JP2.9 ASSESMENT OF THE SEVERE WEATHER ENVIROMENT IN NORTH AMERICA SIMULATED BY A GLOBAL CLIMATE MODEL

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1. INTRODUCTION

The accuracy of climate change predictions hinges on the understanding of current climatologies and the correct simulation of current climatologies by climate models. Severe convective weather events (thunderstorms, hail, tornadoes, etc) are relatively rare atmospheric phenomena due to their very small temporal and spatial scales. Consequently, assessing climatologies of actual severe convective weather events is difficult. Inconsistencies in reporting criteria and improvements in the technology used to observe severe weather make the problem of developing reliable long-term climatologies of severe weather events nearly impossible.

Brown and Murphy (1996) and Brooks et al. (2003) proposed the use of covariates that represent the severe weather environment as proxies for the occurrence of weather events that could not be accurately quantified. Environmental conditions conducive to the occurrence of severe weather can be quantified from meteorological soundings in terms of the convective available potential energy (CAPE) and vertical shear of the horizontal wind. In each of the studies, extreme values of the covariates were closely related to the average occurrence of severe weather. In the context of establishing climatologies of severe convective weather events, the problem is transformed from trying to assess an inherently inadequate database of observed severe convective weather events to trying to establish a relationship between better observed environmental conditions and the original events in question.

Previously, it has been shown that most convective parameters derived from reanalysis data are qualitatively similar to convective parameters derived from observed soundings (Lee 2002). Brooks et al. (2003) calculated CAPE values using the mixed layer within the lowest 100 hPa of the atmosphere and shear values over the 0-6 km range. They concluded that the higher the CAPE and shear, the greater the probability became that the environmental conditions would be associated with severe convective weather. This is consistent with the results of Rasmussen and Blanchard (1998) using observed environmental parameters from neighboring meteorological soundings.

Currently, global climate models are incapable of resolving actual severe weather events as these events occur at scales are well below the horizontal resolution within the models. As a result, assessing the distribution of severe weather within a global climate model is limited to assessing environments associated with severe convective weather. This project evaluates how well a modern global climate model represents the severe weather environment and, in turn, if the severe weather environments of modern global climate models can be used as a covariate for estimating future distributions of observed severe weather events.

Preliminary results are presented from an investigation of the ability of the NCAR Community Climate System Model 3 (CCSM3) to simulate severe convective weather environments. The model severe weather environments are compared with the severe weather environments from global reanalysis data discussed in Brooks et al. (2003). This will serve as the basis for future analysis aimed at describing changes in the severe weather environment under different future climate change scenarios.

The following sections include a brief description of the CCSM3 model as well as a concise discussion of the severe weather environment from the global reanalysis data. Then attention turns to presenting early results from analyzing one year of CCSM3 output followed by preliminary conclusions.

2. DESCRIPTION OF THE CLIMATE MODEL

The CCSM3 is a coupled global climate model consisting of atmosphere, land surface, sea-ice, and ocean component (Collins et al., 2006). Each component is a model in itself joined together through a flux coupler. For this particular study a control run (b30.030e) with green house gases held constant was chosen in an effort to assess how well climate models can simulate current severe weather environments.

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The atmospheric portion of the CCSM3, the Community Atmospheric Model (CAM3), is a spectral model with 85-wavenumber triangular truncation (approximately 1.4 degree} in the horizontal with 26 terrain following hybrid levels in the vertical (Collins et al., 2006). Specifically, CAM3 vertical resolution contains 4 levels below 850 hPa and 13 levels below 200 hPa. CAM3 output fields are archived every 6 hours. Fields used in calculating CAPE are the 3-dimensional fields of temperature (T), mixing ratio (Q), geopotential height (Z3) and pressure (P). Additionally, surface geopotential and surface pressure are necessary but can be taken from the lowest level of the corresponding vertical fields. It should be noted that in calculating the CAPE fields the model data was used on its own vertical grid and not interpolated.

