SST Impact on U. S. Winter Seasonal Climate in CFSv2 AMIP Simulations

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Abstract

The analysis is focus on the role of SST variability on winter precipitation and T2m over contiguous United States (CONUS) using observation and CFSv2 model experiments. The tropical SST impact is mainly confined to the southeastern and northern parts of CONUS, which is different from the impact of classical ENSO. The model is able to simulate observed feature of observation of winter precipitation, T2m and upper level circulation pattern over CONUS. The tropical heat anomaly may influence the winter precipitation and T2m anomaly in the southeastern and northern parts of CONUS via exciting a teleconnection from the west tropical Pacific Ocean to the North Atlantic Ocean via North Pacific and North America. This connection may provide secondary source of predictability of the winter precipitation in CONUS other than ENSO.

Data and model simulation

The monthly mean OI version 2 (OIv2) SST starting from 1981 to 2022 (Reynolds et al. 2002). The Niño3.4 index is defined as the averaged SSTA in the region (5°S−5°N, 170°W−120°W) to represent ENSO. SSTA averaged in (20°S-20°N, 40°-110°E) is used to represent the Indian Ocean Basin mode (IOBM), while the difference of averaged SSTAs between the western (10°S-10°N, 50°-70°E) and eastern (10°S-0°, 90°-110°E) Indian Ocean is used to represent the Indian Ocean Dipole mode (IOD) (Saji et al. 1999). Monthly mean geopotential heights at (HT200) data are derived from the reanalysis of the National Center for Environmental Prediction (NCEP; R1) at a 2.5° X 2.5° resolution for the period 1981 to 2022. Monthly mean precipitations are from a global satellite-rain gauge merged product at a 2.5° × 2.5° spatial resolution starting from 1981-2020 (Janowiak and Xie 1999). The monthly T2m over land is used starting from 1981-2022 (Fan and Hugg 2008).The anomalies are referred to climatologies of 1991-2020.

To examine the impact of global and regional SST on the predictability and variability of North American winter precipitation and T2m, AMIP experiments are designed and analyzed. In the AMIP experiments, the atmospheric general circulation model is the atmospheric component (Global Forecast System; GFS) of CFSv2 (Saha et al. 2014). The experiments forced by observed global and tropical Indian Ocean (20°S-20°N, 50°-110°E) SST are referred to as GOGA and IOGA are integrated from January 1981 to February 2022 with 18 ensemble members with slightly different atmospheric initial conditions.

Results from observation and model simulations

- Observed, GOGA and IOGA simultaneous regression of winter (DJF) precipitation anomalies with the (a) Niño3.4, (b) IOBM, and (c) IOD SSTA indices. Overall observed regression pattern (north-south) in CONUS, the area with high regression is the largest for Niño3.4 index, the smallest for the regression with the IOD index, and in between for the regressions with the IOBM index.
- GOGA regression north-south pattern for Niño3.4 is similar to observation, but for IOBM and IOD regression pattern is opposite to observation.
- IOGA regression pattern with Niño3.4 is opposite to observation, but with IOBM and IOD is similar to observation.

