TRENDS IN HAILSTORM FREQUENCY AND ATMOSPHERIC CHARACTERISTICS IN SOUTHWEST GERMANY

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(Dated: September 18, 2009)

I. INTRODUCTION

In light of global warming (IPCC, 2007), the question arises whether any evidence suggests an increase in severe thunderstorms either in number or intensity. This question is difficult to answer, because current surface observation systems are too coarse to capture all convective events. A way to overcome the problem of insufficient observations is an approach that links thunderstorm occurrence to large-scale atmospheric conditions. Changes in both the synoptic-scale circulation patterns and atmospheric stability are assumed to have a direct influence on the intensity or the number of thunderstorms. The purpose of the study is to examine whether there are any trends in the atmospheric conditions detectable suggesting alterations in the frequency of hailstorm occurrence in the last decades. The study area is Baden-Württemberg in Southwest Germany, where hail is responsible for nearly 40% of the total damage to buildings.

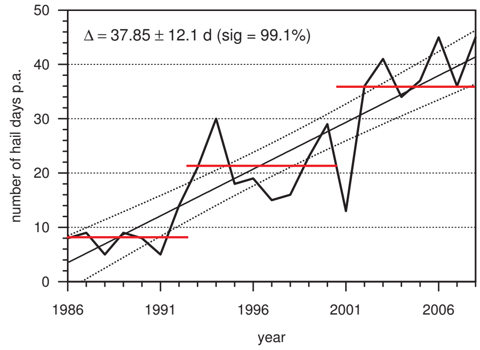

FIG. 1: Number of hail days per year according to damage reports of the SV building insurance company. If on a day a threshold of 10 claims is exceeded, it is defined as a hail day; indicated is the linear trend with 95% confidence intervals and 8-year averages as horizontal bars.

II. DATA SETS AND METHODS

To obtain complementary information about days with severe thunderstorms and a high convective potential of the atmosphere, data sets from different observation systems were combined. Synoptic station data (1949-2003) were used to quantify the number of thunderstorm days according to visible lightning or audible thunder as registered in the past and present weather code. Data relating to losses from a building insurance company between 1986 and 2008 were taken in order to estimate the annual variability of loss and hail days. The data were inflation-adjusted and corrected for the annual variability of the portfolio. Large-scale weather patterns based on the objective weather type classification from German Weather Service (DWD) are related to hail days as detected by the insurance loss data (not discussed here). Finally, several convective indices derived from radio-sounding data at the station of Stuttgart are used to investigate possible long-term trends in atmospheric static stability from 1974 to 2003.

In all examinations the summer-half year (April-Sept) is considered only, where hail occurs almost exclusively.

III. RESULTS

To investigate the annual variability of hail events, all days with hail occurrence in the whole observation period irrespective of the location and the amount of loss was determined from the insurance data. A day was classified as a hail day when a lower threshold of 10 claims was reached on a day, yielding 23 hail days on average. As can be seen in Figure 1, there is a strong increase in the number of hail days per year over the last decades. According to the trend-to-noise ratio and t-statistics, the linear trend indicated is significant on the 99% level. In contrast, the number of thunderstorm days detected at the synoptic stations confirm the high annual variability in the occurrence frequency, but not a trend.

Hence, the rising number of hail days and claims may be attributed to two different scenarios concerning atmospheric stability: the number of days with a potential for deep convection could have increased and/or atmospheric instability on thunderstorm days could have increased. To examine the two possible scenarios separately, the analyses of the convective indices is based on the number of days per year above a certain threshold according to the study of Kunz (2007) and different percentiles of the respective convective index. An example is shown in Figure 2 for the convective available potential energy (CAPE). Both the number of days above certain thresholds and the different percentile values show a significant increase in the past decades (sign. level of 95%).

