025



Observed Anomaly DJF2024/2025



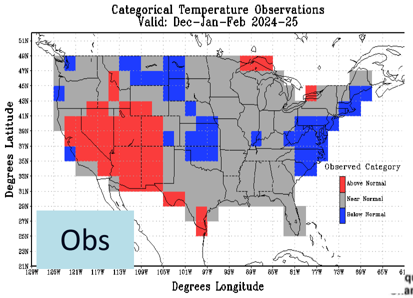
Observed Anomaly DJF2024/2025

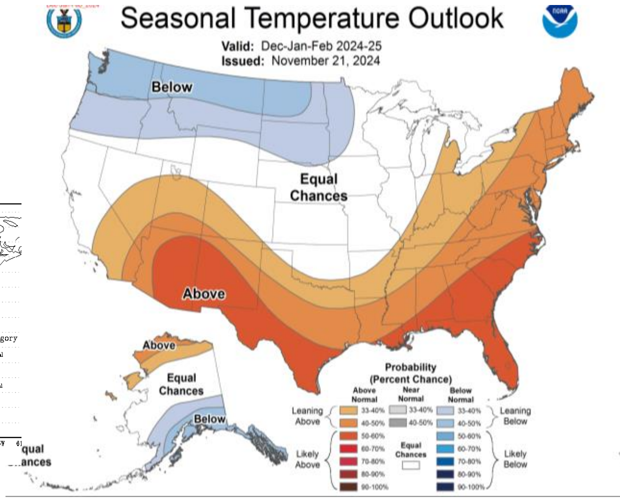


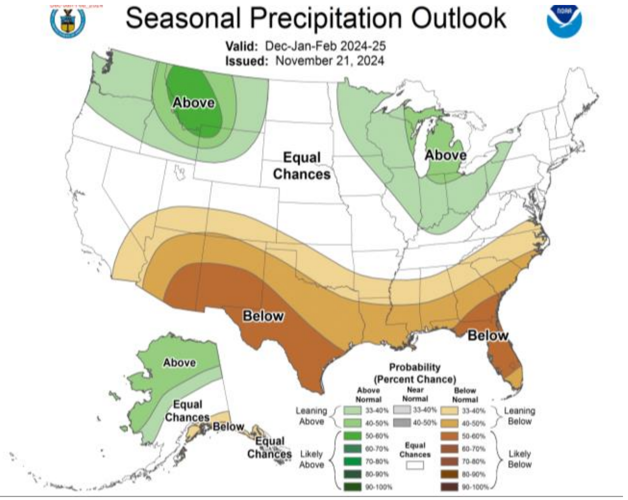
CPC Seasonal Outlooks and NMME Forecasts

CPC

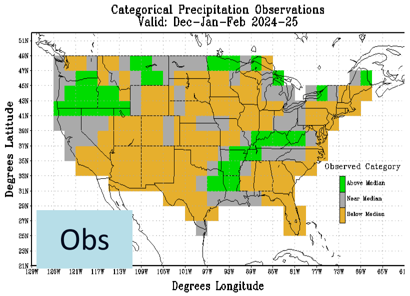
Temp nonEC
HSS=-7

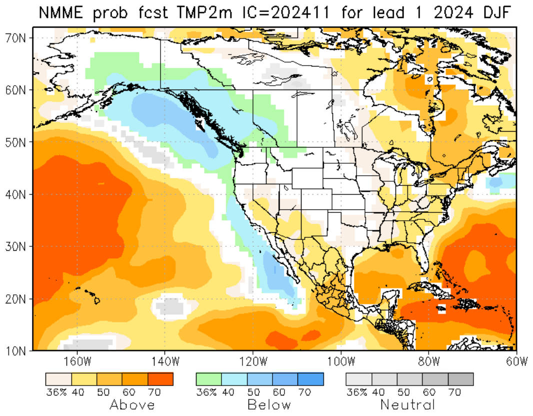




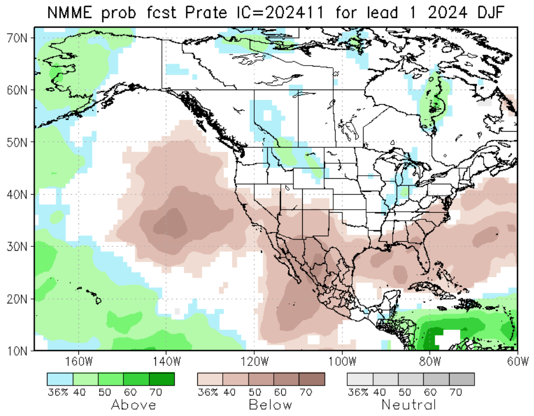


Prec nonEC
HSS=33





NMME



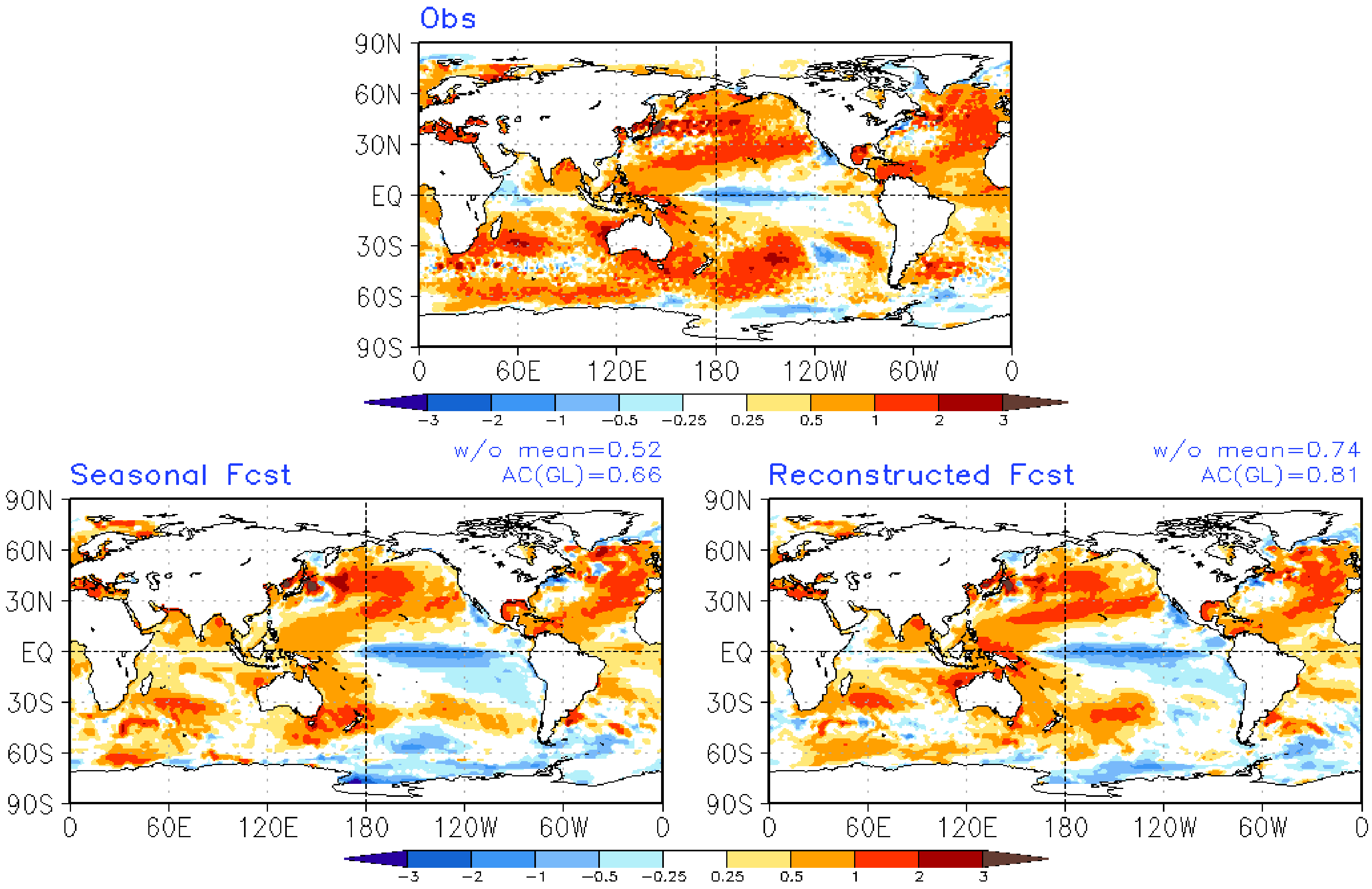
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2024/202411_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

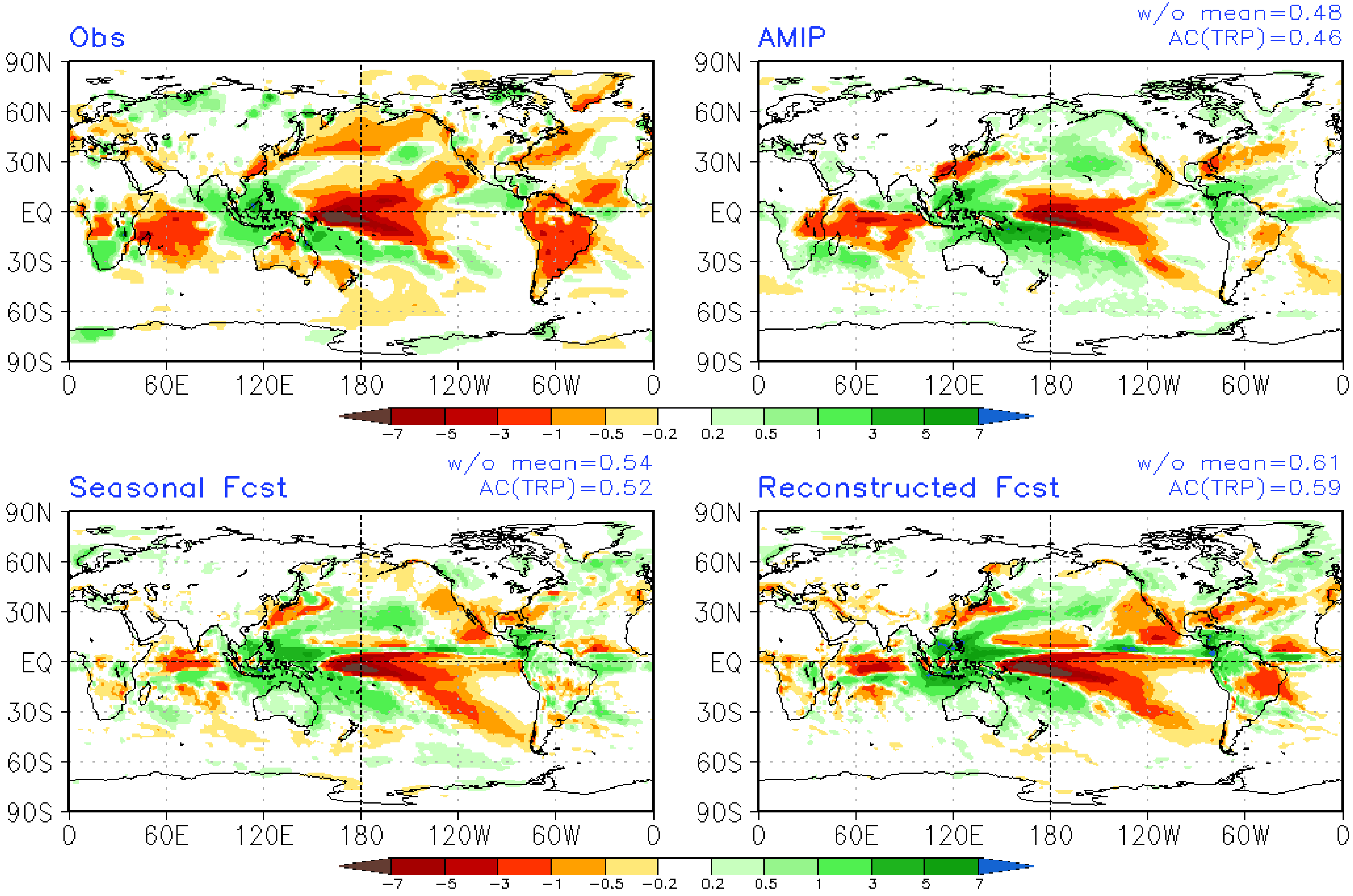
Model Simulated/Forecast Ensemble Average Anomalies

- 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 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). “w/o mean” is AC with area mean removed.

DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)

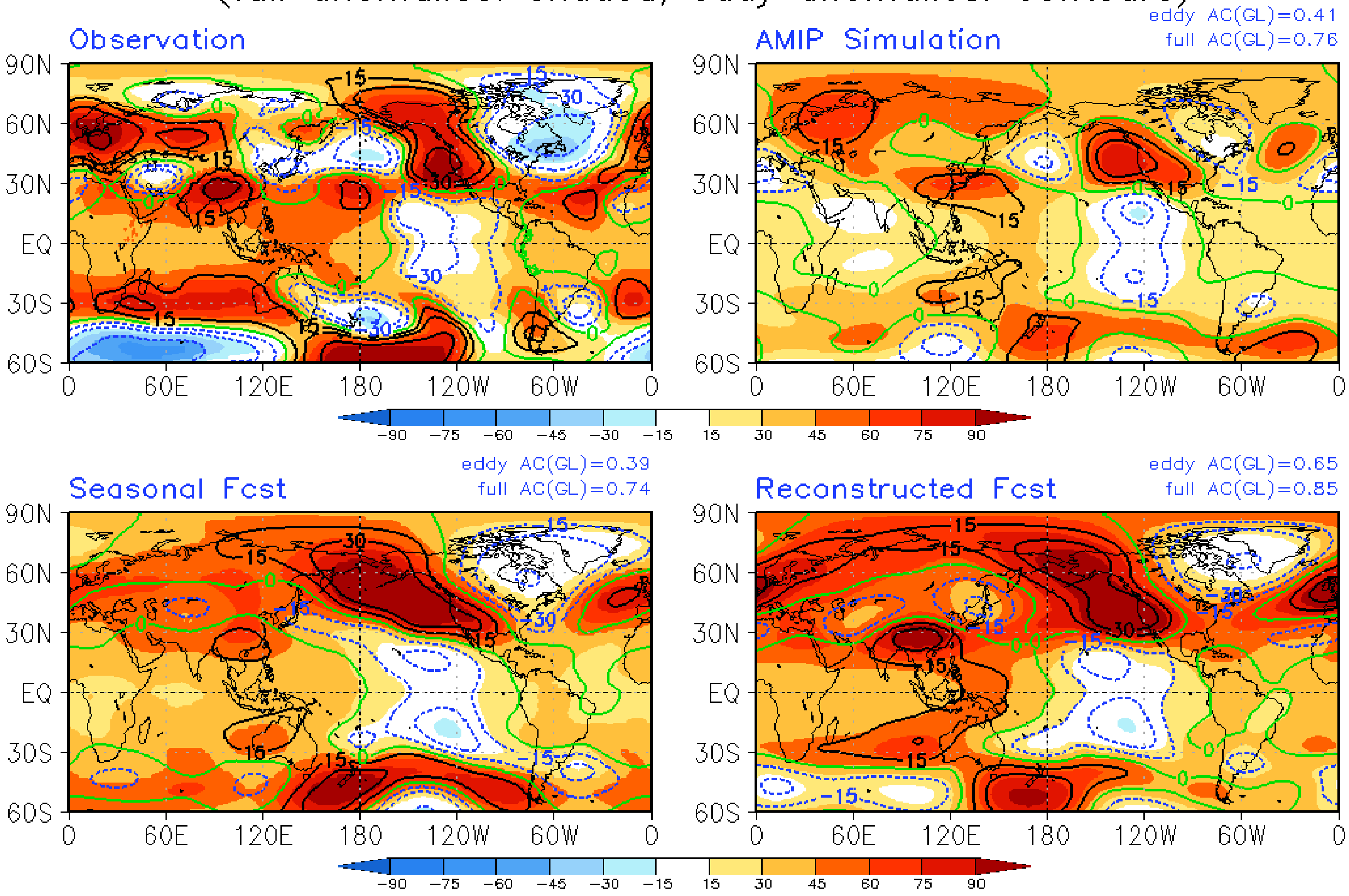


DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)