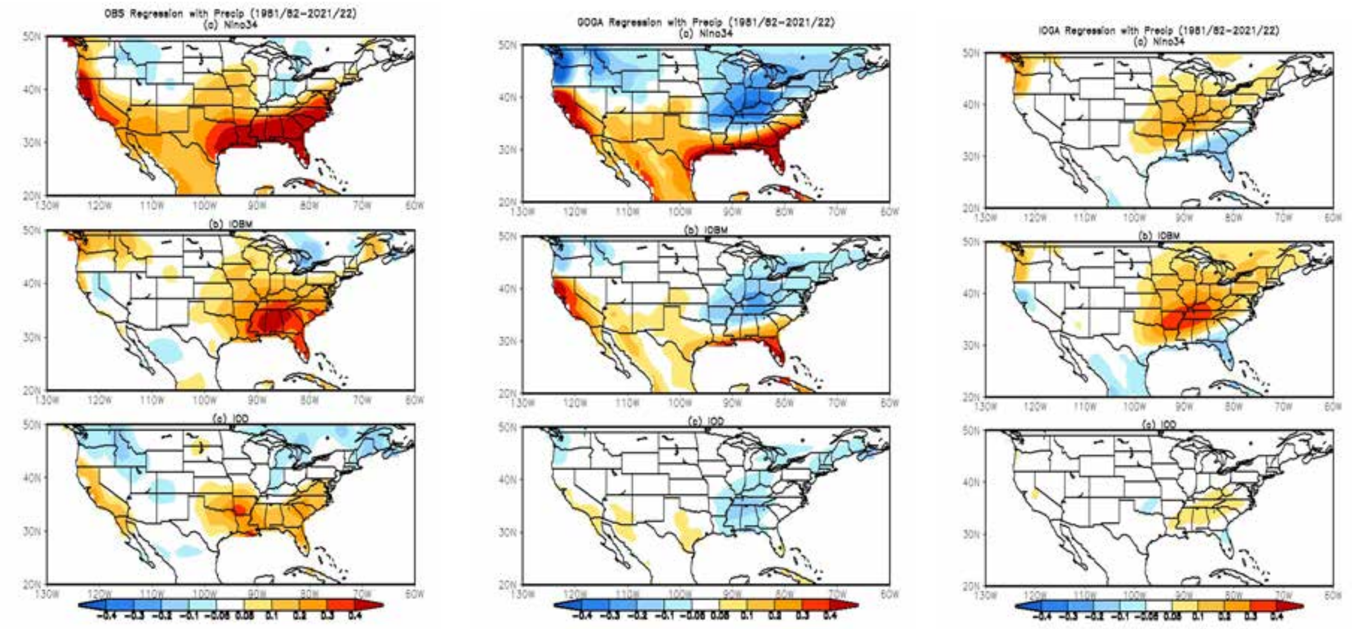

Figure 1: Observed , GOGA and IOGA simulantinous regression of DJF precipitation anomaly with (a) Niño3.4, (b) IOBM, and (c) IOD indices DJF 1981/82-2021/22

- The observed, POGA and IOGA relations between winter precipitation variation in the southeastern and northern parts of CONUS and the tropical and Pacific Ocean SSTAs are further confirmed in Figure 2 (shading). Here, the precipitation anomaly averaged in (30°-40°N, 80°-90°W; the black rectangle) is used to represent the southeastern CONUS. The positive regression pattern in the tropical Ocean and the central and eastern tropical Pacific Ocean (shading) are consistent with the regression pattern shown in Fig. 1
- These diagnoses suggest that for the winter precipitation anomalies in the southeastern and northern parts of CONUS, tropical ocean basin-wide warming or cooling may play a important role than ENSO in some years. Tropical ocean heat anomaly carries on its influence on the winter precipitation anomaly in the southeastern CONUS through exciting a teleconnection from the west tropical Ocean to the North Atlantic Ocean via North Pacific and North America.

