Trends of CAPE in ERA-40

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I. INTRODUCTION

Convective available potential energy (CAPE) plays a major role in severe storms and tornado development (Romero et al., 2007; Brooks et al., 2003). The influence of global warming on severe weather during the last decades is a major issue, thus a trend analysis on CAPE is made to explore whether the climate change has an impact on CAPE. The trend is analysed for each season based on monthly mean values of CAPE calculated from the ECMWF reanalysis (ERA-40) between 1958 and 2001. First results show that CAPE decreases in the Mediterranean in winter.

II. DATA AND METHODOLOGY

Surface based CAPE has been calculated pseudoadiabatically from temperature and relative humidity of the ERA-40 for the years 1958 until 2001. It has been calculated globally on a horizontal grid with a spacing of 1.125°.
CAPE is analysed by applying the Mann Kendall trend test which is a robust trend estimator applicable for any theoretical distribution. Although the Mann Kendall Score S varies in space, S indicates only if a given trend is positive (positive sign) or negative (negative sign) irrespective of the value of the score. Trends are only examined if their probability exeeds 90%.

$$S = \sum_{i<j} \left(sign\left(x\left[j\right] - x\left[i\right]\right) * sign\left(y\left[j\right] - y\left[i\right]\right)\right) \qquad (1)$$

A linear regression is made to estimate the magnitude of a given trend. However, the results of the linear regression come only up to the maximum likelihood estimator and are discussed in this study if the error ε (EQN. 2) of the regression is normally distributed. The regression equation is:

$$y = X\beta + \varepsilon \qquad (2)$$

Temperature plays an important role in the calculation of CAPE. Bengtsson et al. (2004) point out that the temperature of the lower troposphere in ERA-40 has an artificial warming trend until 1979. Therefore additional trend tests are done for the time periods 1958 until 1978 and 1979 until 2001.

III. RESULTS AND CONCLUSION

The Mann Kendall trend test shows that trends of CAPE exist in most parts of the world, with the exception of the Antarctic, throughout the year between 1958 and 2001 (FIG. 1). The regions with positive trends outnumber the regions with negative trends considerably.

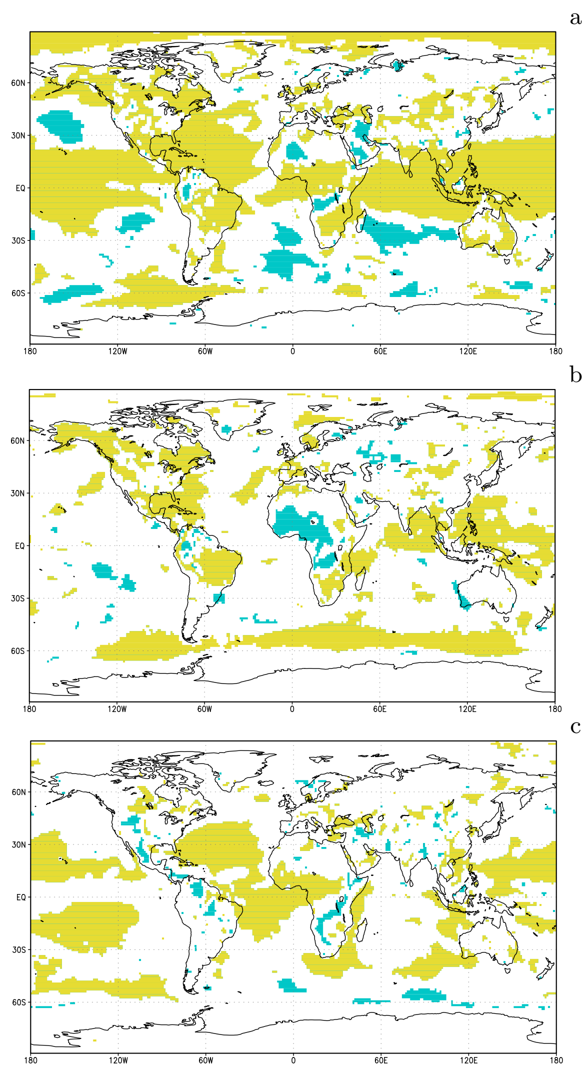

FIG. 1: Mann Kendall Score S with a 90% significance. Yellow indicates a positive trend of CAPE, blue indicates a negative trend of CAPE. Trends are shown for the summer seasons (a) between 1958 and 2001, (b) between 1958 and 1978 and (c) between 1979 and 2001.

