Attribution of Seasonal Climate Anomalies
July-August-September 2020

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

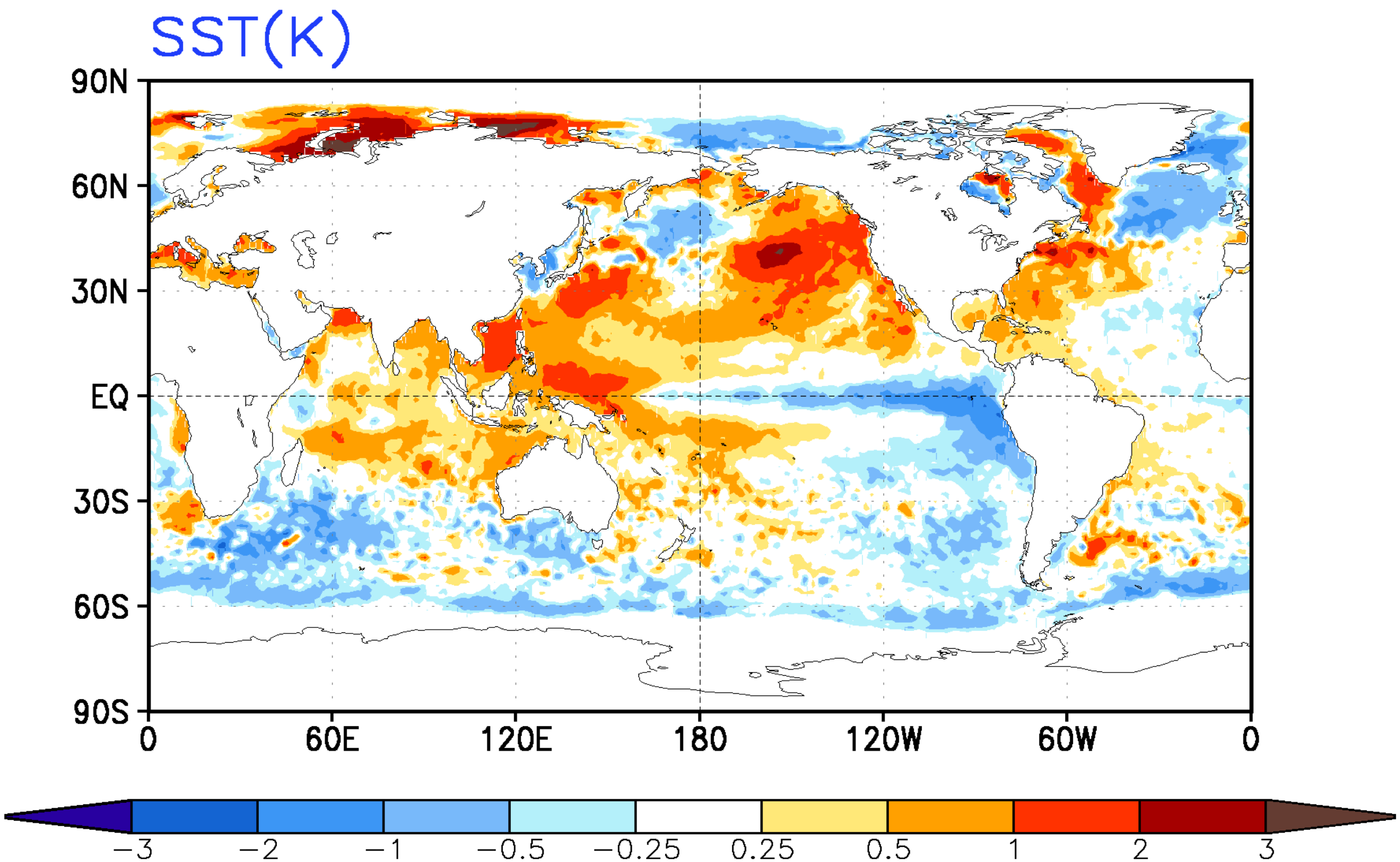
Summary of July-August-September 2020 Observed Conditions and Outlooks

- The sea surface temperature (SST) anomalies in the equatorial western Pacific Ocean continued to be on the warm side while central/eastern Pacific continued its cooling trend leading to an enhanced east-west SST gradient (slide 4).
- The observed positive land temperature anomalies over northern Asia, Alaska, northeast Canada, northwest Australia, and S. America were well predicted in CFSv2 and other multi-model ensemble MME forecasts (slide 5, 13, 33, 34, and 38).
- In general, the large-scale distribution of negative and positive precipitation anomalies in tropics was well predicted in CFSv2 and other MME forecast systems (slide 11, 33, 34, & 39).
- The north-south pattern of high and low height anomalies between 60°N-90°N was in the weakly negative phase of the AO pattern. The initialized CFSv2 captured the large-scale structure of the observed positive height anomalies over tropics, while missing some variations over extra-tropics (slide 12 & 15).
- The initialized CFSv2 prediction captured most of warm anomalies over the NA, while it missed the cold anomalies over the central US. The NMME forecast predicted tendency for negative T2m anomalies over the central US (slide 16 & 34).
- The monthly forecasts from the shortest 3-day-leads initial conditions predicted most of T2m negative anomalies over the range from the central Canada to central and NE US for Aug 2020 (slides 31).
- Only the short lead precipitation forecast were able to capture the above normal precipitation anomalies in the southeast US (slide 30).

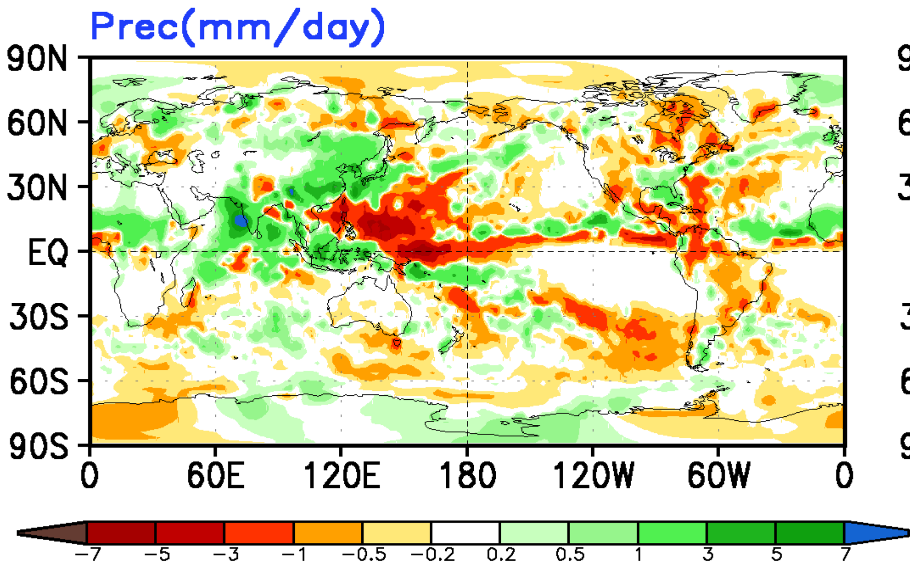
Observed Seasonal Anomalies

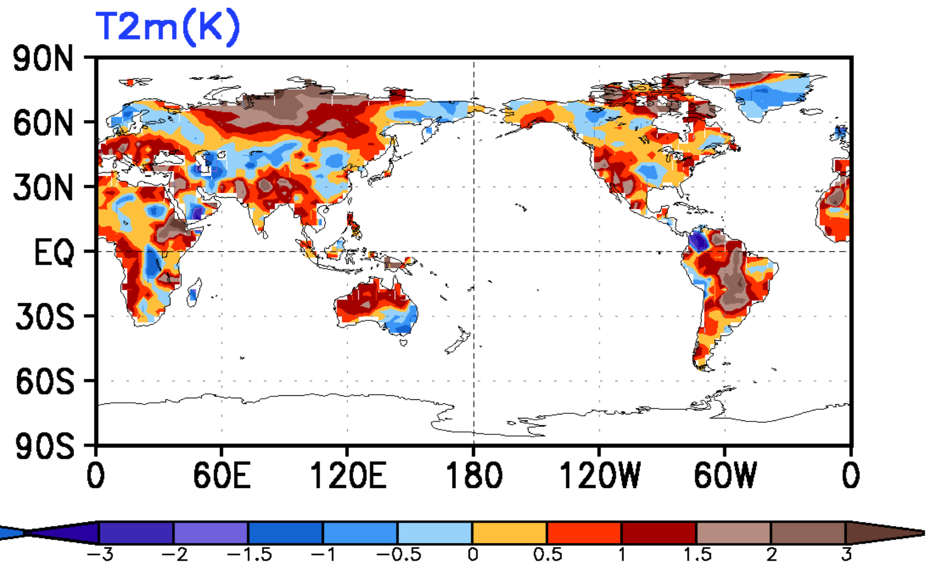
Global and North America

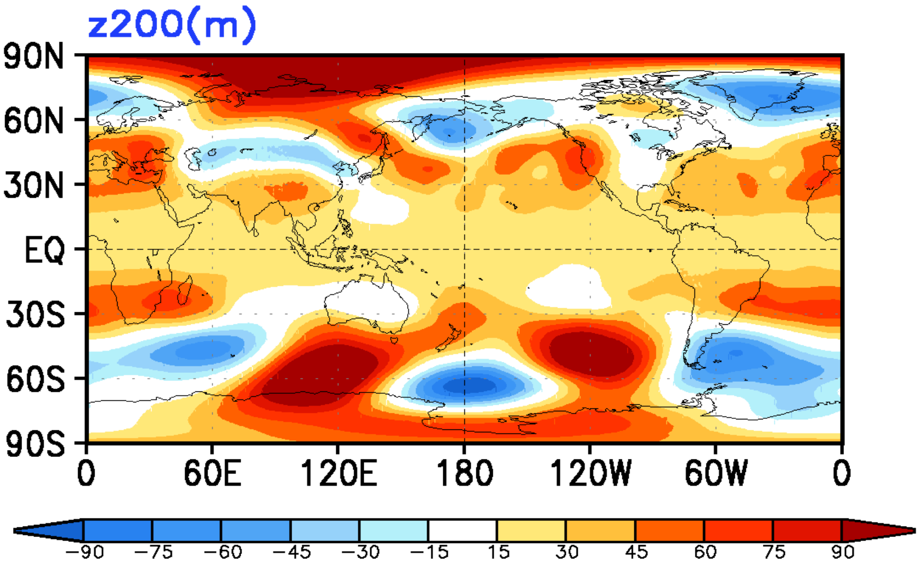
Observed Anomaly JAS2020



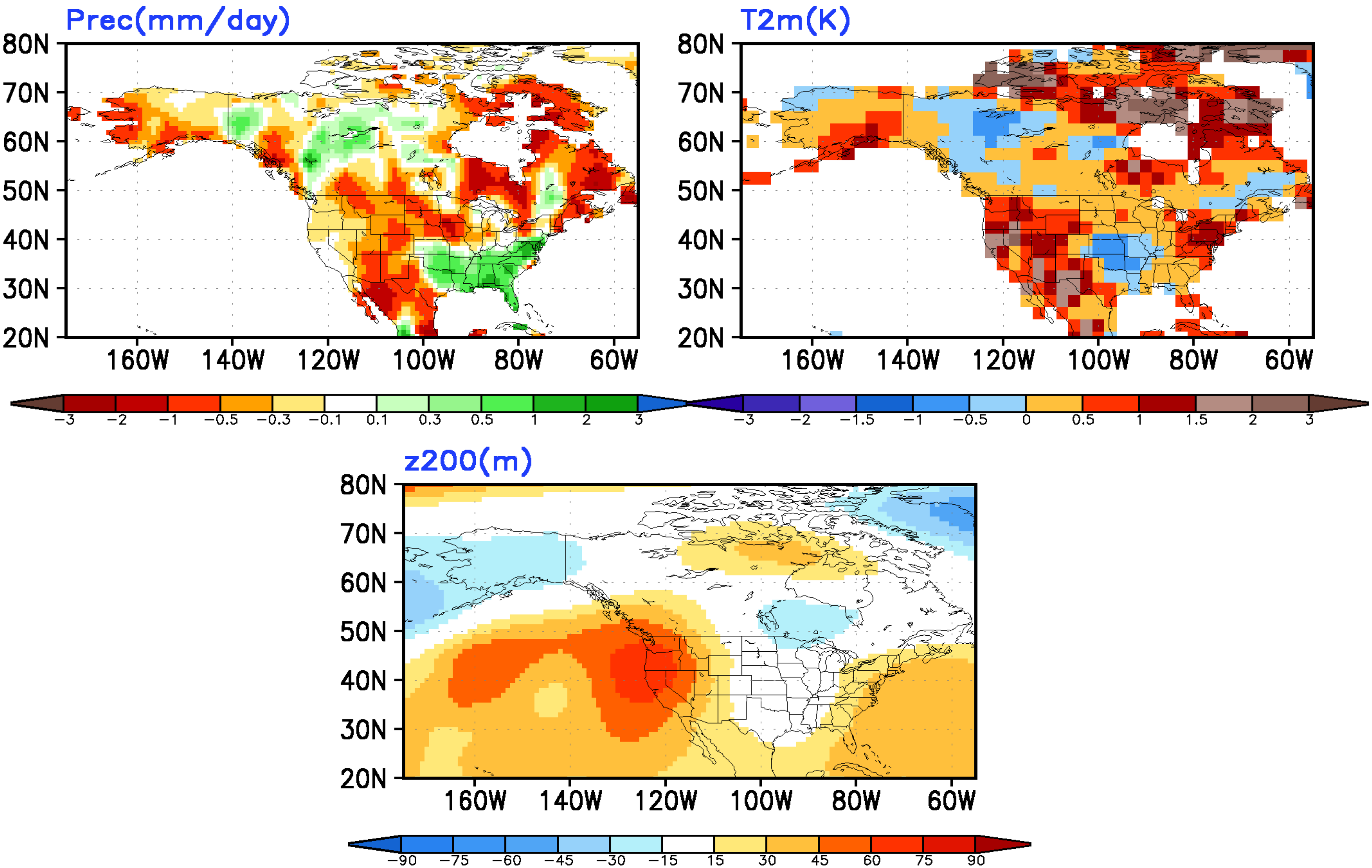
Observed Anomaly JAS2020







Observed Anomaly JAS2020

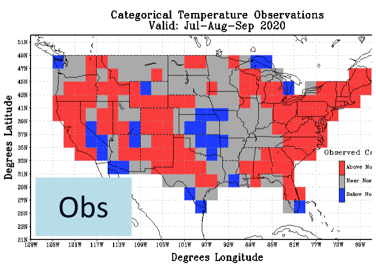


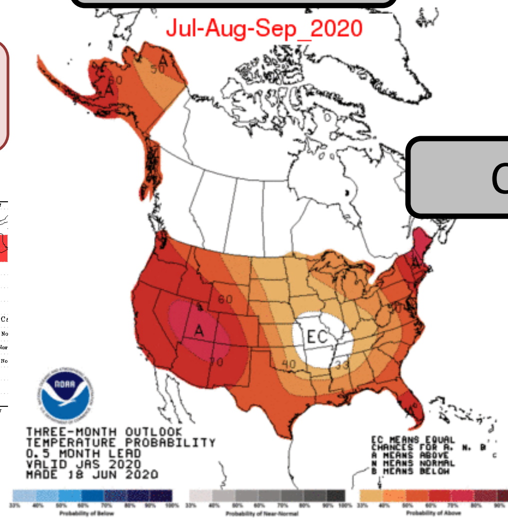
JAS2020 CPC Seasonal Outlooks and NMME Forecasts

