Attribution of Seasonal Climate Anomalies
October-November-December 2024

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

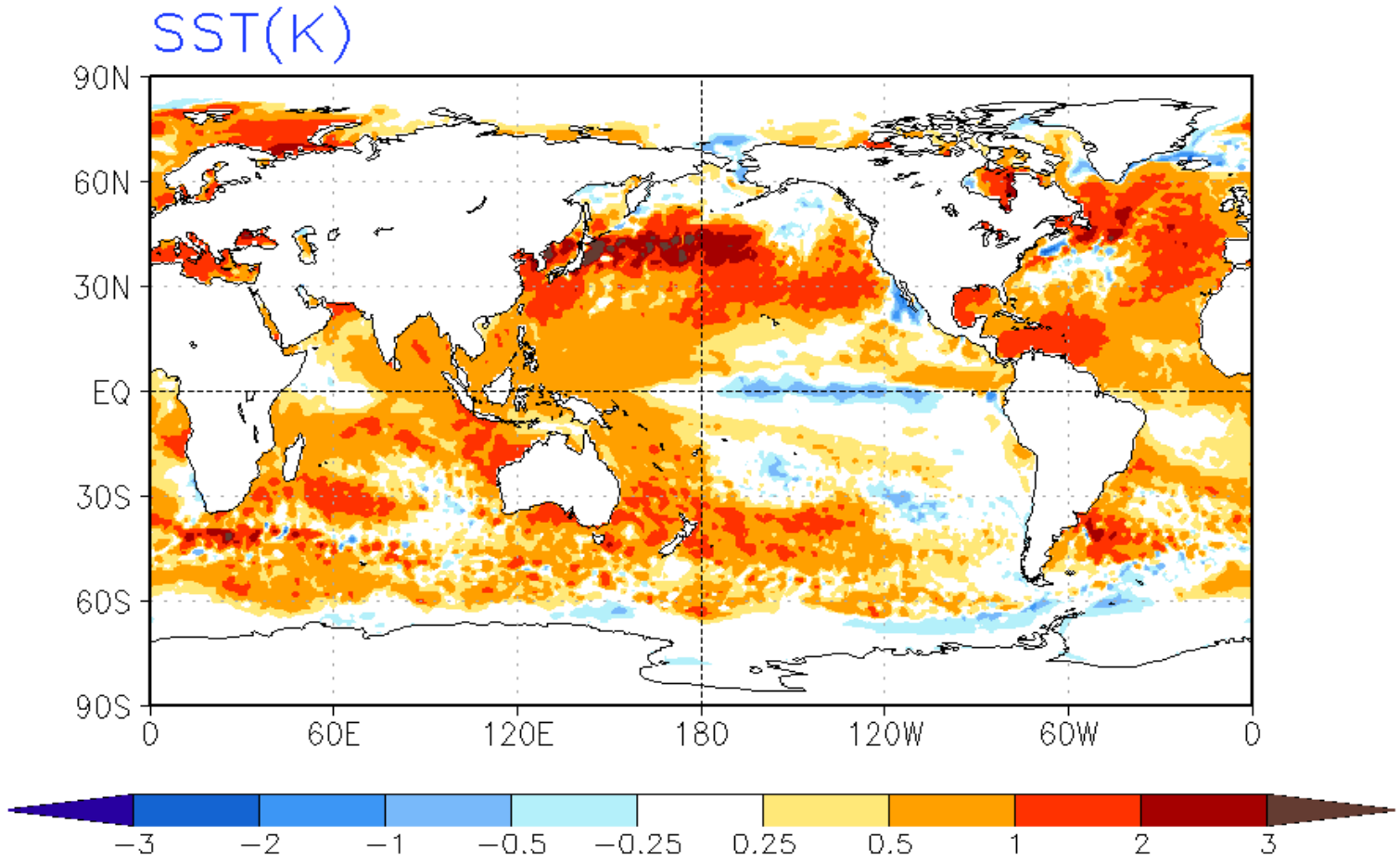
Summary of Observed Conditions and Outlooks

- In OND2024, SST anomalies in the central-eastern and far eastern equatorial Pacific remained marginally cold. Meanwhile, warm SST anomalies persisted across most other ocean basins, including the North Pacific, central and southern Pacific, tropical and North Atlantic, and the Indian Ocean (slide 4). The tropical Atlantic , in particular, remained anomalously warm and has been so for over a year.
- The CFSv2 model accurately captured the large-scale structure of observed SST anomalies but had a tendency towards cold prediction bias in the equatorial eastern Pacific, northern Pacific, tropical Atlantic, and 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 canonical La Nina response. However, the forecast pattern differed from the observations. Specifically, the forecast had much smaller coverages for negative anomalies over tropical northern Pacific and larger positive anomalies in the vicinity of the Maritime Continent (Slide 11, 37-39).
- Although the cold SST anomalies in the central and eastern Pacific were marginally cold on an absolute basis, the canonical La Nina response in models could be because with a general warming of tropical and global oceans, the relative SST anomalies were colder.
- The model successfully captured the general observed warming trend in 200-mb height and land surface temperature. However, it dislocated the centers of positive and negative height anomalies over the Pacific-North America region, which led to erroneous forecasts of land surface temperature over northern North America (slides 12, 13, 15, 16).
- The model predicted a precipitation anomaly pattern consistent with the La Nina response and captured most of the observed negative anomalies over southern North America (slide 14).
- Dec 2024, the monthly forecast skill for North America's 200-mb height and T2m showed improvement from the shortest leads (slides 33, 34).

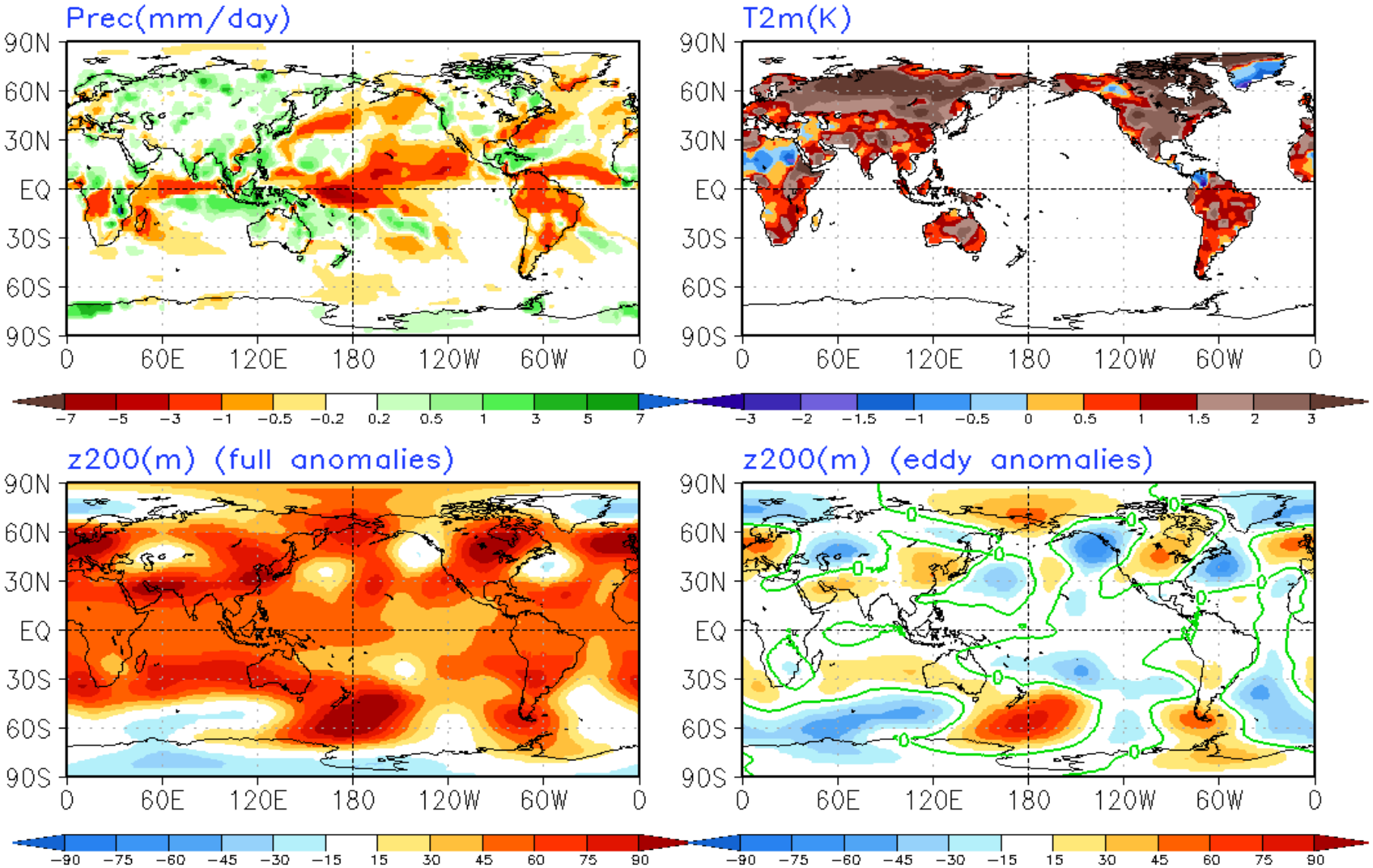
Observed Seasonal Anomalies

Global and North America

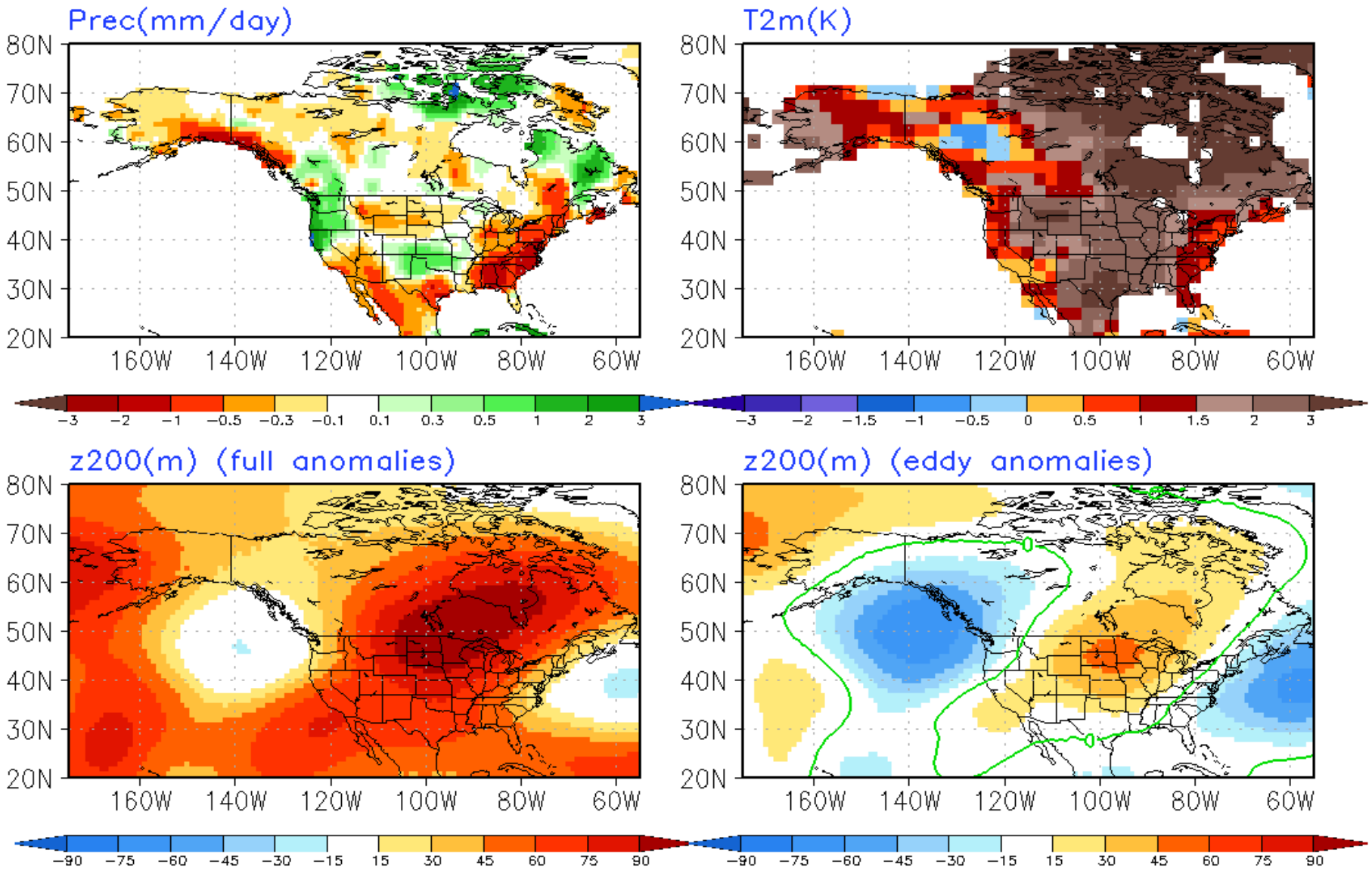
Observed Anomaly OND2024



Observed Anomaly OND2024



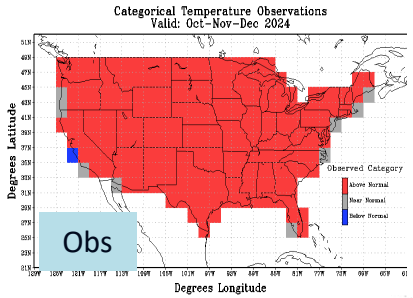
Observed Anomaly OND2024



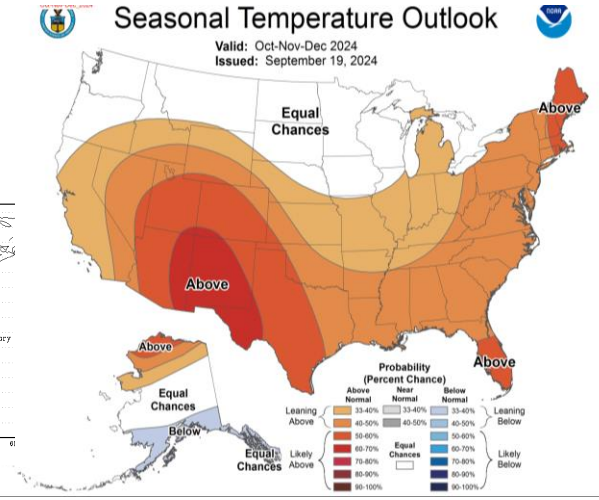
CPC Seasonal Outlooks and NMME Forecasts

