Assessment of the Severe Weather Environment in North America Simulated by a Global Climate Model

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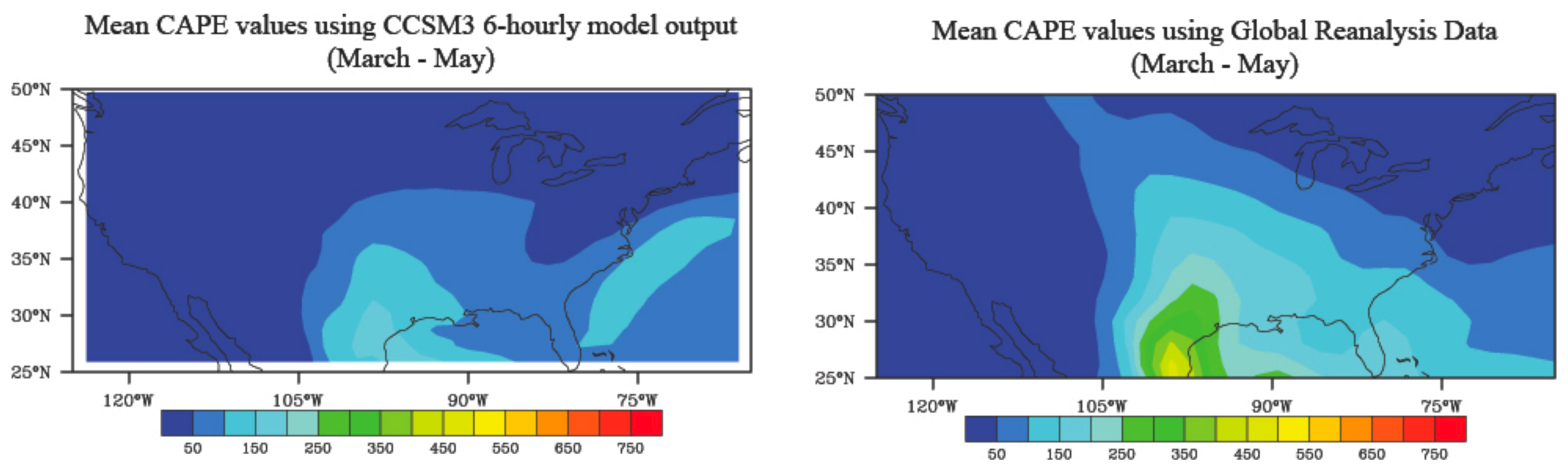

Mean CAPE values using CCSM3 6-hourly model output (March - May)

Mean CAPE values using Global Reanalysis Data (March - May)

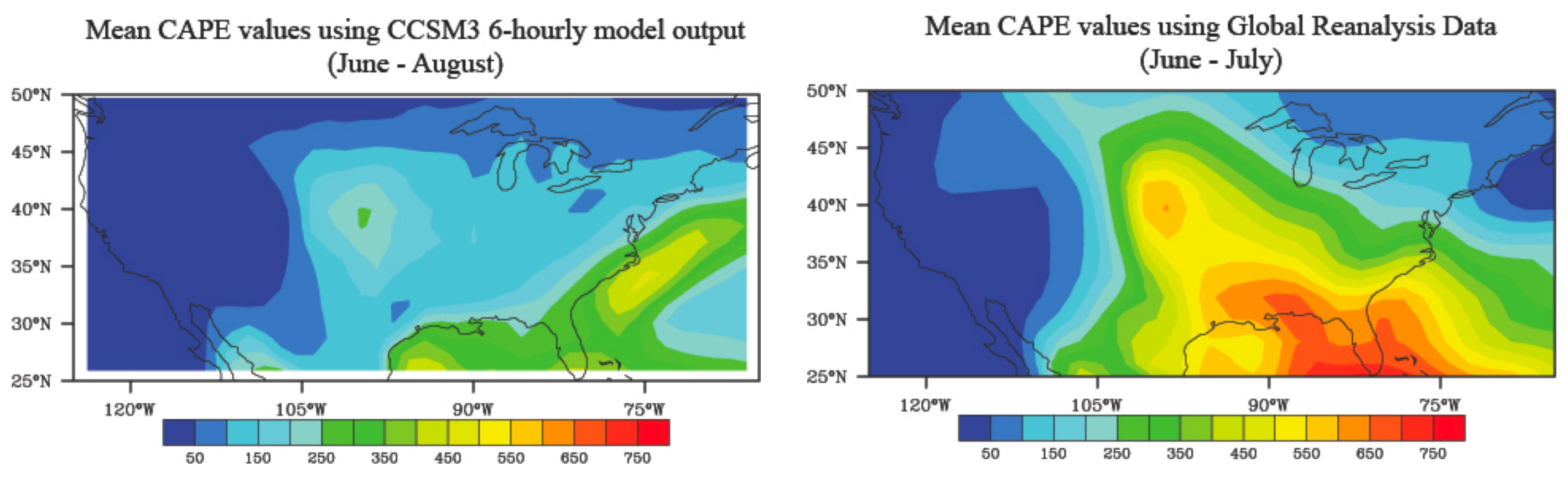
Figure 1. Comparison of CAPE values from CCSM3 output (left) and Global Reanalysis Data (right) for March through May