3. REANALYSIS OBSERVATIONS

The premise behind the reanalysis dataset is to create a best representation of the atmosphere for every 6 hours by:

1. Recover all available observations from each time and synthesize them with a static data assimilation system.
2. Use observational fields to initialize a model for a 6 hour forecast. This global reanalysis model used was identical to the NCEP global operational model except that the horizontal resolution was half that of the operational model.
3. Use the forecast as a first-guess in conjunction with concurrent observational fields. This constituted the reanalysis output data. An optimal interpolation technique was used to generate the reanalysis fields.
4. Repeat process every 6 hours.

The resolution of the global reanalysis dataset is 1.875º in the longitude, 1.915º in the latitude, and 28σ levels (σ is defined as pressure divided by surface pressure) in the vertical of which 10σ levels are located between the surface and 700 hPa (Brooks et al., 2003).

The resolution of the reanalysis data is roughly that of the CCSM3 model output. The atmospheric parameters necessary for construction of a sounding were derived from the six available global reanalysis fields: surface geopotential, virtual temperature, specific humidity, divergence, and vorticity.

The mixed layer CAPE taken from the reanalysis data was averaged over all times for each season: Winter (December, January, February), Spring (March, April, May), Summer (June, July, August), and Autumn (September, October, November) for the region 25ºN to 50ºN and 135ºW to 65ºW.

The overall distribution of CAPE for all times (1958-1999) is bimodal with a subtle peak between 25 and 50 J/kg and a more substantial peak between 400 and 650 J/kg. The distribution is characterized by a rapid increase in occurrence of a given CAPE value up to the first peak with a slight drop off before continuing with an even steeper climb to the overall peak. Frequency of CAPE values above the peak drops off extremely quickly.

4. GLOBAL CLIMATE MODEL ANALYSIS

The CAM3 archived output does not include the CAPE field. To produce the CAM3 CAPE field, the NCAR Command Language (NCL) rip_cape_3d routine was used. This routine takes arrays ordered top to bottom of pressure, temperature, geopotential height and mixing ratio as well as arrays of surface pressure and surface geopotential. Since the CAM3 uses hybrid levels in the vertical a separate NCL routine was used to convert the hybrid pressure levels to true pressure levels needed for the pressure level array in the rip_cape_3d routine.

For this paper a single year was chosen and CAPE values are once again averaged for all times over each season in the region extending from 25ºN to 50ºN and 135ºW to 65ºW. It is very important to point out that while the reanalysis CAPE observations were computed using a mixed layer of the lowest 100 hPa that the global climate model's CAPE field is calculated using the maximum CAPE value.

The overall distribution of CAPE for one year at all times is also bimodal with a subtle peak between 40 and 65 J/kg and a more substantial peak between 650 and 1000 J/kg. The distribution is characterized by a gradual increase in occurrence of a given CAPE value up to the first peak with a slight drop off before continuing with a steep climb to the overall peak. Frequency of CAPE values above the peak also drops off extremely quickly.

5. PRELIMINARY RESULTS

The average CAPE field derived from the CAM3 model output qualitatively agrees with the CAPE field derived from the reanalysis data. In winter and spring the CAM3 CAPE field is roughly collocated with the reanalysis data albeit with values a little higher. In summer and autumn the CAM3 and the global reanalysis produce highest values of CAPE in the southeastern United States along with lesser values in the southwest United States.

Of substantial interest is the lack of CAPE values in the CAM3 output over the central plains of the United States during the summer. When looking at time series of CAPE values for the summer it becomes apparent that the model does not produce CAPE on a day to day basis in the central plains; however, the CAM3 does produce CAPE when synoptic scale disturbances move across the plains. It is too early to speculate as to the reason for the lack of CAPE, but of primary interest is the lack of moisture in the central portion of the United States.