Temperature

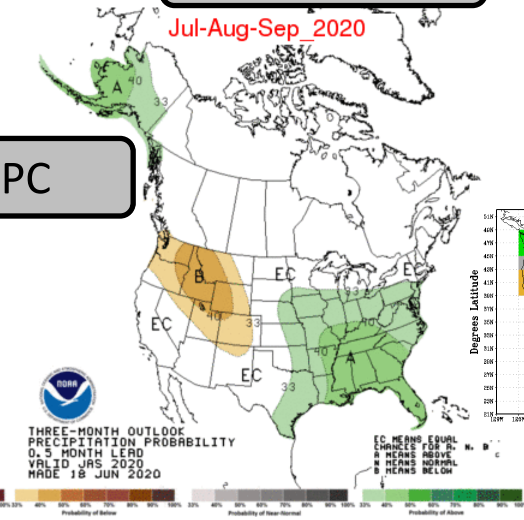
Precipitation

Temp nonEC
HSS=30

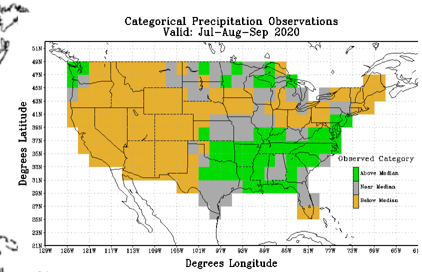


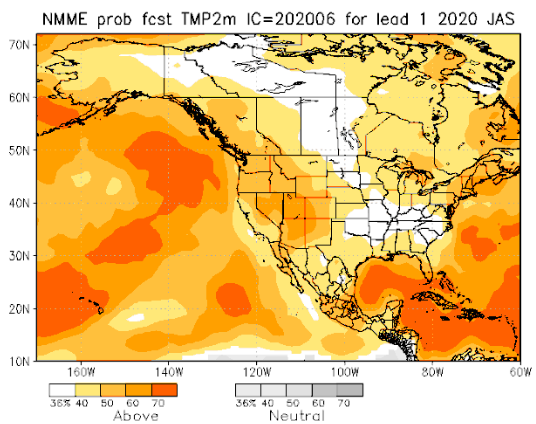


CPC

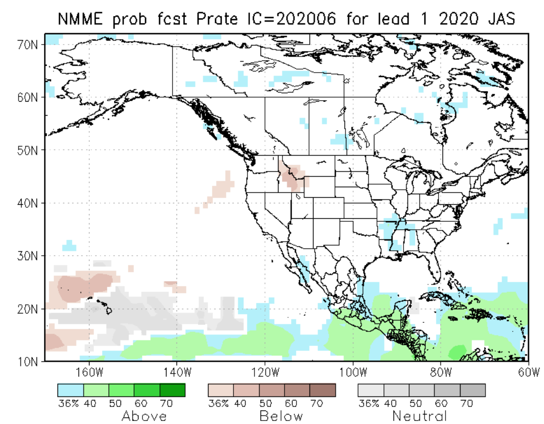


Prec nonEC
HSS=45





NMME



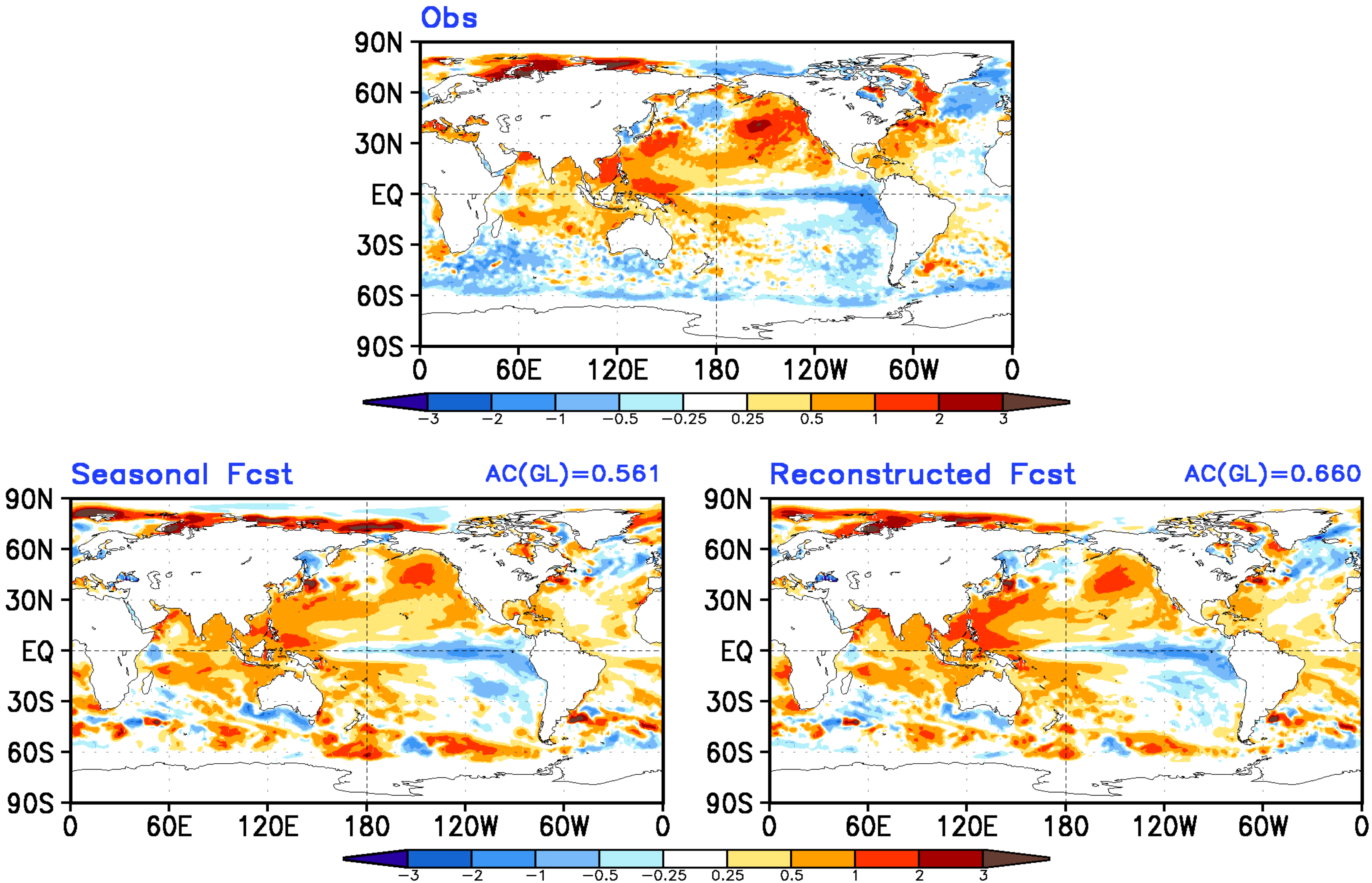
For the rationale behind CPC outlooks see https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2020/202006_PMD90D

Model Simulated/Forecast Ensemble Mean Anomalies

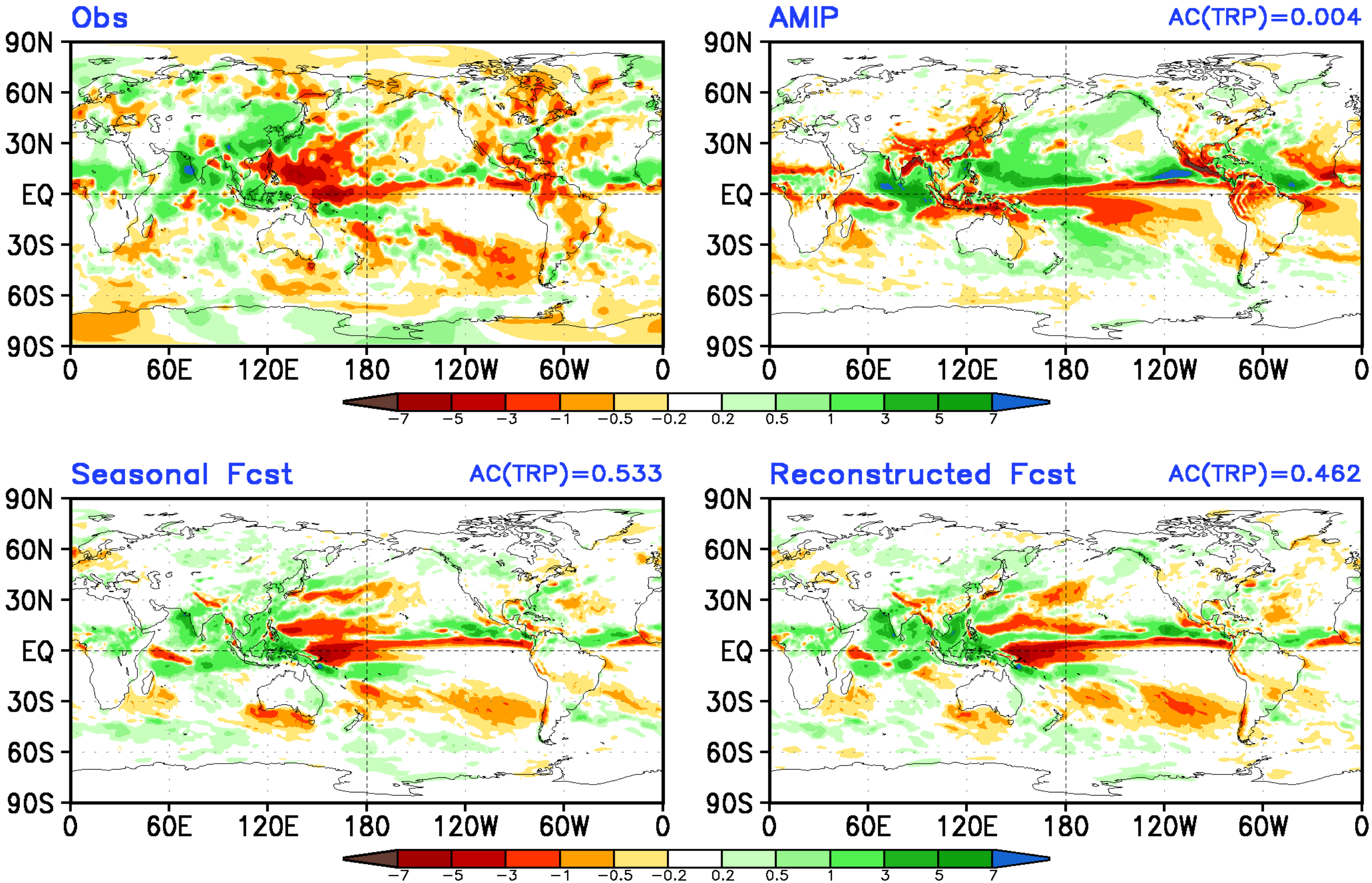
Model Simulated/Forecast Ensemble Average Anomalies

- CFS AMIP simulations forced with observed sea surface temperatures (18 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).

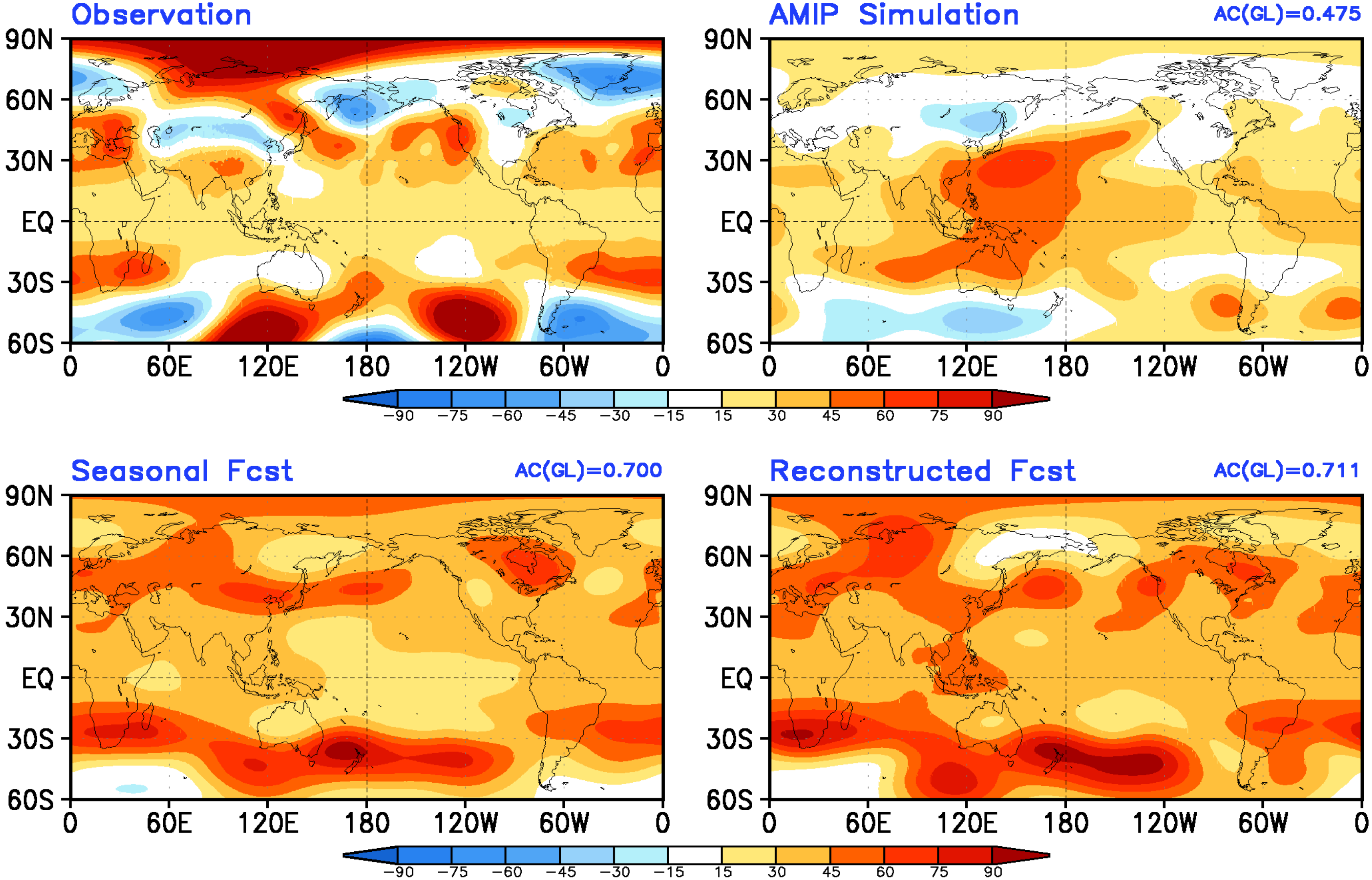
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)



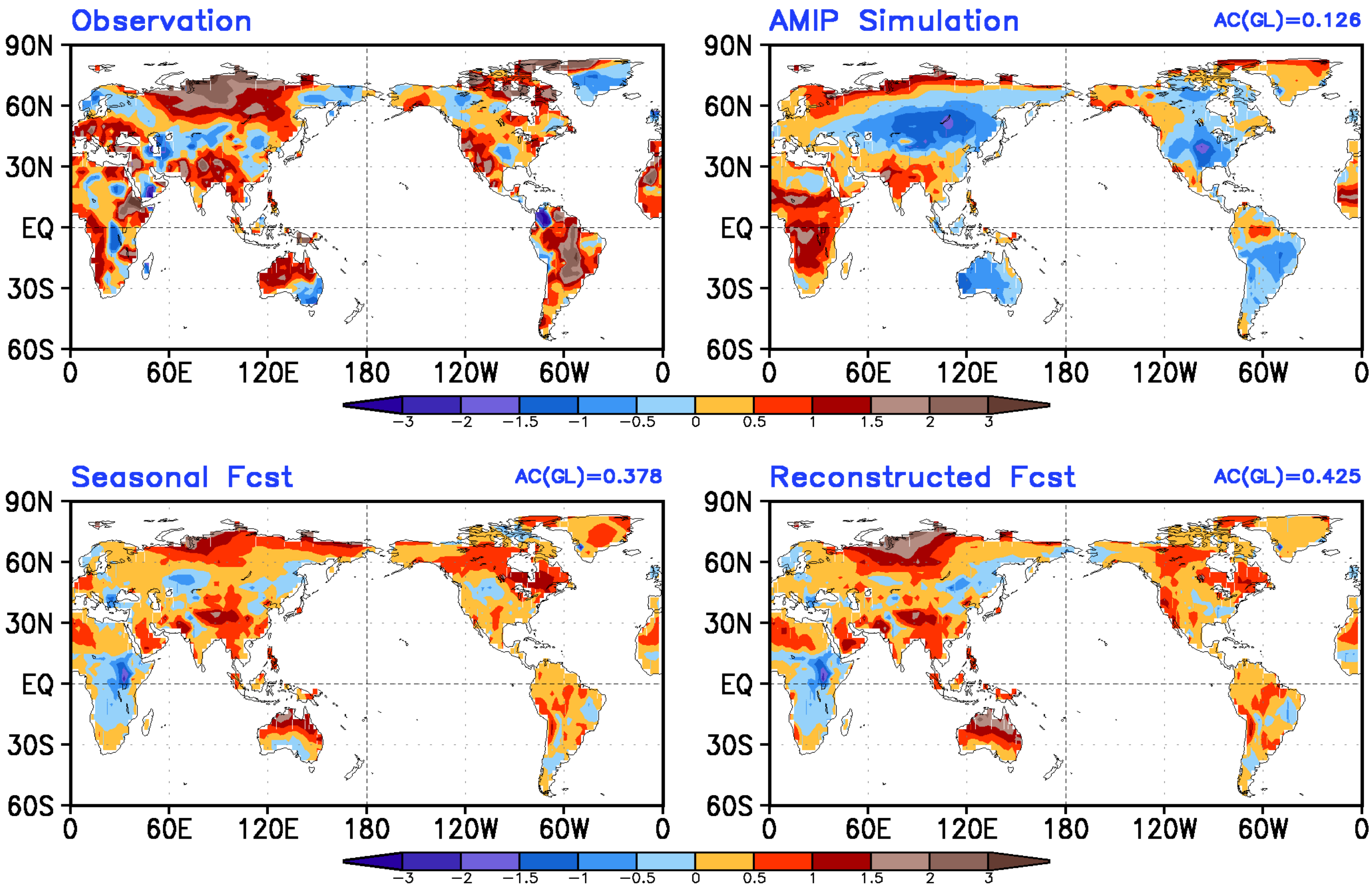
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



