Attribution of Seasonal Climate Anomalies
October-November-December 2023

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

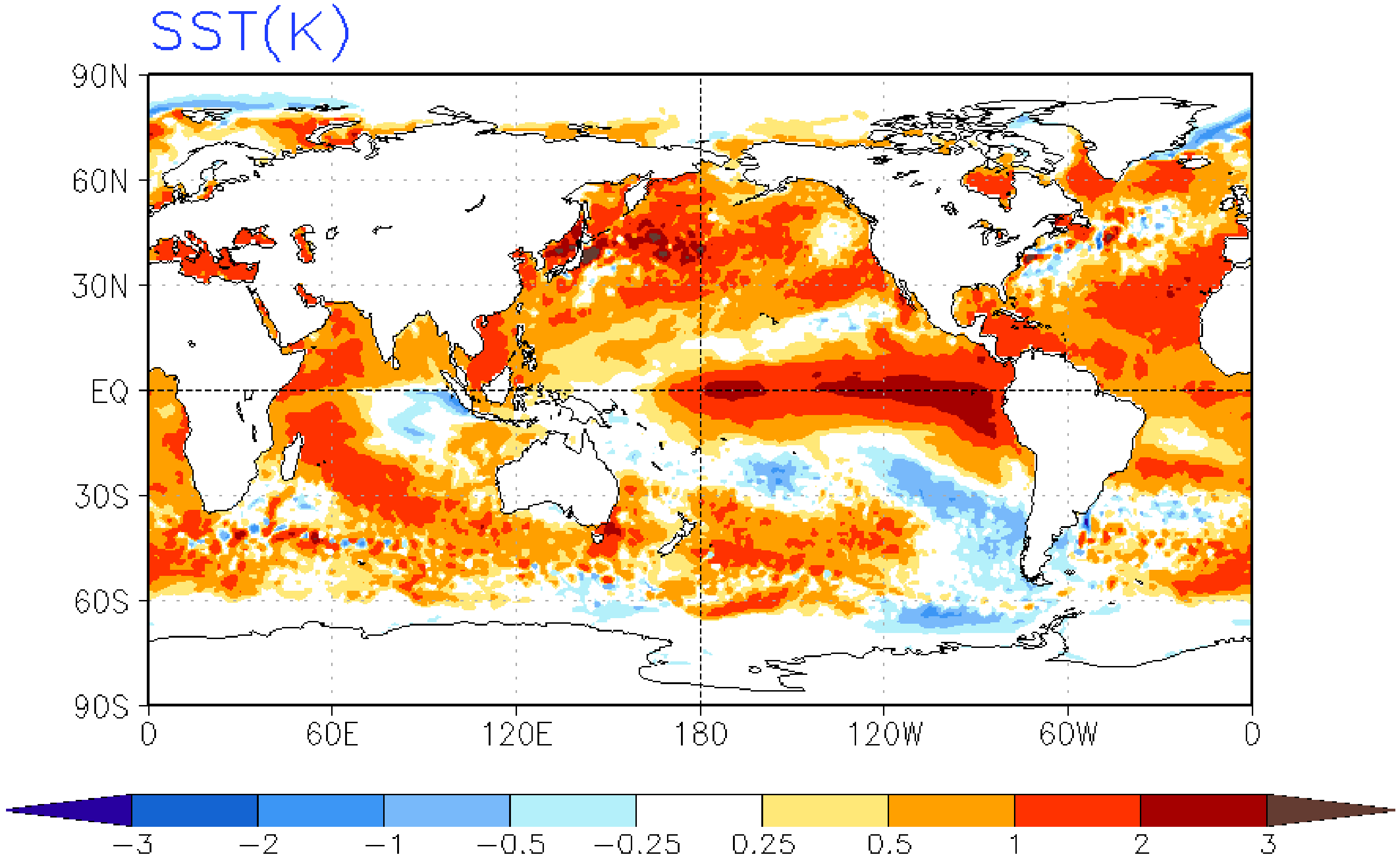
Summary of Observed Conditions and Outlooks

- In OND2023, warm SST anomalies associated with El Niño conditions continued in the equatorial eastern Pacific with a reduction in warming anomalies along the coastal regions of South America. Almost over all ocean basins, specifically, over the North Pacific, central southern Pacific, northern Atlantic, western and southern Indian Ocean, the SST warm anomalies persisted as well (slide 4). Initialized with warm SST anomalies, CFSv2 maintained the large-scale structure of the observed SST anomalies (slide 10).
- The AMIP simulations, the initialized forecasts, and other MME forecasts all captured the large-scale distribution of observed precipitation anomalies in tropical latitudes – below (above) normal anomalies in the equatorial eastern and southern Indian Ocean and Maritime Continent (equatorial western Pacific) and wetter conditions stretching along a narrow equatorial band across the entire Pacific basin (slides 11, 37-39).
- Another distinctive feature in rainfall was below normal anomalies in the equatorial eastern Indian Ocean associated with the positive phase of the Indian Ocean Dipole Mode and was reproduced in model simulations and predictions (slide 11).
- Consistent with the notion of SSTs constraining atmospheric variability, the tendency for above normal 200-mb heights and land surface temperature anomalies continued almost throughout the globe both in observations and model predictions and simulations (slide 13).
- The initialized CFSv2 forecasts predicted well the observed 200-mb height positive anomalies responses to warm SSTs that resulted in good prediction in the large-scale distribution of observed above normal temperature anomalies in general (slide 12, 13, 15, 16).
- December 2023 monthly mean forecasts predicted well the observed North America warm temperature anomalies from the early November initial conditions but failed in the predictions of precipitation anomalies (slides 34-35).

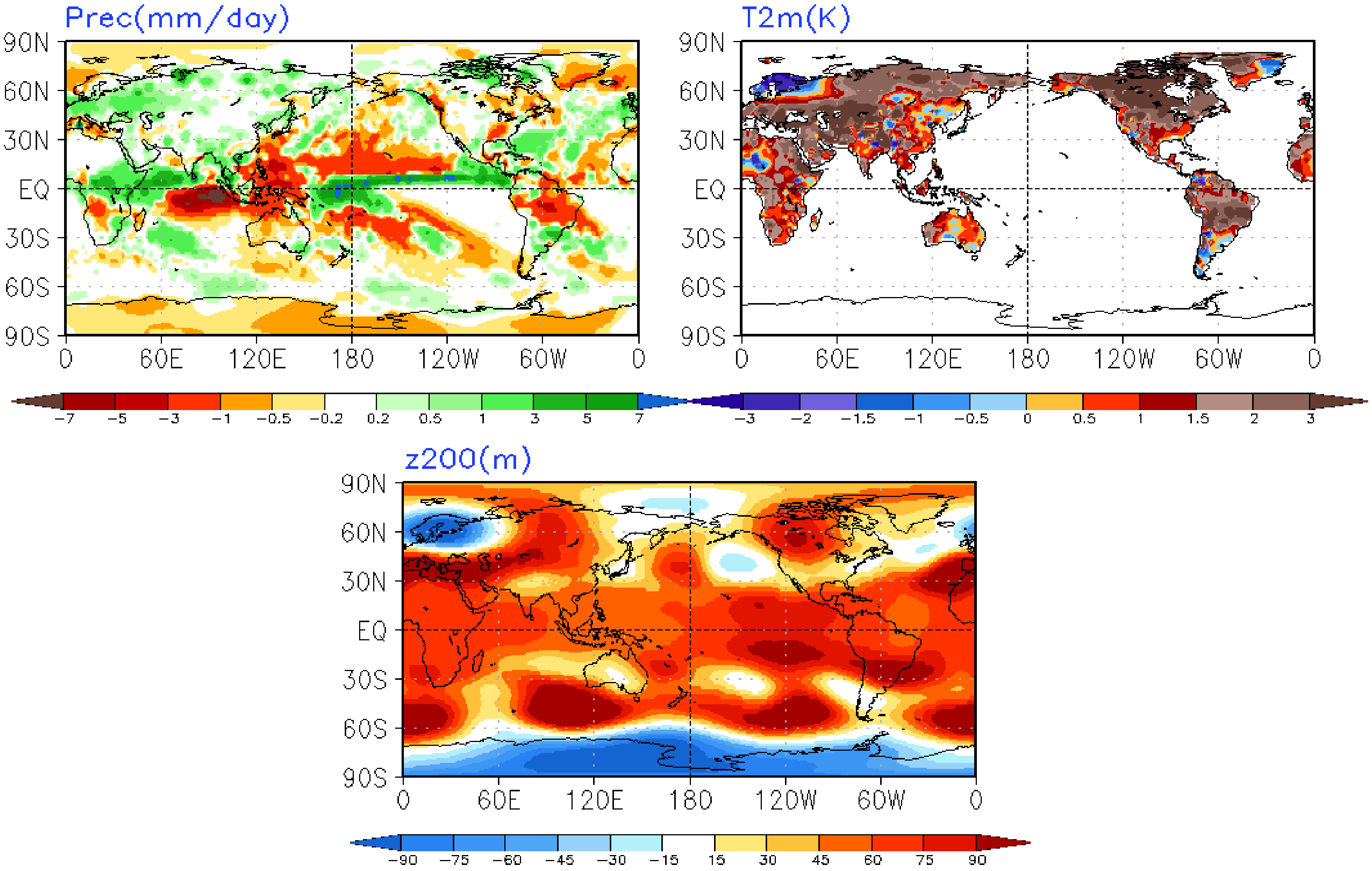
Observed Seasonal Anomalies

Global and North America

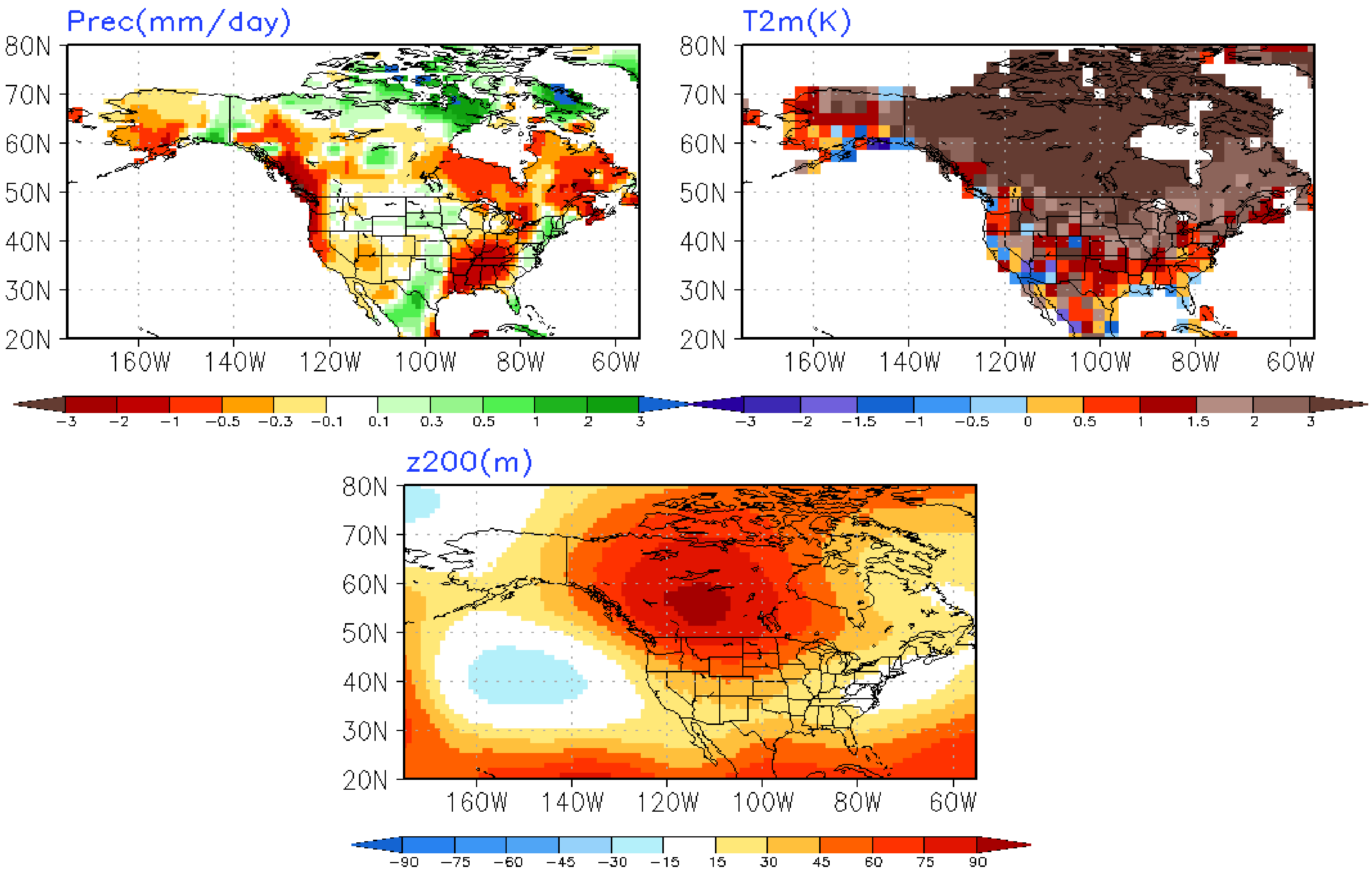
Observed Anomaly OND2023



Observed Anomaly OND2023



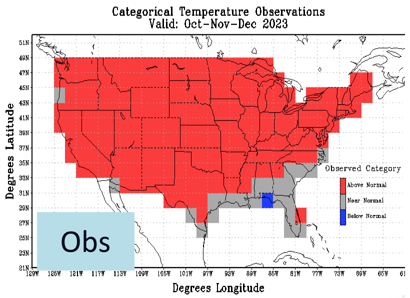
Observed Anomaly OND2023

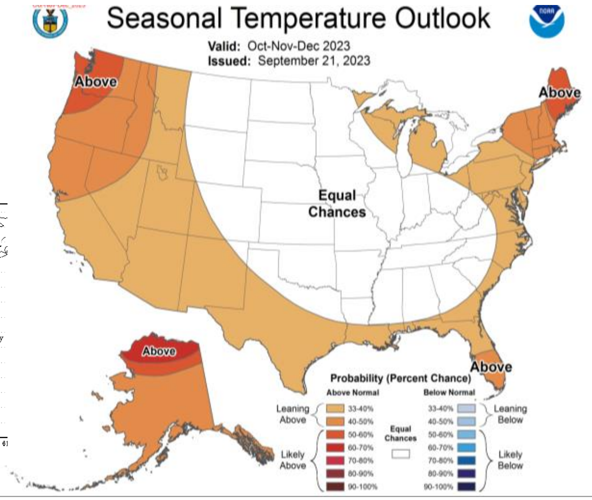


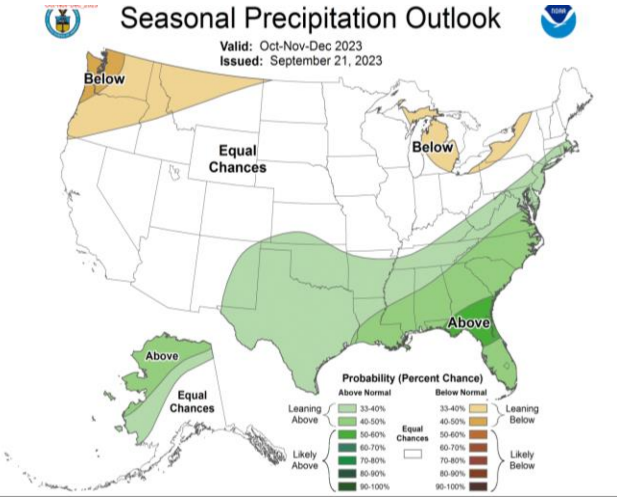
CPC Seasonal Outlooks and NMME Forecasts