Positive trends can be found in every region except the Antarctic. Negative trends can only be found in all oceans but not in the North Atlantic. They can also be found in the regions of the Middle East and South America throughout the year. Additionally, negative regions are found in the Mediterranean and Central Africa during the winter months and in Mali and in Angola in summer of the years 1958 to 2001. One notices that positive as well as negative trends are found in regions close-by as for example in Africa during summer. The results of the time periods 1958 until 1978 and 1979 until 2001 are surprisingly different from those of the years 1958 until 2001. The region of Central Africa shows a negative trend between 1958 and 1978 while the same region shows a positive trend between 1979 and 2001. Furthermore, the regions around the Arctic show a positive trend between 1958 and 1978, while in some of these regions a negative trend can be found between 1979 and 2001. Additionally, only a few regions with a positive trend can be found in the Pacific between 1958 and 1978, while large regions with a positive trend can be found in the Pacific as well as in the Atlantic between 1979 and 2001. The results of the Mann Kendall test show that trends in CAPE vary significantly over space and time beween 1958 and 2001.

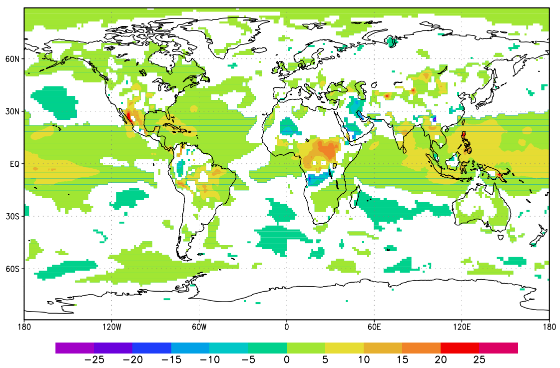

FIG. 2: Magnitude of the trend calculated with linear regression. The trends are shown for the same regions plotted in FIG.1. Trends are shown for the summer seasons between 1958 and 2001. The units are J/(kg*44y).

The results of the linear regression of those regions with normally distributed errors cover a lot less regions than are covered by the 90% trend probability. FIG 2. shows the results of the linear regression for the same regions plotted in FIG.1. However, not all of the regions shown in FIG.2 have a normally distributed ε. The results of these regions are therefore not discussed in this abtract. The magnitude of the trend of the regions covered ranges from -25 J/(kg*44y) in a small region in China during summer to 25 J/(kg*44y) in Colombia during the winter months of the years 1958 to 2001. However, the magnitude over the two shorter periods of time from 1958 to 1978 and from 1979 to 2001 ranges from -50 J/(kg*21y) to 70 J/(kg*21y) during the first period of time and from -50 J/(kg*23y) to 50 J/(kg*23y) during the second period of time. These differences occur due to the changing sign of the trend in some regions. The regions with the largest trends are concurrent with those regions which show the largest trend differences over time. One of these regions is the region on Central Africa. While the trend ranges from -10 J/(kg*21y) to -50 J/(kg*21y) during the first period of time, the trend ranges from 10 J/(kg*23y) to 50 J/(kg*23y) in Central Africa throughout the year during the second period of time. Moreover, the trend ranges in Angola between -10 J/(kg*23y) and -20 J/(kg*23y) during the winter months of the same time period. The fact that regions with positive trends and negative trends are sometimes close-by might be due to topography. The northern region of South America is another example of changing trends during the two periods of time: During winter in the first period of time a positive trend up to 70 J/(kg*21y) can be found in Peru additionally to a negative trend of -10 J/(kg*21y) to -20 J/(kg*21y) in Brazil. However, during winter in the second period of time a negative trend of -10 J/(kg*23y) to -20 J/(kg*23y) can be found in Peru while a positive trend of 10 J/(kg*23y) to 30 J/(kg*23y) shows up in Brazil.

Overall, the results of the linear regression resemble the findings of the Mann Kendall test. In addition to the trend test on CAPE another trend test on the 2 meter temperature has been done (not shown). The results of the temperature trend analysis resemble the results of the CAPE trend analysis. The distribution of the CAPE trends have a similar pattern compared to the distribution of the temperature trends between 1958 and 2001. Furthermore, the two shorter periods of time show the same change of trends in Central Africa and Brazil. These findings reveal not only a strong connection between 2 m temperature and CAPE but also that the climate change seems to have an impact on CAPE. However, further research needs to be done to calculate the magnitude of the regions which are not covered by the linear regression. These regions need to be analysed with another method which is independent of the theoretical distribution of the data and therefore is able to cover every trend measured by the Mann Kendall test.

IV. REFERENCES

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