Report as of FY2011 for 2011VI186B: "Lesser Antilles Specific Assessment of the IPCC AR5 Models for the Current Climate"

Publications

Project 2011VI186B has resulted in no reported publications as of FY2011.

Report Follows

LESSER ANTILLES SPECIFIC ASSESSMENT OF THE IPCC AR5 MODELS FOR THE CURRENT CLIMATE

Problem and Research Objectives

The sustainability of a society and in this context of island nations of the Lesser Antilles is critically dependent on the fresh water availability. A significant source of the fresh water in these islands comes from precipitation. Therefore there is considerable interest to understand how precipitation in particular would change as a result of the global climate change. So before the climate model projections over the region of the Lesser Antilles can be analyzed for the late 21st century, it is important to examine the their 20th century simulation. In this research, we are examining the fidelity of reconstructing the Atlantic Warm Pool (AWP) variations in the 20th century in the climate models participating in the Coupled Model Inter-comparison Project 5 (CMIP5) which will be extensively used in preparing the International Panel for Climate Change (IPCC) Assessment Report 5 (AR5). Our previous study (Chan et al. 2011) revealed that the Atlantic Warm Pool (AWP) has a significant influence on the low level tropospheric flow, rainfall and its diurnal variability over the Lesser Antilles. For example, Chan et al (2011) showed that over the larger islands (with area approximately greater than 100 km^2) both daily maximum and minimum 2-meter temperature (T_{2m}) are increased during the large AWP years. However, the change of daily T_{2m} maximum at interannual scales is clearly larger than the daily T_{2m} minimum. This is because during the nighttime, the decoupled boundary layers and land breezes keep the islands essentially isolated. It may also be noted that with the resolution of the CMIP5 models are around 100km grid resolution, which is obviously insufficient to resolve the Lesser Antilles Islands. Therefore it is prudent to analyze the AWP, a large-scale climate feature that has a significant influence on the Lesser Antilles climate.

Wang and Lee (2007) also relate the variability of the AWP to tropical cyclone activity in the Atlantic. They suggest that the AWP acts as a conduit for the observed relationship of Atlantic multi-decadal oscillation and Atlantic tropical cyclone activity. The AWP-induced atmospheric changes of vertical shear and convective instability are identified as the dynamical mechanisms by which the AWP controls tropical cyclone activity in the region. Furthermore, there is a huge gradient of the ocean heat content between the deeper mixed layer in the northern Caribbean Sea and the shallower warm pool depths along the northern coast of South America, which could also possibly influence hurricane tracks and intensification (Enfield et al. 2001). Similarly, in large AWP years, the North Atlantic Subtropical High (NASH) is relatively weak compared to small AWP years. An anomalously strong NASH or an anomalously southward displacement of the NASH, when accompanied by a southward shift of the eastern Pacific ITCZ, would lead to a dry summer in the Caribbean (Giannini et al. 2000). A westward protrusion of the NASH contributes to the Caribbean mid-summer drought (Mapes et al. 2005) and the Caribbean Low Level Jet (CLLJ) and CLLJ’s westward moisture transport (Wang and Lee 2007; Wang 2007; Muñoz et al. 2008). The position and strength of the NASH during summer are also found to be critical to the tracks of tropical cyclones in the region (Wang 2011).

At the end of 2011, only 4 models had their complete 20th century simulation datasets reported at the CMIP5 data portal (http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html). They were NASA's two models (GISS-E2-H and GISS-E2-R), Australia's (CSIR-Mk3.6), and Canada's (CanESM2). In this report we will therefore examine the simulation of the AWP variations in the 20th century of these 4 models. However since the beginning of this year 6 other models have reported their data at the website and many more models are anticipated to report their datasets very soon. In examining the CMIP3 models that had nominal horizontal resolutions of around 200km, which were used in the IPCC AR4, Misra et al. (2009) showed that a majority of these models had a very cold bias in the AWP region. As a result the 28.5^0C isotherm was not even resolved in these model simulations. But given the fact that the CMIP5 models have nearly doubled the resolution of their model compared to CMIP3, and there have been other developments in the physics of the climate models, there is anticipation of improved performance.