CPC

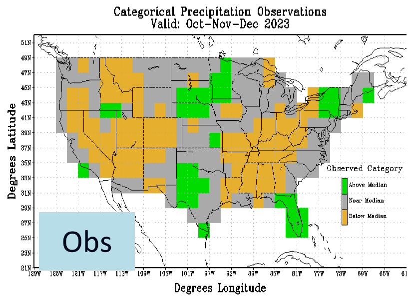
Temp nonEC
HSS=78

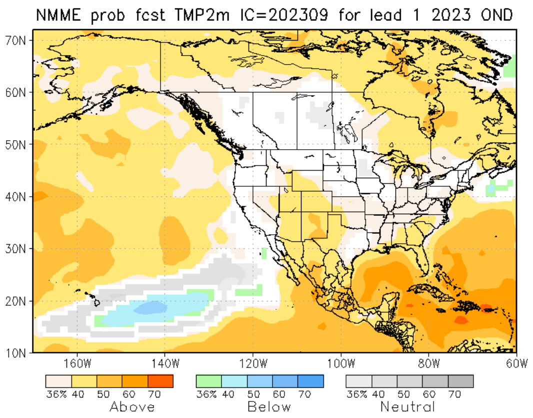




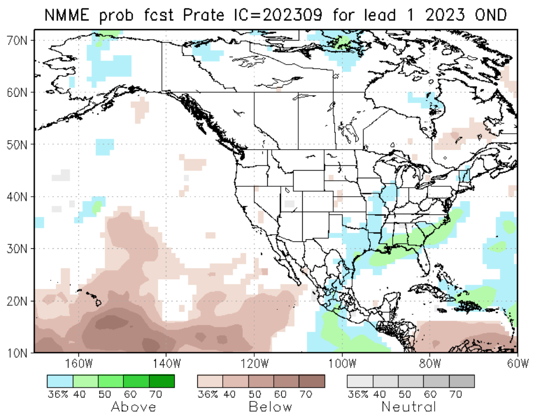


Prec nonEC
HSS=-8





NMME



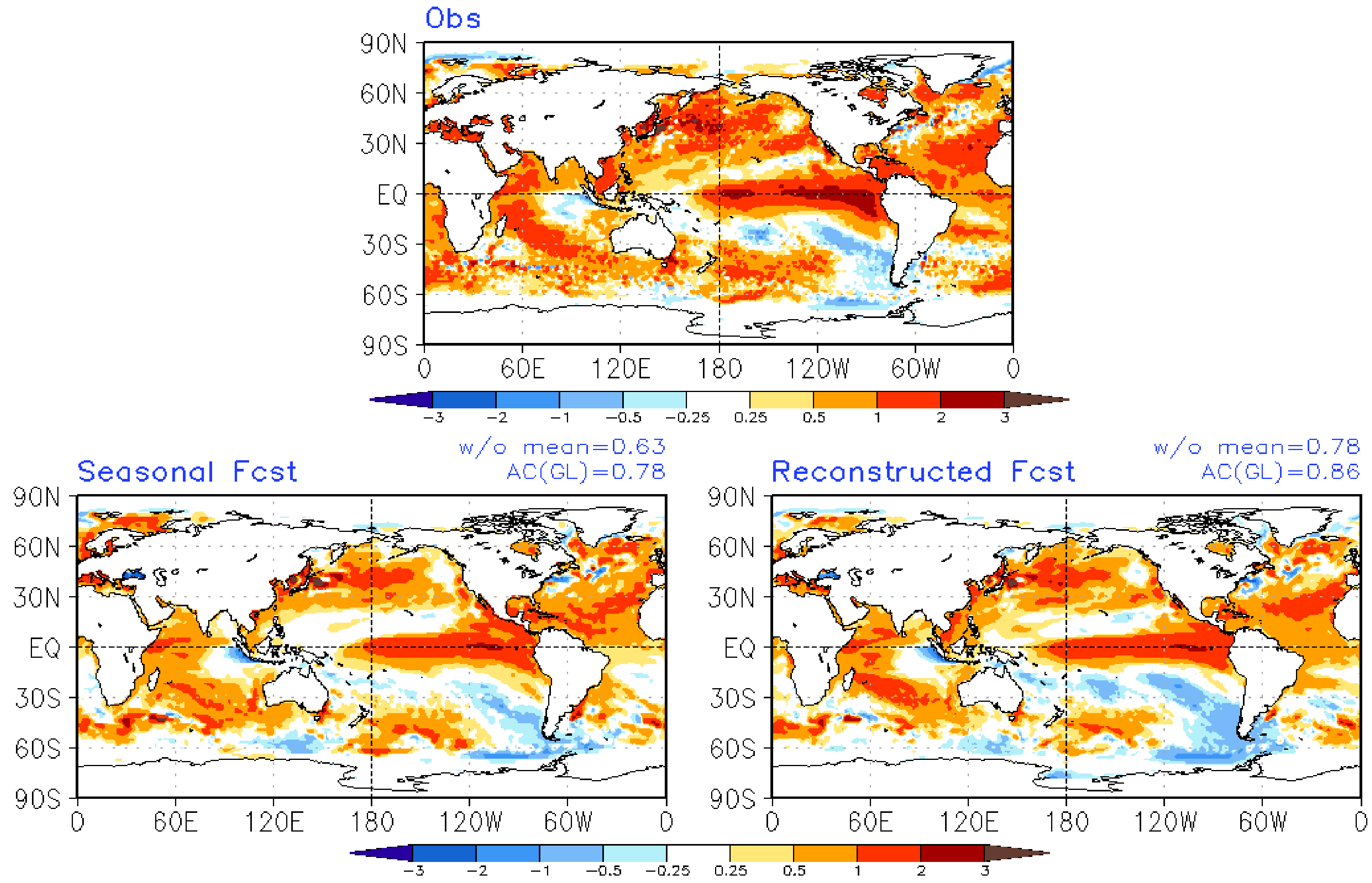
For the rationale behind CPC outlooks see: https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2023/202309_PMD90D

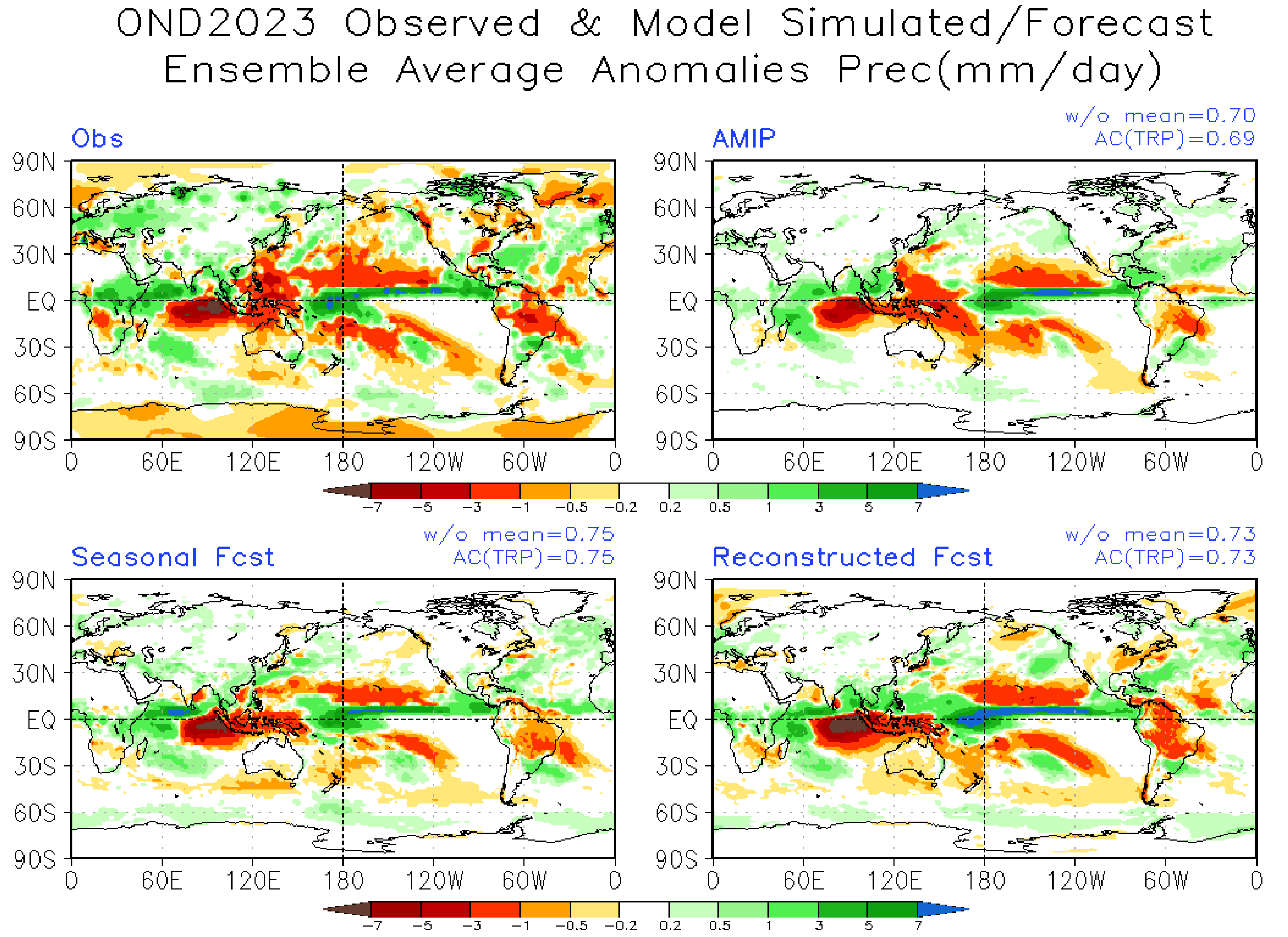
Model Simulated/Forecast Ensemble Mean Anomalies

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.

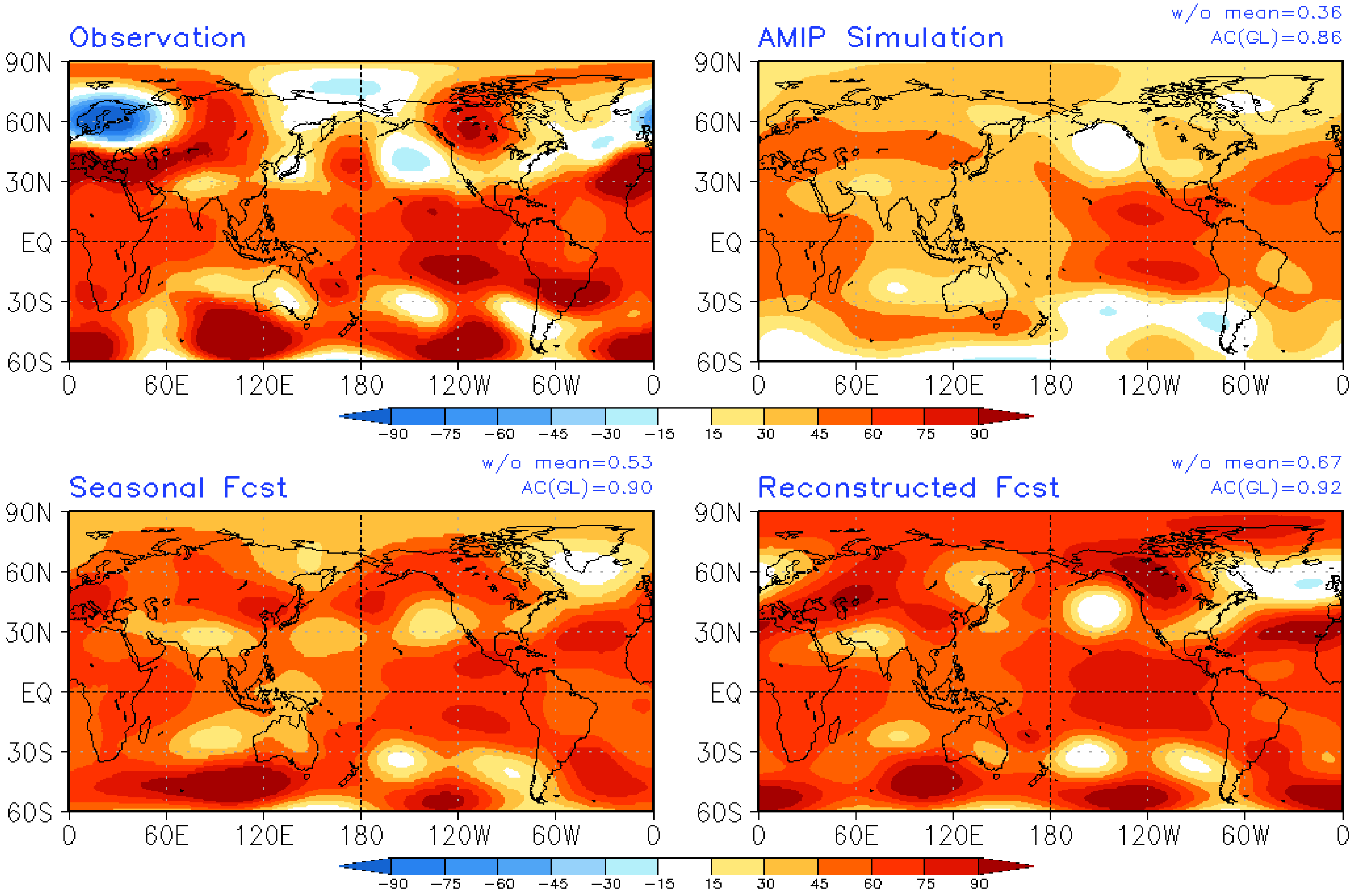
OND2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



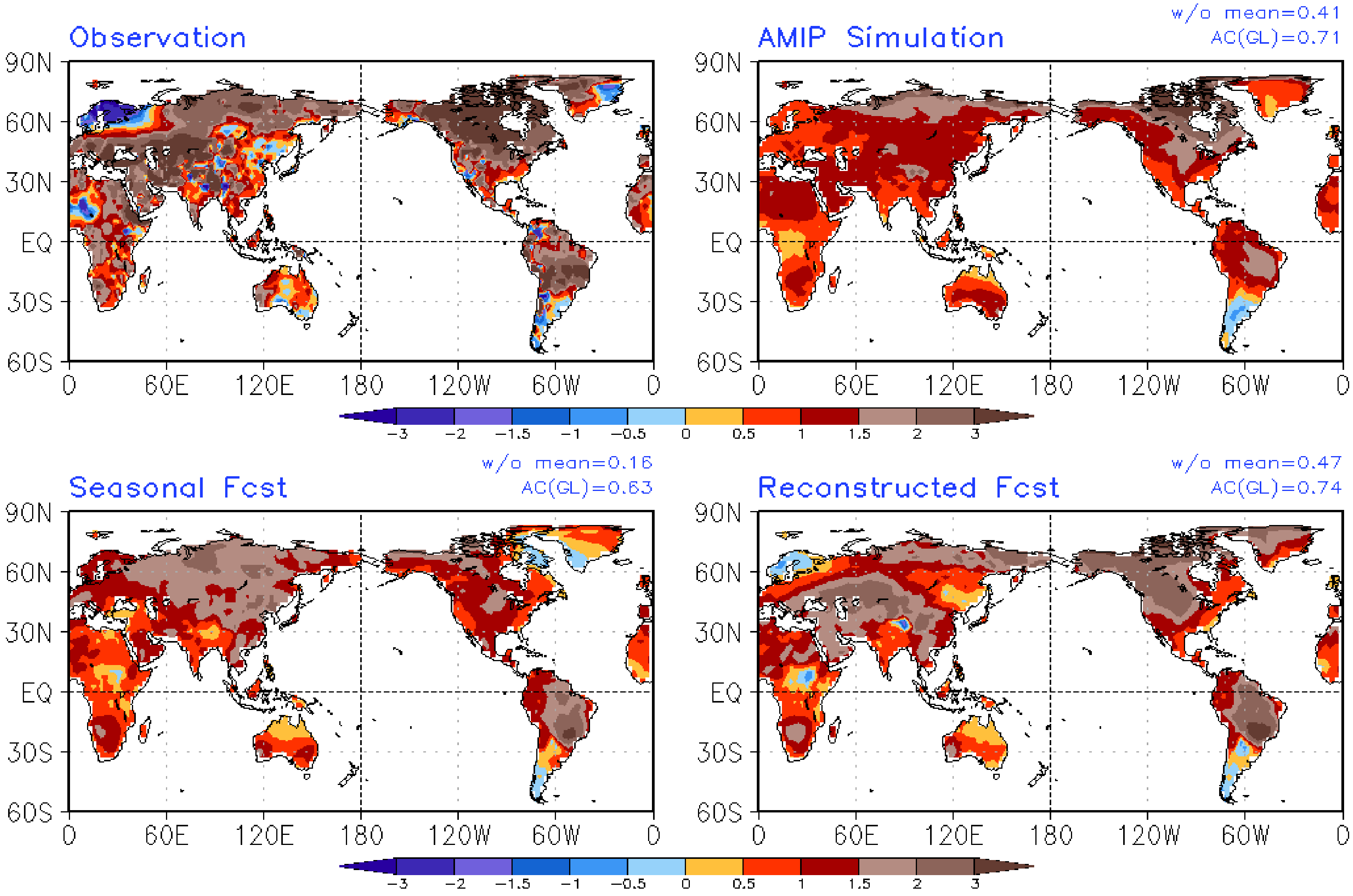


OND2023 Observed & Model Simulated/Forecast
Ensemble Average Anomalies Prec(mm/day)
Obs
AMIP
w/o mean=0.70
AC(TRP)=0.69
Seasonal Fcst
w/o mean=0.75
AC(TRP)=0.75
Reconstructed Fcst
w/o mean=0.73
AC(TRP)=0.73
90N 60N 30N EQ 30S 60S 90S
0 60E 120E 180 120W 60W 0
−7 −5 −3 −1 −0.5 −0.2 0.2 0.5 1 3 5 7

