Supporting Information for

A New GFSv15 based Climate Model Large Ensemble and Its Application to Understanding Climate Variability, and Predictability

Tao Zhang[1,2], Weiyu Yang[2,3], Xiao-Wei Quan[4,5], Jieshun Zhu[2], Bhaskar Jha[2,3], Arun Kumar[2], Martin P. Hoerling[4,5], Joseph J. Barsugli[4,5], and Wanqiu Wang[2]

[1]ESSIC, University of Maryland, College Park, MD

[2]NOAA/National Centers for Environmental Prediction, College Park, MD

[3]ERT Inc Laurel, MD

[4]NOAA/Physical Sciences Laboratory, Boulder, CO

[5]CIRES, Univ. of Colorado Boulder, Boulder, CO

Corresponding Author: Tao Zhang, tao.zhang@noaa.gov

Contents of this file

Introduction

This supplement supports the submitted manuscript.

Text S1

Text S1 describes the results of the probability density functions (PDF) of surface air temperature and precipitation from GFSv2 AMIP runs over the contiguous United States. Fig. S1 top in the supplementary material shows the frequency distributions of wintertime surface air temperature (top left) and precipitation (top right) from GFSv2 AMIP runs for the first 5-yr period (blue curve) and last 5-yr period (red curve) of the simulations based on 450 (30 members multiply by 15 months for 5-yr period) model samples. The two curves of surface air temperature are significantly different while those of precipitation are statistically indistinguishable according to the Kolmogorov-Smirnov test. It is clear that the red curve is shifted toward warmer conditions compared to the blue curve, indicating the latter period is warmer than the earlier period and there is a US warming trend during the winter.

During summer, the two curves for both surface air temperature and precipitation are significantly different based on the Kolmogorov-Smirnov test (Fig. S1 bottom). The red curve is shifted toward warmer and wetter conditions compared to the blue curve. GFSv2 results suggest that there is a US warming trend for both DJF and JJA seasons but there is no consensus on the precipitation trend.

Text S2

Text S2 describes the forced atmospheric variability during 1979-2021 wintertime by using the 30-member ensemble mean of GFSv2 AMIP simulations (Fig. S2). The three

leading EOFs of the ensemble mean GFSv2 AMIP simulations together explain 84.4% of the total boundary forced ensemble mean height variance.

The leading mode of the forced variability describes the TNH pattern associated with ENSO, explaining 44.2% of the total boundary forced component of extratropical NH wintertime model simulated ensemble mean height response variability. The temporal correlation of the time series for this leading mode with Nino-3.4 SST variability is 0.84. The corresponding SST regression against PC1 time series confirms that this mode is clearly related to ENSO.

The second forced mode is related to anthropogenically forced climate change and the explained variance by this forced mode is 28.8%. The structure of this mode features a same sign hemisphere-wide pattern and the PC2 times series has a distinct upward trend. The corresponding SST regression against PC2 time series shows a dominant SST warming pattern over the global oceans except for the cold tongue region.

Explaining 11.4% of the total boundary forced height variability over the NH extratropics, the forced third mode describes a wave train resembling the PNA pattern resulting from atmospheric sensitivity to ENSO asymmetry and from sensitivity to a tropical precursor SST for ENSO development. For a detailed physical explanation for this mode see the discussion of Figure 7 in the manuscript.

