Influence of sounding derived parameters on the strength of tornadoes in Europe and the USA from Reanalysis data

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I. INTRODUCTION

The influence of parameters such as convective available potential energy (CAPE), wind shear and the lifting condensation level (LCL) on the formation of tornadoes has been examined by several authors and these parameters have been found to discriminate well between tornadic and non-tornadic thunderstorms (e.g. Brooks et al., 2003; Rasmussen and Blanchard, 1998). However, what is still open to question is how they influence the strength of tornadoes. Thus, the effect of combinations of the mentioned parameters are analyzed on weak (F0, F1) and significant (F2+) tornadoes in Europe as well as in the US.

In Europe, the dataset for the weak tornadoes is small. Also, the underreporting of F0 tornadoes is apparent in Europe (Dotzek et al., 2009). Thus, for Europe, distributions of the parameter combinations for the F0 and the F1 tornadoes are compared to the distributions of the unrated tornadoes to see if the unrated tornadoes resemble the F1 or the F0 tornadoes in order to include them into the dataset for the weak tornadoes for extension of that data set.

II. PRESENTATION OF RESEARCH

The values of the parameters WMAX (CAPE in terms of updraft velocity, here based on a parcel that is mixed over the lowest 100 hPa), LCL, DLS (deep layer shear, 0 to 6 km wind difference) and LLS (low level shear, 0 to 1 km wind difference) that are associated with tornadic environments have been used to analyse how they affect the strength of tornadoes in Europe and the USA. The updraft velocity WMAX is based on a parcel theory and is defined as WMAX=sqrt(2xCAPE) (Holton, 1992).

These parameters have been derived by taking the information about where and when a tornado occured from data from the European Severe Weather Database (ESWD) for the years 1958 to 1999 and from data from the Storm Prediction Center (SPC) for the years 1991 to 1999 for the US. Then, for these times and places the proximity soundings deduced from the National Center for Atmospheric Research (NCAR)/United States National Center for Environmental Prediction (NCEP) reanalysis (Kalney et al., 1996) were used and with help of the the Skew-t/Hodograph Analysis and Research Program (SHARP) (Hart and Korotky, 1991) the mentioned parameters were derived from the reanalysis soundings.

Density distributions for the parameter combinations WMAX/DLS, LCL/DLS and LCL/LLS have been generated for weak as well as for significant tornadoes for Europe and the US. In addition, for Europe, density distributions for these parameter combinations have also been generated for the unrated, the F1 and F0 tornadoes.

Before generating the distributions, a gaussian smoother has been applied to the parameter combinations. While applying the smoother on each combination, an analysis grid was created where each analysis grid point contains a value of how likely it is for the combination of parameter values that it represents to appear in a tornado sounding. The density distributions are based on the values of these analysis grids.

III. RESULTS AND CONCLUSIONS

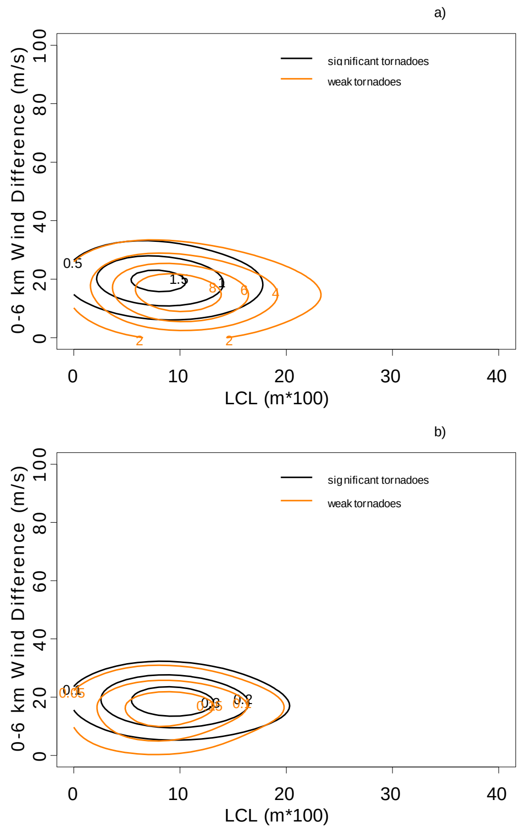

FIG. 1: Density distributions of weak and significant tornadoes for the parameter combination LCL/deep-layer shear for the US (a) and Europe (b). Values of contour lines, from inside to outside, are 1.5, 1 and 0.5 for significant and 8, 6, 4 and 2 for weak tornadoes (a) and 0.3, 0.2 and 0.1 for significant and 0.15, 0.1 and 0.05 for weak tornadoes (b)