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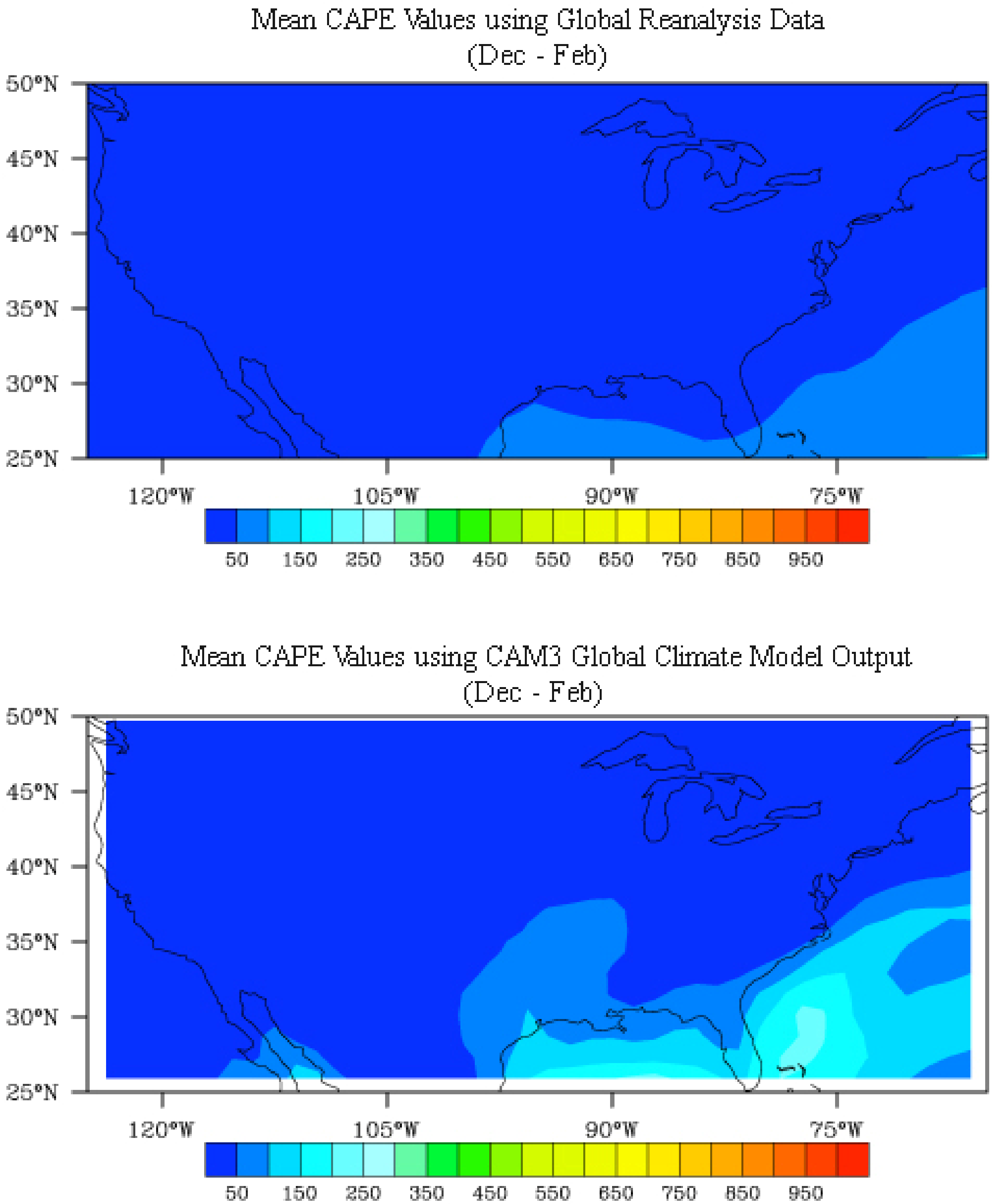

FIGURE 1. *CAPE values averaged over all times for December through February using global reanalysis data (top) and CAM3 global climate model output (bottom).*

