Attribution of Seasonal Climate Anomalies November-December-January 2021

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

- Below normal SST anomalies continued in the equatorial central and eastern Pacific (La Nina conditions); the equatorial Atlantic and N Pacific Ocean remained on the warm side (slide 4). In general, the large-scale distribution of SST anomalies was predicted well (slide 10);
- In general, the large scale distribution of wet and dry precipitation anomalies in the equatorial eastern Indian Ocean, the Maritime Continent and the equatorial western, central Pacific Ocean (a reflection of La Niña conditions) were predicted well in the initialized CFSv2 and other MME models (slides 11, 35, 36, 38 & 39).
- The initialized CFSv2 forecasts predicted the observed 200mb height anomalies globally leading to a good prediction in the large-scale distribution of temperature anomalies. The positive and negative height anomalies over the PNA region were predicted well and resulted in skillful prediction of temperature anomalies over the North America regions (slides 12, 13, 15, &16).
- The initialized CFSv2 forecasts predicted dry precipitation anomalies over California and the southern US (slide 14); the monthly mean forecasts with the shortest leads did not add to the skill (slide 30, 31); the observed cold anomalies over the eastern US in Jan2022 were not predicted with the shortest leads either (slide 32, 33).
Observed Seasonal Anomalies

Global and North America
Observed Anomaly NDJ2021/2022

SST(K)

![Map showing observed anomaly NDJ2021/2022 with temperature anomalies on a color scale from -3 to 3.]
Observed Anomaly NDJ2021/2022

Prec(mm/day)

T2m(K)

z200(m)
CPC Seasonal Outlooks and NMME Forecasts

Temperature

Precipitation

Temp nonEC
HSS=55

CPC

Prec nonEC
HSS=5

For the rationale behind CPC outlooks see: [https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2021/202110_PMD90D](https://www.cpc.ncep.noaa.gov/products/archives/long_lead/PMD/2021/202110_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).
NDJ2021/2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies SST(K)

- Obs
- Seasonal Fcst, AC(GL)=0.721
- Reconstructed Fcst, AC(GL)=0.809
NDJ2021/2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec (mm/day)

- **Obs**
- **AMIP**
  - AC(TRP)=0.276
- **Seasonal Fcst**
  - AC(TRP)=0.598
- **Reconstructed Fcst**
  - AC(TRP)=0.607
NDJ2021/2022 Observed & Model Simulated/Forecast
Ensemble Average Anomalies T2m(K)

Observation

AMIP Simulation
AC(GL)=0.458

Seasonal Fcst
AC(GL)=0.518

Reconstructed Fcst
AC(GL)=0.629
NDJ2021/2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies Prec(mm/day)

Observation

AMIP Simulation

Seasonal Fcst

Reconstructed Fcst
NDJ2021/2022 Observed & Model Simulated/Forecast Ensemble Average Anomalies T2m(K)

Observation

AMIP Simulation  AC=0.298

Seasonal Fcst  AC=0.514

Reconstructed Fcst  AC=0.624
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.
NDJ2021/2022 Anomaly Correlation for Individual AMIP Simulation with Observation -- z200(20N–90N)
Observed & AMIP Ensemble Average Anomalies
NDJ2021/2022 z200(m) 18 runs/worst 2 runs/best 2 runs

18 runs  AC=0.465(20N–90N)

worst 2 runs  AC=0.018(20N–90N)

best 2 runs  AC=0.530(20N–90N)
NDJ2021/2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation —— z200 (20N–90N)

Seasonal Fcst

Reconstructed Fcst

model members

model members
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 z200(m) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

AC=0.474(20N−90N)
AC=−0.07(20N−90N)
AC=0.681(20N−90N)
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 z200(m) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

AC = 0.654 (20N–90N)
NDJ2021/2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation — Prec(NA)/SST(30S–30N)
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 Prec (mm/day) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 Prec (mm/day) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

AC = 0.172
AC = -0.11
AC = 0.299
NDJ2021/2022 Anomaly Correlation for Individual CFSv2 Forecast with Observation -- T2m(NA)/SST(30S–30N)

**T2m Seasonal Fcst**

- **Correlation**
  - 0–1 d–L
  - 2–3 d–L
  - 4–5 d–L
  - 6–7 d–L
  - 8–9 d–L
- **Model Members**
  - 4, 8, 12, 16, 20, 24, 28, 32, 36, 40
- **Ensemble Mean**

