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MOTOR VEHICLES IN TORNADIC WINDS

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ABSTRACT

Data were collected on 70 vehicles parked outdoors within 10 m of homes and apartments struck by the Arkansas tornadoes of 21 January 1999 and the Cincinnati tornado of 9 April 1999. The F-scale damage to the home was recorded along with information on whether the vehicle was moved (>1 m) by the tornado, whether it was tipped over by the tornado, and whether the vehicle would have had seriously injured occupants. Among vehicles parked at homes with F1/F2 damage (n=38), 61% were not moved by the wind, none were tipped by the wind, and 87% would not have had seriously injured occupants. Among vehicles parked outside homes with F3/F4 damage (n=32), 50% were not moved by the wind, 84% were not tipped over, and 69% would not have had seriously injured occupants.

INTRODUCTION

Communication of a tornado warning to the public and the effectiveness of the warning depend on the level of community preparedness and the response of individuals. Vulnerability of individuals is a function of access to shelter and quick movement to the position of best shelter. An underground shelter or a small interior room of a sturdy building is the safest position during a tornado or any other severe wind, as they offer protection from flying debris and other impacts of the wind.

Mobile homes, also known as manufactured homes, are known to be unsafe during strong winds due to characteristics of their construction and anchorage to the ground (AMS 1997). This is clear from the high fatality rates for occupants of mobile homes during tornadoes. About 15 million people, 7% of the United States population, live in mobile homes, but 44% of the fatalities due to tornadoes during the 1990's were occupants of mobile homes.

The United States is an automobile-oriented society and millions of people are on the roads during the late afternoon and evening peak of the diurnal tornado frequency. Vehicles are vulnerable to being lifted and thrown by violent tornadoes with many deaths in some cases (Glass et al. 1980) but the general effects of severe winds on vehicles are not known (Schmidlin and King 1996).

The National Weather Service, in cooperation with the American Red Cross, has developed and distributed severe weather safety recommendations as part of their preparedness programs. The tornado preparedness guide instructs that "mobile homes, even if tied down, offer little protection from tornadoes and should be abandoned" (NOAA 1992). For persons in automobiles when a warning is issued, they instruct "get out of automobiles" and "leave (them) immediately." For persons in mobile homes or in vehicles who do not have a sturdy building for shelter during a tornado warning, the National Weather Service and Red Cross recommend "if caught outside or in a vehicle, lie flat in a nearby ditch or depression" (NOAA 1992). No recommendation is given on actions to take when a ditch or depression is not available.

We observed during our fieldwork after the March 1994 Georgia tornadoes (Schmidlin and King 1994) that vehicles often remained upright with little damage at sites where mobile homes were destroyed and occupants killed. This led to the suggestion that mobile home residents without nearby sturdy shelter may be safer in their vehicles than in the mobile home or on the ground outdoors during the storm (Schmidlin and King 1995). This has generated some controversy and has increased the need for clarifying research on the topic (Schmidlin 1997; Lopes 1997).

The source of the assumption that a person is safer outdoors than in a motor vehicle for the 45-60 minute duration of a tornado warning is unknown and is apparently not supported by research (Schmidlin and King 1996). The National

Weather Service and American Red Cross recommendation of leaving a vehicle or mobile home to lie down outdoors for the duration of a tornado warning has been questioned by others (Brenner and Noji 1993; Carter at al. 1989; Duclos and Ing 1989). Glass et al. (1980) found that persons outdoors had seven times the risk of injury as persons in mobile homes during the 1979 Wichita Falls tornado. The goal of this research is to build upon our previous research on vehicles in tornadoes (Schmidlin et al. 1998a, 1998b) to establish the relative safety of vehicles in tornado winds with respect to building damage (F-scale) and estimated wind speed at the site.

RESEARCH PROBLEM

The relative safety of persons in motor vehicles during high winds is not known. This casts doubt on the official' recommended actions for persons in vehicles or mobile homes when a tornado warning is issued. Study of vehicles actually exposed to tornadic winds next to buildings where damage and wind speeds can be assessed provides information on the relative safety of vehicles during severe winds.