The accuracy of climate change prediction hinges on the understanding of current climatologies and the correct simulation of current climatologies by climate models. Severe convective weather events 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.

Currently, global climate models are incapable of resolving actual severe weather events as these events occur at scales 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.

The premise behind the reanalysis dataset is to create a best representation of the atmosphere for every 6 hours. 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). Since the resolution of the reanalysis data is roughly that of the CCSM3 model output (used in this study) it makes a natural choice to be used to verify parameter distributions within the CCSM3 model.

Seasonal averages of CAPE values derived from CCSM3 output qualitatively agree with the seasonal averages taken from the reanalysis data. While values are lower in the CCSM3 CAPE field, than in reanalysis data, the spatial structure is roughly the same - as seen in figures 1 and 2. It should e noted that the CCSM3 calculated CAPE is a maximum CAPE, while the global reanalysis CAPE is a 100hPa mean layer CAPE.

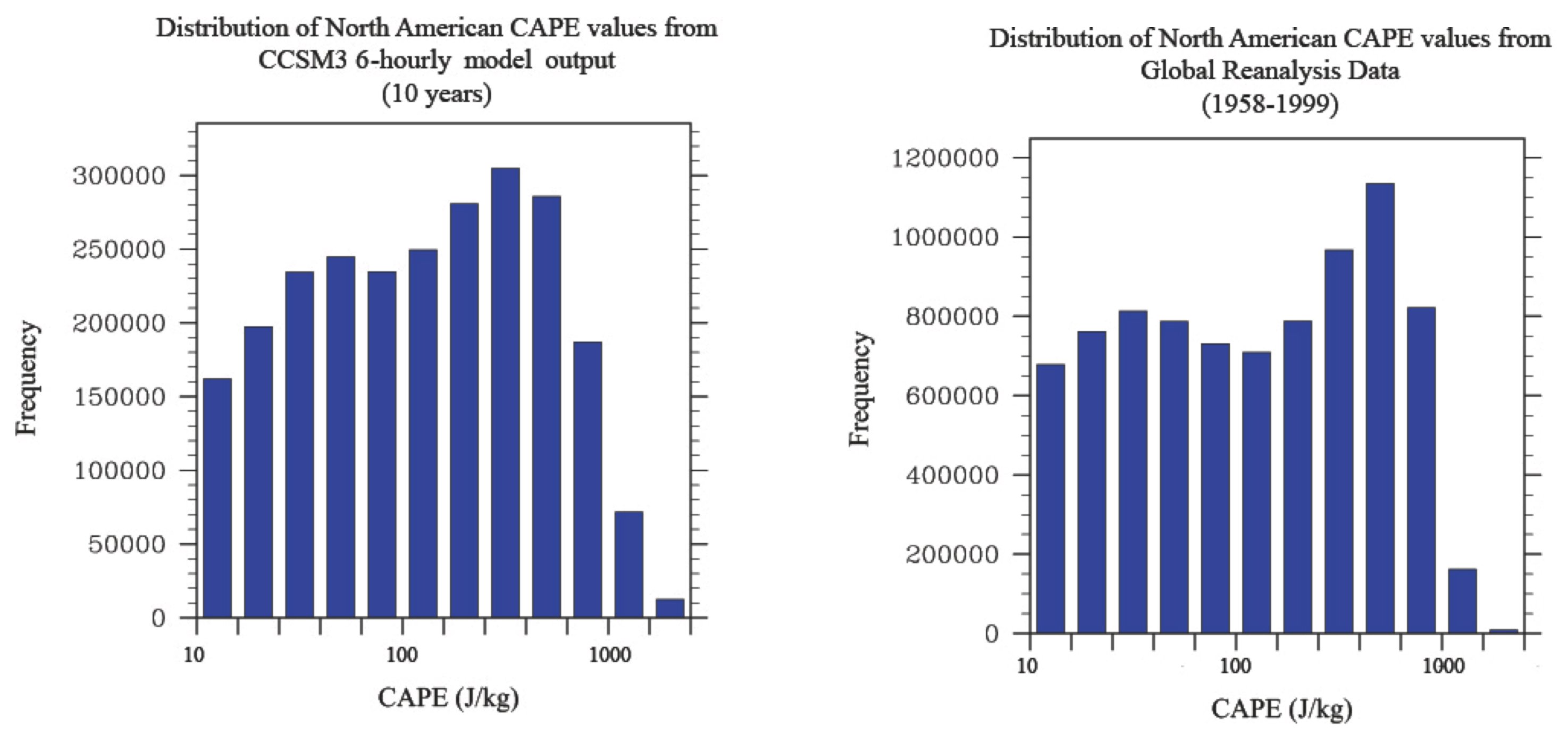

Mean CAPE values using CCSM3 6-hourly model output (June - August)

Mean CAPE values using Global Reanalysis Data (June - July)

Figure 2. Comparison of CAPE values from CCSM3 output (left) and Global Reanalysis Data (right) for June through July

References:

Lee, J. W., 2002: Tornado proximity soundings from the NCEP/NCAR reanalysis data. M. S. Thesis, University of Oklahoma, 61 pp.


Distribution of North American CAPE values from CCSM3 6-hourly model output (10 years)

Distribution of North American CAPE values from Global Reanalysis Data (1958-1999)

Figure 3. Distribution of CAPE from CCSM3 output (left) and Global Reanalysis Data (right)

In addition to the general spatial structure being the same, the frequency distribution of CAPE in the CCSM3 output is roughly the same as the distribution of CAPE in the reanalysis data. Both distributions are slightly bimodal with the second peak being larger than the first peak. In the CCSM3 output the first peak occurs between 40-60 J/kg while the reanalysis data has its first peak between 25-40 J/kg. Interestingly, the CCSM3 output’s second peak occurs between 250 400 J/kg while the reanalysis’ second peak occurs between 400-600 J/kg. These frequency distributions can be seen in figure 3.

CAPE is not the only severe convective weather parameter of interest. The magnitude of the deep layer shear (0-6km) also plays an important role. The frequency distribution of the deep layer shear‘s calculated magnitude from the CCSM3 output (figure 4) makes physical sense - higher quantities of lower values and lower quantities of higher values.