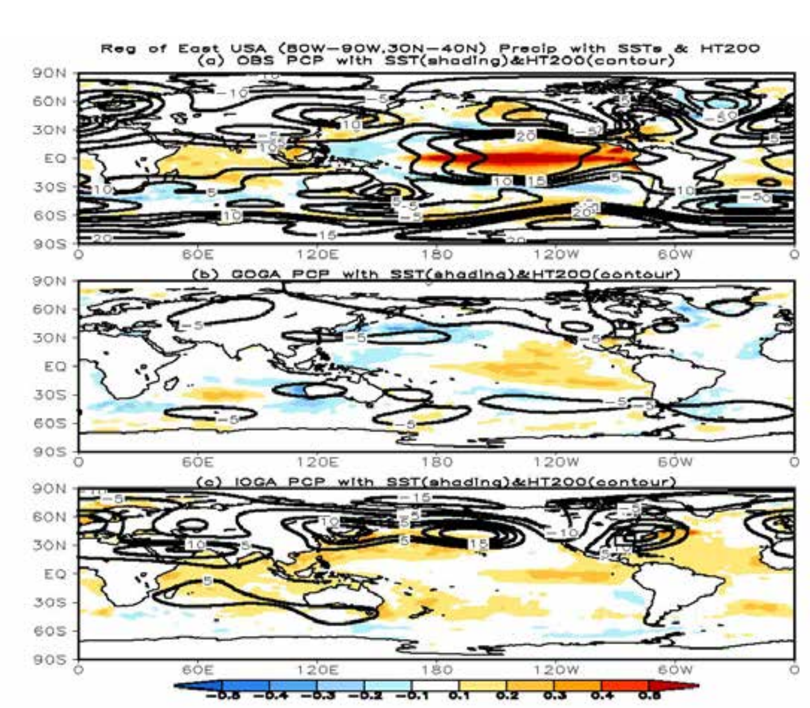

Figure 2: Observed, GOGA and IOGA simulantinous regression of DJF SST (shading) and HT200 (contour) anomalies with eastern U. S. precipitation indices in DJF 1981/82-2021/22.

DJF 2018/2019 and 2019/2020 precipitation anomaly: These diagnoses further suggest that for the winter precipitation anomalies in the southeastern and northern parts of CONUS, tropical ocean basin-wide warming or cooling may play a more important role than ENSO in some years. Tropical ocean heat anomaly carries on its influence on the winter precipitation anomaly in the southeastern CONUS through exciting a teleconnection from the Indian Ocean to the North Pacific and North America (like PNA).

OBS- Weak El Nino and borderline IOBM
GOGA-Not like OBS response over SE US (opposite sign)
IOGA- Like OBS over SE and not like over NW US

OBS- Borderline El Nino and large IOBM
GOGA-Not like OBS response over SE US (opposite sign)
IOGA- Better, Like OBS over SE and NW US (high regression)

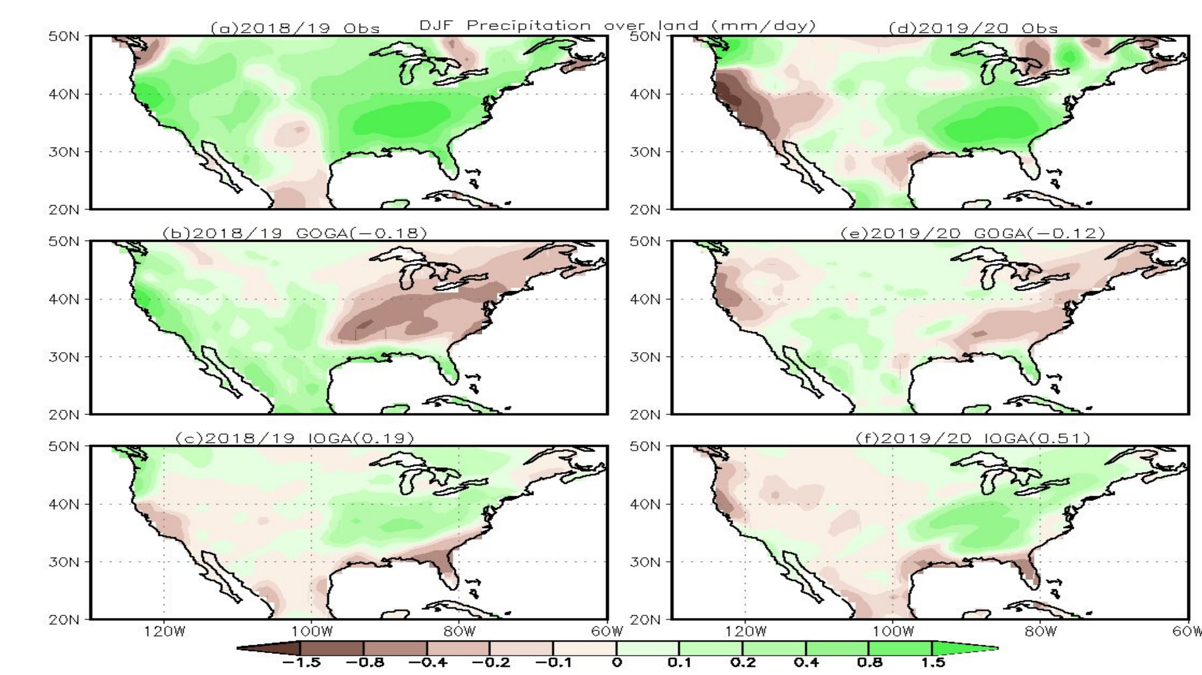

Fig. 3 Precipitation DJF observed, GOGA and IOGA 2018/2019 (left panel) and 2019/2020 (right panel)