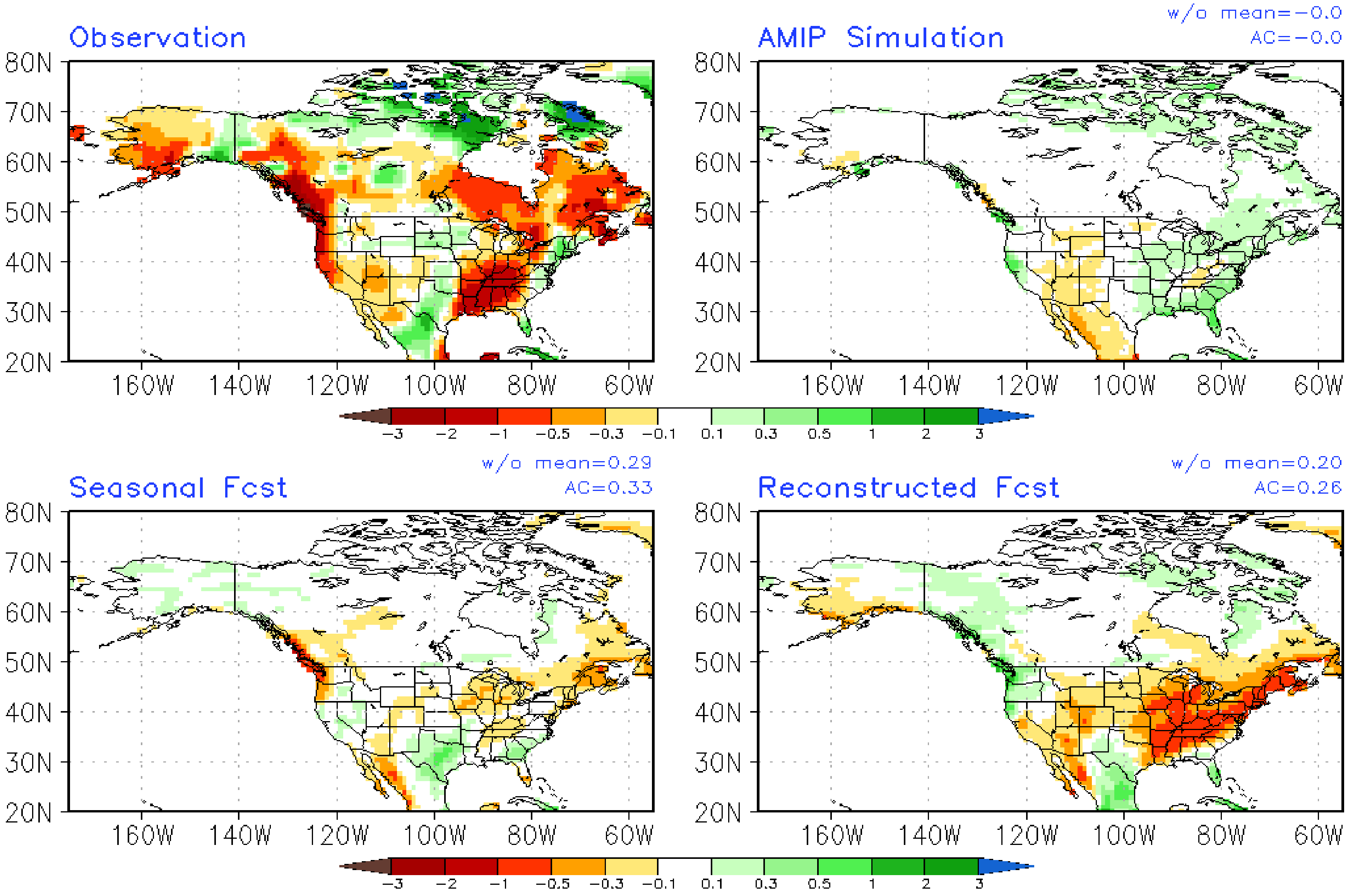
OND2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



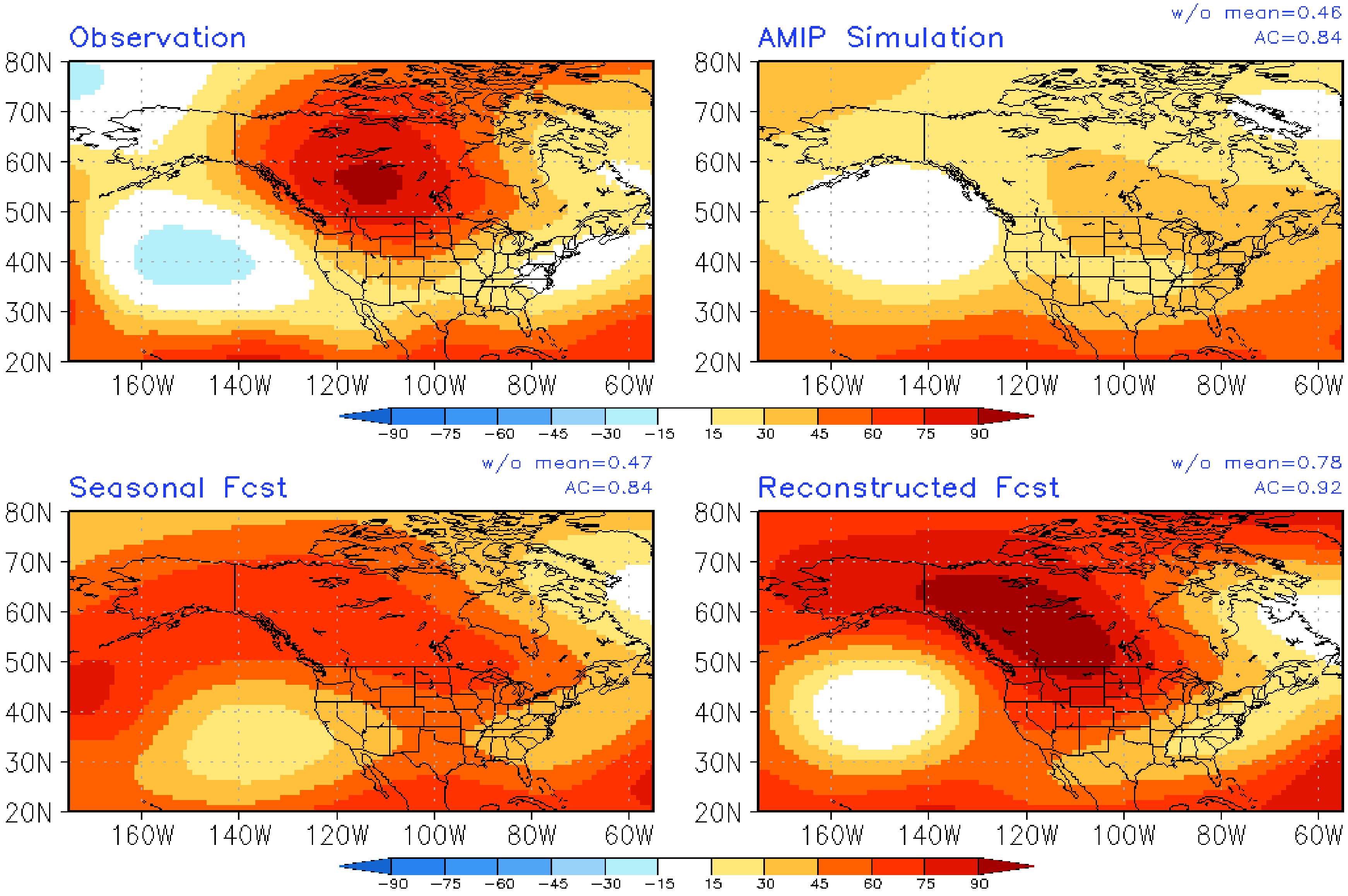
OND2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

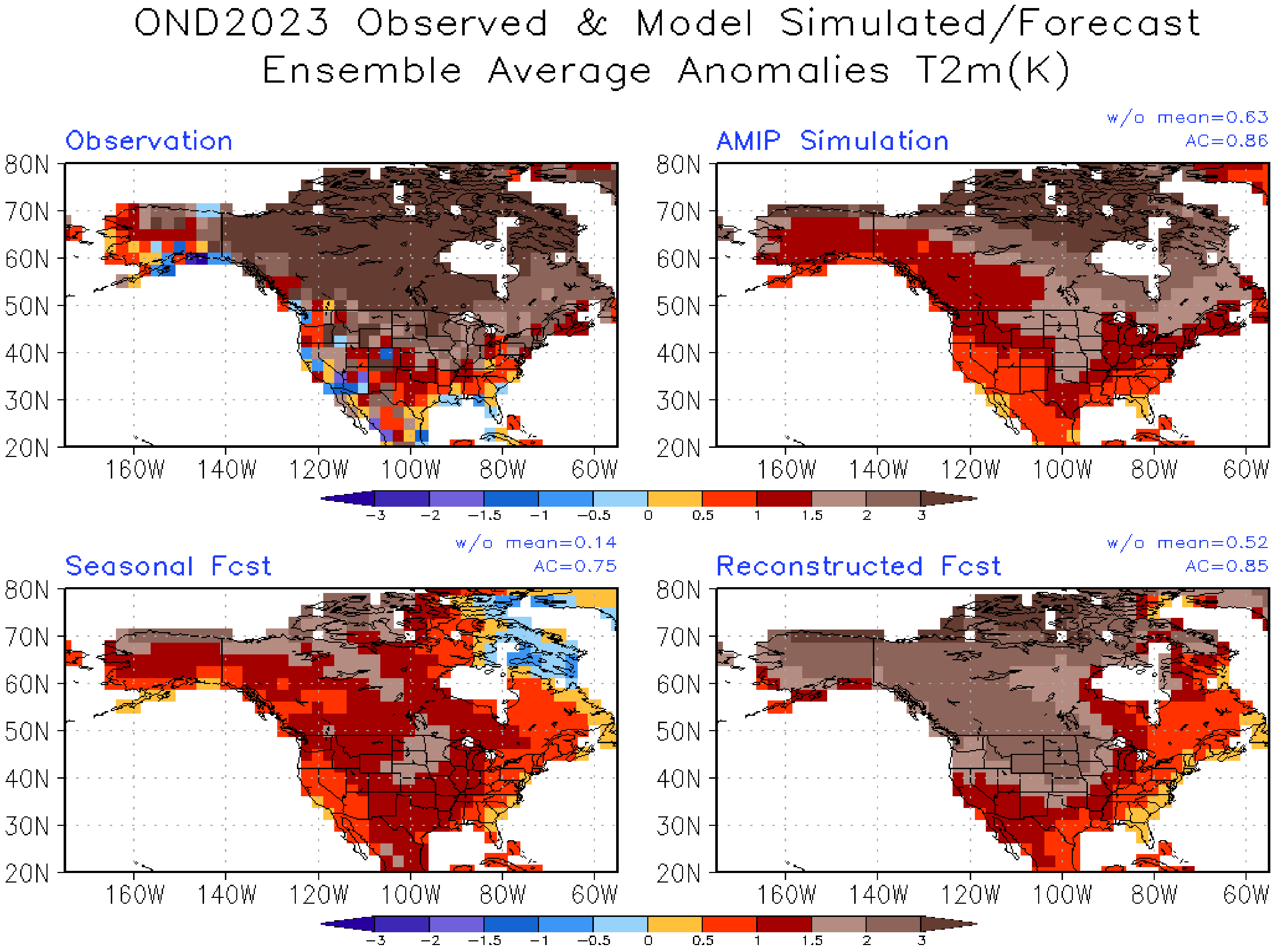


OND2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



OND2023 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



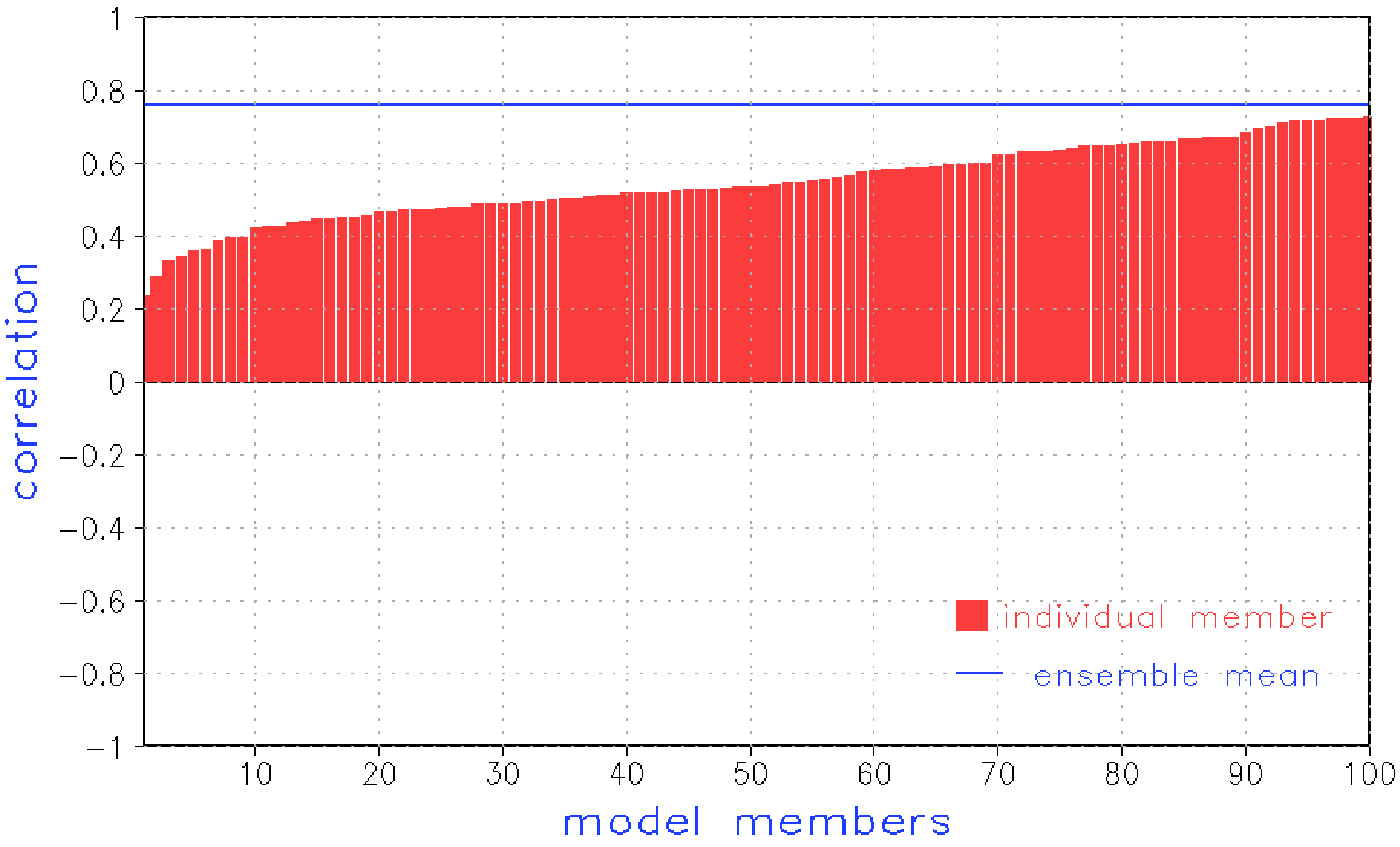

OND2023 Observed & Model Simulated/Forecast
Ensemble Average Anomalies T2m(K)
Observation
AMIP Simulation
w/o mean=0.63
AC=0.86
Seasonal Fcst
w/o mean=0.14
AC=0.75
Reconstructed Fcst
w/o mean=0.52
AC=0.85
80N 70N 60N 50N 40N 30N 20N
160W 140W 120W 100W 80W 60W
−3 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3