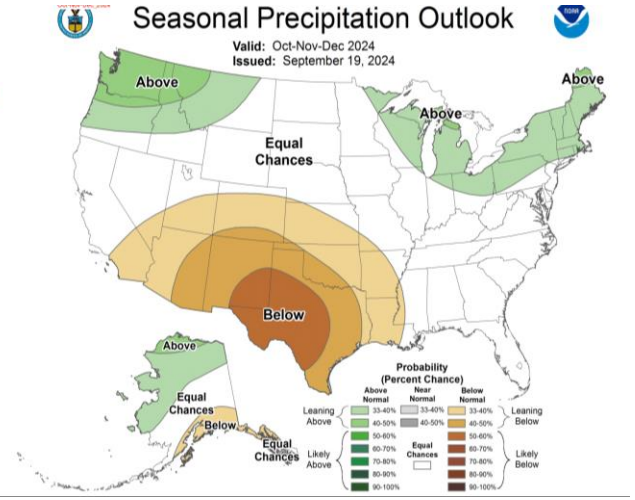
CPC

Temp nonEC
HSS=93

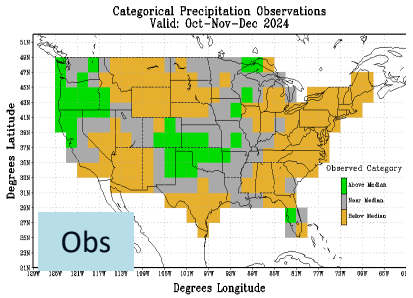


Obs



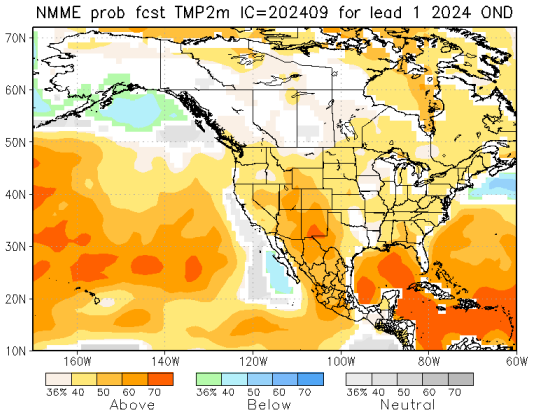


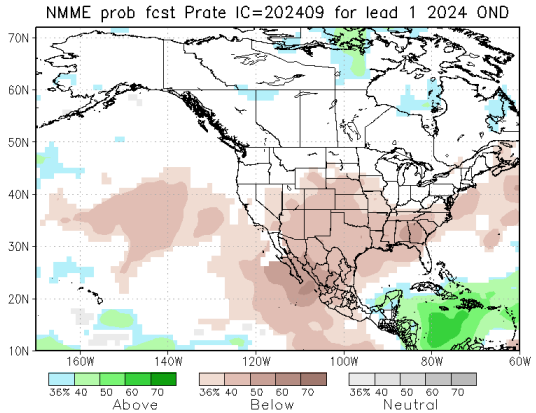
Prec nonEC
HSS=-1



Obs

NMME





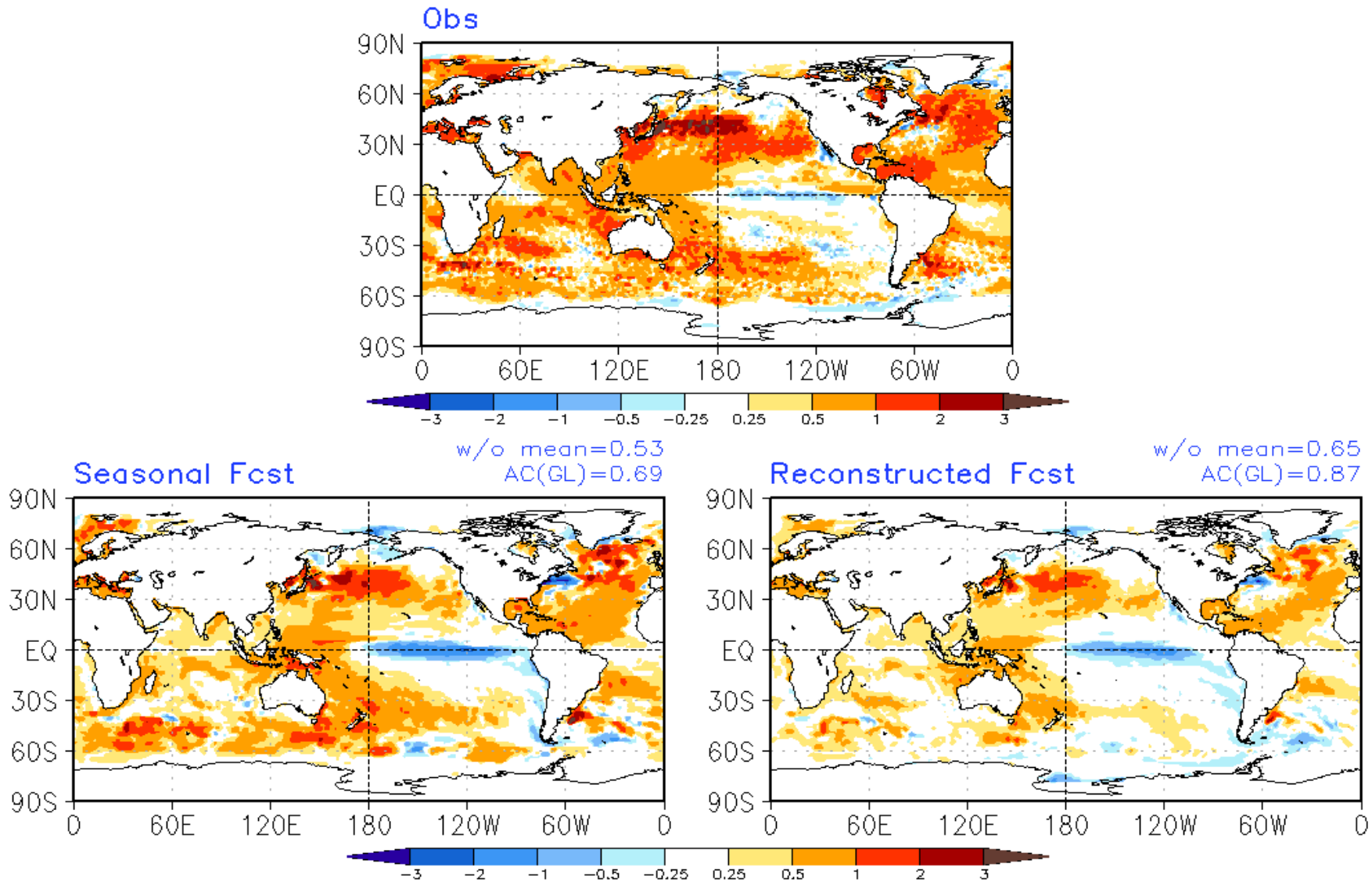
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2024/202409_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

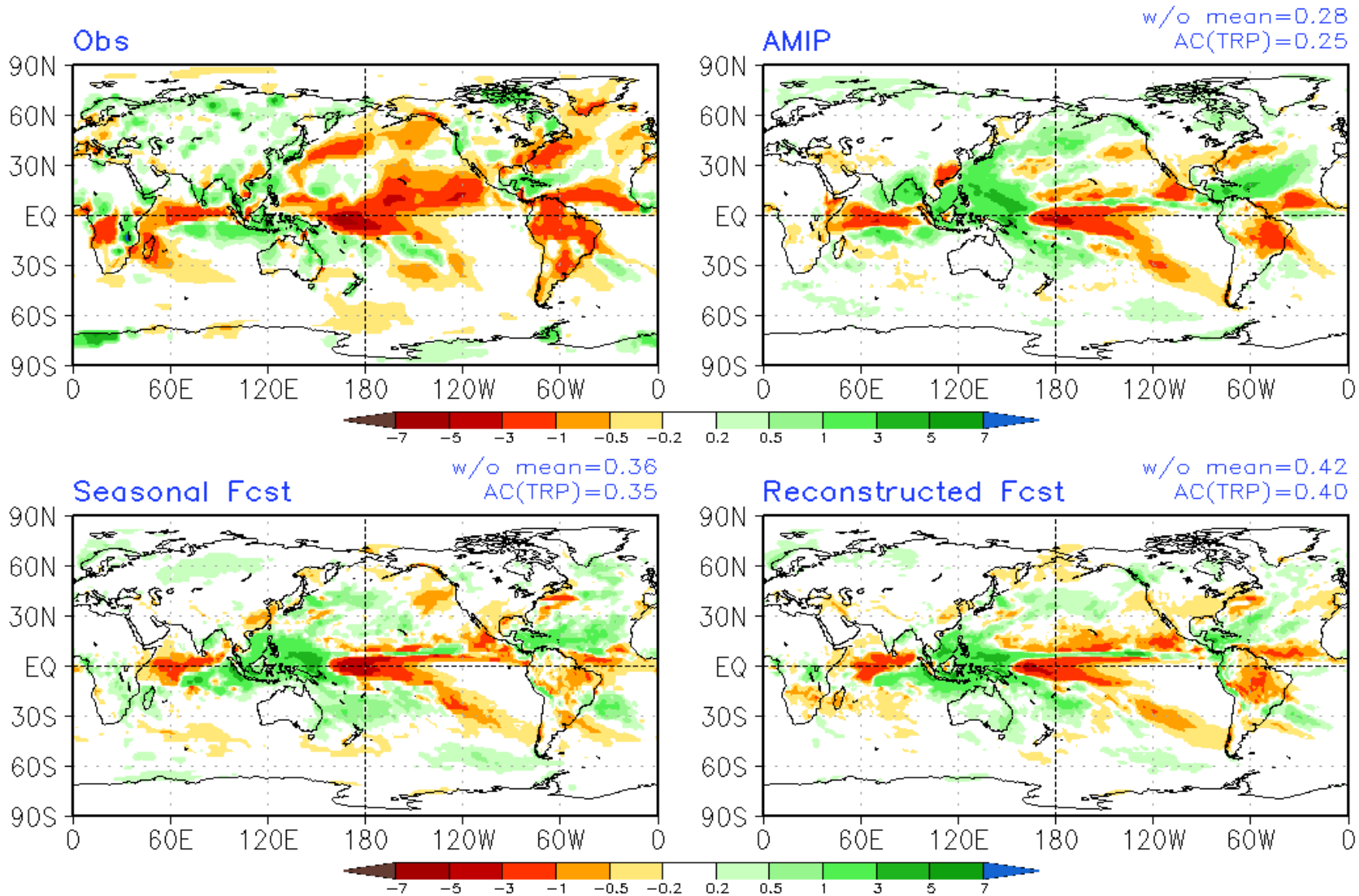
Model Simulated/Forecast Ensemble Average Anomalies

- 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.

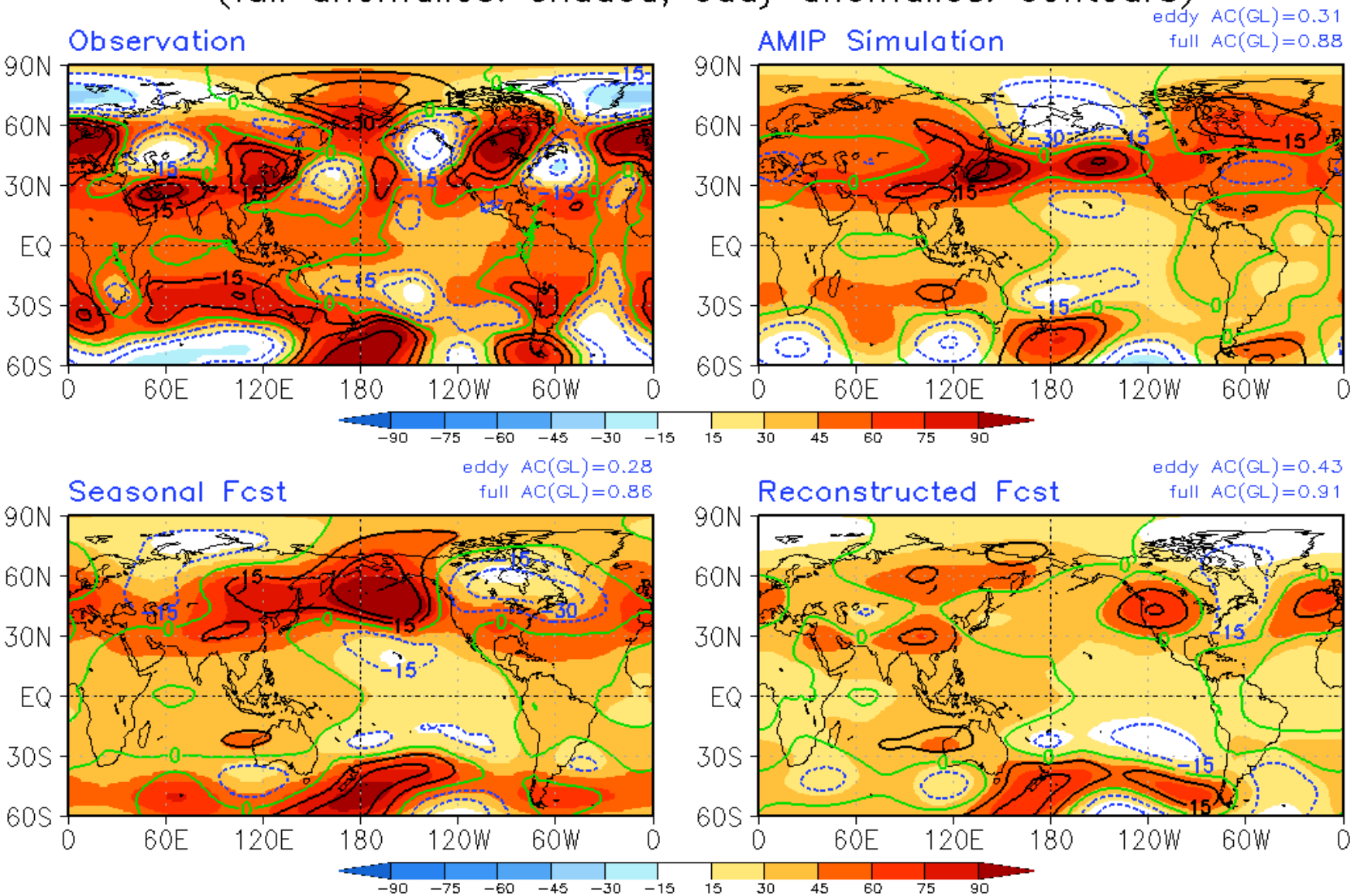
OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies SST(K)



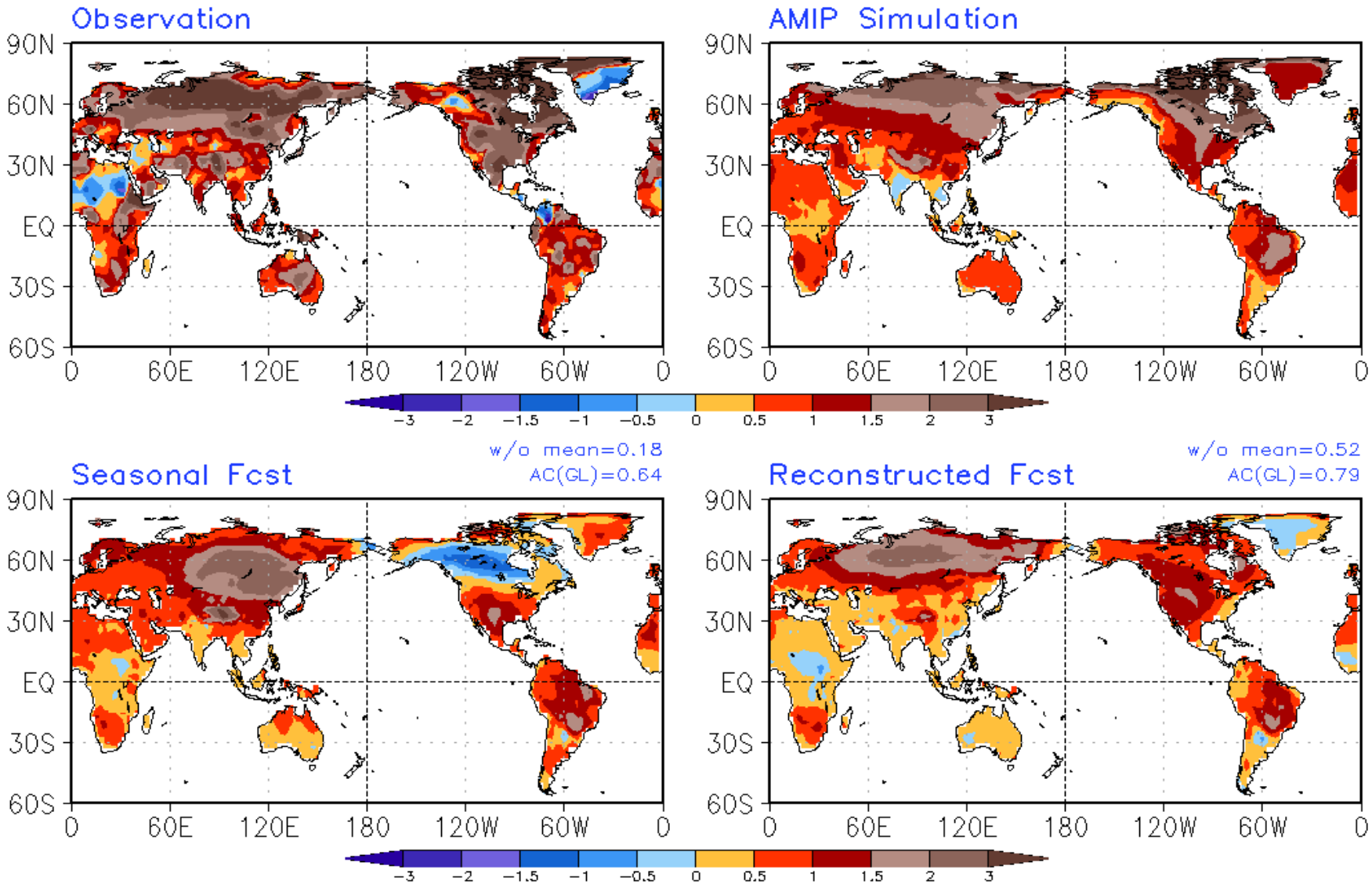
OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies Prec(mm/day)