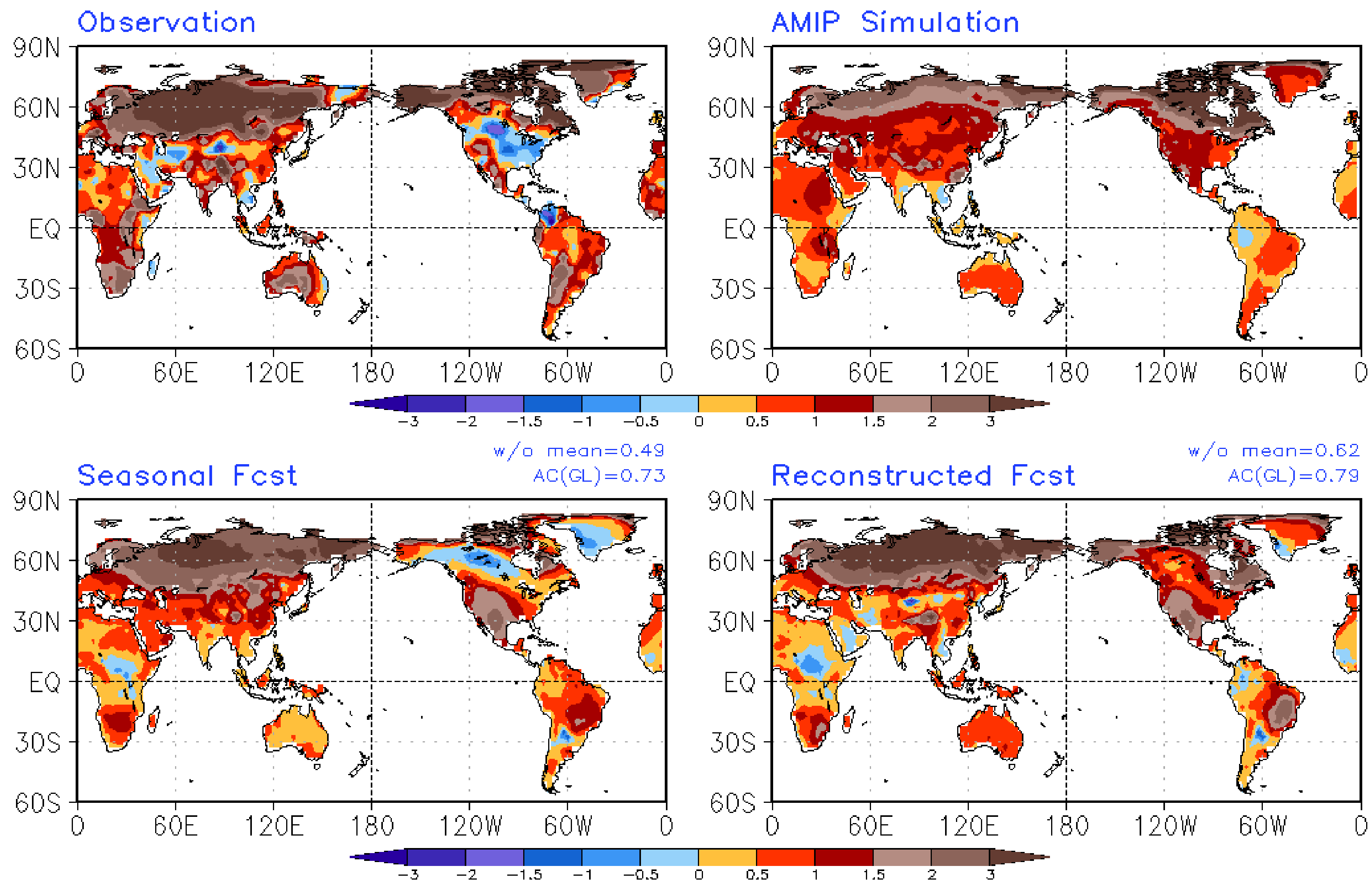


DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)

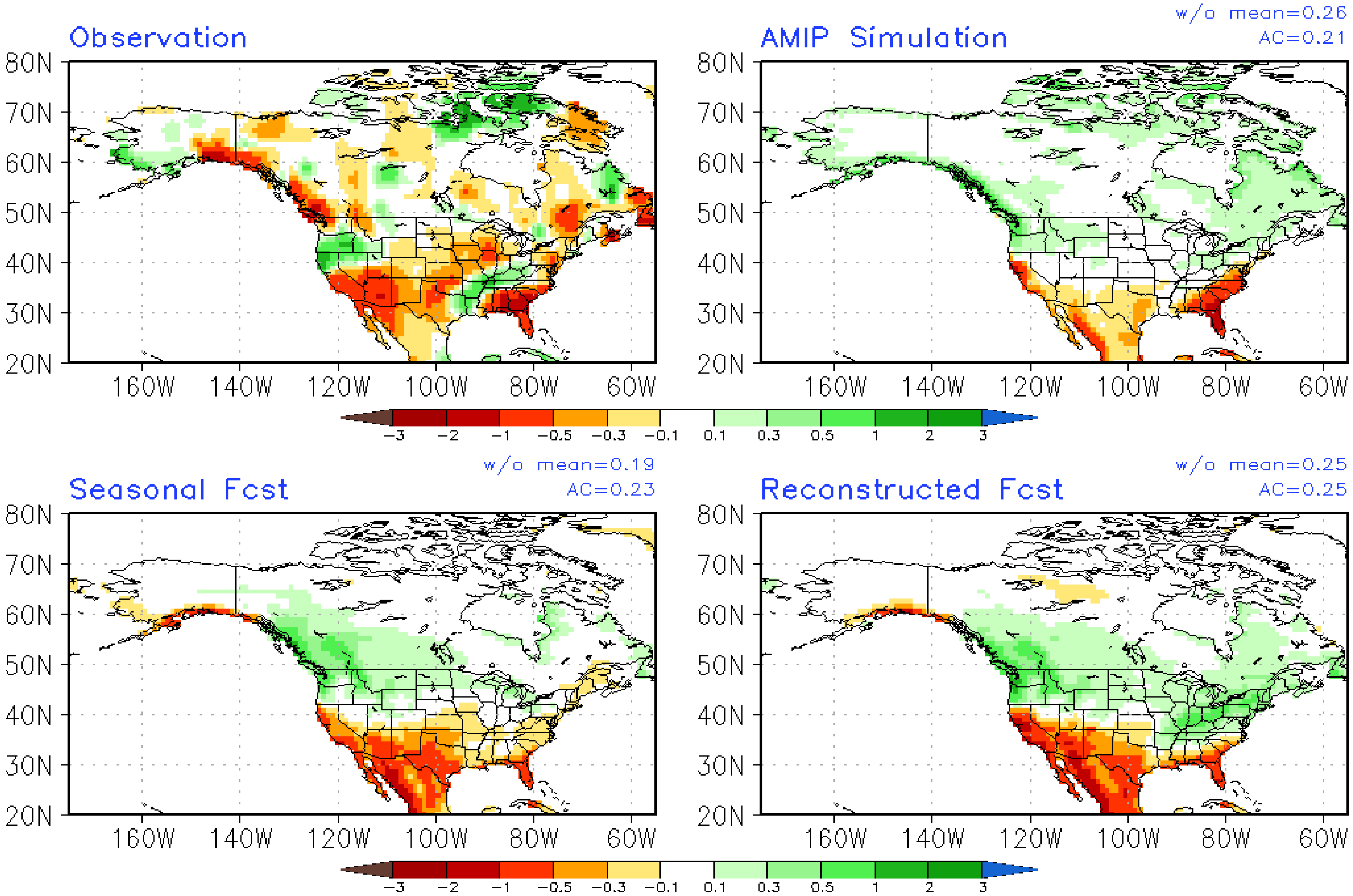
(full anomalies: shaded; eddy anomalies: contours)

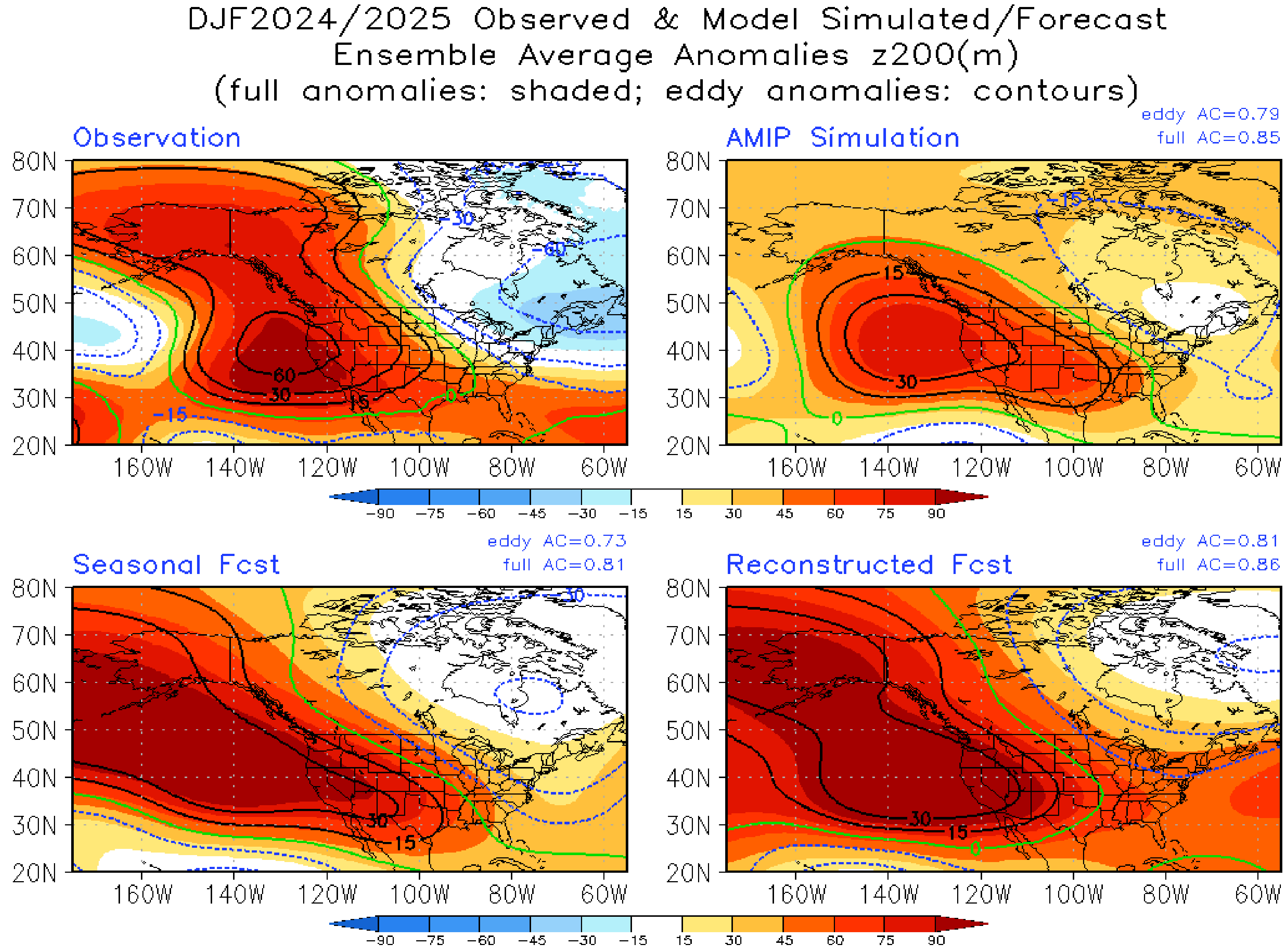


DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

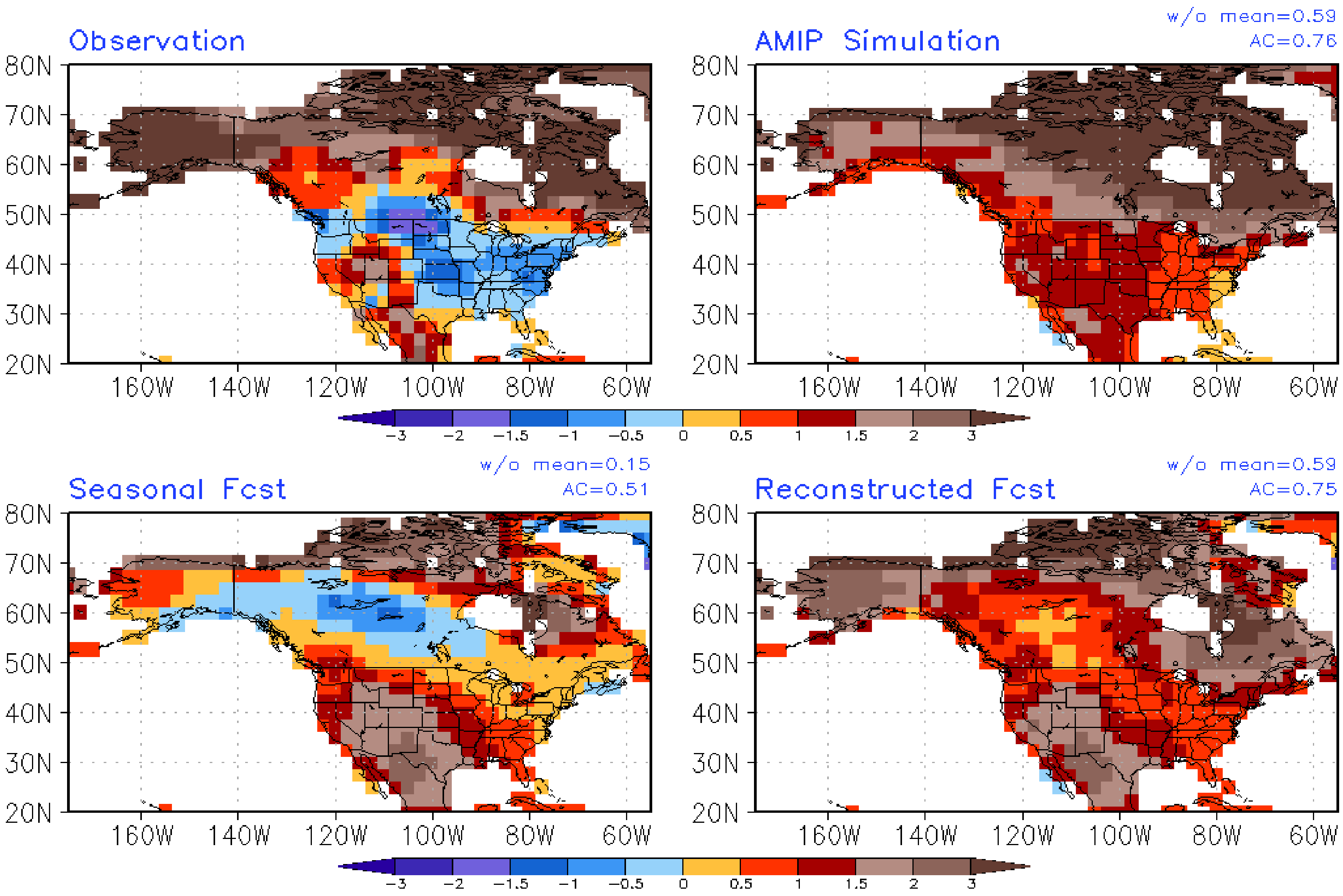


DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)




