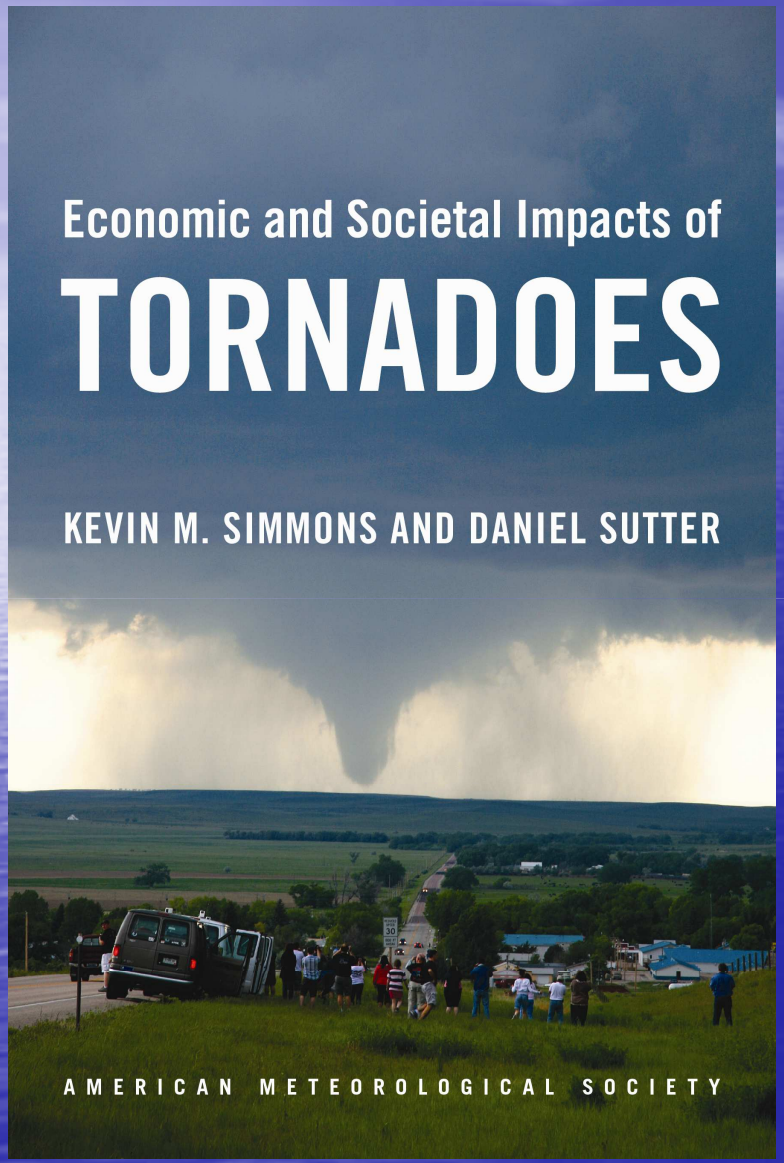
The Economic and Societal Impacts of Tornadoes

Kevin M. Simmons
Austin College

Fulbright Research Scholar
International Centre for GeoHazards
Oslo, Norway



Economic and Societal Impacts of Tornadoes

By Kevin M. Simmons and Daniel Sutter
© 2010, 296 pages in paperback
ISBN: 978-1-878220-99-8

AVAILABLE NOVEMBER 2010
from the American Meteorological Society and the University of Chicago Press

AMS BOOKS

RESEARCH ◆ APPLICATIONS ◆ HISTORY

Acknowledgements

- Several individuals have contributed to parts of this research project as co-authors: Daniel Sutter, Dave Merrell, Somer Erickson, Marc Poitras
- Funding for this research has been provided by NOAA, the Institute for Catastrophic Loss Reduction, and the Natural Hazards Center at the University of Colorado
- Numerous individuals in the National Weather Service, the Storm Prediction Center, the National Severe Storms Laboratory, and NOAA have shared data included in this analysis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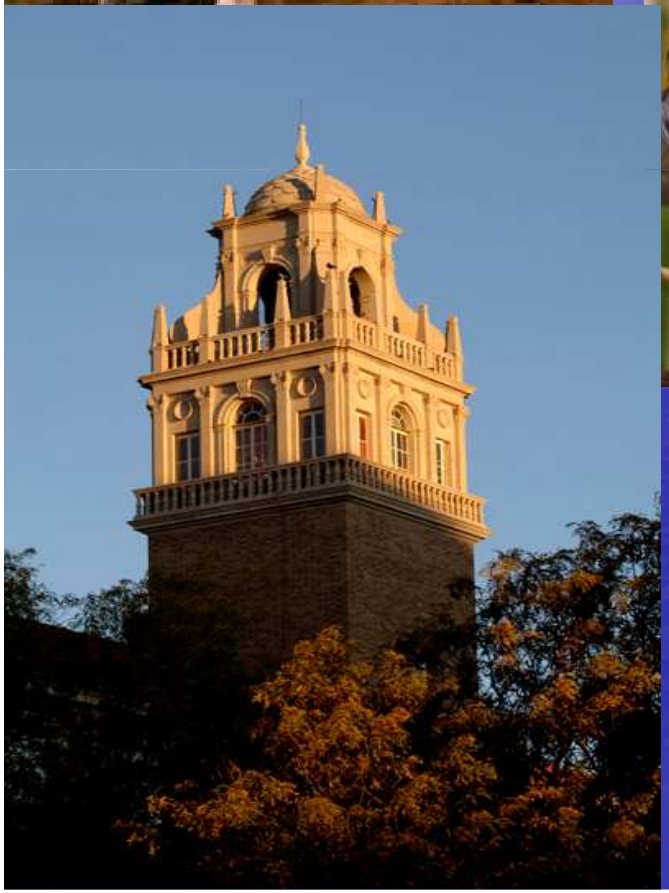



AUTO PARTS


Cash America International


WHEN YOU

Economics of Natural Hazards

The research agenda is fundamentally interdisciplinary.

Strong links with engineering, meteorology, law, sociology and others.

". . . what has so often excited wonder, the great rapidity with which countries recover from a state of devastation; the disappearance, in a short time, of all traces of the mischief's done by earthquakes, floods, hurricanes, and the ravages of war . . . all the inhabitants are ruined, and yet in a few years after, everything is much as it was before."

– J.S. Mill (1848)

Economics of Natural Hazards

- Macro topics
  - Effect of a large disaster on:
    - Regional Price Levels
    - Regional Output
    - Regional Employment

Economics of Natural Hazards

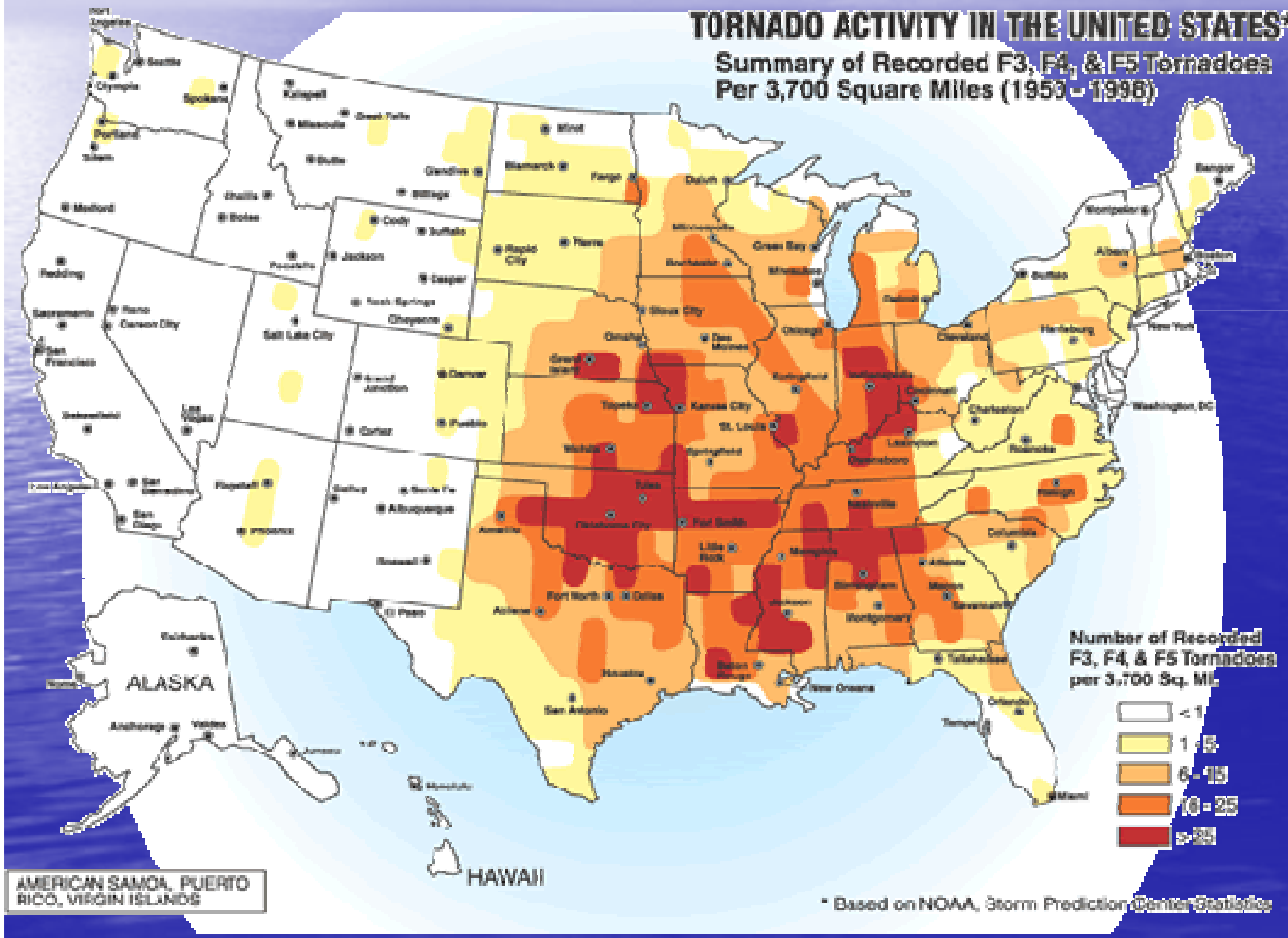
- Micro topics
  - Public Policy Concerns
    - Public Investment in:
      - Warning Systems
      - Mitigation
    - Land Use and Code Enforcement
  - Risk and Uncertainty