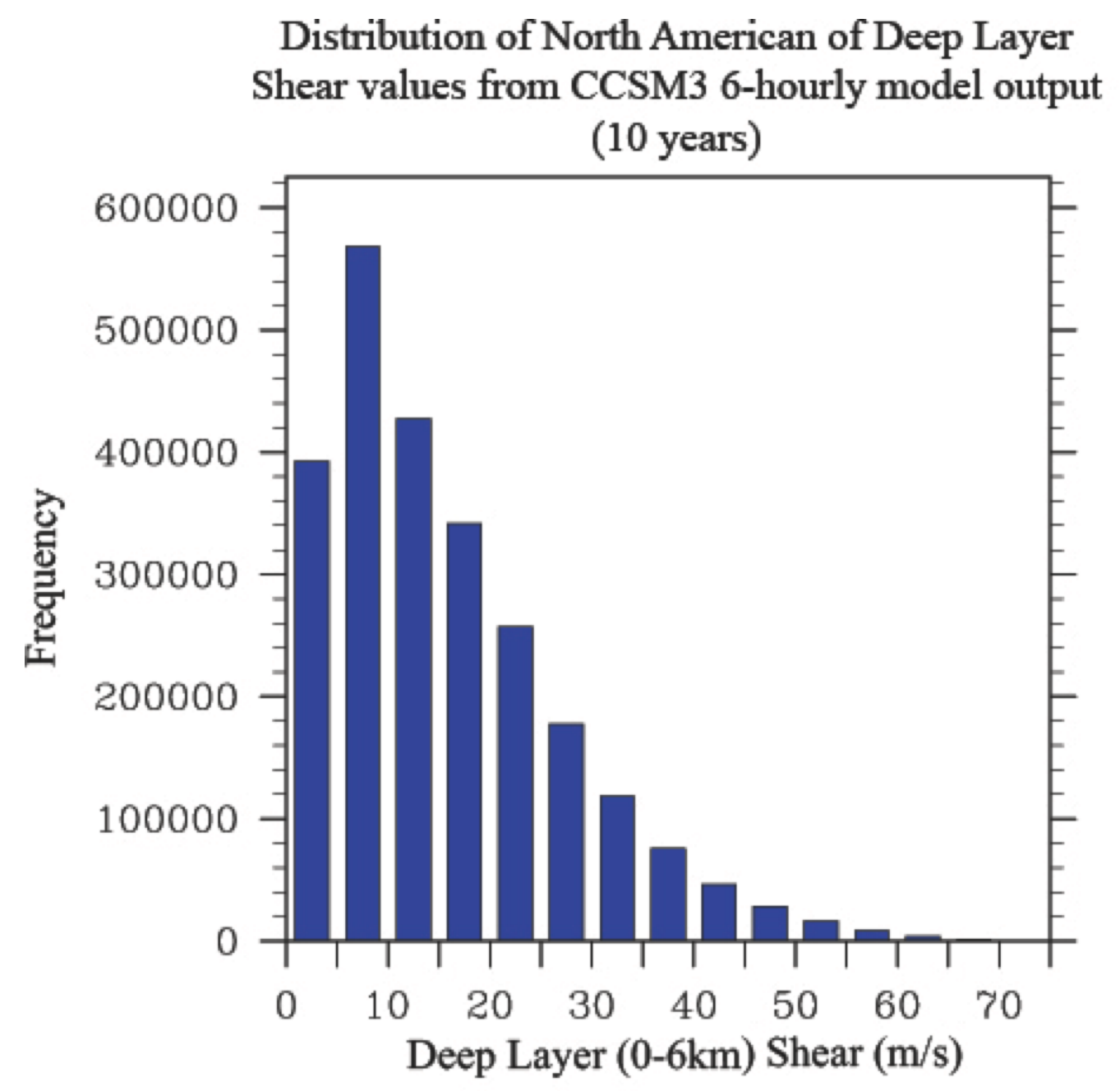