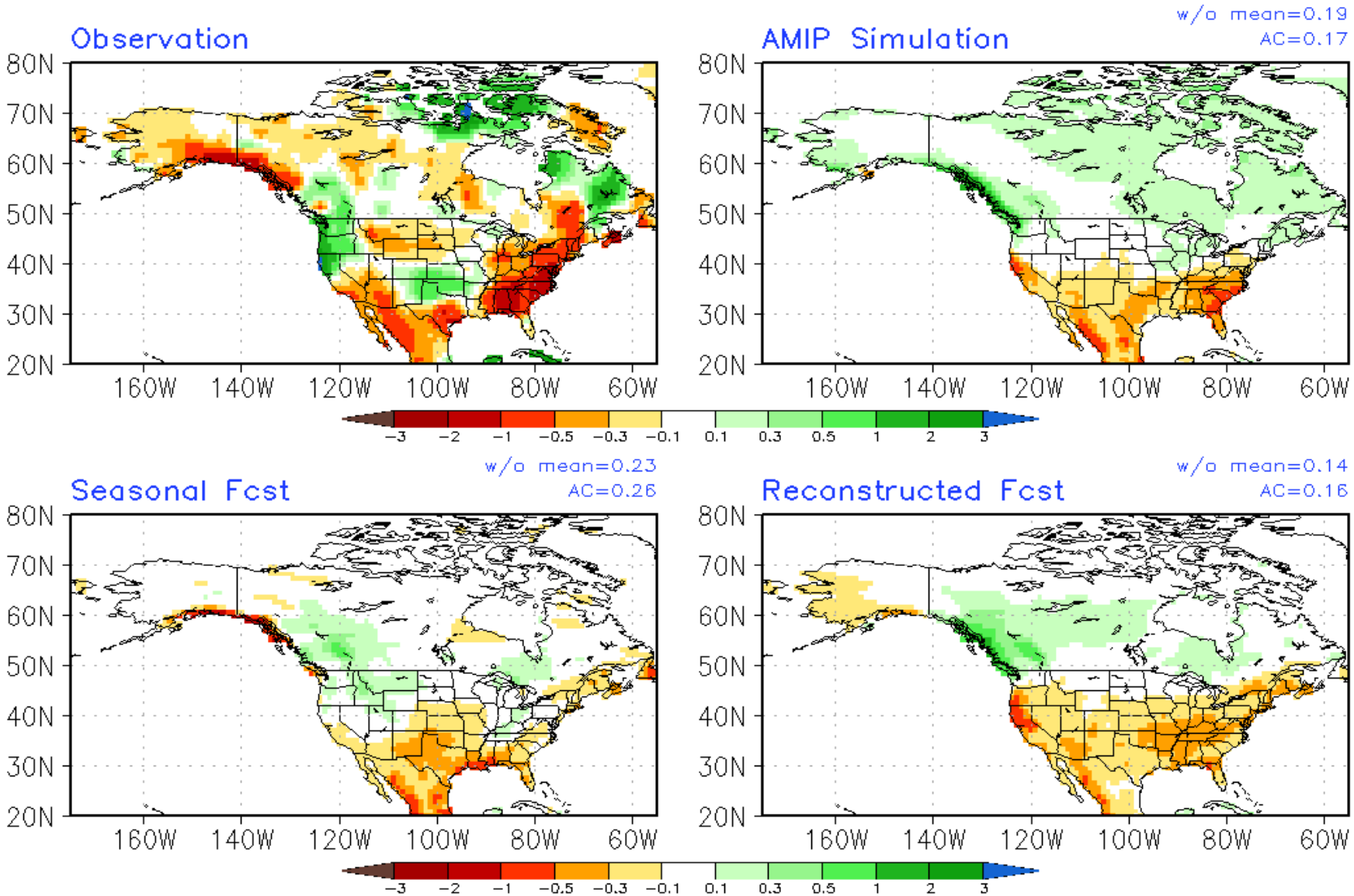
OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies z200(m)
(full anomalies: shaded; eddy anomalies: contours)



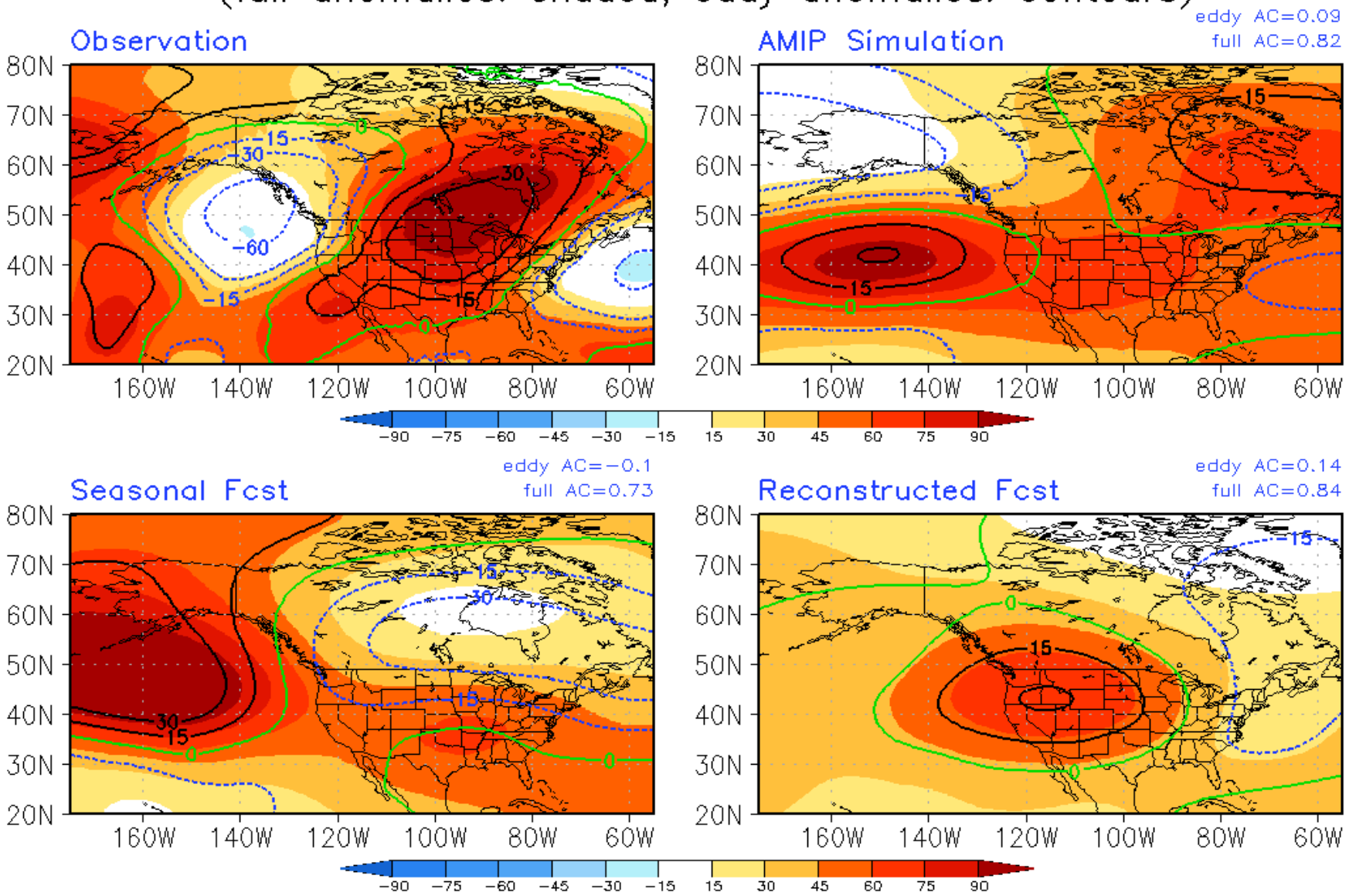
OND2024 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



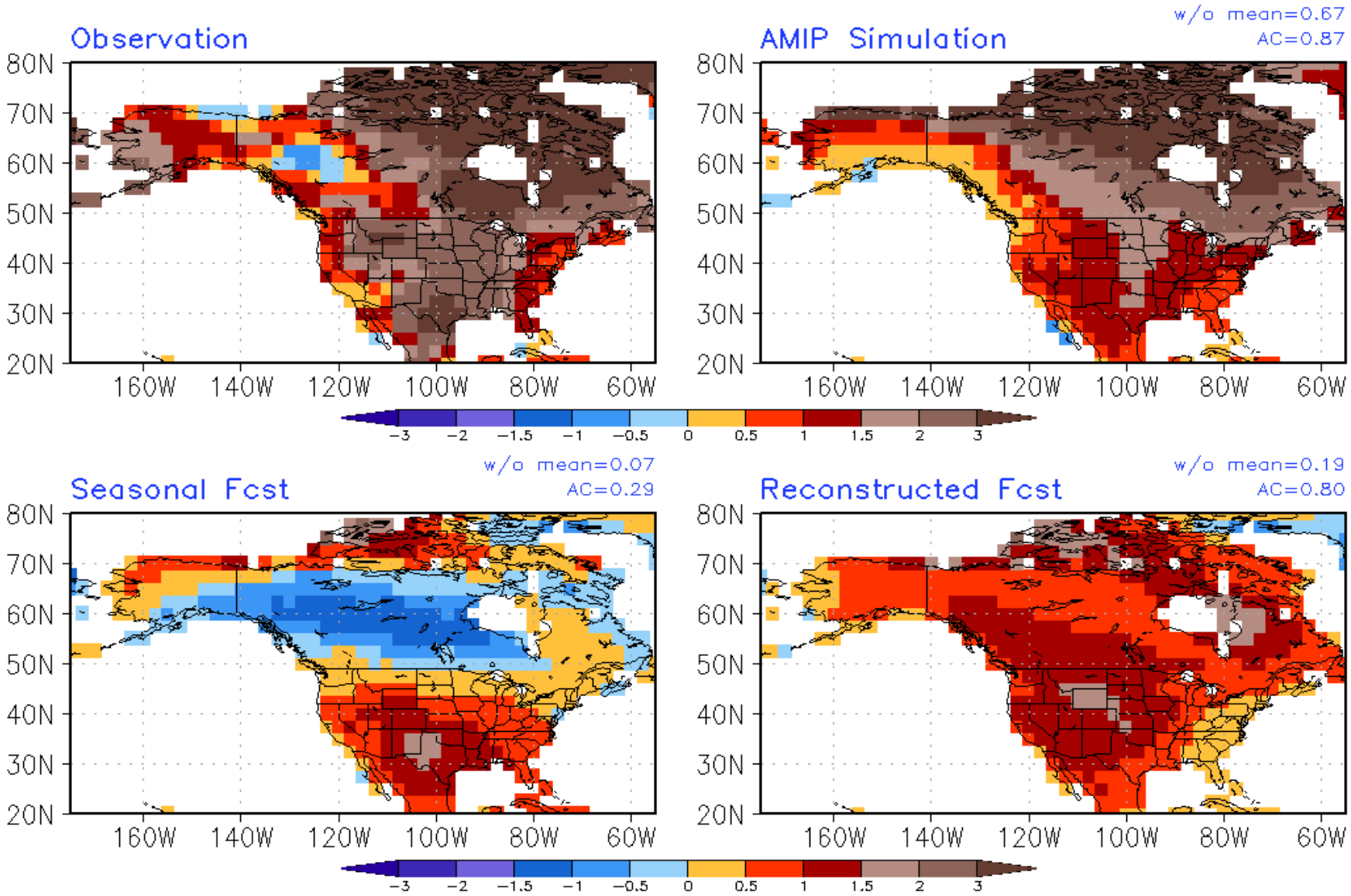
OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies Prec(mm/day)



OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies z200(m)
(full anomalies: shaded; eddy anomalies: contours)



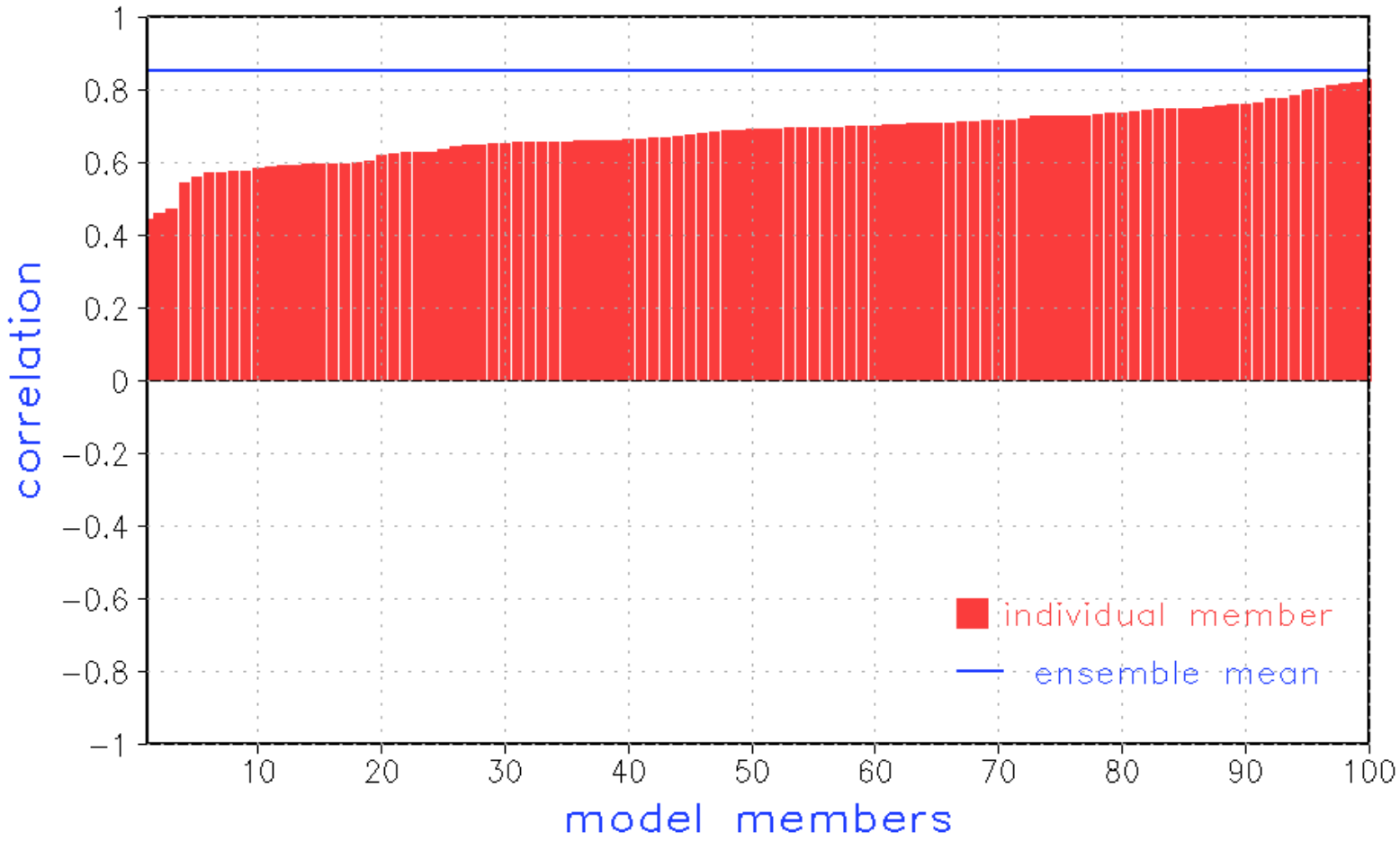
OND2024 Observed & Model Simulated/Forecast
Ensemble Average Anomalies T2m(K)