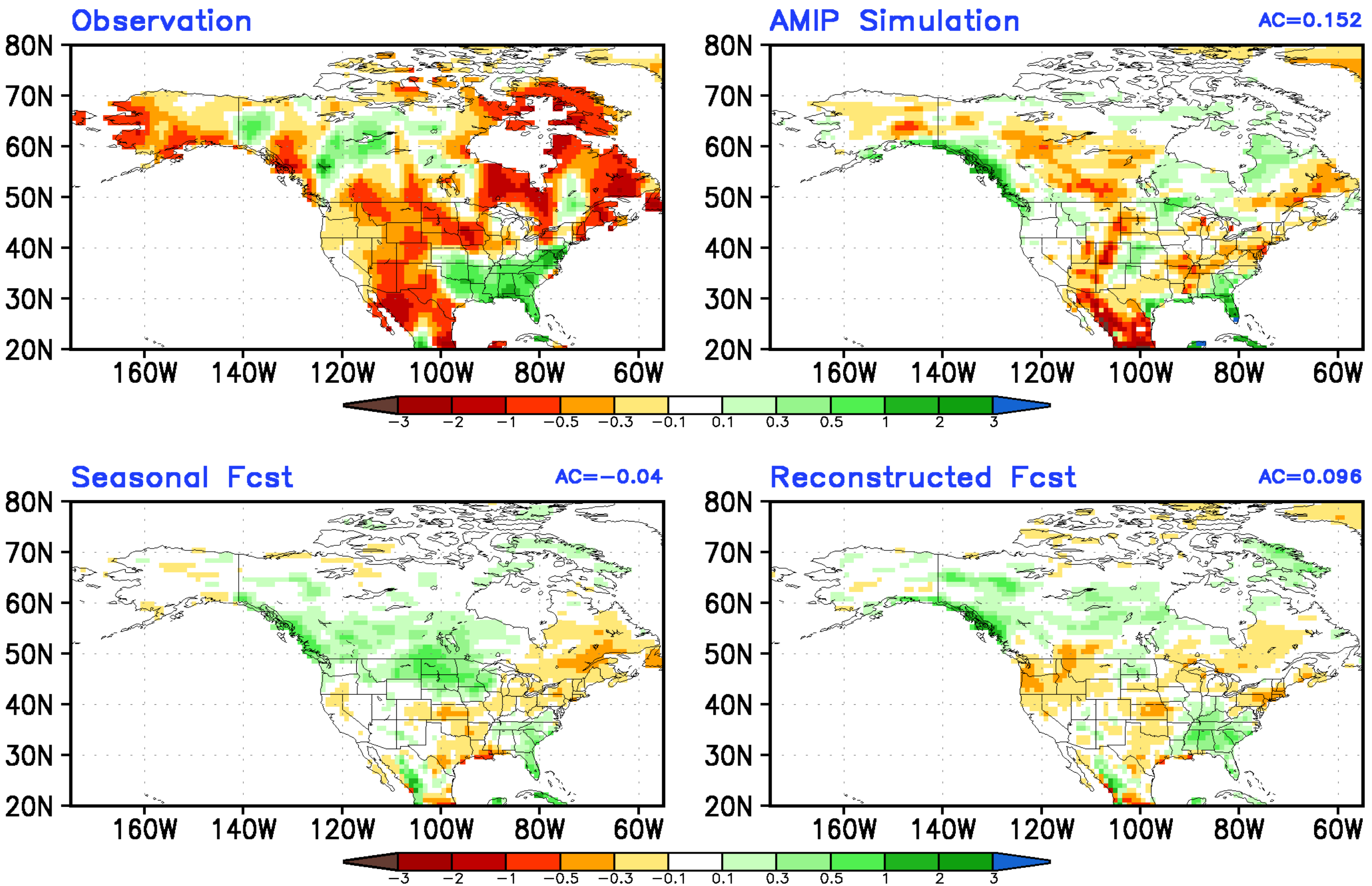
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



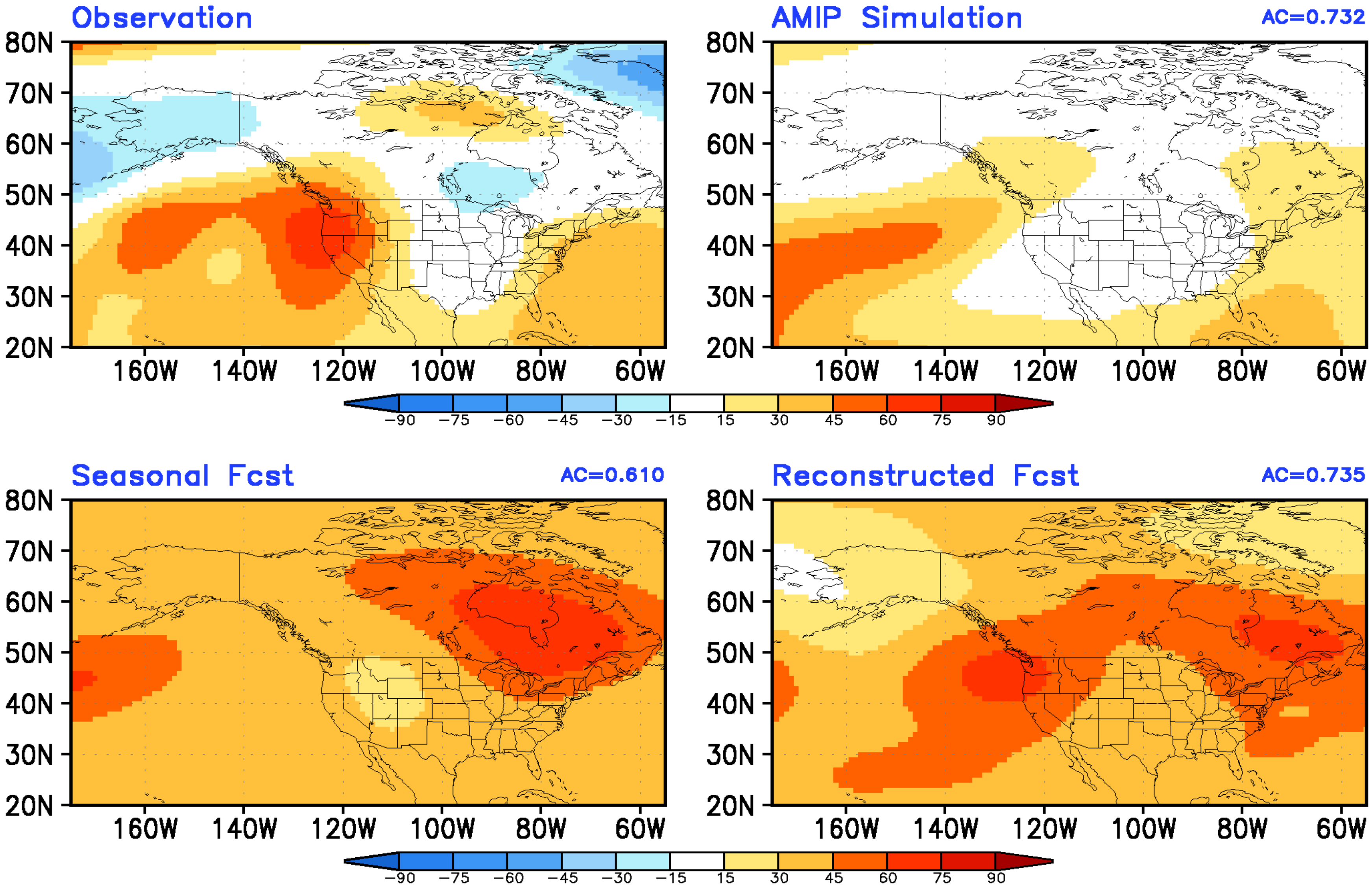
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



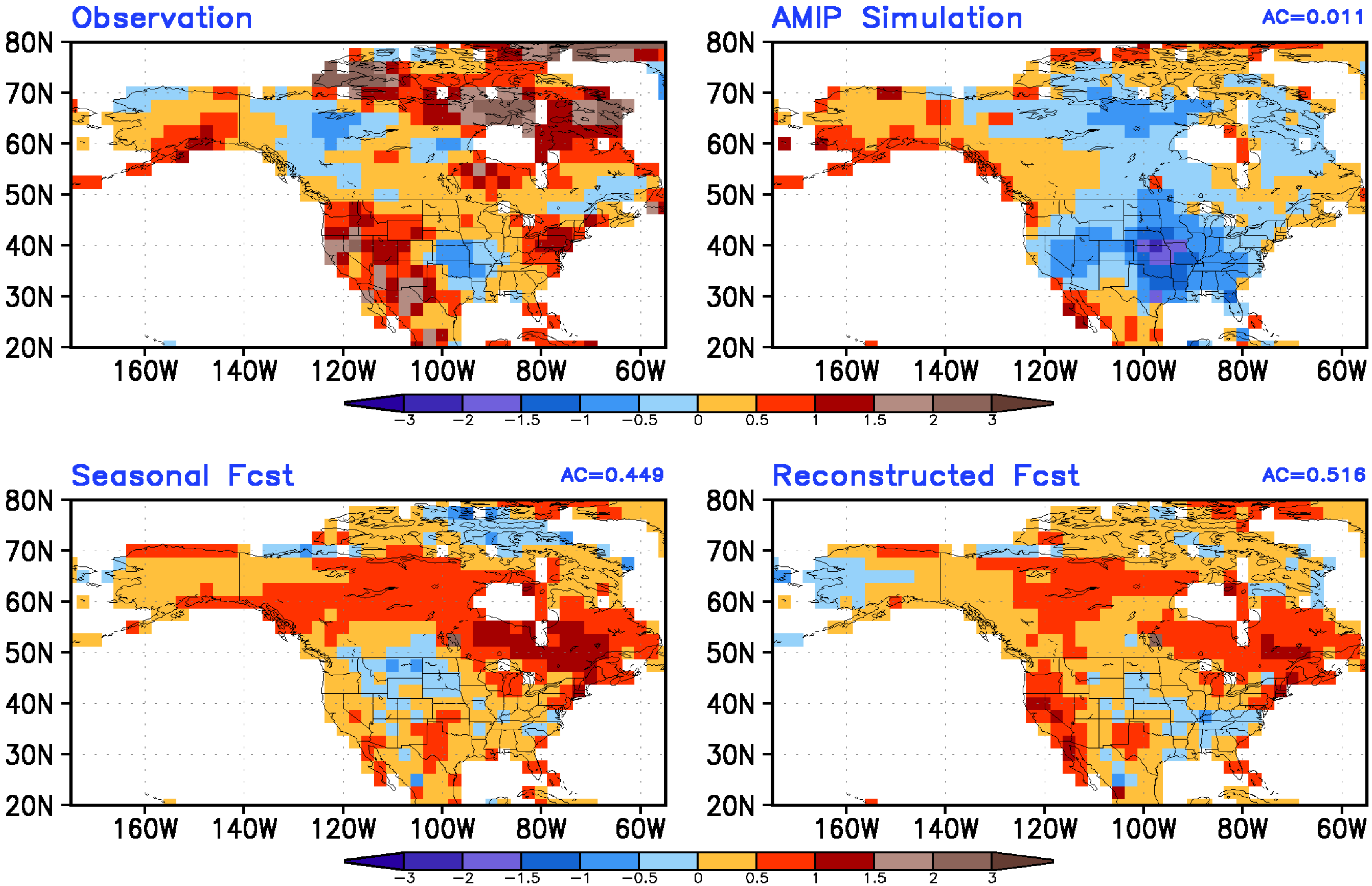
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)



JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)



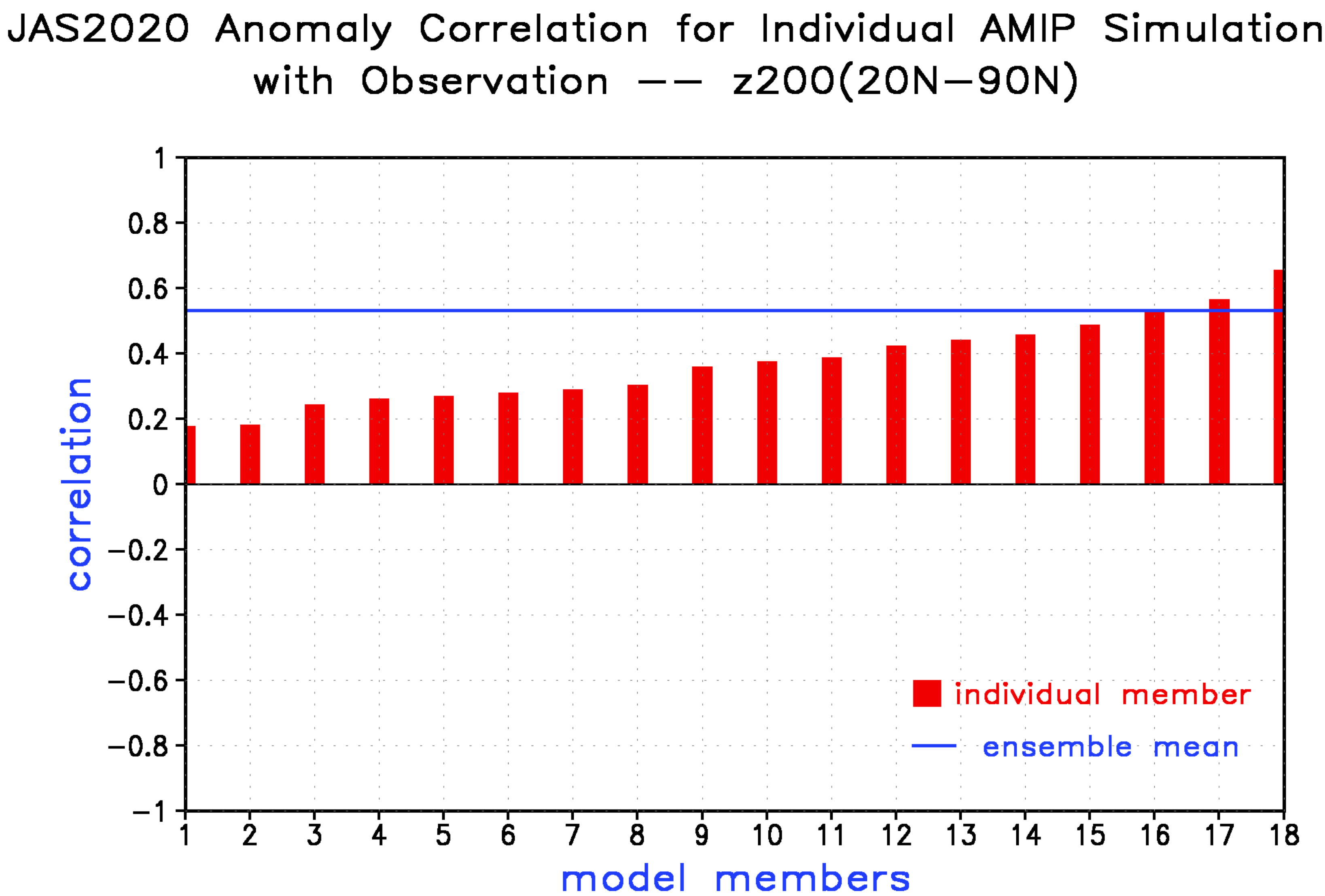
JAS2020 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)