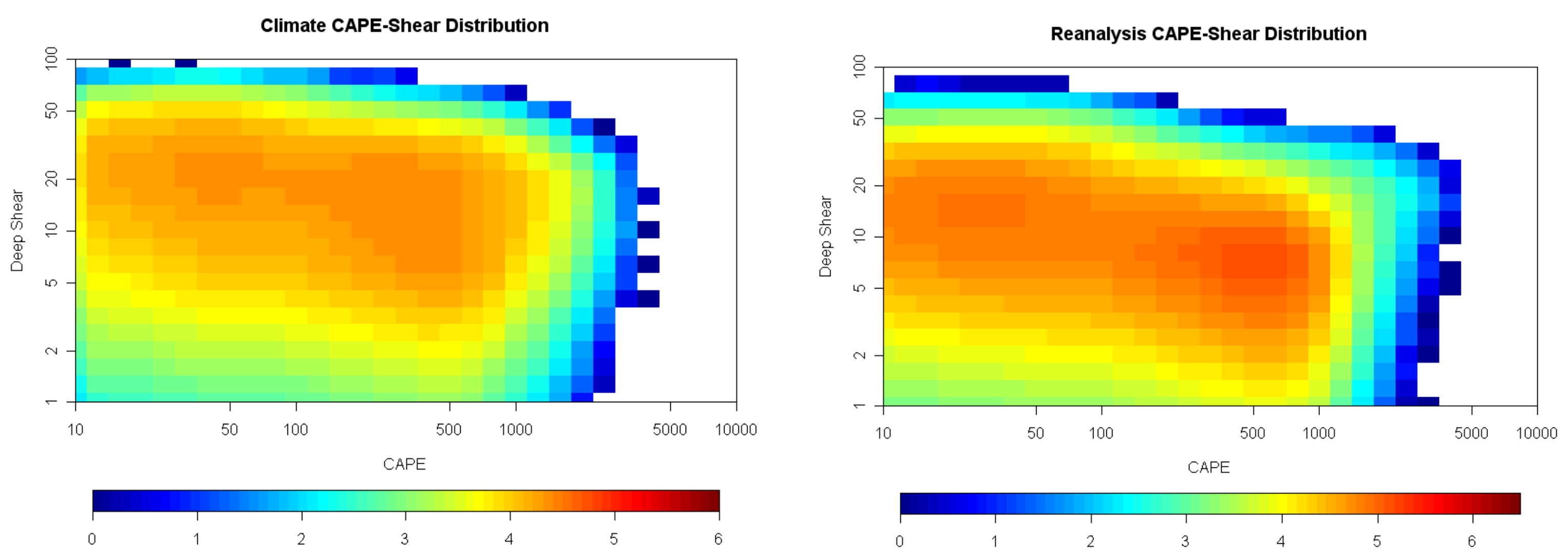