Economics of Natural Hazards

- Consumers of this research:
  - Government policy makers
  - Insurance Industry
  - Weather Industry

Tornadoes

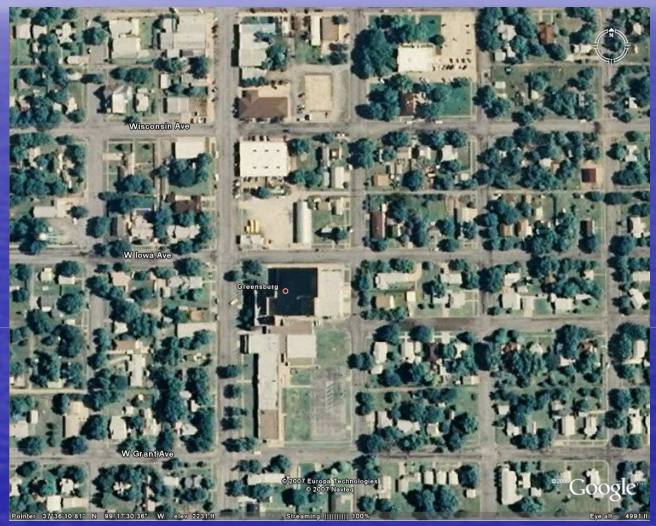
Tornado Climatology



- About one thousand tornadoes hit the US each year
- Tornadoes kill around 60 people per year
- Thunderstorms cause tornadoes

Fujita Scale

- Dr. Fujita in 1970's developed a damage scale for winds, which related the degree of damage to the intensity of winds
- F0 (40-72 mph)
- F1 (73- 112 mph)
- F2 (113-157 mph)
- F3 (158-206 mph)
- F4 (207-260 mph)
- F5 (261- 318 mph)