OBS- Weak El Nino and borderline IOBM
GOGA-Not like OBS response.
IOGA- Not like OBS most of parts of US except some parts of NW

OBS- Borderline El Nino and large IOBM
GOGA- like OBS response over except some parts of NW US.
IOGA- Better, Like OBS over US (high regression)

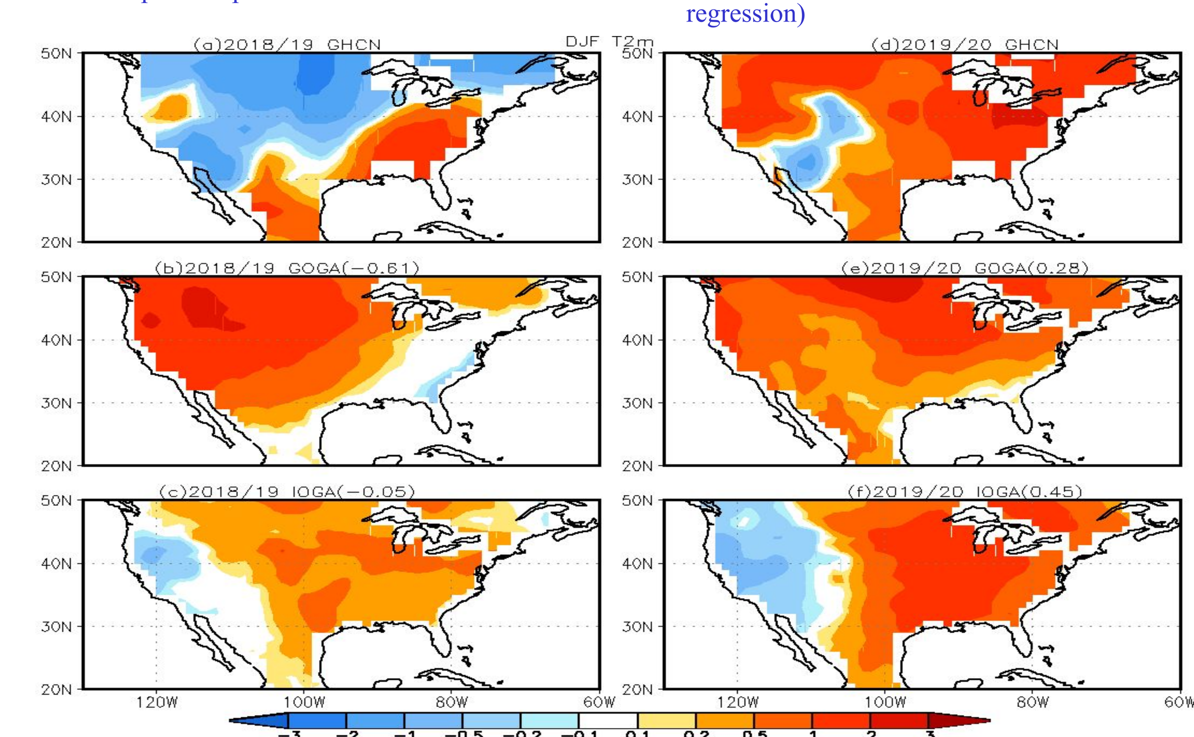

Fig. 4 Same as Figure 3, but for T2m .

OBS- Weak El Nino and borderline IOBM
GOGA- Response is opposite to OBS
IOGA- Like OBS with same sign (high regression)

OBS- Borderline El Nino and large IOBM
GOGA- Response is not good
IOGA- Like OBS with same sign (high regression)

