Attribution of Seasonal Climate Anomalies
June-July-August 2021

(https://www.cpc.ncep.noaa.gov/products/people/mchen/AttributionAnalysis/)
Summary of Observed Conditions and Outlooks

- SST anomalies were near-normal over tropical Pacific and Indian Ocean; N Pacific Ocean remained on the warm side (slide 4).
- In general, the large-scale distribution of SST anomalies were predicted well (slide 10), while precipitation anomalies over the region extending from the tropical W. Pacific to E. Indian Ocean were not well predicted (slides 10, 11, 35, 36, 38 & 39).
- The average of JJA2021 height anomalies had a weak projection on positive phase of AO pattern. The AMIP simulation and initialized CFSv2 forecasts didn’t predict the z200 negative anomalies over the polar region and trough positions over the central Asia and E Canada, that led to errors in forecasting cold anomalies there (slides 12, 13, 15, 16).
- The AMIP simulation and the initialized forecasts predicted the observed precipitation positive (negative) anomalies over the southeast (northwest) US (slide 14) and cold anomalies over the central US (slide 16).
Observed Seasonal Anomalies

Global and North America
Observed Anomaly JJA2021

SST(K)

Map showing observed SST anomalies for the JJA2021 season with color scale ranging from -3 to 3.
Observed Anomaly JJA2021

Prec(mm/day)

T2m(K)

z200(m)
CPC Seasonal Outlooks and NMME Forecasts

Temperature

Precipitation

Temp nonEC HSS=38

Prec nonEC HSS=44

For the rationale behind CPC outlooks see: [https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2021/202105_PMD90D](https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2021/202105_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 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).
JJA2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)

Obs

Seasonal Fcst  AC(GL)=0.603

Reconstructed Fcst  AC(GL)=0.719
JJA2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)

- Obs
- AMIP: AC(TRP)=0.198
- Seasonal Fcst: AC(TRP)=0.247
- Reconstructed Fcst: AC(TRP)=0.300
JJA2021 Observed & Model Simulated/Forecast
Ensemble Average Anomalies z200(m)

Observation

AMIP Simulation
AC(GL)=0.163

Seasonal Fcst
AC(GL)=0.658

Reconstructed Fcst
AC(GL)=0.745
JJA2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

Observation

AMIP Simulation

AC(GL)=0.197

Seasonal Fcst

Reconstructed Fcst

AC(GL)=0.568

Climate Prediction Center/NCEP/NWS/NOAA
JJA2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)

Observation

AMIP Simulation

Seasonal Fcst

Reconstructed Fcst

AC=0.319

AC=0.160

AC=0.364
JJA2021 Observed & Model Simulated/Forecast Ensemble Average Anomalies z200(m)

Observation

AMIP Simulation
AC = -0.20

Seasonal Fcst
AC = 0.813

Reconstructed Fcst
AC = 0.896
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.

JJA2021 Anomaly Correlation for Individual AMIP Simulation with Observation — z200(20N–90N)
Observed & AMIP Ensemble Average Anomalies
JJA2021 z200(m) 18 runs/worst 2 runs/best 2 runs

Obs

18 runs  AC=-0.00(20N-90N)

worst 2 runs  AC=-0.25(20N-90N)

best 2 runs  AC=0.285(20N-90N)
JJA2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation — z200 (20N–90N)
Observed & CFSv2 Forecast Ensemble Average Anomalies
JJA2021 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast
JJA2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- Prec(NA)/SST(30S–30N)

- **ensemble mean**

**Prec Seasonal Fcst**

**Prec Reconstructed Fcst**

**SST Seasonal Fcst**

**SST Reconstructed Fcst**
Observed & CFSv2 Forecast Ensemble Average Anomalies
JJA2021 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast
Observed & CFSv2 Forecast Ensemble Average Anomalies
JJA2021 Prec(mm/day) 40 runs/worst 4 runs/best 4 runs

Reconstructed Forecast

AC=0.364

AC=-0.04

AC=0.334
JJA2021 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S–30N)
Observed & CFSv2 Forecast Ensemble Average Anomalies
JJA2021 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

Obs

40 runs

AC=0.376

worst 4 runs

AC=-0.02

best 4 runs

AC=0.615
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 Prec(mm/day) Observed & Forecasts
(at long leads)

Top row: Observed anomaly

Middle row: CFSv2 monthly forecasts from the initial conditions near 10\textsuperscript{th} day of the month prior to the target month.

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20\textsuperscript{th} day 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.
Monthly Means T2m(K) Observed & Forecasts

Top row: Observed anomaly

Middle row: CFSv2 monthly forecasts from the initial conditions near 10\textsuperscript{th} day of the month prior to the target month.

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20\textsuperscript{th} day of the month prior to the target month.
Seasonal Forecasts from WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME)

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

Simple Composite Map
Beijing, CPTEC, ECMWF, Exeter, Melbourne, Montreal, Moscow, Seoul, Tokyo, Toulouse, Washington

2m Temperature: JJA2021
(issued on May 2021)

Precipitation: JJA2021
(issued on May 2021)
LC-LRFMM Seasonal Forecasts (probabilities)  
(https://www.wmolc.org/)

Probabilistic Multi-Model Ensemble Forecast
Beijing,CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Seoul,Tokyo,Toulouse,Washington

- 2m Temperature: JJA2021 (issued on May 2021)
- Precipitation: JJA2021 (issued on May 2021)
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

OBS vs. Linear Model Response to Tropical Heating
Heating is converted from Prate in 15S–15N

Pattern COR: global=0.27, tropics(30S–30N)=0.47
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.
• 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.
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 from CFSv2 (provided by Dr. Bhaskar Jha/CPC)**
  - 18 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)**