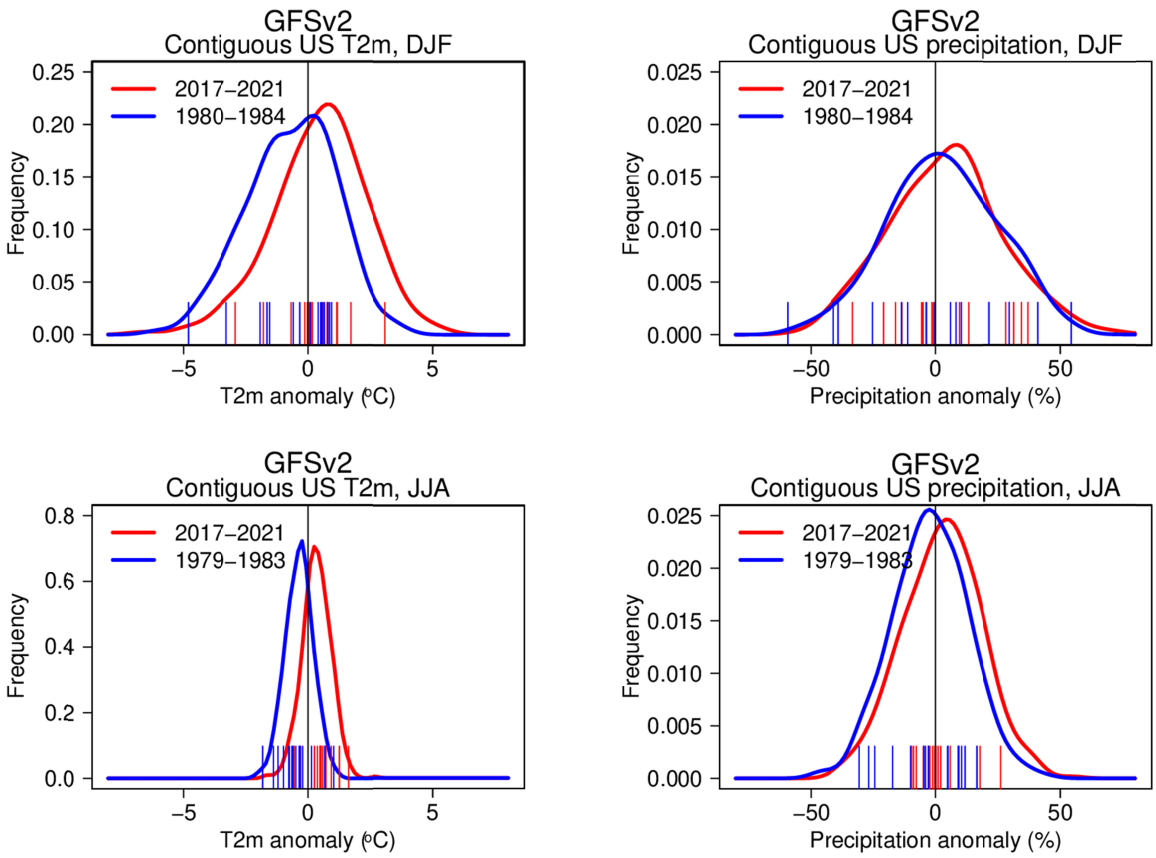

Figure S1: PDFs of contiguous U.S. (top) DJF and (bottom) JJA (left) surface air temperature anomalies (°C) and (right) precipitation anomalies (percent departure) for the first (blue curves) and last (red curves) 5-yr periods of 1979-2021. Results are based on 30-member GFSv2 AMIP simulations. Large tick marks at the bottom show observed values for 15 months of the first (blue) and last (red) 5-yr periods of 1979-2021.

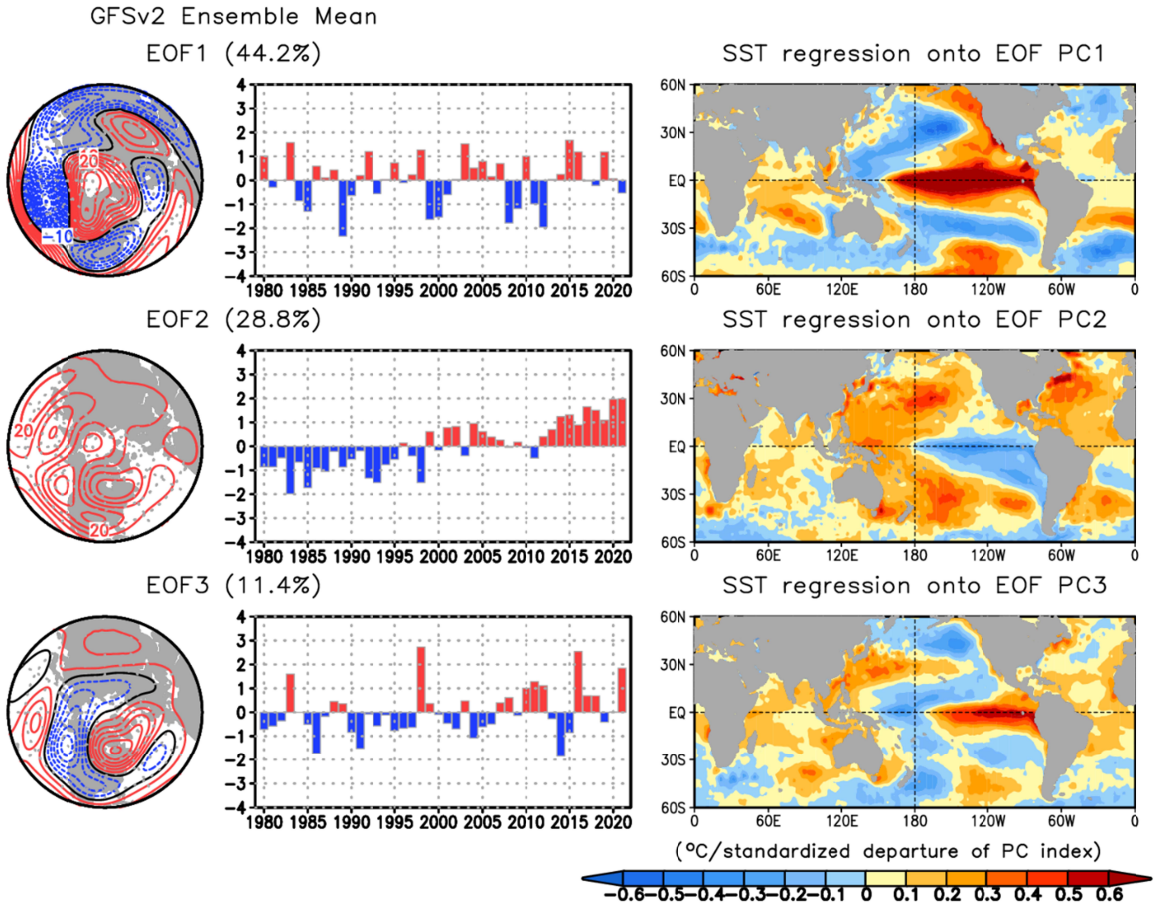

Figure S2: (left) The spatial pattern and (middle) standardized PC time series of the leading three EOFs of GFSv2 simulated 30-member ensemble mean DJF 200-hPa heights. (right) Regressions of observed DJF SST on the PC time series of the leading three EOFs of GFSv2 simulated 30-member ensemble mean DJF 200-hPa heights. The EOF analysis is computed over the 20°–90°N domain for 1979/80–2020/21. The EOF patterns are shown as the regressions of the heights onto the standardized PC time series and drawn at the interval of 5m for a 1 standardized departure of PC index.