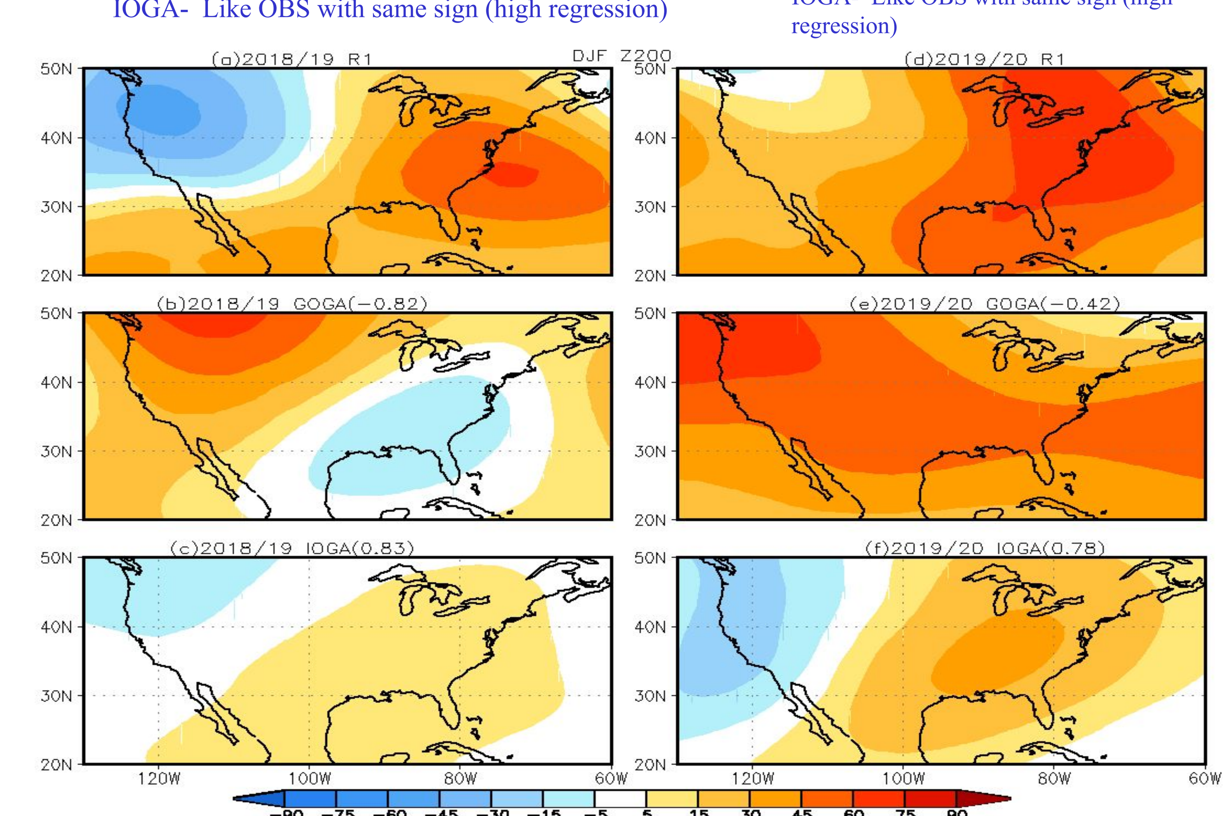

Fig. 5: Same as Fig. 3, but for HT200.

DJF precipitation correlation with observation (left panel) and SNR (right panel) for 1981/82-2021/22. Signal to Noise Ratio (SNR) is defined as the ratios of the standard deviations of the ensemble mean to the standard deviation of the departure of each ensemble member from its ensemble mean. It is noted that large SNR is located in southeastern, Pacific coast and southern parts of CONUS with high predictability (consistent with ENSO response) for GOGA. The large SNR is present in northern portions of Great plains for IOGA. The spatial pattern of correlation is consistent with SNR.

