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AUTOMATED MAPPING OF MAXIMUM TORNADO WINDSPEEDS IN THE UNITED STATES AS A FUNCTION OF OCCURRENCE PROBABILITIES

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1. INTRODUCTION

The maximum windspeed of tornadoes expected to occur at a given point in the United States varies from location to location. It is important to note that the speed also varies with the probability of the occurrence as expressed by probability per year. Naturally, the lower the probability (rare tornado) the higher the windspeed.

An automated method of computing the maximum windspeed was developed at the University of Chicago, making it possible to generate computer printouts of the maximum windspeed distribution for given probabilities. Presented in this paper are maximum windspeed maps with occurrence probabilities of 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7} per year.

2. BACKGROUND

Attempts to calculate tornado risk probabilities have been numerous and varied (Abbey and Fujita, 1975). Of those tornado risk models which have as their specific objective the determination of windspeed as a function of occurrence probabilities, Abbey and Fujita proposed the Damage Area Per Path Length (DAPPL) method for computing tornado hazard probabilities. Refinements were made to the path length statistics that form the data base (Abbey and Fujita, 1979). As an extension of this DAPPL method, this automated procedure was completed.

3. PROBABILIY COMPUTATION BY THE DAPPL METHOD

P(F,V), the probability of experiencing a specific windspeed, V, for a particular F-scale, F, is computed by:

$$P(F,V) = \frac{\text{Area of specific windspeed}}{\text{Area x Statistical year}} \quad (1)$$

$$= \frac{\Sigma L_F \times DAPPL(F,V)}{A \times \overline{Y}_F}\ \text{year}^{-1} \quad (2)$$

where (1) denotes the definition of tornado probability at a given point. (2) is written by replacing the windspeed area by the product of the path length, L_F, and DAPPL(F,V), the DAPPL index (Abbey and Fujita, 1979). This DAPPL(F,V) is the damage area of V caused by the particular F-scale tornado.

For convenience, (2) is grouped into

$$P(F,V) = \dot{L} \times DAPPL(F,V) \quad (3)$$

$$\text{where } \dot{L} = \frac{\Sigma L_F}{A \times \overline{Y}_F}\ \text{mi}^{-1}\ \text{year}^{-1} \quad (4)$$

is called the weighted statistical path length.

In order to compensate for unreported tornadoes in the early years, Fujita developed a concept of weighted statistical years defined by:

$$\overline{Y}_F = (n-1960+1)\frac{\sum_{1916}^{n} L(F,n)}{\sum_{1960}^{n} L(F,n)} \quad (5)$$

where L(F,n) is the normalized path length, and n = latest year.

DAPPL is defined: $DAPPL(F,V) = 10^{N(F)}$ mi (6)

For each F-scale category: $N(F) = -A \times V^a$ (7)

where A and a are empirical constants.

Finally, the total probability, TP(F,V), is the sum of all the individual F-scale probabilities (F_0, F_1, ..., F_4, F_5).

$$TP(F,V) = \sum_{F=0}^{n} P(F,V) \quad (8)$$

4. PROCEDURES AND ANALYSIS FOR AUTOMATED MAPPING OF DAPPL METHOD

Automated mapping of maximum windspeed is performed on a fixed resolution of 15' x 15' of longitude and latitude (subbox) for every area of the contiguous United States. The data source is the DAPPL tornado tape containing data for 30,371 tornadoes during the period 1916-1984, each subbox containing relevant data.

(3) is used in the probability computation for a subbox.