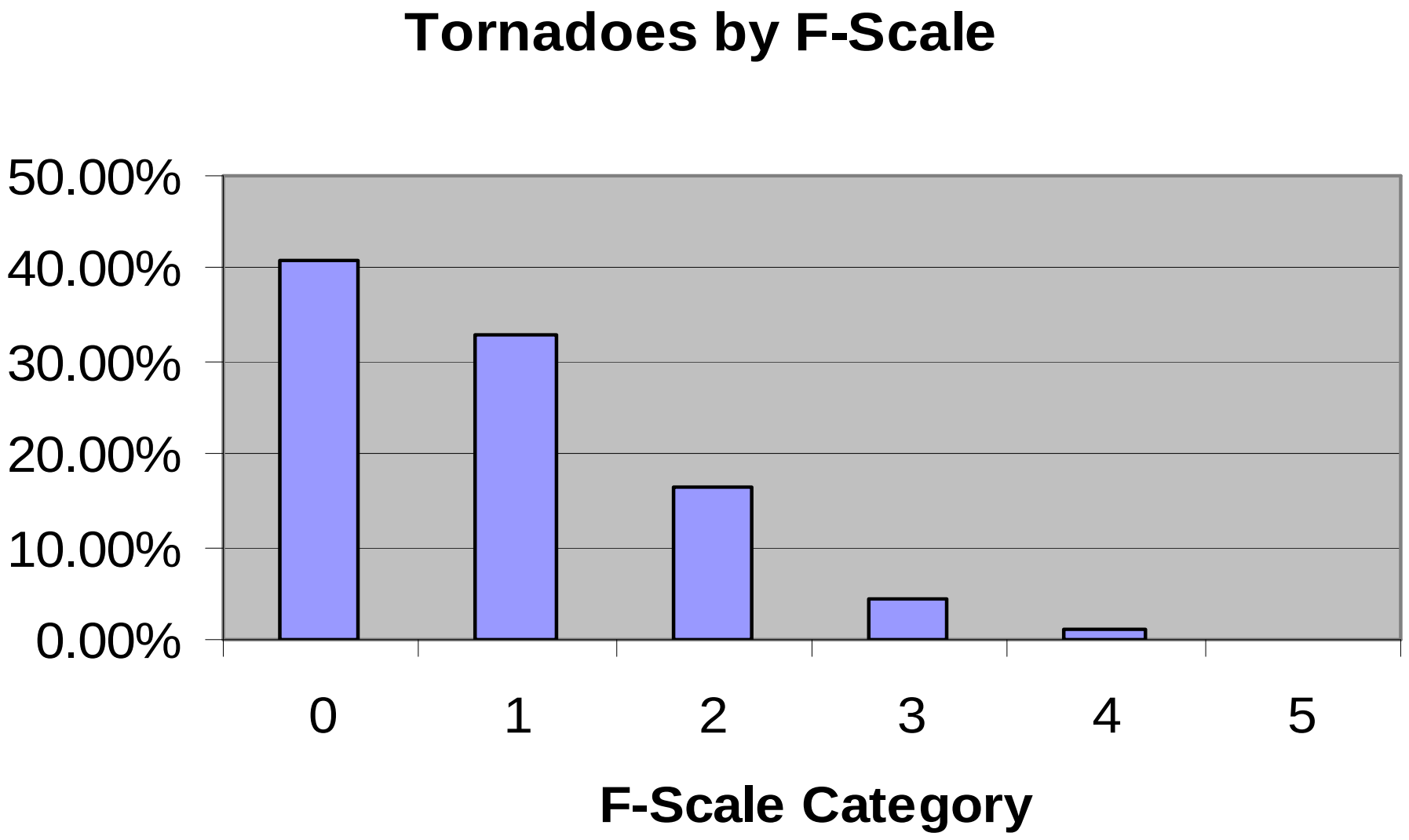
Before

After

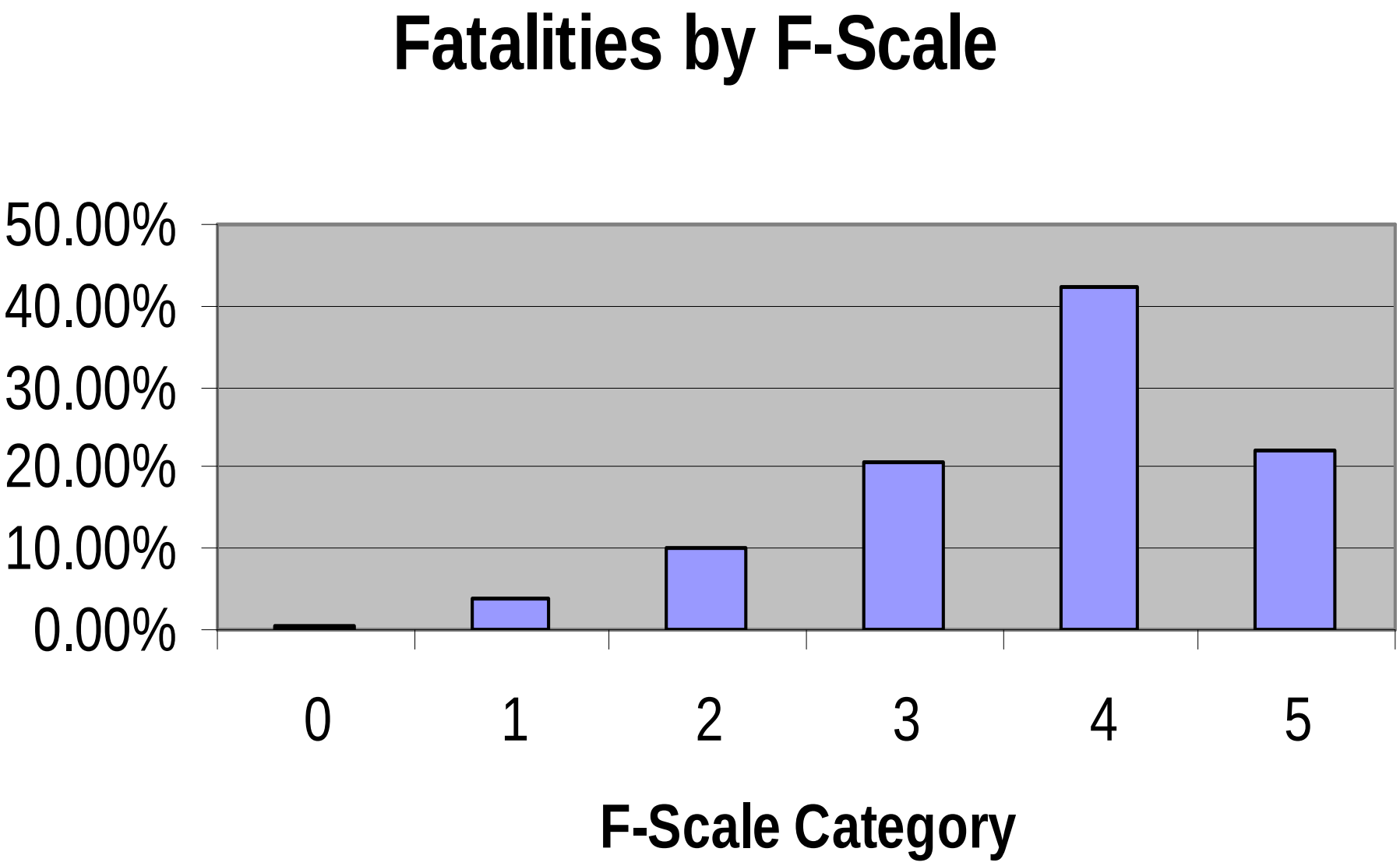
Some Statistics 1950-2007

- 50,445 tornadoes
- 609 tornadoes rated F4 or F5
- 1,288 killer tornadoes, 4,860 fatalities
- 6,574 injury tornadoes, 82,062 injuries
- Most tornadoes aren't killers: 228 tornadoes had 5+ fatalities (.045% of tornadoes), account for 66% of fatalities