DJF2024/2025 Observed & Model Simulated/Forecast
Ensemble Average Anomalies z200(m)
(full anomalies: shaded; eddy anomalies: contours)
Observation
AMIP Simulation
eddy AC=0.79
full AC=0.85
Seasonal Fcst
eddy AC=0.73
full AC=0.81
Reconstructed Fcst
eddy AC=0.81
full AC=0.86
80N
70N
60N
50N
40N
30N
20N
160W
140W
120W
100W
80W
60W
-90 -75 -60 -45 -30 -15 15 30 45 60 75 90

DJF2024/2025 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

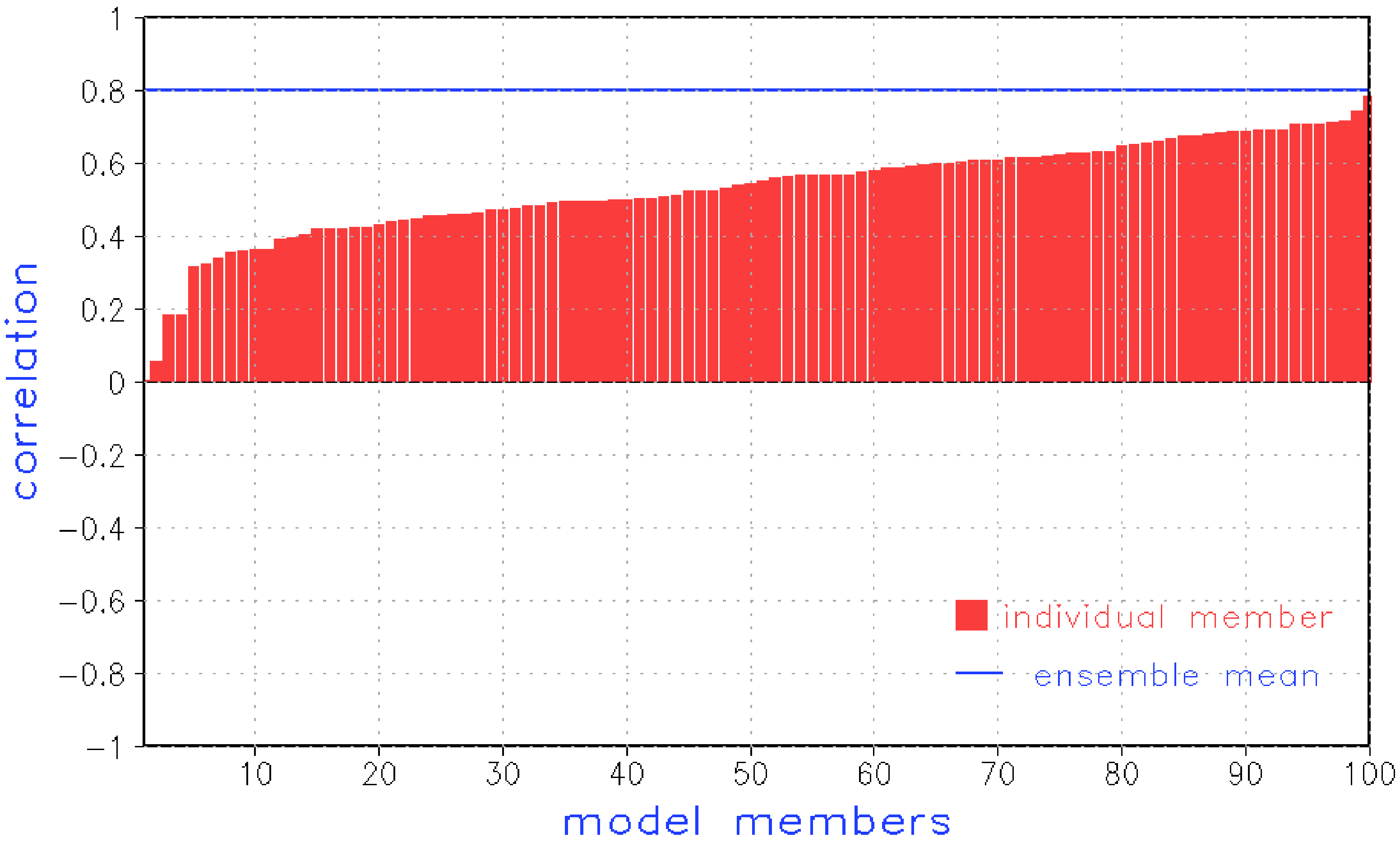


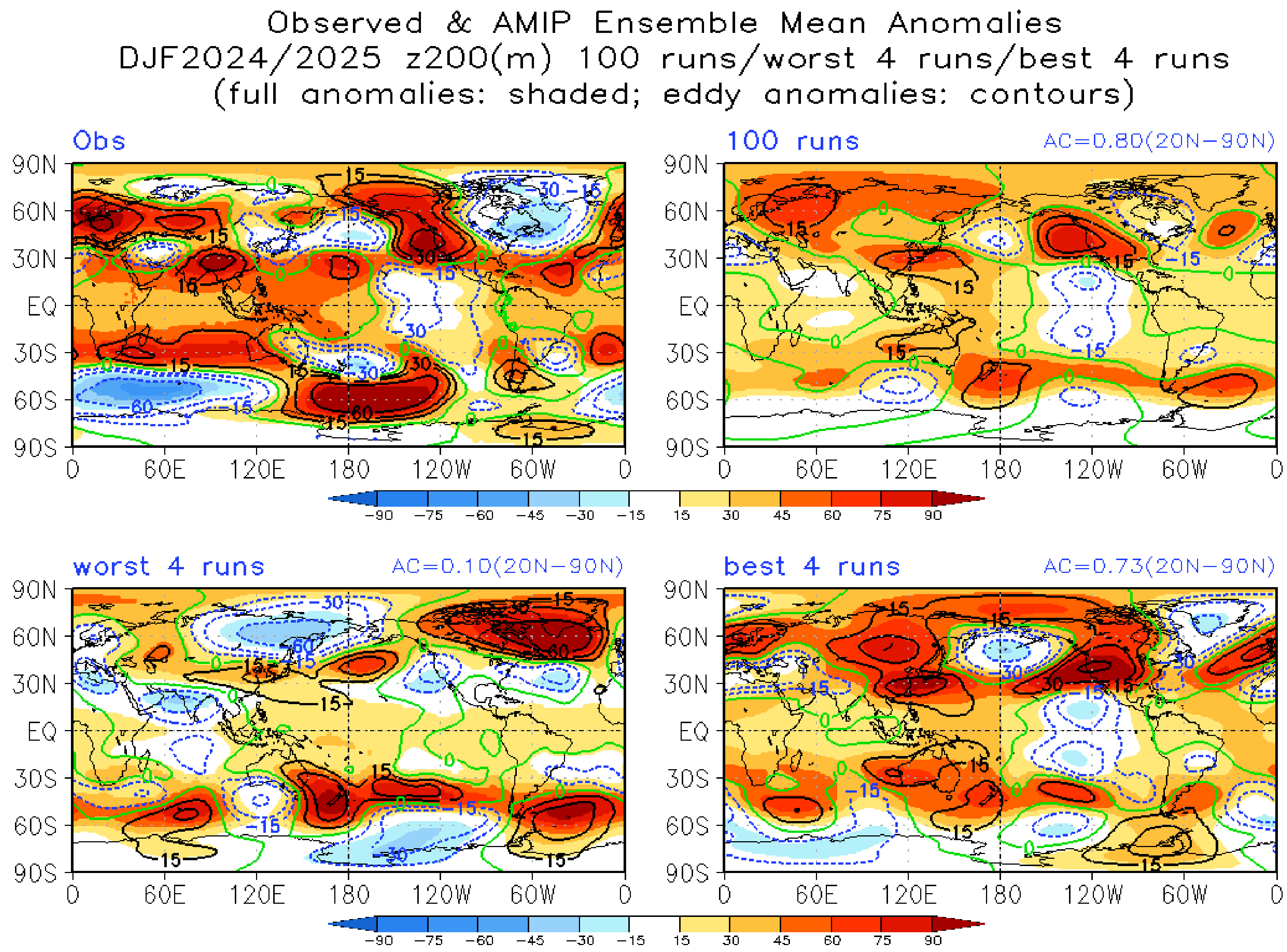
Model Simulated/Forecast Anomalies: Individual Runs

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.

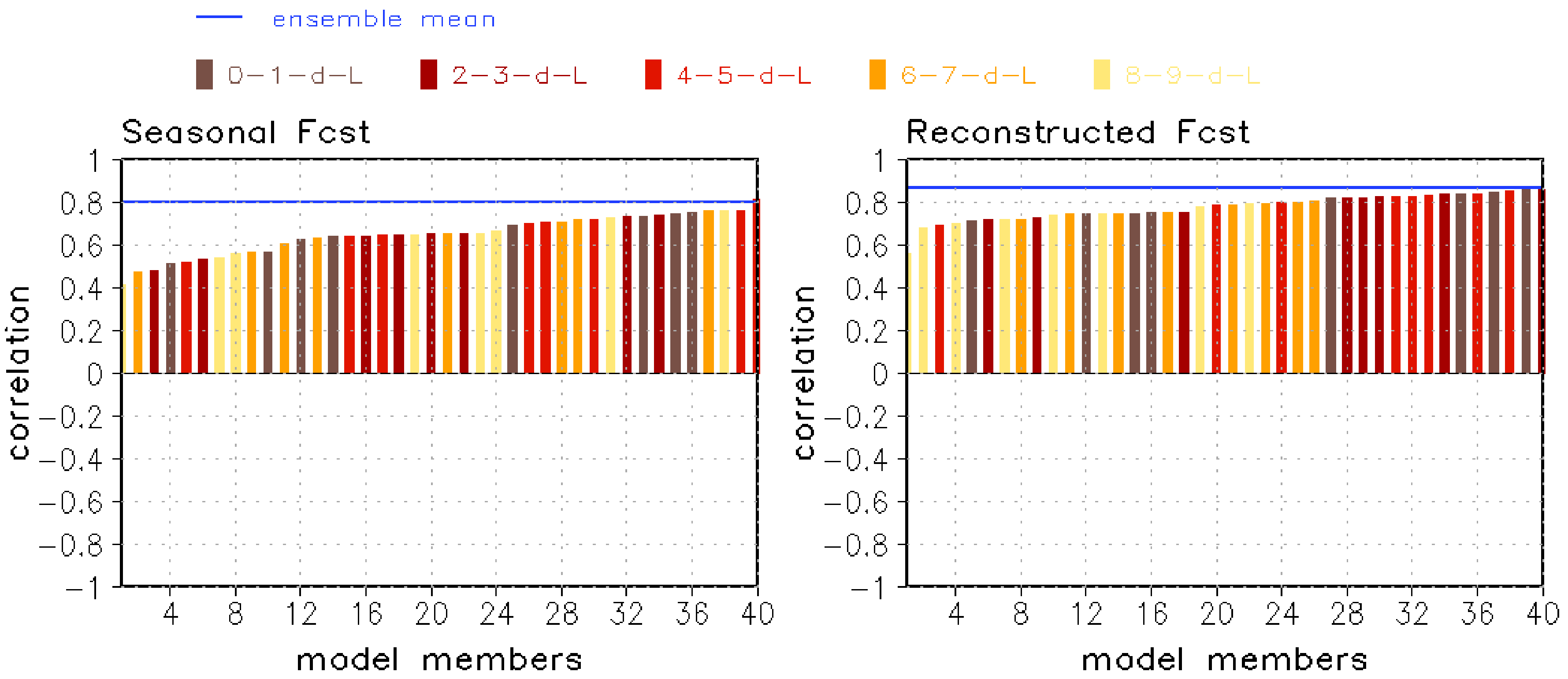
DJF2024/2025 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)





Observed & AMIP Ensemble Mean Anomalies
DJF2024/2025 z200(m) 100 runs/worst 4 runs/best 4 runs
(full anomalies: shaded; eddy anomalies: contours)
Obs
100 runs
AC=0.80(20N-90N)
worst 4 runs
AC=0.10(20N-90N)
best 4 runs
AC=0.73(20N-90N)
90N 60N 30N EQ 30S 60S 90S
0 60E 120E 180 120W 60W 0
-90 -75 -60 -45 -30 -15 15 30 45 60 75 90

DJF2024/2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)