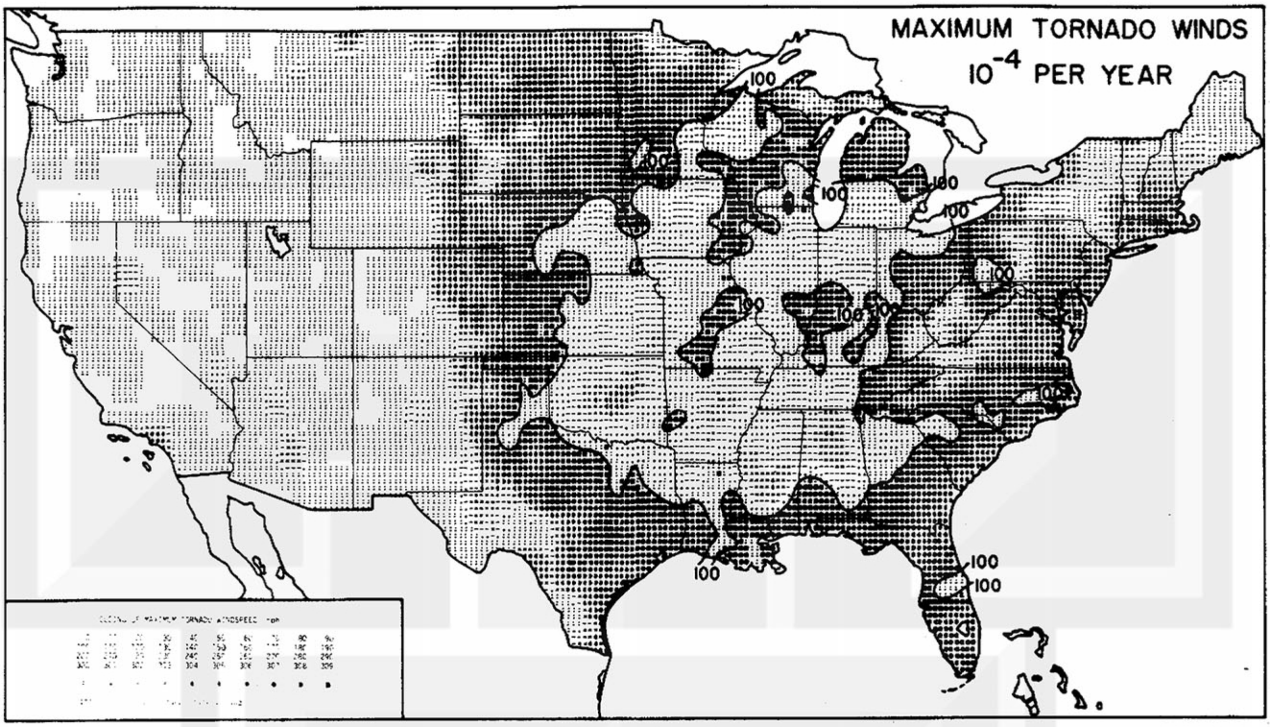

Fig. 1 Computer-generated map of maximum tornado winds computed for 10^{-4} total probability per year. 145 mph (65 m/s) peak winds show up in central Oklahoma with a small spot in northern Alabama. 135 mph (60 m/s) winds appear in central Arkansas and southern Mississippi. Blank spaces are no tornadoes in the subbox. 100 mph contour lines are shown. Data is from the 1916-1984 DAPPL tape.

