Atlantic Warm Pool Variability and its Climate Impacts in the IPCC AR4 Models

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Abstract

The Atlantic Warm Pool (AWP) shows strong variability on seasonal to multidecadal time scales and plays a significant role in the climate system by affecting summer precipitation over the North America and Atlantic hurricane activity. In this study we analyzed 22 state-of-the-art Coupled General Circulation Models (CGCMs) provided by IPCC-AR4 to evaluate how well current CGCMs represent AWP variability and its climate impacts. Results show that only in four models the seasonal cycles are in good accordance with observations, while other 18 models suffer from a cold SST bias **(Figure 1)**. Spectrum analysis reveals that only the multidecadal band of variability of the AWP is significant in observations but many models show that either interannual or decadal variability is dominant **(Figure 2)**. During large AWP years, the Great Plains low-level jet and the associated moisture transport from the AWP to U.S. are reduced. Thus, a large AWP is associated with reduced rainfall over most of the North America away form the Gulf coast. However, such connection is not well simulated in the CGCMs **(Figure 3 and 4)**. A large AWP reduces the vertical wind shear over the main development region for Atlantic hurricanes, and thus facilitates the formation and development of Atlantic hurricanes. It appears that the CGCMs can capture the reduced vertical wind shear over the MDR in association with large AWPs **(Figure 5)**. A large AWP also induces barotropic stationary wave patterns that weaken the North Atlantic subtropical high and produce the eastward flow anomalies along the eastern seaboard of the United States. This feature is somewhat reproduced in the CGCMs **(Figure 6)**.

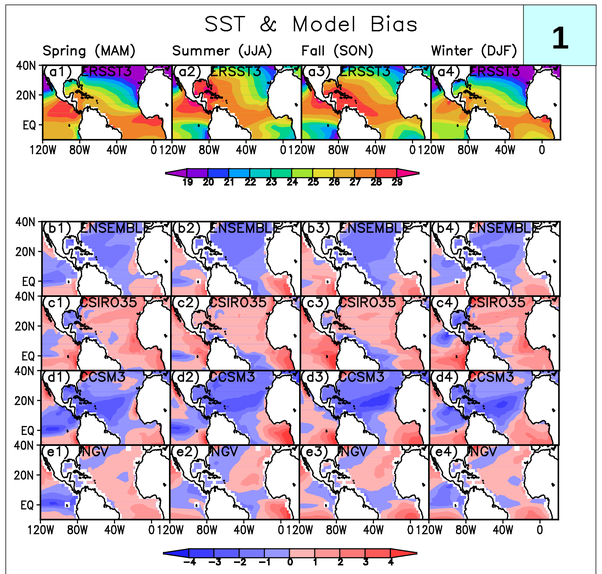

Figure 1. Observational SST and model SST bias in four seasons. Shown are (a1-a4) ERSST SST averaged in four seasons, (b1-b4) the seasonal SST bias of the 22 model ensemble, and (c1-c4, d1-d4, e1-e4) the seasonal SST bias for selected models. Unit is ˚C.

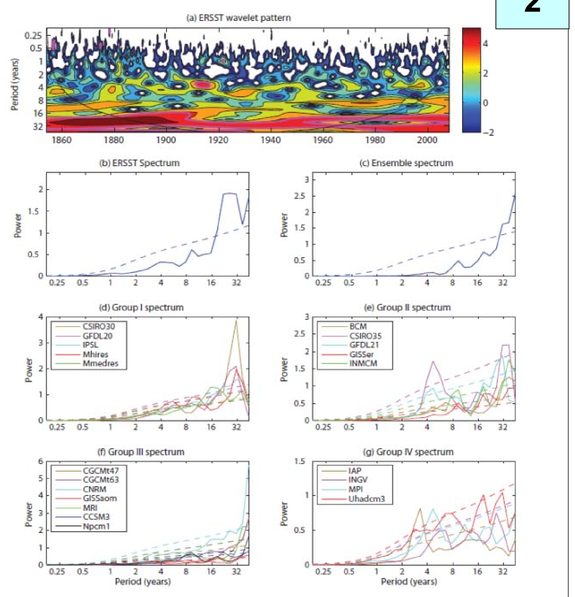

Figure 2. (a) Wavelet power spectrum of ERSST. Power above the 95% confedence level is plotted using pink contour line. X axis is time. Y axis is the wavelet period in years. (b) Global spectrum of ERSST. Y axis is power in Unit ˚C2. X axis is the wavelet period in years. The dashed line indicates 95% significance level. (c), (d), (e), (f) and (g) are the same as (b) for the ensemble of 22 models, Group I, II, III and IV models respectively.