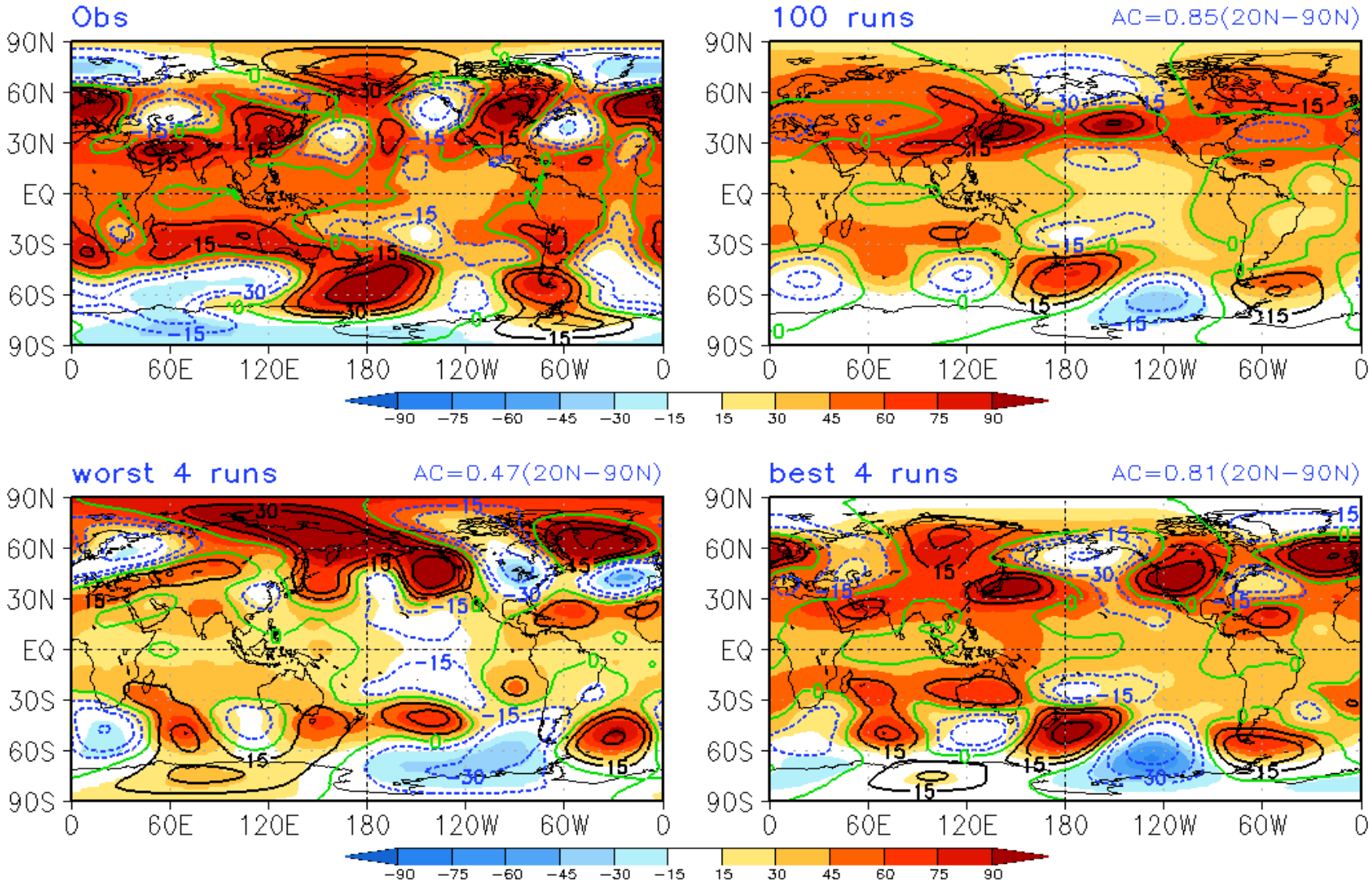
Model Simulated/Forecast Anomalies: Individual Runs

Model Simulated/Forecast Anomalies: Individual Runs

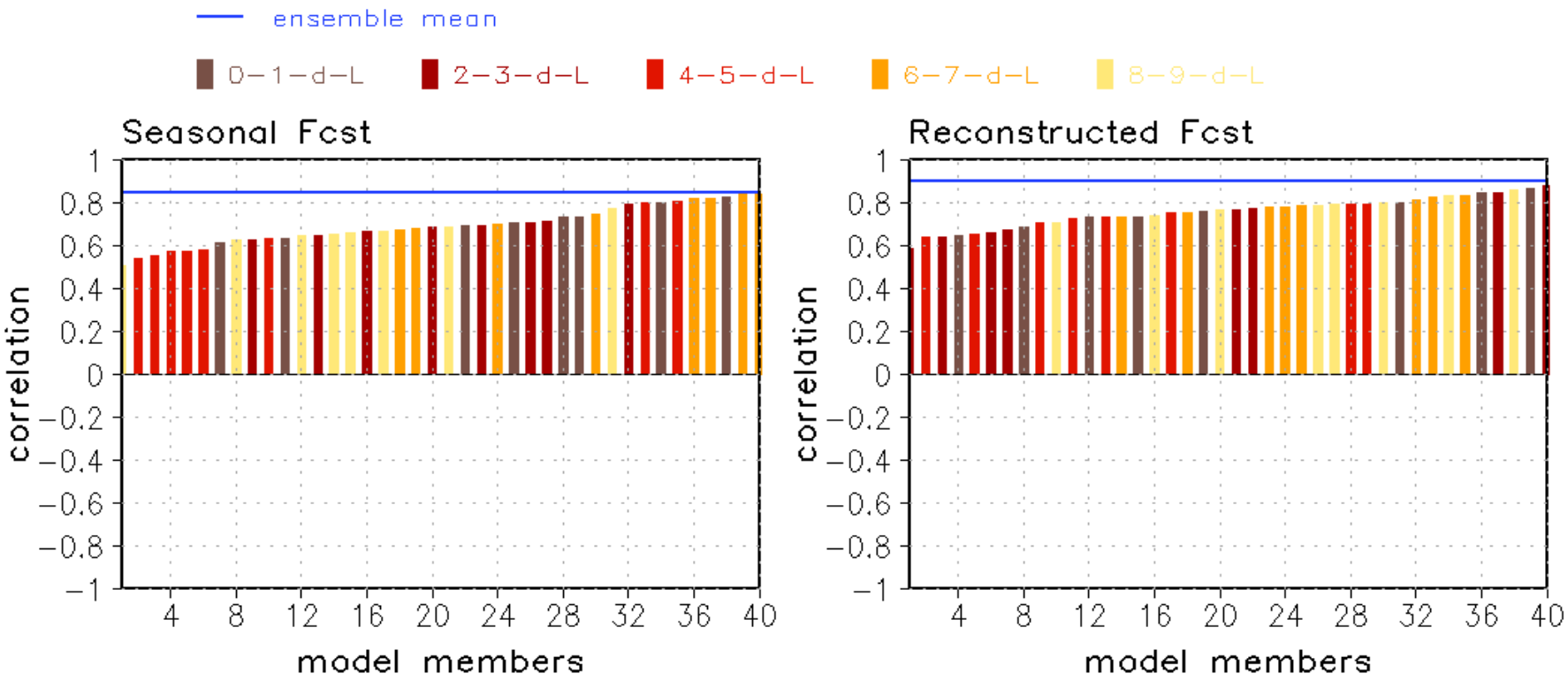
- In this analysis, anomalies from individual model runs are compared against the observed seasonal mean anomalies. The spatial resemblance between them is quantified based on anomaly correlation (AC).
- The distribution of AC across all model simulations is indicative of probability of observed anomalies 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.


OND2024 Anomaly Correlation for Individual AMIP Simulation
with Observation -- z200(20N-90N)
correlation
model members
individual member
ensemble mean
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
10
20
30
40
50
60
70
80
90
100

Observed & AMIP Ensemble Mean Anomalies
OND2024 z200(m) 100 runs/worst 4 runs/best 4 runs
(full anomalies: shaded; eddy anomalies: contours)



OND2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)

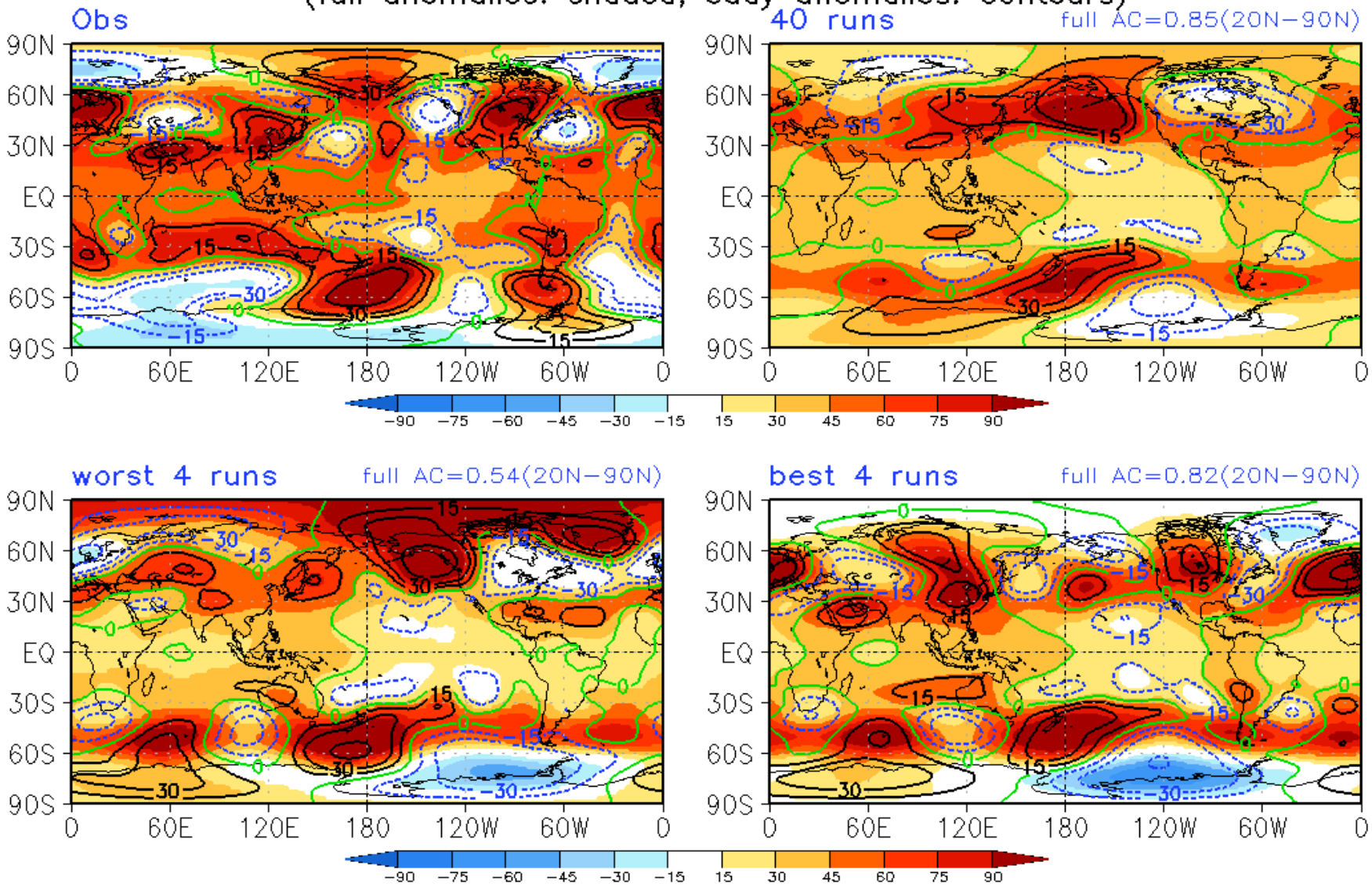


Observed & CFSv2 Forecast Ensemble Average Anomalies

OND2024 z200(m) 40 runs/worst 4 runs/best 4 runs

Seasonal Forecast

(full anomalies: shaded; eddy anomalies: contours)

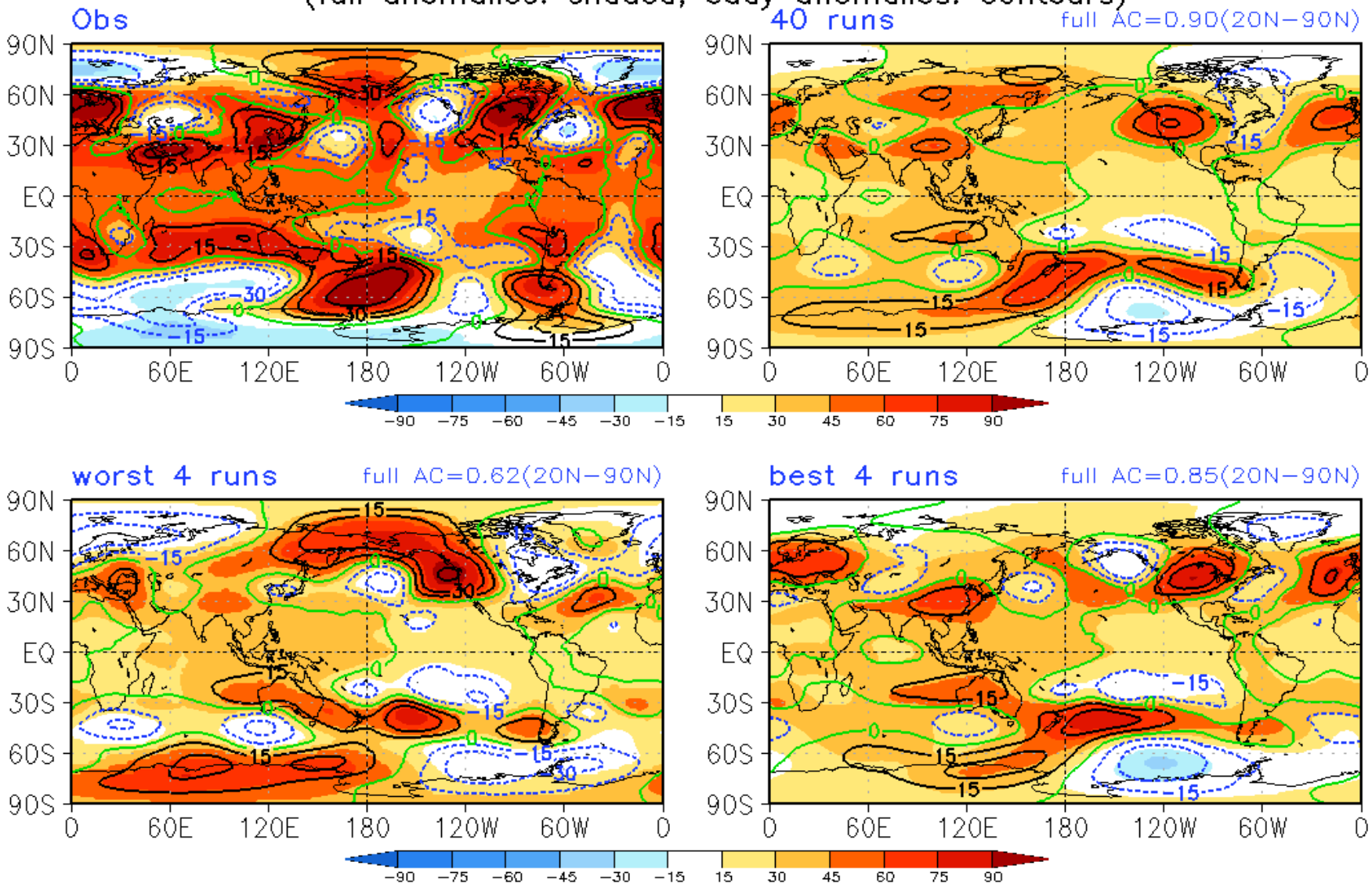


Observed & CFSv2 Forecast Ensemble Average Anomalies

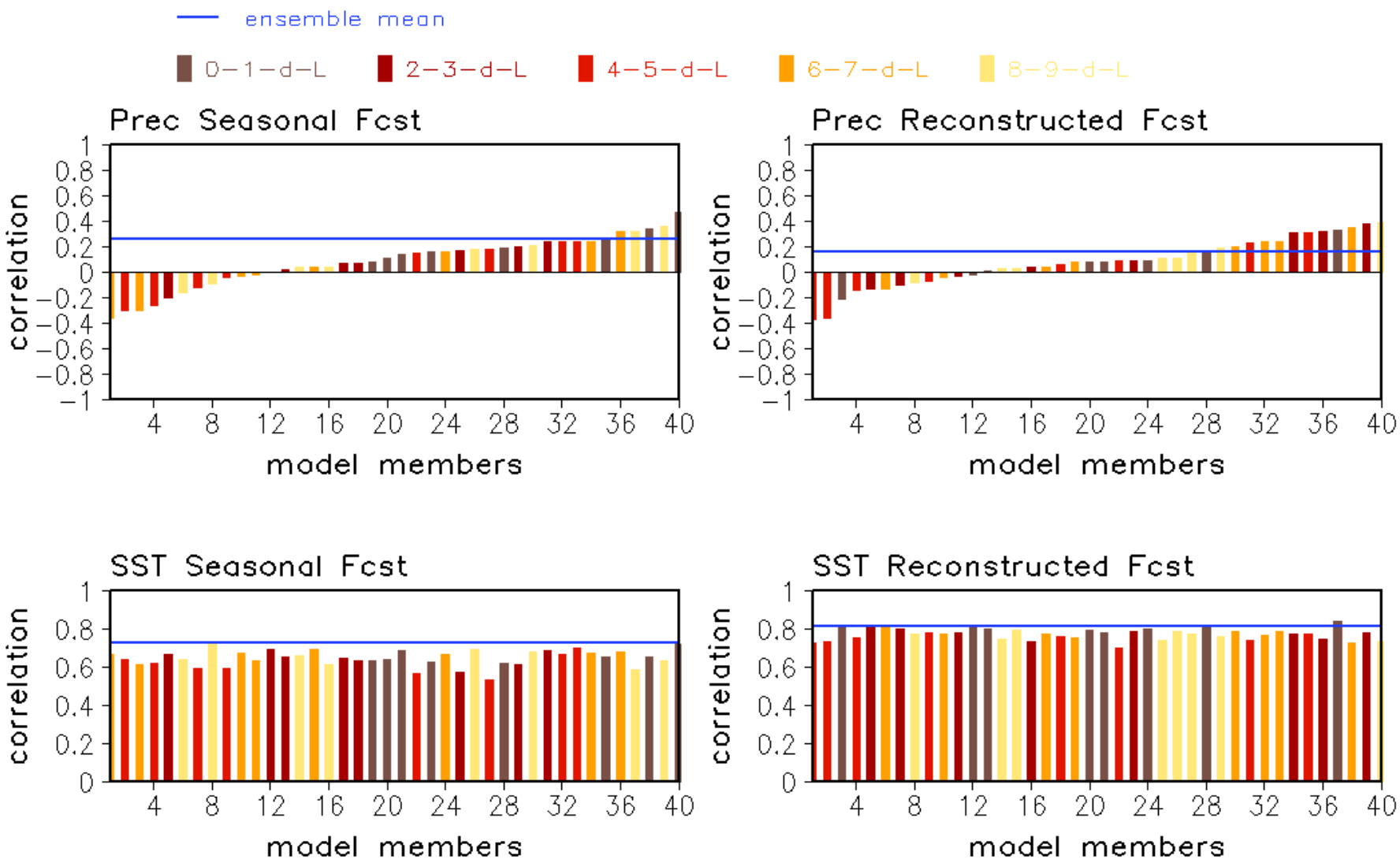
OND2024 z200(m) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast