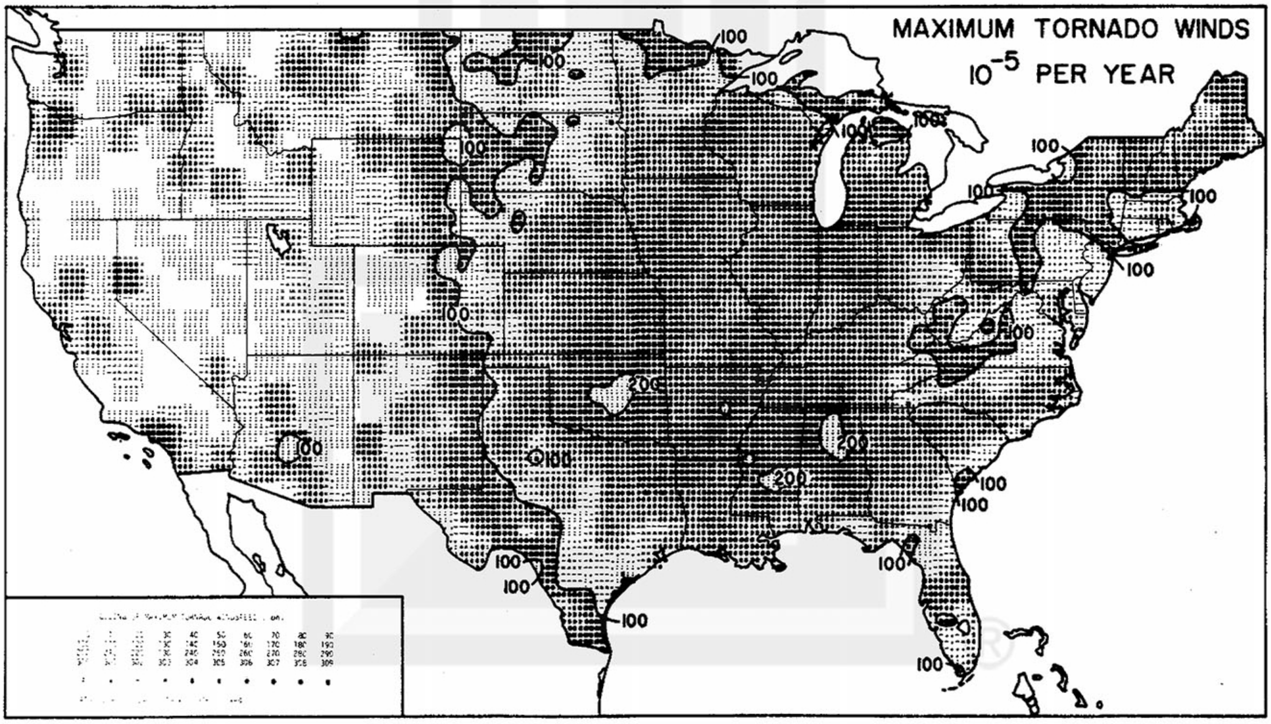

Fig. 2 Computer-generated map of maximum tornado winds computed for 10^{-5} total probability per year. 205 mph (92 m/s) appear in central Oklahoma, southern Mississippi and northern Alabama. A very small pocket shows up in central Arkansas. Blank spaces are no tornadoes in the subbox. Data is from the 1916-1984 DAPPL tape.

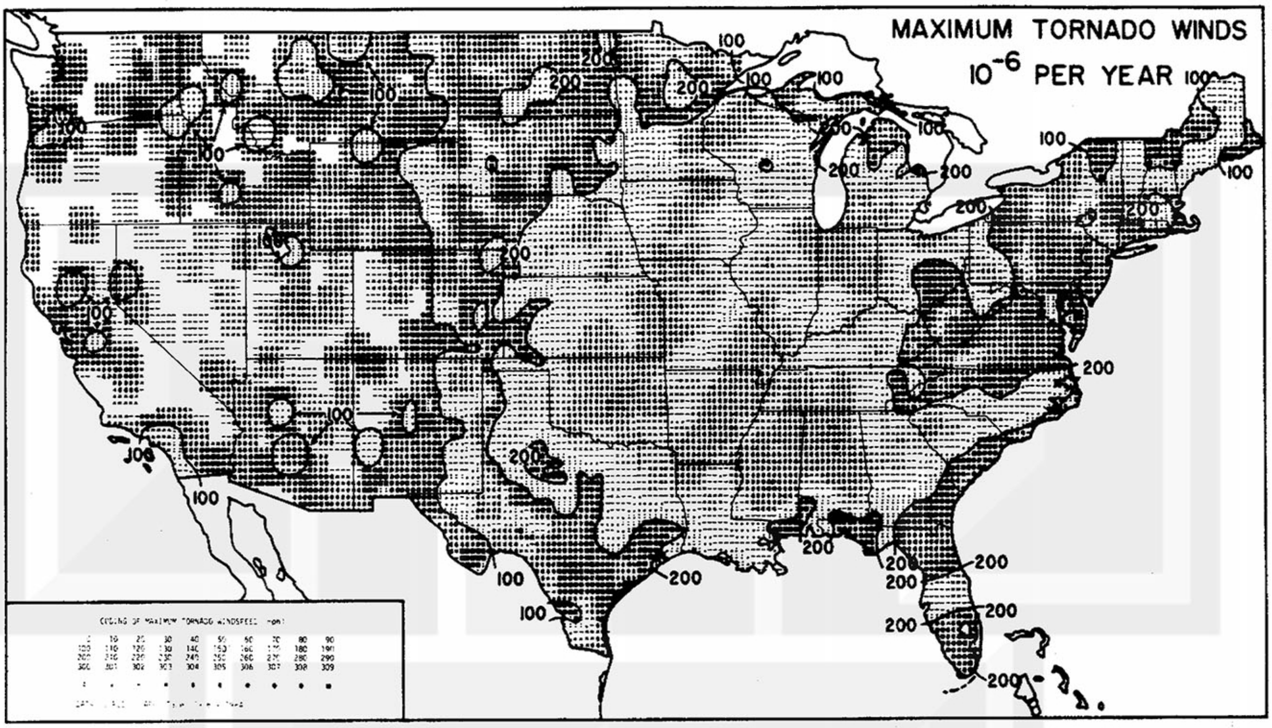

Fig. 3 Computer-generated map of maximum tornado winds computed for 10^{-6} total probability per year. 265 mph (118 m/s) peak winds are seen in central Oklahoma and northern Alabama, while 255 mph (114 m/s) winds predominate in central Arkansas and southern Mississippi. Blank spaces are no tornadoes in the subbox. Data is from the 1916-1984 DAPPL tape.