Methodology

We have compared the results of the CMIP5 models with the Sea Surface Temperature (SST) Analysis from Extended Range SST version 3b (ERSSTv3; Smith et al. 2008) and the National Centers for Environmental Prediction (NCEP)-Department of Energy (DOE) atmospheric reanalysis (hereafter R2; Kanamitsu et al. 2002). ERSSTv3 is generated using in situ SST data and improved statistical methods that allow stable reconstruction using sparse data. The monthly analysis extends from January 1854 to the present, but because of sparse data in the early years, the analyzed signal is damped before 1880. It is available at 2^0 grid resolution. R2 analysis is available on 2.5^0 grid resolution from 1979 to the present. The analysis scheme used in R2 is the spectral statistical interpolation scheme, which is a three-dimensional variational scheme cast in spectral space (Derber et al. 1991; Parrish and Derber 1992). For analysis of the interannual variations we make sure to improve the linear trends in all the analyzed variables for both the model generated data and the corresponding verification data. Since the AWP has a seasonal peak in August-September-October (ASO) season, we will be specifically examining the CMIP5 results in this season. The analysis of the modeling results in the project will involve using a new technique of Ensemble Empirical Mode Decomposition (EEMD; Wu & Huang 2009). EEMD will be used to decompose the time series of the AWP to estimate its variability in the AR5 models and compare them with the corresponding observations. EEMD is an extension on the Empirical Mode Decomposition (EMD; Huang et al. 1998). EMD is capable of decomposing the local characteristic temporal variations into complete sets of near orthogonal components called Intrinsic Mode Functions (IMFs). The IMFs can be thought of as basic functions, which are determined by the time series itself rather than pre-determined kernels. Thus it is a self-adaptive signal processing method, which is most suited for nonlinear and non-stationary time series. EEMD, a noise-assisted data analysis method, defines its IMFs through an ensemble of trials, wherein each trial involves adding white noise to the time series. This enables the components of the signal in the time series to automatically project onto proper scales of reference established by the background white noise. However the IMFs obtained will consist of the signal and the white noise, which will be rather noisy. But the noise in each trial will be different. Thus this noise component in the IMF can be substantially decreased or eliminated by taking the mean of several trials, thereby retaining the true estimate of the signal in the time series.

Principal Findings and Significance

Mean AWP climate: Figure 1 shows the mean SST for the ASO season for the 20th century with the 28.5^{0}C isotherm in bold black line. Off the 4 CMIP5 it is apparent that GISS-E2-R and CSIRO-Mk3.6 have a well-defined 28.5^0 C isotherm defined in the Gulf of Mexico and in the Caribbean Sea region. Both GISS-E2-H and the CanESM2 have a

