Simulation and Prediction of Warm Season Drought in North America

Hailan Wang[1], Yehui Chang[2,3], Siegfried D. Schubert[1,2], Randal D. Koster[2]
[1]Science Systems and Applications Inc. (SSAI); [2]NASA Goddard Space Flight Center, Global Modeling and Assimilation Office; [3]Morgan State University
E-mail: Hailan.Wang@nasa.gov

1. Introduction

The subseasonal prediction of warm season drought in North America remains a great challenge. The prediction skill of North American drought during warm season, drought development in particular, in current NOAA operational drought forecast system is rather limited. This study attempts to explore processes that contribute to the warm season drought development by focusing on the role of leading modes of subseasonal atmospheric circulation variability. These leading modes are often present in the form of stationary Rossby waves, and have been crucial in the development of many recent short-term warm season climate extremes over North America. Our recent studies have shown that these waves can serve as a potential source of predictability for subseasonal development of North American droughts; in order to properly represent the effect of stationary Rossby waves and exploit this source of predictability, a forecast model needs to be able to predict the source of the waves as well as correctly simulate the warm season jet streams in the Northern Hemisphere. The present study builds upon our prior work, and investigates the representation of this source of subseasonal drought predictability in NASA GEOS-5 AGCM and assesses the impact of model bias by using a bias tendency correction approach.

2. NASA MERRA-2, GEOS-5 AGCM and Experiments

NASA MERRA-2; NASA GEOS-5 AGCM (tag: Ganymed4.0/MERRA-2)

Bias Tendency Correction Approach

Compute 6-hourly climatological analysis tendency terms (relative to MERRA-2) and apply them to model basic state variables within a free-running AGCM.

Standard and Bias Corrected Daily AGCM Hindcasts

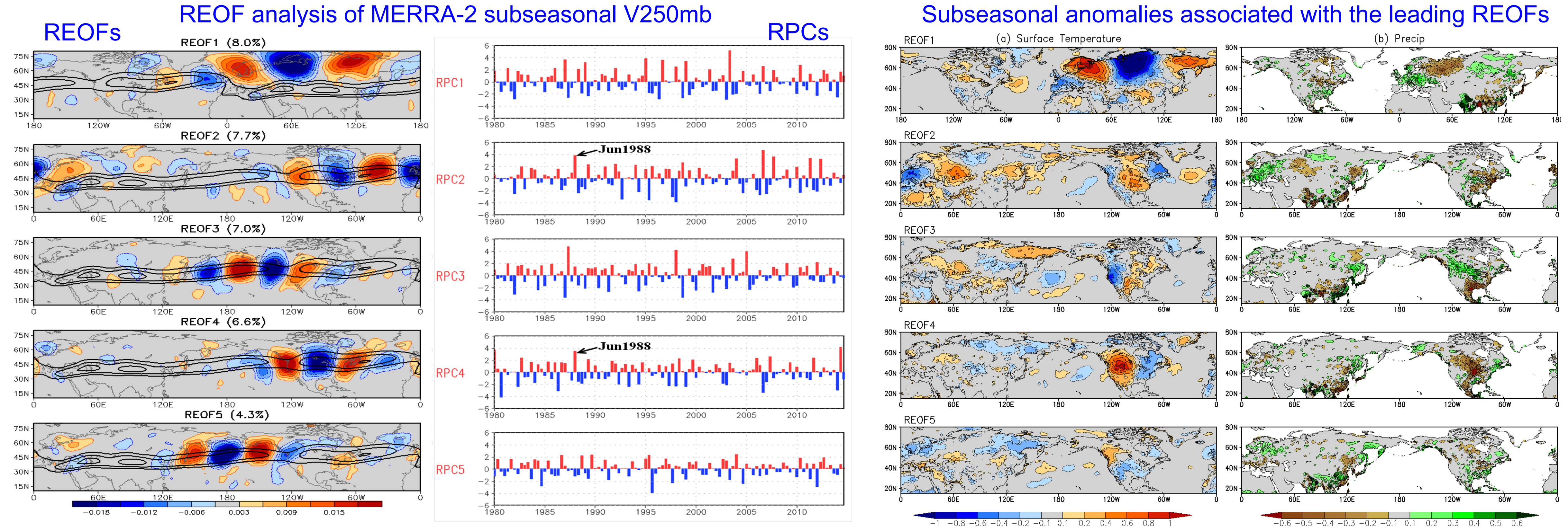
- **Standard**: Daily hindcasts from (May 1 - Jun 30) to August 31 for years 1988, 1998, 2000-2015, initialized at 21z of same date from MERRA-2.
- **Bias Corrected**: Same as standard hindcasts except that the model bias is corrected by applying 6-hourly climatological corrections to model basic state variables within the free-running AGCM.