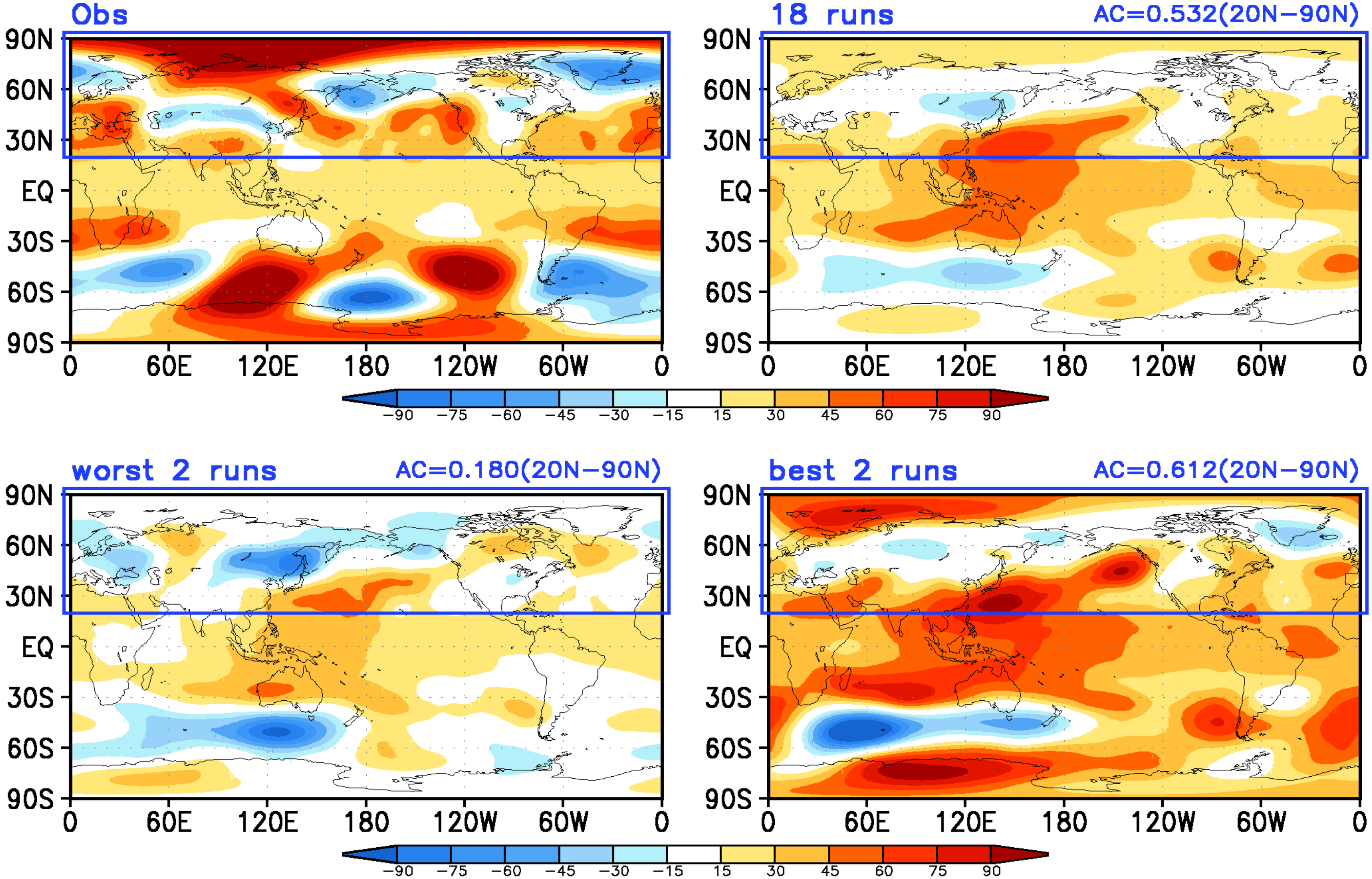
Model Simulated/Forecast Anomalies: Individual Runs

Model Simulated/Forecast Anomalies: Individual Runs

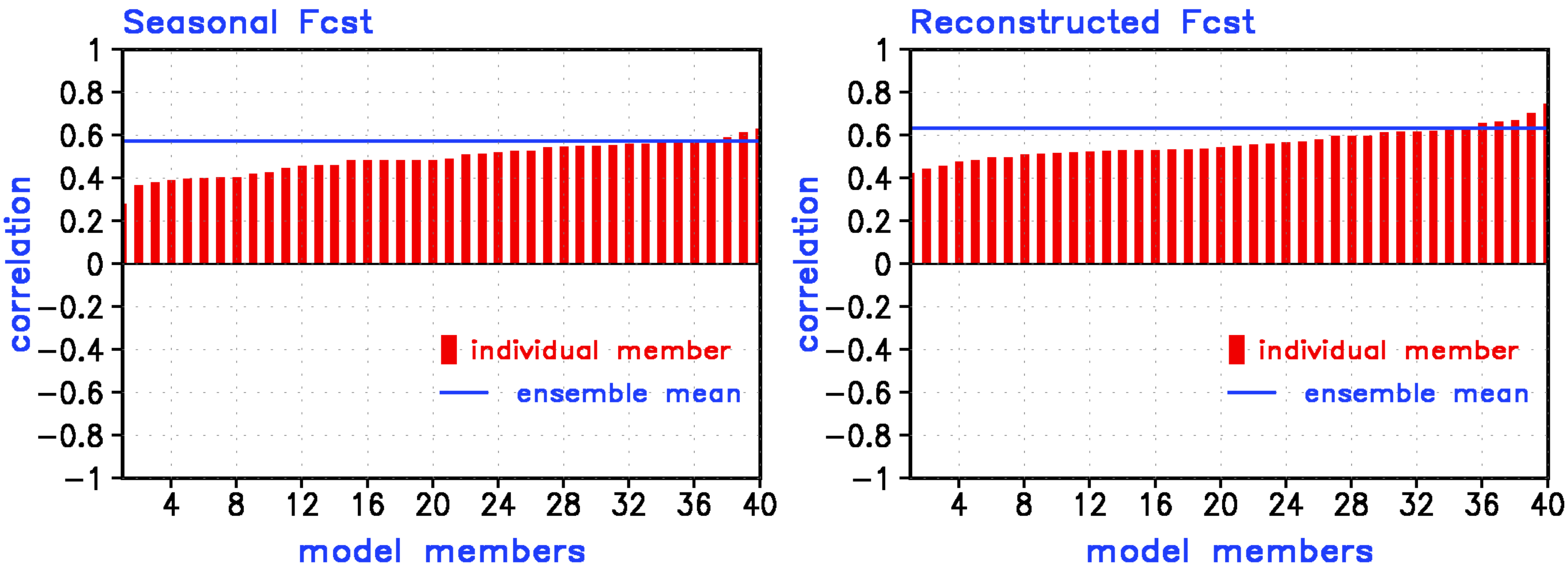
- In this analysis, anomalies from individual model runs are compared against the observed seasonal mean anomalies. The spatial resemblance between them is quantified based on anomaly correlation (AC).
- The distribution of AC across all model simulations is indicative of probability of observed anomalies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


JAS2020 Anomaly Correlation for Individual AMIP Simulation
with Observation -- z200(20N-90N)
correlation
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
model members
individual member
ensemble mean

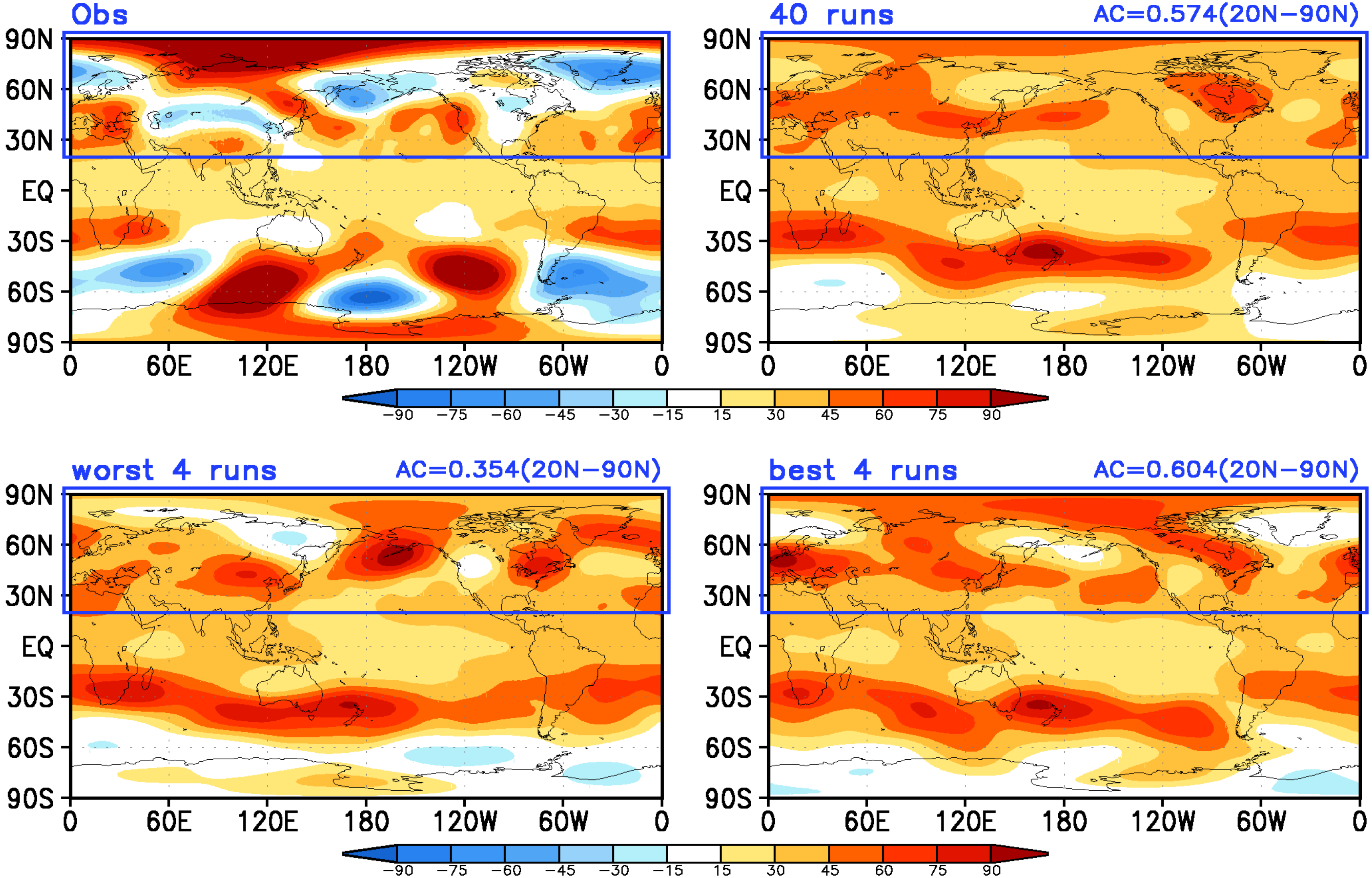
Observed & AMIP Ensemble Average Anomalies
JAS2020 z200(m) 18 runs/worst 2 runs/best 2 runs



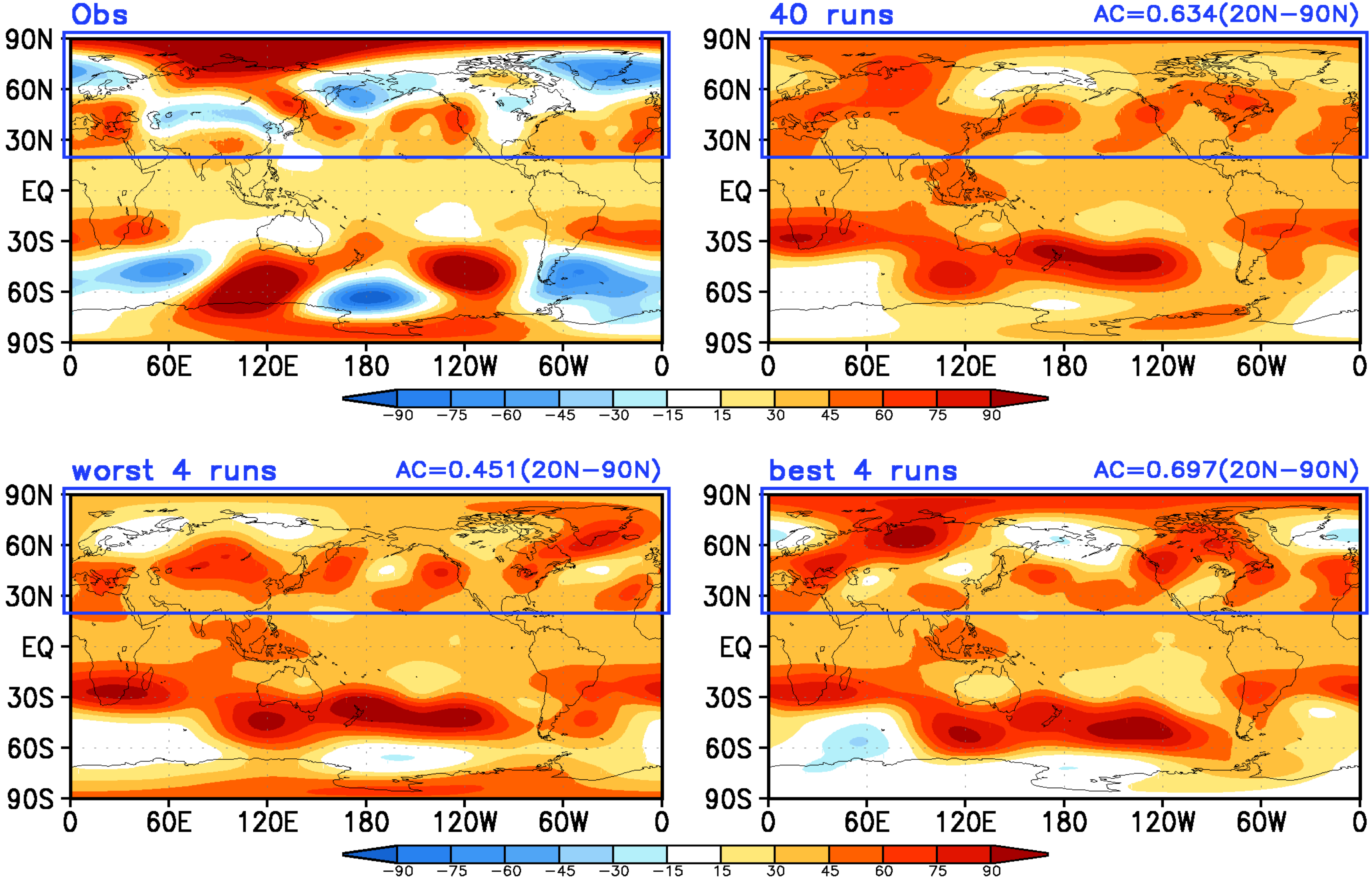
JAS2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- z200 (20N-90N)