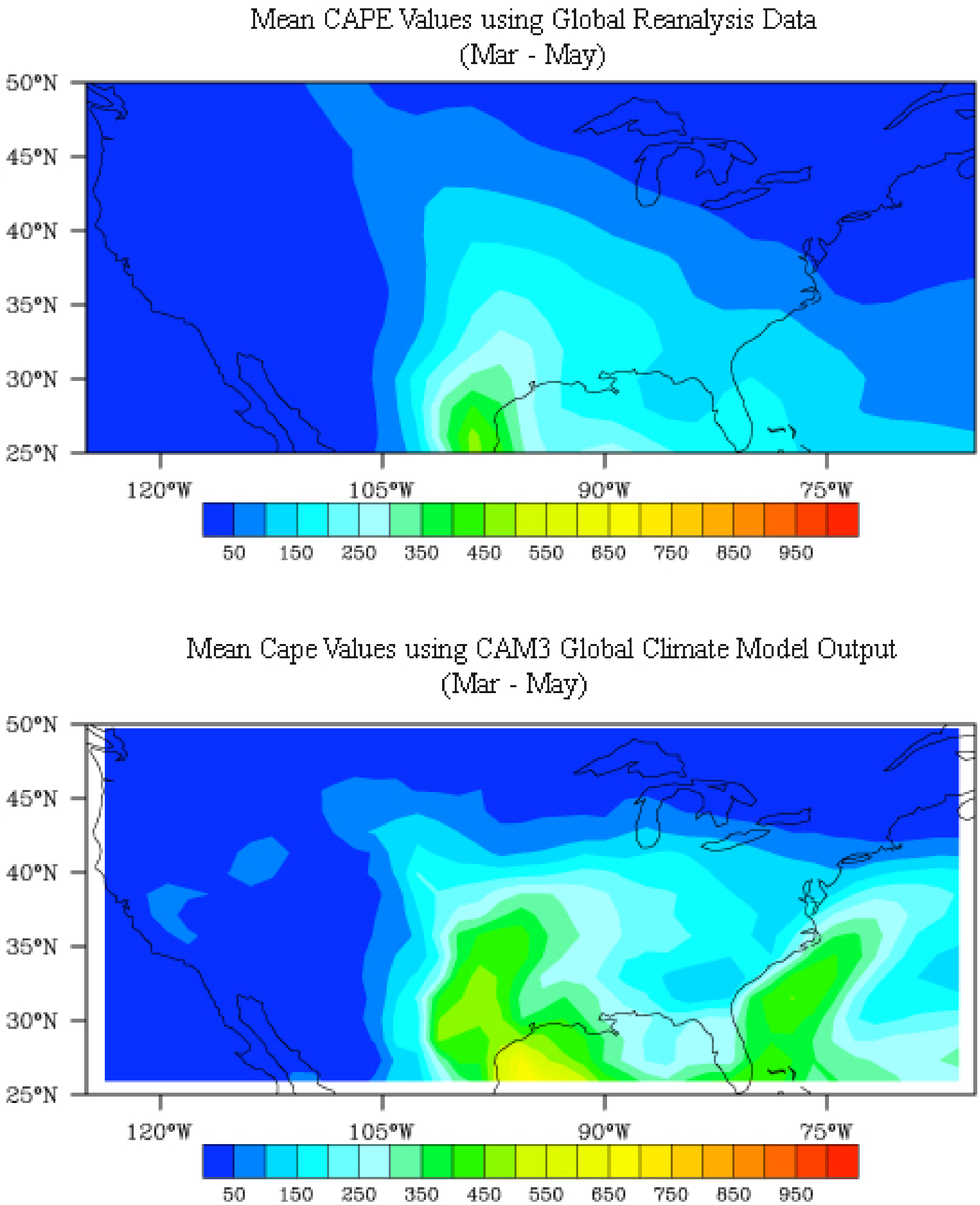

FIGURE 2. *CAPE values averaged over all times for March through May using global reanalysis data (top) and CAM3 global climate model output (bottom).*