Considering the large variety of convective indices, it is found that all indices determined from temperature and moisture of the lowest layers show an increase in both extreme values and the number of days above/below certain thresholds (Fig. 3). In contrast, indices based on levels above the surface exhibit either a negative or no significant trend. A relationship can be established between the number of hail days according to insurance data (Fig. 1) and all indices with a positive

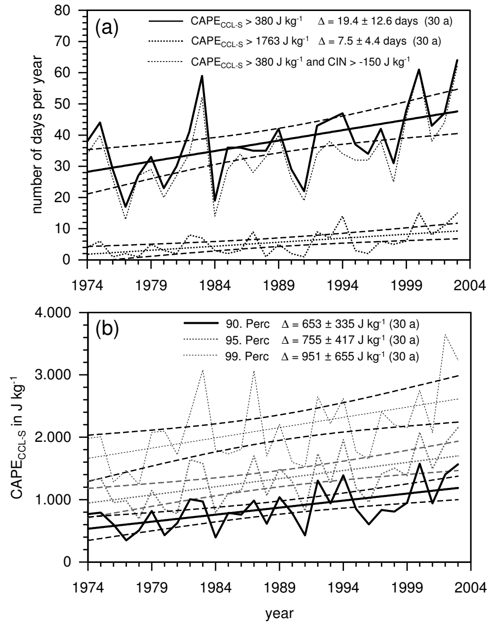

FIG. 2: Time series of different percentiles of the CAPE (a) and number of days per year above two specific thresholds (b) with 95% confidence intervals.

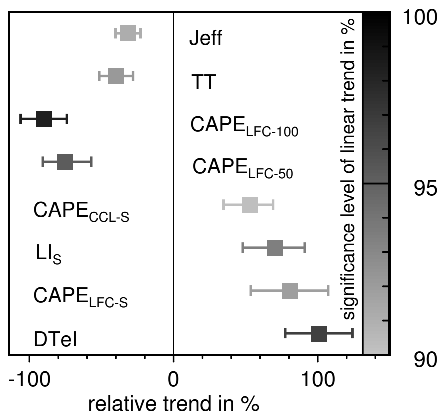

FIG. 3: Relative linear trends of the number of days per year above / below a thresholds of the convective indices where thunderstorms are expected (1974-2003) with 95% confidence intervals.

trend, yielding correlation coefficients between 0.74 and 0.8. This means that more than 55% of the annual variance of the damage-related hail days can be explained by the convective indices and, hence, by an increase of days with an unstable atmosphere.

The different trend directions of the convective indices is due to a strong increase of temperature and moisture in the lowest layers, and only marginal or even reverse trends aloft. The increase in wet-bulb potential temperature indicates the presence of warmer parcels throughout the whole troposphere during convection.

IV. CONCLUSIONS

The examinations provide some evidence suggesting an increase in hailstorm intensity and probability. Whereas thunderstorm occurrence remained constant in the last decades, severe thunderstorms associated with hail show a significant increase, in particular due to an increase in temperature and water vapor at near-surface levels.

However, the reasons for the opposing trends observed on lowest and higher levels in the atmosphere, in particular that of moisture, are not yet fully understood. One plausible physical argument is that air masses of the free atmosphere likely have their source over the Atlantic, where global warming exhibits a certain time delay due to the damping effect of the ocean. On the other hand, air parcels within the planetary boundary layer are altered by exchange processes between the land surface, which is strongly modified by global warming, and the atmosphere. This hypothesis is supported by the fact that the surface-based relative humidity shows no trend at all as also suggested by global or regional climate models.

Even if our analysis provides an indication for an increase of severe thunderstorms in the past decades, these trends cannot be extrapolated into the future. Within the scope of the project HARIS-CC (Hail Risk and Climate Change), the investigations will be extended to Central Europe by examining in detail the prevailing atmospheric conditions from highly resolved re-analysis data and from an ensemble of regional climate models.

V. ACKNOWLEDGMENTS

The authors thank the SV Sparkassenversicherung for providing detailed insurance data and the DWD for providing station and radiosounding data. The work is partly funded by the Center for Disaster Management and Risk Reduktion Technology (CEDIM).

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