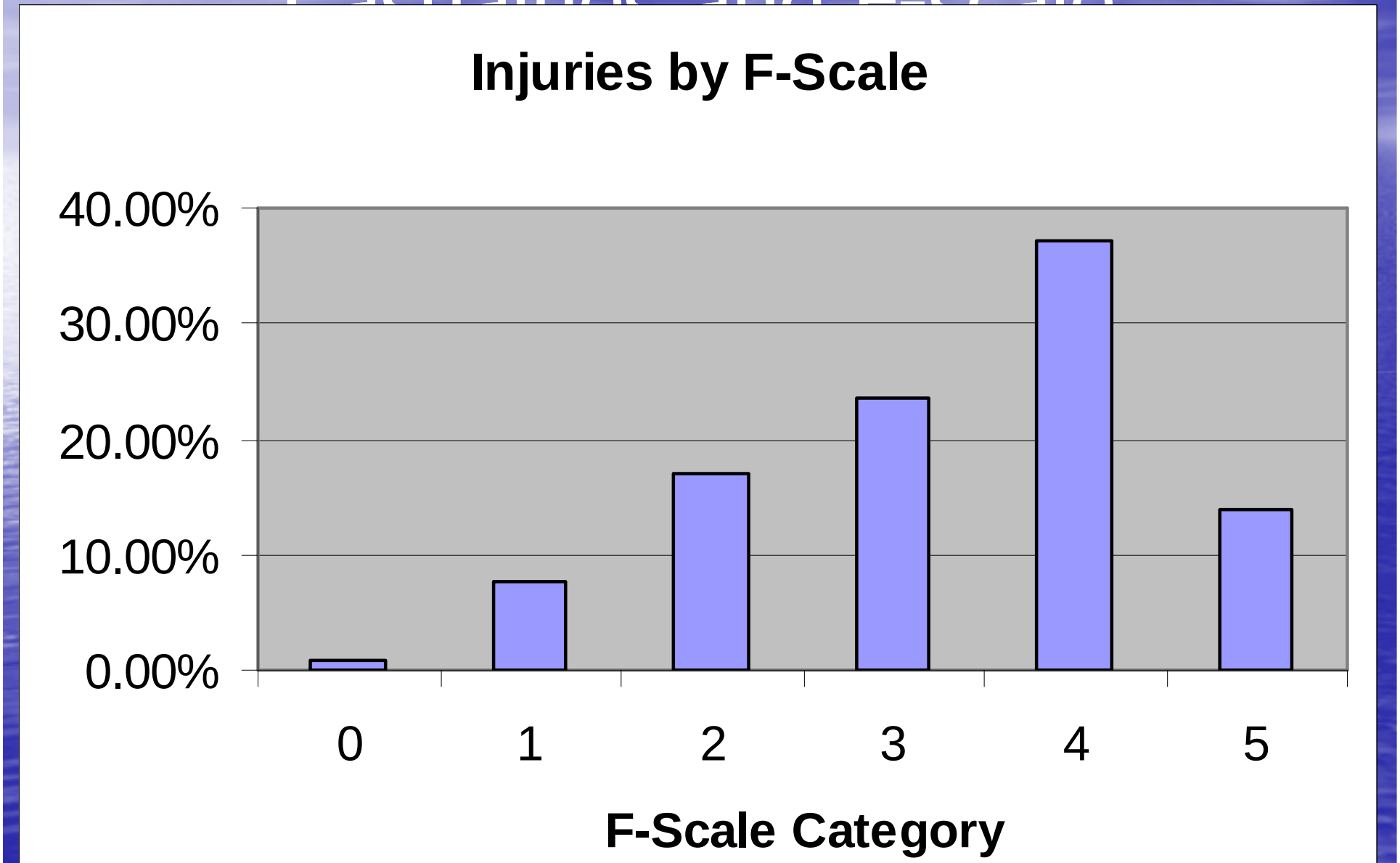
Casualties and F-scale



Casualties and F-scale



Casualties and F-scale

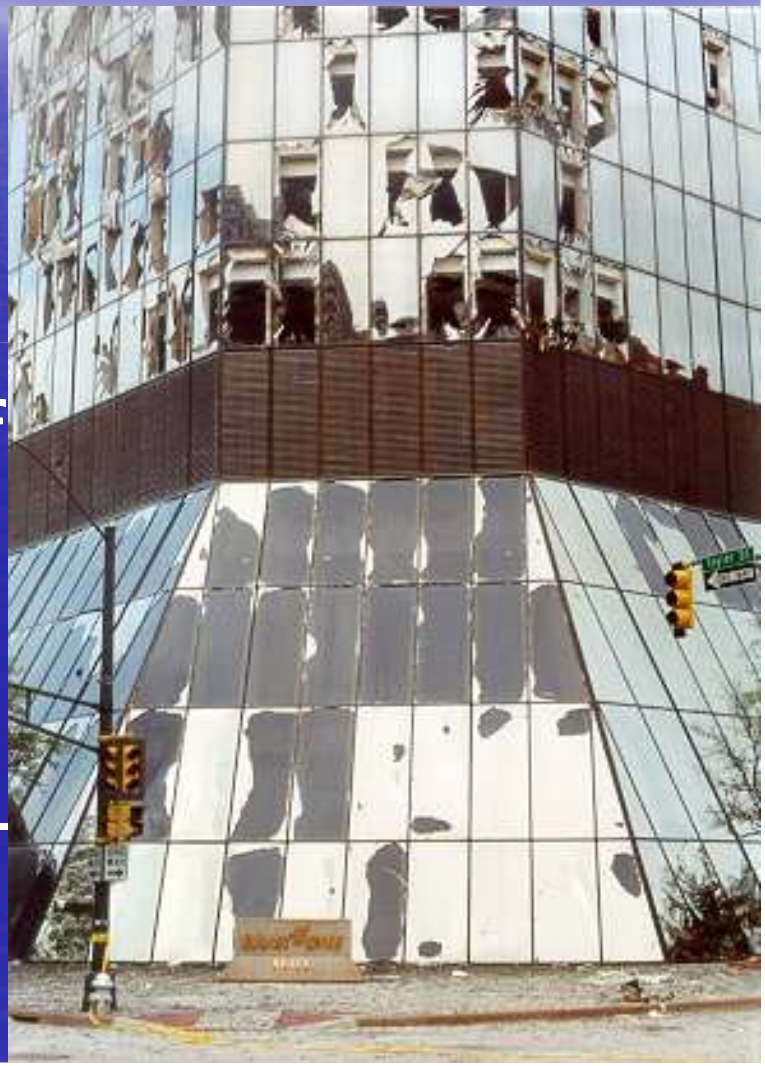


Why Study Tornadoes

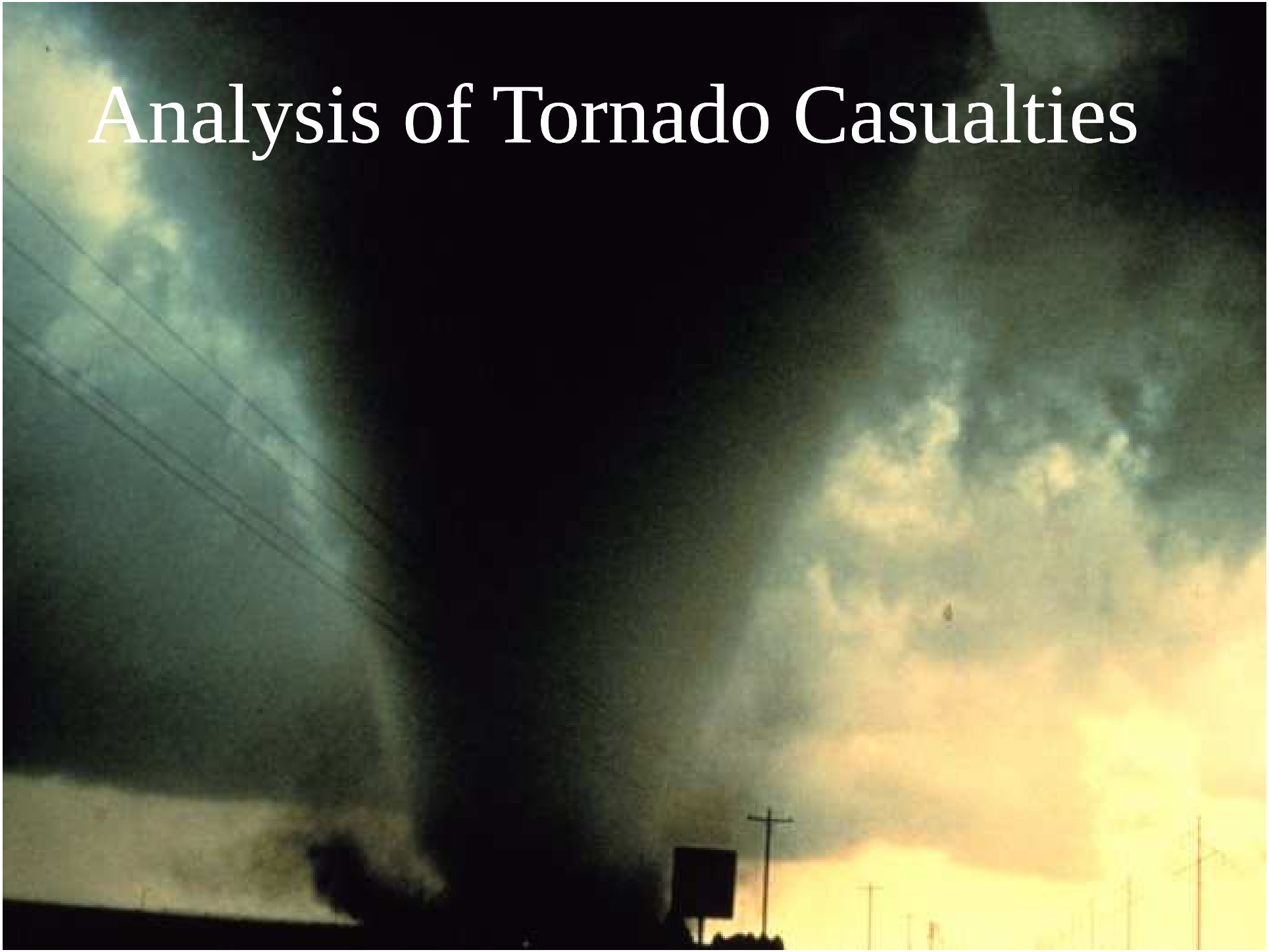
- How do tornadoes kill people, and how can we reduce casualties?
- Do warnings reduce casualties?
- Do people suffer from low probability event bias?
- How do manufactured homes and tornado shelters affect vulnerability?

Societal Impacts

- Property Damage
- Fatalities – monetary value can be assigned using estimates of the value of a statistical life
- Injuries – can apply value of statistical injuries, but distribution of injuries by severity not known
- Time spent under warnings - reduces casualties but has an opportunity cost



Analysis of Tornado Casualties



Econometric Models

- The number of persons killed or injured in a tornado takes on nonnegative integer values with a large portion of zeros, and thus is count data.
- We estimate Poisson models of casualties and test for overdispersion. Injuries are generally overdispersed, but not fatalities, so we estimate Negative Binomial models for injuries.

Data Set for Tornadoes

- Storm Prediction Center national tornado archive
- NWS Tornado Warning Verification records
- County warning areas of NWS forecast offices, Doppler radar installation dates
- Census data at county level

Jarrell, TX Tornado 27 May 97 2032Z

Tornado at photo time (3:32 pm CDT) is about 1 mi N of Jarrell, headed into town, as documented by storm chaser Lon Curtis. Image used by permission.

Control Variables in Tornado Casualty Analysis

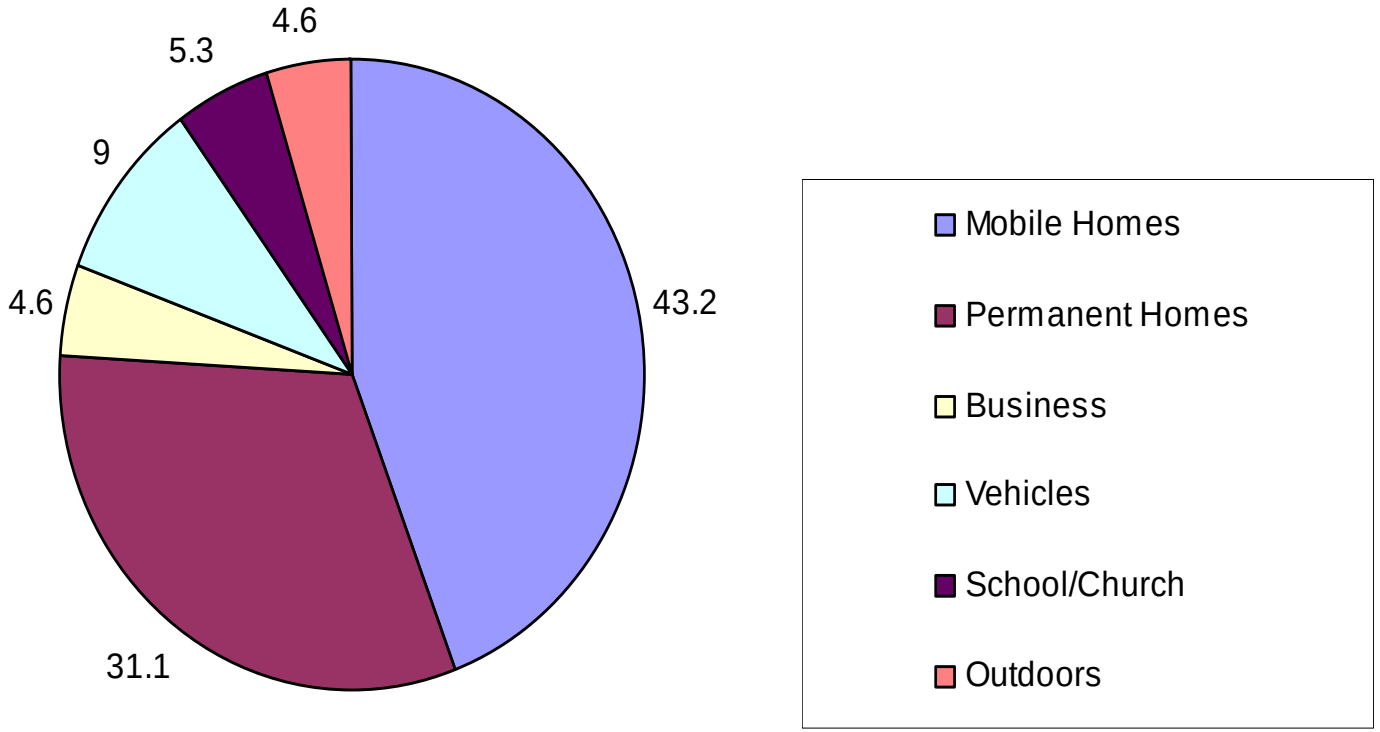
- Tornado characteristics: Rating on the Fujita(F) scale, path length, time of day, month of year, day of week
- Path characteristics: Economic and demographic variables for the counties struck by each tornado
- Warning variables: Warning in effect, lead time, false alarm ratio