Regional Replay Experiments

- Constrain model basic state variables to be close to those of a reanalysis over select regions
- Performed two experiments:
  - **Tibet** (70°E-110°E; 17°N-50°N), **Tropical Atlantic** (120°W-0°; 0°-25°N)
  - Each experiment consists of 31 ensemble members respectively for the summers of 1980-2010, initialized from Apr 30 using MERRA-2, and integrated through Sep 2 of the same year.

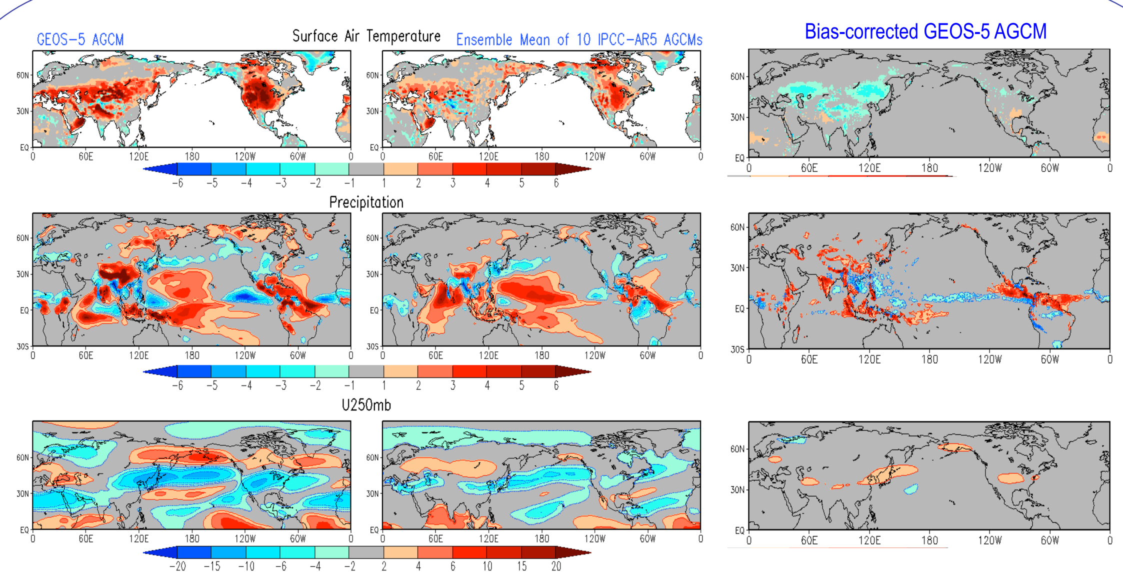
3. Results

A. Leading Modes of Subseasonal Atmospheric Circulation Variability during JJA



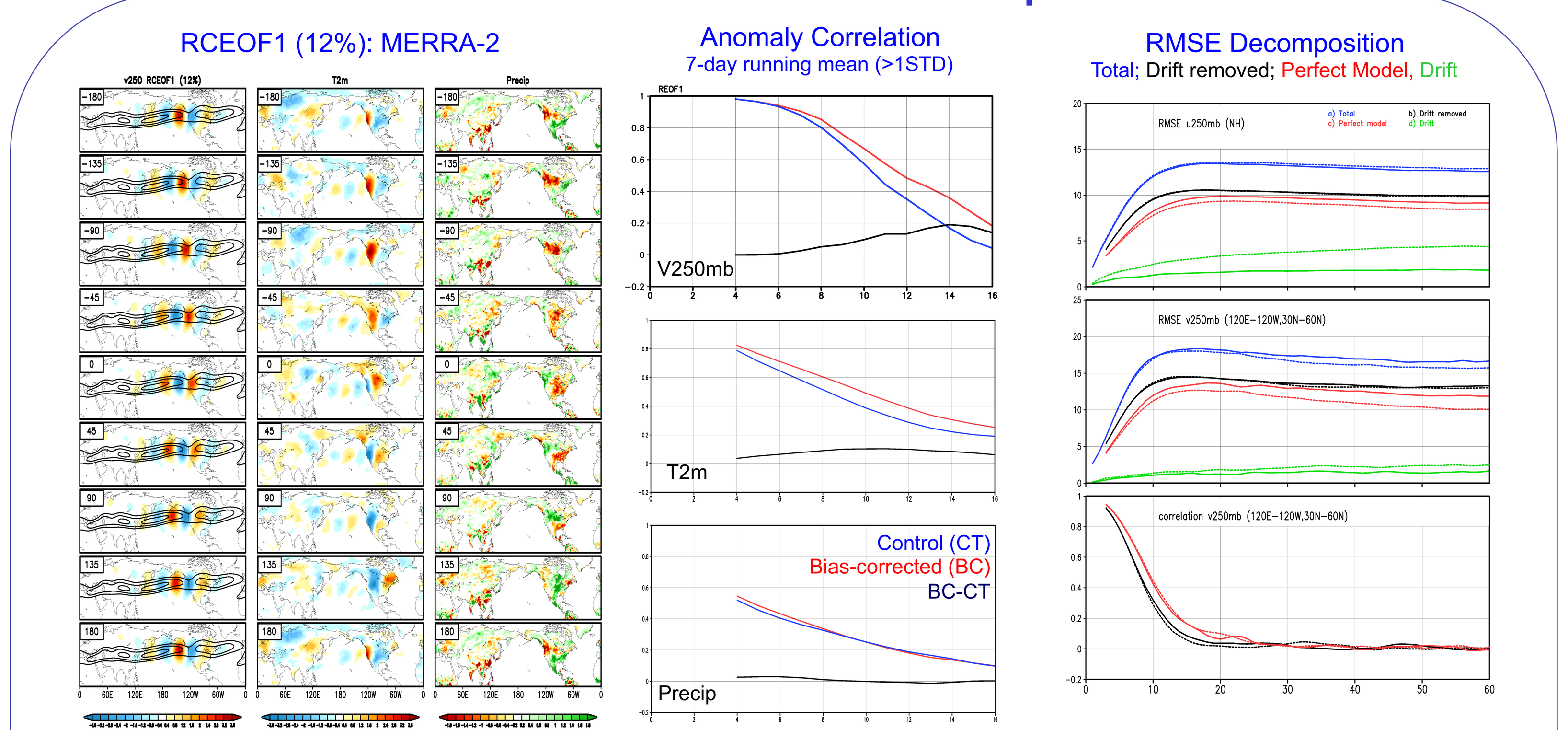
- The leading modes of subseasonal atmospheric circulation variability are guided by mean jet streams.
- These leading modes contribute to a number of climate extremes over North America (e.g., 1988, 1998 North American drought).