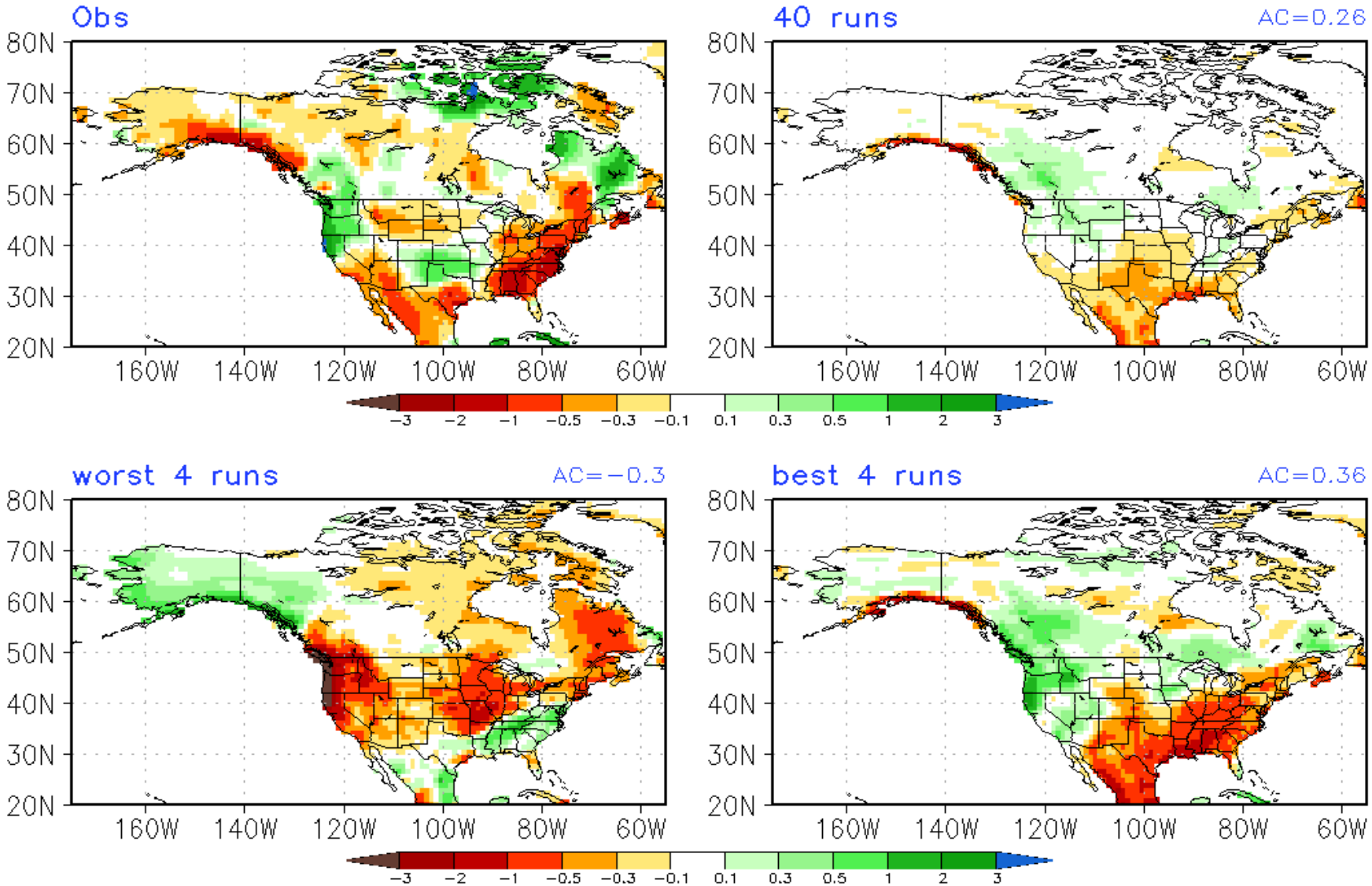
(full anomalies: shaded; eddy anomalies: contours)



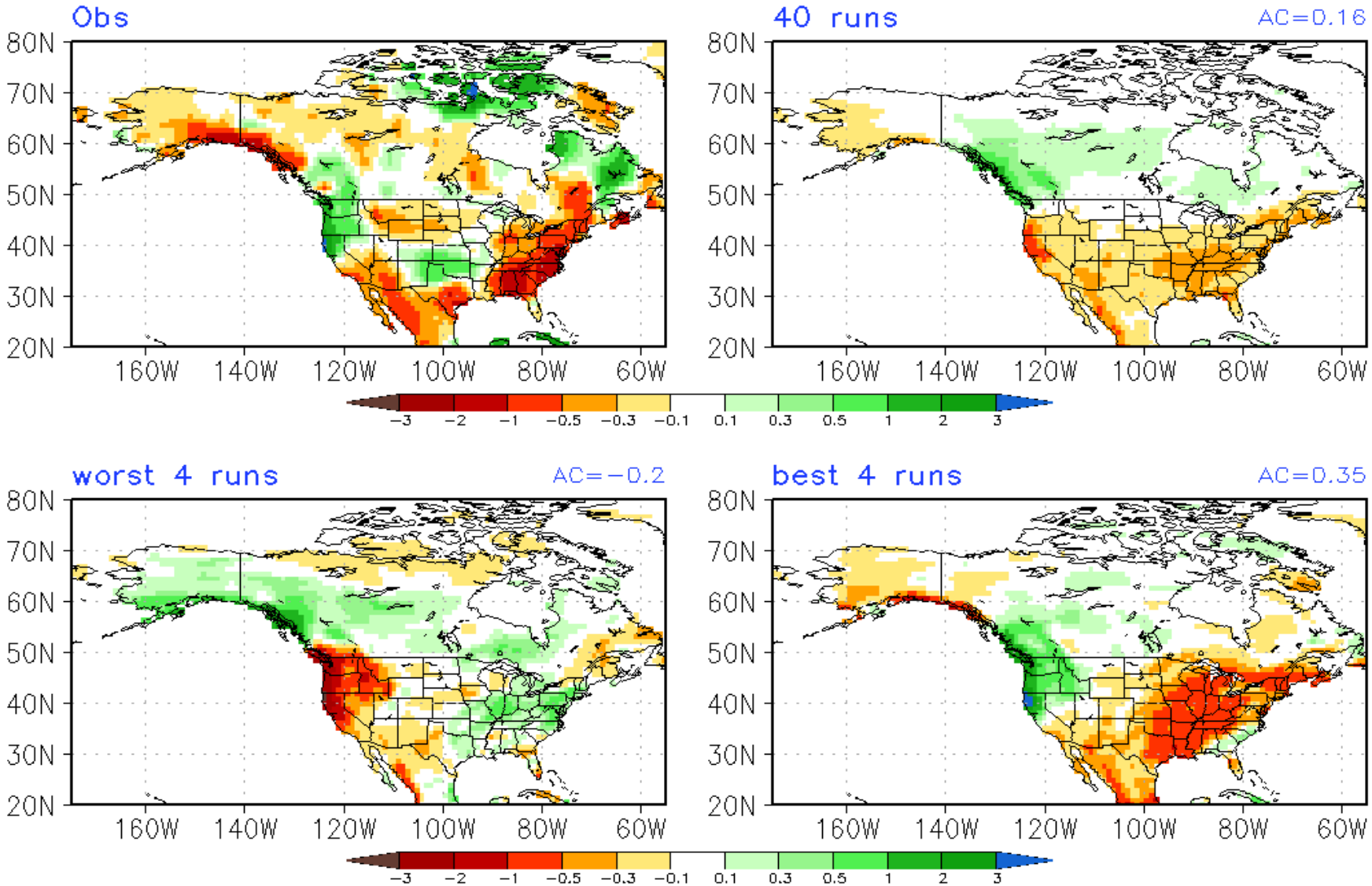
OND2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



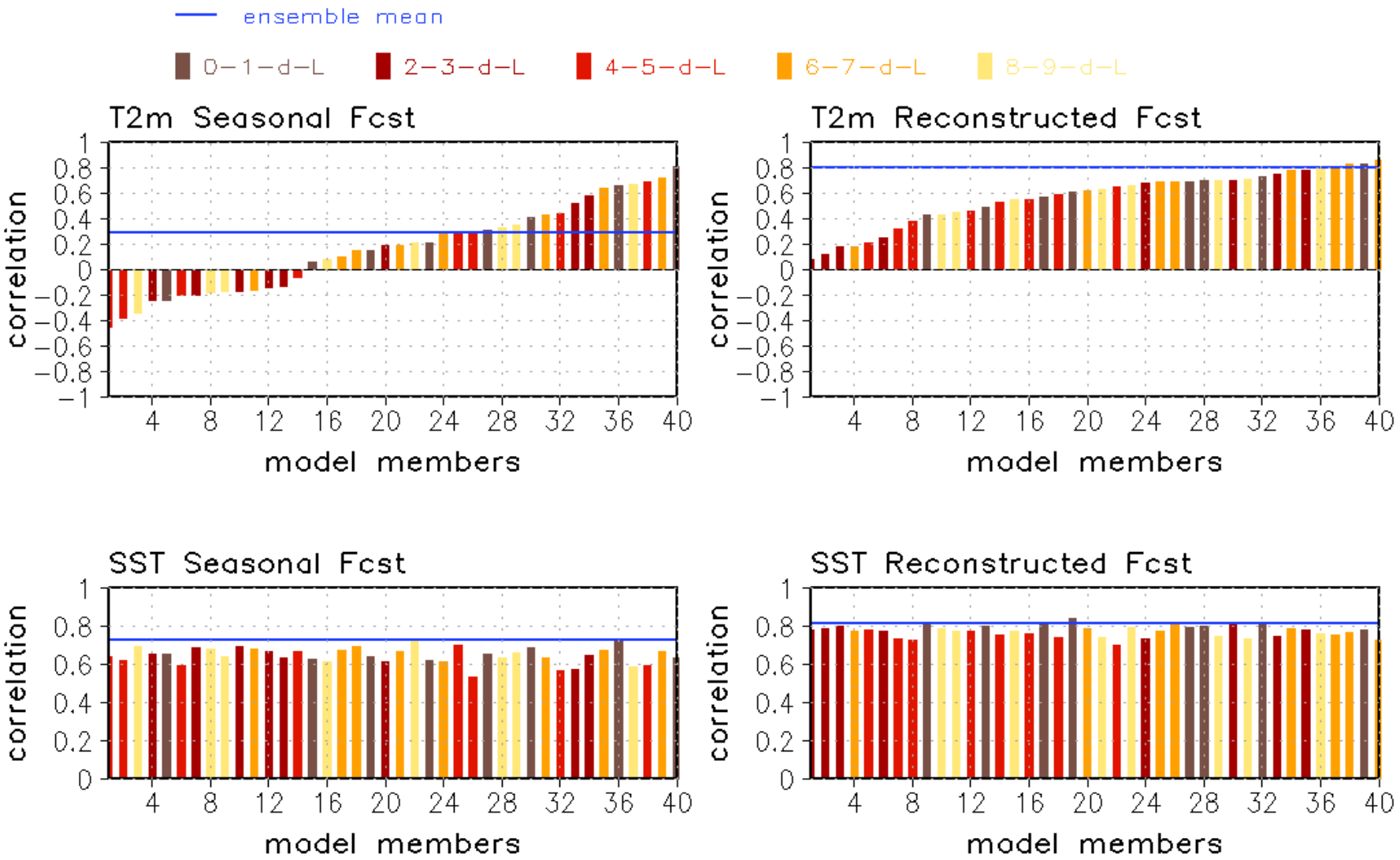
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



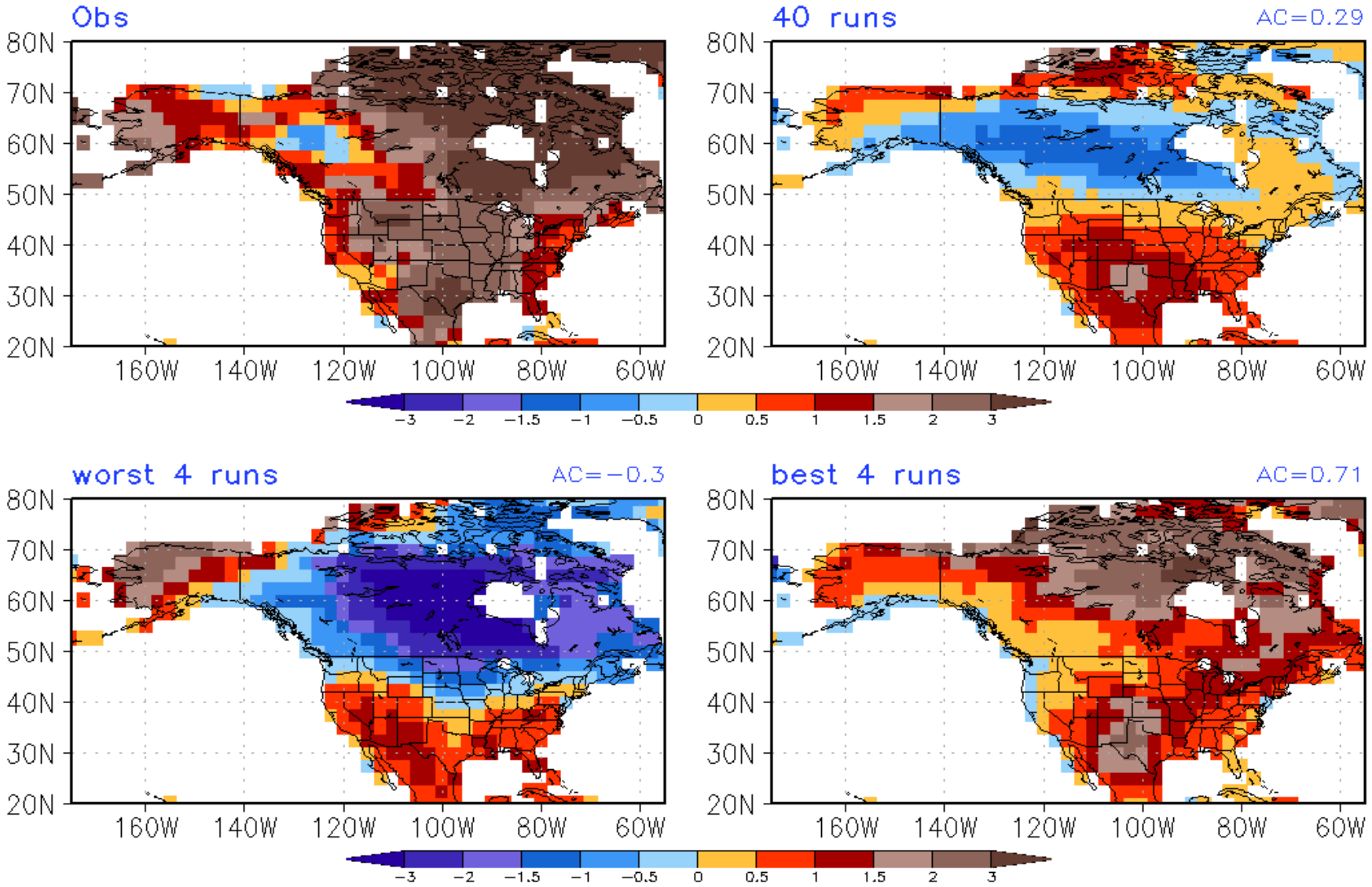
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2024 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