Distribution of North American of Deep Layer Shear values from CCSM3 6-hourly model output (10 years)

Figure 4. Distribution of Deep Layer Shear from CCSM3 output


Climate CAPE-Shear Distribution

Reanalysis CAPE-Shear Distribution

Figure 5. Density of the CAPE-Shear distribution from CCSM3 output (left) and Global Reanalysis Data (right)

Comparing the combined distributions of CAPE and Shear (figure 5), it appears the shear is higher in the model than the reanalysis. When looking at the distance between the two maxima in the bimodal distribution, the low peak in the reanalysis data is at a lower CAPE value than the CCSM3 model. However, the high peak has a higher value. Owing to the way CAPE values are calculated, it would be expected that the model would yield a higher CAPE value (closer to being a maximum CAPE than a mean-layer CAPE). Qualitatively, it appears that the model is conservative in its creation of CAPE and the parcel used in the calculation shifts the model’s distribution towards higher CAPE.

The probability of severe convection increases with increasing CAPE and shear. By looking at the product of CAPE and the magnitude of deep layer shear it is possible to locate areas of increased favorability for severe convection. Using a threshold of 20000 for this product, the spatial distribution of the mean number of 6-hourly periods with favorable severe parameters has an expected maximum in the central plains (excluding points over oceans).