Model Simulated/Forecast Anomalies: Individual Runs

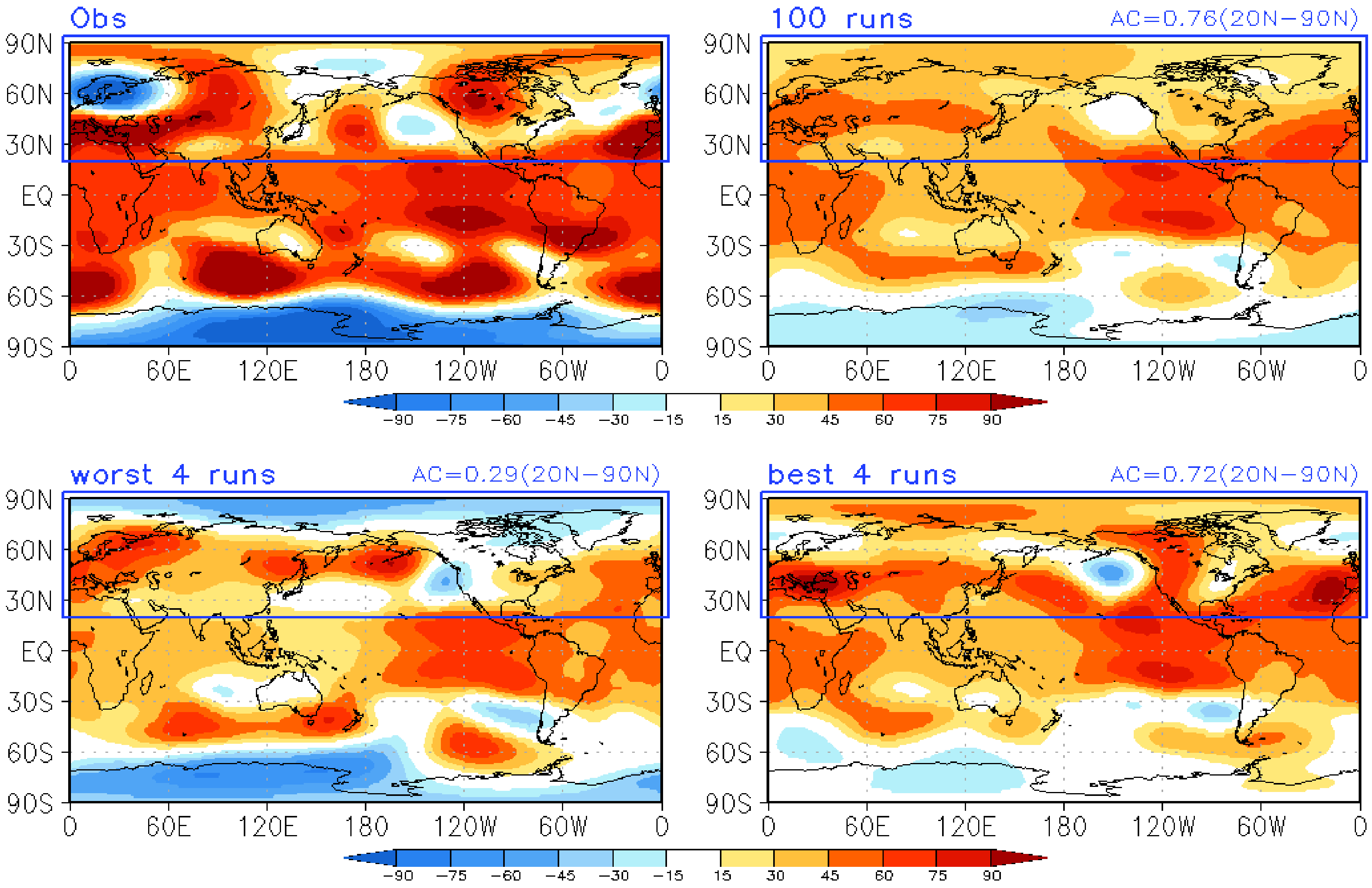
Model Simulated/Forecast Anomalies: Individual Runs

- 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.

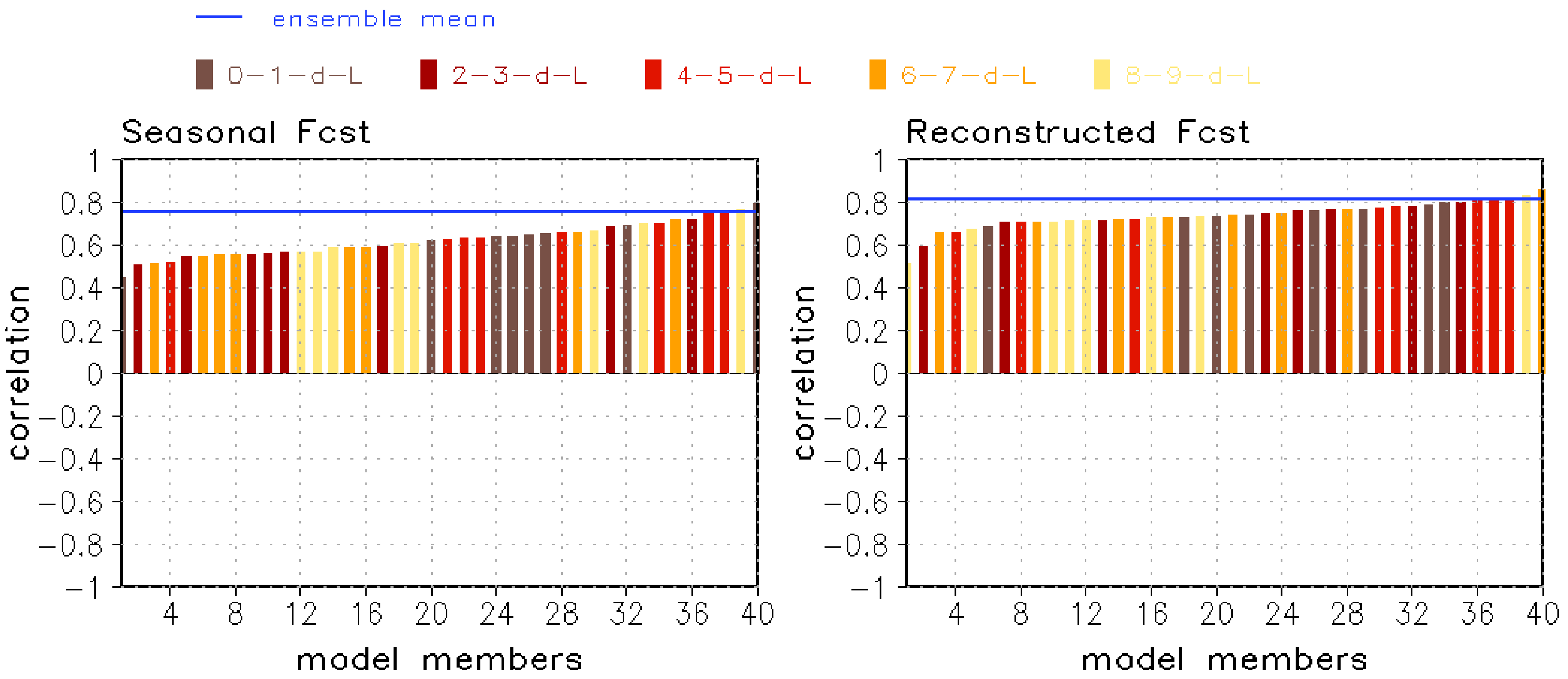
OND2023 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N-90N)



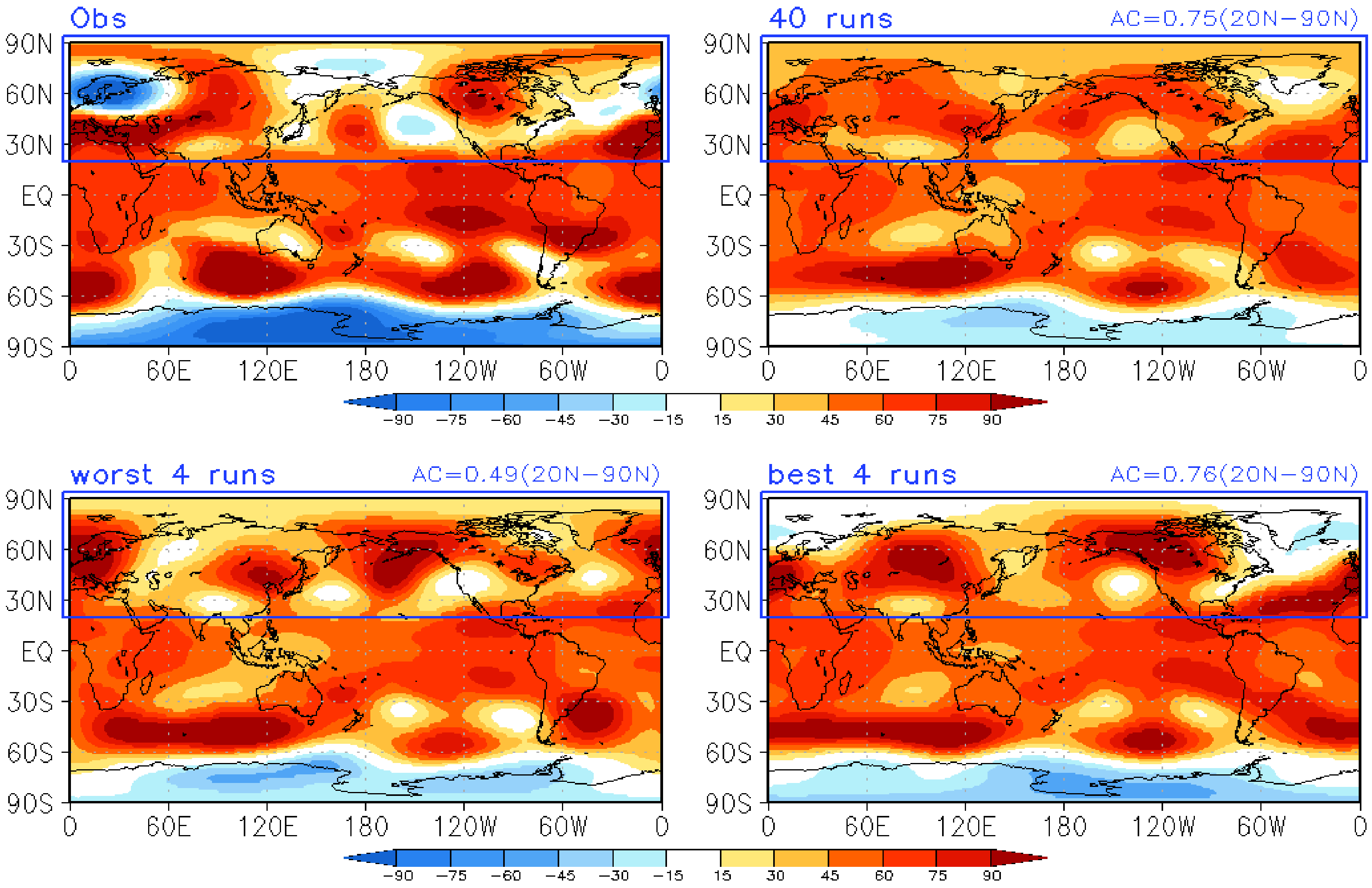
Observed & AMIP Ensemble Mean Anomalies
OND2023 z200(m) 100 runs/worst 4 runs/best 4 runs

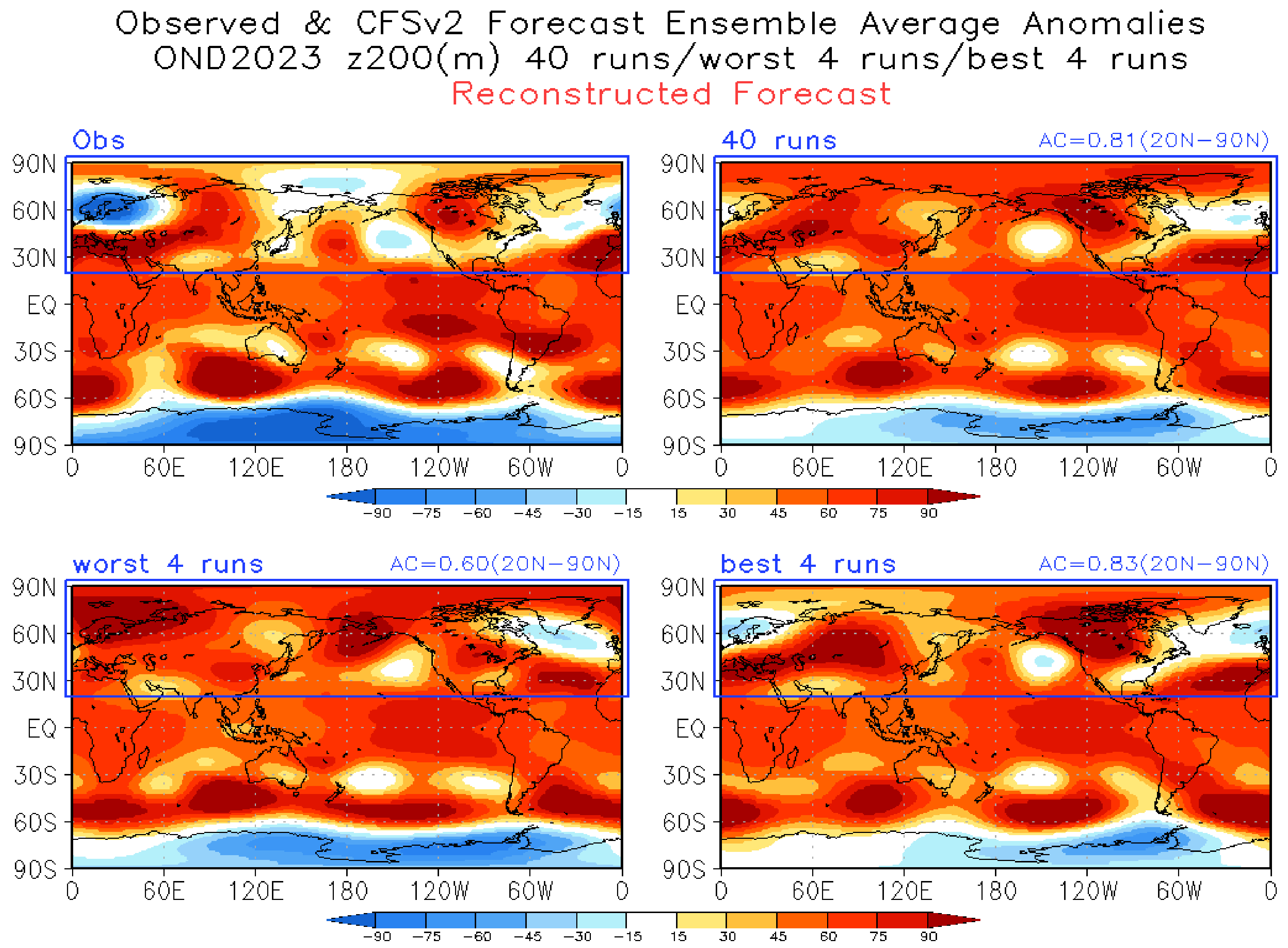


OND2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



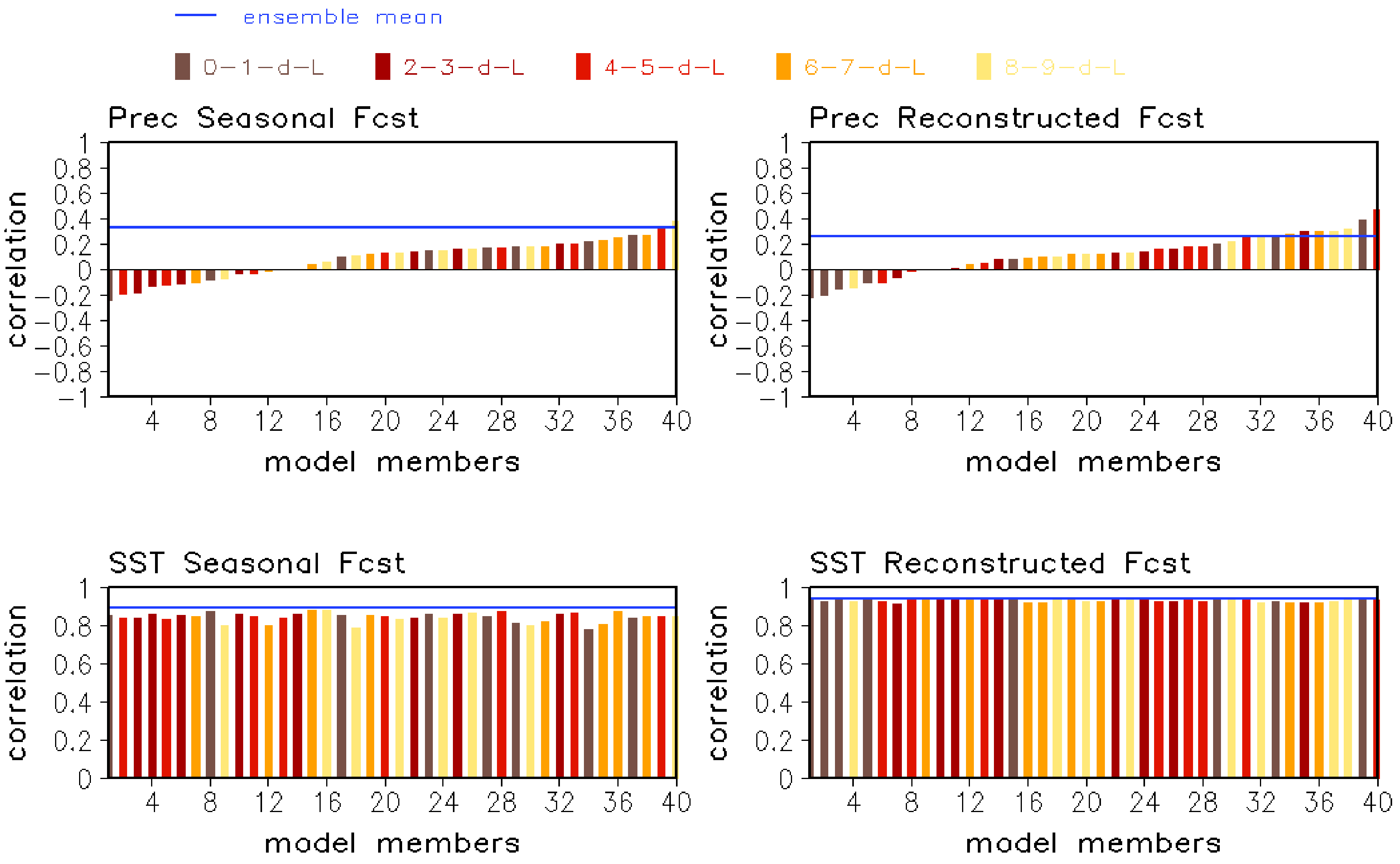
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