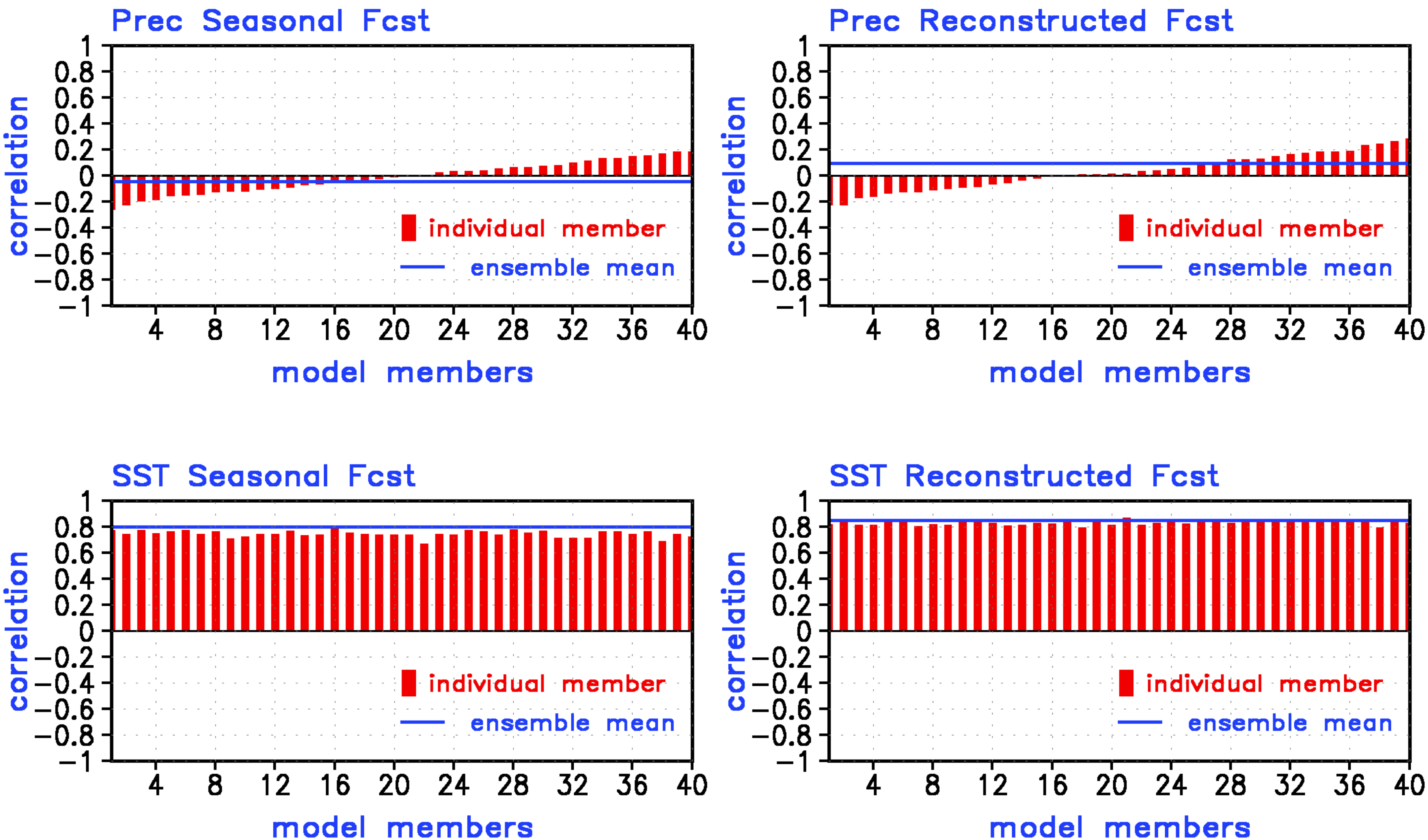
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

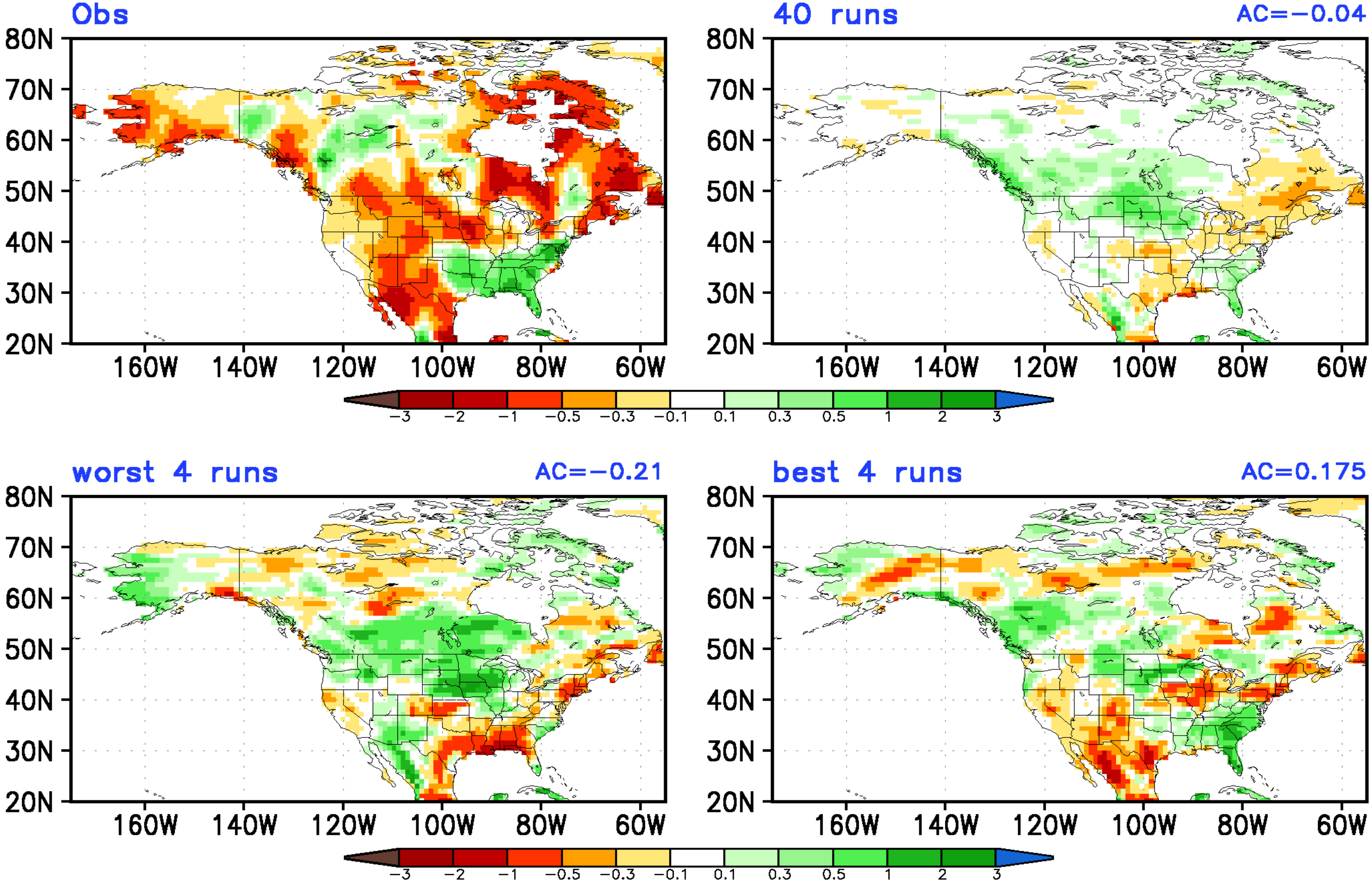


JAS2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S-30N)

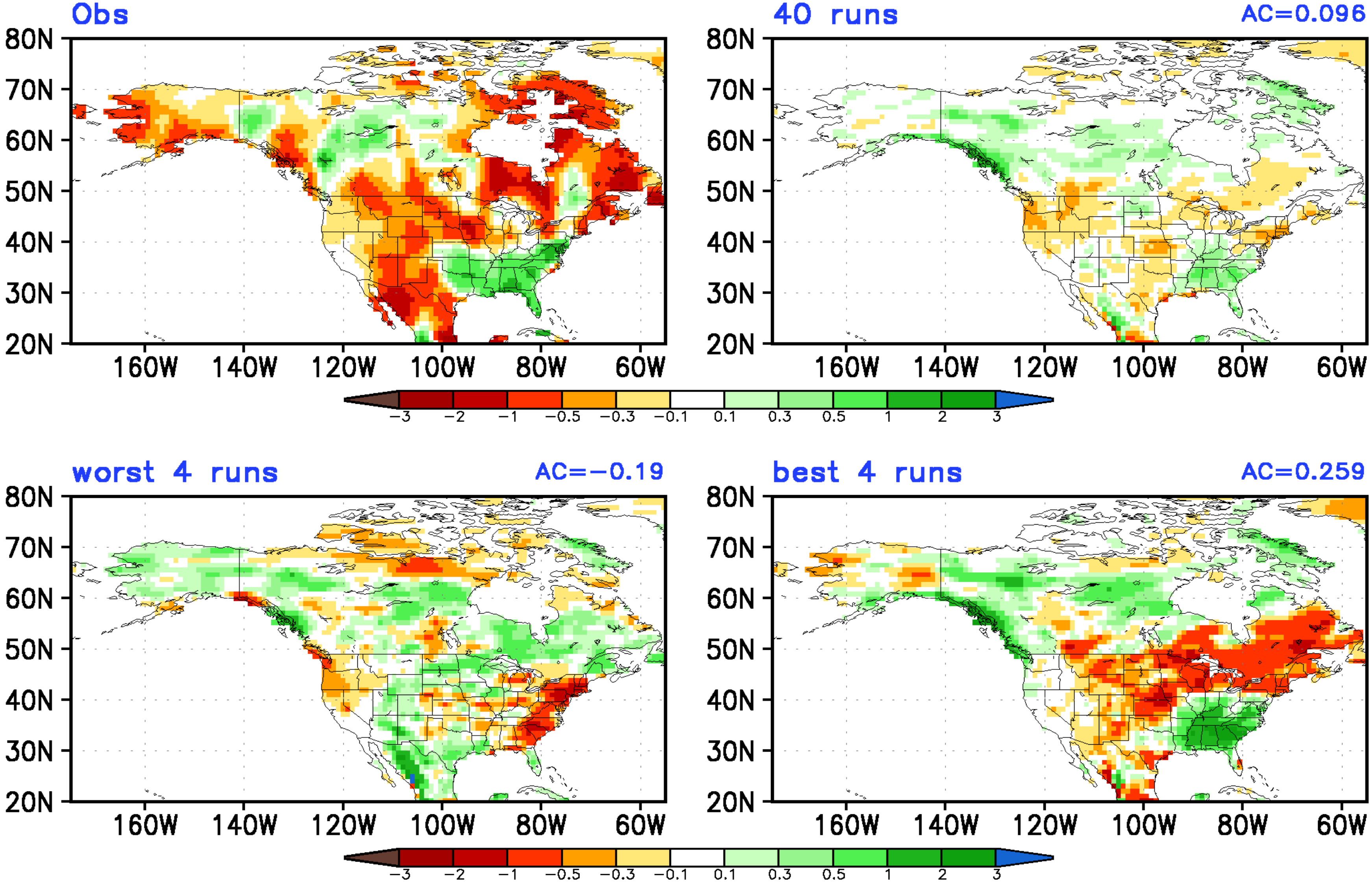


Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs

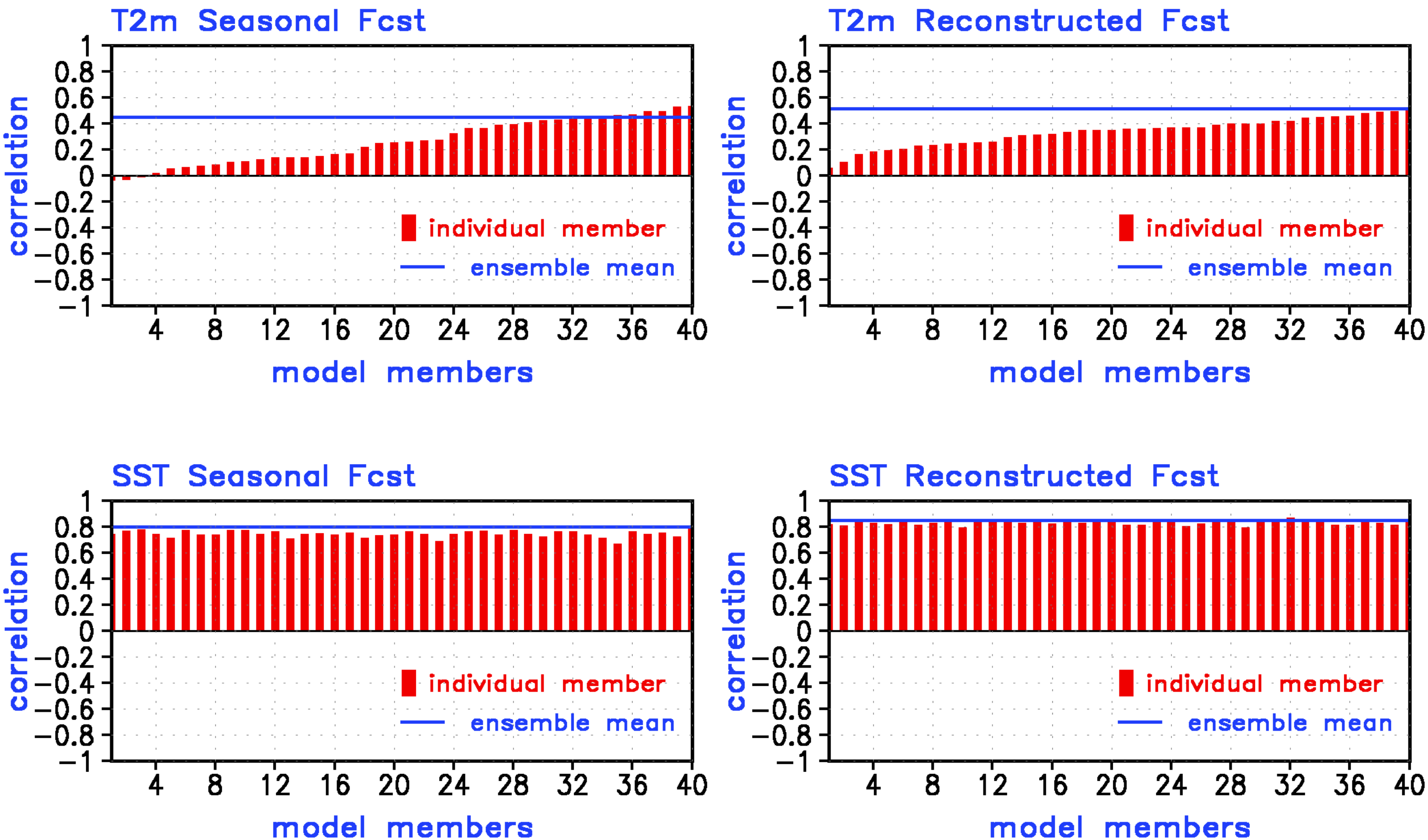
Seasonal Forecast



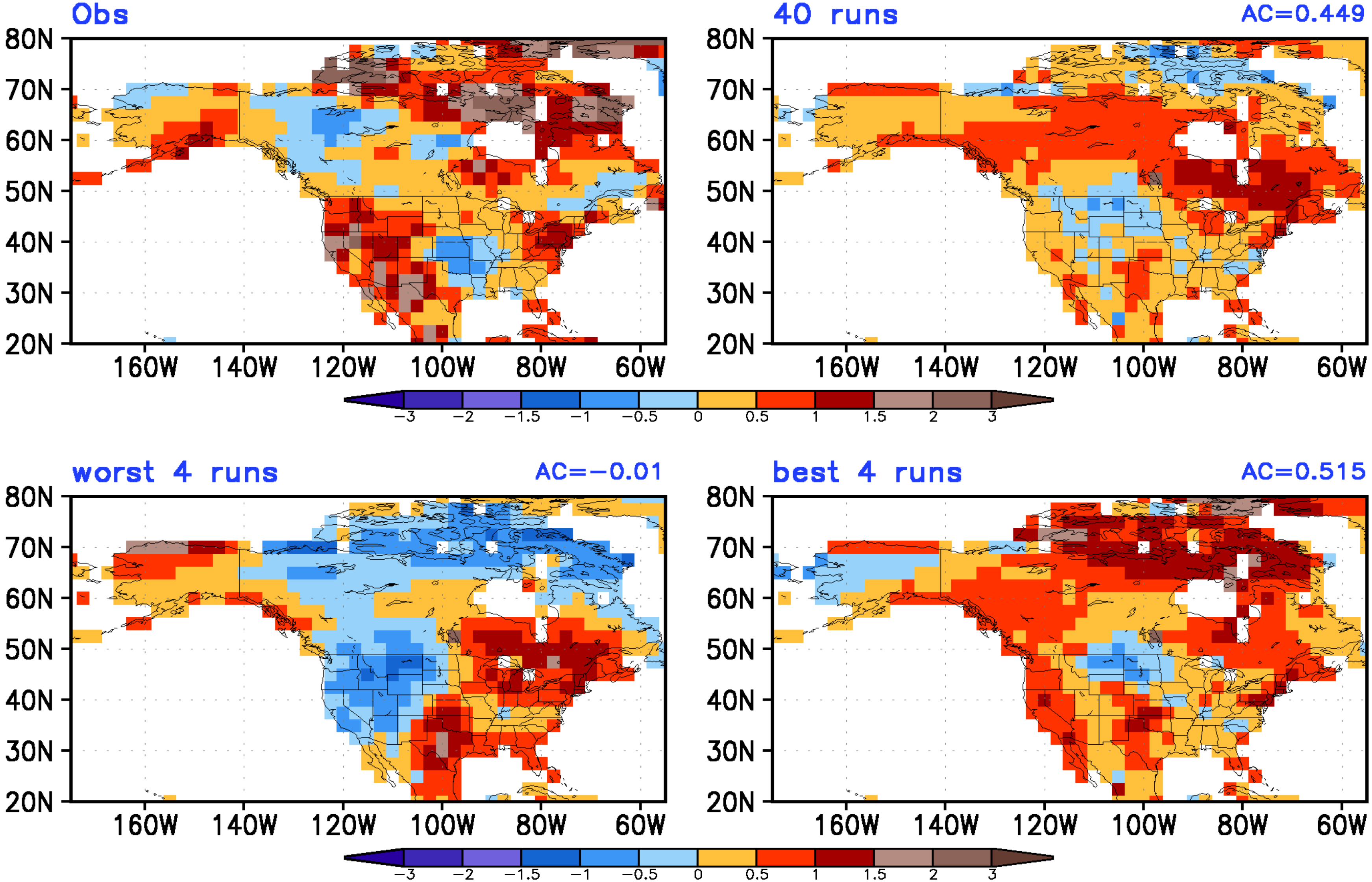
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