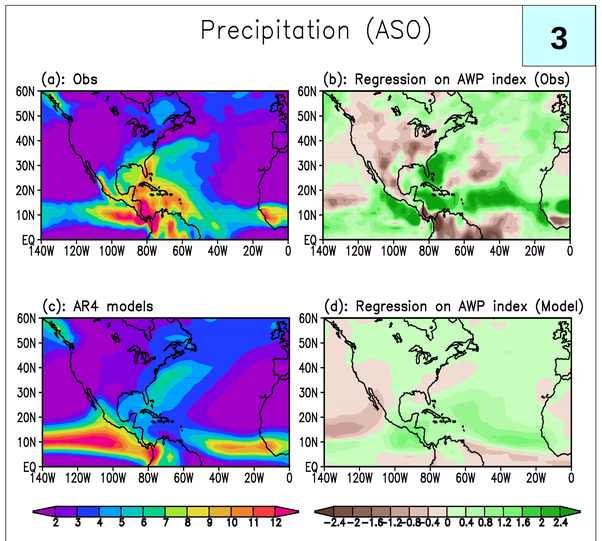

Figure 3. (a) The climatology of precipitation in ASO from observations. Unit is 10^5 Kg/m^{2}s. (b) Regression of precipitation onto AWP index (ASO) from observations. (c) Same as (a) from the ensemble of AR4 models. (d) Same as (b) from the ensemble of AR4 models.

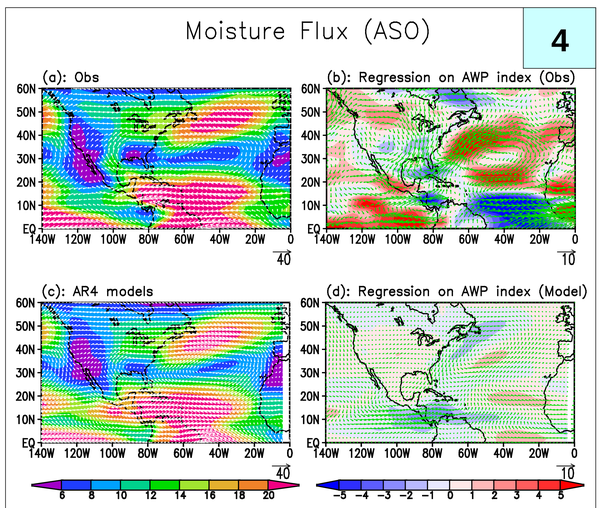

Figure 4. (a) The climatology of vertical integrated moisture flux from sea surface to 300mb in ASO from observations. Unit is Kg.mb/ms^2. Arrows indicate the moisture flux vector and colors represent the amplitude of the moisture flux (b) Regression of moisture flux onto AWP index (ASO) from observations. (c) Same as (a) from the ensemble of AR4 models. (d) Same as (b) from the ensemble of AR4 models.

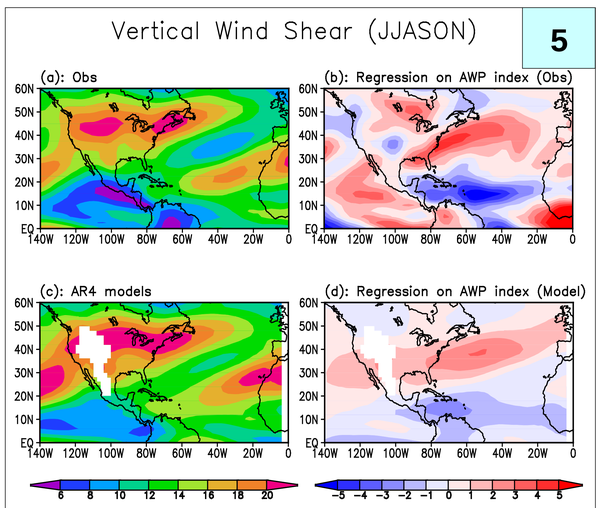

Figure 5. (a) The climatology of vertical wind shear in JJASON from observations. Unit is m/s. (b) Regression of wind shear onto AWP index (ASO) from observations. (c) Same as (a) from the ensemble of AR4 models. (d) Same as (b) from the ensemble of AR4 models.

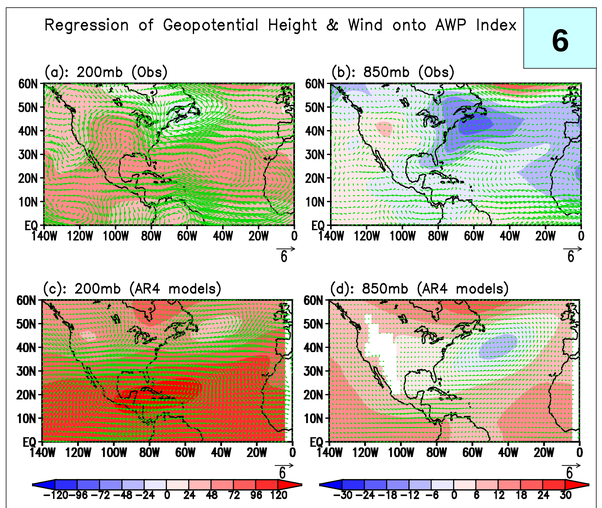

Figure 6. (a) Regression of the climatology of geopotential height (shading) and wind (arrows) at 200mb in JJASON onto AWP index from observations. Geopotential height unit is m. and wind unit is m/s. (b) Same as (a) at 850mb from observations. (c) Same as (a) from the ensemble of AR4 models. (d) Same as (b) from the ensemble of AR4 models.

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