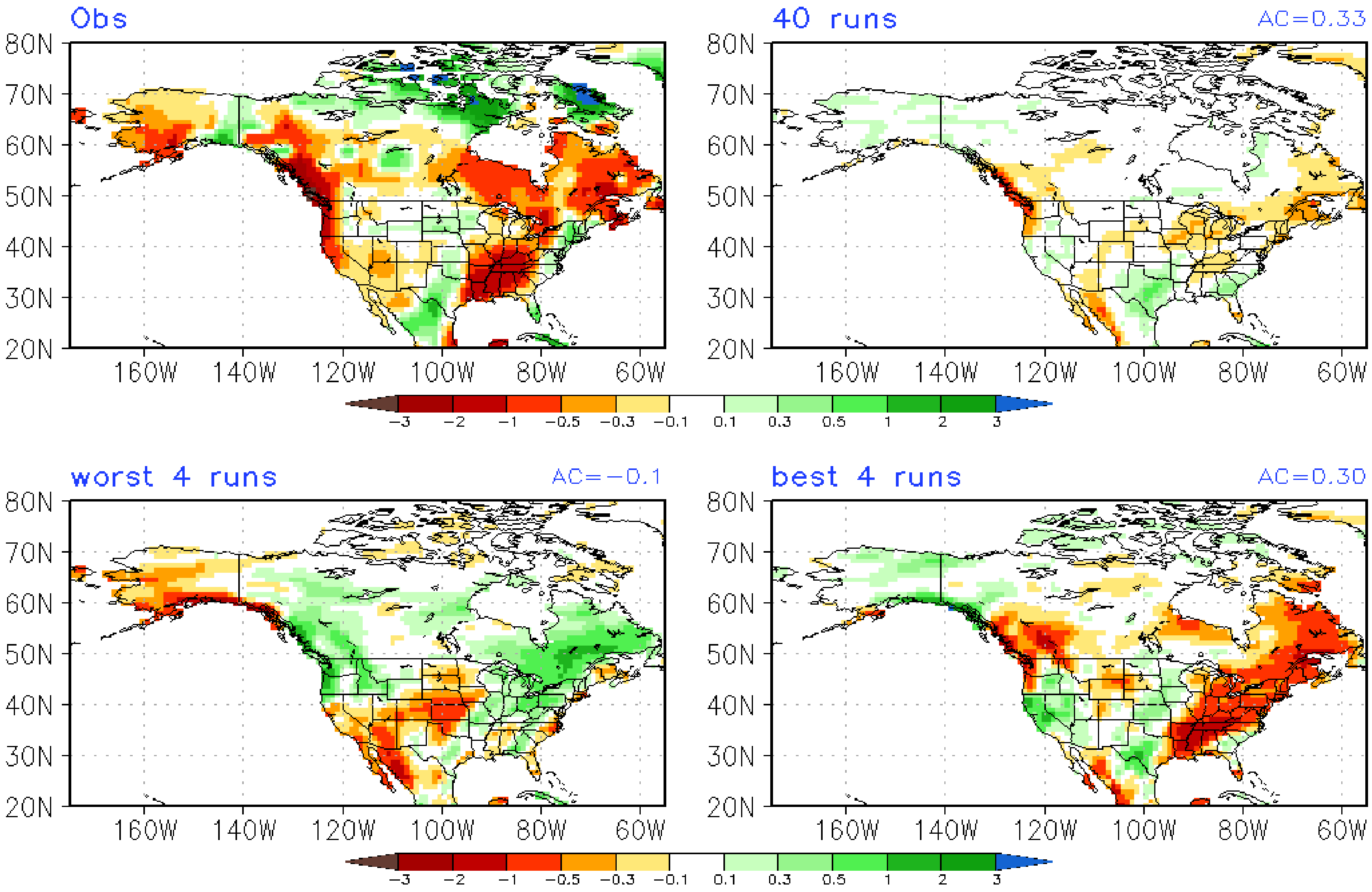


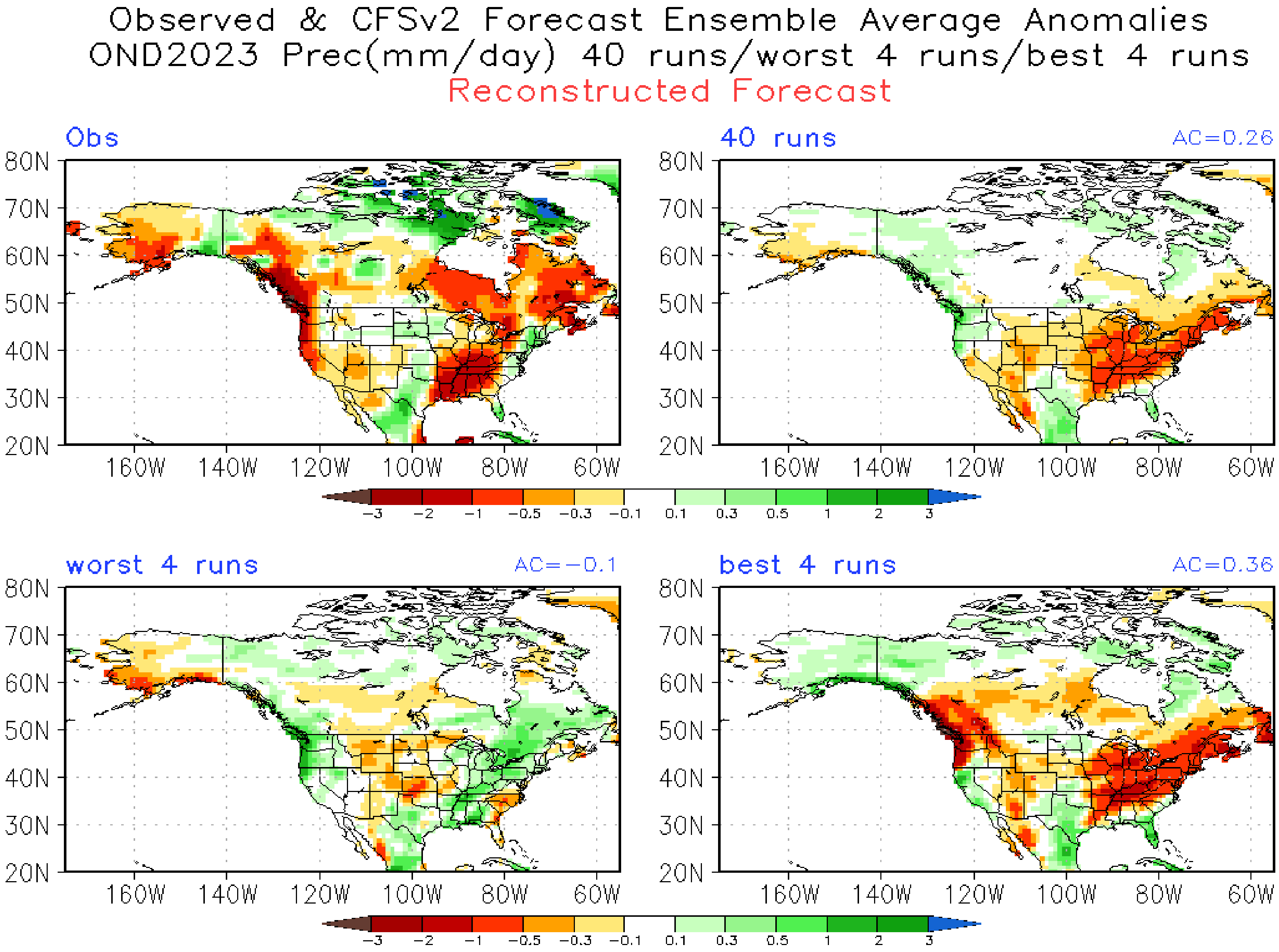
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast
Obs
40 runs
AC=0.81(20N-90N)
worst 4 runs
AC=0.60(20N-90N)
best 4 runs
AC=0.83(20N-90N)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
-90 -75 -60 -45 -30 -15 15 30 45 60 75 90

OND2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)



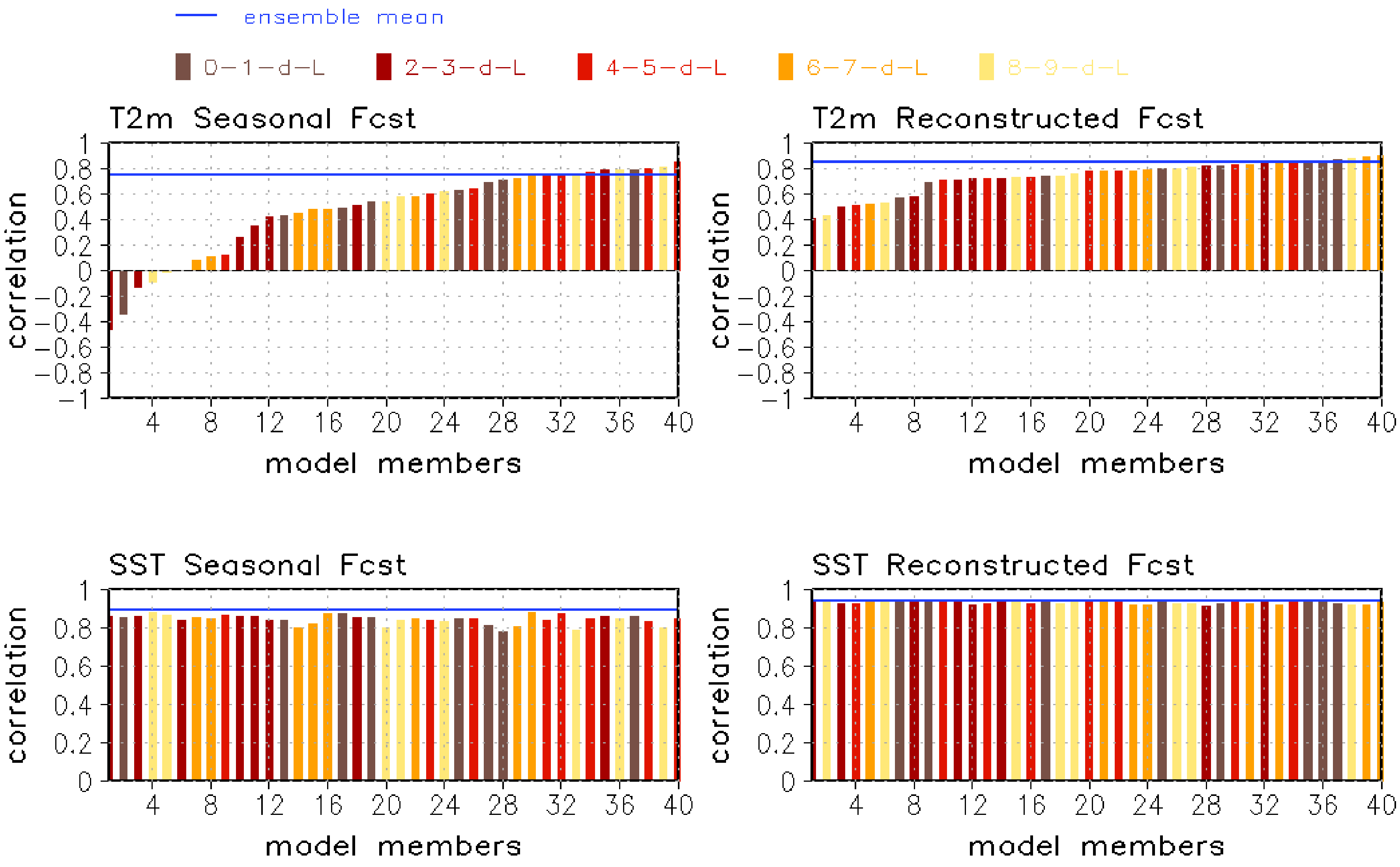
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



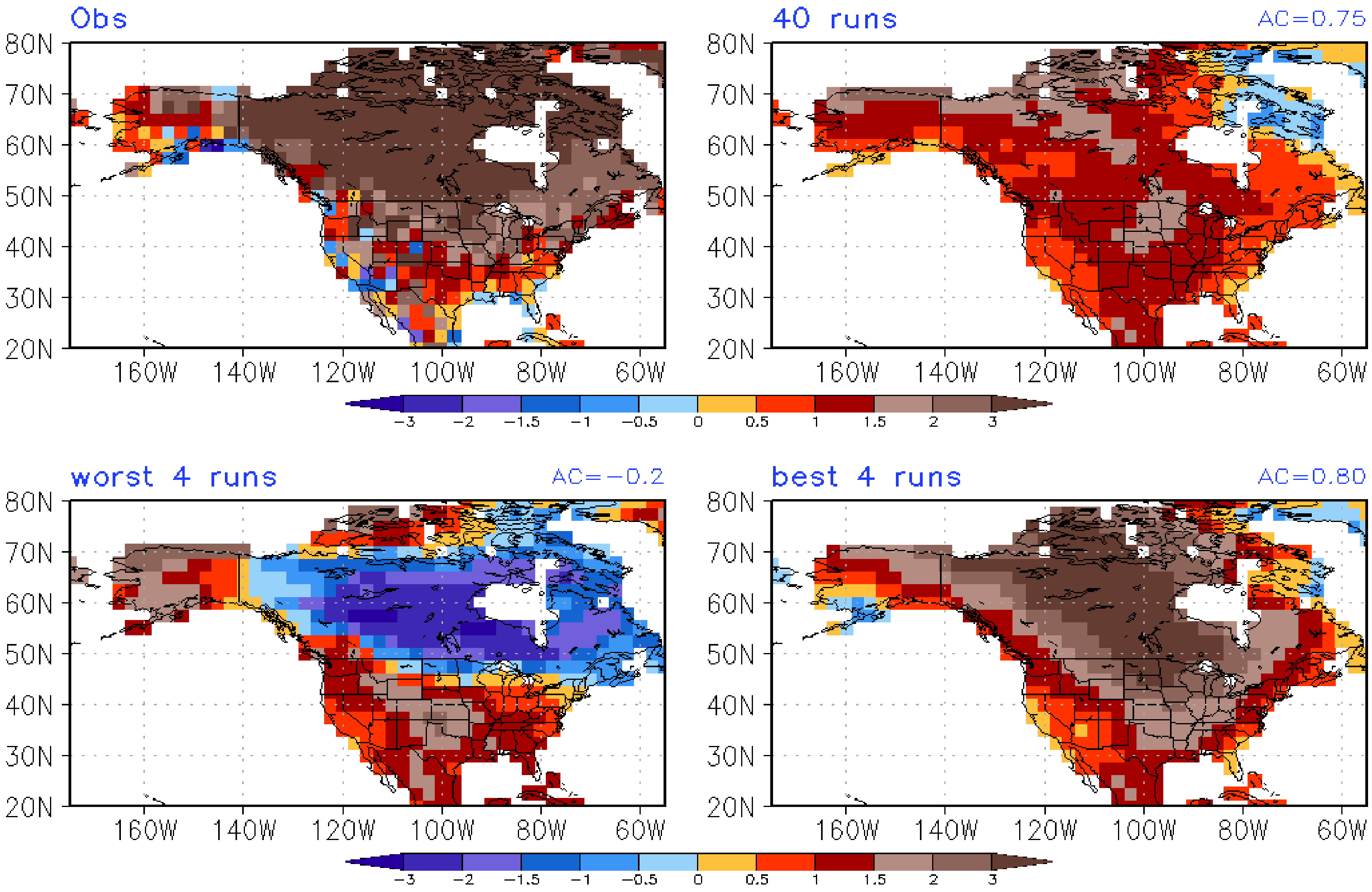


Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast
Obs
40 runs
AC=0.26
worst 4 runs
AC=-0.1
best 4 runs
AC=0.36
80N
70N
60N
50N
40N
30N
20N
160W
140W
120W
100W
80W
60W
-3
-2
-1
-0.5
-0.3
-0.1
0.1
0.3
0.5
1
2
3