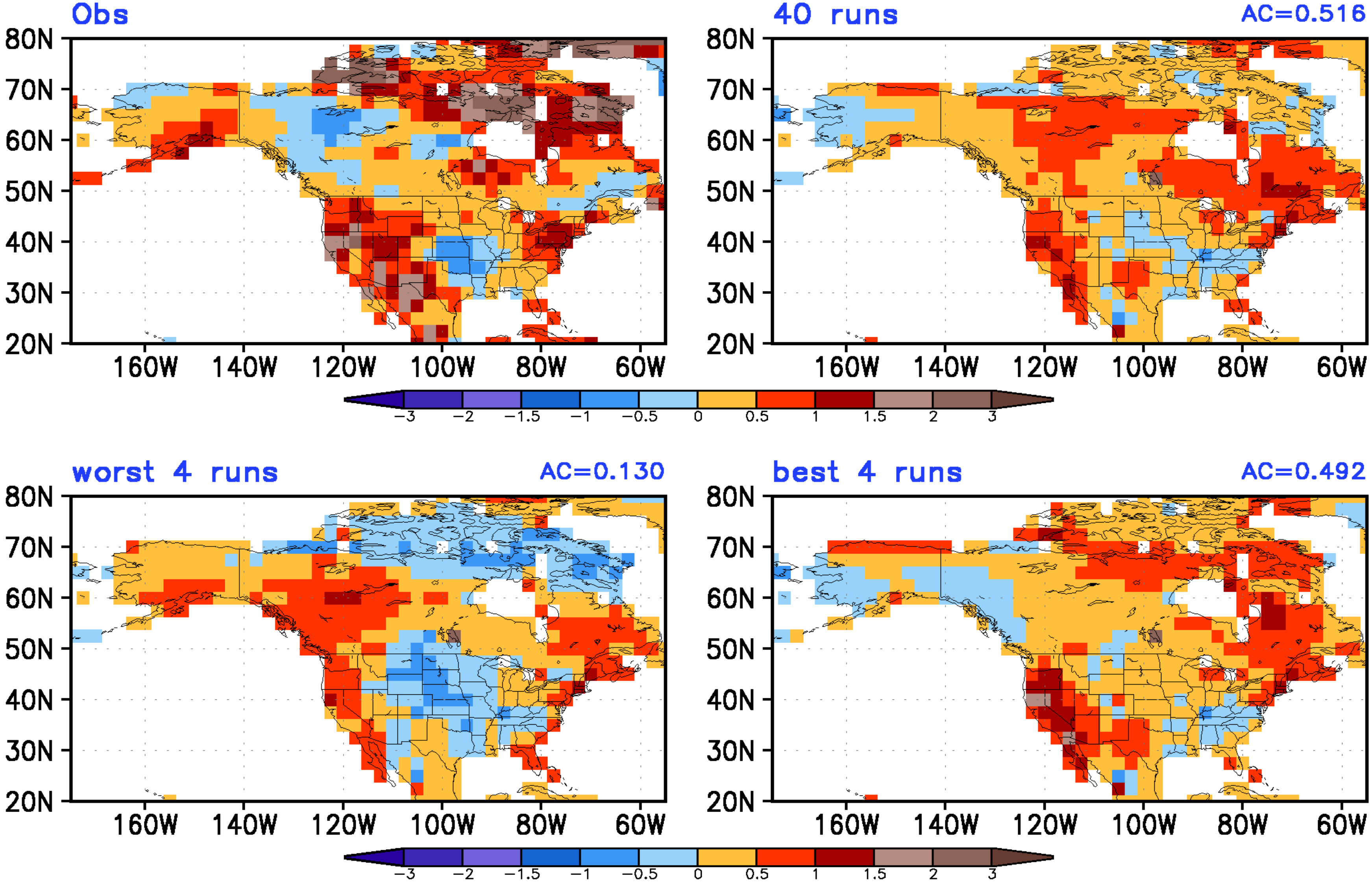
JAS2020 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S-30N)



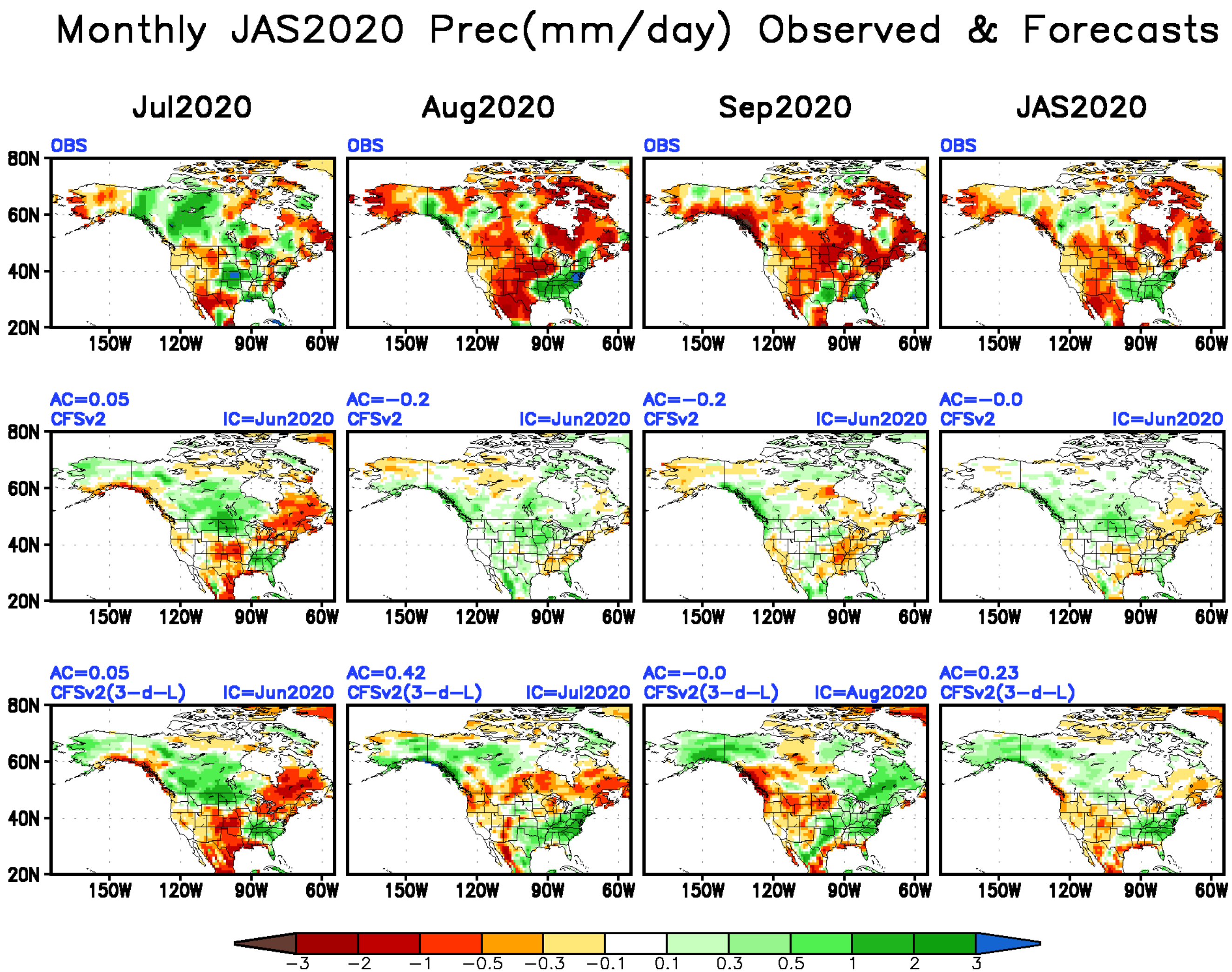
Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast



Observed & CFSv2 Forecast Ensemble Average Anomalies
JAS2020 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast



Monthly Means Prec(mm/day) Observed & Forecasts

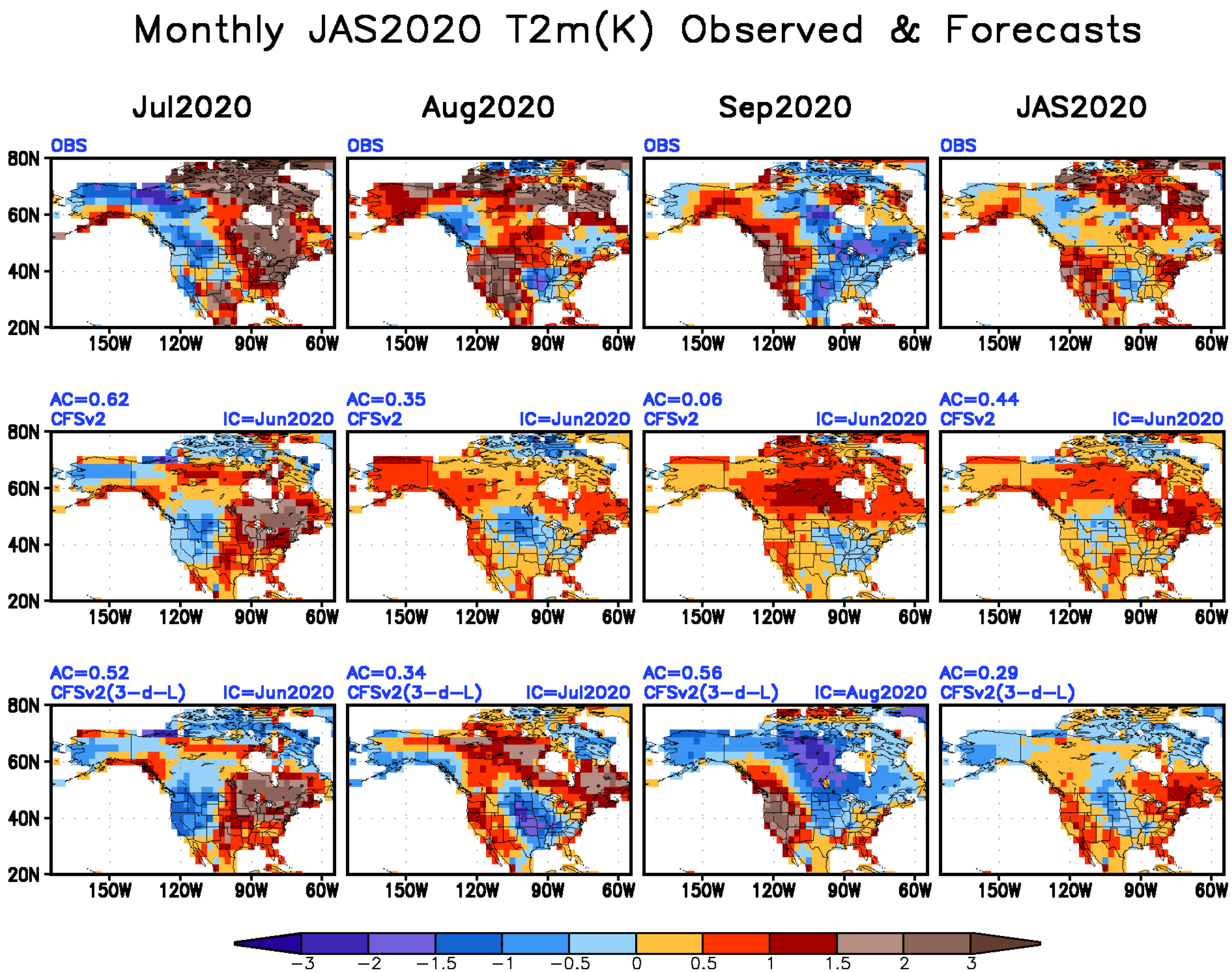


Top row: Observed anomaly

Middle row: CFSv2 seasonal forecasts from the initial conditions from the month prior to the target season.

Bottom row: CFSv2 monthly forecasts from the last three days of the month prior to the target month.

Monthly Means T2m(K) Observed & Forecasts



Top row: Observed anomaly

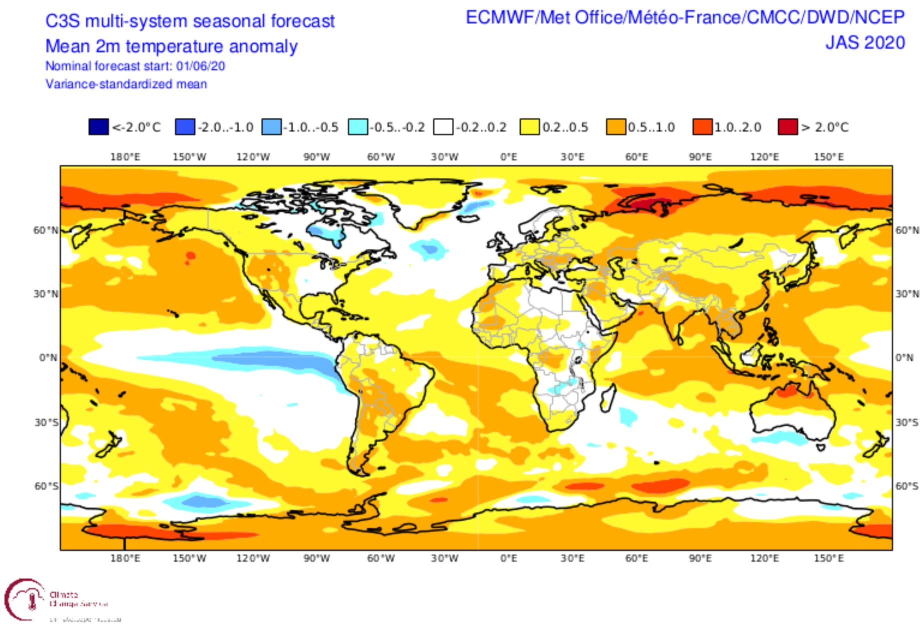
Middle row: CFSv2 seasonal forecasts from the initial conditions from the month prior to the target season.