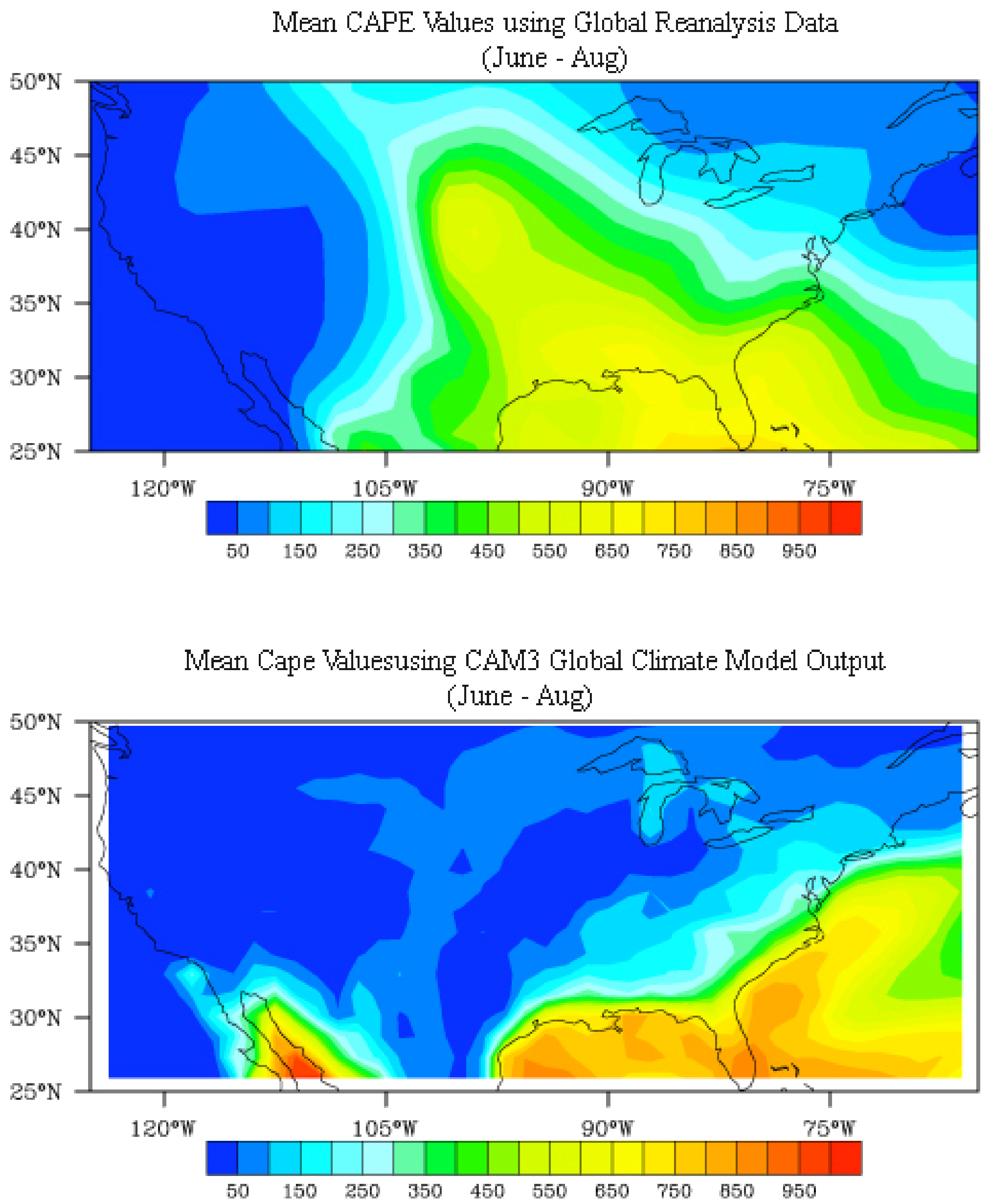

FIGURE 3. *CAPE values averaged over all times for June through August using the global reanalysis data (top) and the CAM3 global climate model output (bottom).*