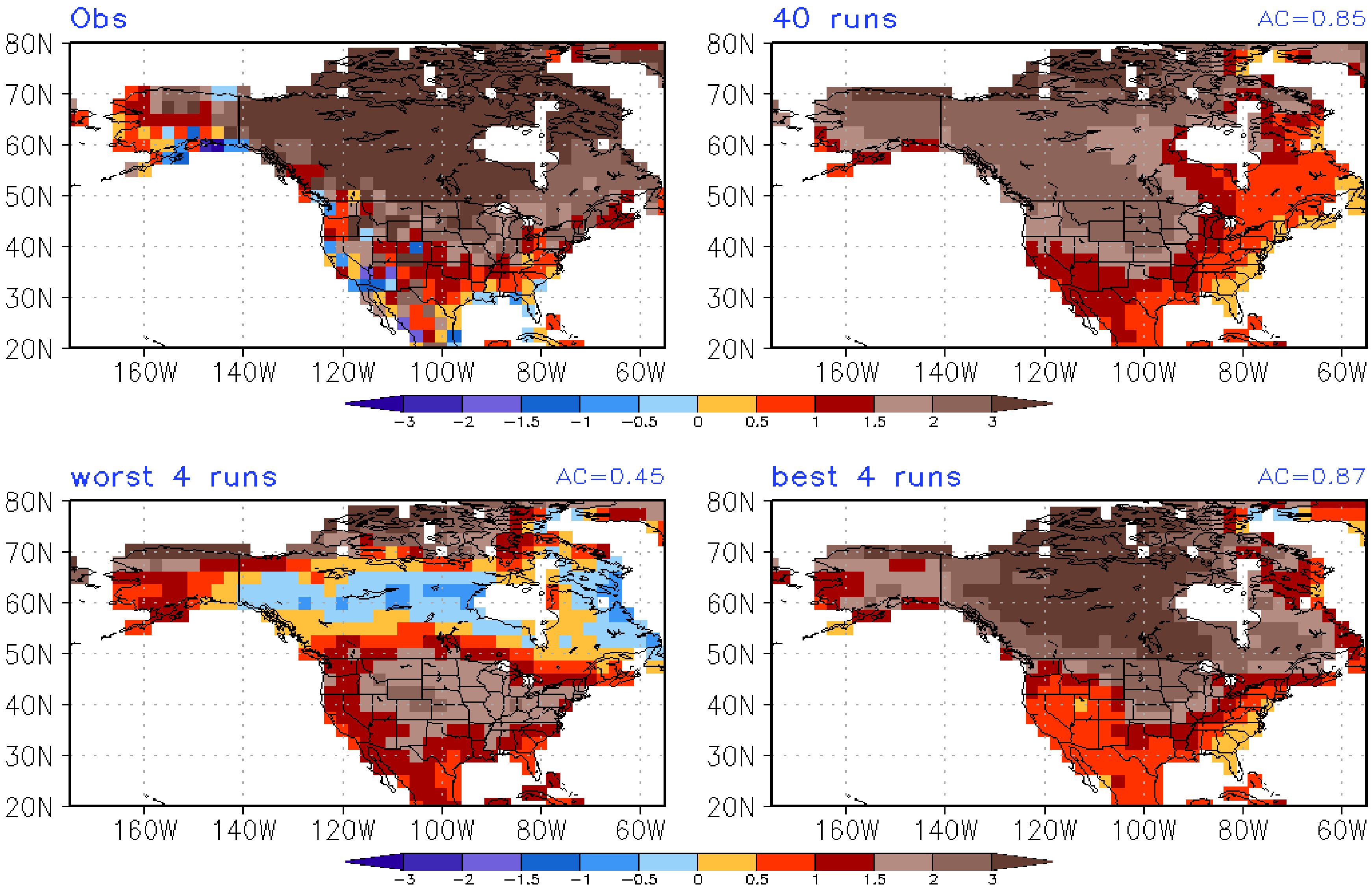
OND2023 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



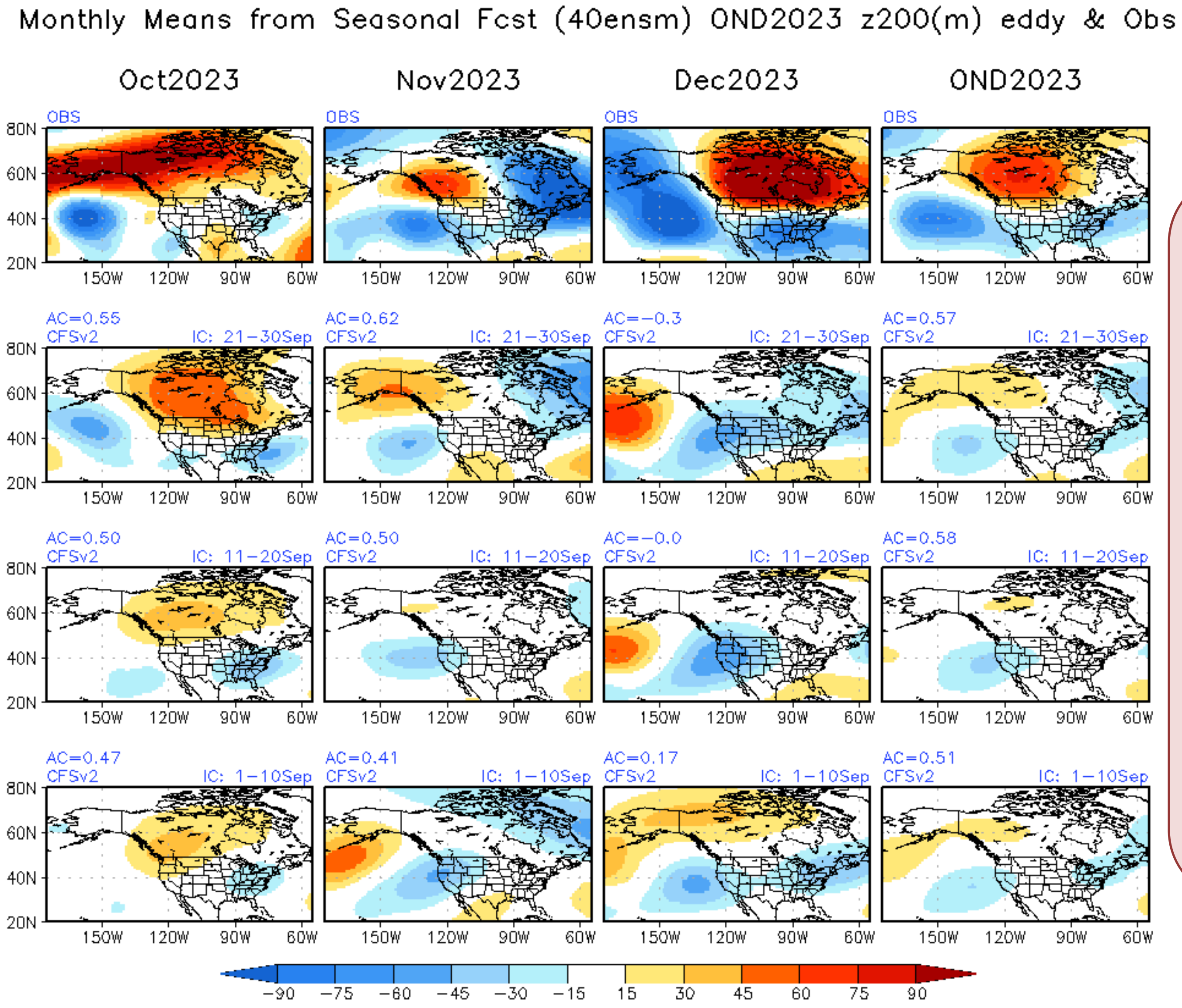
Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
OND2023 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



z200(m) Monthly Means from Seasonal Forecast

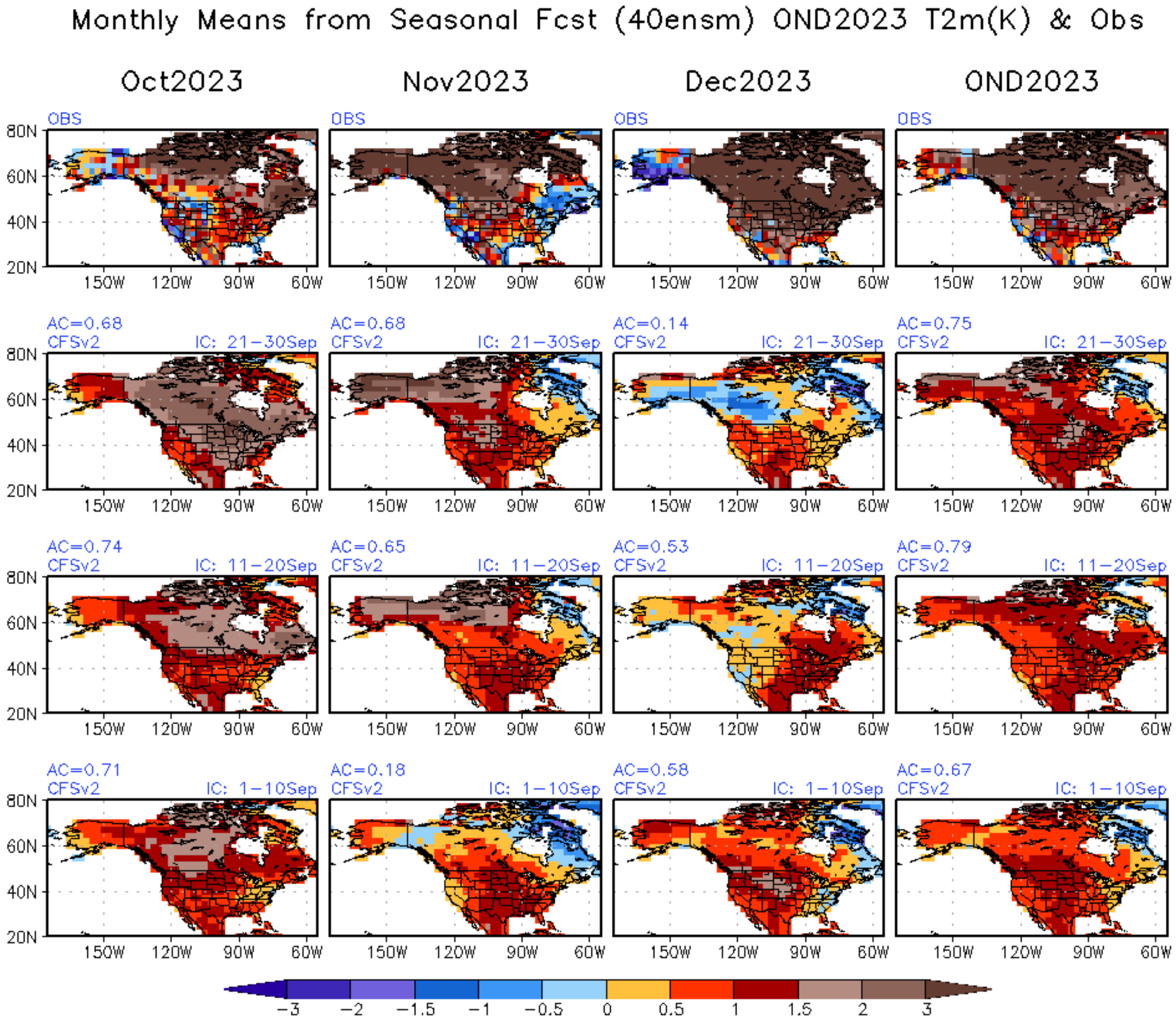


Top row: Observed anomaly.

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

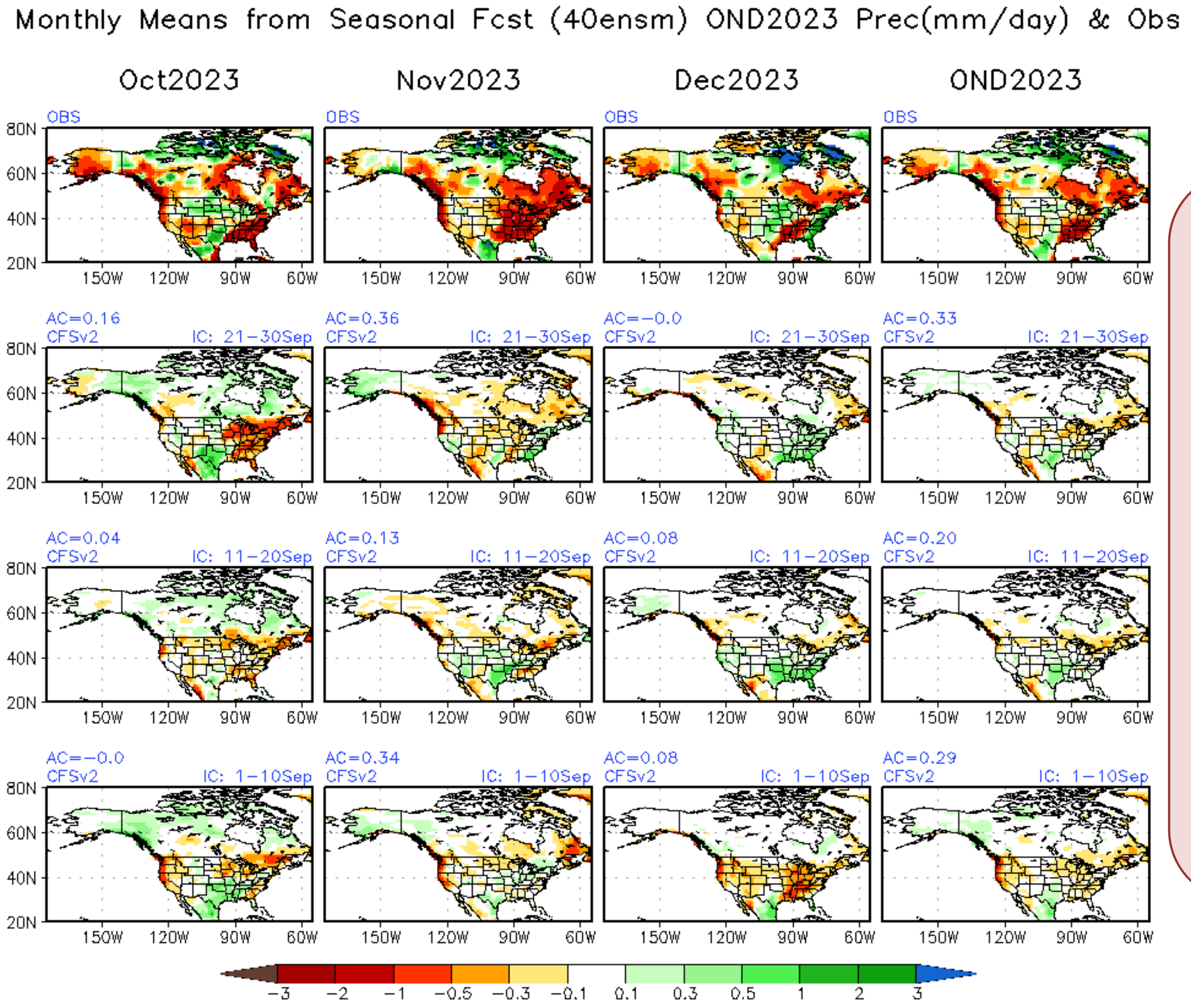


Top row: Observed anomaly.