DJF precipitation correlation DJF precipitation SNR

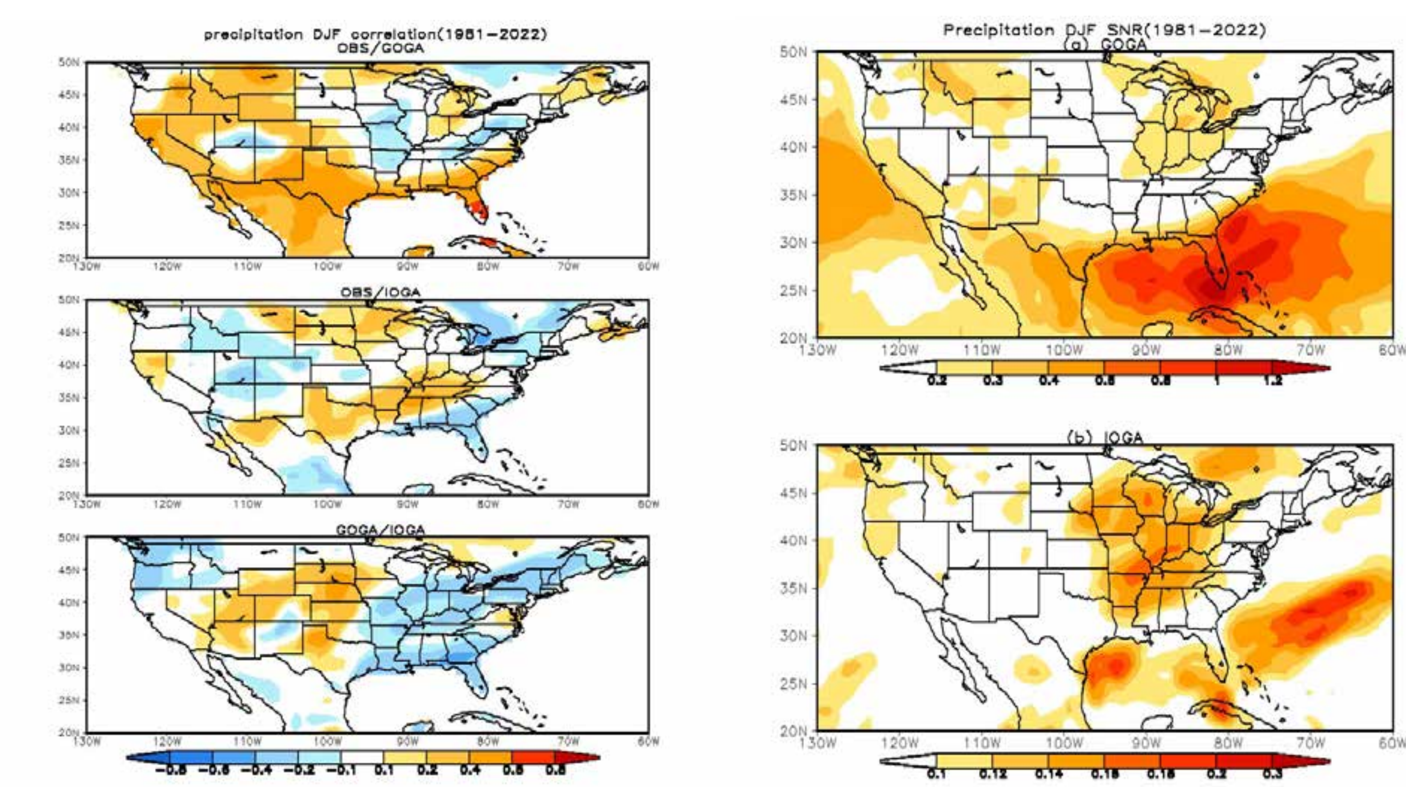

Fig. 6: DJF precipitation correlation and SNR for 1981-2022.

- DJF T2m with observation (left panel) and SNR (right panel) for 1981-2022. The large T2m SNR is consistent with precipitation over northern part of Great Plains for IOGA.