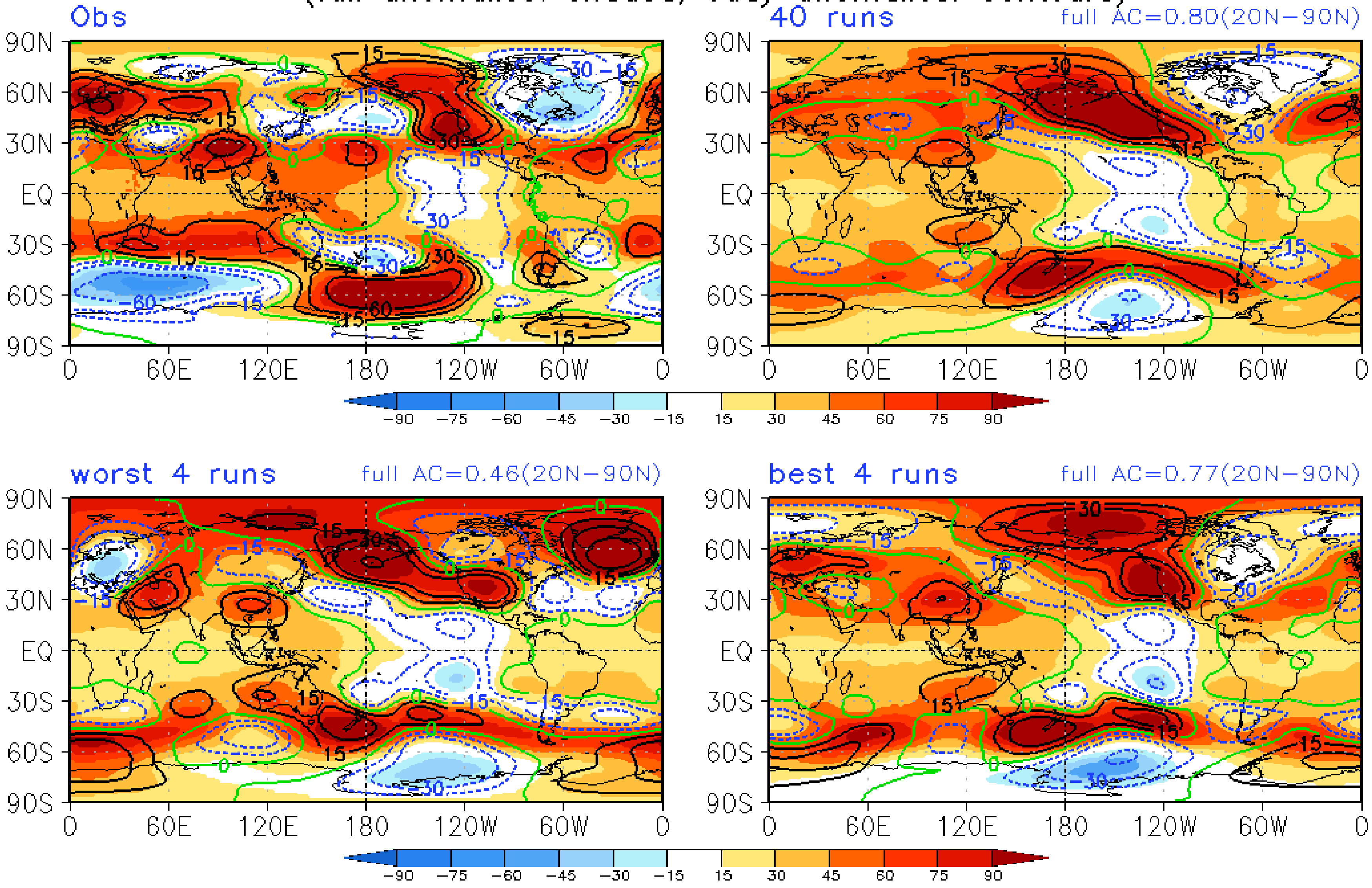


Observed & CFSv2 Forecast Ensemble Average Anomalies

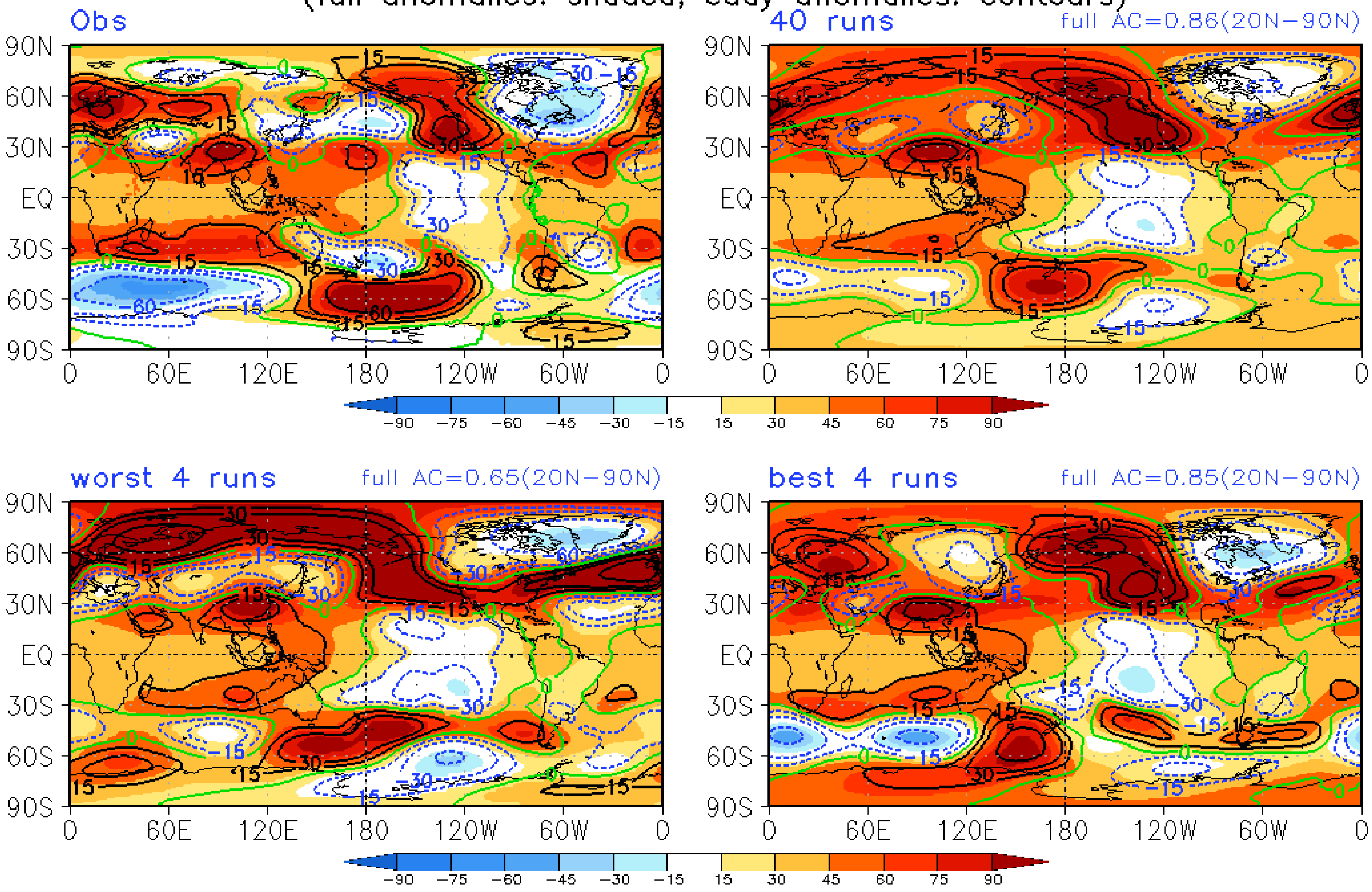
DJF2024/2025 z200(m) 40 runs/worst 4 runs/best 4 runs

Seasonal Forecast

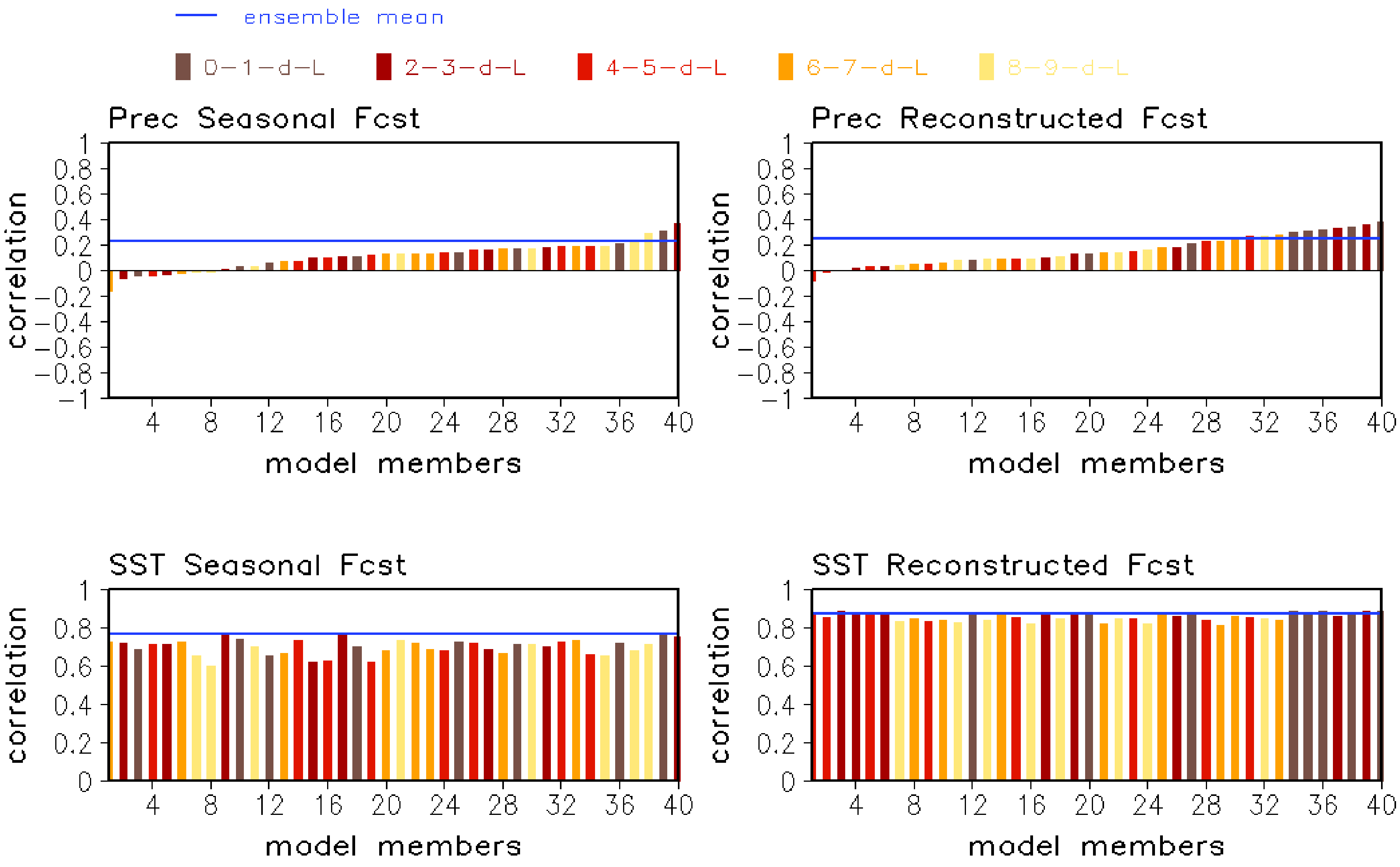
(full anomalies: shaded; eddy anomalies: contours)



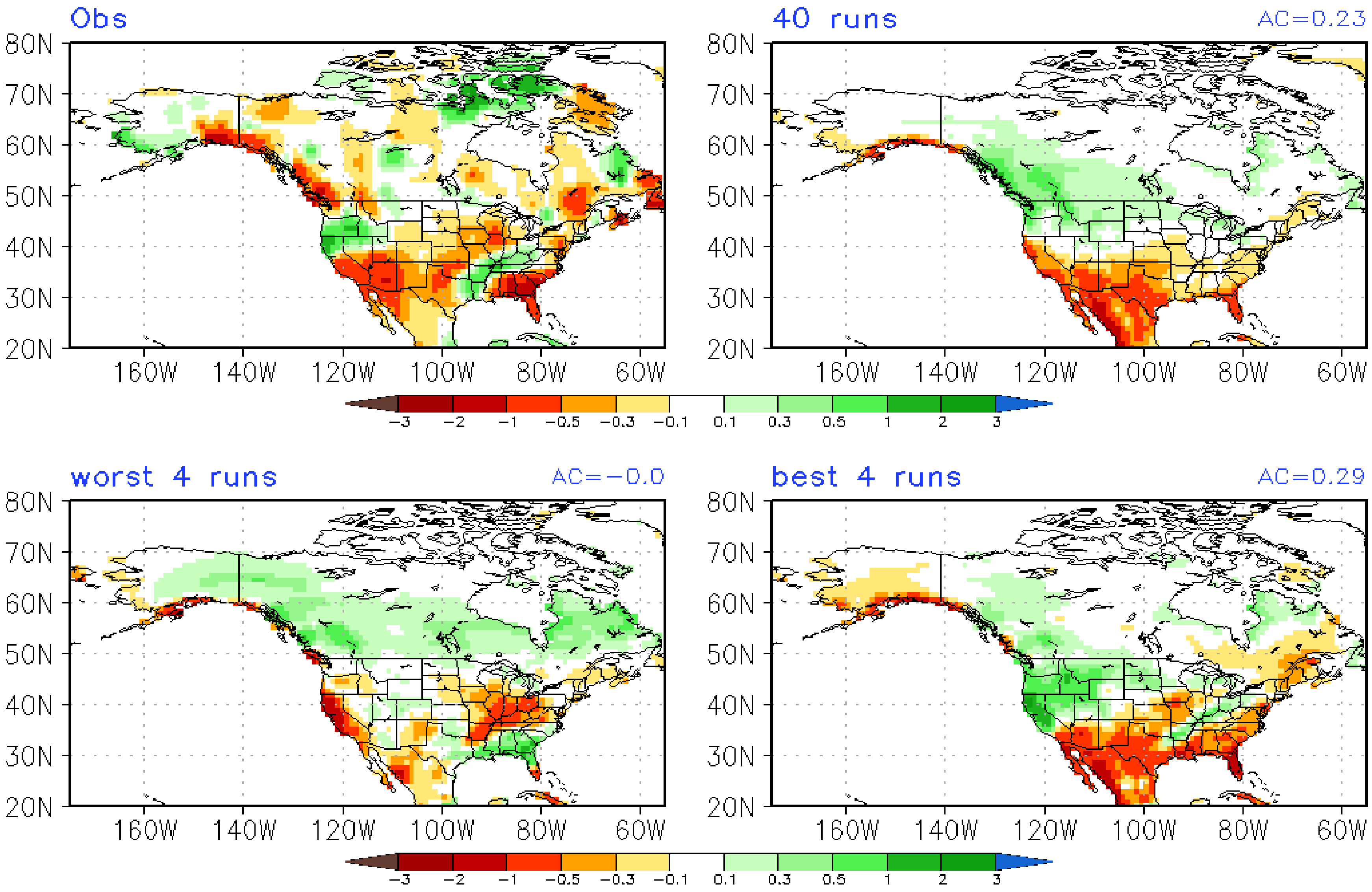
Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2024/2025 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast
(full anomalies: shaded; eddy anomalies: contours)



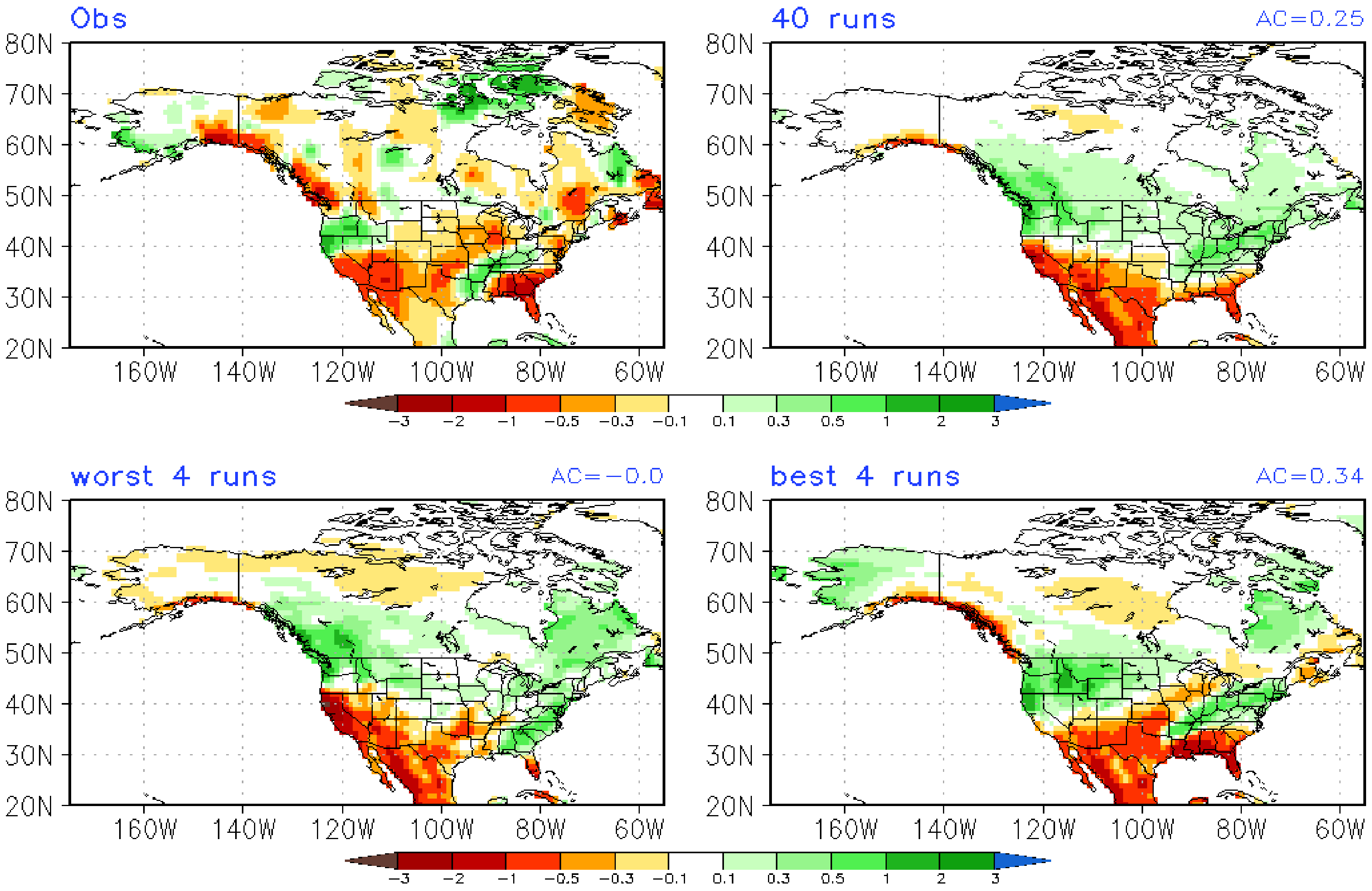
DJF2024/2025 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