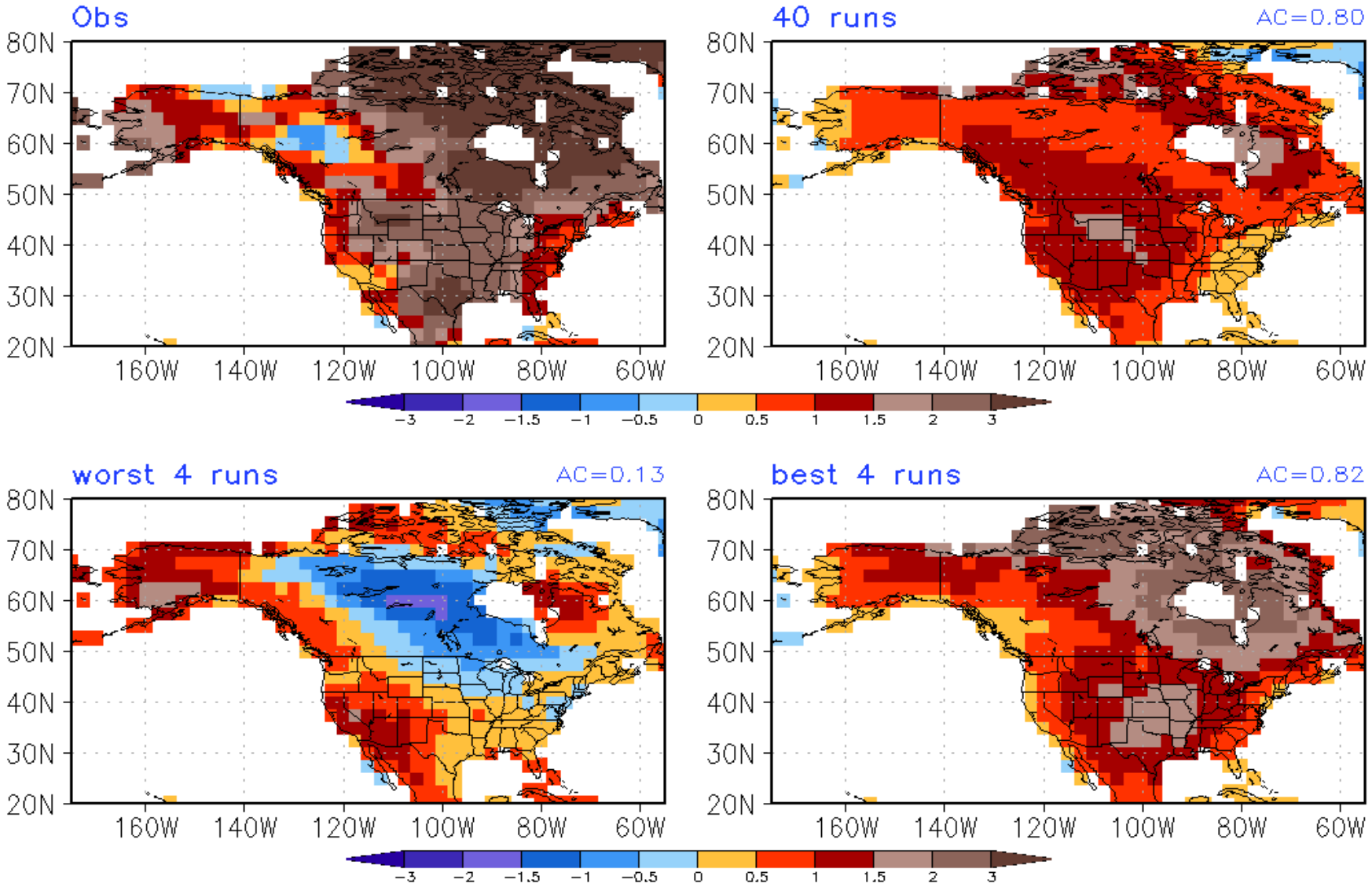
OND2024 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



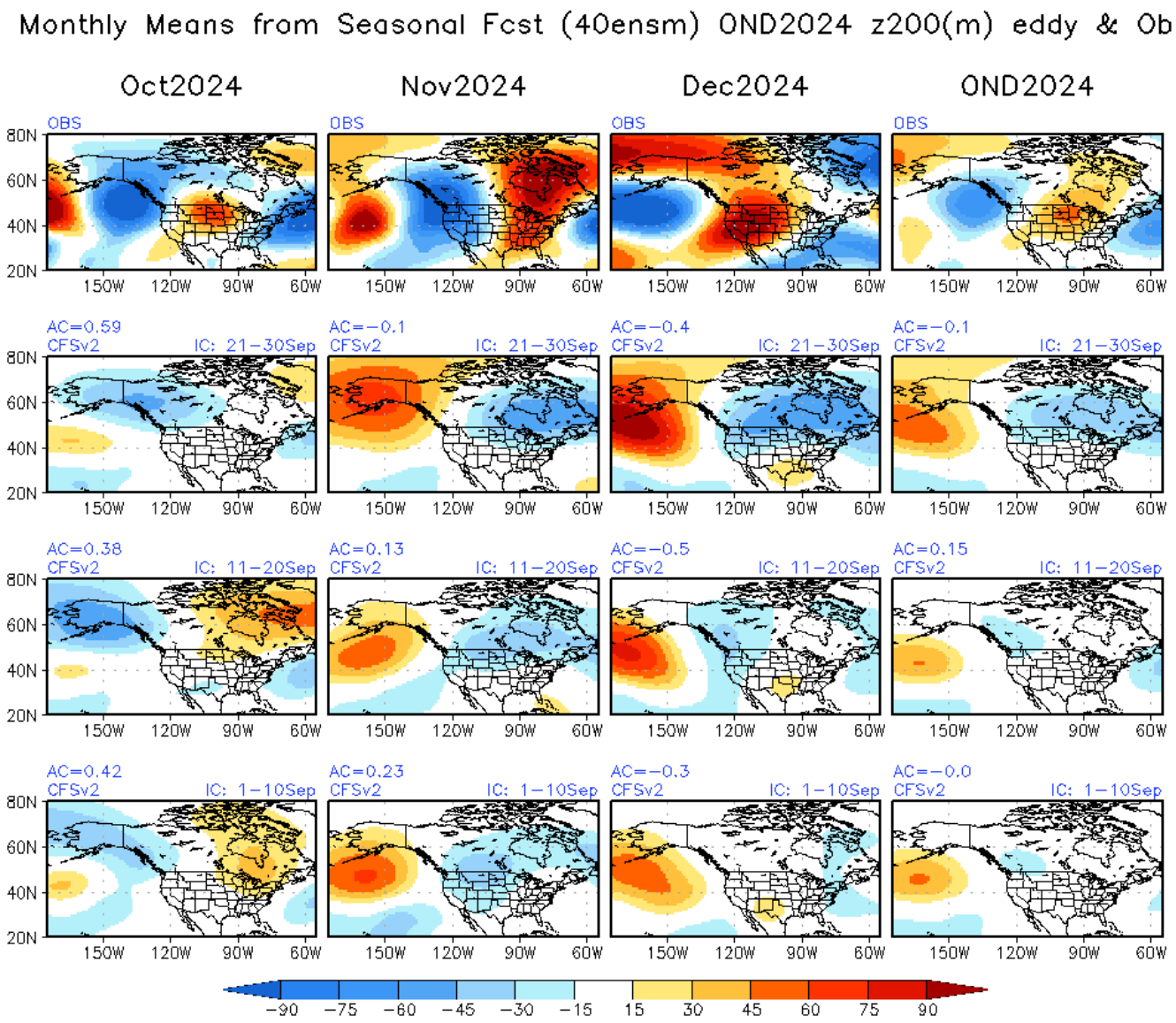
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2024 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

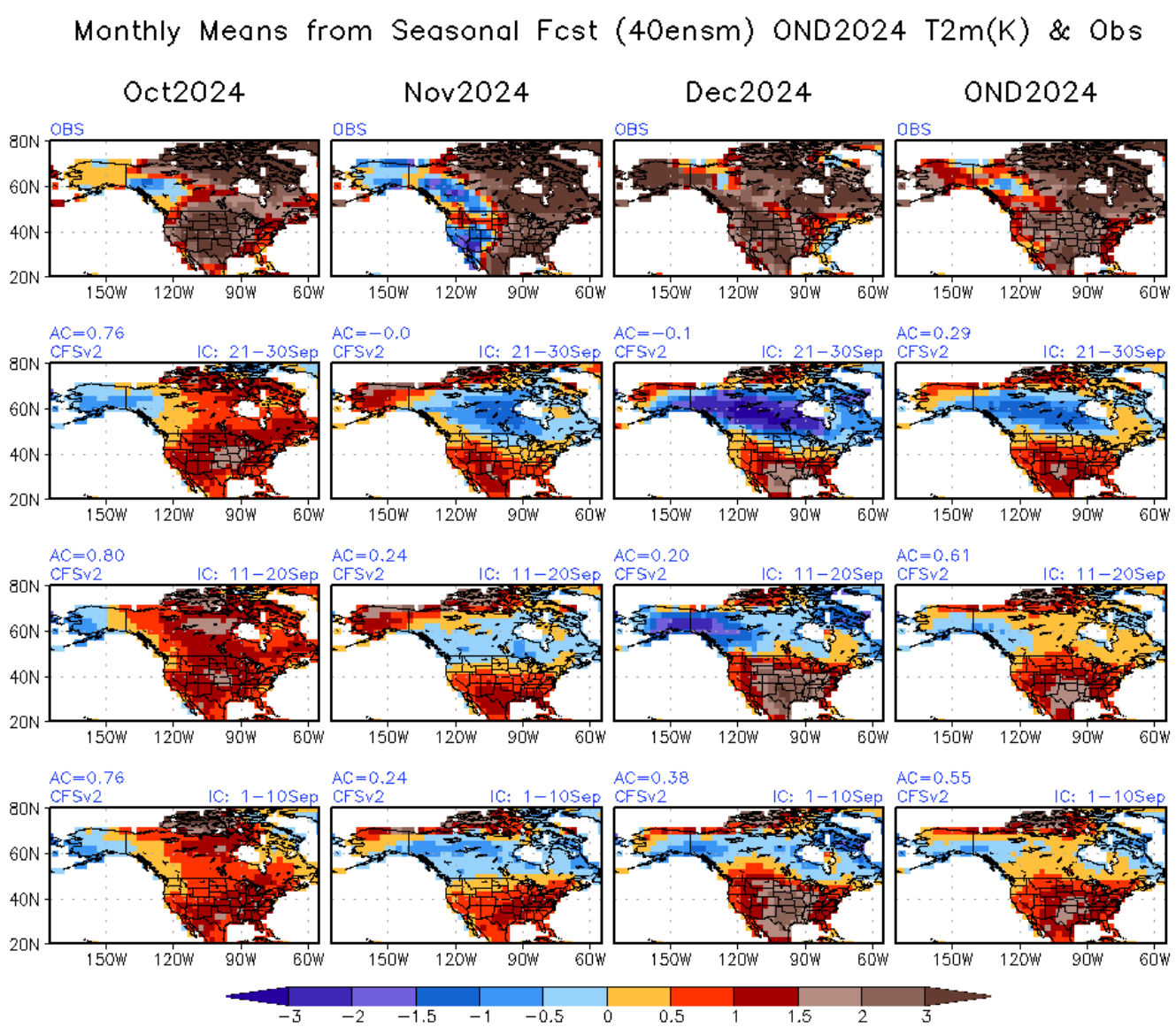


Top row: Observed anomaly.

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



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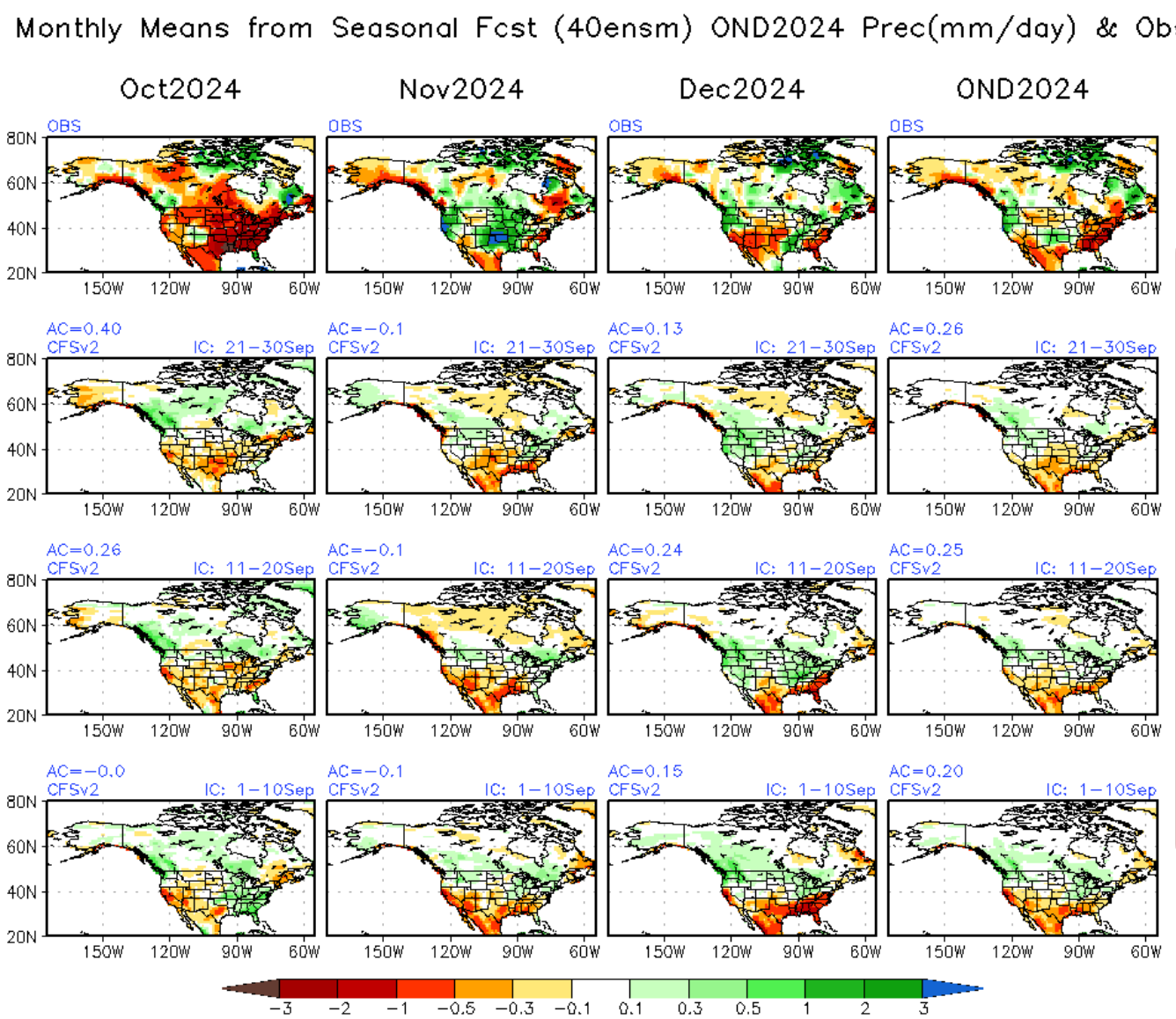
- 4th row: 1st - 10th of the prior month.

Prec(mm/day) Monthly Means from Seasonal Forecast



Top row: Observed anomaly.