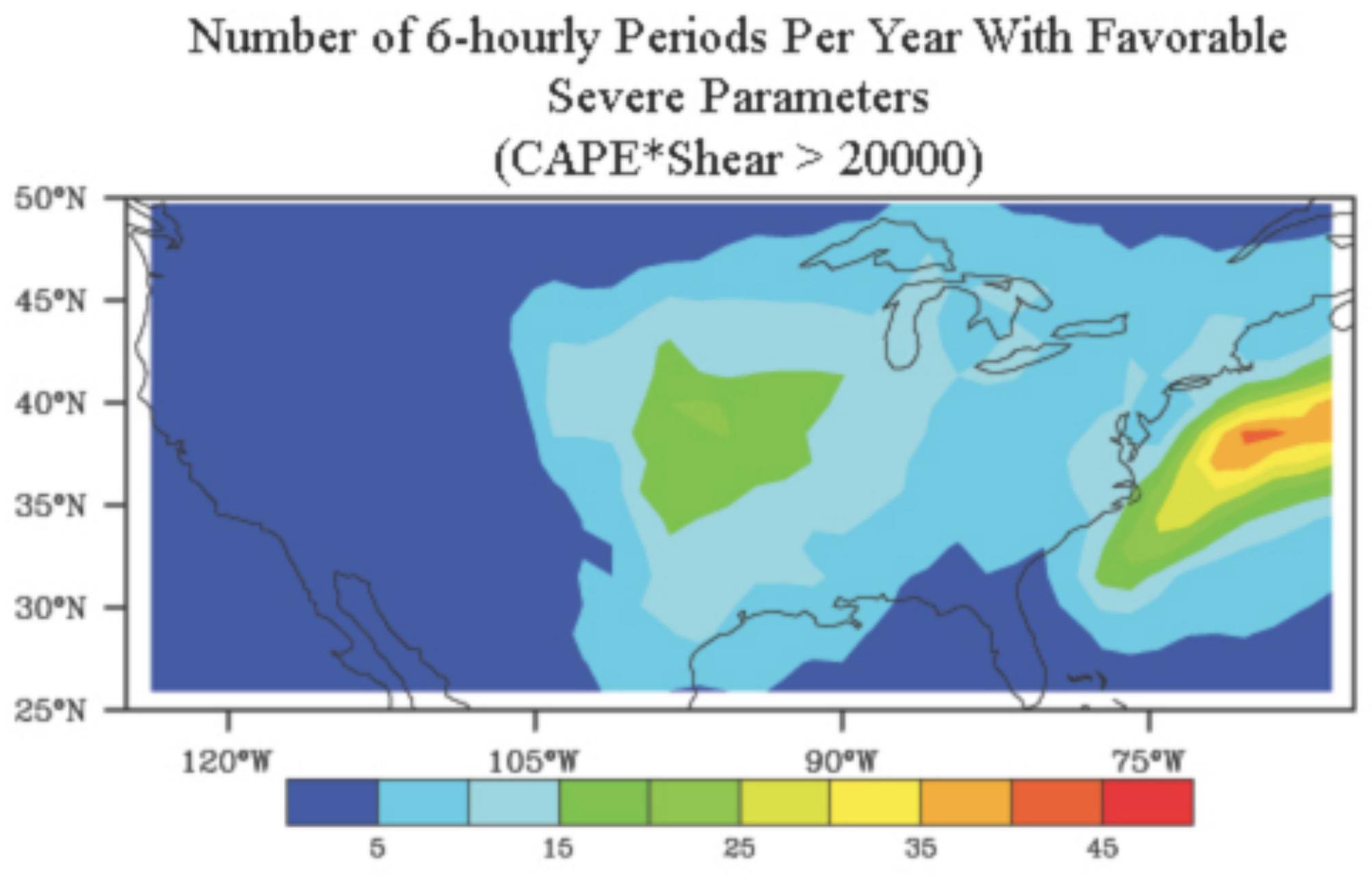

Number of 6-hourly Periods Per Year With Favorable Severe Parameters (CAPE*Shear > 20000)

Figure 6. Number of 6-hourly periods per year with favorable shear parameters. (CAPE is in J/kg and shear is in m/s.)

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