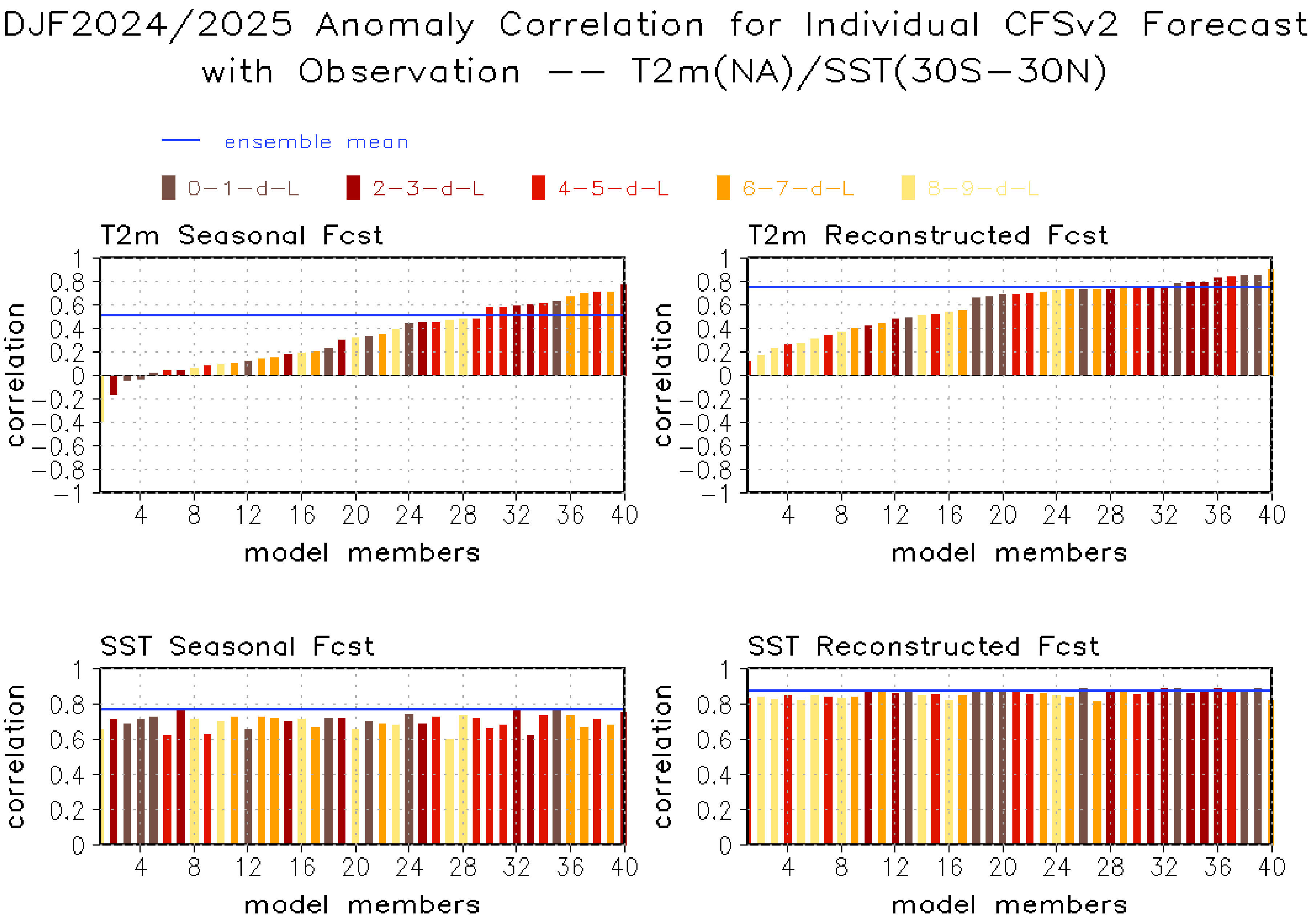


Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2024/2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

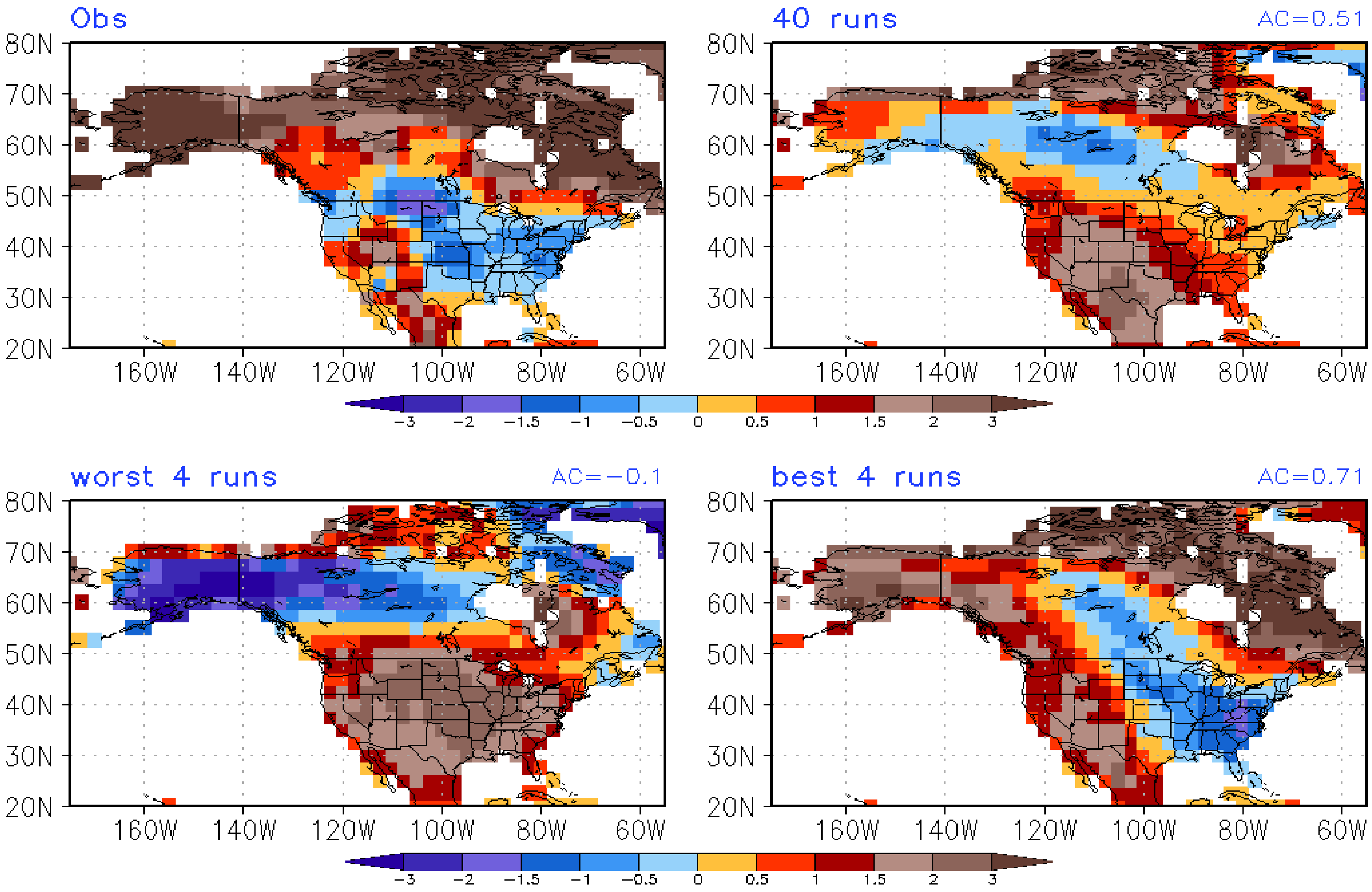


Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2024/2025 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



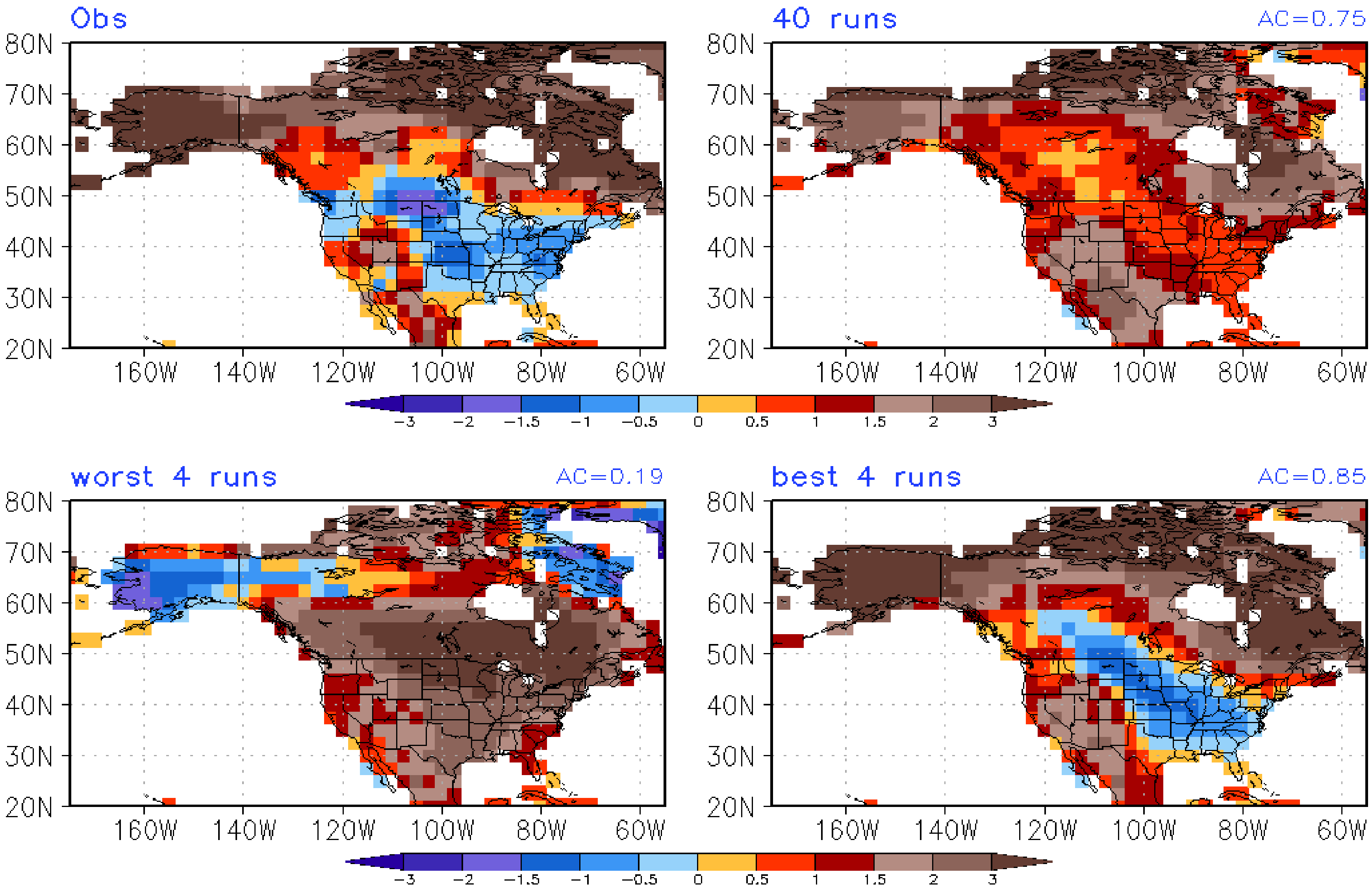

DJF2024/2025 Anomaly Correlation for Individual CFSv2 Forecast
with Observation -- T2m(NA)/SST(30S-30N)
ensemble mean
0-1-d-L
2-3-d-L
4-5-d-L
6-7-d-L
8-9-d-L
T2m Seasonal Fcst
T2m Reconstructed Fcst
SST Seasonal Fcst
SST Reconstructed Fcst
correlation
model members

Observed & CFSv2 Forecast Ensemble Average Anomalies
DJF2024/2025 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

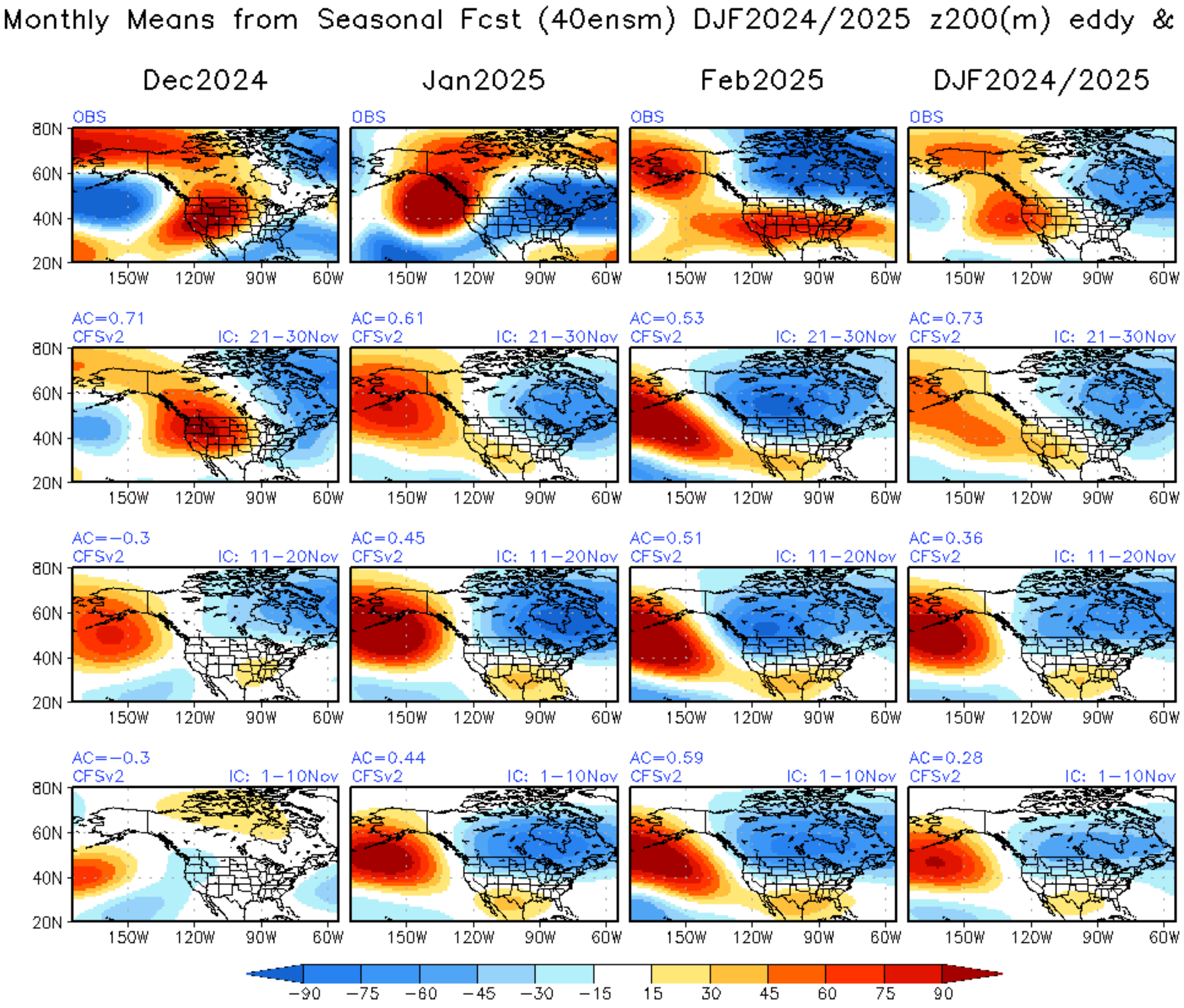


Observed & CFSv2 Forecast Ensemble Average Anomalies DJF2024/2025 T2m(K) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