DJF T2m correlation **DJF T2m SNR**

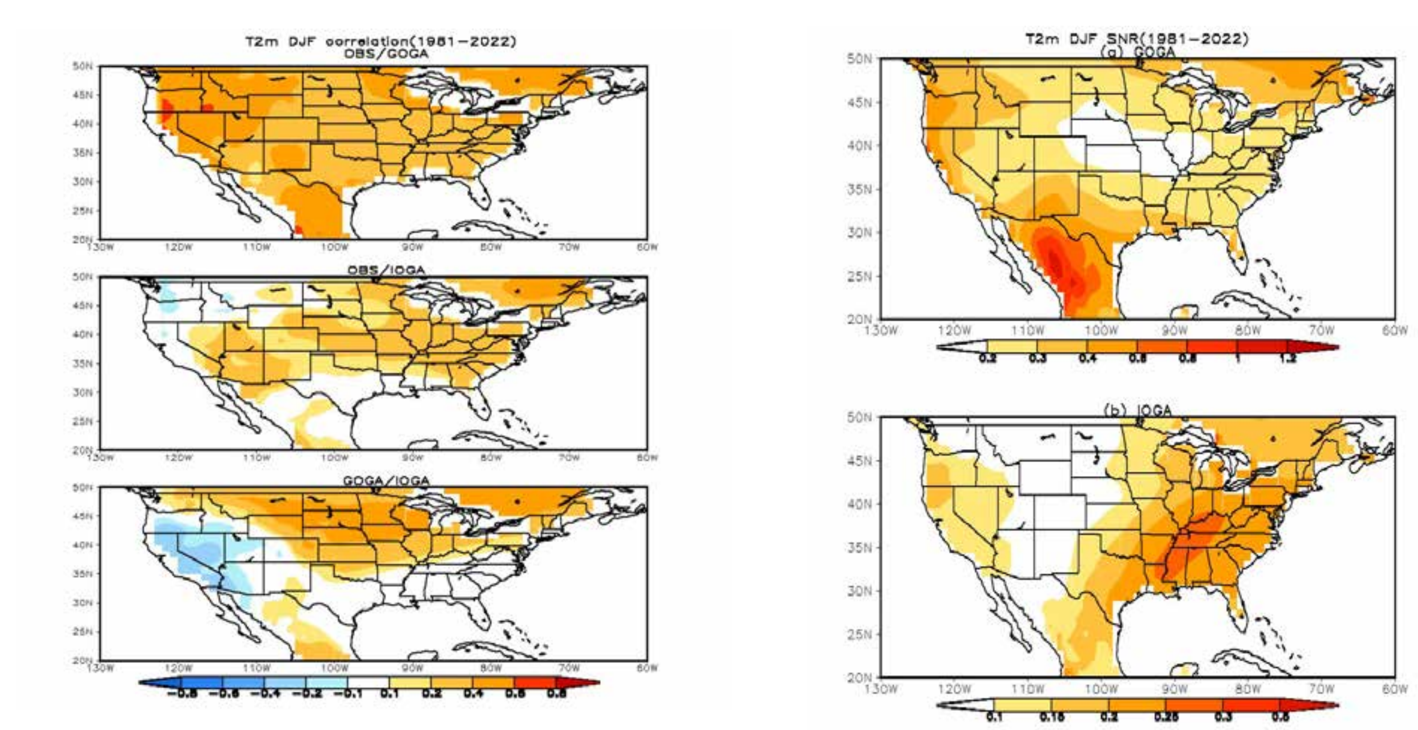

Fig. 7: Same as, Fig. 6 but for T2m.

Summary and discussion

1. This analysis examined the role of the SSTs on the winter precipitation and T2m variations in the CONUS. The impact of the tropical Pacific SSTA associated with ENSO mainly leads to opposite winter precipitation anomalies between the southern and northern tiers of CONUS, while the influence of tropical Ocean basin-wide warming or cooling confined to the southeastern and northern parts of CONUS. The tropical Ocean warming and cooling may play a important role than ENSO in the winter precipitation and T2m in southeastern and northern parts of CONUS in the years with small or moderate tropical SSTA. The tropical Ocean heat anomaly carries on its influence on the winter precipitation and T2m anomaly in the southeastern and northern plains of CONUS through exciting a teleconnection from the west tropical Ocean to the North Pacific and North America. This connection may provide secondary source of predictability of the winter precipitation and T2m in CONUS in addition to that of the tropical Pacific SSTA associated with ENSO.
2. The observed connection between winter precipitation and T2m in the southeastern and northern parts of CONUS and tropical Ocean basin wide warming or cooling is well reproduce by CFSv2 IOGA model.
3. The CFSv2 IOGA simulation simulate precipitation, T2m and HT200 reasonably well during 2018/2019 and 2019/2020 compared to GOGA model.
4. The CFSv2 IOGA simulation is able to simulate high winter correlation and SNR of precipitation and T2m over southeastern and northern parts of CONUS compared to GOGA simulation.
5. The source of tropical Ocean basin-wide SSTA need further more analysis, it may be due to influence of changing pattern of ENSO to different Ocean basin (e.g. Indian and Atlantic Ocean) or long term warming trend of global SSTA.