Regional Variability of CAPE and Deep Shear from Reanalysis

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Introduction / Background

From the perspective of a convective forecaster, it is vital that one understands the environmental conditions in which he/she expects convection to occur. Using the ingredients based forecasting technique that Doswell et al. (1996) described to forecast flash floods, one can employ parameters that are relevant to convection, or perhaps deep moist convection, to develop a conceptual model that would resemble an environment favorable for the development of such events. This is sufficient from a day to day forecasting point of view, but the proposal is to try to understand the distribution of convective environments. In turn, this study will not be useful in predicting the environment on a day to day basis; however, it will be especially useful in determining which areas are climatologically favorable for convective environments. This will also allow one to analyze how frequent, and what times of the year a forecaster would expect a convectively favorable environment. Brooks et al. (2003) have taken the first step towards trying to understand the global distribution of convectively favorable parameters. This research has analyzed the variability of these distributions, including the change of their spatial and temporal characteristics. It has been accomplished by analyzing trends of convectively important variables for three domains. It will then be valuable to compare and contrast the parameters across domains to determine the variability of each data set. In order to get a sense of what past environments resemble, especially the vertical profile, it is useful to analyze data from the National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) global reanalysis dataset. Kalnay et al. (1997) describes this 42 year reanalysis project. Researchers desire to use observed data for analysis, but the spatial and temporal sampling of observed soundings are not adequate enough to allow thorough analysis of regions. On the other hand, reanalysis provides spatial and temporal continuity in the form of spacing of 1.875° longitude by 1.915° latitude and soundings taken every six hours at 00 UTC, 06 UTC, 12 UTC, and 18 UTC.

Methodology

This study will focus on the 42 year reanalysis data set (1958-1999) and look for annual variability of thermodynamic parameters that would be typical of a preconvective environment. Reanalysis data provides standard 6 hr intervals of best estimate profiles for the atmosphere for 18,048 points on the globe. So far, this study has focused on three main areas: The Central United States, Eastern United States, and Southeastern South America. Each area has domain of 15 ° latitude by 15° longitude. This geographic area produces 72 points in both the Central and Eastern United States regions. The North American regions will have approximately 4.4×10^6 soundings. The South American dataset only has 64 points because of the placement of the domain, but still has about 3.9×10^6 soundings. It is important to note that for this study we will disregard all soundings with zero CAPE in all regions because we do not wish to look at the probability of CAPE occurring, we want to analyze the variability of CAPE.

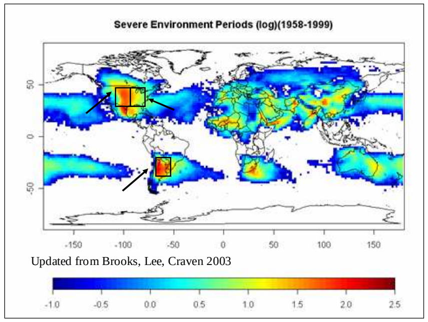

Figure 1. Showing the frequency of severe environments across the globe. (From NCEP/NCAR Reanalysis) Boxes indicate the three regions that this research is focusing on.

CAPE can be described as: $$\text{CAPE} = g\int_{Z_{LFC}}^{Z_{EL}} \left(\frac{T_{vp} - T_{ve}}{T_{ve}}\right) dz$$

Based on the parcel theory, extreme values of CAPE give the preconvective environment a better chance to produce severe convection in the form of stronger updrafts. For this reason we will look at the 90th percentile CAPE values for all three domains. The 90th percentile, in this study, is the value that is exceeded by only 10 percent of the soundings. By observing the 90th percentile across all domains, one can get a sense of the variability of each domain, trends within domains, and even global scale relationships between regions. Developing this kind of distribution across a 42 year period allows researchers to understand the interannual variability of convective environments. Understanding the past variability of our climate is essential if we are ever to try to understand what convective environments will resemble in the future. For this study, these particular regions were chose for their high frequency of severe environments. If trends want to be detected, these areas of high frequency would show the first signs of changing in comparison with other regions.

Results

The Central United States is one of the regions with the most frequent combinations of CAPE and deep shear (Brooks et al. 2003). The Central United States domain consists of 30 to 45 degrees north and 105 to 90 degrees west. Figure 2.a. depicts the annual distribution of CAPE in the Central United States. The plot shows that for any given sounding, the y-axis corresponds to the probability of exceeding the x-axis CAPE value. This type of chart allows one to interpret the annual cycle of CAPE in the Central United States. Figure 2.b. shows the annual distribution of 90th percentile CAPE values for the three domains. The Central United States peaks in CAPE values in June while the Eastern United States peaks in the July period. Since South America is in the southern hemisphere, its peak is around the November timeframe. This figure also shows the much larger range of values in the United States as compared to South America. This could be due to the latitude differences of the two regions, which would suggest that South America has CAPE a higher percentage of the time than the United States.