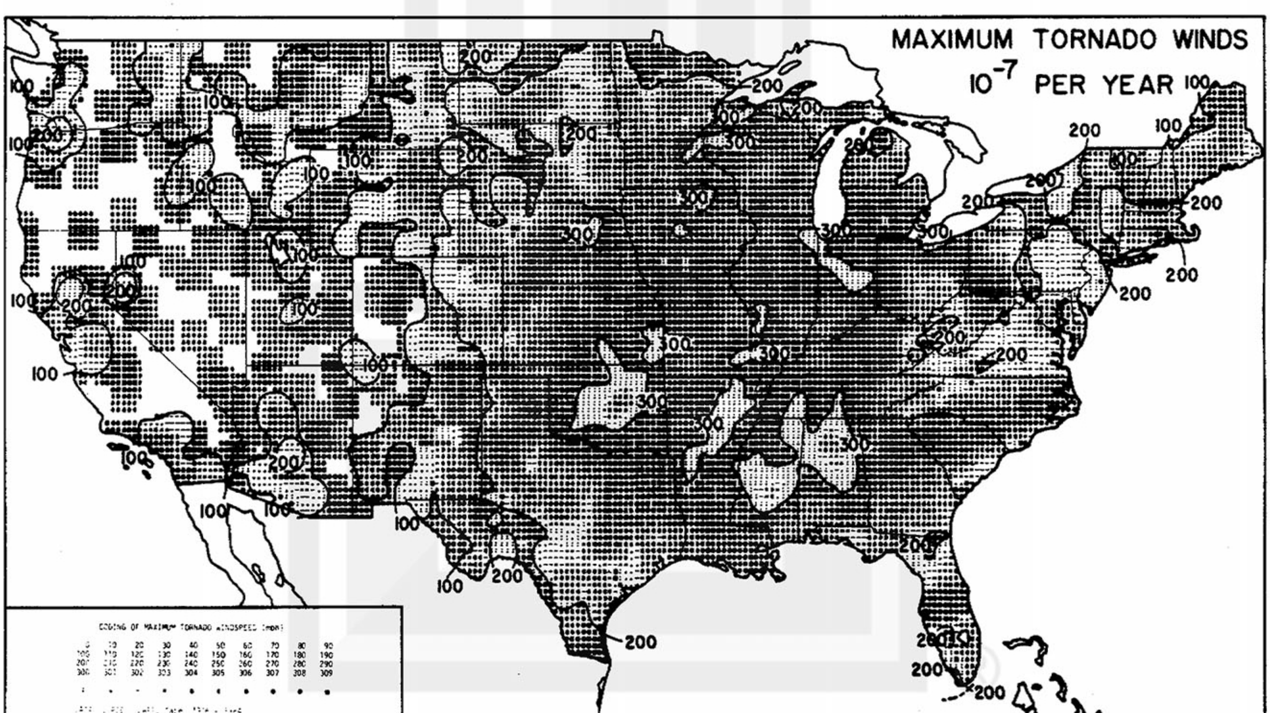

Fig. 4 Computer-generated map of maximum tornado winds computed for 10^{-7} total probability per year. The following maximum winds are seen: 308 mph (138 m/s) in central Oklahoma, 306 mph (137 m/s) in northern Alabama, 305 mph (136 m/s) in southern Mississippi, while an area of 300 mph (134 m/s) maximum winds appear in northern Illinois, and in central Indiana, central Arkansas and Tennessee. Data is from the 1916-1984 DAPPL tape.