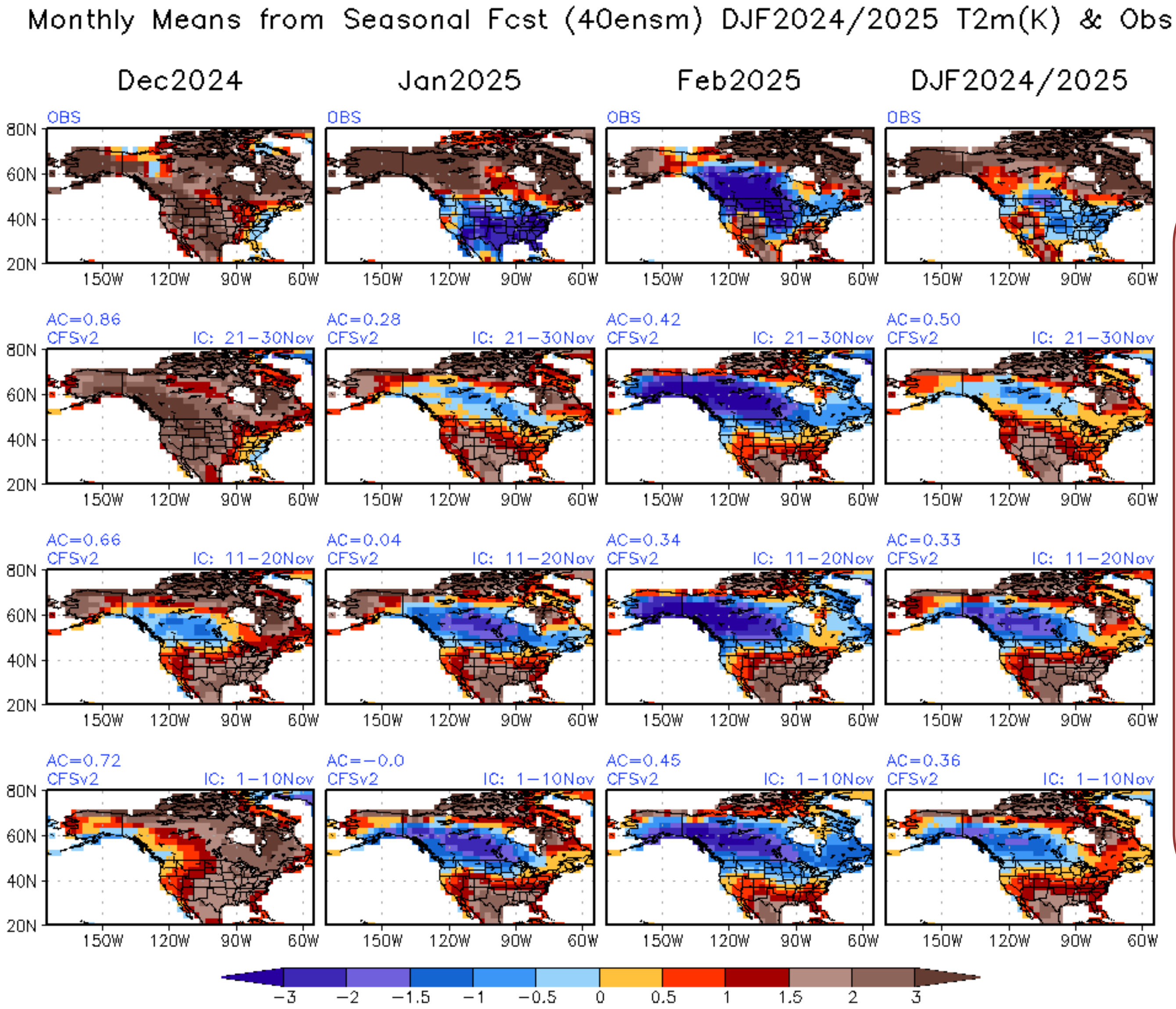


Top row: Observed anomaly.

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



Top row: Observed anomaly.

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

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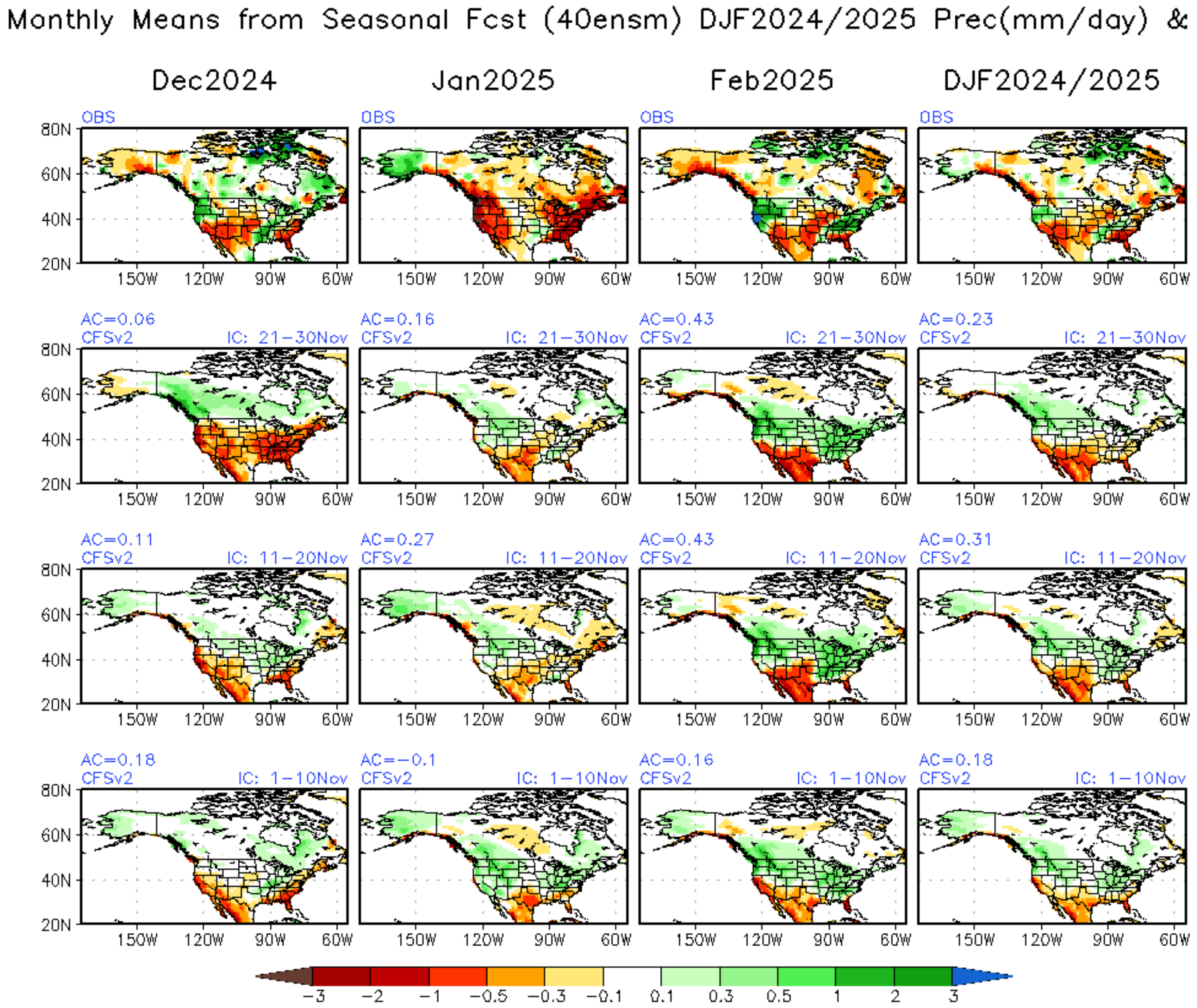
- 3rd row: 11th - 20th of the prior month.
- 4th row: 1st - 10th of the prior month.

Prec(mm/day) Monthly Means from Seasonal Forecast



Top row: Observed anomaly.

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

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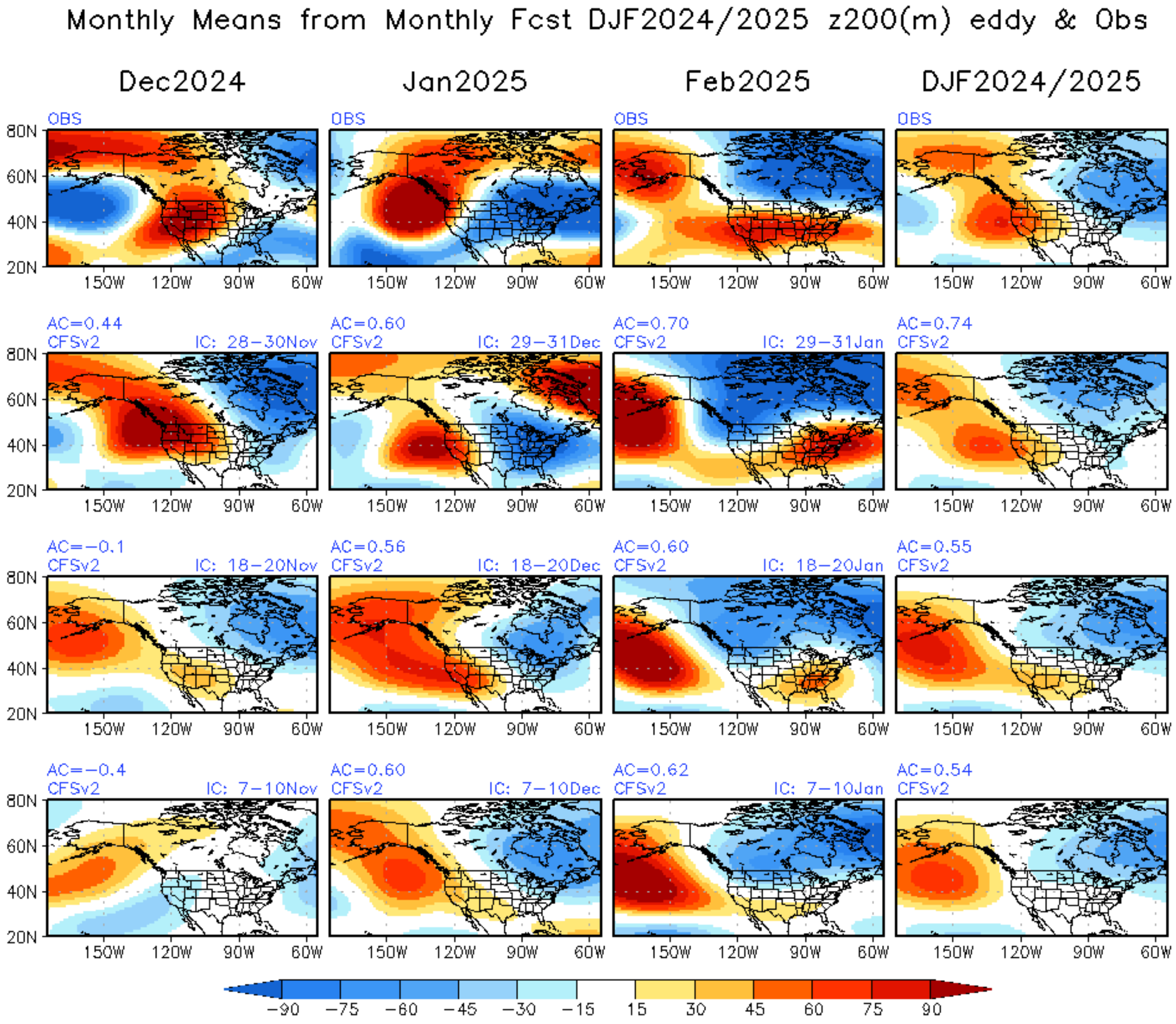
- 3rd row: 11th - 20th of the prior month.
- 4th row: 1st - 10th of the prior month.

z200(m) Monthly Means from Monthly Forecast

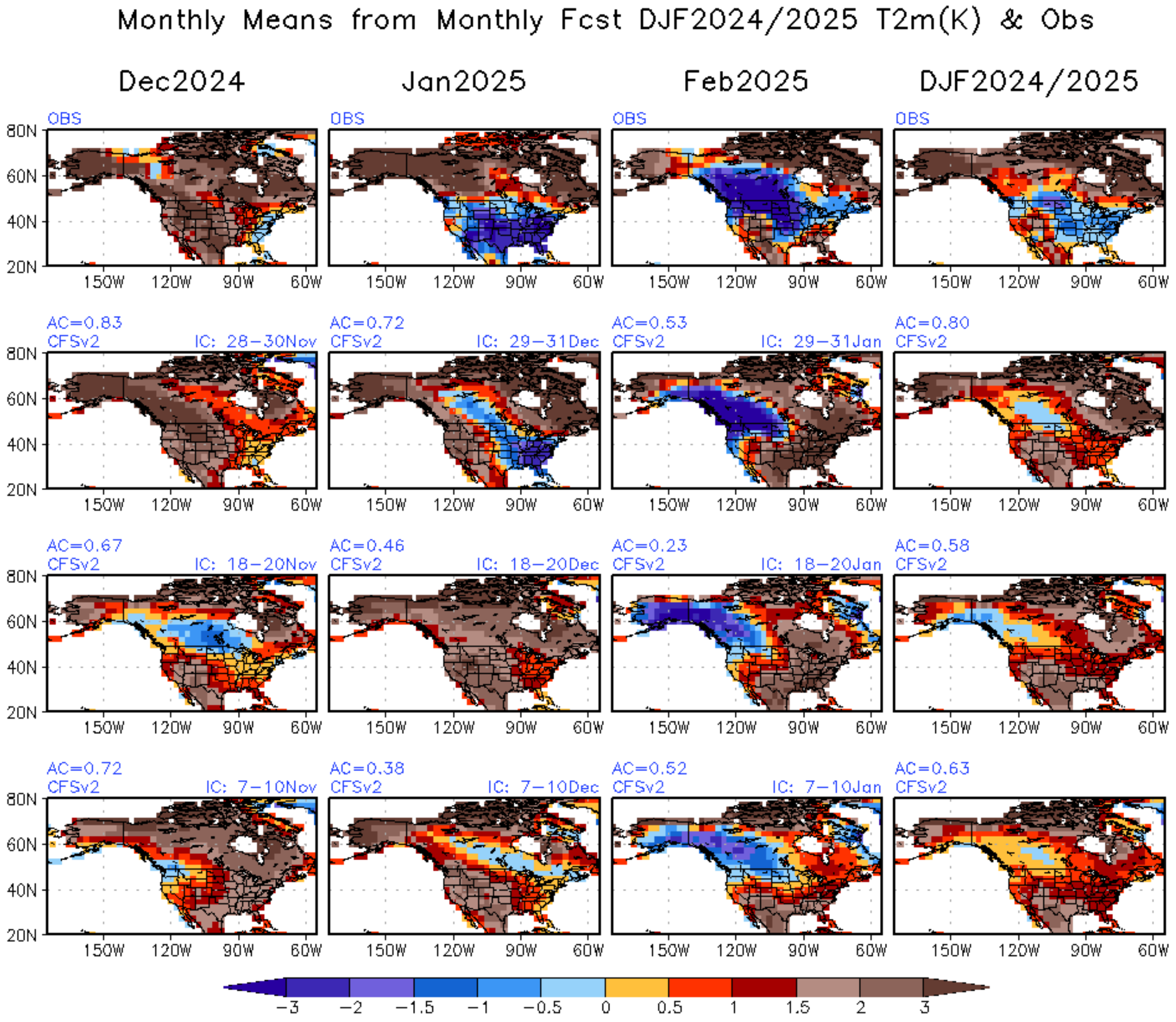


Top row: Observed anomaly.