CAPE Distribution/Variability

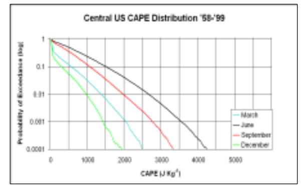

Figure 2a. Each line represents the probability that CAPE from a sounding will exceed values on the horizontal axis, given that CAPE is present. For example, the probability that any given sounding in June will exceed 1,500 J Kg^{-1} is 10 percent.

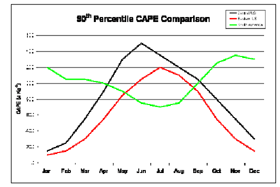

Figure 2b. The annual distribution of 90th percentile CAPE values in each region. Note the differences in the peaks of the 90th percentile CAPE values and the different ranges of the 90th percentile CAPE values.

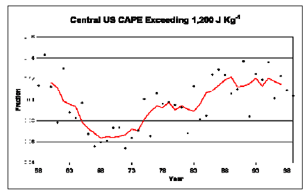

Figure 3a. Distribution of percent of soundings that exceed 1,200 J Kg^{-1} (90th percentile). Red line indicates the five year running mean. For example, about 12 percent of soundings exceeded 1,200 J Kg^{-1} in 1988

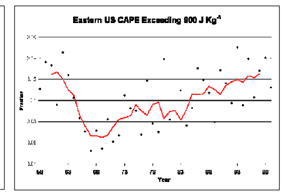

Figure 3b. Same as Figure 3 except for the Eastern United States. Note the difference of the values of the 90th percentile for the regions.

There is need for an understanding of how different convective parameters vary with time so that researchers and forecasters can adjust their approach to studying and forecasting these convective environments. This is accomplished in this study by observing five-year running means to help smooth the data and identify trends. Figure 3a. is a plot of the 90th percentile CAPE values for each year for the Central United States. In other words, for any given year, the y-axis value corresponds to the percent of soundings that exceed the 90th percentile value, which in this case is 1,200 J Kg-1. It is easy to diagnose high and low CAPE periods by using these types of charts. For example, in Figure 3a. one can see the relatively low CAPE period in the mid 1960's through the 1970's and the reasonably high CAPE period from the late 1980's through the 1990's. This suggests that in the 30 year period from about 1967 to 1998 the number of soundings that reach the 90th percentile CAPE value have increased in the Central US.

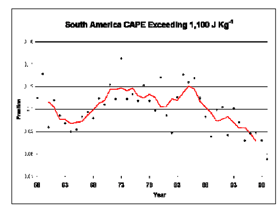

Figure 4. Distribution of percent of soundings that exceed 1,200 J Kg^{-1} (90th percentile). Red line indicates the five year running mean. For example, about 12 percent of soundings exceeded 1,200 J Kg^{-1} in 1988

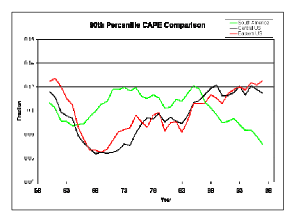

Figure 5. Comparison of all 3 region's 90th Percentile CAPE 5 year running means. Note the different behavior since the late 1980's.

CAPE & Shear Variability

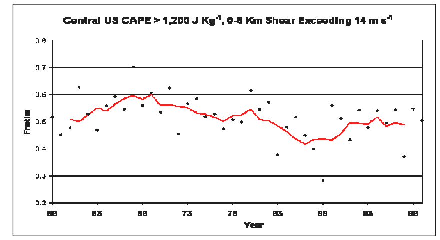

Figure 6. Similar to Figure 3 except with the distribution of Central United States Median Shear in the presence of CAPE greater than 1,200 J Kg^{-1} (90th Percentile). Note the outlier points in 1976 and 1988. 1976 would suggest a very favorable environment for severe weather while 1988 shows that when CAPE was present, shear values were very low.

Discussion

The Central and Eastern United States have shown an increasing trend in the amount of soundings that have surpassed the 90th percentile, while the South American domain has shown a decreasing trend. In the Central United States, the values of CAPE have been shown to be increasing by along with deep shear values. In Southeastern South America, deep shear has also been relatively constant, but CAPE values have been decreasing in the last decade. Since convection depends on a wide variety of different variables and processes to occur, it is beyond this study to show that convection was also on the increase or decrease during these years. However, since the environmental conditions that house deep moist convection are being studied, it is possible to show areas that would be more or less favorable to accommodate this type of activity if synoptic or mesoscale processes were in place.

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