The density plots for the combination LCL/DLS show that in the US (Fig. 1a) most significant tornadoes occur at higher DLS and lower LCL than most weak tornadoes, with a density maximum at LCL heights between 650m and 1400 m and DLS values between 10 m/s and 21 m/s for the weak tornadoes and between 550m and 1100m and 16 m/s and 23 m/s for the significant tornadoes. In Europe on the other hand, most significant tornadoes occur at slightly higher DLS, but at slightly higher LCL than the weak tornadoes, with a density maximum at LCL heights between 500 m and 1300 m and DLS values between 10 m/s and 22 m/s for the weak tornadoes and between 600 m and 1300 m and 15 m/s to 24 m/s for the significant tornadoes. Thus, whereas in Europe the DLS shows similar behaviour concerning the strength of tornadoes as in the US, the LCL shows the opposite behaviour. This is also true for the combination LCL/LLS (not shown here). In the US, most significant tornadoes occur at higher LLS and lower LCL than most weak tornadoes, whereas in Europe most significant tornadoes occur at slightly higher LLS, but slightly higher LCL.

Since the differences between weak and significant tornadoes for the combination LCL/DLS are bigger in the US, than in Europe (Fig. 1), the combination LCL/DLS is a better discriminator between weak and significant tornadoes in the US than in Europe. This is also the case for the distribution LCL/LLS. The reason for the different behaviour of the LCL height in Europe compared to the US might be that in Europe another factor or other factors have an influence on the strength of tornadoes that compensate for the higher LCL heights. Future research should be done to find out about this.

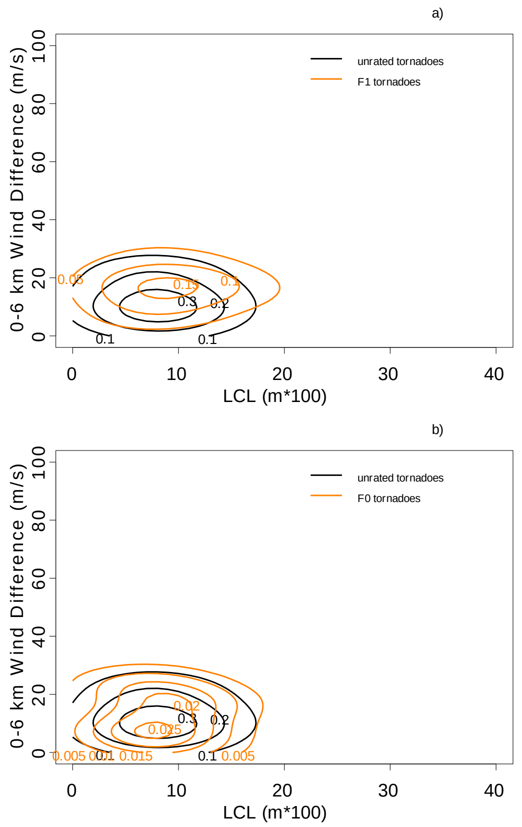

FIG. 2: Density distributions of unrated and F1 tornadoes (a) and of unrated and F0 tornadoes (b) for the parameter combination LCL/deep-layer shear. Values of contour lines, from inside to outside, are 0.3, 0.2 and 0.1 for unrated (a and b), 0.15, 0.1 and 0.05 for F1 (a) and 0.025, 0.02, 0.015, 0.01 and 0.005 for F0 tornadoes (b).

The combination WMAX/DLS (not shown here) is a better discriminator between the strength of tonadoes in Europe, than it is in the US, because in the US the WMAX does almost not vary for weak and significant tornadoes. In the US, most significant tornadoes occur at higher DLS, but at about the same WMAX as most weak tornadoes. In Europe, most significant tornadoes occur at higher DLS, but also higher WMAX, than the weak tornadoes.

The density plot for the combination LCL/DLS for the unrated and the F1 tornadoes (Fig. 2a) shows that most unrated tornadoes occur at lower DLS and slightly lower LCL than most F1 tornadoes. Since it was found for Europe that the higher the DLS and the higher the LCL, the stronger a tornado, the unrated tornadoes should be weaker than the F1 tornadoes and accordingly they must be F0 tornadoes then. Fig. 2b shows that the F0 tornadoes correspond rather well to the unrated tornadoes. However, since the density maximum of the F0 tornadoes is located at the lower DLS and slightly lower LCL part of the maximum for the unrated tornadoes the unrated tornadoes appear to be slightly stronger than the F0 tornadoes. This implies that the unrated tornadoes mostly contain F0 tornadoes, since they show the best correspondence to the unrated tornadoes, but also some stronger tornadoes, which might be F1 tornadoes only. Comparison between unrated and F1 and F0 tornadoes for the other two parameter combinations (not shown here) showed the same results. Since the unrated tornadoes resemble the F0 tornadoes rather well, it is reasonable to include the unrated tornadoes into the dataset for the weak tornadoes in future studies.

IV. AKNOWLEDGMENTS

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