B. GEOS-5 Model Bias



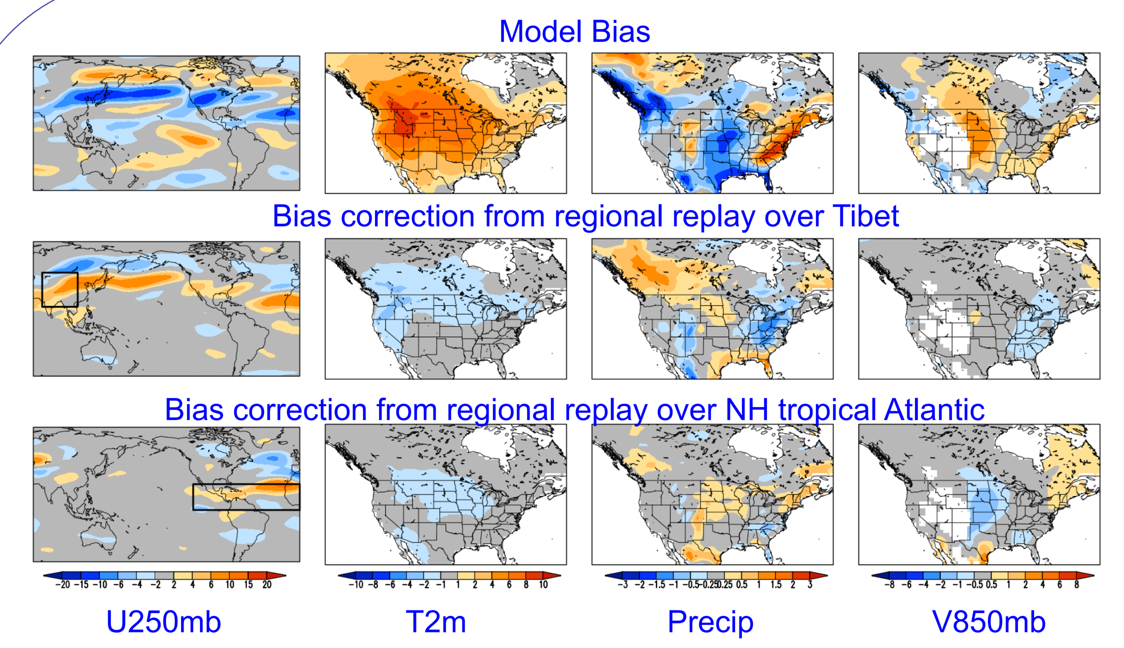
- Notable summertime biases in GEOS-5 AGCM (left panels), which are common across many other models (middle panels), include distinct wet biases over the west and central Pacific and west tropical Atlantic, warm biases over much of the NH extratropical land, and a dry bias over the central US. These biases adversely impact the proper representation of stationary Rossby waves and their effects in these models.
- Much of the bias in the GEOS-5 AGCM (relative to MERRA-2) can be removed by using a bias tendency correction approach (right panels).

C. Model Prediction Skill Assessment and Impact of Model Bias



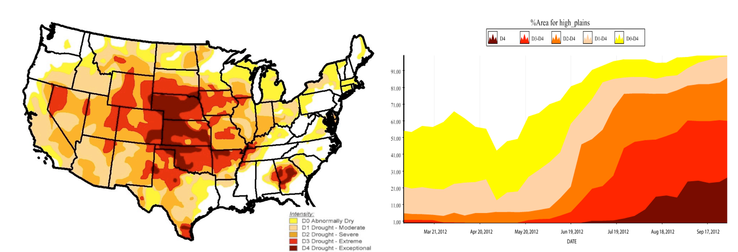
- The bias tendency correction leads to some noticeable skill improvement for atmospheric circulation and surface air temperature, but the improvement for precipitation is only marginal.
- The overall modest skill improvement involves the competing influences of the loss of predictability and the time it takes for climate drift to start having a significant impact on forecast skill.