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

- 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

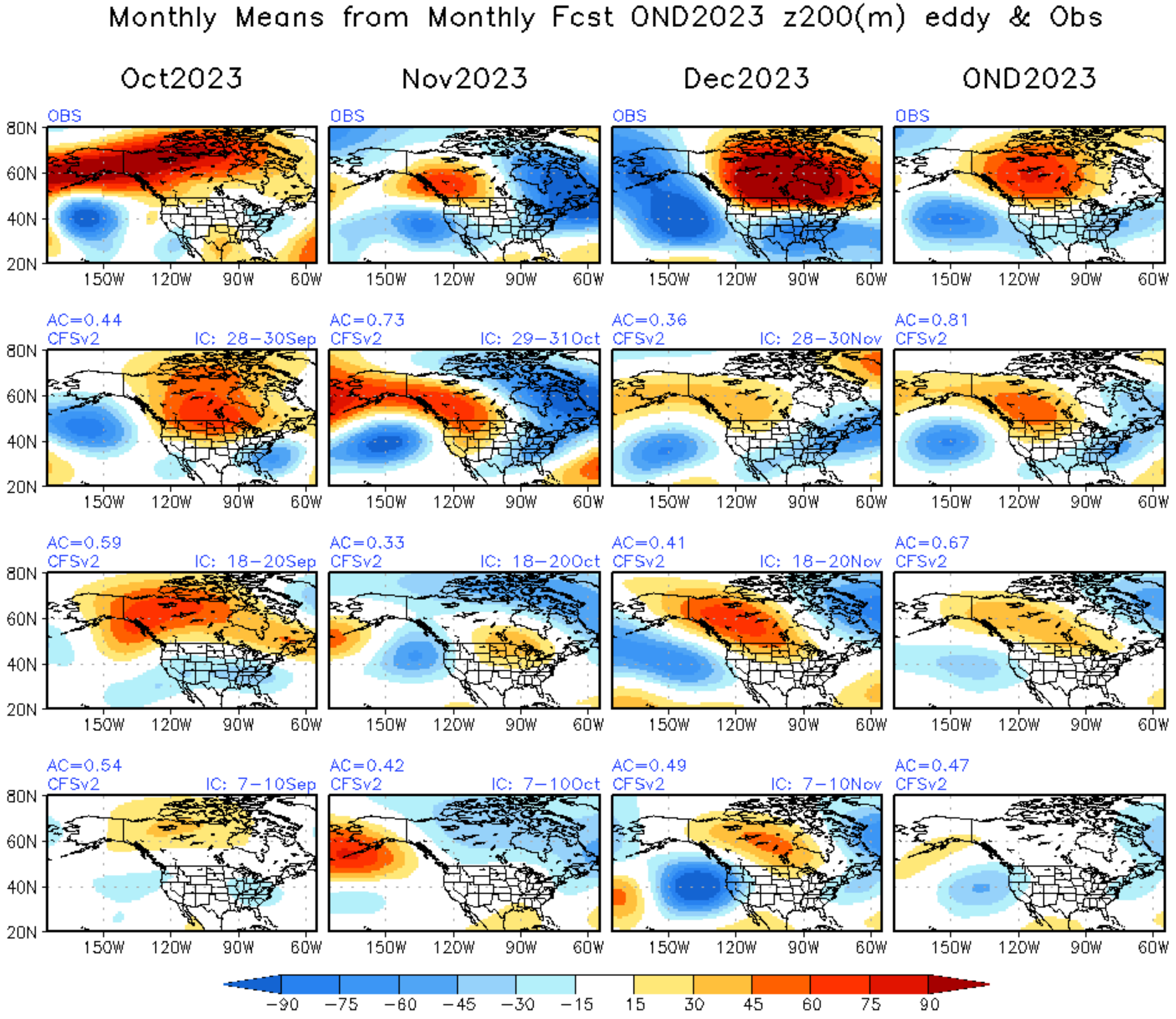


Top row: Observed anomaly.

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

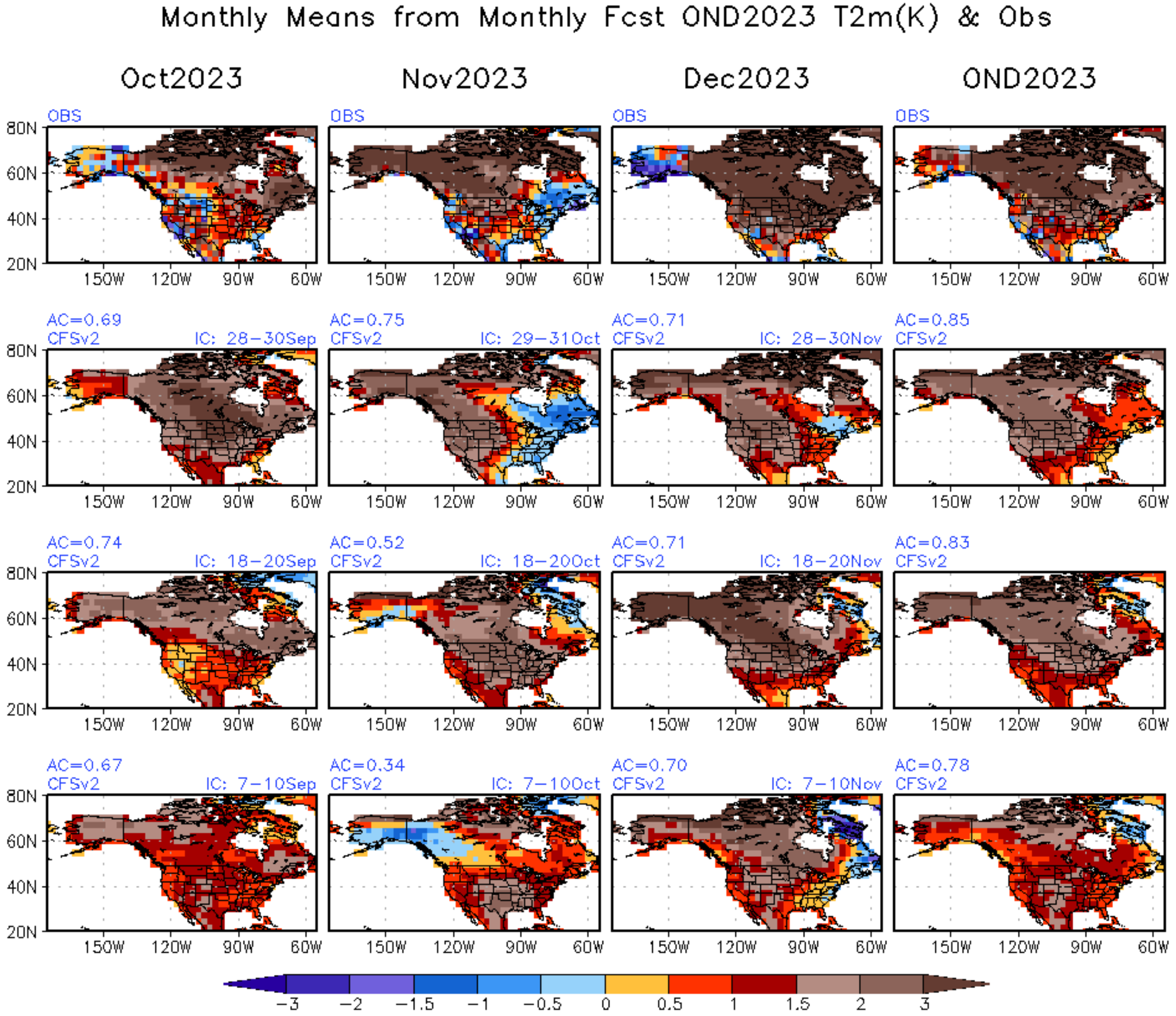


Top row: Observed anomaly.

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

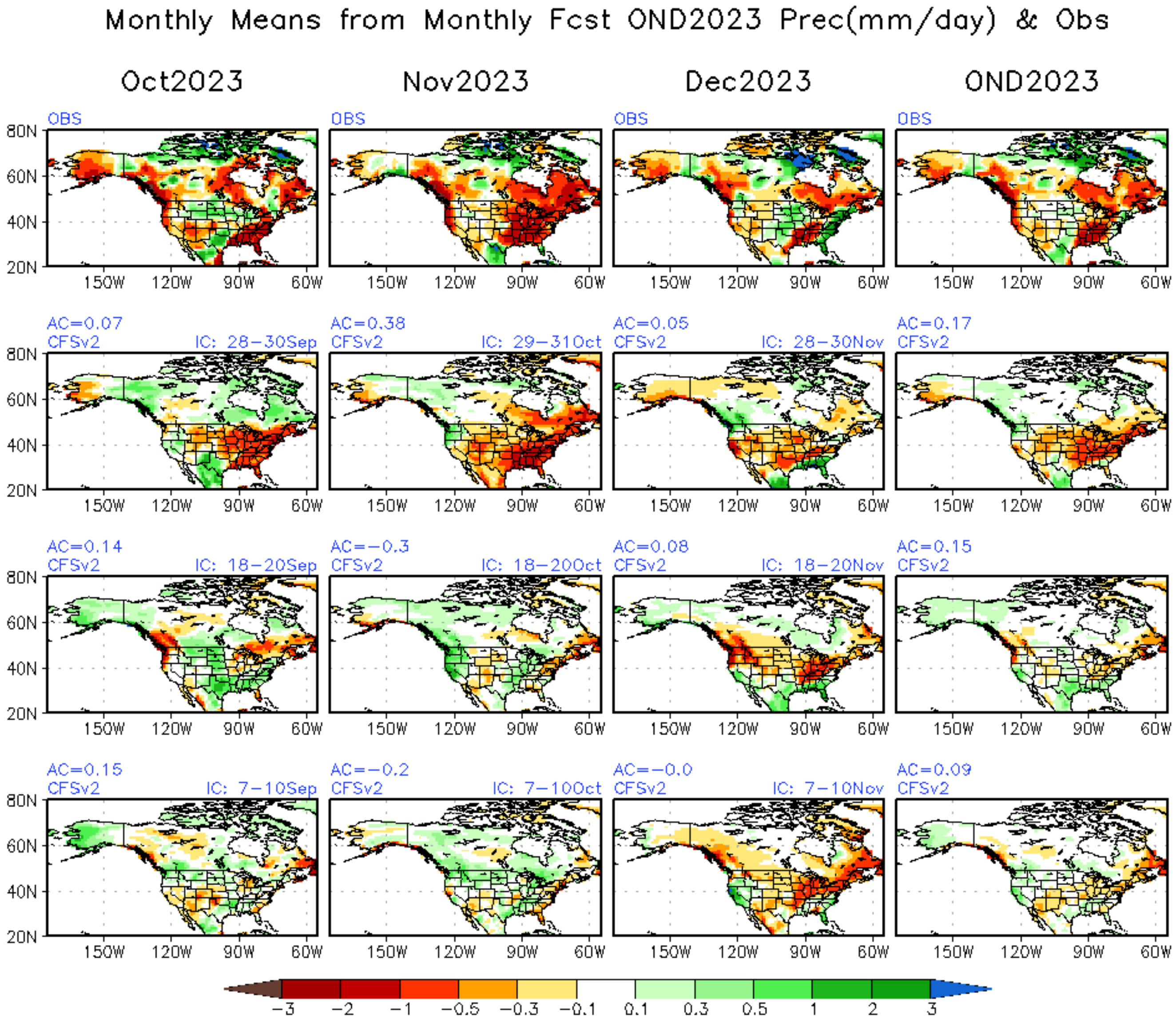


Top row: Observed anomaly.

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

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

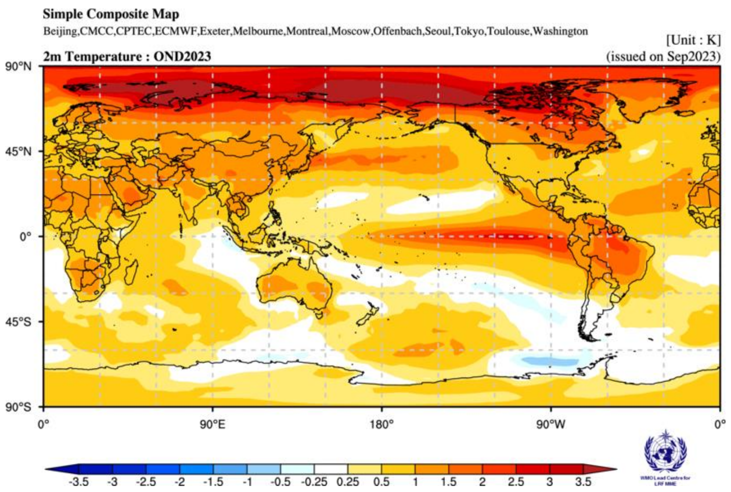
Seasonal Forecasts from Multi-Model Ensemble Systems

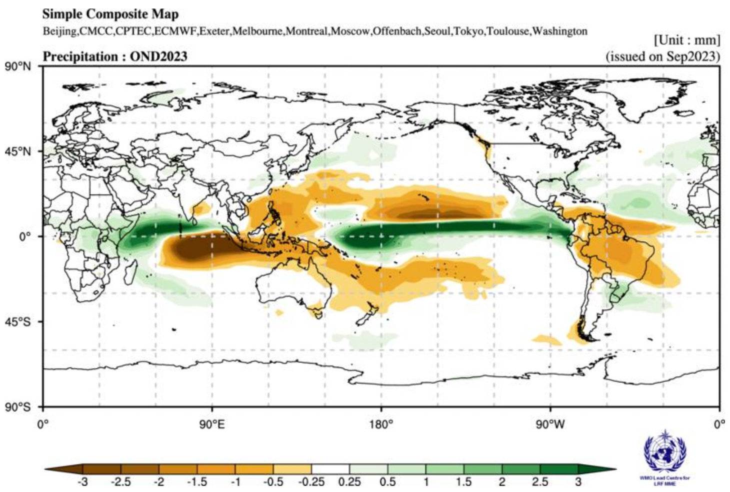
- WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME). https://www.wmolc.org/
- Copernicus Climate Change Service (C3S) Multi-model seasonal forecasts. https://climate.copernicus.eu/charts/c3s_seasonal/
- North American Multi-Model Ensemble (NMME) seasonal forecasts. https://www.cpc.ncep.noaa.gov/products/NMME/

LC-LRFMM Seasonal Forecasts

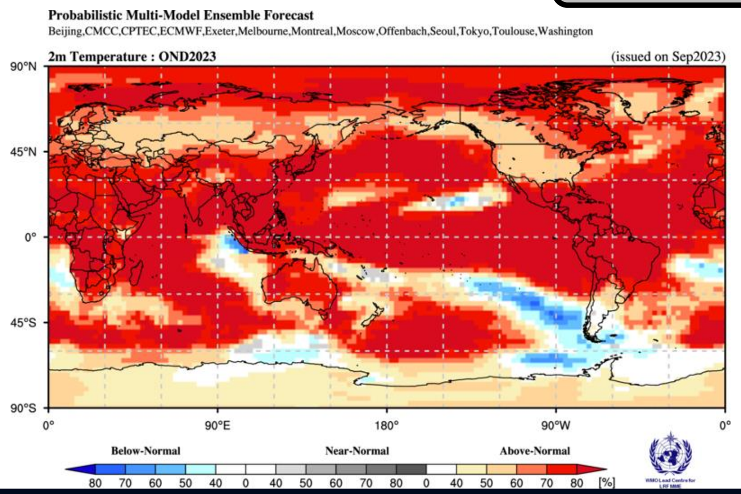
(https://www.wmolc.org/)