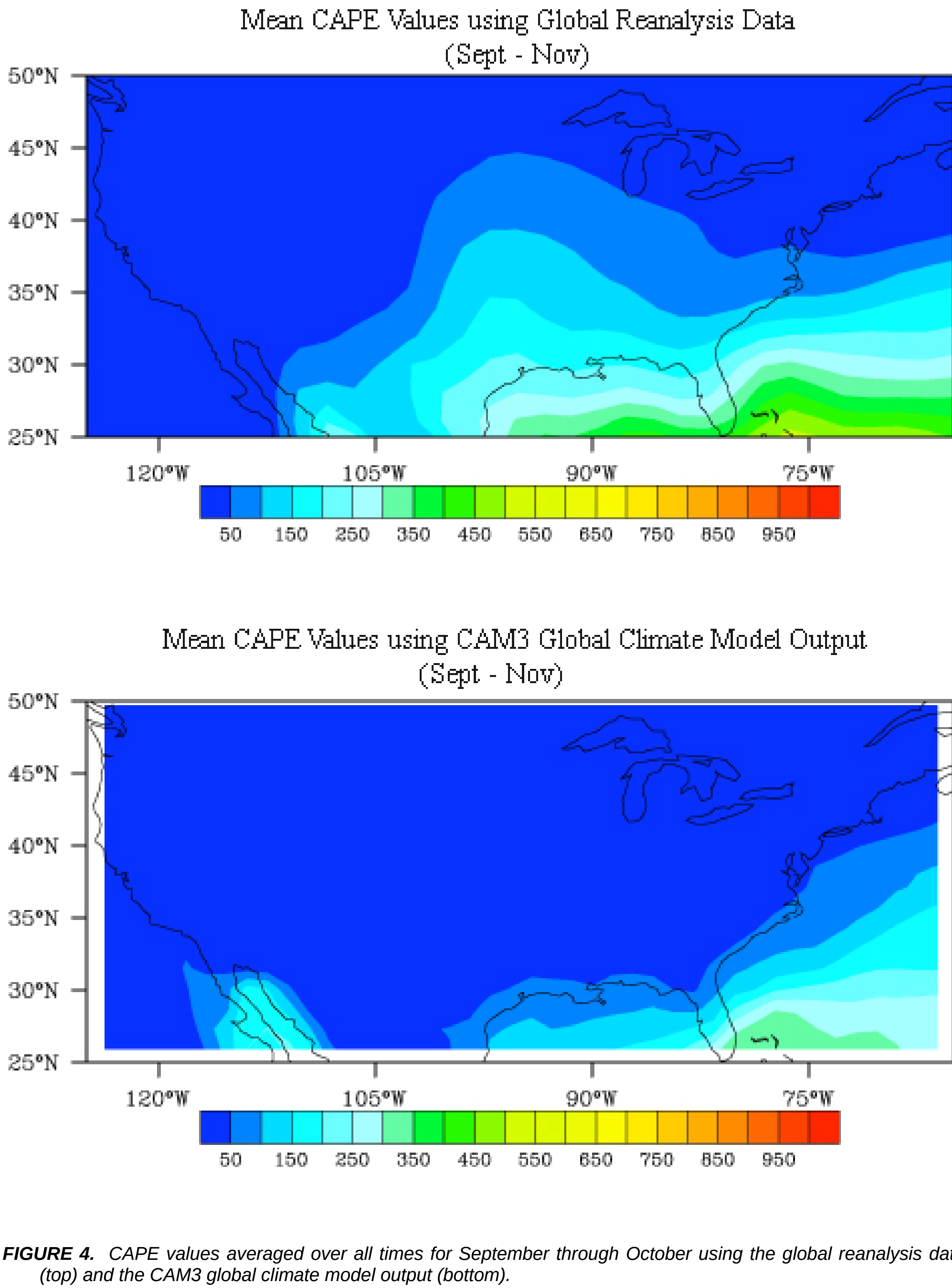

FIGURE 4. *CAPE values averaged over all times for September through October using the global reanalysis data (top) and the CAM3 global climate model output (bottom).*