Broad Outlines of Casualty Analysis

- Location
- Timing
- Warnings

Casualties and Location

Fatalities by Location

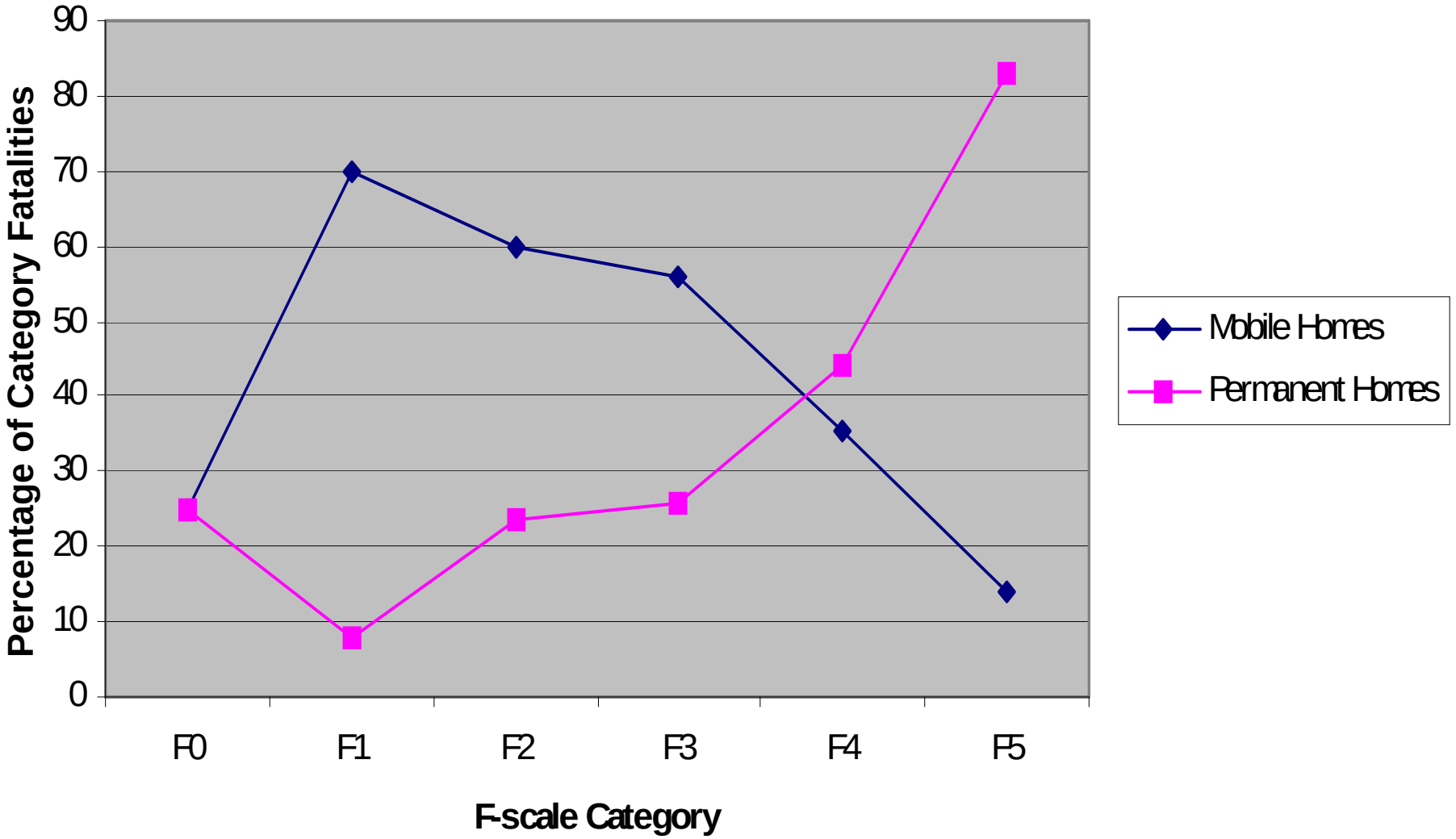


The Mobile Home Problem

The Mobile Home Problem

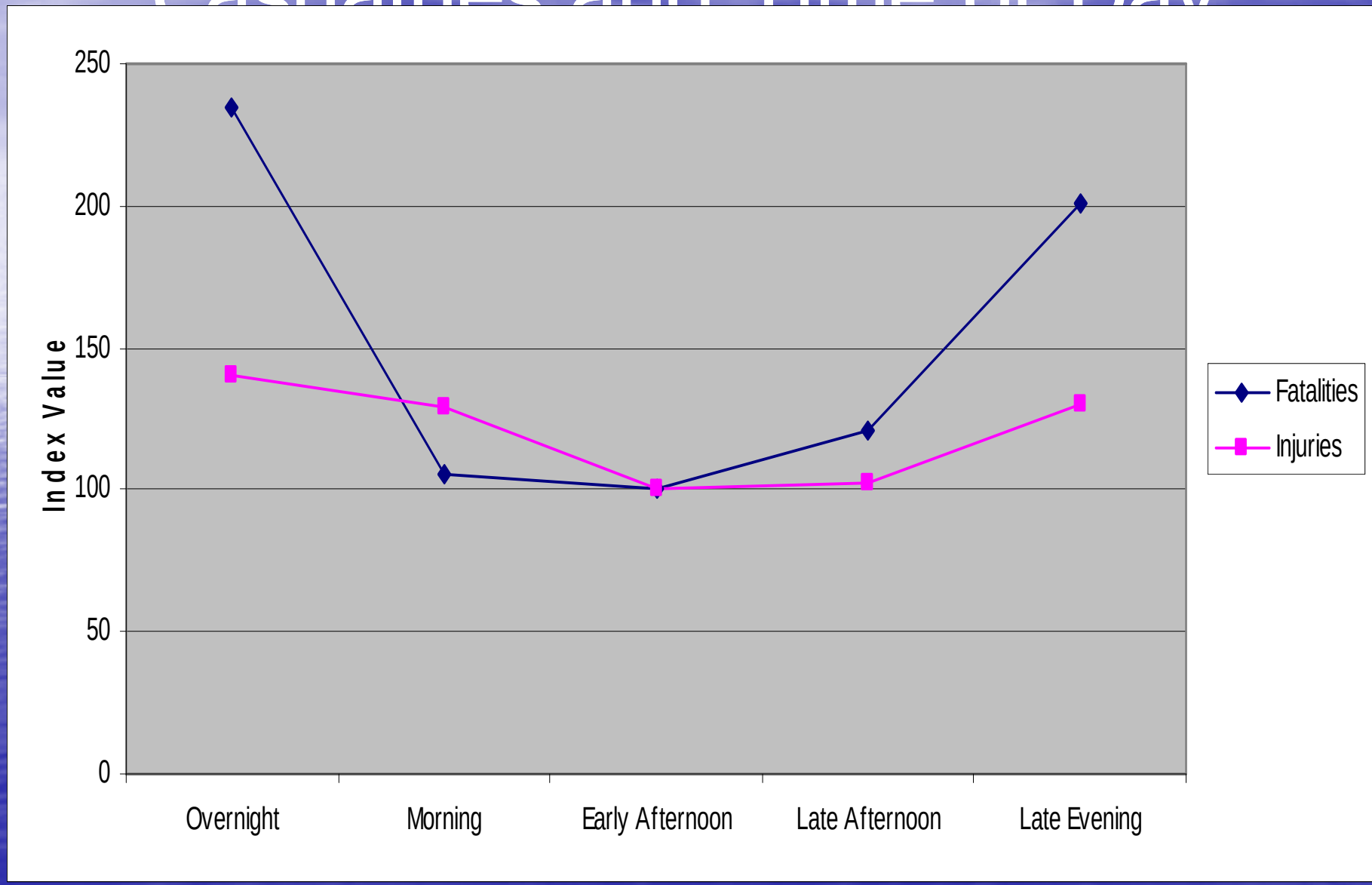
- 43% of tornado fatalities occurred in mobile homes, although only 7.6% of U.S. housing units in 2000.
- A one standard deviation in the proportion of mobile homes in housing stock (8.3 percentage points) increases fatalities by 36% and injuries by 18%.