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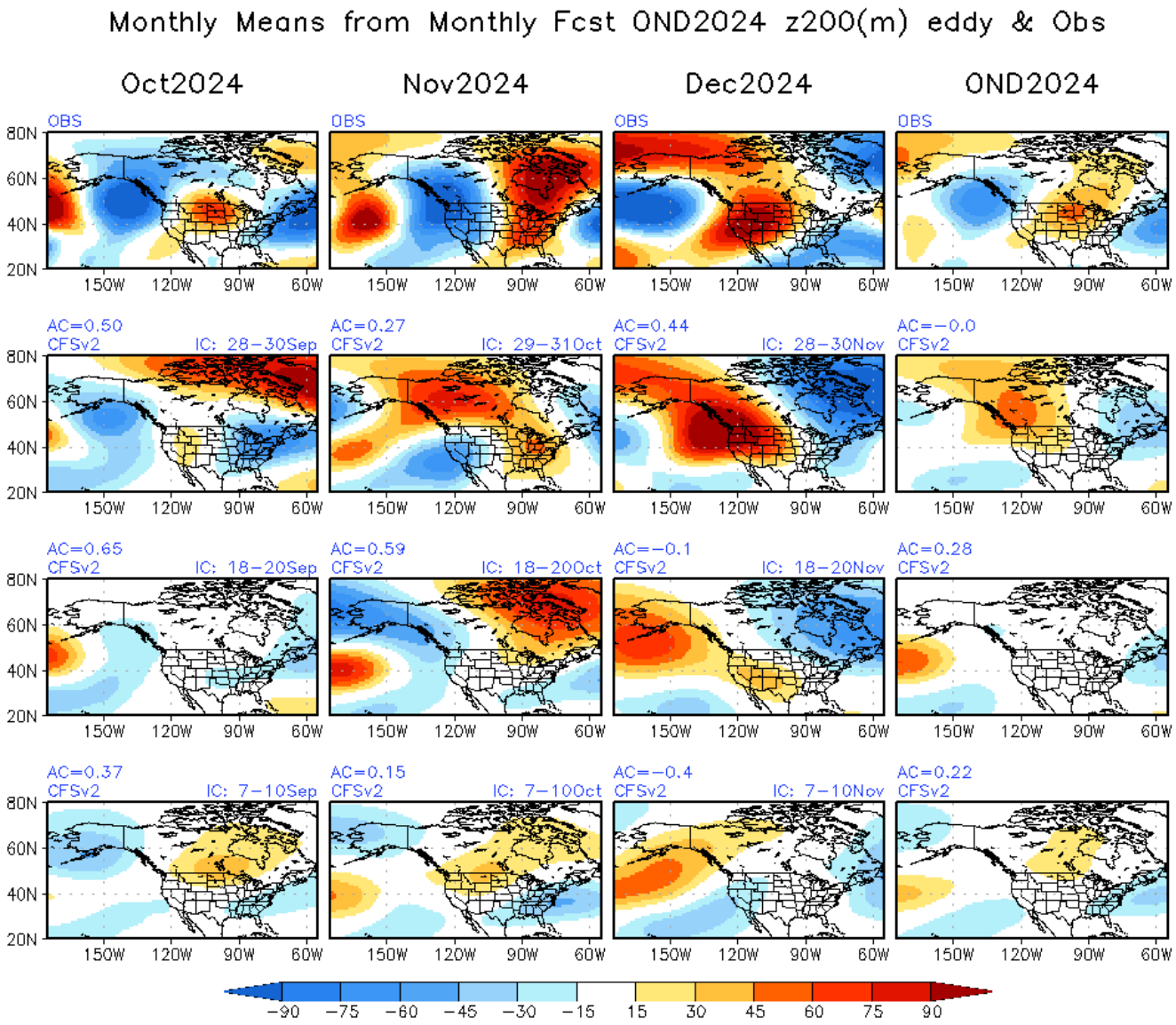
- 4th row: 1st - 10th of the prior month.

z200(m) Monthly Means from Monthly Forecast

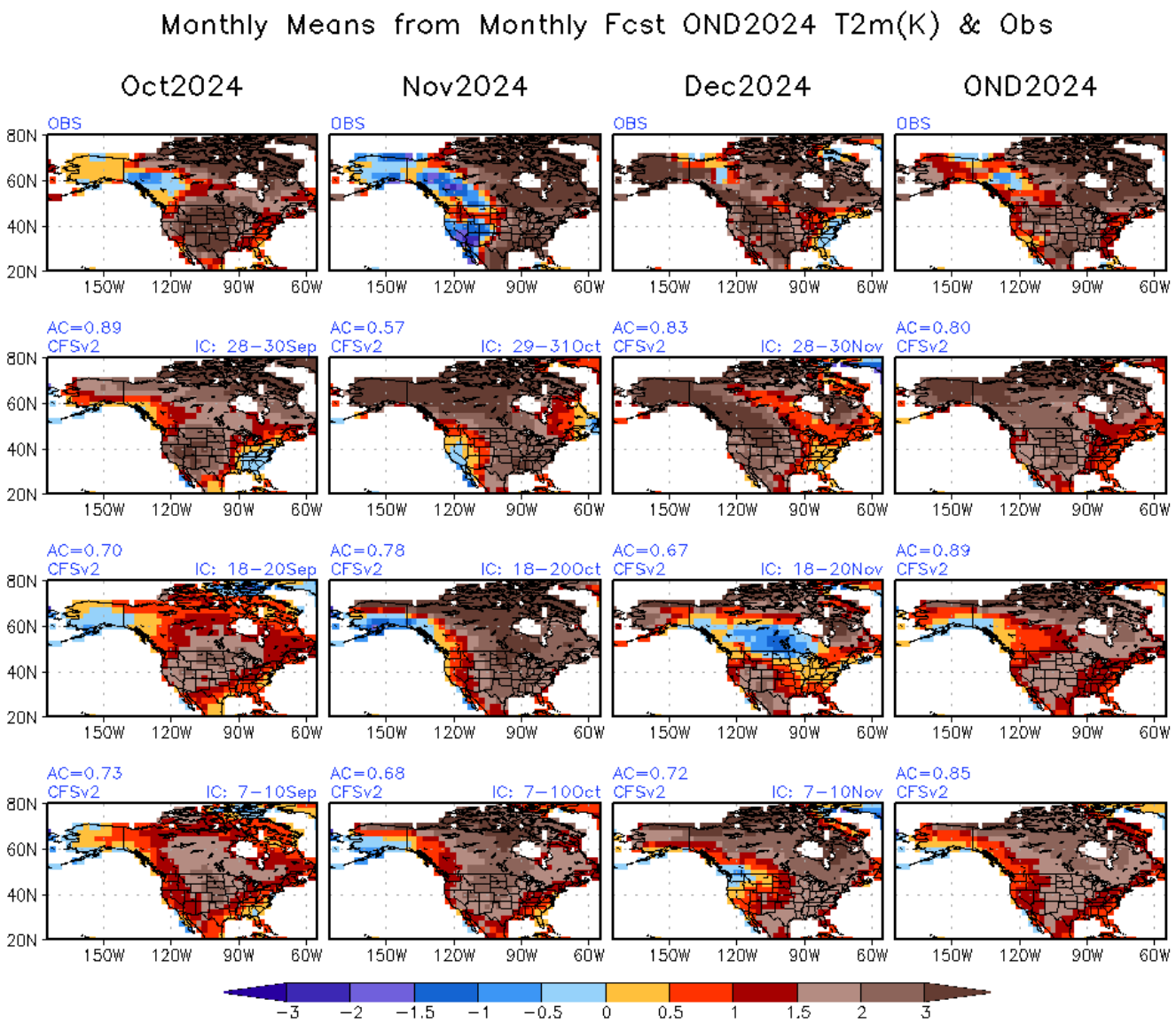


Top row: Observed anomaly.

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

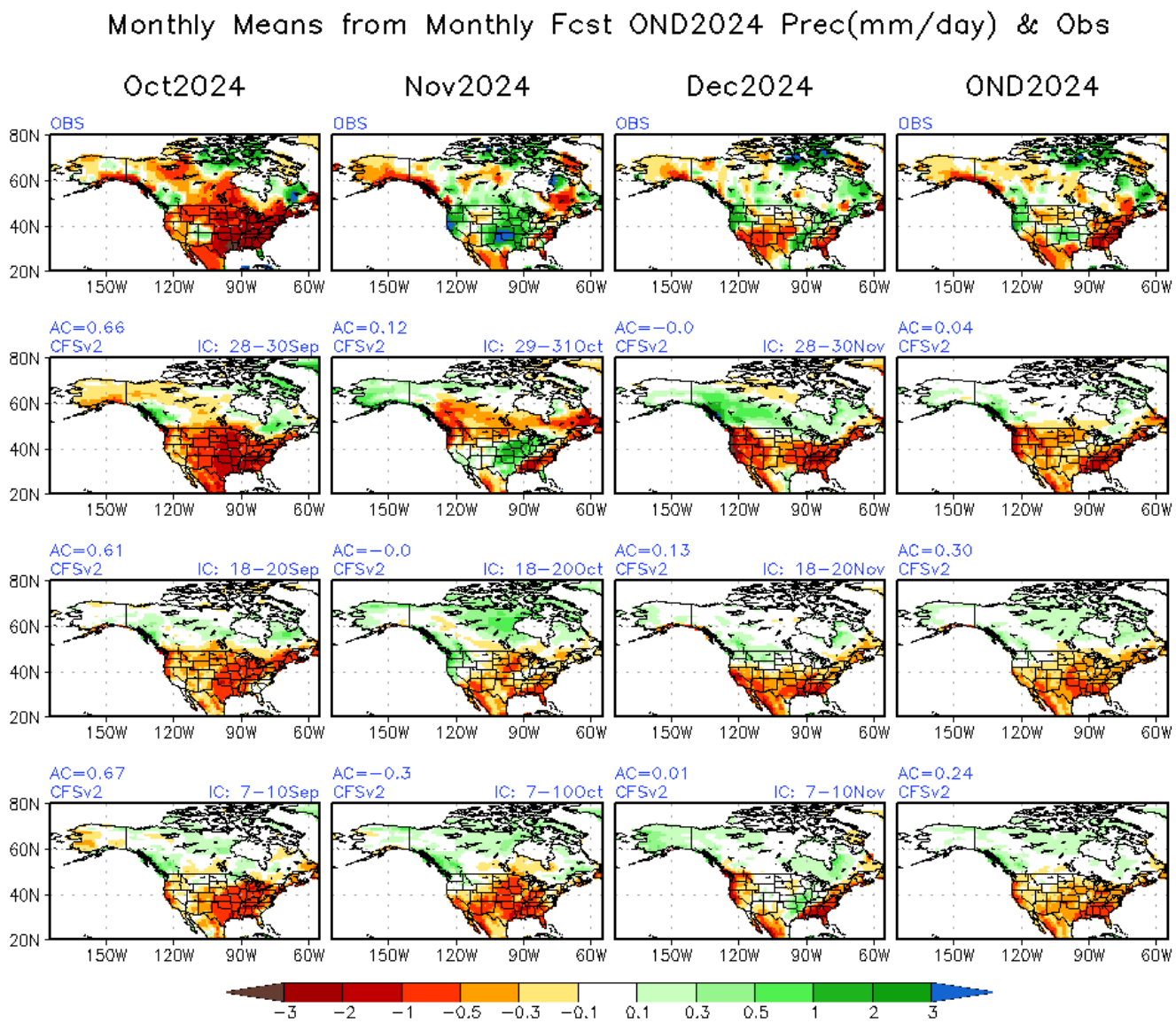


Top row: Observed anomaly.

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

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

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



Top row: Observed anomaly.

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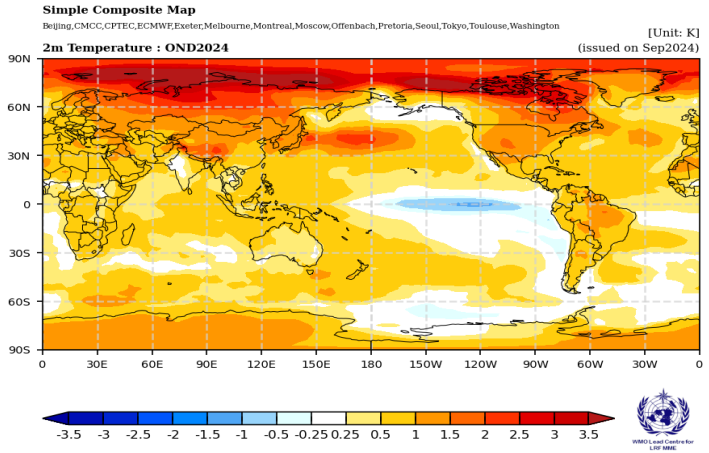
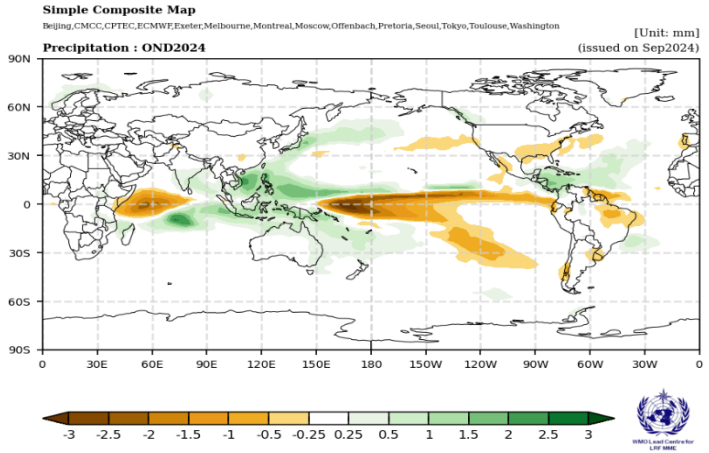
Seasonal Forecasts from Multi-Model Ensemble Systems

- 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/

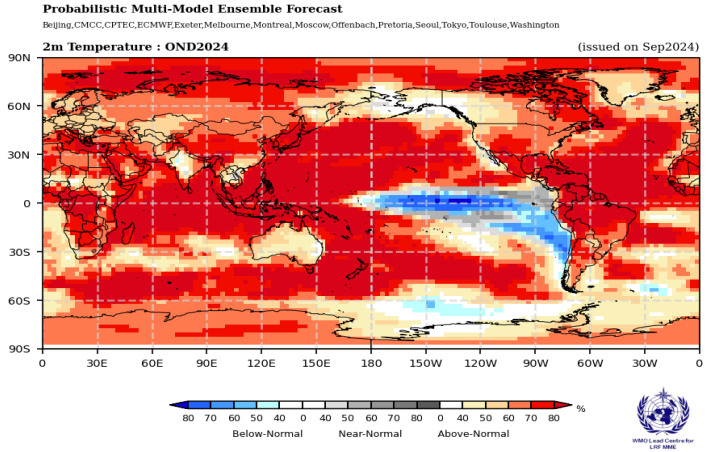
LC-LRFMM Seasonal Forecasts
(https://www.wmolc.org/)