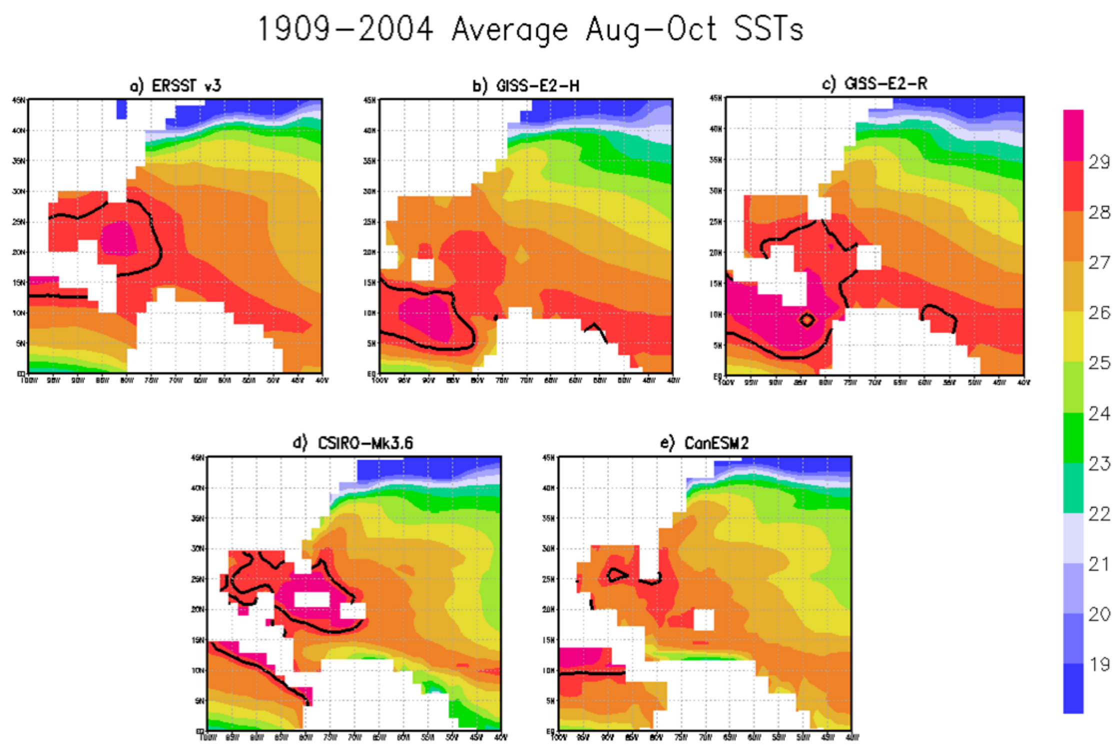

Figure 1: Climatological 1909-2004 August-September-October (ASO) Average SST (°C) in the Atlantic Basin from a) detrended ERSST v3 observations, and b-e) various detrended CMIP5 models. The mean 28.5°C isotherm (heavy black line) is overlaid on top of the shaded SSTs to highlight the size and location of the Atlantic Warm Pool (AWP) in each individual model.

cold bias compared to the observations in ERSSTv3.

Interestingly, when we examine the seasonal cycle of the AWP (Fig. 2), then all 4 models show a seasonal peak in the area of the AWP in the ASO season. GISS-E2-R and CSIRO-Mk3.6 also get the magnitude of the AWP area that is quite comparable to

ERSSTv3. However, the magnitude of the seasonal peak of AWP area is considerably diminished in GISS-E2-H and CanESM2.

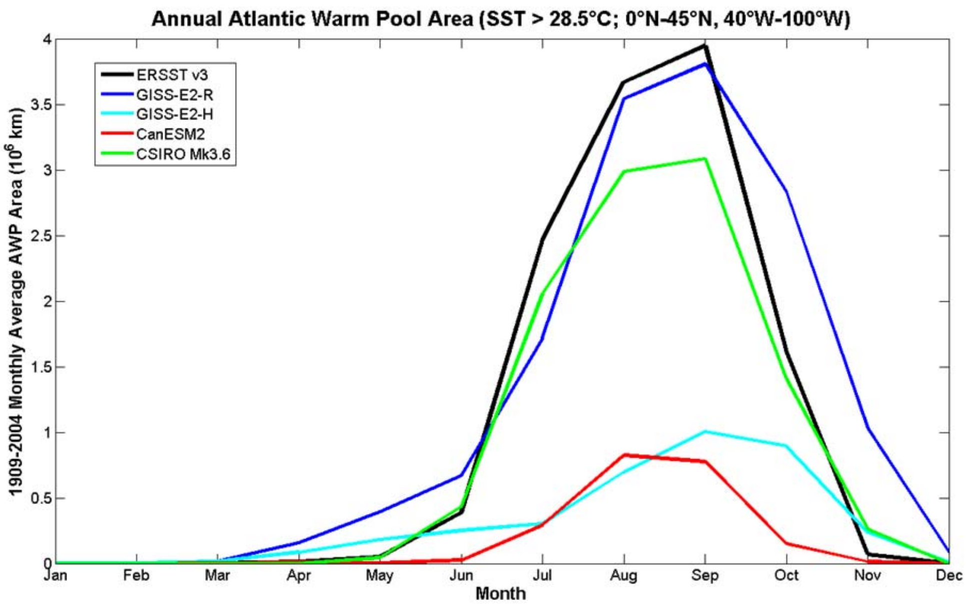

Figure 2: The climatological distribution of the area of the 28.5^{0}C isotherm defining the AWP, as measured by detrended ERSST v3 observations.

Variability of AWP: The AWP is found to be a rich amalgam of variability across many time scales. Besides the interannual variations there are decadal variations and a linear trend of increasing area of the AWP. Wang and Lee (2007) suggest that the AWP acts as a conduit for the observed relationship of Atlantic multi-decadal oscillation and Atlantic tropical cyclone activity.