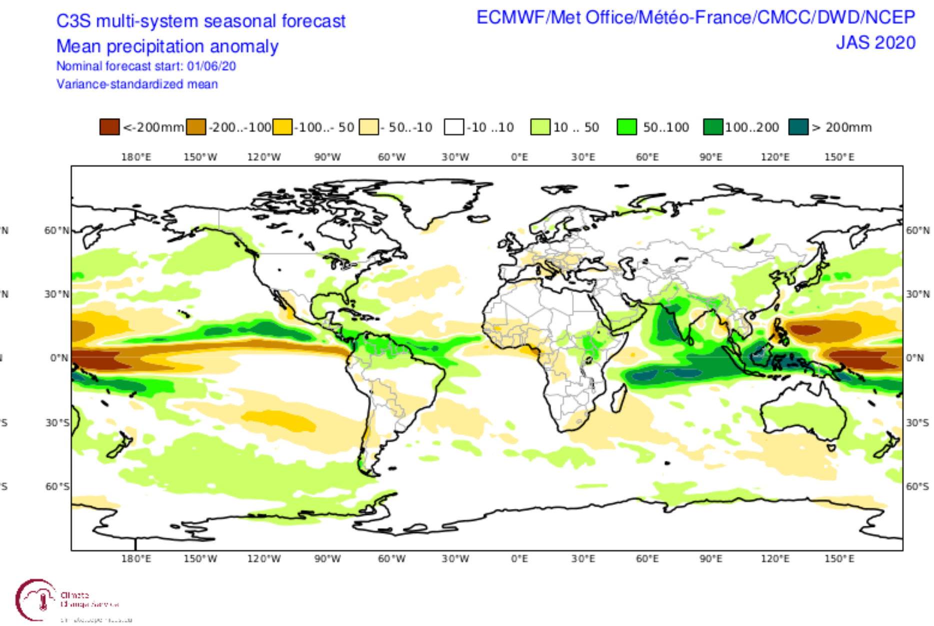
Bottom row: CFSv2 monthly forecasts from the last three days of the month prior to the target month.

Seasonal Forecasts from other multi-model systems and linear models

C3S Seasonal Forecast

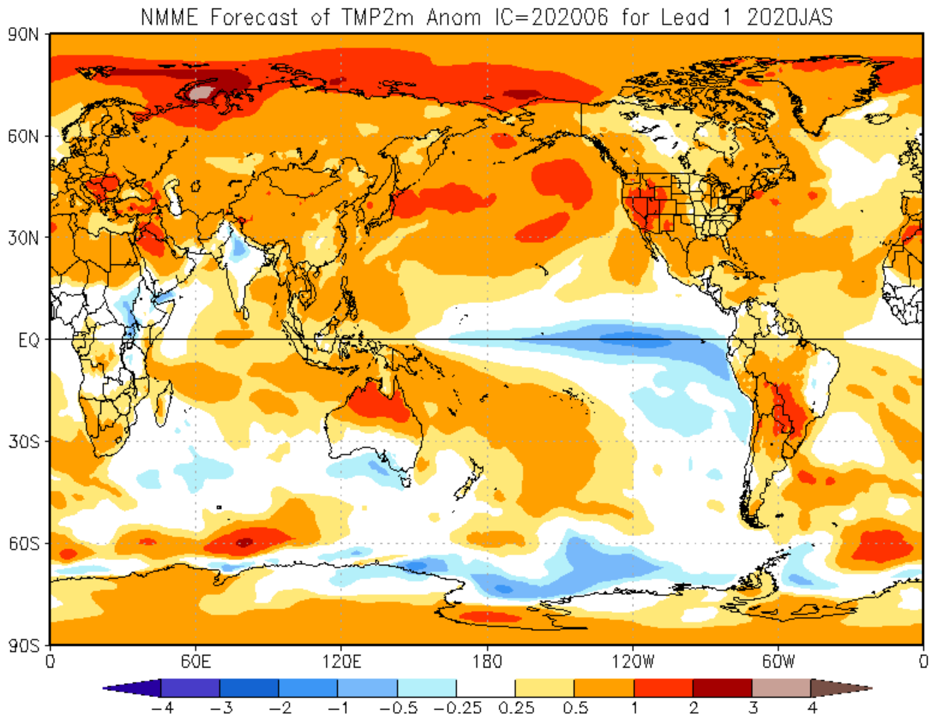
(https://climate.copernicus.eu/charts/c3s_seasonal/)

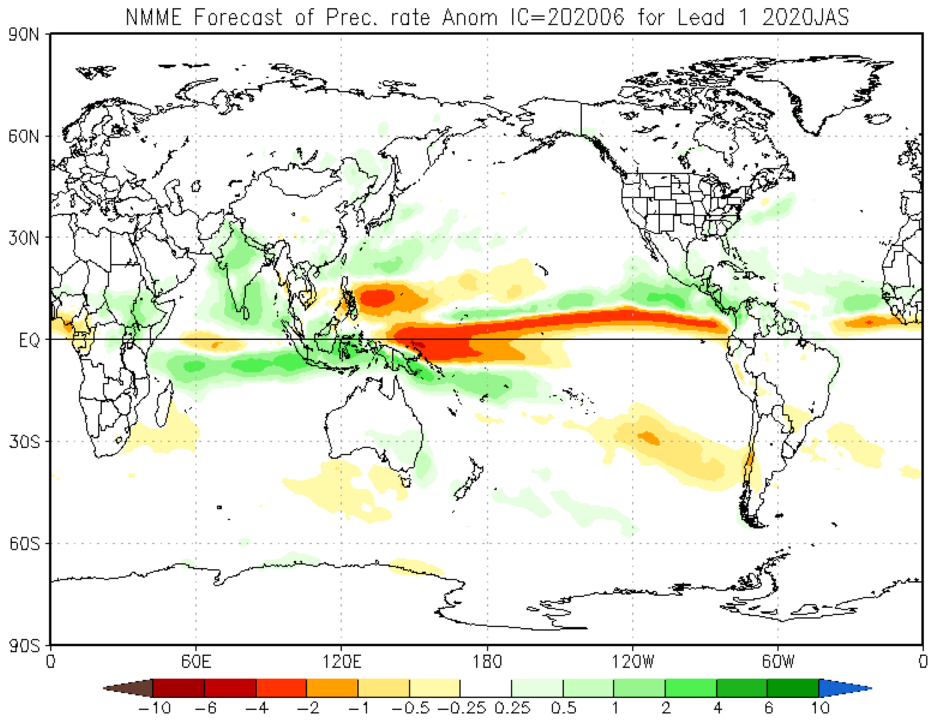




North American Multi-Model Ensemble Seasonal Forecast

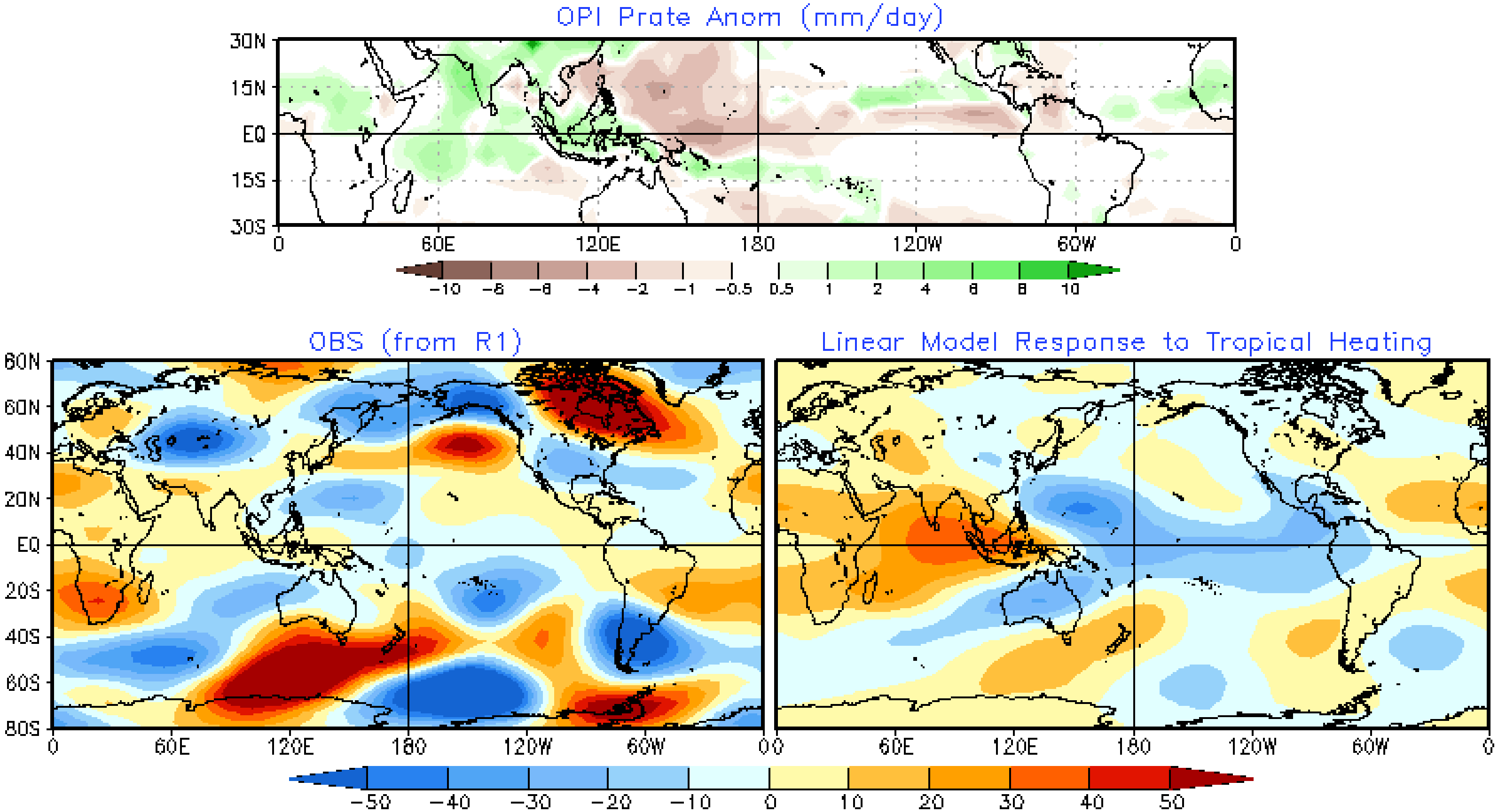
(https://www.cpc.ncep.noaa.gov/products/NMME/)





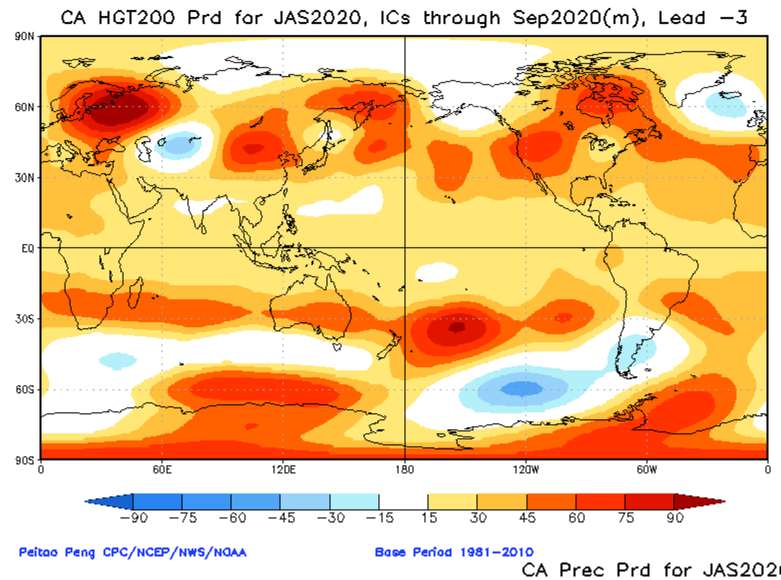
200mb Height from Linear Model

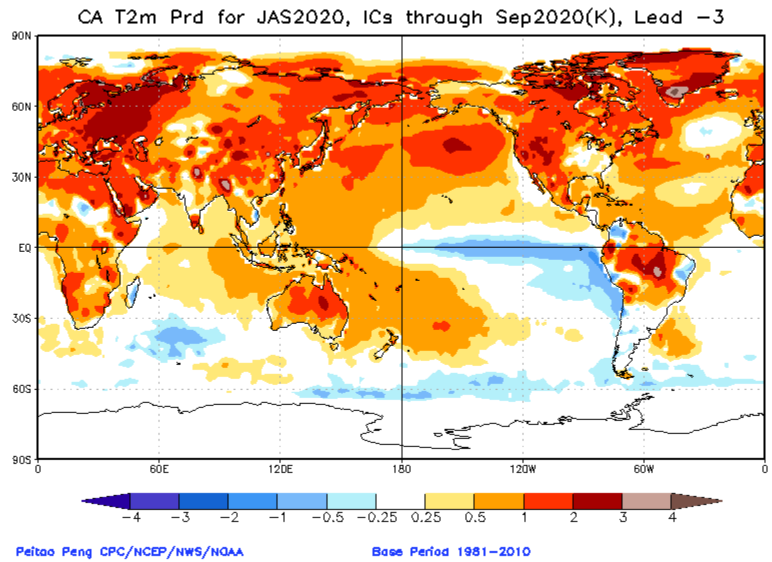
JJA2020 200mb Eddy HGT(m)
OBS vs. Linear Model Response to Tropical Heating
Heating is converted from Prate in 15S–15N