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



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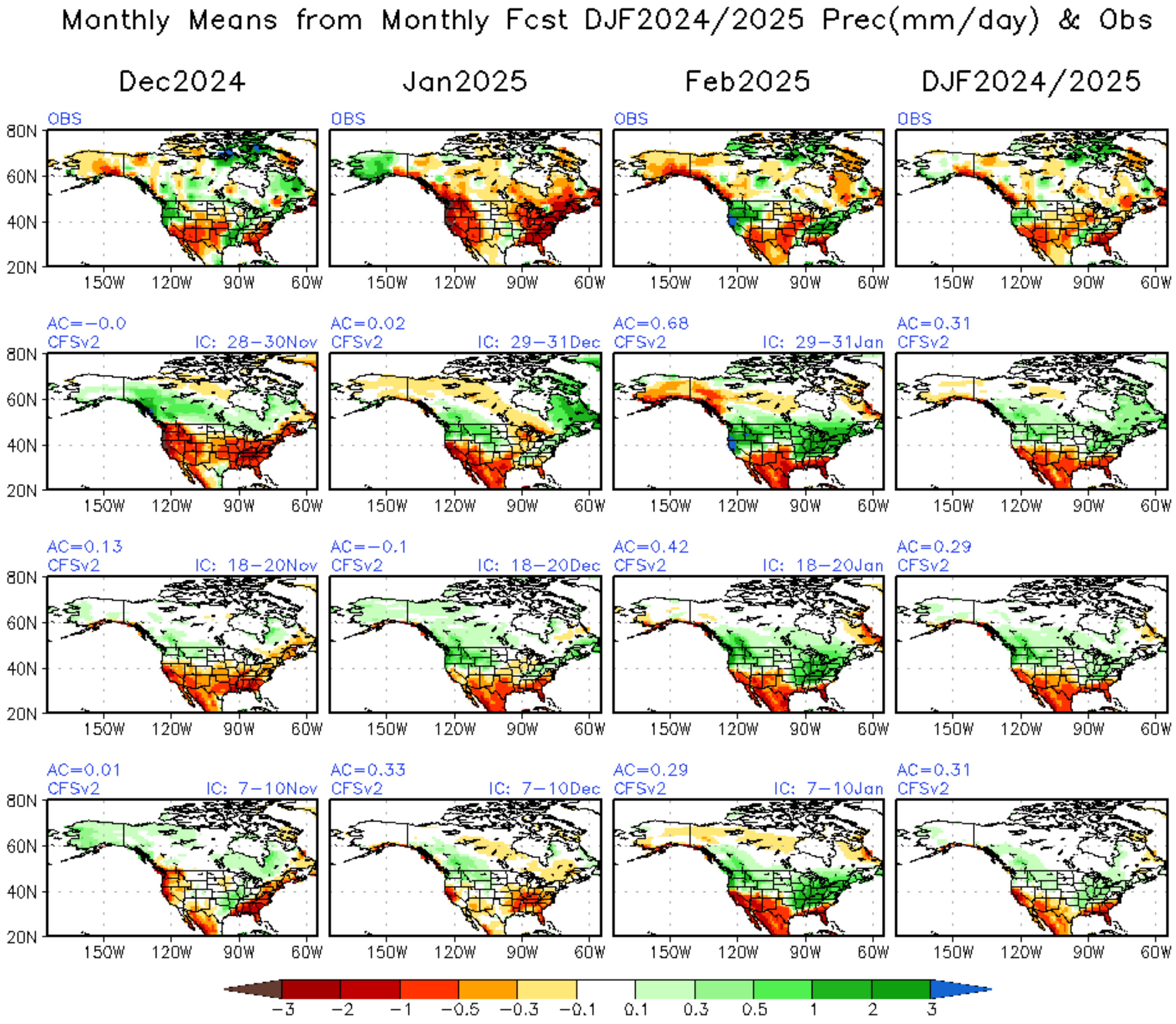
- 4th row: 7th – 10th of the prior month.

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



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.

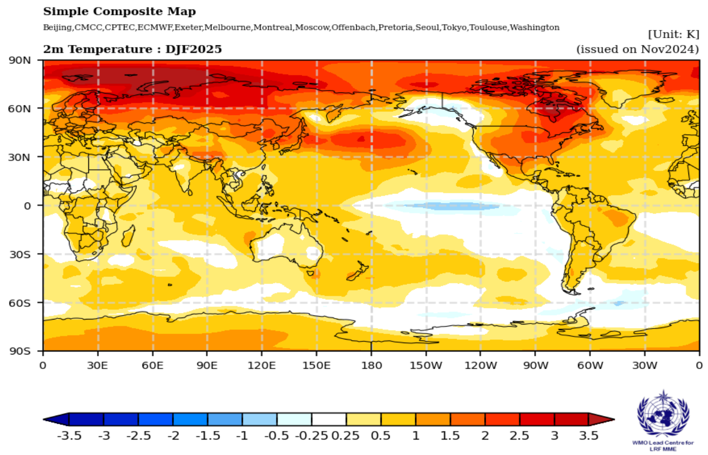
Seasonal Forecasts from Multi-Model Ensemble Systems

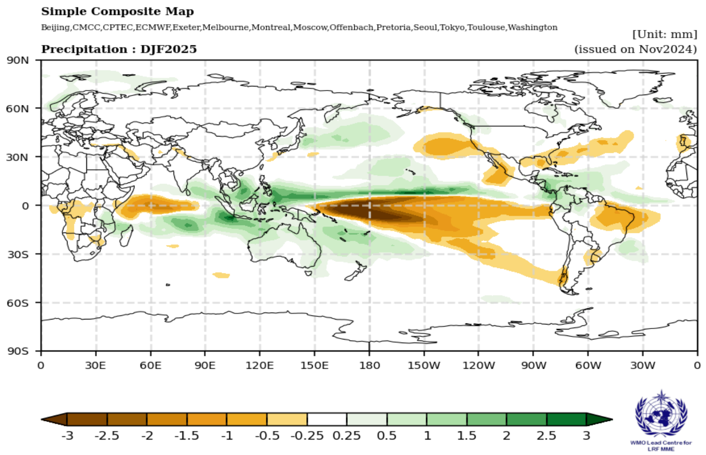
- WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME). https://www.wmolc.org/
- Copernicus Climate Change Service (C3S) Multi-model seasonal forecasts. https://climate.copernicus.eu/charts/c3s_seasonal/
- North American Multi-Model Ensemble (NMME) seasonal forecasts. https://www.cpc.ncep.noaa.gov/products/NMME/

LC-LRFMM Seasonal Forecasts

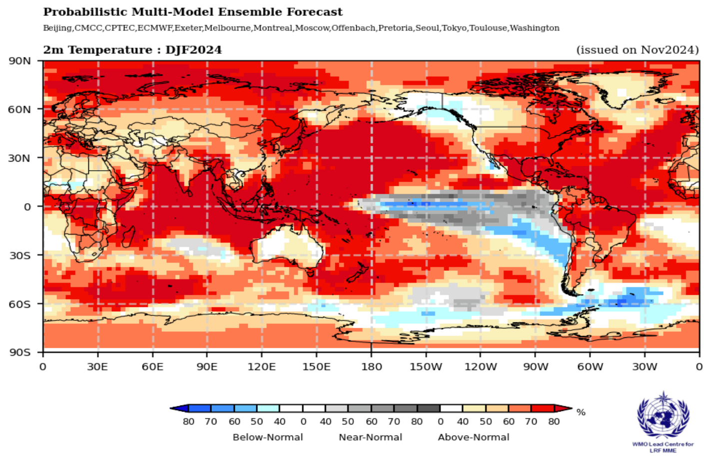
(https://www.wmolc.org/)