**T2m Reconstructed Fcst**

- **Correlation**
  - 0–1 d–L
  - 2–3 d–L
  - 4–5 d–L
  - 6–7 d–L
  - 8–9 d–L
- **Model Members**
  - 4, 8, 12, 16, 20, 24, 28, 32, 36, 40
- **Ensemble Mean**

**SST Seasonal Fcst**

- **Correlation**
  - 0–1 d–L
  - 2–3 d–L
  - 4–5 d–L
  - 6–7 d–L
  - 8–9 d–L
- **Model Members**
  - 4, 8, 12, 16, 20, 24, 28, 32, 36, 40

**SST Reconstructed Fcst**

- **Correlation**
  - 0–1 d–L
  - 2–3 d–L
  - 4–5 d–L
  - 6–7 d–L
  - 8–9 d–L
- **Model Members**
  - 4, 8, 12, 16, 20, 24, 28, 32, 36, 40
- **Ensemble Mean**
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 T2m(K) 40 runs/worst 4 runs/best 4 runs
Seasonal Forecast

Climate Prediction Center/NCEP/NWS/NOAA
Observed & CFSv2 Forecast Ensemble Average Anomalies
NDJ2021/2022 T2m(K) 40 runs/worst 4 runs/best 4 runs
Reconstructed Forecast

40 runs
AC=0.624

worst 4 runs
AC=0.203

best 4 runs
AC=0.724
Monthly Means Prec(mm/day) Observed & Forecasts

Monthly NDJ2021/2022 Prec(mm/day) Observed & Forecasts (at shortest leads)

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 NDJ2021/2022 Prec(mm/day) Observed & Forecasts (at long leads)

Top row: Observed anomaly

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

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20th day of the month prior to the target month.
<table>
<thead>
<tr>
<th>Month</th>
<th>Observed anomaly</th>
<th>CFSv2 Seasonal Forecast</th>
<th>CFSv2 Monthly Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 2021</td>
<td>OBS</td>
<td>AC=0.67 IC: 22-31 Oct</td>
<td>AC=0.59 IC: 29-31 Oct</td>
</tr>
<tr>
<td>Dec 2021</td>
<td>OBS</td>
<td>AC=0.28 IC: 22-31 Oct</td>
<td>AC=0.65 IC: 28-30 Nov</td>
</tr>
<tr>
<td>Jan 2022</td>
<td>OBS</td>
<td>AC=0.04 IC: 22-31 Oct</td>
<td>AC=0.16 IC: 29-31 Dec</td>
</tr>
<tr>
<td>NDJ 2021/22</td>
<td>OBS</td>
<td>AC=0.51 IC: 22-31 Oct</td>
<td>AC=0.61 IC:</td>
</tr>
</tbody>
</table>

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 (at long leads)

Top row: Observed anomaly

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

Bottom row: CFSv2 monthly forecasts from the initial conditions near 20th 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.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.
LC-LRFMM Seasonal Forecasts (ensemble means)

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

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

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

2m Temperature: NDJ2021
Issued on Oct 2021

Precipitation: NDJ2021
Issued on Oct 2021
Seasonal Forecasts from other multi-model systems and linear models
C3S Seasonal Forecast
(https://climate.copernicus.eu/charts/c3s_seasonal/)

C3S multi-system seasonal forecast
Mean 2m temperature anomaly
Nominal forecast start: 01/10/21
Variance-standardized mean

C3S multi-system seasonal forecast
Mean precipitation anomaly
Nominal forecast start: 01/10/21
Variance-standardized mean

Climate Prediction Center/NCEP/NWS/NOAA
North American Multi-Model Ensemble Seasonal Forecast
(https://www.cpc.ncep.noaa.gov/products/NMME/)
200mb Height from Linear Model

NDJ2021–22 200mb Eddy HGT(m)
OBS vs. Linear Model Response to Tropical Heating
Heating is converted from Prate in 15S–15N

OPI Prate Anom (mm/day)

OBS (from R1)  Linear Model Response to Tropical Heating

Pattern COR: global=0.29, tropics(30S–30N)=0.47
Seasonal Forecasts from the Constructed Analog Model

CA HGT200 Prd for NDJ2021/2022, ICs through Jan2022(m), Lead -3

CA T2m Prd for NDJ2021/2022, ICs through Jan2022(K), Lead -3

CA Prec Prd for NDJ2021/2022, ICs through Jan2022(mm/day), Lead -3
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.
• 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)