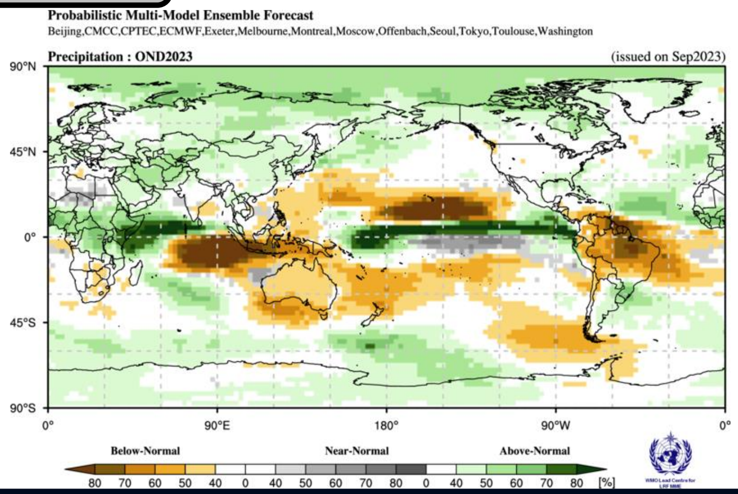
Ensemble means





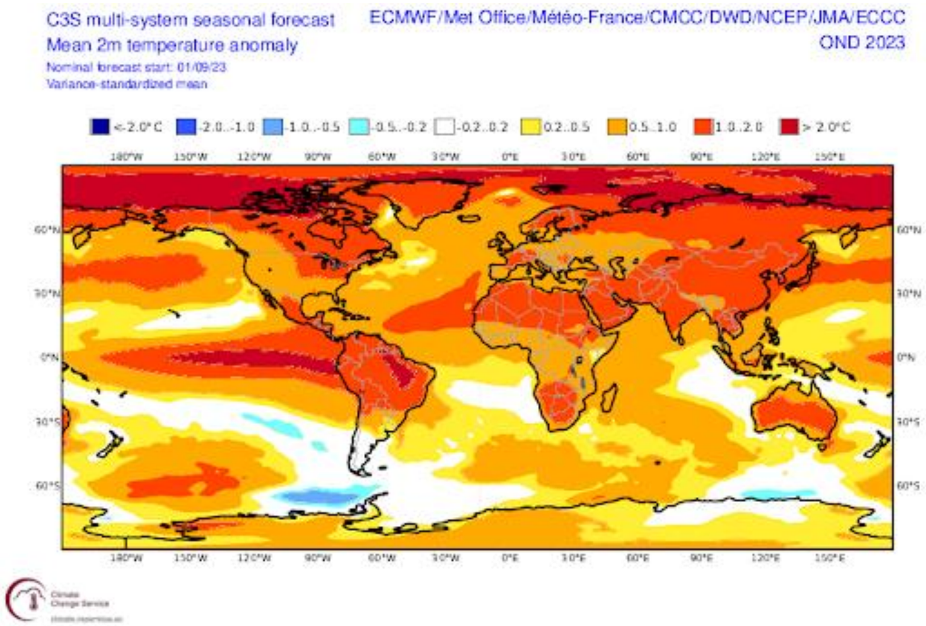
Probabilities

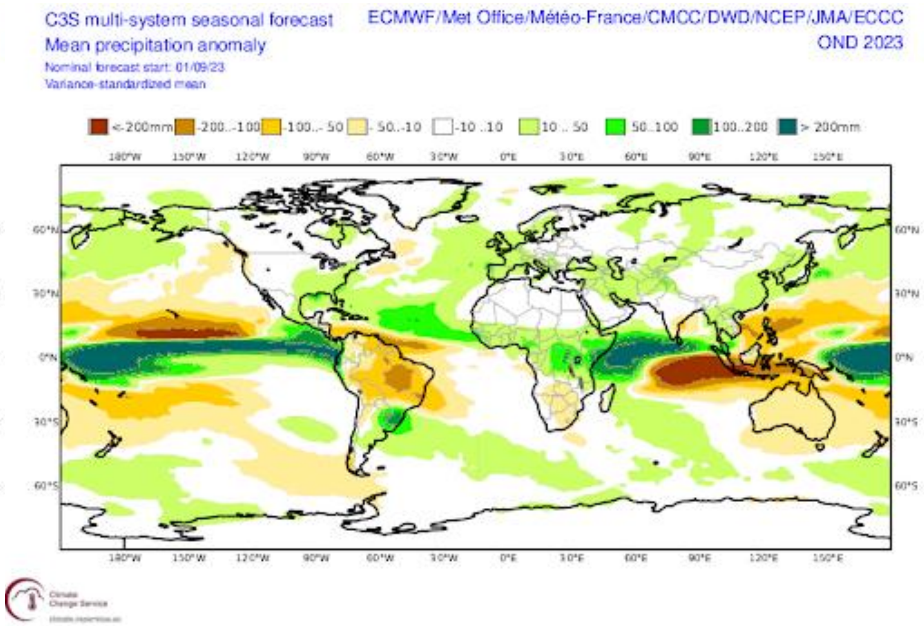




C3S Seasonal Forecast

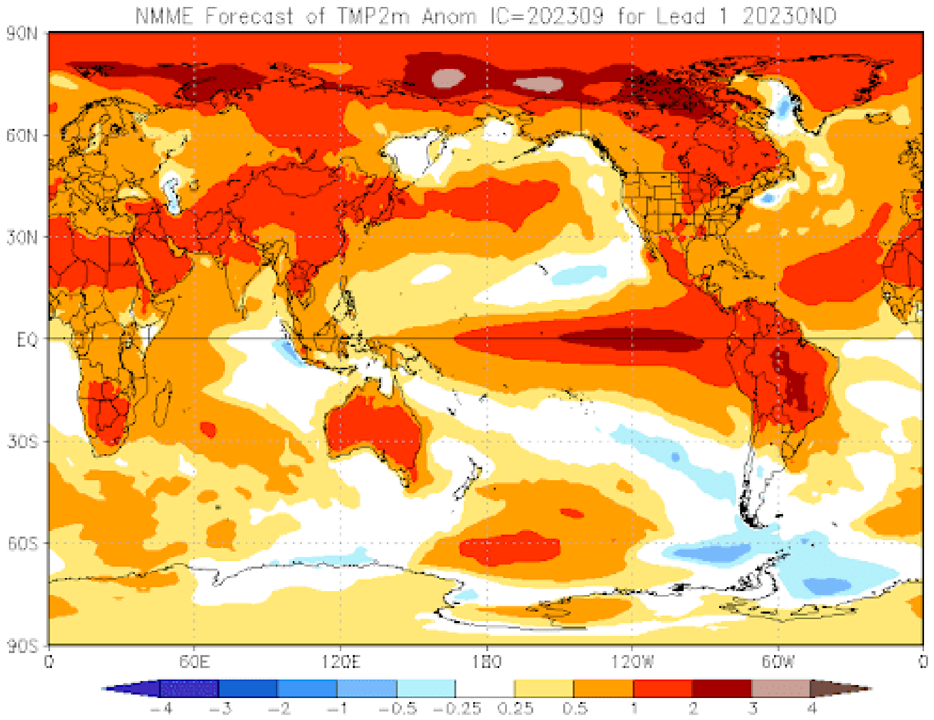
(https://climate.copernicus.eu/charts/c3s_seasonal/)

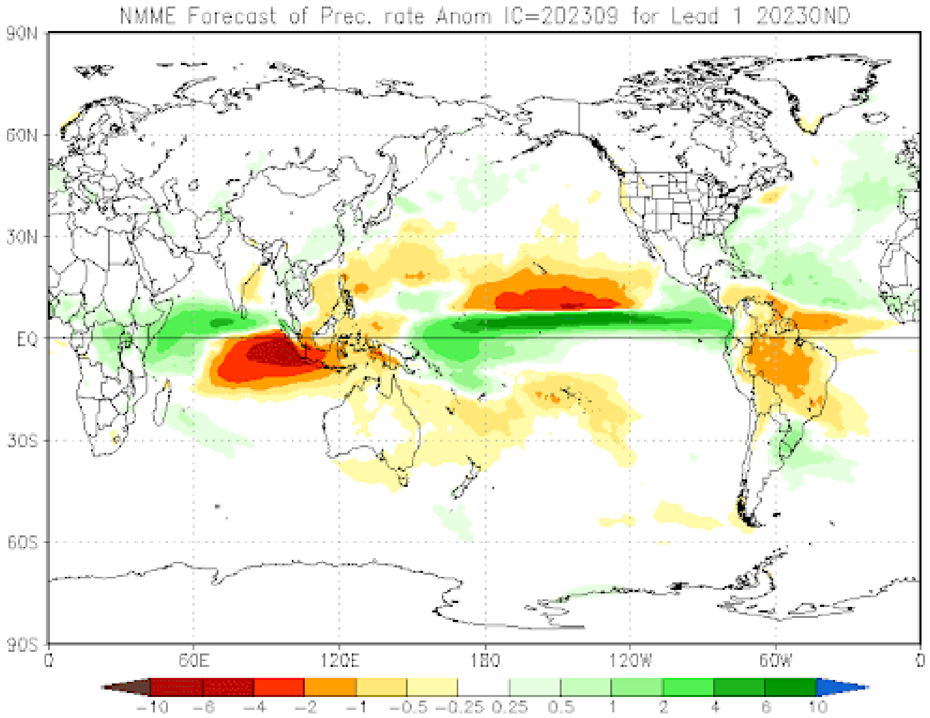




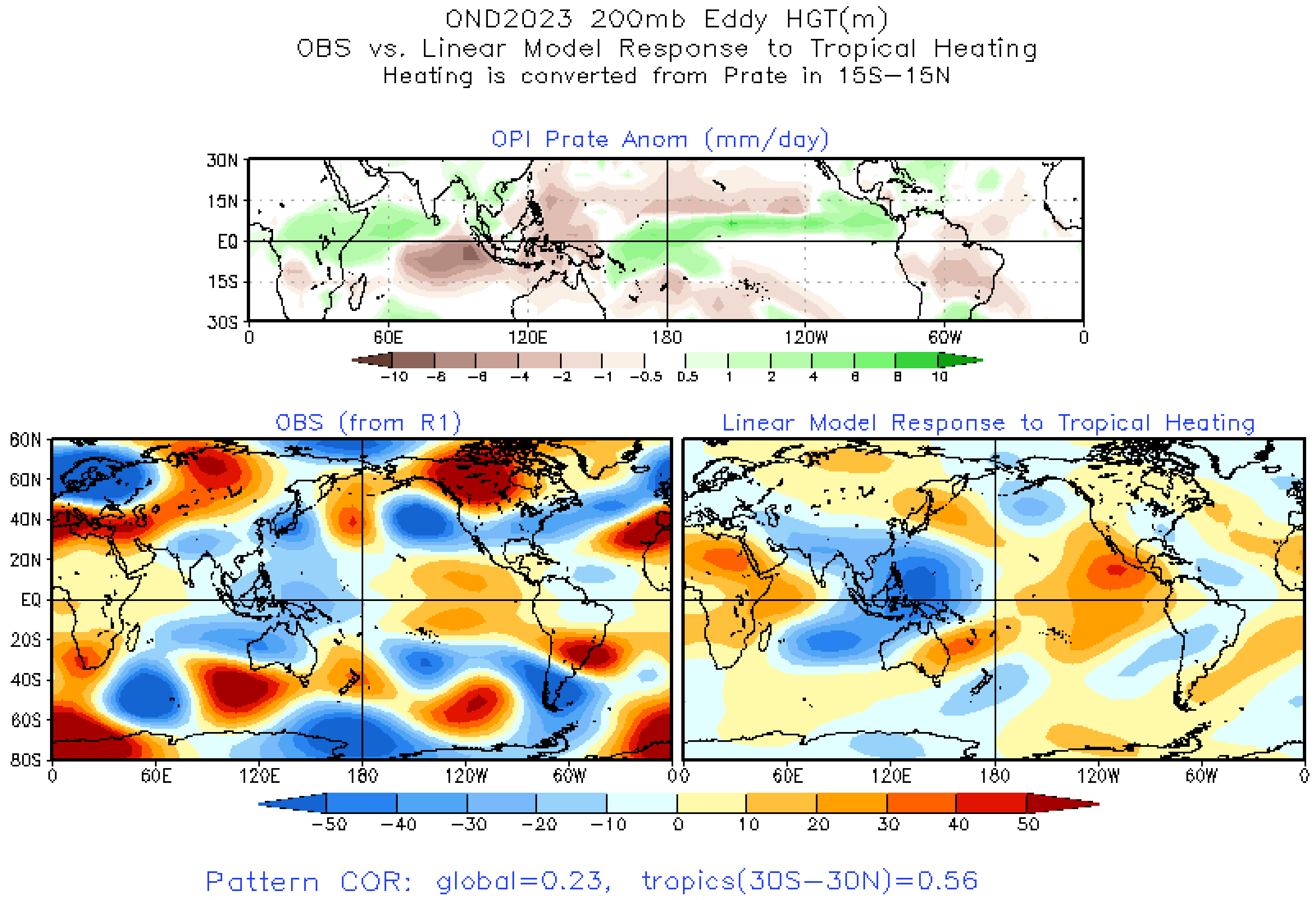
North American Multi-Model Ensemble Seasonal Forecast

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

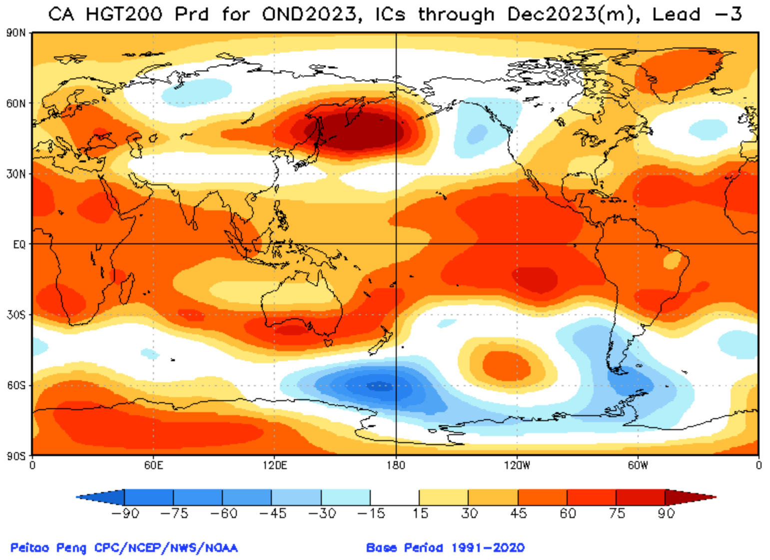


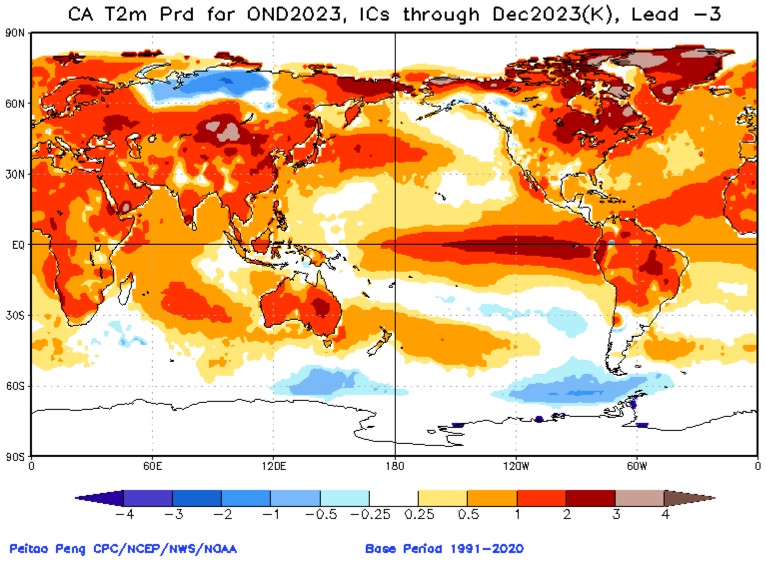


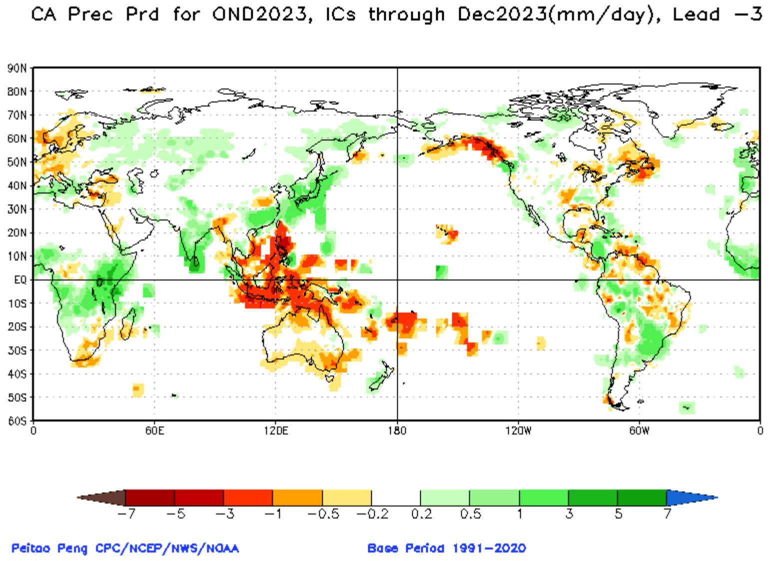
200mb Height from Linear Model



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 (provided by Dr. Peitao Peng/CPC)
- Seasonal mean anomalies of z200, T2m, and Prec forecasted from the Constructed Analog Model (provided by Dr. Peitao Peng/CPC)