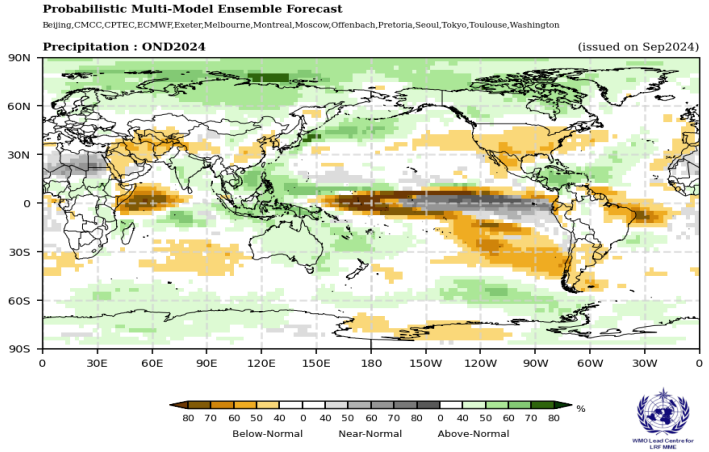
Ensemble means





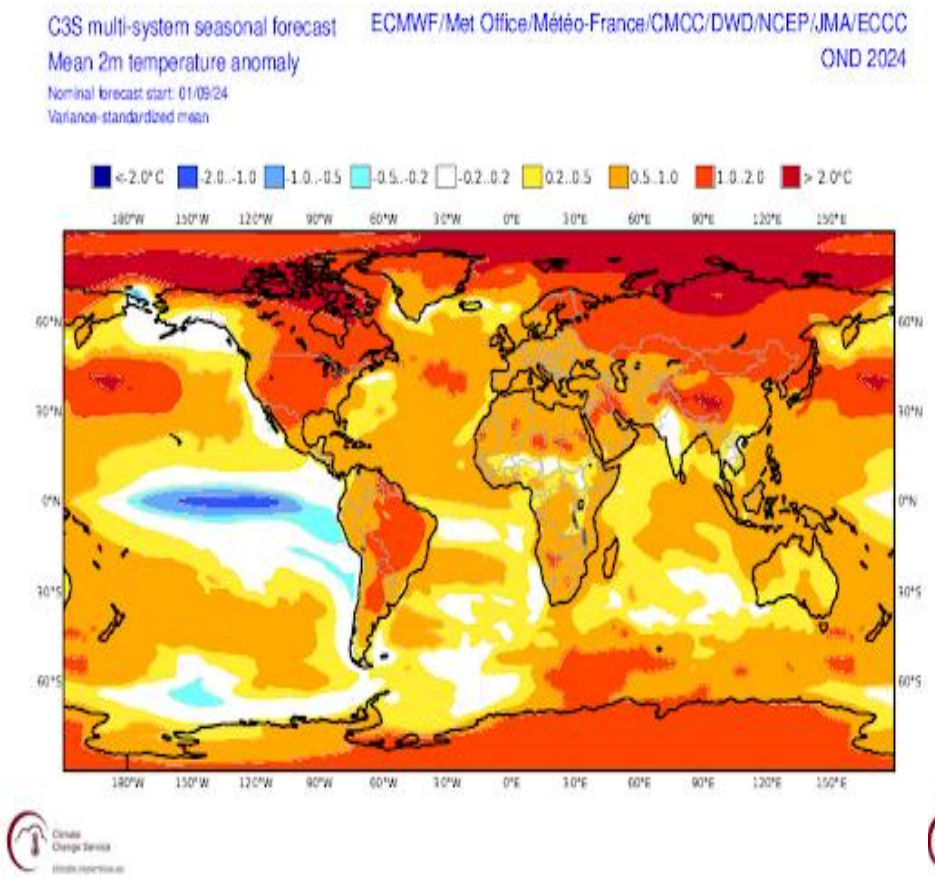
Probabilities

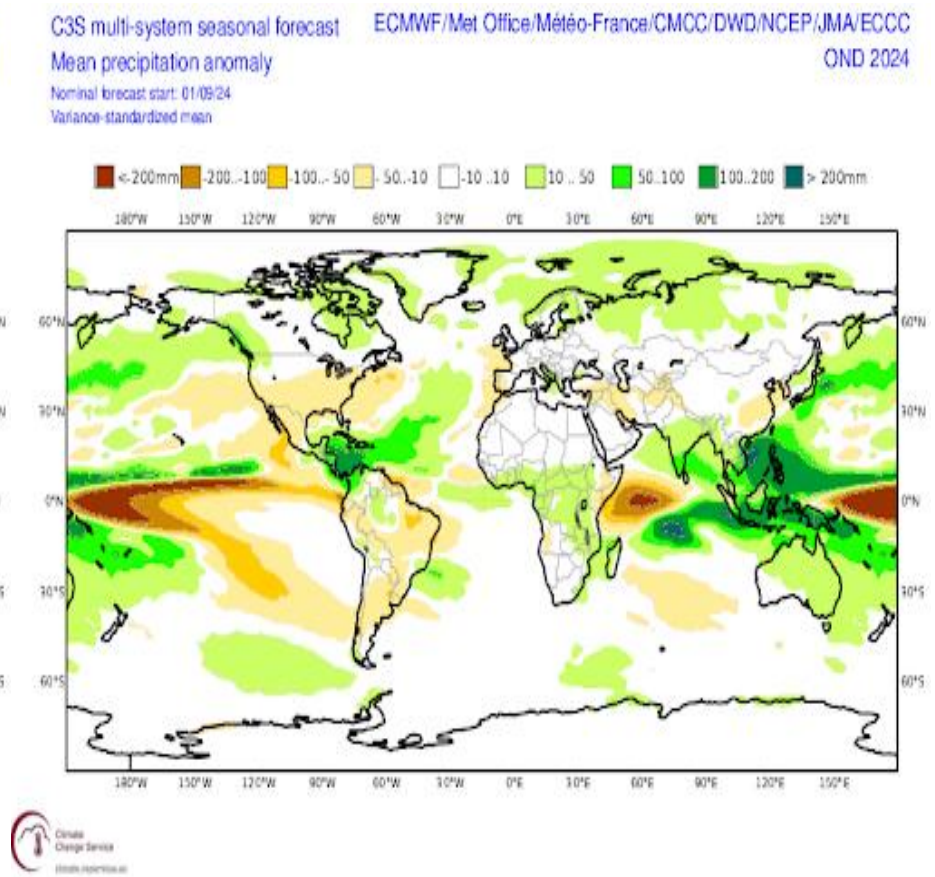




C3S Seasonal Forecast

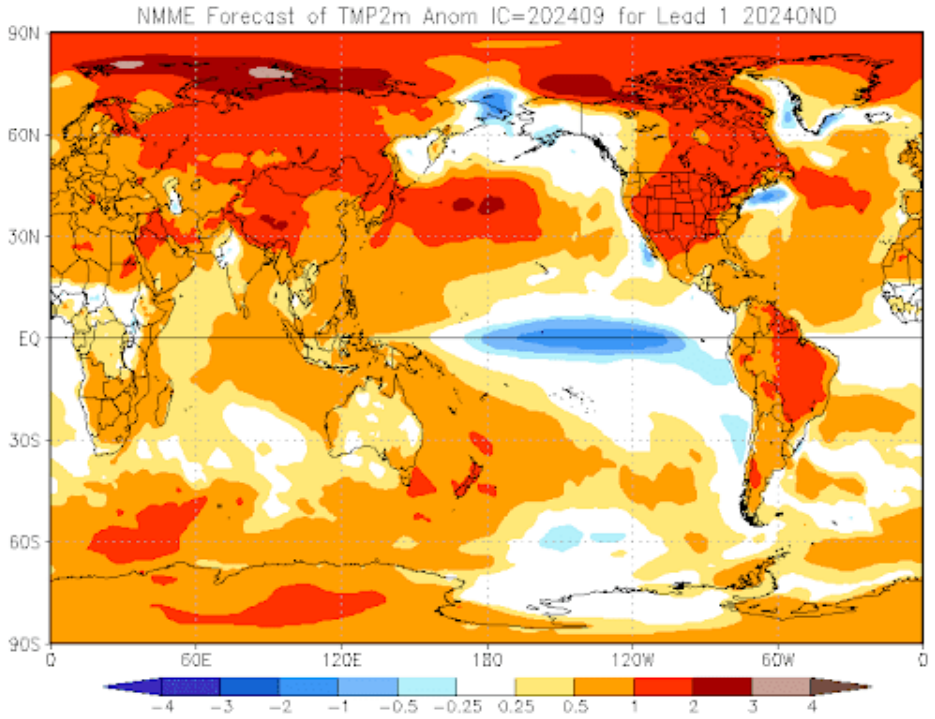
(https://climate.copernicus.eu/charts/c3s_seasonal/)

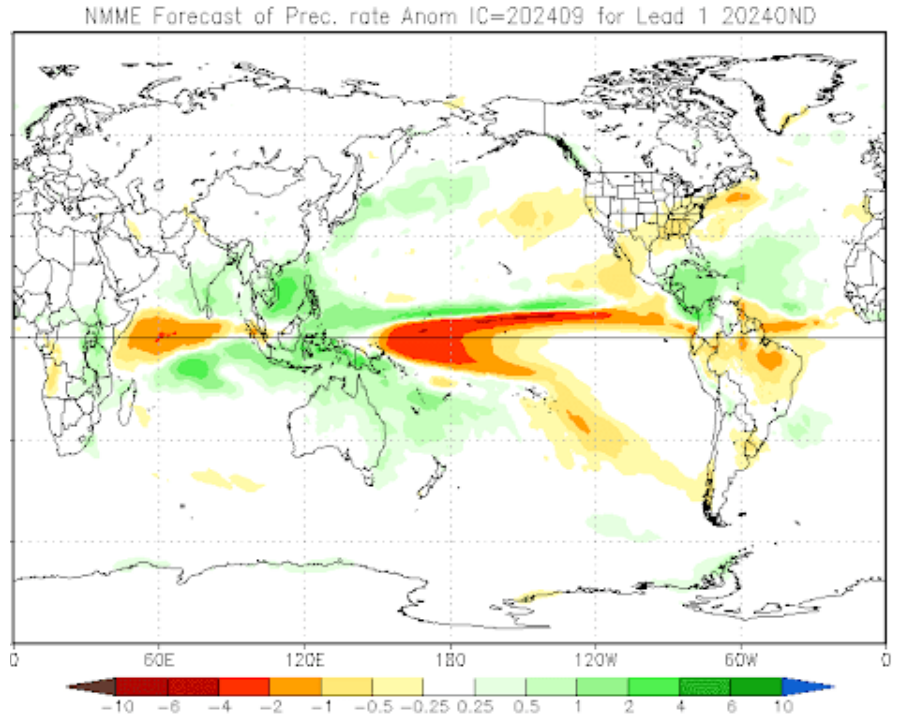




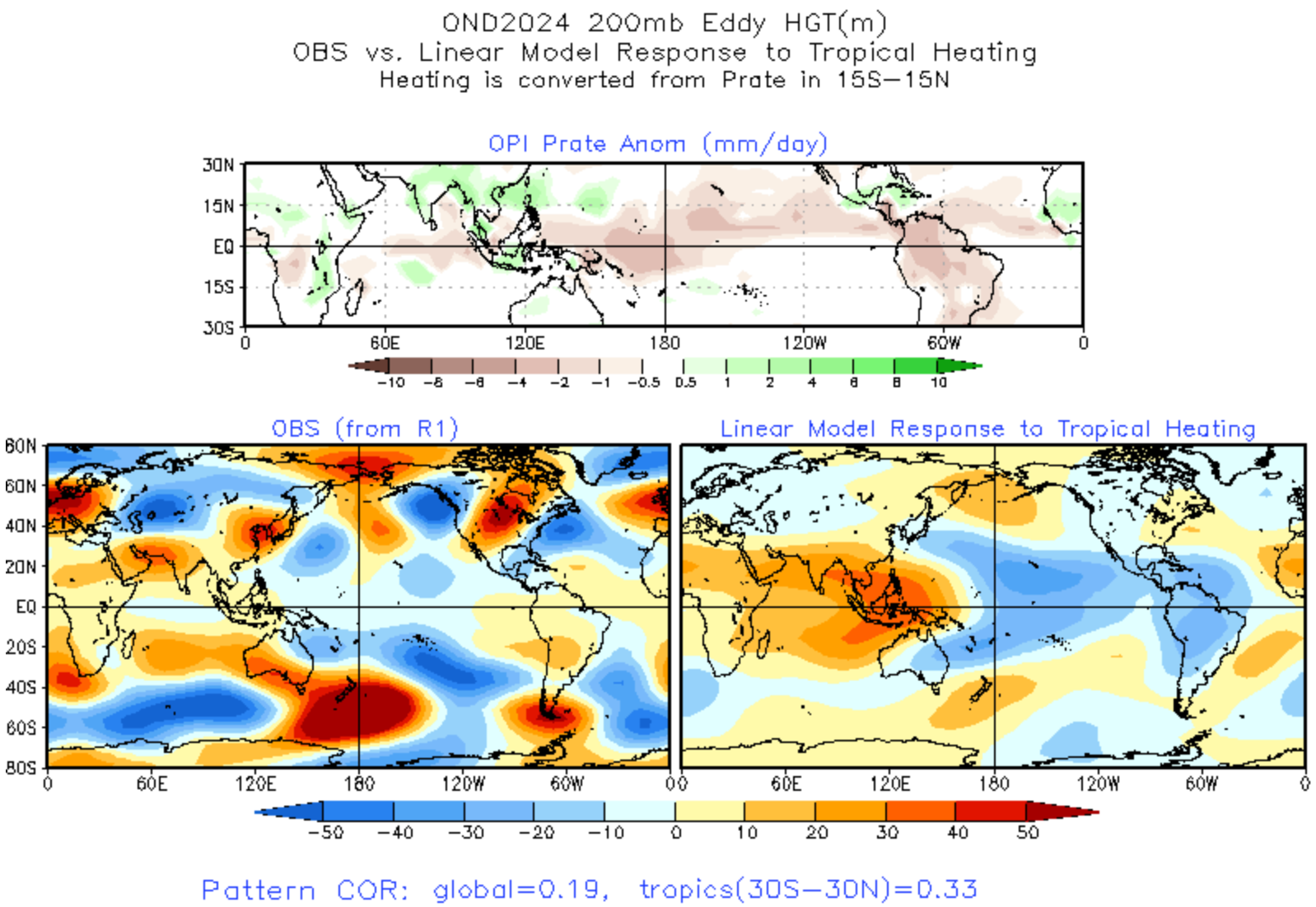
North American Multi-Model Ensemble Seasonal Forecast

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

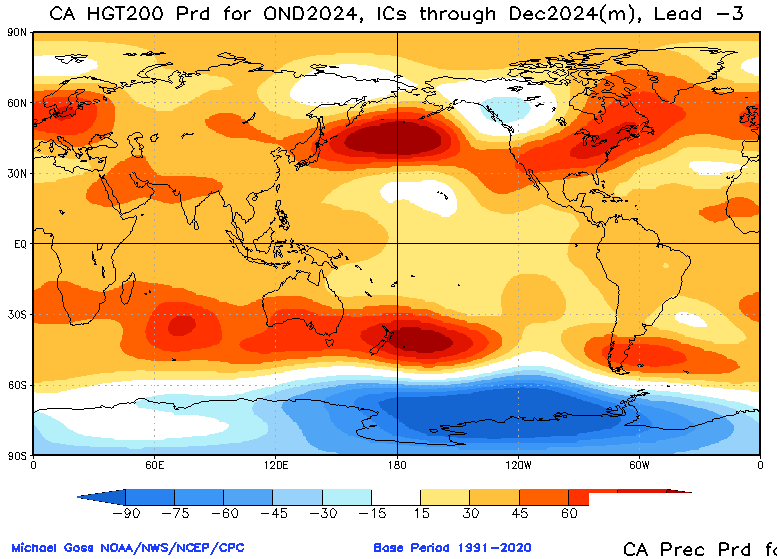


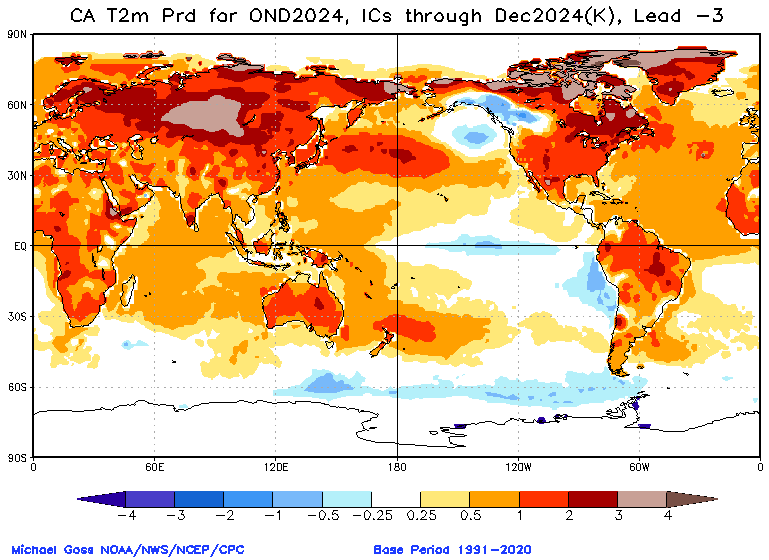


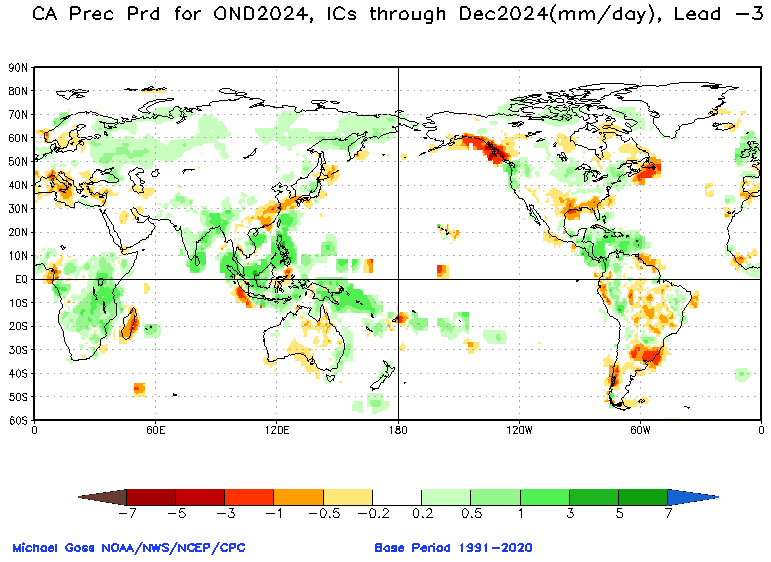
200mb Height from Linear Model



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.