E. Diagnosis of Model Bias over North America

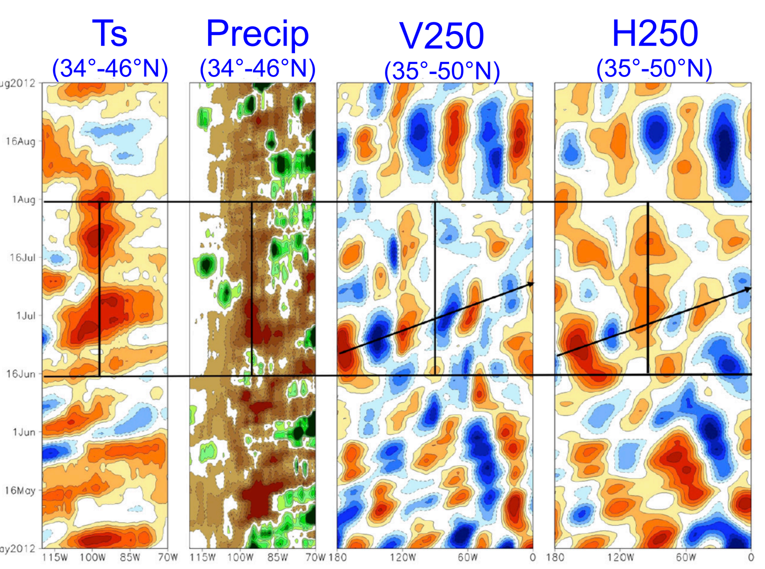


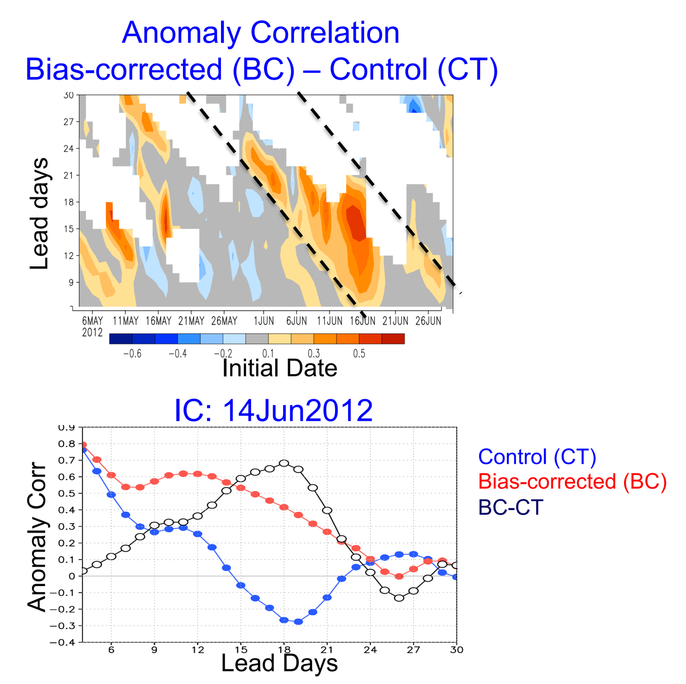
- The warm and dry bias over the US Great Plains (1st row), the dominant model bias over North America during boreal summer, results from the combined contribution from i) the lack of sufficient weather systems entering North America due to model's rather weak north Pacific jet stream (2nd row), ii) a too strong Great Plains Low-Level Jet (LLJ) associated with model convective bias in the NH tropical Atlantic (3rd row), and iii) model deficiencies in simulating local processes (e.g. mesoscale convective systems) (not shown).

D. An Extreme Event: the 2012 Great Plains Drought



- Rapid development, established in ~one month
- Costliest natural disaster in 2012
- Not foreseen in operational seasonal forecasts





- The rapid drought development from mid-June to mid-July 2012 was associated with considerable eastward propagating wave activities across the north Pacific.
- Correcting the model bias can potentially improve the prediction skill by ~9 days.

4. Summary and Conclusions

- The GEOS-5 AGCM biases in north Pacific jet and tropical convection during warm season, which are common across many other models, limit the model's capability in properly representing stationary Rossby waves and their effects over North America.
- An objective bias tendency correction approach has been developed to correct much of model bias (relative to MERRA-2) in the GEOS-5 AGCM.
- The bias correction improves GEOS-5 AGCM prediction skill of stationary Rossby waves and surface temperature anomalies over North America, but the skill improvement for precipitation is only marginal.
  - The overall modest skill improvement involves the competing influences of the loss of predictability and the time it takes for climate drift to start having a significant impact on forecast.
- Future Work:
  - Investigate select climate extreme events, and explore sources of predictability that can lead to enhanced prediction skill; diagnose origin of model biases for model development.