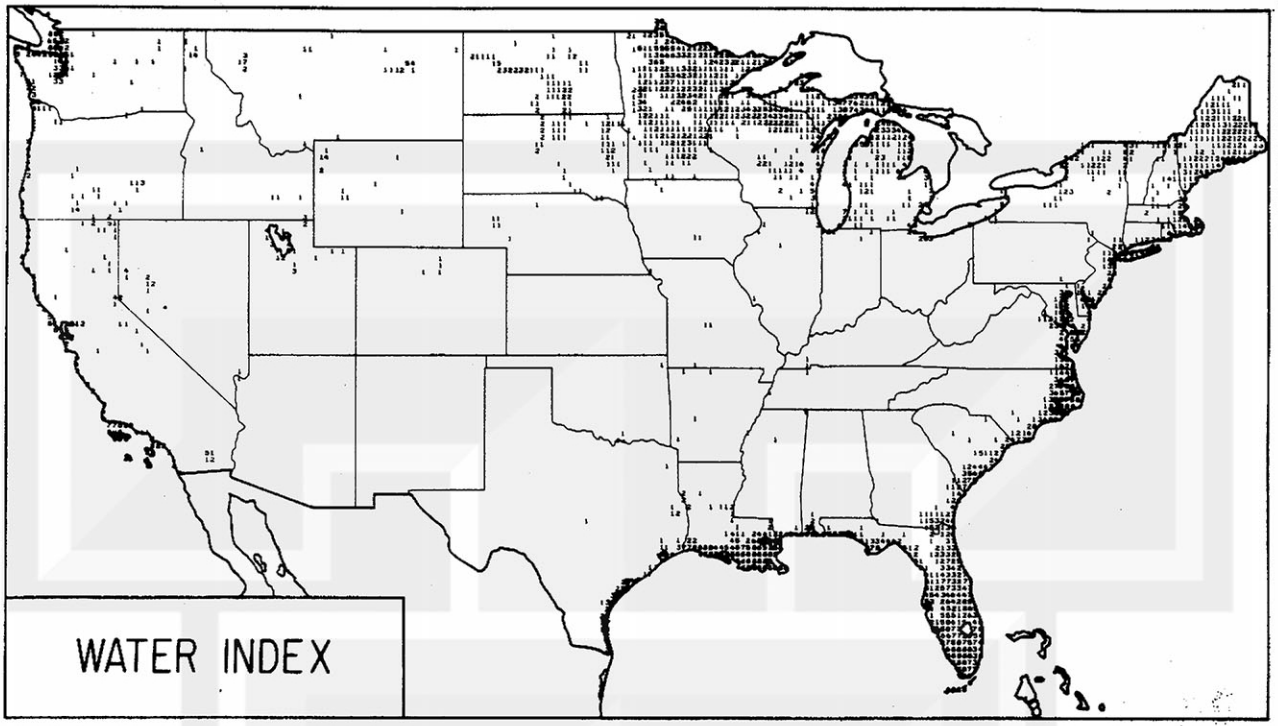

Fig. 5 Water index map of the continental United States. Values are amounts x 10^{-1} of water in each subbox. Blank areas over land indicate no significant water area.

For the optimum size of the area, A, it was decided to use a square area containing 5 subboxes on each side in determining the windspeed applicable to the center subbox. Within this area, the L_F and the land area, derived from the water index for each subbox, are counted and adjusted. Figure 5 shows the water index for each subbox in the continental United States. Tornado path lengths are normalized using the cosine function to account for the differences brought about by the latitude changes. Actual land areas are derived from the water index determined for each subbox location.

Windspeed intervals can be arbitrarily selected to depict printout values. For easy visual comparison between probability maps, a 10 mph (5 m/s) interval speed from 0-300 mph (134 m/s) was employed. Thereafter, it was narrowed down to 1 mph (0.5 m/s) maximum windspeed increment. Every 10 mph interval from 0-90 mph, 100-190, 200-290, and every 1 mph interval after 300 mph (134 m/s) is printed in progressively darker shading using a 3-overstrike print. For each occurrence probability map, the maximum windspeed value for each subbox is printed in overprint character once the probability level is reached. The maximum windspeeds for each subbox for 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7} year^{-1} probability, including 100 mph (45 m/s) contour lines are shown in Figs. 1 through 4, respectively. Blank areas inside the continent denote no tornado.

5. CONCLUSIONS

Automated mapping of the maximum windspeed distribution revealed that the peak windspeeds of 145 mph (65 m/s) with at 10^{-4} per year probability are located in central Oklahoma. The peak windspeeds with 10^{-7} per year probability are seen in central Oklahoma at 308 mph (138 m/s) and in northern Alabama at 306 mph (137 m/s).

During 1984 and 1985, there were two major tornado outbreaks in the eastern part of the United States and in southern Canada. These tornadoes alter the distribution of the maximum windspeeds. It is therefore necessary to update tornado data based on the survey of unusual tornadoes and to compute the most probable estimate of the maximum windspeeds.

Acknowledgement

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