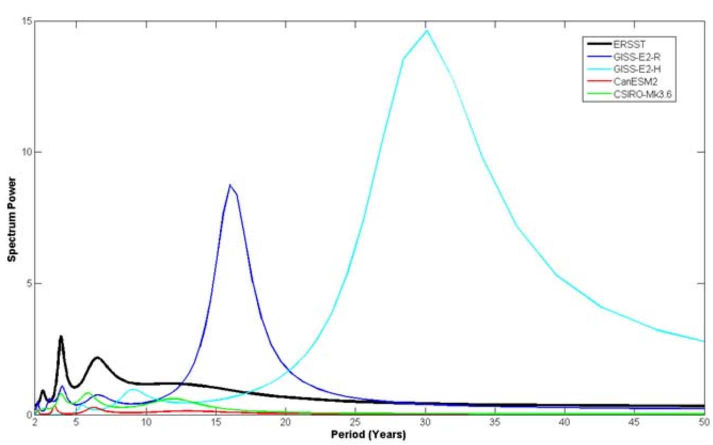

Figure 3: Maximum entropy spectrum (M=10) of the 1909-2004 areal AWP index. To focus on higher-frequency variability, the power spectrum is calculated for the sum of the first three IMFs of the AWP index, obtained through an EEMD.

Figure 3 shows the spectrum

diagnosed from the Maximum Entropy Method (MEM; Ghil et al. 2002) of the first three IMFS's of the centennial time series of the AWP area. The ERSSTv3 dataset exhibits a relatively strong variability on interannual (ENSO) time scales and at intra-decadal (5-10 year) time scales that correspond to the North Atlantic Oscillation. On the other hand CSIRO-Mk3.6 and GISS-E2-R and CSIRO-Mk3.6 exhibit a spectral peak at around 15 year and 30 year time scales, which correspond to the Pacific-Decadal Oscillation and the Atlantic Multi-decadal Oscillation.

Figure 4 shows the lagged correlation of the ASO area of the AWP with the global SST anomalies of the previous seasons of two season lag (February-March-April [FMA]), one season lag (May-June-July [MJJ]) and zero season lag (ASO). The corresponding observational figures from ERSSTv3 are shown in Fig. 5. It is clearly seen that the two models that showed reasonable climatology of the AWP have the variations of AWP erroneously associated with the equatorial Pacific SST variations. In the observations it is clearly seen that the ASO variation is largely independent of the ENSO variations in the equatorial Pacific. The variability is intrinsic to the tropical Atlantic Ocean.

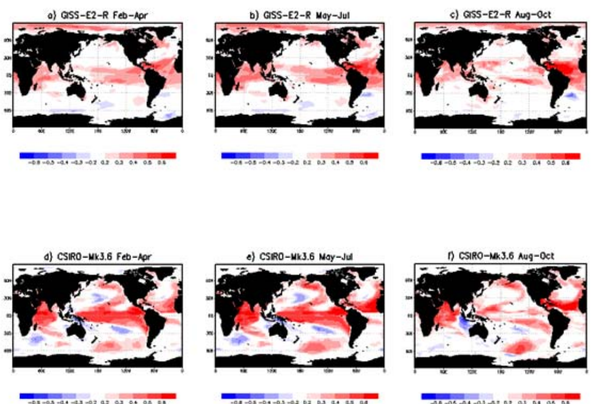

Figure 4: The correlation of 1909-2004 ASO averaged AWP area with a) preceding February-March April (FMA), b) preceding May-June-July (MJJ), and c) contemporaneous ASO global SSTA from GISS-E2-R. d), e), and f) similar to a), b), and c) but from CSIRO-Mk3.6. Only statistically significant values at 95% confidence interval according to t-test are shown.

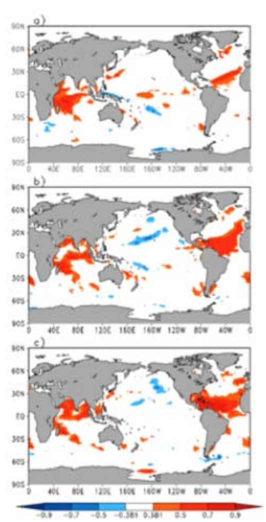

Figure 5: Same as Fig. 4 but for ERSSTv3.

Conclusion

In conclusion, the four models examined in the CMIP5 suite of models indicate that two (CSIRO-Mk3.6 and GISS-E2-R) have reasonable climatology but with erroneous interannual variations. The other two models (GISS-E2-H and CanESM2) have a cold bias that renders them to not have an AWP in the boreal season.

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