THE 21 JANUARY 1999 ARKANSAS TORNADOES AND 9 APRIL 1999 OHIO TORNADO

More than 30 tornadoes occurred across central and northeast Arkansas, eastern Tennessee, and northwest Mississippi during the afternoon and night of 21-22 January 1999. The strongest storms were ranked F3 on the Fujita Scale and struck portions of Little Rock and Beebe, Arkansas. Seven people were killed and scores injured. A tornado that produced brief F4 damage and considerable F3 damage struck suburban Cincinnati, Ohio, at 5:20 AM on 9 April 1999. There were four deaths and about 200 homes were destroyed.

RESEARCH METHODS

The Quick Response grant was activated after the Arkansas tornadoes of 21 January. Paul King and Barbara Hammer traveled to Arkansas on 26 January and Yuichi Ono arrived on 28 January. The team departed on 31 January. Prior to our travel, telephone contacts were made with local police and disaster relief agencies, NWS and various news web sites were consulted, and we phoned the EMA and Arkansas State police for information and permission to enter the affected areas. Upon arrival in Arkansas, we provided information on our previous and current research to the National Guard and obtained an access pass. Field work began in Little Rock on 27 January, moved to the communities of Beebe and McRae on 28 January, into rural areas near Center Hill, Joy, Sunnydale, and Newark on 29 January, and to Jackson, Tennessee on 30 January. An opportunity became available for additional field work when a tornado struck near Cincinnati, Ohio, on 9 April 1999. Barbara Hammer and Yuichi Ono traveled to Cincinnati on 10 April and conducted field work in northern Hamilton County on 11-12 April.

We methodically walked or drove the damage paths with street-level maps seeking residents who could provide information on vehicles parked outdoors when the tornado struck. We completed a brief survey for each vehicle that was parked outdoors within 10 m of a home when the tornado struck. The survey assessed the F-scale damage to the home with care taken to account for changes in the structure since the tornado occurred and for strength of construction. Vehicles parked outside of mobile homes were not considered since F-scale rankings on mobile homes cannot exceed F2 (complete destruction). The survey asked whether the vehicle was moved (> 1 m) by the wind, whether it was tipped over by the wind, and whether potential occupants would have been seriously injured. A serious injury was defined as one that required admission to a hospital. A vehicle was said to have had seriously injured occupants if any portion of the roof was crushed to the bottom of the windows or if large debris was in the passenger compartment. The movement of the car during the tornado, degree of damage to the vehicle, and relative risk of injury to potential occupants was assessed in the context of estimated wind speed at the site (F-scale). Chi-square tests on contingency tables were applied to the data to determine whether differences existed in vehicle stability and safety among the F-scale categories of damage and estimated wind speed. We have used the survey and these methods successfully after previous tornadoes, as reported by Schmidlin et al. (1998a and 1998b).

RESULTS AND DISCUSSION

Surveys were completed for 50 vehicles in Arkansas and 20 vehicles in Ohio for a combined sample size of 70. Eleven of the vehicles were parked at homes with F1 damage, 27 were in F2 damage, 29 in F3 damage, and 3 in F4 damage. Fifty-one of the vehicles were cars, 11 were pick-ups, and 8 were vans or sport-utility vehicles (SUVs). As found in our previous research (Schmidlin et al 1998a), there were no statistical differences between cars and high-profile vehicles (pick-ups, vans, SUVs) in the percentage moved, tipped, or with seriously injured potential occupants.

Our previous research (Schmidlin et al 1998a, 1998b) showed there was no statistical difference in the percentage of cars moved, tipped, or with seriously injured potential occupants between F1 and F2 damage and between F3 and F4 damage, however, there were differences between F2 and F3 damage. Therefore, we combined data on vehicles at sites with F1 and F2 damage, called F1/F2 (n=38) and combined data on vehicles at sites with F3 and F4 damage, called F3/F4 (n=32).