The Mobile Home Problem

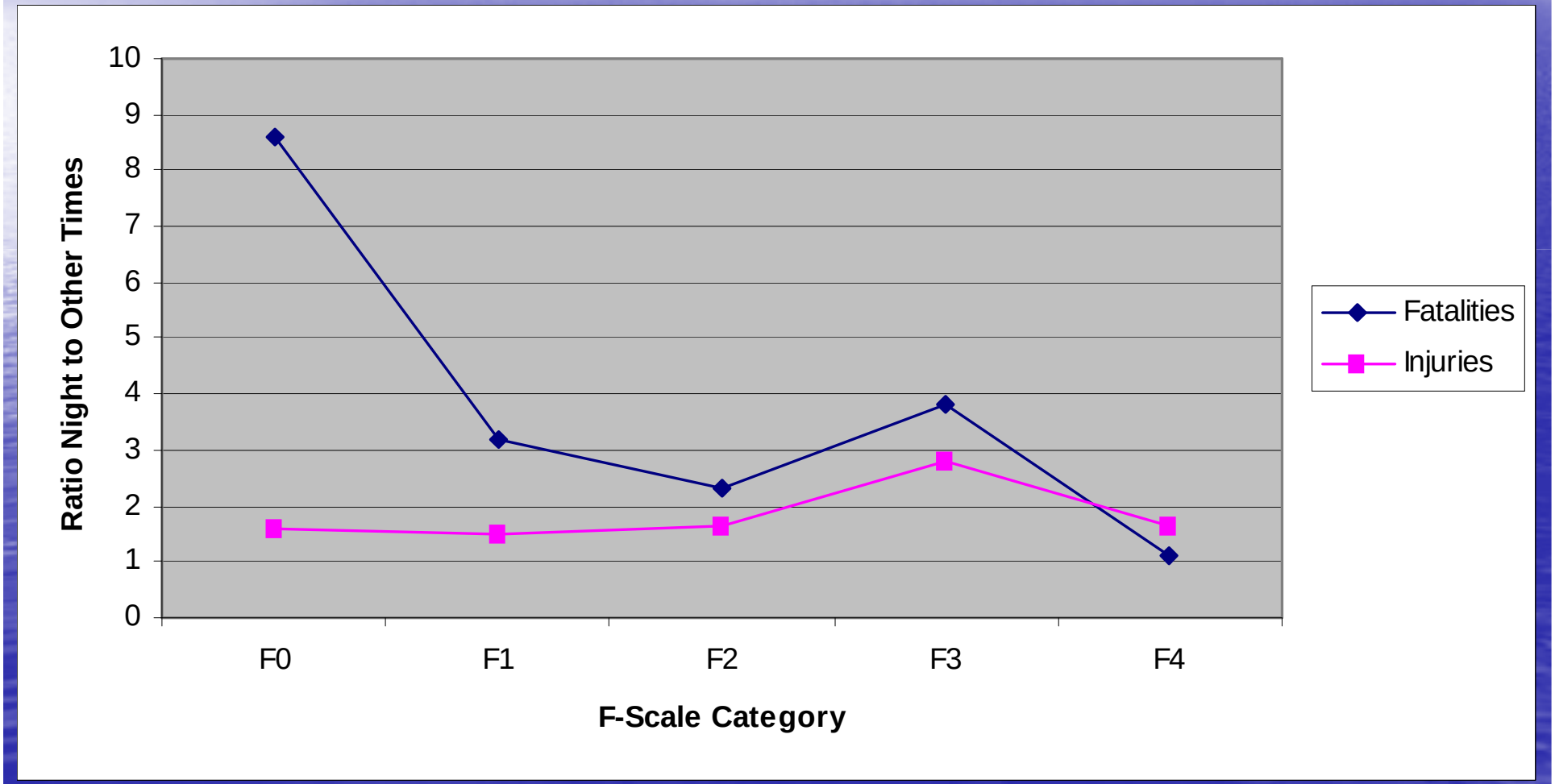


Casualties and Timing

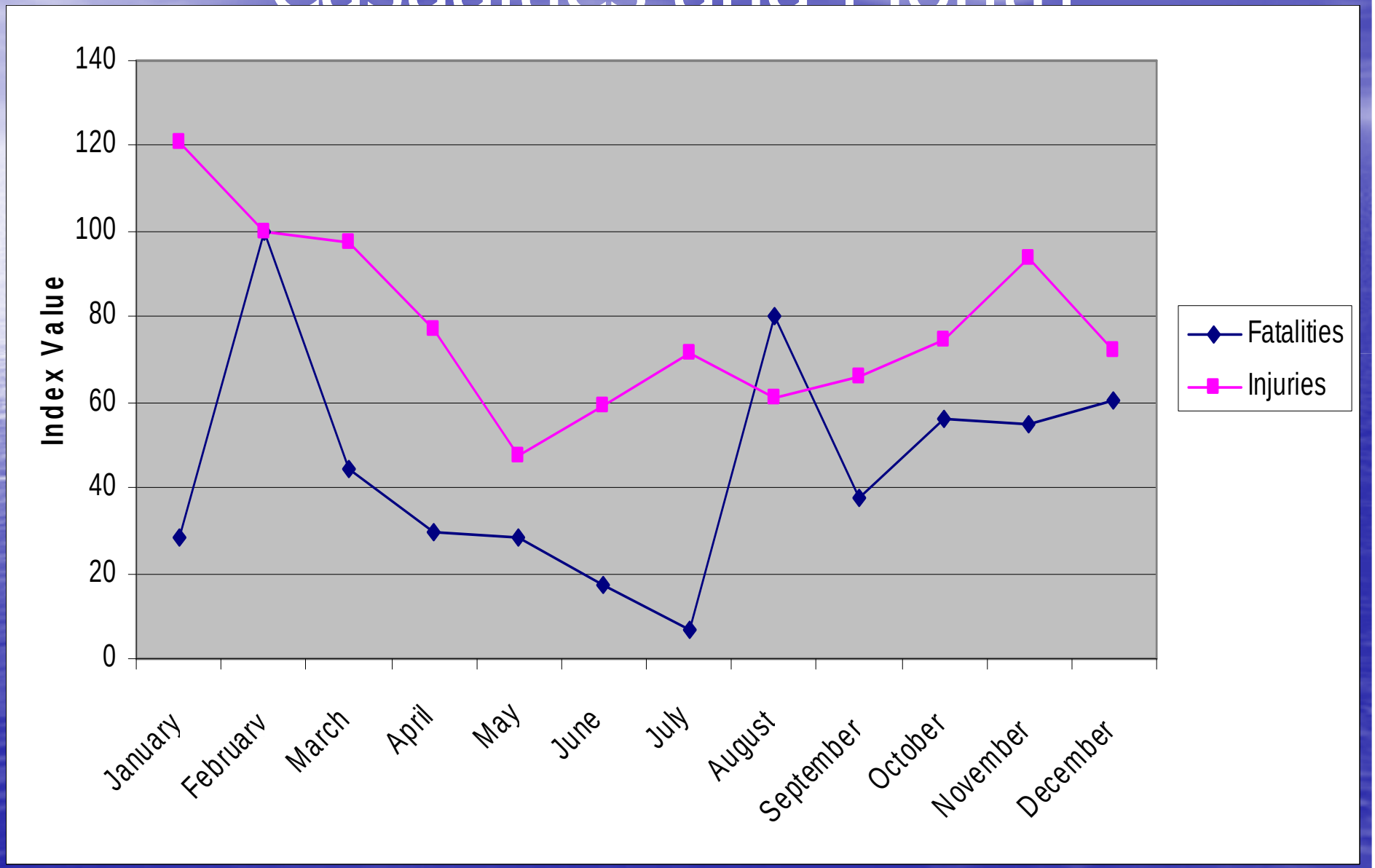
Casualties and Time of Day



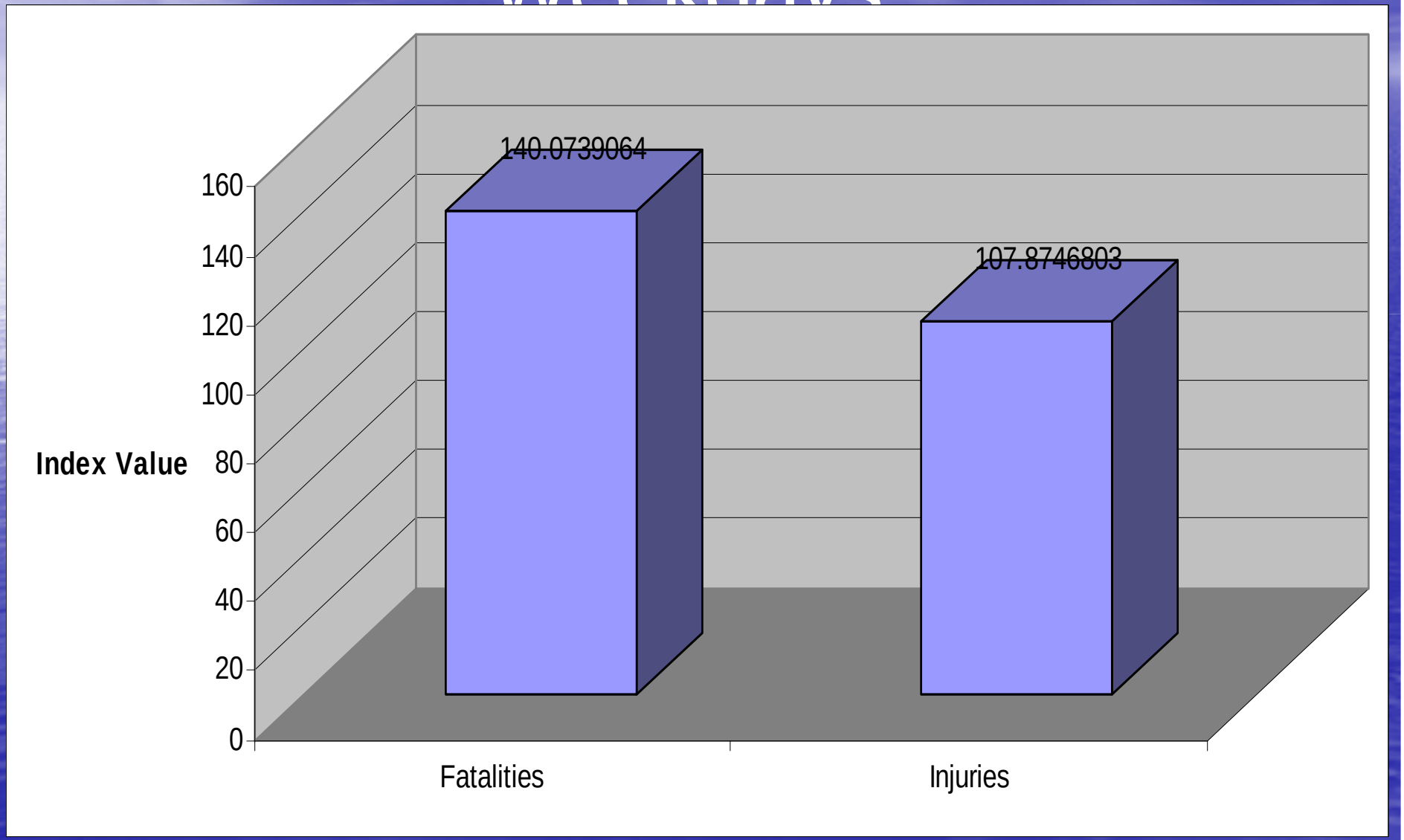
Nocturnal Tornadoes



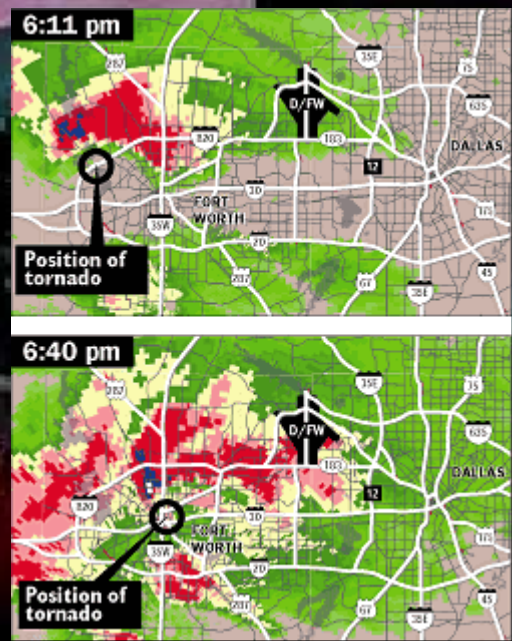
Casualties and Month



Casualties: Weekends vs. Weekdays



Casualties and Warnings



Tornado Warnings

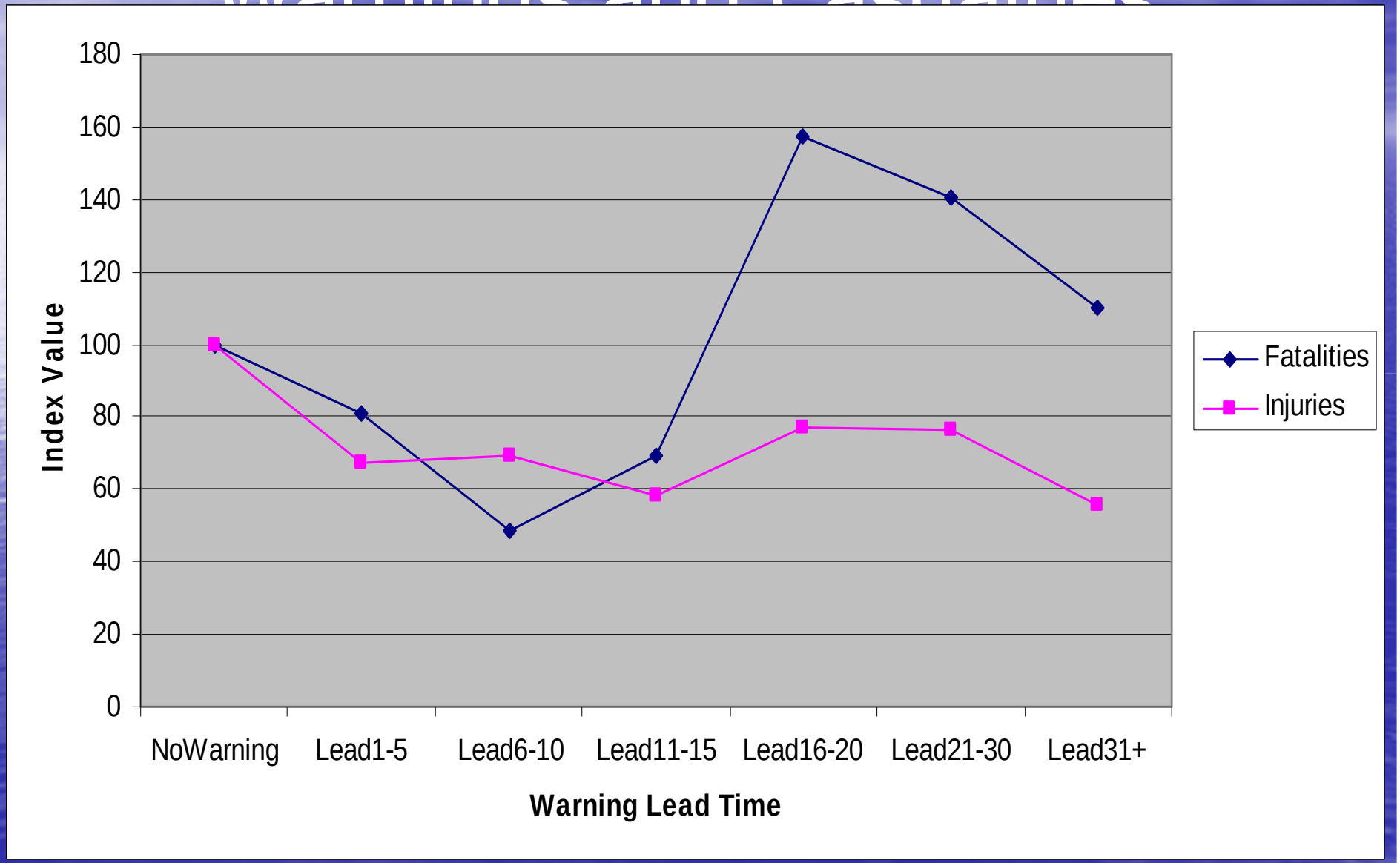
- We were provided with NWS tornado warning verification records, 1986-2004. We were able to construct variables to control for whether a warning was issued for the individual tornadoes in our data

- We have examined three warning variables: a dummy variable for whether the tornado was warned for or not, the lead time as an integer variable, and lead time interval dummy variables.