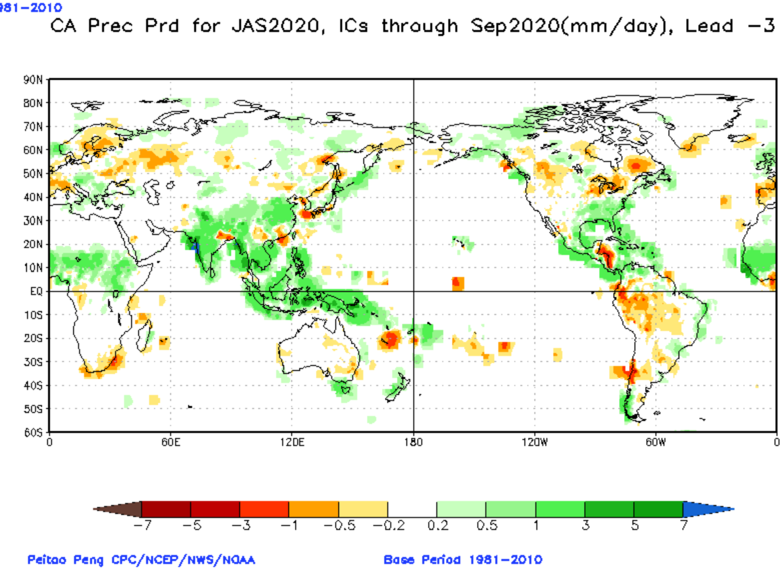


Pattern COR: global=0.28, tropics(30S–30N)=0.47

Seasonal Forecasts from the Constructed Analog Model





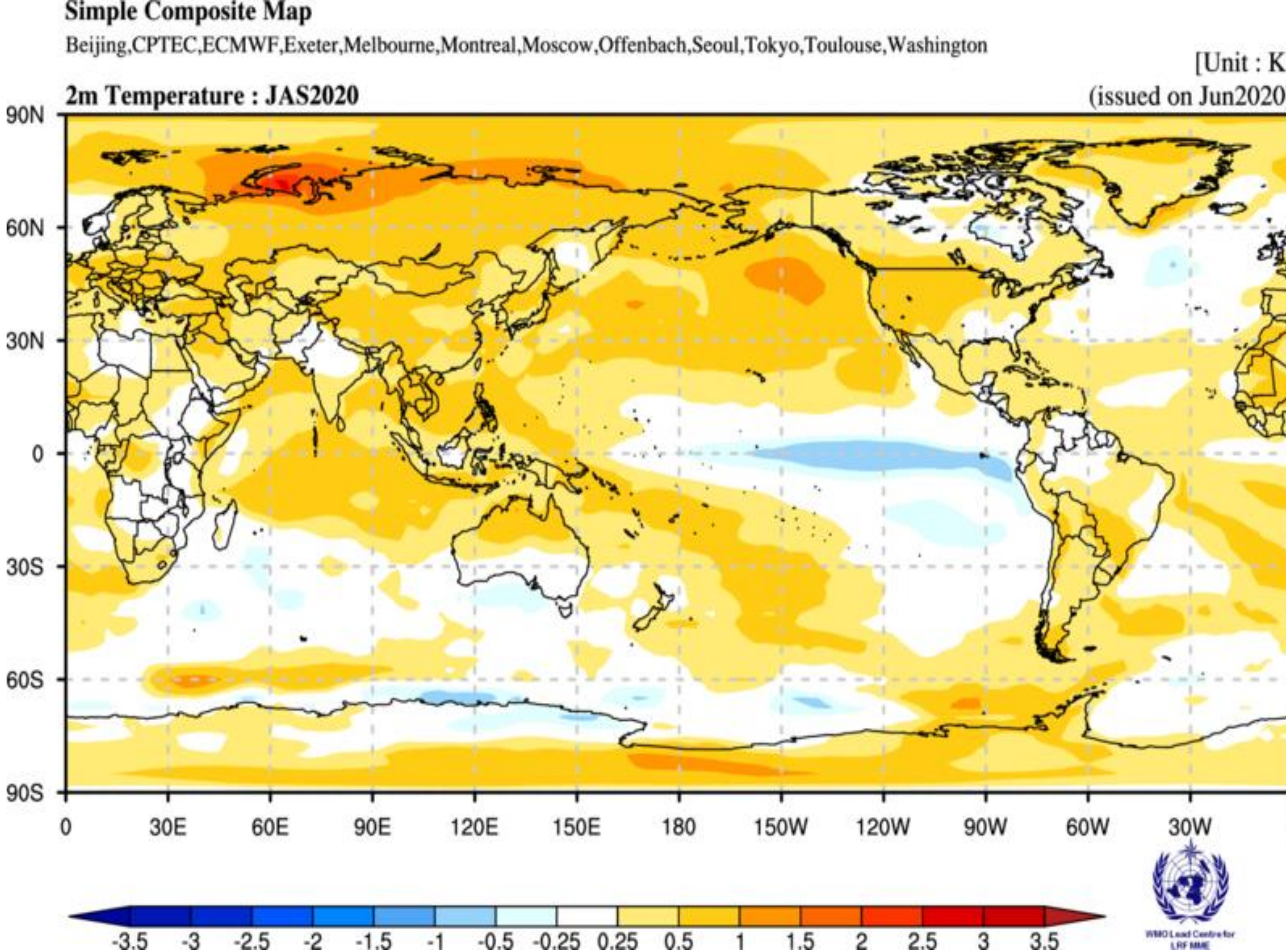


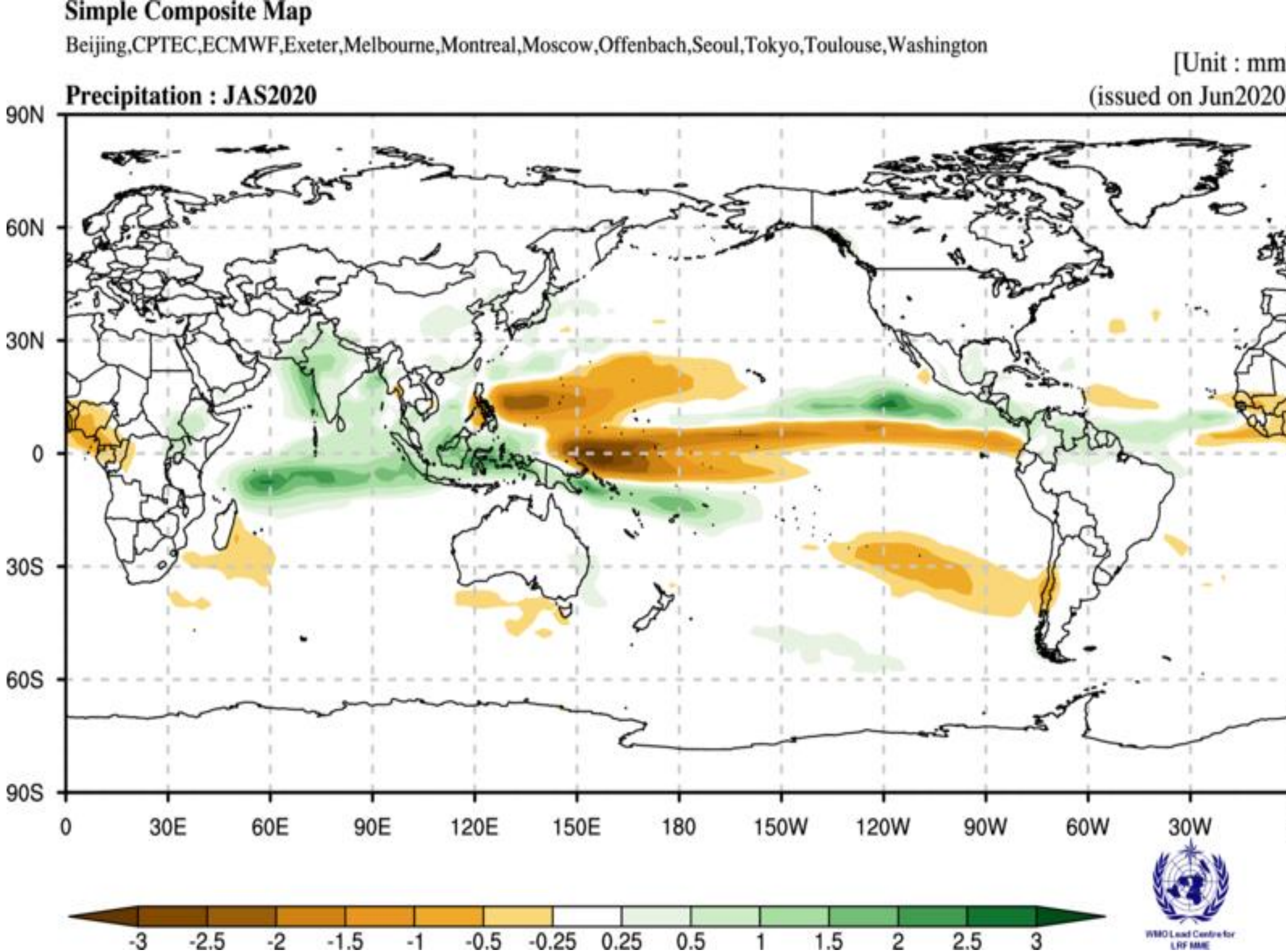
Seasonal Forecasts from WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME)

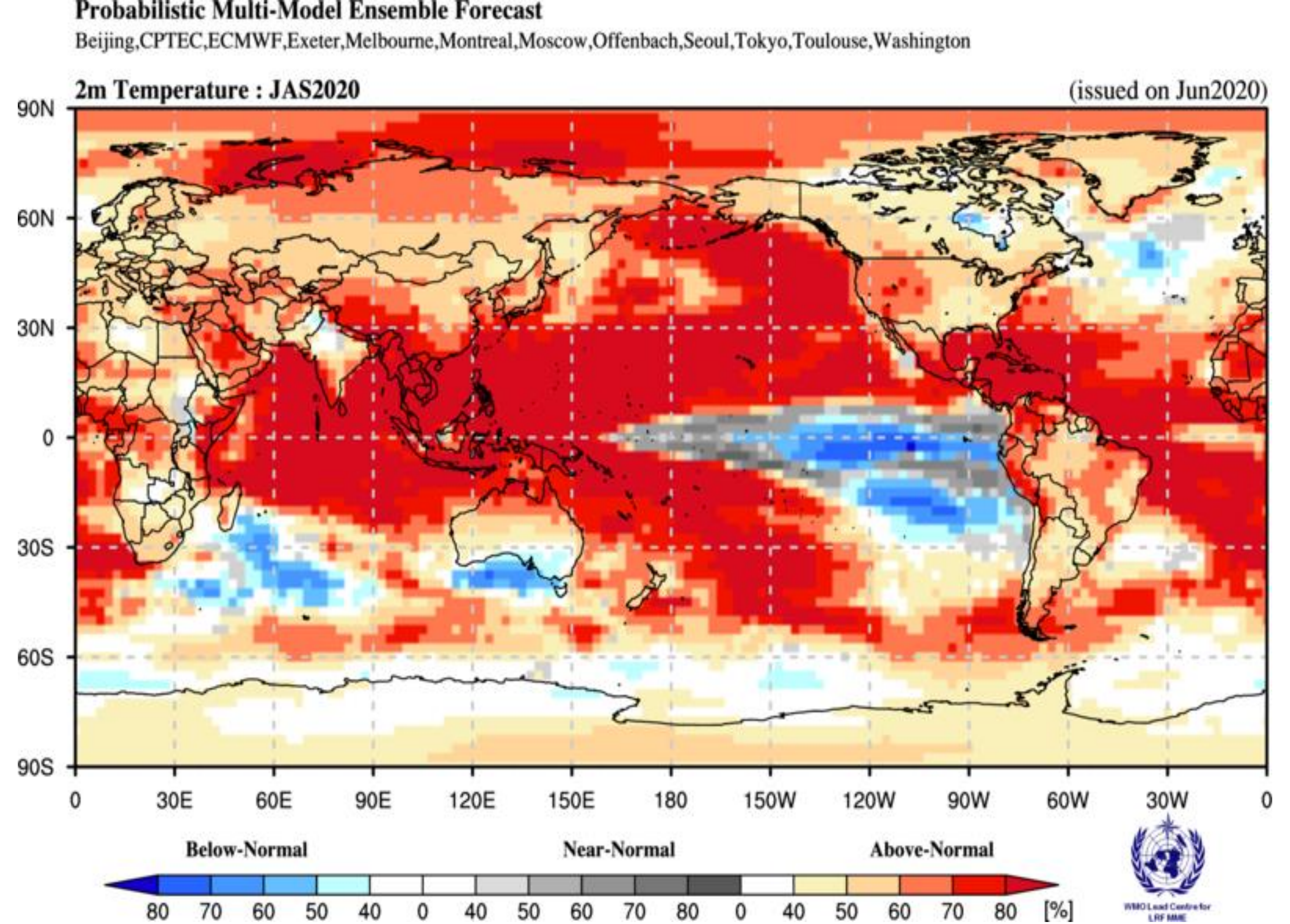
https://www.wmolc.org/

- LC-LRFMME seasonal forecast are based on forecasts provided by WMO recognized Global Producing Centers (GPCs) for Long-Range Forecasts to the LC-LRFMME. Contribution of all GPCs is acknowledged.
- Seasonal forecasts from GPCs are merged into a multi-model ensemble forecast.
- LC-LRFMME forecasts are based on GPC seasonal forecast systems run during the first week of the month for the next season. For example, forecasts runs in first week of January for the seasonal mean of February-March-April.
- Forecasts in slides 42-45 are from the Lead Center.
- For latest seasonal outlook guidance see http://www.wmo.int/pages/prog/wcp/wcasp/LC-LRFMME/index.php

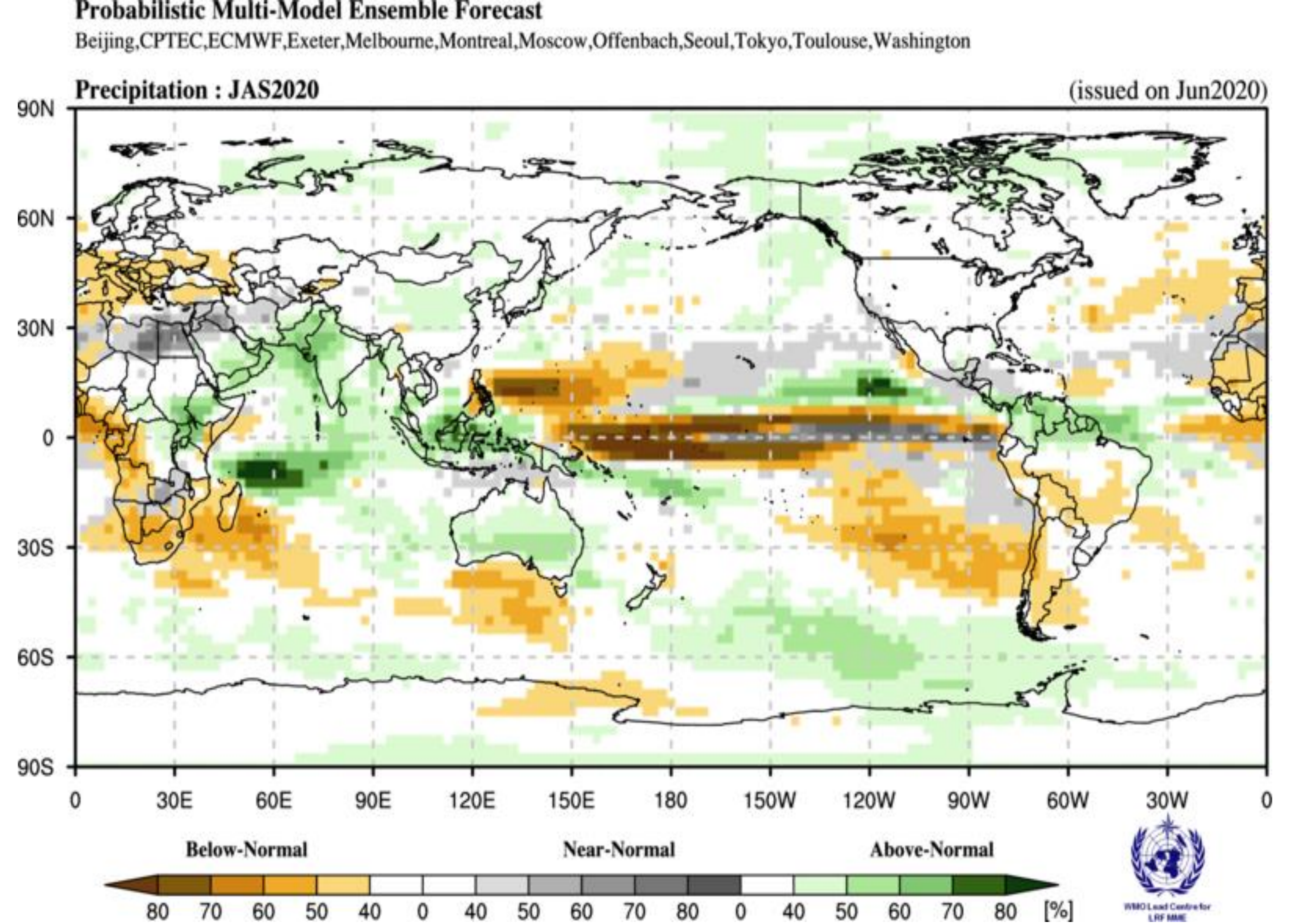
- *For more information see visit Lead Center website; also see Graham, R., and Co-authors, 2011: New perspectives for GPCs, their role in the GFCS and a proposed contribution to a 'World Climate Watch'. Climate Research, **47**, 47-55.*


Simple Composite Map
Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington
[Unit : K]
2m Temperature : JAS2020
(issued on Jun2020)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-3.5 -3 -2.5 -2 -1.5 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5
WMO Lead Centre for LRF MME


Simple Composite Map
Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington
[Unit : mm]
Precipitation : JAS2020
(issued on Jun2020)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
-3
-2.5
-2
-1.5
-1
-0.5
-0.25
0.25
0.5
1
1.5
2
2.5
3
WMO Lead Centre for LRF MME



Probabilistic Multi-Model Ensemble Forecast
Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington
2m Temperature : JAS2020
(issued on Jun2020)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
Below-Normal
Near-Normal
Above-Normal
80 70 60 50 40 0 40 50 60 70 80 0 40 50 60 70 80 [%]
WMO Lead Centre for LRF MME


Probabilistic Multi-Model Ensemble Forecast
Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Seoul,Tokyo,Toulouse,Washington
Precipitation : JAS2020
(issued on Jun2020)
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
Below-Normal
Near-Normal
Above-Normal
80 70 60 50 40 0 40 50 60 70 80 0 40 50 60 70 80 [%]

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: NCDC daily OI 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 from CFSv2 (provided by Dr. Bhaskar Jha/CPC)
  - 18 members
- All above seasonal mean anomalies are based on 1999-2010 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)