At sites with F1/F2 damage, 61% of the vehicles were not moved, none of the vehicles were tipped over, and 87% would not have had seriously injured occupants. At sites with F3/F4 damage, 50% of the vehicles were not moved, 84% were not tipped over, and 69% would not have had seriously injured occupants. The hypothesis of no difference in percentage of vehicles that were moved by the wind between vehicles at F1/F2 damage sites (39%) and at F3/F4 sites (50%) was not rejected ($p>0.25$). There was no statistical difference. The hypothesis of no difference in percentage of vehicles that were tipped over by the wind between F1/F2 (0%) and F3/F4 (16%) was rejected ($p<0.025$). Similarly, the hypothesis of no difference in the percentage of vehicles that would have had seriously injured occupants between F1/F2 (13%) and F3/F4 (31%) was rejected ($p=0.07$). Thus, the percentage of vehicles that were tipped by the wind was greater in F3/F4 damage than in F1/F2 damage. The percentage of vehicles that would have had seriously injured occupants was greater in F3/F4 damage than in F1/F2 damage.

These results are not substantially different from our previous results on 221 vehicles from field work in seven states during 1994-98 (Schmidlin et al 1998a, 1998b). Combining these 1999 results with our earlier work (total n=291) shows that for vehicles parked outdoors within 10 m of homes with F1/F2 damage, 70% of the vehicles were not moved by the tornado, 96% of the vehicles were not tipped over, and 84% of the vehicles would not have had seriously injured occupants. For vehicles parked outdoors within 10 m of homes with F3/F4 damage, 50% were not moved by the tornado, 82% were not tipped over, and 64% would not have seriously injured occupants.

These results indicate that vehicles are relatively stable in winds that commonly destroy mobile homes (F1/F2). Red Cross and National Weather Service preparedness guides state that motorists and residents of mobile homes should leave immediately when a tornado warning is issued and, if sturdy shelter is not available, lie in a nearby ditch or depression. Thus, for millions of motorists and for the portion of the 15 million mobile home residents in the United States who do not have sturdy shelter, the choices when a tornado warning is issued are limited to (1) using a vehicle to drive to safer shelter, (2) following official recommendations to run outside and lie in a ditch or depression until the tornado warning is canceled 30-60 minutes later, or, (3) for mobile home residents, staying in the mobile home during the tornado warning. An underground shelter or a sturdy above-ground shelter is the safest location during tornado warnings. Some persons do not have access to these shelters when a warning is issued. More research is needed to determine the relative safety of being in a vehicle and being outdoors during a tornado warning.

ADDENDUM

Yuichi Ono conducted field work in Oklahoma following the tornadoes on 3 May 1999. Although not included in the analysis and discussion of this Final Report, some initial results are included here. Research focused on the most heavily damaged areas. Data were collected on 50 vehicles parked outdoors within 10 m of homes when the tornado struck. All of the vehicles were at homes with F3 or F4 damage. Among the 50 vehicles, 90% were moved (>1 m), 64% were tipped over, and 68% would have had seriously injured occupants. These are higher values than found in our previous work on vehicles parked at homes with F3 or F4 damage (n=126) across eight events in seven states during 1994-99 where the results showed 50% of vehicles were moved, 18% tipped over, and 36% with seriously injured potential occupants. The reasons for these differences are not known but we offer speculation. The Fujita Scale has a large range of wind speeds for each category and perhaps this Oklahoma sample was biased toward the upper end of the F-4 category. Our previous data came mostly from the Deep South. Differences in housing strength may systematically affect F-scale determinations between the South and the Plains. The relative lack of large trees in the Oklahoma tornado path compared to the mostly forested tornado paths studied in the South may lead to greater movement or damage to vehicles. The Oklahoma tornado may have subjected sites to a longer period of high winds and perhaps this affects vehicles more than homes. Sampling that depends largely on information provided by residents affected by the tornado may have local or regional idiosyncracies that affect the results. These surprising results indicate that more data are needed from the Great Plains and other regions to explore for regional differences in results.

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