Doppler Weather Radar

- In the 1990s, the NWS installed a national Doppler radar network. We used the installation date of the new radar in each NWS forecast office to construct a Doppler radar treatment variable.
- Simmons and Sutter (2005) found that expected fatalities and injuries were each reduced about 45% and 40% after Doppler radar was introduced; also measures of tornado warnings improved. In current analysis with additional control variables and more years of data we find 30% and 44% reductions in fatalities and injuries.

Warnings and Casualties



False Alarms and the Cry Wolf Effect

- The value of a weather forecast or warning in an expected value framework depends on the reliability of the information signal.
- Two error probabilities are relevant, the probability a tornado occurs unwarned, and the probability a warning is issued when no tornado occurs.
- The second probability corresponds to the False Alarm Ratio (FAR) that the NWS reports for tornadoes and other types of warnings.

The False Alarm Effect

- A higher FAR should reduce the value of a tornado warning and might induce people to ignore the warning.
- Yet evidence of a false alarm effect in the field has been elusive.
- A recent study notes "Evidence for the cry-wolf effect in natural hazards research, however, has not been forthcoming." (Barnes et al. 2007)

False Alarms and Casualties

- We calculate a recent, local FAR, use this as a control variable in our casualty regressions. If false alarms reduce warning response, this should translate into more casualties, everything else equal.
- A one standard deviation increase in the FAR increases fatalities by 10% and injuries by 9%, with both impacts statistically significant.
- We have tried six different definitions of the FAR in our research, and each yields a statistically significant increase in fatalities and injuries.

Reducing Tornado Impacts

- Our findings allow us to offer several insights on reducing tornado impacts in a cost effective manner. They concern:

Tornado Warnings

Tornado Shelters

Manufactured Homes

Nocturnal Tornadoes

Property Losses

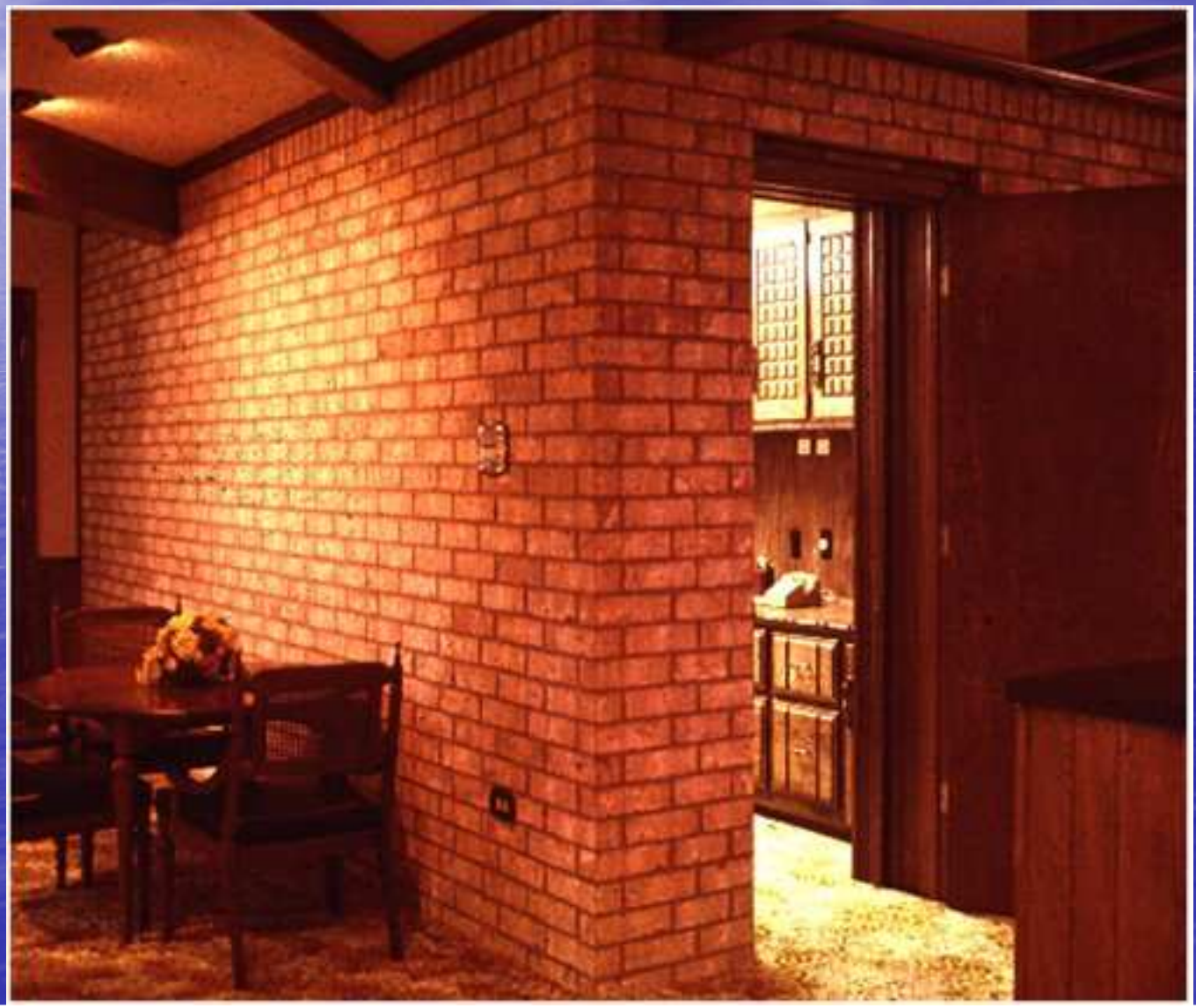
Improved Warnings

- An optimal warning reduces fatalities 50%, injuries 41% relative to no warning.
- Between 2000-04, 45.5% of tornadoes had warning of 5 minutes or less, or were underwarned.
- If the warning on these tornadoes could be extended to 6 to 15 minutes, could reduce fatalities by 21%, injuries by 15%.

Tornado Shelters

- Engineers have designed new underground shelters and above ground safe rooms which should protect residents from even the most powerful tornadoes.
- Shelters cost $2000 to $2500, and safe rooms $5000+.
- Are they worth the investment?

Tornado Shelters



Tornado Shelters

From the perspective of public subsidies for Safe Rooms, the answer is no. The cost per avoided fatality falls well above the amount most experts estimate of what is considered a “reasonable” cost per life saved.

Do Shelters Have Market Value?

- Residential sales data on homes in Oklahoma County, OK, during 2005.
- Tax Assessor Data
- State Inventory of Shelters
- Total Observations – 13,641

Do Shelters Have Market Value?

- A shelter significantly increased the sales price by about 3 ½ percent for the average home.
- This represents a $4200 premium for the typical home in our sample.
- This premium is within the range of estimated cost of shelter installation which varies from $1500 on the low end to almost $10,000 on the upper end.

Building Safer Mobile Homes

- In 1994, HUD enacted new wind load requirements for manufactured homes in coastal areas.
- In February 2007, two tornadoes struck Lake County, Florida, killing 21 people, all in mobile homes.
- In no case did we find that anybody died in a mobile home built after 1994.
- Homes built to the wind code were 79% less likely to be destroyed than homes built prior to 1976.

Tornadoes After Dark

If the lethality of tornadoes during the overnight and late evening hours could be reduced to that of afternoon tornadoes, fatalities could be reduced by 16%, injuries by 7%.

Conclusion

- Detailed knowledge of weather impacts is crucial in identifying cost effective ways warnings and forecasts can reduce impacts.
- Tornado warnings provide great value to society.
- Several societal vulnerabilities have been identified, and they point the way to cost effective ways to reduce tornado impacts.