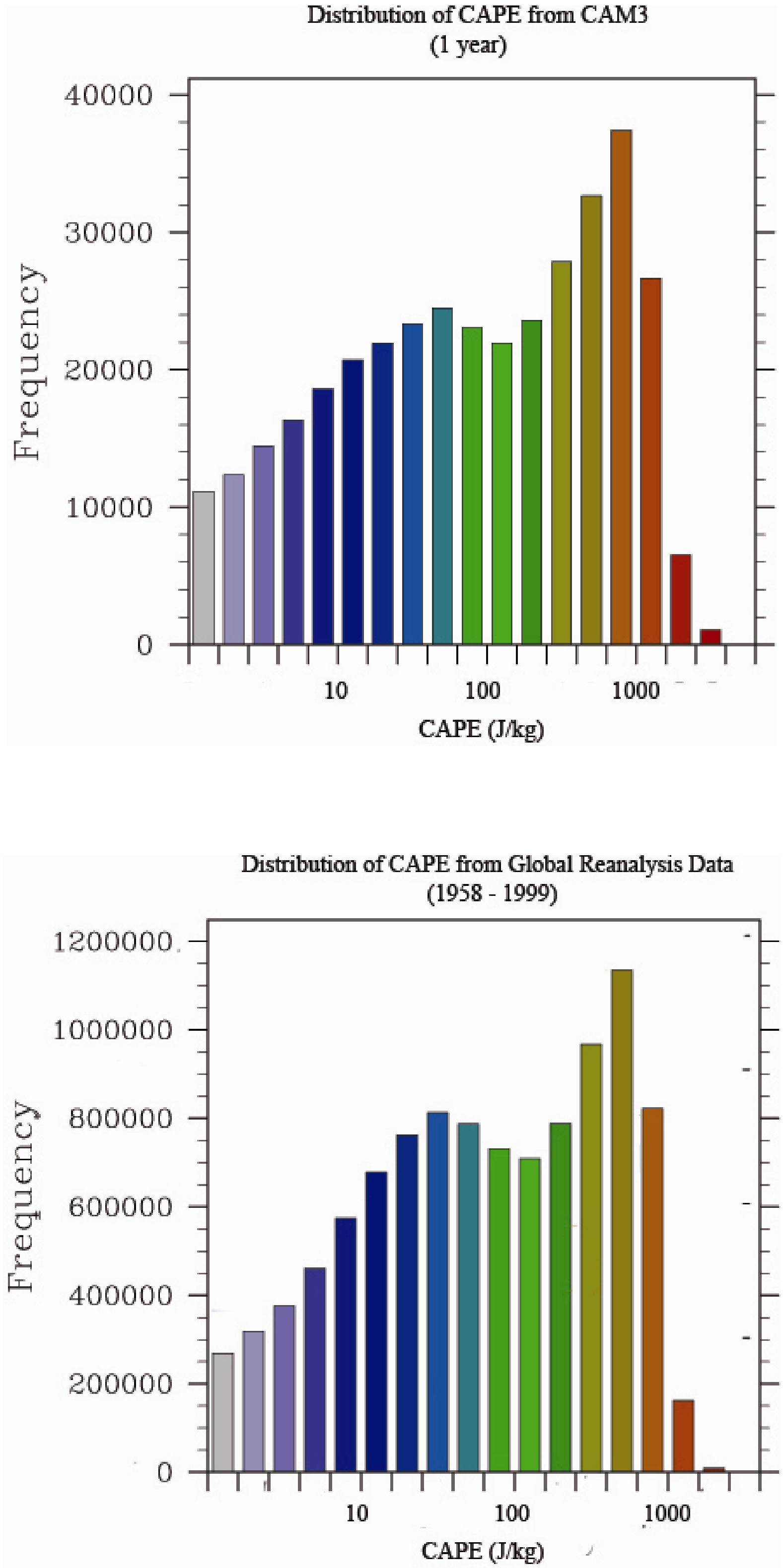

FIGURE 5. *(Top)Distribution of all CAPE values between 1958 and 1999 using global reanalysis data. (Bottom) Distribution of all CAPE values for one year using CAM3 global model output.*