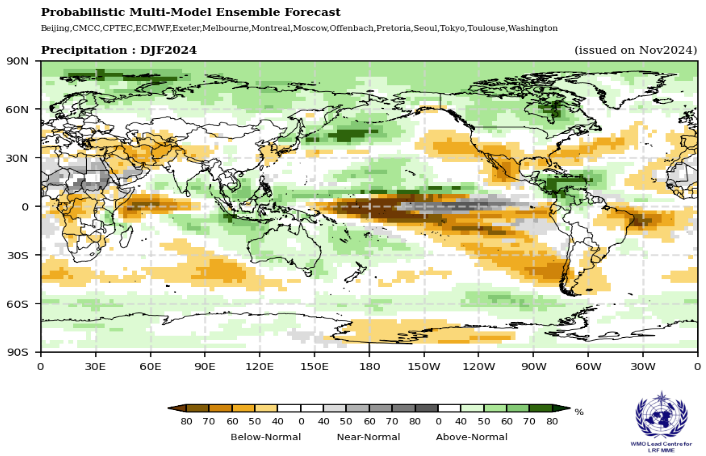
Ensemble means





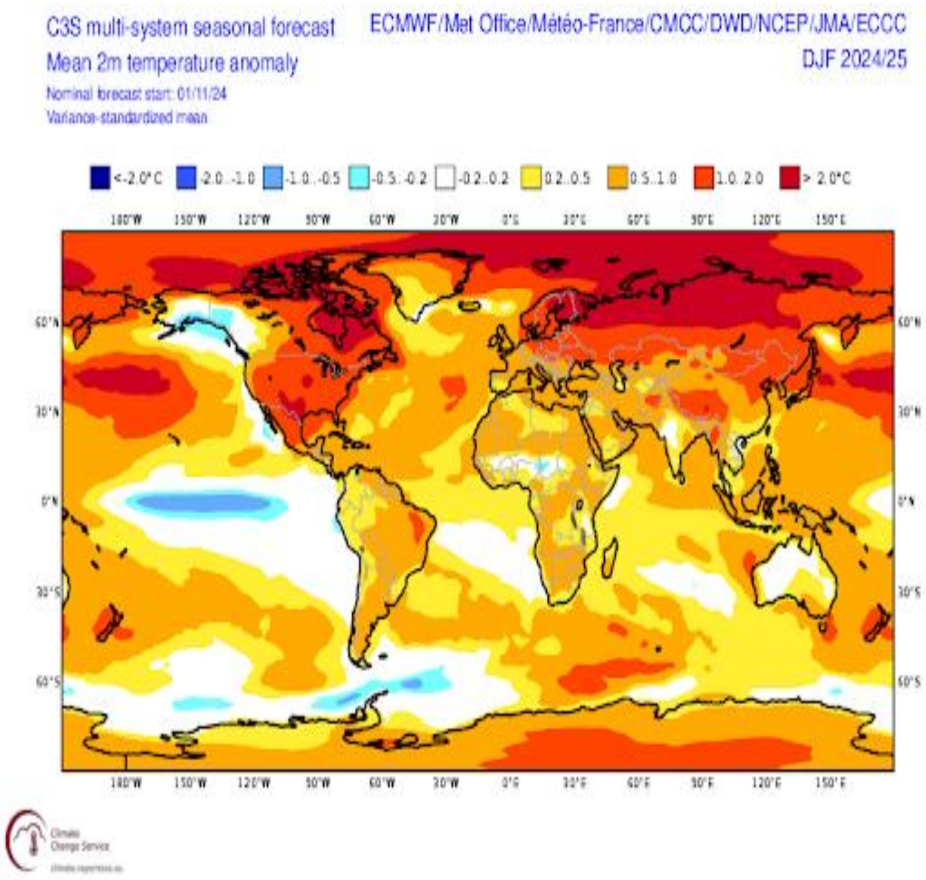
Probabilities

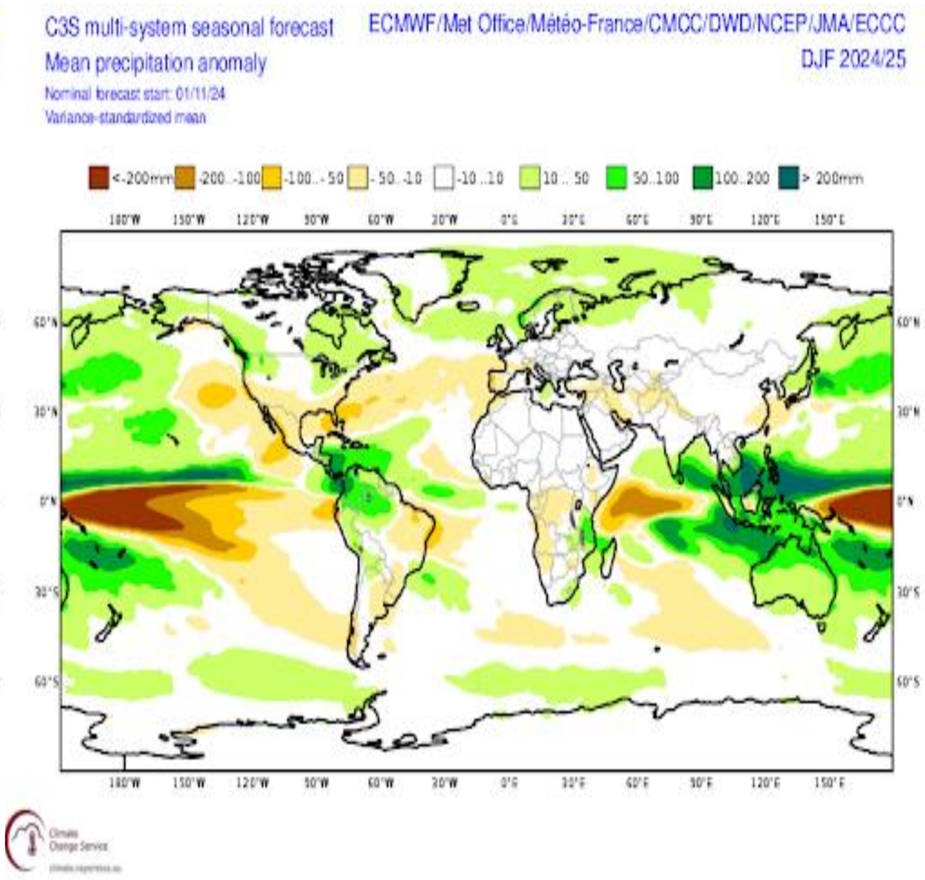




C3S Seasonal Forecast

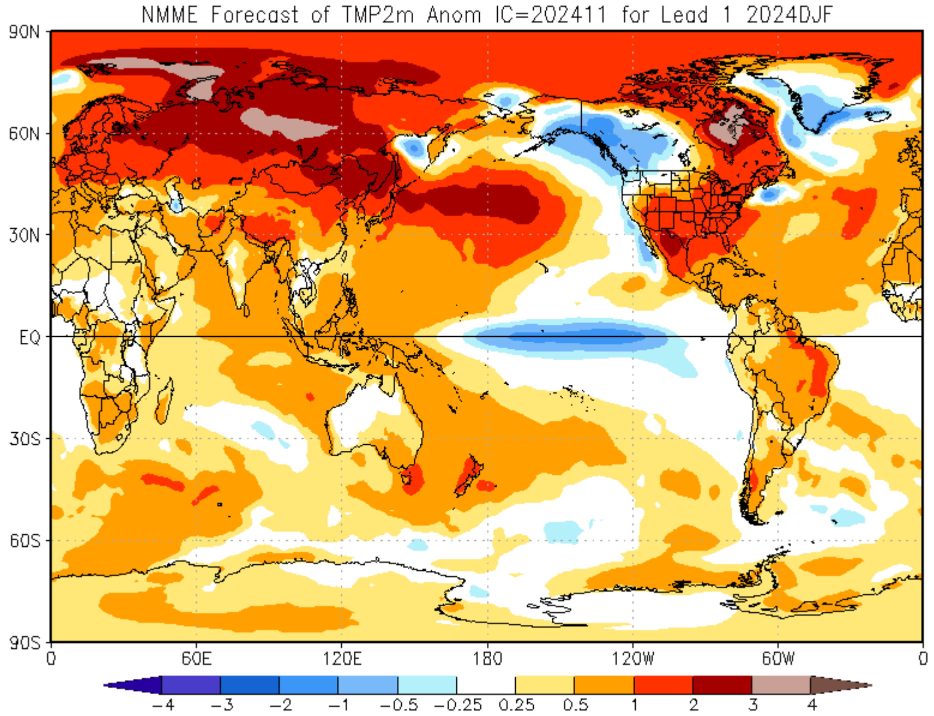
(https://climate.copernicus.eu/charts/c3s_seasonal/)

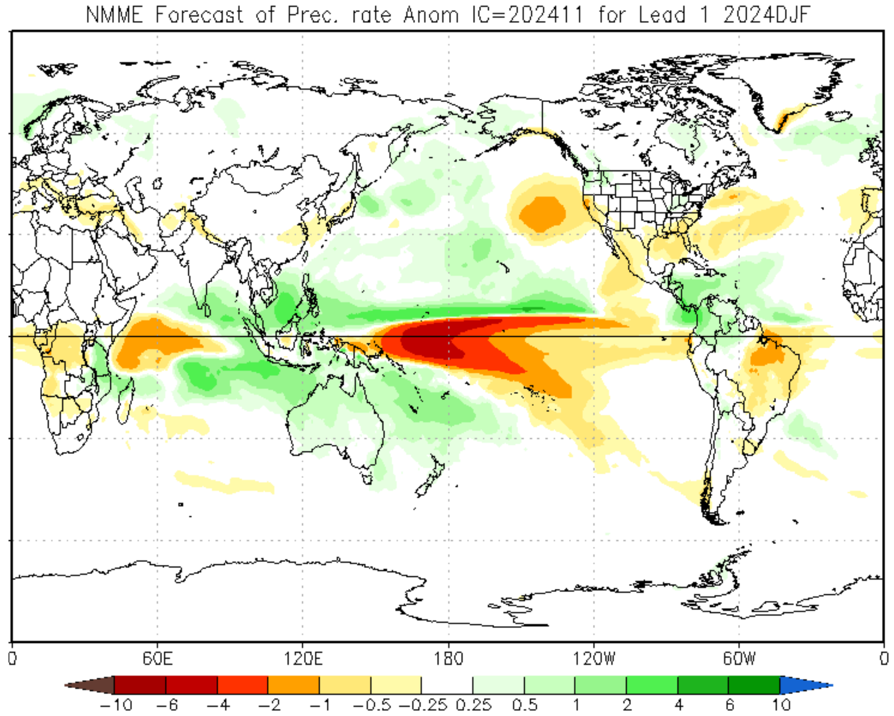




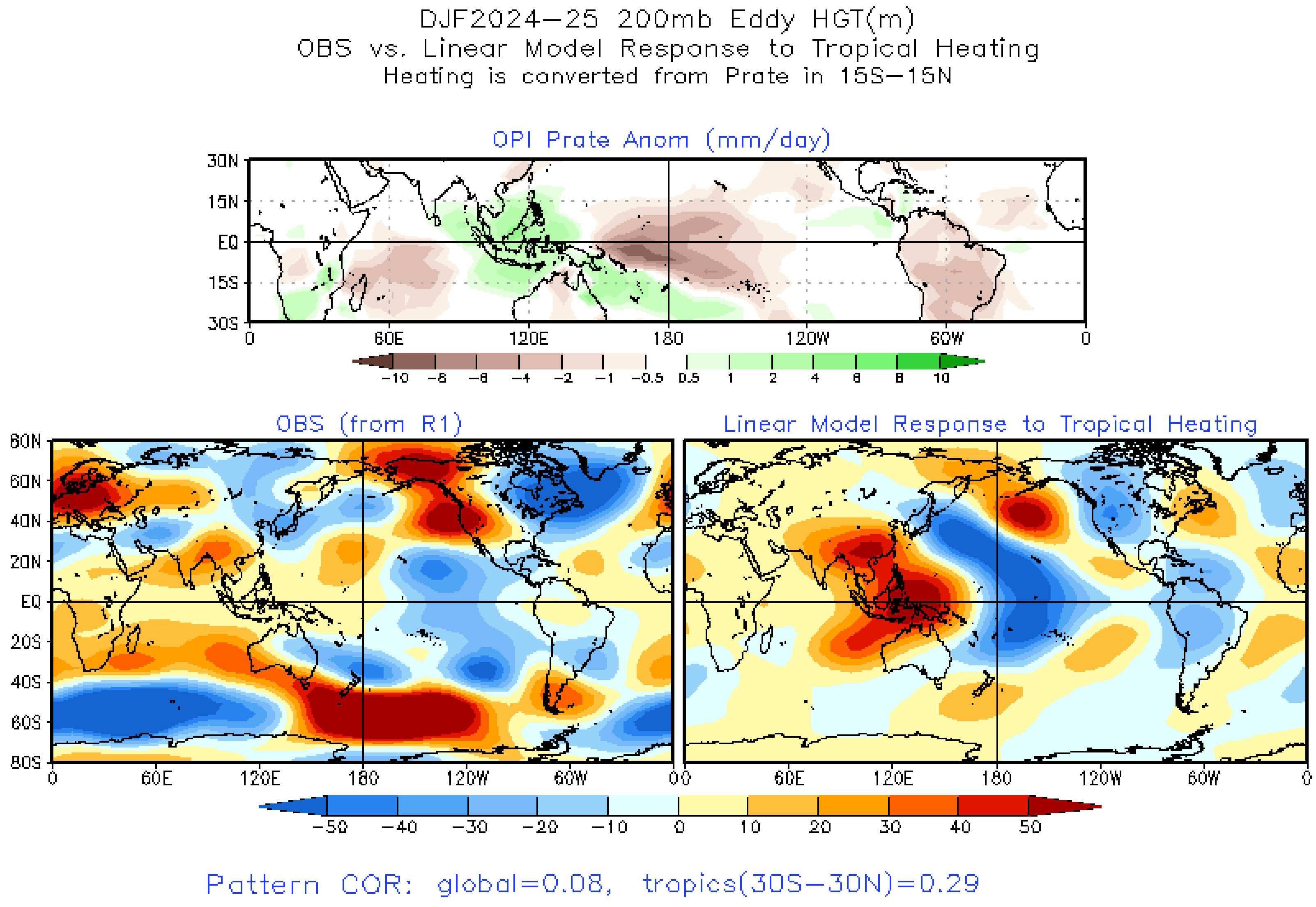
North American Multi-Model Ensemble Seasonal Forecast

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

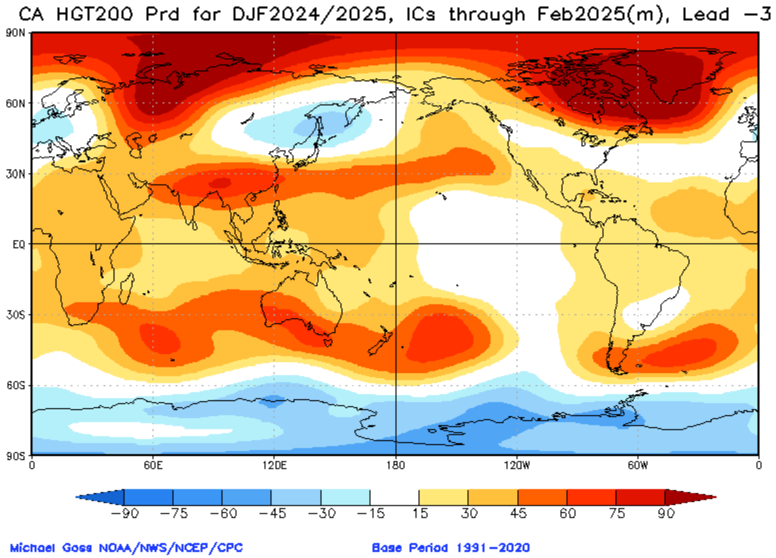


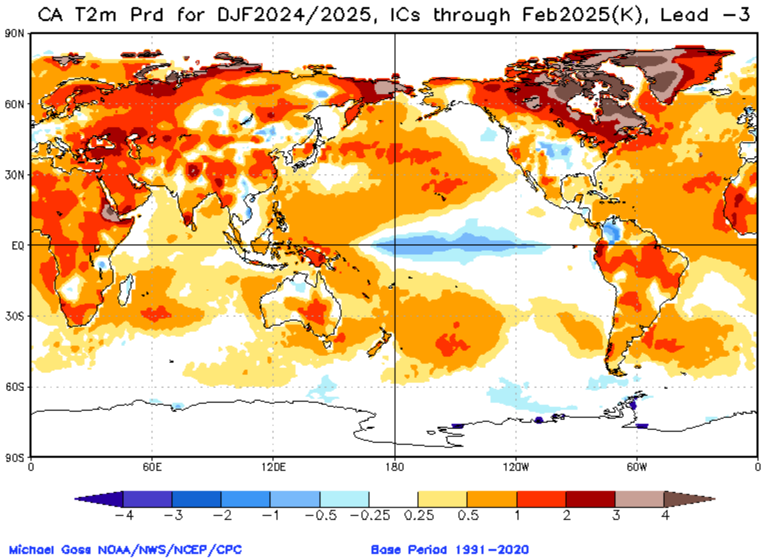


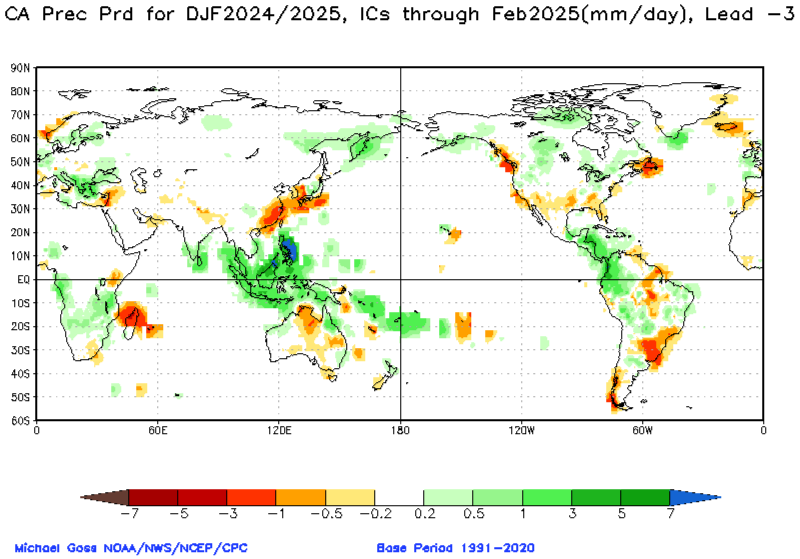
200mb Height from Linear Model



Seasonal Forecasts from the Constructed Analog Model







Background & Methodology

Attribution of Seasonal Climate Anomalies

- Goal
  - In the context of prediction of seasonal climate variability, utilize seasonal climate forecasts and atmospheric general circulation model (AGCM) simulations to attribute possible causes for the observed seasonal climate anomalies.
  - The analysis can also be considered as an analysis of predictability of the observed seasonal climate anomalies.

Methodology - 1

- Compare observed seasonal mean anomalies with those from model simulations and forecasts.
- Ensemble averaged model simulated/predicted seasonal mean anomalies are an indication of the predictable (or attributable) component of the corresponding observed anomalies.
- For seasonal mean atmospheric anomalies, predictability could be due to
  - Anomalous boundary forcings [e.g., sea surface temperature (SSTs); soil moisture etc.];
  - Atmospheric initial conditions.
- The influence of anomalous boundary forcings (particularly due to SSTs, can be inferred from the ensemble mean of AGCM simulations forced by observed SSTs, the so called AMIP simulations). This component of predictability (or attributability) is more relevant for longer lead seasonal forecasts.

Methodology - 2

- The influence of the atmospheric initial state can be inferred from initialized predictions. This component is more relevant for short lead seasonal forecasts.
- The influence of unpredictable component in the atmospheric variability can be assessed from the analysis of individual model simulations, and the extent anomalies in individual runs deviate from the ensemble mean anomalies.
- The relative amplitude of ensemble averaged seasonal mean anomalies to the deviations of seasonal mean anomalies in the individual model runs from the ensemble average is a measure of seasonal predictability (or the extent observed anomalies are attributable).
- Observed anomalies are equivalent to a realization of a single model run, and therefore, analysis of individual model runs also gives an appreciation of how much observed anomalies can deviate from the component that is attributable (Kumar et al. 2013).

Data

- Observations
  - SST: OI version 2 analysis (Reynolds et al., 2007)
  - Prec: CMAP monthly analysis (Xie and Arkin, 1997)
  - T2m: GHCN-CAMS land surface temperature monthly analysis (Fan and van den Dool, 2008)
  - 200mb height (z200): CFSR (Saha et al., 2010)
- 0-month-lead seasonal mean forecasts from CFSv2 (Saha et al. 2014)
  - Seasonal forecast: the seasonal mean forecasts based on 40 members from the latest 10 days before the target season (0-month-lead);
  - Reconstructed forecast: the seasonal mean forecasts constructed from 3 individual monthly forecasts with the latest 10 days initial conditions for each individual monthly forecasts. This approach for constructing seasonal mean anomalies has more influence from the initial conditions (Kumar et al. 2013);
- Seasonal mean AMIP simulation 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.